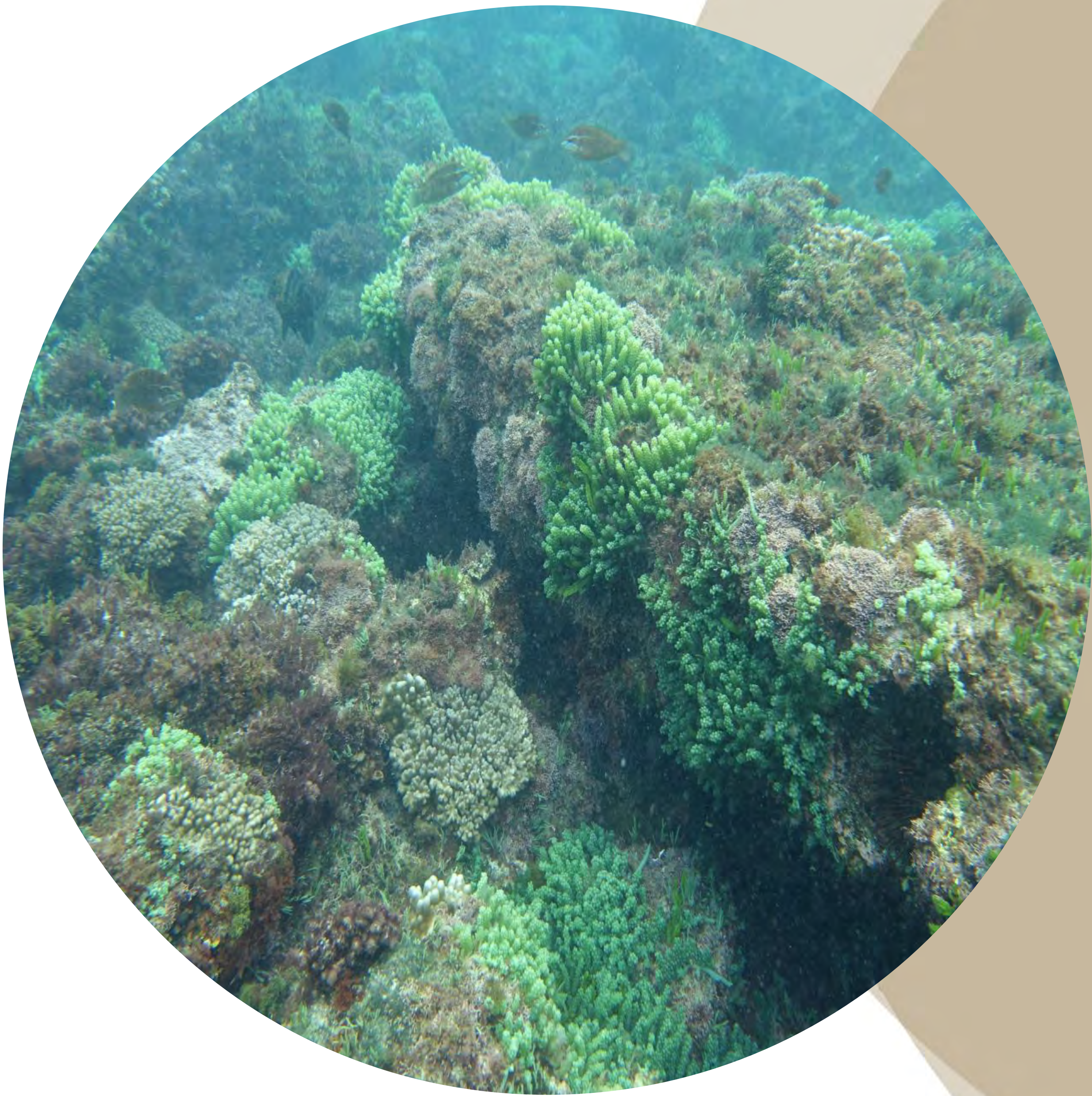

Kingston Pier Channel Construction Project

Marine and Terrestrial Ecology Assessment

Department of Infrastructure, Transport, Regional Development and Communications (DITRDC)

27 July 2021

311015-00061_Final

advisian.com

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Worley Group

Australian Government
Department of Infrastructure, Transport, Regional Development and Communications

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Department of Infrastructure, Transport, Regional Development and Communications

PROJECT 311015-00061_Final: Kingston Pier Channel Construction Project - Marine and Terrestrial Ecology Assessment

Rev	Description	Author	Review	Advisian approval	Revision date	Client approval	Approval date
A	For Internal Review	K. Newton / T. Kane	H. Houridis		1/5/2020		
B	Draft for Client Review	K. Newton	H. Houridis		21/5/2020		
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O_v4	Final report	K. Newton	H. Houridis	H. Houridis	27/7/21		

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Executive Summary

Kingston is the capital of Norfolk Island and is Australia's second oldest town behind Sydney. Kingston Pier, located on the south side of the Island, is one of two waterway import/export and access locations on the island. Limited water depth is available adjacent to Kingston Pier at lower tides and presents a safety risk for users due to inadequate under-keel clearance. The Department of Infrastructure, Transport, Regional Development and Communications (DITRDC) (the Department) engaged Advisian to undertake the delivery of the Kingston Pier Channel Construction Project (the Project).

The Kingston Pier Channel Construction Project Marine and Terrestrial Environment Assessment has been prepared by Advisian to determine the potential impacts on the local marine and terrestrial environment likely to result from the Project.

The Assessment was prepared using a combination of background data review and marine and terrestrial ecology field surveys which were undertaken within the study area in February 2020.

Potential impacts of the Kingston Pier Channel Construction Project on marine and terrestrial habitats and fauna within the study area were identified and mitigation measures to manage and/or mitigate these are discussed.

Assessments of Significance for threatened marine and terrestrial fauna listed under Environment Protection and Biodiversity Conservation Act 1999 were undertaken. These found that no significant impact on habitats or species, particularly on threatened species, are likely to occur if the proposed mitigation measures are adopted. As no significant impacts on species listed under the EPBC Act 1999 are expected to occur, no additional assessment is required.

1 Project Overview

1.1 Introduction

Kingston is the capital of Norfolk Island and is Australia's second oldest town behind Sydney. Kingston Pier (Figure 1-1) located on the south side of the Island, is one of two waterway import/export and access locations on the island, the other being Cascade Pier. Break-bulk cargo is transhipped from cargo ships moored offshore using the launches and lighters. Cargo is lifted out of lighters at the pier using either a shore mounted crane or mobile crane. Limited water depth is available adjacent to Kingston Pier at lower tides and presents a safety risk for users due to inadequate under-keel clearance. Localised deepening and widening of the channel approach and berthing areas adjacent to the pier are required to provide safer access to vessels at all tides.

The Department of Infrastructure, Transport, Regional Development and Communications (DITRDC) (the Department) has engaged Advisian to undertake the delivery of the Kingston Pier Channel Construction Project (the Project).

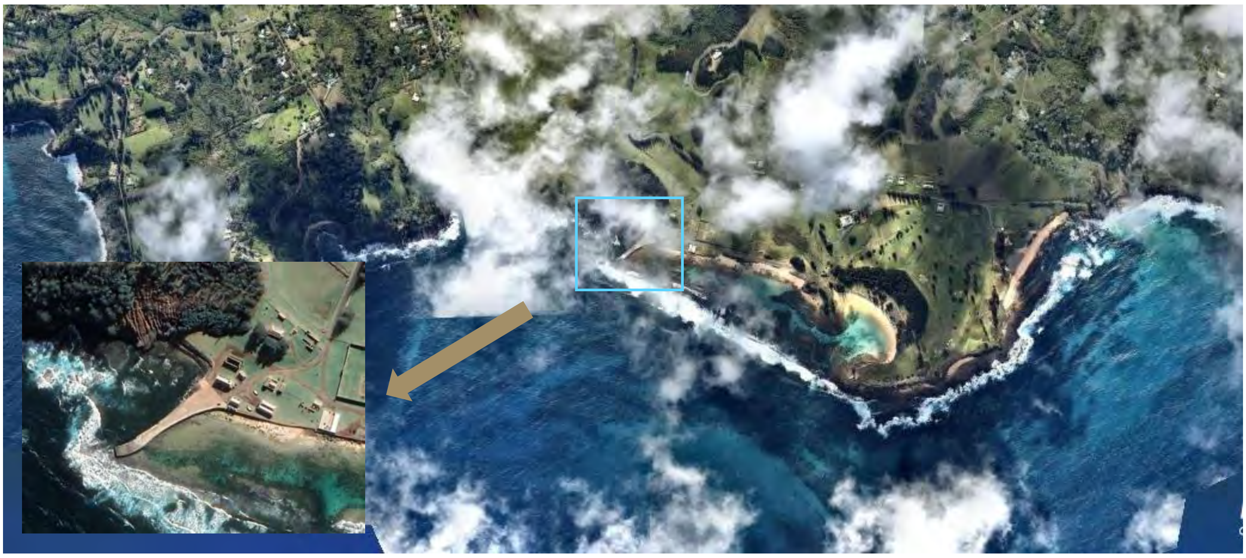


Figure 1-1 Kingston Pier and part of KAVHA, Norfolk Island.

1.2 Project Description

The Project involves locally deepening and widening the channel approach and berthing areas adjacent to the pier to provide safer access to vessels at all tides. This can be achieved by the removal of around 2,500 m^3 – 8,000 m^3 of the seabed material adjacent to the western side of Kingston Pier to a level of 2.7 m to 3.2 m below mean sea level.

The Project site is located within an environmentally sensitive area, being a marine park and an area of maritime archaeological significance. The Project site is also exposed to open ocean waves and currents. The works would generally be untaken using a backhoe mounted on a jack-up barge and transporting the material onshore for disposal. Maritime artefacts recovered during the works would be managed in accordance with a Maritime Management Plan.

1.3 Key Objectives

The key objectives of the Project are as follows:

- Provide a deeper and wider approach channel for commercial and recreational vessels.
- Increase the availability of Kingston Pier for berthing of vessels by providing a safer berthing approach.
- Cause minimal impact to existing port operations and structures during construction.
- Use local labour and resources where possible and appropriate.
- Ensure the project is sympathetic to and complies with the KAVHA Heritage Management Plan.
- Ensure the project considers and minimises environmental, social and economic impacts.
- Ensure community and stakeholders are communicated to in a timely manner and involved in key decisions made, such as selection of the preferred design channel.
- Consider future allowance for larger vessels to enter the channel.
- To deliver the project by the end of the year 2021 and within the project budget.

1.4 Site Conditions

1.4.1 Characteristics of the Pier

Kingston Pier is a historic stone pier approximately 150 m long, located on the southern coast of Norfolk Island in Sydney Bay. The Pier was constructed using convict labour between 1839 and 1847. The finished structure varies from original plans. Kingston Pier has been in use for over 150 years as a cargo transfer facility and is considered an irreplaceable part of the Norfolk Island infrastructure.

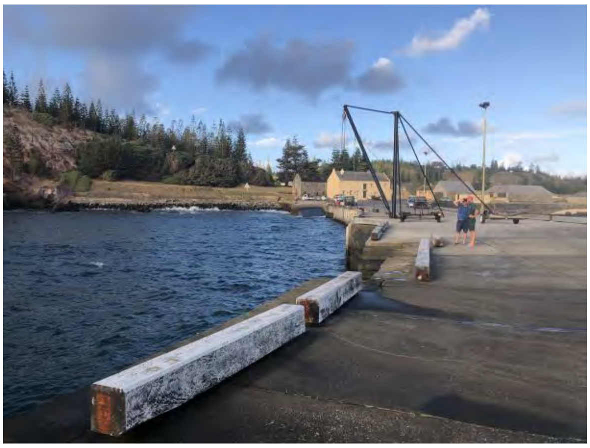
The Pier has the following characteristics:

- Constructed of locally sourced calcarenite stone.
- The eastern face is battered.
- The western face is near vertical and includes two sets of steps to facilitate transfer of personnel to and from boats.
- Situated along the western edge of an existing reef.
- Damage occurred due to a severe storm event (reportedly in 1897) and excessive use by heavy equipment during World War II.
- Repaired in 1953, which included installation of steel sheet piles and a concrete capping beam.
- Refurbished in 2007 with additional sheet-piling.
- Is considered to be of high cultural and heritage significance.

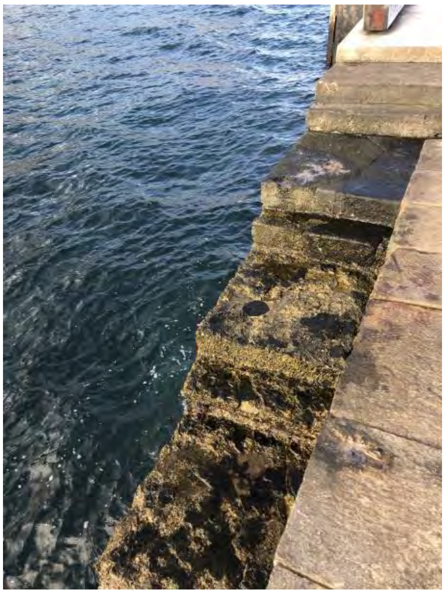
The Kingston Pier is located seaward of a shallow rock shelf that is exposed at lower tide levels and provides some sheltering of waves for vessels in the lee. The existing entrance channel is over rocky reef with sea bed levels ranging from around -2.4 m to -3.4 m CD offshore and adjacent to the rock shelf. Landward of the rock shelf and next to the pier seabed levels are around -0.7 m to -1.5 m CD. Seabed levels have been sourced form a hydrographic survey undertaken by Don Taylor on 1

December 2006. More recent survey of the area is currently being sought potentially from the Navy and the CSIRO although as the seabed is rocky reef, the Don Taylor survey is still considered valid.

Images of the various aspects and features of the Kingston Pier are provided in Figure 1-2.

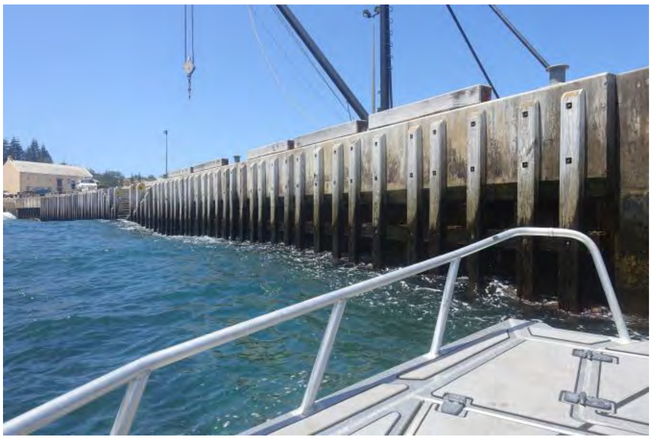


Looking north from the seaward end of Kingston Pier.

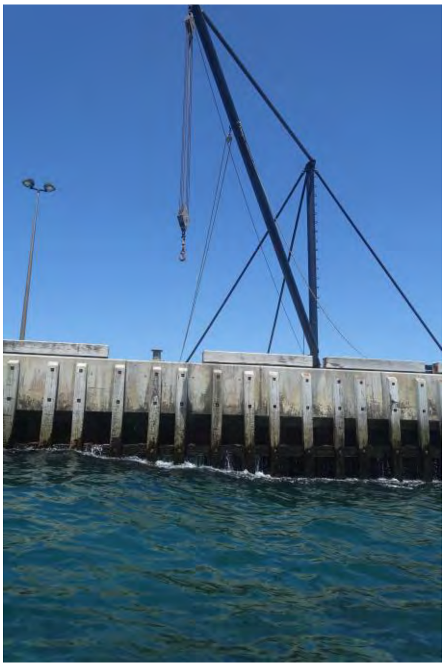


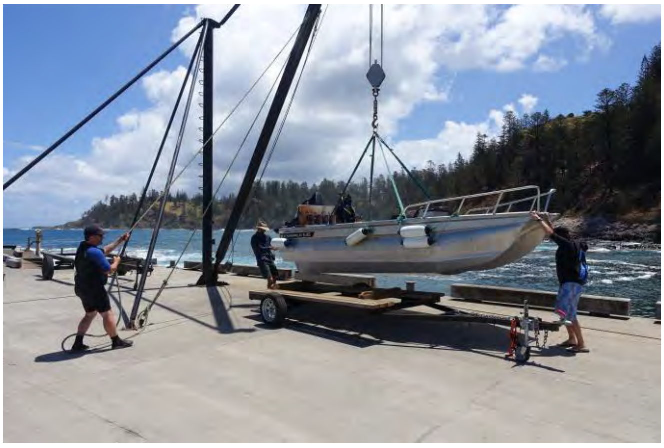
Old steps on the western face of Kingston Pier.

New steps on the western face of the Pier.



Western face of the Kingston Pier.





Vessel travel lift and a boat retrieval taking place on the western face of the Kingston Pier.

Figure 1-2 Kingston Pier.

1.4.2 Bathymetry

The Kingston Pier is located seaward of a shallow rock shelf that is exposed at lower tide levels and provides some sheltering of waves for vessels in the lee. The existing entrance channel is over rocky reef with sea bed levels ranging from around -3 m to -4 m MSL offshore and adjacent to the rock shelf. Landward of the rock shelf and next to the pier seabed levels are around -1 m to -3m MSL.

Seabed levels have been sourced from a combination of a hydrographic survey undertaken by Don Taylor on 1 December 2006 and a hydrographic survey undertaken by the Royal Australian Navy on 28 October 2015. The Don Taylor survey informs the levels of the seabed within nearby proximity of the channel and the levels of the rock-shelf. The Royal Australian Navy survey informed the offshore levels of the harbour.

1.4.3 Ocean Currents

Ocean currents at the site are a result of tide and wave action and would vary from negligible, to over 2 m/s when adverse wave and tide conditions are present.

1.4.4 Geological Profile

As outlined in JK Geotechnics Report from July 2006, the geological profile consists of a capping layer of very high strength silcrete which is limited to the south-eastern side of the pier (i.e. not in the existing channel). The capping is underlain by calcarenite and elsewhere calcarenite forms the surface layer. The calcarenite overlies a deeply weathered volcanic profile comprising tuff containing very high strength basalt cobbles and boulders. The calcarenite is generally not present in the existing channel (some scattered pockets are located close to the Pier), likely due to previous deepening works. However, the calcarenite forms the surface layer beyond the extents of the existing channel and would be encountered during the proposed works. Table 1-1 outlines each rock type's properties, locations and qualitative description.

Table 1-1 Rock description and properties.

Rock type	Description	UCS (unconfined compressive strength)
Silcrete	The silcrete material is generally medium grained, slightly weathered to fresh and of very high rock strength. Silcrete is similar to calcarenite in properties but shows more continuity with less fracturing and higher strength. The silcrete is not expected to be encountered during the works,	54MPa to 130MPa
Calcarenite	The calcarenite material is generally medium grained, distinctly weathered, highly porous and with voids typically of 20 mm to 50 mm. The core logs showed zones of core loss and may represent the level of fracturing in the calcarenite rock. The calcarenite is expected where the channel is widened. It is typically 0.5 m thick.	14MPa to 60MPa
Tuff	The tuff material is a deeply weathered volcanic profile generally assessed to be of very low rock strength. The tuff comprises most of the material in the channel. The depth of the tuff extends well below the channel design levels.	<1Mpa
Basalt	There are sporadic basalt core stones and inclusions within the volcanic profile, which are typically of very high rock strength. It is possible basalt is encountered during the works.	76MPa to 90MPa

The deeply weathered volcanic tuff material in the existing channel was confirmed by the seabed condition survey undertaken by Waterway Constructions in August 2016 (intended to identify any vessel navigation obstructions at the time). Waterway Constructions first inspected the seabed with divers and then broke off two high spots using a jack hammer. Core drilled and loose samples were taken, but not tested. Recovered core-drill samples were visually identified as tuff, and loose samples identified as pumice. Overall, Waterway Constructions found the seabed condition a lot softer than first thought following the visual inspection with the core drill getting to depth with ease, and the jack hammer breaking off large sections of rock with little effort.

2 Proposed Channel Design and Construction

2.1 Design Options

The Kingston Pier channel design was required to provide a suitable channel profile for vessels to safely access Kingston Pier, without significantly impacting upon the existing built and natural environment. Four potential channel design options (Option 1, 2, 3 and 4) were considered and are outlined in detail in the Kingston Pier Channel Construction Project 30% Design Report (Advisian, April 2020). Two additional options were proposed in June 2020 after stakeholder consultation and review of the original four options (i.e. Option 1a and 3a)(Advisian, Memo: June 2020). These six options are summarised below:

Table 2-1 Proposed channel design options.

Option	Design Vessel	Entrance Channel Width	Interior Channel Width	Channel Depth	Material Volume
Option 1	Current vessel fleet	20 m	18 m	-2.7 m MSL	2,500 m^3
Option 1a	Current vessel fleet	20 m	22.5 m	-2.7 m MSL	2,750 m^3
Option 2	Current vessel fleet	26.5 m	24 m	-2.7 m MSL	4,000 m^3
Option 3	Future vessel fleet	20 m	27 m	-3.2 m MSL	4,400 m^3
Option 3a	Future vessel fleet	20 m	22.5 m	-2.7 m to -3.2 m MSL	4,000 m^3
Option 4	Future vessel fleet	32.5 m	36 m	-3.2 m MSL	8,200 m^3

Consideration was given to removing the bombora off the SE side of the channel. While removal of the bombora may assist with navigation in some instances, it is not deemed necessary given a 60 m clearance (more than 10 beams) between the bombora and rock shelf is presented. The location of the bombora does not restrict vessels to navigate perpendicular to incoming wave crests when using the channel. Furthermore, there is a concern that the removal of the bombora may further impact the nearshore wave climate. The bombora appears to be a hard basalt pinnacle and would be possible to removed but require some effort, likely with a rock breaker attachment or similar. Therefore, it has been decided the benefits of removing the bombora do not outweigh the associated costs and risks and was not included in the design options.

2.2 Preferred Dredge Options

Preferred Options are Option 1, Option 3, Option 1a and Option 3a which are discussed further below.

2.2.1 Option 1

Option 1 is the narrowest channel proposed for Kingston Pier. It has been designed for the safe and effective navigation of the PTVs and Cruise Vessel Tenders, the largest current vessels using Kingston Pier, with the minimal channel widths that have been accepted by stakeholders. Vessel operators at Norfolk Island are more accepting of a narrower channel '"than typical" to limit waves penetrating along the channel. Figure 2-1 shows the extents of the design channel and colour shading showing the extent of cut required to meet the design seabed level.

2.2.1.1 Design vessel

Vessel	Value
Current vessel fleet length	12 m
Current vessel fleet beam	5.3 m
Current vessel fleet draft	1 m

2.2.1.2 Channel dimensions

Channel dimension	Value
Entrance Channel Width	Entrance Channel = Max (20 m,3×Vessel Beam)=Max (20 m,16 m)=20 m
Interior Channel Width	Interior Channel =1.5×Vessel Length=18 m
Channel Depth	Channel Depth=-0.7 m MSL - 1 m - 0.5 m - 0.5 m=-2.7 m MSL

2.2.1.3 Excavated volume estimate

Option 1 would approximately remove a volume of 1,884 m^3. The volume accounts for batter slopes but excludes a cut tolerance factor (i.e. over deepening). Over deepening could be up to 0.3 m below the design depth that would result in an additional volume up to 660 m^3 giving a total volume of around 2,500 m^3.

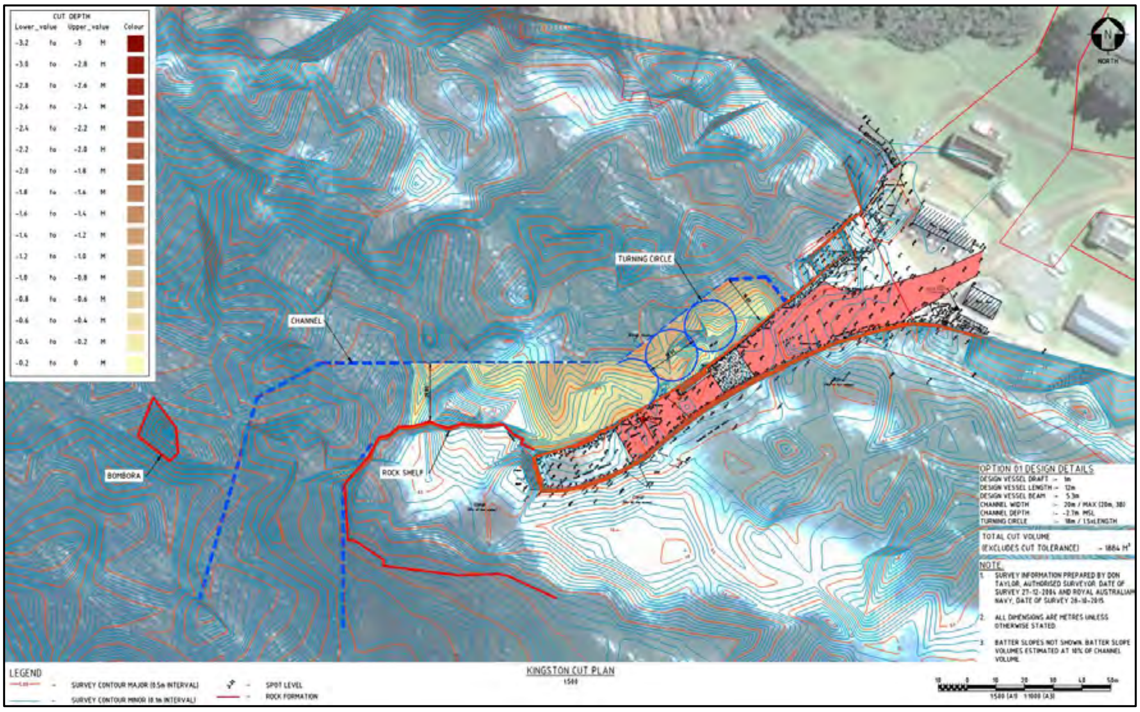


Figure 2-1 Kingston Pier Channel Cut Plan for Option 1.

2.2.2 Option 3

This option proposes a design channel depth and width dimensions for the potential future vessels such as large supply/transshipment barges visiting Kingston Pier. The channel width is derived from the Australian Standards AS3962 minimum width. Figure 2-2 shows the extents of the design channel and colour shading showing the extent of cut required to meet the design seabed level.

2.2.2.1 Design vessel

Vessel	Value
Future vessel fleet length	18 m
Future vessel fleet beam	6.5 m
Future vessel fleet draft	1.5 m

2.2.2.2 Channel dimensions

Channel dimension	Value
Entrance Channel Width	Entrance Channel = Max (20 m,3×Vessel Beam)=Max (20 m,19.5 m) = 20 m
Interior Channel Width	Interior Channel = 1.5×Vessel Length=27 m
Channel Depth	Channel Depth=-0.7 m MSL - 1.5 m - 0.5 m - 0.5 m=-3.2 m M

2.2.2.3 Excavated volume estimate

Option 3 would approximately remove a volume of 4,593 m^3. The volume accounts for batter slopes but excludes a cut tolerance factor (i.e. over-deepening). Over deepening could be up to 0.3 m below the design depth that would result in an additional volume up to 840 m^3 giving a total volume of around 4,400 m^3.

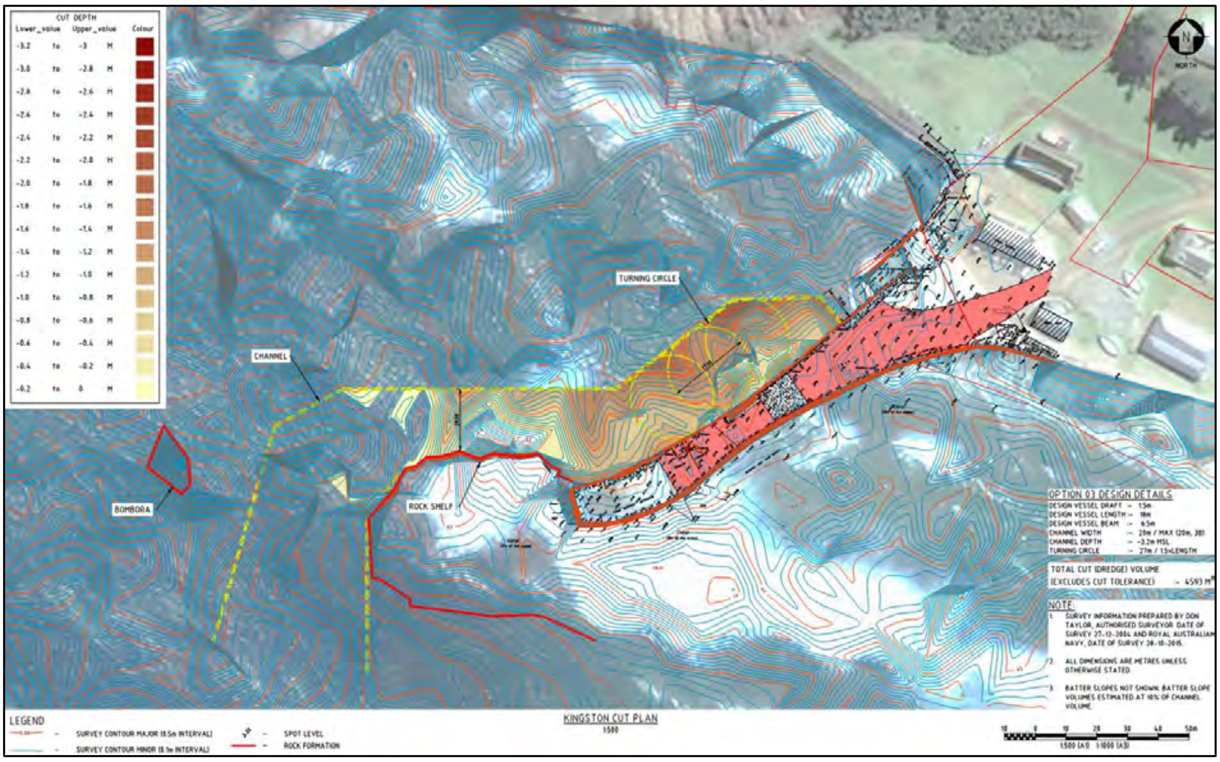


Figure 2-2 Kingston Pier Channel Cut Plan for Option 3.

2.2.3 Option 1a and 3a

Generally, amongst stakeholders, Options 1 and 3 were well supported. However, suggestions to improve the channel design Options 1 and 3 were provided as follows:

- An interior channel width (i.e. the area adjacent to the berth face) between that provided in Options 1 and 3 would better assist with manoeuvrability, especially when more than one vessel is in this area; and,
- The deeper R.L. -3.2 MSL channel depth would be beneficial for vessels with larger draughts. The channel depth could slope up to R.L. -2.7 MSL closer to the berth face, limiting the initial impact to the sheet pile wall, as well as being able to be deepened to R.L. -3.2 MSL in the future with on-island equipment if and when needed.

The four initial channel design options and the two additional design options are shown on Figure 2-3.

Options 1a and 3a only vary from Options 1 and 3 respectively between approximate chainages CH 25 to CH 95. Option 1a has slightly increased proposed dredging from Option 1, while Option 3a has slightly reduced dredging from Option 3. A cross section at Chainage CH 50 and the plans presented in Figure 2-4, Figure 2-5 and Figure 2-6 highlight the variances.

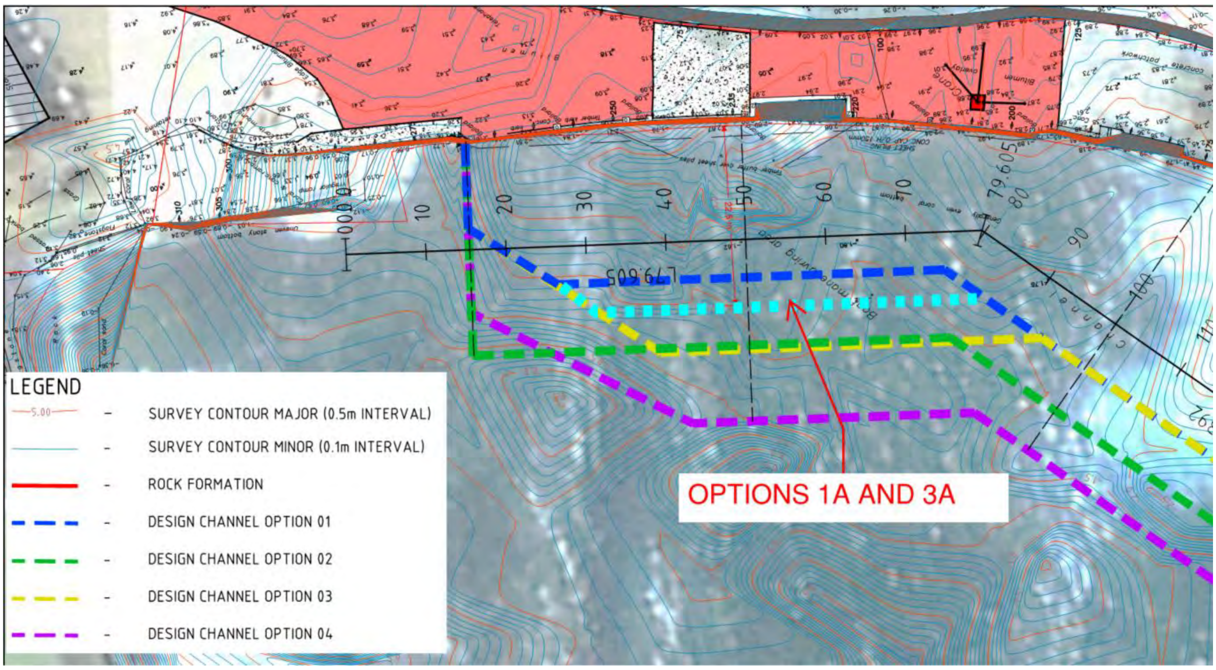


Figure 2-3 Channel design options.

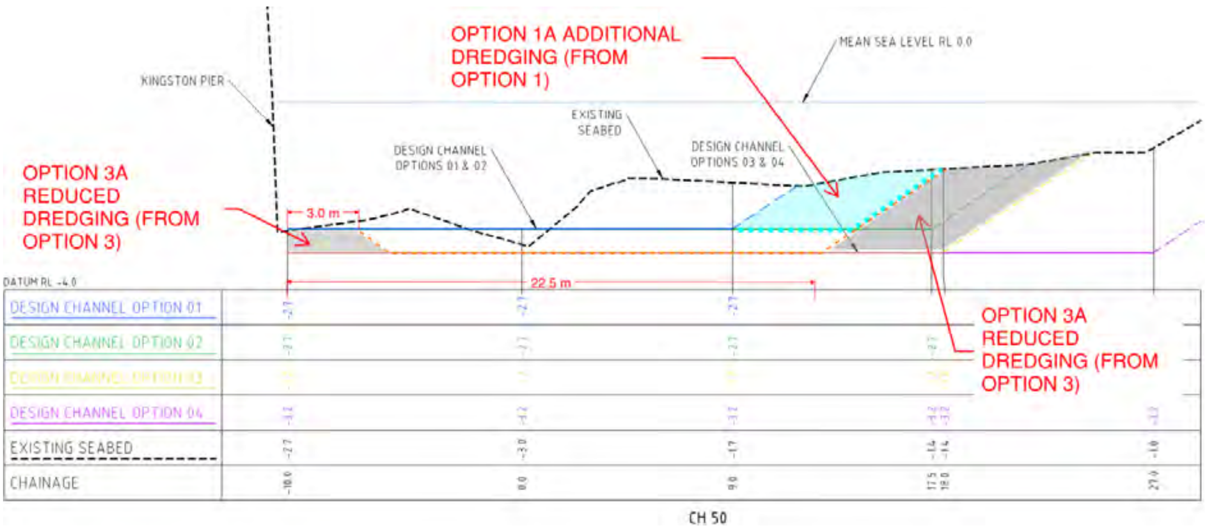


Figure 2-4 Channel design at Chainage 50 for all six options.

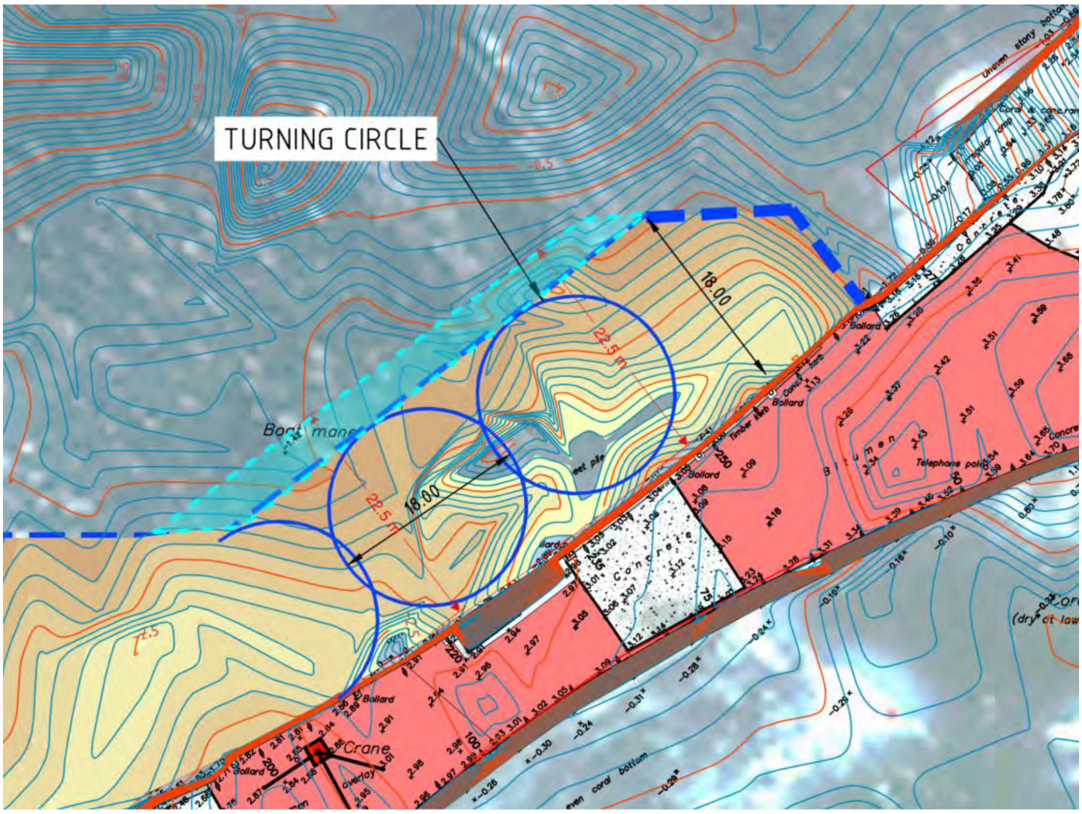


Figure 2-5 Option 1a additional channel width (cyan shading) compared to Option 1 (dark blue dashed line).

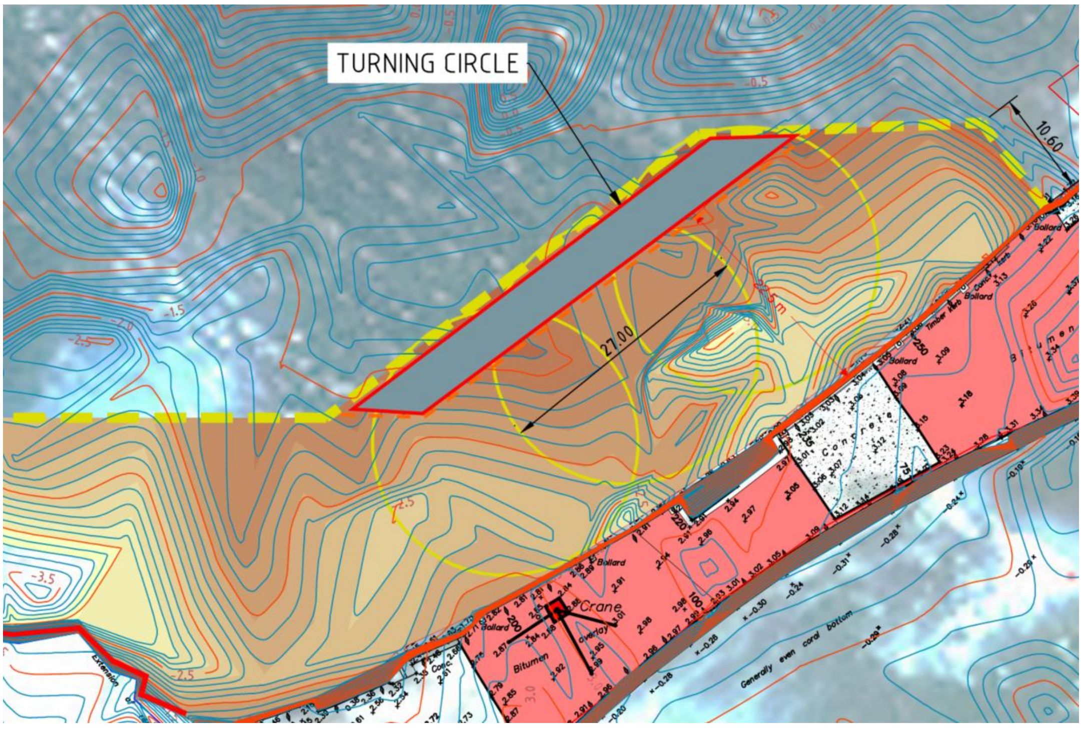


Figure 2-6 Option 3a reduced channel width (grey shading with red outline)) compared to Option 3 (yellow dashed line).

2.3 Pier Stabilisation Works

The Project will involve deepening of the seabed adjacent to Kingston Pier, which poses a risk to potentially undermining the pier’s existing sheet-pile wall. A recent hydrographic survey and underwater visual assessment by divers showed that this undermining was already occurring (see Figure 2-7), with evidence of loose gravel fill escaping from between the old and existing sheet-pile wall (Figure 2-8).

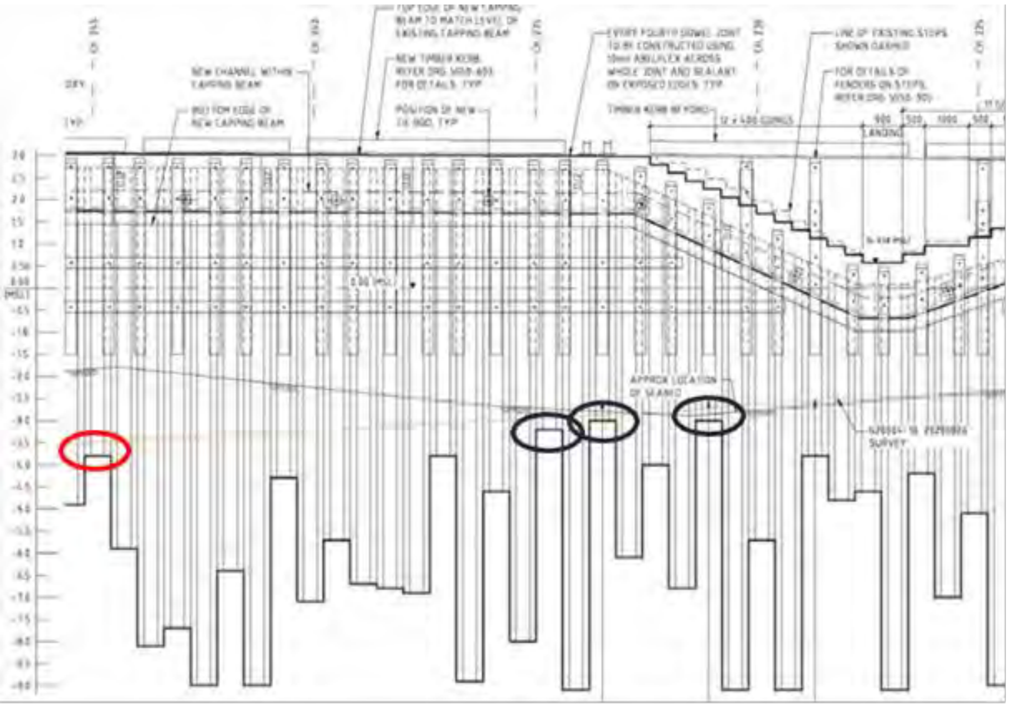


Figure 2-7 Locations at the toe of the pier where the existing sheet-pile wall toe is close to seabed levels.

Figure 2-8 Loose gravel identified adjacent to sheet-pile wall.

The structural capacity of the pier is highly reliant on the sheet-pile wall system. Therefore, it was recommended based on a structural assessment that prior to the dredging works, in order to withstand the loads of having a crane carry skip bins from a jack-up barge to the pier, the pier structure should be stabilised.

The potential expected repairs for Kingston Pier based on the current sheet-pile structural assessment include the following works:

- Welding together each sheet-pile of the existing sheet-pile wall to facilitate distribution of stress across the whole wall.
- Grouting up the cavities between the old sheet-pile wall and existing sheet-pile wall to form a gravity retaining wall system.
- Installing a concrete toe at the bottom of the sheet-pile wall to prevent future undermining of the sheet-pile wall.

2.4 Rock Revetment Repairs

The Kingston Pier Rock Revetment, shown in Figure 2-9, is west of and adjacent to Kingston Pier. The revetment is in need of repair and upgrading, to protect the integrity of the masonry and sheet pile wall behind it and repair erosion that has occurred adjacent to the structure.

The revetment comprises a rock berm that has been constructed in front of a masonry block wall that had suffered damage since the original wall was constructed in 1839. The design for the rock berm indicates a minimum rock armour size of 300 kg, but only a single layer of primary armour. The damage to the masonry wall has the potential to allow loss of material through the structure, with the structure losing its retaining properties. There is evidence that the rock revetment is unravelling and rock armour has been displaced from the structure.

It is proposed for the western extent, profile and rock sizes of the revetment to be re-designed to extend the service life of the revetment and protect the wall behind it. This would be undertaken with land based excavator tracking along the revetment and using locally sourced rock.

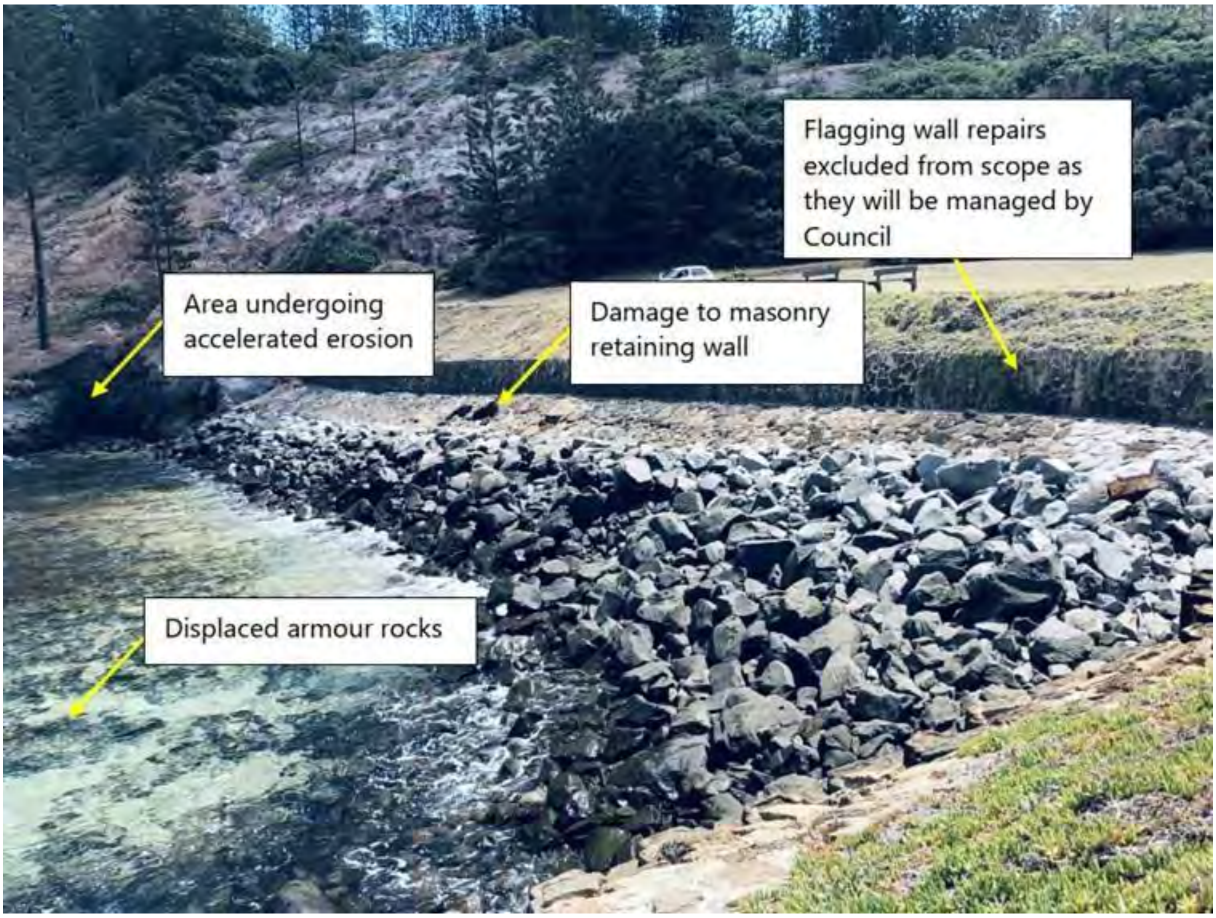


Figure 2-9 Location of rock revetment defects.

2.5 Recommended Construction Methods

A construction methodology is recommended however, it would be refined by the contractor during the construction tender stage to suit available plant and equipment. Environmental measures and considerations including the provision of sediment controls would form part of the assessment of the preferred contractor.

2.5.1 Recommended Methodology

1. Major plant and equipment are expected to be mobilised from either the east coast of Australia or New Zealand and would generally include:
    a. a venturi suction pipe
    b. a jack-up barge
    c. an appropriately sized backhoe
    d. a hopper/flat barge and skip bins
    e. a tug.

    Where possible, local plant and equipment would be used such as smaller excavators and trucks.

2. A temporary site compound area would be established near the pier to store plant and equipment. On the pier, a small screening area would be established for screening of archaeological artefacts in the removed material. This requires access to seawater to assist with moving sediment through the screens.
3. A pre-construction hydrography survey would be undertaken by the construction contractor.
4. Remove loose sediment material (with potentially culturally significant artefacts) from the existing channel, and gullies and cracks of the calcarenite layer using a venturi suction pipe, which would transfer the material into a perforated sediment box sitting on the seabed. The process is as follows:
   a. The sediment box once sufficiently filled would be lifted onto the pier using the fisherman's crane and sieved through to identify any artefacts. There is an opportunity to involve the local community in the sieving of the artefacts.
   b. The artefacts would be moved to a secure location (potentially an empty work shed near the Pier) for assessment of significance and subsequent management. Previously a KAVHA building adjacent to the pier was made available in the 2007 pier refurbishment project and enquiries will be made to see if it could be made available again.
   c. All artefacts found would be recorded, and the significant artefacts would be transferred to KAVHA ownership and managed appropriately (i.e. for storage or display in the KAVHA museum, while the remainder would be reburied in the water near the site or discarded according to the Kingston Pier Underwater Archaeological Management Plan that will be formulated and implemented.).
   d. The remaining sediment transported to the onshore disposal area.
5. Remove the calcarenite layer with a backhoe mounted on a jack-up barge and using hand tools near the pier. The calcarenite would be placed directly into trucks on the pier, or the platform of the jack-up barge and transferred to the Pier with a floating hopper or flat topped barge. Given the wave climate at the site, it is not considered appropriate for a floating barge to be moored for extended periods while it is being progressively filled with material as it is removed. Skip bins could be considered, to be filled and transported to improve material handling efficiency. The size of the skip bins would be subject to the allowable load for the jack-up barge and trucks to operate. Furthermore, the skip bins could be fitted with a filter over the sump and assist with dewatering the material. Once the material is onshore, it is to be screened for artefacts at the required frequency (to be determined as part of the environmental assessment where for example one bin/load sampled out of three) and transported to the disposal site. Screening could involve manually breaking up calcarenite over a sieve. Recovered artefacts would be managed as previously described.) and transported to the disposal site. Recovered artefacts would be managed as previously described.
6. Remove the tuff rock material using a backhoe mounted on a jack-up barge and using hand tools near the pier and transported to the disposal site. Screening of artefacts is either not expected to be required or screened at a lesser frequency that the calcarenite (to be confirmed as part of the environmental assessment).
7. Pier stabilisation works would be undertaken to mitigate structural impacts, if any, of the channel deepening on Kingston Pier. This would potentially involve concrete plugs and welding existing sheet-piles.
8. If required, a single piled channel marker would be installed at the rock-shelf edge. The marker would be constructed from a steel pile potted into the rock shelf while working the lower tides.

9. A post-construction hydrography survey would be carried out to ensure the channel has met the design channel depth. The seabed would be made clean by removal of any loose or stray rocks in the area.
10. Construction site would be demobilised and plant removed from the island.

2.6 Material Disposal and Reuse Options

The calcarenite material, which is of relatively high strength but variable, weathered fragmented, may be reused for non-structural fill, and possibly for sub-base of foot paths if crushed and cleaned. However, it is considered the most appropriate and cost effective use of the removed calcarenite is for non-structural fill unless it was cement stabilized. The tuff material, which is of very low strength, would be also be considered most appropriate and cost effective as non-structural fill unless cement stabilized. Non-structural applications considered include fill for the Cascade Pier apron raising (subject to design), remediating the old quarry, or landscape mounding. There is high likelihood that the Cascade Pier works would require structural fill, which the disposed material would not meet the requirements of. Therefore, this option has been discounted.

Offshore disposal is an option for the removed material, however there are several difficulties surrounding an offshore option for dredging, which includes the following:

- No currently registered offshore disposal sites located around Norfolk Island. To apply for an offshore disposal site will require a lengthy approval and permitting process.
- If the dredging material is required to be lifted from the barge onto the surface for archaeological screening purposes, then the material would have to be lifted back onto a barge to transport to the disposal location. This would be an ineffective use of time and equipment, leading to increased costs.

Advisian have developed options for the channel which will remove an estimated volume of 2,500 m^3 – 8,200 m^3. There are currently three (3) onshore disposal options proposed as follows:

- Old Quarry.
- Raising Cascade Pier Aprons.
- School Playing Fields Restoration.

2.6.1 Old Quarry

The old quarry (see Figure 2-10 and Figure 2-11) adjacent to Cascade Pier is proposed as an option to be used both a disposal area and also a temporary stockpile location for the Cascade Pier option (refer to Section 2.6.2). The quarry is proposed to be rehabilitated and the fill would contribute to this activity. Disposal at the old quarry is considered to be the most preferred options as it aligns with the council’s objective to rehabilitate the quarry in future, which the disposed material would contribute towards.

Figure 2-10 Aerial view of the old quarry shown by the red box (Source: Nearmap 2019).

Figure 2-11 Photograph of the old quarry (Source: Advisian 2020).

2.6.2 Raising of the Cascade Pier Aprons

Works are proposed at Cascade Pier (Figure 2-12 and Figure 2-13) to raise the level of its aprons. The removed material could be beneficially reused as non-structural fill if required (subject to design) for the purposes of raising the aprons. Due to uncertainty of the delivery timeline of these works, a temporary stockpile location would be required for the disposed material. It is recommended for the Old Quarry to temporarily stockpile the material until Cascade Pier construction works begin. There is high likelihood that the Cascade Pier works would require structural fill, which the disposed material would not meet the requirements of. Therefore, this option has been discounted in preference to the Old Quarry option as it is less reliable.

Figure 2-12 Aerial photography of Cascade Pier and the aprons (Source: Nearmap 2019).

Figure 2-13 Photo of Cascade Pier from the cliff overlooking the pier (Source: Advisian 2020).

2.6.3 Restoration of the School Playing Fields

There is currently restoration work (Figure 2-14 and Figure 2-15) being undertaken at the school fields north-east of Norfolk Island Central School and north of the existing playing fields. The disposed material could be used as non-structural fill for the restoration works. This could be in the form of landscape mounding. However, the community has unfavourable views towards using this location as a convenient disposal option for projects, and therefore stockpiling at this location is not recommended.

Figure 2-14 Aerial photography of the school playing fields being restored (Source: Nearmap 2019).

Figure 2-15 Site photo of the playing fields (Source: Advisian 2020).

2.7 Proposed Operation

Vessel operators such as commercial charter, fishing vessels and emergency responders as well as local launches and lighters would enter and exit the harbour adjacent to Kingston Pier through the newly augmented channel. Vessels would be guided by new channel navigation aids.

The augmented channel would support greater use of Kingston Pier by various vessel operators, particularly as critical infrastructure for freight and cruise ship passengers. In addition, it is expected that safer navigation of the harbour and increased use of Kingston Pier would have positive opportunities for tourism as well as community and economic development on Norfolk Island.

3 Marine Environment

The Norfolk Island group lies on a plateau 100 km long on the Norfolk Ridge, which runs from New Zealand to New Caledonia. It consists of Norfolk Island which is the largest and the two smaller islands of Phillip and Nepean which are located off the southern coastline of Norfolk (Francis 1993). The islands of the Norfolk Island group are situated in an area known as the Tasman Front – where the warm nutrient poor waters of the Coral Sea meet the cool nutrient-rich waters of the Tasman Sea – making the islands and surrounding marine ecosystem an integral link between tropical and temperate oceanic environments (NIRC 2018).

A review of existing information for marine habitats and fauna occurring within the study area was undertaken to assist in the marine environmental impact assessment. The background information included within this report includes but is not limited to the surveys completed in the 1960s by the Australian Museum, published literature as well as more recent assessment completed by the Commonwealth Government and other consultants as part of other proposed developments on the island. An EPBC Act 1999 Protected Matters Search was also generated for the project (provided in **Appendix A**).

The background data review provides an overview of the existing aquatic (marine) environment on Norfolk Island (specifically Kingston Pier and Slaughter Bay). It includes a description of marine habitats and flora, marine protected areas and critical habitat, marine fauna (including threatened and protected species), and provides background water and sediment quality data from the study area (see Section 4).

3.1 Marine Habitats

3.1.1 Temperate East Marine Region

3.1.1.1 General Info

Norfolk Island lies within the Temperate East Marine Region. This marine region is comprised of Commonwealth waters extending from the southern boundary of the Great Barrier Reef Marine Park to Bermagui in New South Wales (Figure 3-1). This also includes the waters surrounding Lord Howe Island and Norfolk Island. The region covers an approximately 1.47 million km^2 of temperate and subtropical waters. The region extends from shallow waters on the continental shelf, 3 nautical miles (5.5 km) from shore, to the deep ocean environments at the edge of Australia's exclusive economic zone, 200 nautical miles from shore (DSEWPC 2012).

Figure 3-1 Location of the Temperate East Marine Region (and Norfolk Island).

The main physical features of the Temperate East Marine Region are:

- Three seamount chains that run parallel to the east coast (the Tasmantid and Lord Howe seamount chains and the Norfolk Ridge).
- The East Australian Current (EAC), which dominates oceanography of the region.
- The Tasman Front, which forms between 20 and 30 degrees south and represents the meeting point of the Coral Sea and the Tasman Sea.
- The canyons of the eastern continental slope, which add critical habitat diversity to the region.

There are a range of conservation values within the Temperate East Marine Region, which are defined as elements in the region that are:

- Key Ecological Features (KEFs) of the Commonwealth Marine Area.
- Species listed under Part 13 of the EPBC Act 1999 that live in the Commonwealth Marine Area or for which the Commonwealth Marine Area is necessary for a part of their lifecycle.
- Protected places including marine reserves, heritage places and historic shipwrecks in the Commonwealth Marine Area.

The conservation values of Temperate East Marine Region include the following:

- Biodiversity – The region supports high levels of species richness and diversity (particularly among corals, crustaceans, echinoderms, molluscs, sea sponges and fish). The EAC connects remote communities through the transport of species between areas.
- KEFs – Eight KEFs have been identified in the Temperate East Marine Region, including:
  - Shelf rocky reefs.
  - Canyons on the eastern continental slope.
  - Tasman Front and eddy field.
  - Upwelling off Fraser Island.
  - Tasmantid seamount chain.
  - Lord Howe Seamount chain.
  - Norfolk Ridge.
  - Elizabeth and Middleton reefs.
- Protected species – Species listed under the EPBC Act 1999 are listed as either threatened species, migratory species, and cetaceans and marine species. Species groups identified as conservation values in the Temperate East Marine Region area:
  - Bony fishes (10 species).
  - Cetaceans (9 species).
  - Marine reptiles (24 species).
  - Seabirds (34 species).
  - Sharks (6 species).
- Biologically Important Areas (BIAs) – These areas are particularly important for the conservation of protected species where individuals display biologically important behaviours.
- Protected places – Within the Temperate East Marine Region, these include:
  - Elizabeth and Middleton Reefs Marine National Nature Reserve.
  - Solitary Islands Marine Reserve (Commonwealth waters).
  - Cod Grounds Commonwealth Marine Reserve.
  - Lord Howe Island Marine Park (Commonwealth waters).
  - Norfolk Island Marine Park (Commonwealth Waters) (see further information in Section 3.1.2.1).

3.1.1.2 Temperate East Marine Region Management Plan

The Australian Marine Parks *Temperate East Marine Parks Network Management Plan* was developed in 2018. The plan's main objectives are to provide for the protection and conservation of biodiversity and other natural, cultural and heritage values of marine parks, and provide ecologically sustainable use and enjoyment of the natural resources within marine parks in the Temperate East network.

The plan enables a range of activities to be conducted that would otherwise be prohibited or controlled by the EPBC Act 1999 and EPBC Regulations. The plan sets out activities which are allowed subject to being consistent with zone objectives, allowable with authorisation, or not allowed due to being inconsistent with zone objectives. For those activities that are allowed or allowable, the plan also sets out the assessment and decision-making process for authorisation of an activity, the type of authorisation that may be issued, and how activities must be undertaken. Depending on the type of activity, other provisions of the EPBC Act 1999 or other legislation may also be applicable (Director of National Parks 2018).

3.1.2 Marine Protected Areas

A Marine Protected Area (MPA) is an area of sea especially dedicated to the protection and maintenance of biodiversity and of natural and associated cultural resources, managed through legal or other effective means. MPAs include marine parks, nature reserves and locally managed marine areas that protect reefs, seagrass beds, shipwrecks, archaeological sites, tidal lagoons, mudflats, saltmarshes, mangroves, rock platforms, underwater areas on the coast and sea beds in deep water.

3.1.2.1 Norfolk Island Marine Park

The Norfolk Island Marine Park was proclaimed under the EPBC Act on 14 December 2013. The long, narrow, steep-sided undersea of Norfolk Ridge runs through the marine park, which acts as a line of oceanic stepping stones, connecting deep water marine species from New Zealand to New Caledonia and supports diverse temperate and tropical marine life (Australian Marine Park 2020). The Norfolk Island Marine Park begins approximately 1,400 km offshore and covers 188,444 km^2 with depths of up to 5,000 m. The marine park comprises a number of zones, including a National Park, Multiple Use and Special Purposes zone, shown in Figure 3-2. The Special Purpose Zone is located directed around Norfolk Island and allows for both conservation and sustainable use in a highly valued natural area (Australian Marine Park 2020).

The marine park contains the wreck of HMS Sirius, one of the first fleet flagships which floundered in 1790. HMS Sirius was the flagship of the First Fleet, which set out from Portsmouth, England, in 1787 to establish the first European colony in New South Wales, Australia. In 1790, the ship was wrecked on the reef, south east of Kingston Pier, in Slaughter Bay, Norfolk Island.

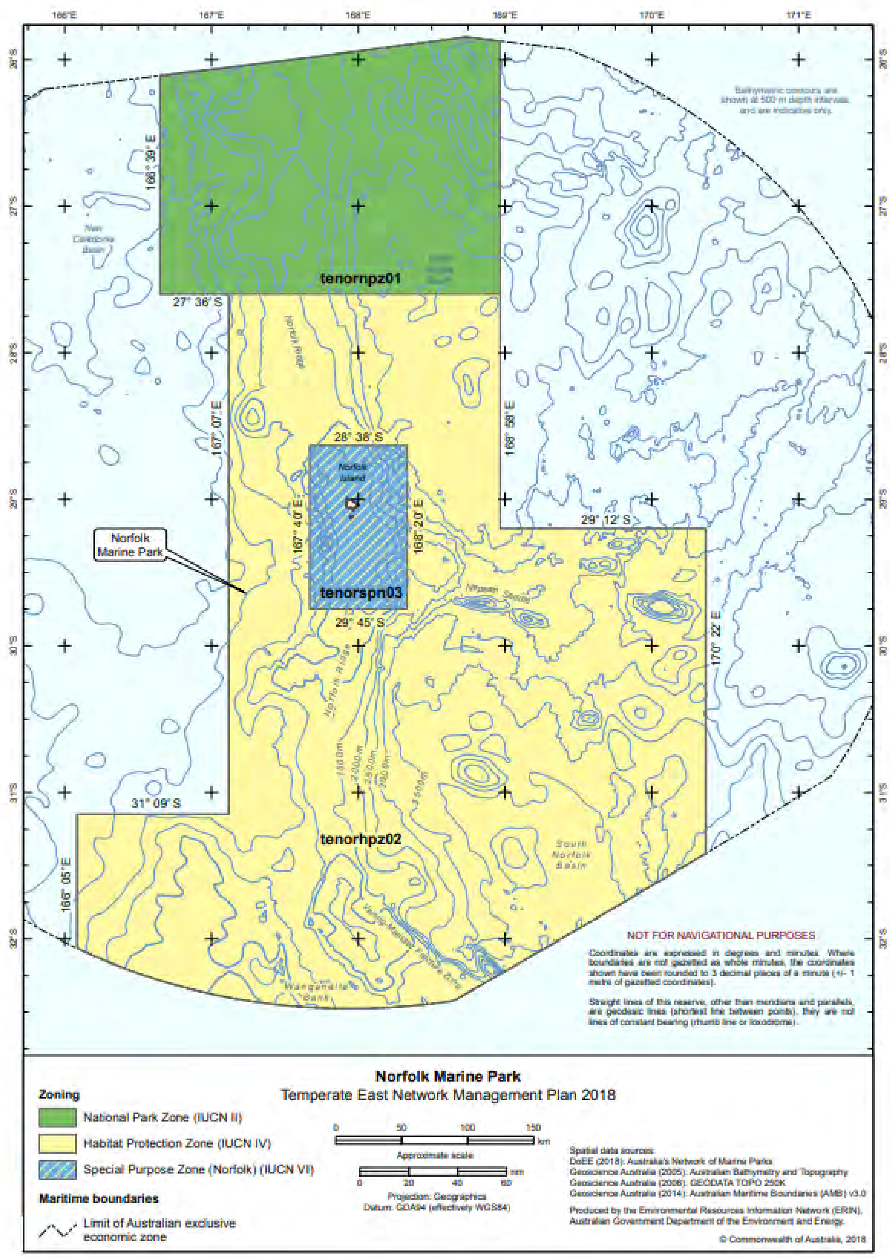


Figure 3-2 Norfolk Marine Park (Source: Marine Parks Australia 2020).

3.1.3 Matters of National Environmental Significance

Matters of National Environmental Significance (MNES) associated with marine habitats as identified in the EPBC Act 1999 Protected Matters Search (**Appendix A**) which are known to occur within a 10 km radius of the study site are listed below.

- No Wetlands of International Importance occur.
- The Great Barrier Reef does not occur within the study area.

- The Commonwealth Marine Area occurs within the study area.
- No listed Threatened Ecological Communities occur within the study area.
- 89 listed threatened species occur within the study area (12 are marine)
- 41 listed migratory species occur within the study area (22 are marine)

Other Matters listed under the EPBC Act 1999 and identified in the Protected Matters Search include:

- 38 Listed Marine Species occur within the study area.
- 28 Whales and Other Cetaceans occur within the study area.
- No Critical Habitats occur within the study area.
- One Australian Marine Park (Norfolk Island Marine Park) occurs within the study area.

3.1.4 Critical Habitat

The Register of Critical Habitat as declared under the EPBC Act 1999 was reviewed. Areas of Critical Habitat identified under the EPBC Act 1999 include:

1. *Diomedea exulans* (Wandering Albatross) - Macquarie Island, TAS.
2. *Lepidium ginninderrense* (Ginninderra Peppercress) - Northwest corner Belconnen Naval Transmission Station, ACT.
3. *Manorina melanotis* (Black-eared Miner) - Gluepot Reserve, Taylorville Station and Calperum Station, excluding the area of Calperum Station south and east of Main Wentworth Road.
4. *Thalassarche cauta* (Shy Albatross) - Albatross Island, The Mewstone, Pedra Branca, TAS.
5. *Thalassarche chrysostoma* (Grey-headed Albatross) - Macquarie Island, TAS.

None of these areas of listed Critical Habitat under the EPBC Act 1999 occur within the study area and will not be impacted by the Project (Department of Agriculture, Water and the Environment 2020).

3.1.5 Key Ecological Features (KEFs)

The following KEFs are listed in the EPBC Act Protected Matters Search as occurring within a 10 km radius of the study area:

1. Norfolk Ridge
2. Tasman Front and eddy field

Some general information for these KEFs, as taken from the Department of Agriculture, Water and the Environment (2020) Species Profile and Threats Database (https://environment.gov.au/sprat-public/action/kef/view/47 + https://environment.gov.au/sprat-public/action/kef/view/43) is provided.

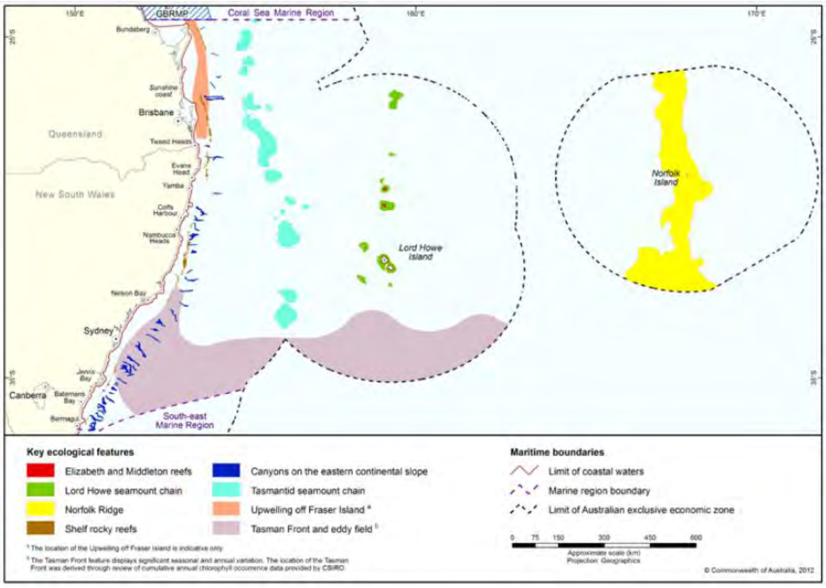


Figure 3-3 Location of KEFs in the Temperate East Marine Region.

3.1.5.1 Norfolk Ridge

Values

Stretching across the Temperate East Marine Region, the Norfolk Ridge provides a rich biological source of benthic biodiversity and endemism. Similarly, to the Lord Howe chain, the ridge also generates localised oceanographic changes which create sites of enhanced productivity and aggregate marine species. Within the Norfolk subregion of the Temperate East Marine Region, 41% of the area is classed as plateau with depths ranging between 50 m and 3,900 m and 1.24% is classed as pinnacles or seamount/guyot, with depths as shallow as 205 m (Keene et al. 2008).

The high diversity in seamount benthos is likely to be caused by relatively productive benthic habitats, which support population densities that are far higher than surrounding regions (de Forges et al. 2000; Dambacher et al. 2011). Benthic habitats along the entire length of Norfolk Ridge are also thought to act as stepping stones for fauna dispersal, connecting deep water fauna from New Caledonia to New Zealand (Williams et al. 2006; Dambacher et al. 2011). However, the semi-permanent Norfolk Eddy may create a closed system that limits connectivity and increases endemism within the South Norfolk Basin (Williams et al. 2006). Significantly higher catch rates of tuna have also been reported from the Norfolk Ridge (Morato et al. 2010).

National and/or Regional Importance

This KEF is recognised for its enhanced ecological functioning and integrity, and biodiversity, which apply to both its benthic and pelagic habitats.

Location

The Norfolk Ridge is set within a region of remnant volcanic arcs, plateaux, troughs and basins (Keene et al. 2008; Dambacher et al. 2011). The ridge runs southward from New Caledonia to New Zealand and lies between the New Caledonia Trough to the west and the Norfolk Basin to the east. The spatial boundary of this KEF, as defined on the Conservation Values Atlas, is based on depth contours identified in the Geoscience Australia Bathymetric contours dataset 2005.

Description

The Tasman Front conveys tropical species to the southern portion of the ridge within the Temperate East Marine Region, and there is a diverse assemblage of tropical and temperate species with evidence of connectivity to the benthic fauna of Lord Howe Rise (Williams et al. 2011; Dambacher et al. 2011).

3.1.5.2 Tasman Front and eddy field

Values

The Tasman Front and eddy field contains complex and dynamic oceanographic processes supporting transient patches of enhanced productivity that, in turn, attract aggregations of species across trophic levels, including top predators such as tuna and sharks. This feature also supports biological connectivity with seamount habitats further offshore.

National and/or Regional Importance

The Tasman Front and eddy field is defined as a key ecological feature as it is an area of high productivity and biodiversity, endemism, and aggregations of marine life.

Location

The Tasman Front is a region of intermediate productivity that separates the warm, nutrient-poor waters of the Coral Sea from the nutrient-rich waters of the Tasman Sea (Condie & Dunn 2006; Denham & Crook 1976; Dambacher et al. 2011). The Tasman Front feature displays significant seasonal and annual variation. The spatial definition of the Tasman Front, as displayed in the Conservation Values Atlas, was derived through review of cumulative annual chlorophyll occurrence data provided by CSIRO.

Description

The front is formed by a meandering current between 27°S and 33°S that moves to the north in winter and to the south in summer (Ridgway & Dunn 2003). The front's boundary can appear diffuse and impermanent, and its associated eddies vary in strength, shape and location. The front is therefore best characterised as an average over time (Dambacher et al. 2011).

Across the southern portion of the Temperate East Marine Region, the Tasman Front creates a complex oceanographic environment with vertical mixing (Ridgway & Dunn 2003; Dambacher et al. 2011). Patches of productivity are important for mid-level consumers including turtles (Boyle et al. 2009; Young et al. 2011) and top fish predators (Dambacher et al. 2011; Young et al. 2011). Fisheries oceanography studies describe a positive relationship between fish catch rates and proximity to frontal features, and a predominance of bigeye tuna and swordfish associated with the Tasman Front (Campbell & Hobday 2003; Dambacher et al. 2011).

This feature is also considered important for providing connectivity to the Lord Howe seamount chain and Norfolk Ridge for tropical species (Dambacher et al. 2011). The front's interaction with bathymetric platforms and basins causes it to meander (Dambacher et al. 2011) and shed a series or field of large, warm-core, quasi-permanent eddies that extend from the southern portion of the Norfolk Basin, south-east of Norfolk Island, to New Zealand's East Cape (Ridgway & Dunn 2003).

3.2 Marine Flora

Marine flora includes marine algae, seagrasses, mangroves and saltmarsh. Marine algae are found in the waters around Norfolk Island and are described further below.

3.2.1 Marine Algae

There are 236 species of marine benthic algae described in *Marine Benthic Algae of Norfolk Island, South Pacific*, with 41 species of Chlorophyta, 41 of Phaeophyta and the remainder (154) Rhodophyta (Millar 1999). Apart from several undescribed taxa, none are endemic to Norfolk Island, compared to Lord Howe Island, where there was found to be much higher levels of endemism. The study found that there are 106 common species between Norfolk and Lord Howe Island, with the species *Solieria anastomosa* and *Dasya fruticulosa* apparently restricted to Norfolk and Lord Howe Island. Around half of Norfolk Island's marine algae was found to be fairly typical of those found on the Great Barrier Reef and the western edge of the Coral Sea (Millar 1999).

Although there are some species for which Norfolk Island represents a major range extension into or within the Pacific (e.g. *Dasycladus ramosus*, *Halicoryne wrightii*, *Anotrichium anthericephalum*, *Herposiphonia arcuata* and *Polysiphonia japonica*), a considerable number of the species are shared with the Great Barrier Reef and the New South Wales coastline as well as Lord Howe Island. Major northern range extensions are recorded for the large temperate brown alga *Ecklonia radiata*, and possibly *Phyllospora comosa* and *Durvillaea antarctica*, although the island more typically hosts numerous tropical algae such as *Trichogloea requienii* and members of the green algal order Dasycladales including *Halicoryne wrightii*, *Bornetella nitida* and *Neomeris annulata*. As a consequence of this survey, the two rhodymeniacean species *Chrysymenia ornata* and *C. digitata* are considered to be conspecific (Millar 1999).

Millar (1999) found that the marine algae species of *Gloiocladia rubrispora*, which has a fairly disjunct distribution, has been found on Norfolk Island. This species was initially found in the central western Atlantic. The presence of *Ptilocladia vestita* and *Gloiocladia halymenioides* around Norfolk Island indicates a strong cool-temperate link, as these species were historically restricted to southern and western Australia.

Marine algae dominates much of the substrate around the high energy area of Kingston Pier (Norfolk Island Public Reserves Plans of Management 2003). The intertidal zone of the harbour side of Kingston Pier is dominated by green and red algae, with dominant species including the sea lettuce "*Ulva ulva*", *Enteramorpha* species and the grape weed *Caulerpa racemose*, locally known as 'dead man's fingers'. Other species of algae found around the Pier included *Ventricaria ventricosa* and *Caulperpa racemosa* (Marges 2005). The algae within the area around Kingston is heavily relied upon by lagoon and other fishes as an important food source.

The lagoon at Slaughter Bay is shallow (2.5 m deep) and has a soft sandy bottom with scattered shells and coral rubble and is dominated by Sargassum, Caulerpa, Cutleria, Helminthocladia, Galaxaura, Liagora and members of the Dictyotales. On the outer reef edge there exists a community of Codium, Caulerpa, Valonia, Dasycladus, and more Dictyotales. The reef top has substantial mats of Hormosira, particularly in winter months. The rock platforms at The Cord and Garnett Point have mats of Caulocystis and Hormosira respectively covering the edges and sides of the rock pools, the interior of which is dominated by Sargassum, Caulerpa and members of the Dictyotales (Millar 1999).

The following marine algae species were reported by Aurecon Australia (2011) as occurring in nearby Ball Bay based on a field survey as well as a desktop investigation (of Christian and Marges 1995 and Coleman 1991).

- Red coralline algae - *Corallina officinalis*
- Grape weed - *Caulerpa racemosa*
- Feather algae - *Caulerpa sertularioides*
- Sailor's eyeballs - *Valonia forbesii*
- *Padina sp.*
- *Codium spongiosum*
- Brown algae - *Dictyota dochotoma*
- Brown algae - *Phaeophyta sp.*
- Red coralline algae - *Rhodophyta Sp.*
- Green algae - *Chlorophyta sp.*
- *Sporolithon durum*
- Sea lettuce - *Ulva sp.*
- *Laurencia sp.*
- *Halmeda cuneata*
- Iridescent bluish algae - *Dictyota dichotoma*

3.3 Marine Fauna

Norfolk Island has a unique assemblage of marine species. While most groups have not been comprehensively documented around 230 species of algae, 57 species of corals, 400 species of molluscs (including 160 species of opistobranchs), 254 species of fish and several mammals have been identified to date. The numbers of species of most groups are low in comparison with Eastern Australia and New Caledonian reefs because of Norfolk Island's extreme isolation, but the mix is unique. There are also a number of endemic species, and a large number of subtropical and Tasman Sea endemics. However, the number of marine endemic species is low compared with the Island's terrestrial biodiversity (Zann et.al 2001).

A general overview of the marine fauna of the Temperate East Marine Region and Norfolk Island is provided below, along with identification of all current threatened and protected marine species listed under the EPBC Act 1999 and identified in a Protected Matters Search (**Appendix A**) as having the potential to occur in the study area (undertaken on 4 February 2020).

3.3.1 Marine Fishes (Bony Fish, Sharks, Rays and Syngnathids)

3.3.1.1 Bony Fish

There are a limited number of available studies documenting fish within the Norfolk Island region, with the most comprehensive study being a checklist of Norfolk Island fish from 1993 (Francis 1993). Other studies adding to this literature include Randall and Gueze (1992), Randall and Francis (1993) and Francis (1996) and Mosley (2001). The data was included in a more recent review of the geographic distribution of marine reef fishes in the New Zealand region (Francis 1996). Tropical and subtropical fish species dominate the fauna of Norfolk Island, with fish fauna appearing to have originated largely by larval dispersal from Australia and the Coral Sea (Francis 1993). In Francis 1996, the geographic distributions of 375 reef and reef-associated fishes are reported for 16 regions ranging from Norfolk and Kermadec Islands in the north to Macquarie Island in the south. Species diversity was reported as being greatest at Norfolk Island (228 species) and lowest at Macquarie Island (6 species). Diversity declined linearly with increasing latitude. Most species were either widespread or had very restricted distributions. Widespread species generally ranged from Three Kings Islands to Stewart Island. The most widespread species occurred in 14 of the 16 regions. Species with restricted distributions were mainly tropical or subtropical species that occurred at one or more of Norfolk Island, Kermadec Islands, and North-East North Island. Species found within the Indo-West-Central Pacific dominate Norfolk Island fish fauna and there is a high proportion of species which are common species between the Island and Australia (Francis 1993). A fish survey conducted by Mosley (2001) showed that approximately 58% of the coastal fish of Norfolk Island are tropical, 33% sub tropical and 8% temperate.

The more recent biodiversity survey completed by Edgar et al (2017) identified 90 fish species from Norfolk Island. Abundance was highest for the Smoky Puller, *Chromis fumea* and Lea's Cardinalfish *Taeniamia leai*. Similar to findings by Francis (1993), Norfolk Island was characterised by endemic, subtropical and temperate species such as Banded Scalyfin, *Parma polylepis*, Pacific rock cod, *Trachypoma macracanthus* and Notch-head Marblefish, *Aplodactylus etheridgii*. Compared to Lord Howe Island (and Middleton and Elizabeth Reefs), Norfolk Island had the lowest biomass and species richness, as well as lowest biomass of large (>20 cm) fishes. A total of 20 cryptic fish species were also recorded from Norfolk Island during the CMR survey of which blennies and cardinalfish were the most abundant (Edgar et al 2017).

The main recreational target species on Norfolk Island include yellowfin tuna (*Thunnus albacares*), kingfish (*Seriola lalandi*) and Australian salmon (*Arripis trutta*), which can all be found around the inshore waters of the island. The harbour side of Kingston Pier is a popular fishing area, with common target species also including large Damsel fish (*Parma polylepis* (Aartuti), wrasse (*Pseudolabris lucelentus* (po'ov)), several species of trevally (ofie), occasional kingfish (*S. lalandi*) as well as garfish and mullets (Marges 2005).

A large number of fish species were identified in a study of fish species of Norfolk Island and surrounds (Francis 1993). These are listed below:

- *Mustelus lenticulatus*
- *Muraenichthys nicholsaw*
- *Myrichthus sp.*
- *Conger wilsoni*
- *Spratelloides delicatulus*
- *Chanos chanos*
- *Gonorynchidae greyi*
- *Plotosus lineatus*
- *Saurida gracilis*

- *Synodus dermatogenys*
- *Synodus doaki*
- *Synodus similis*
- *Synodus variegatus*
- *Trachinocephalus myops*
- *Centroberyx affinis*
- *Aulostomus chinensis*
- *Fistularia commersonii*
- *Ablabys taenianotus*
- *Dendrochirus zebra*
- *Pterois volitans*
- *Scorpaena cookie*
- *Scorpaenodes guamensis*
- *Scorpaenodes scaber*
- *Acanthistius cinctus*
- *Aulacocephalus temmincki*
- *Epinephelus cyanopodus*
- *Epinephelus daemelii*
- *Epinephelus fasciatus*
- *Epinephelus merra*
- *Epinephelus octofasciatus*
- *Epinepheus rivulatus*
- *Pseudanthias pictilis*
- *Lotella phycis*
- *Dermatopsis macrodon*
- *Antennarius pictus*
- *Alabes parvulus*
- *Lepadichthys frenalus*
- *Myripristis berndti*
- *Pseudanthias squamipinnis*
- *Belonepterygion fasciolatum*
- *Plesiops insularis*
- *Kuhlia mugil*
- *Heteropriacanthus cruentatus*
- *Apogon crassiceps*
- *Apogon doederleini*
- *Apogon kallopterus*
- *Apogon norfolcensis*
- *Apogon* sp.
- *Archamia leai*
- *Echeneis naucrates*
- *Remora remora*
- *Carangoides orthogrammus*
- *Caranx melampygus*
- *Caranx sexfasciatus*
- *Elagatis bipinnulata*
- *Pseudocaranx dentex*
- *Seriola dumerili*
- *Euleptorhamphys viridis*
- *Hyporhamphis australis*
- *Ablennes hians*
- *Platybelone argalus*
- *Seriola hippos*
- *Seriola lalandi*
- *Seriofa rivoliana*
- *Trachinotus baillonii*
- *Trachinotus blochii*
- *Arripis trutta*
- *Arripis sp.*
- *Lutjanus fulvus*
- *Lutjanus kasmira*
- *Paracaesio xanthura*
- *Pagrus auratus*
- *Gnathodentex aureolineatus*
- *Gymnocranius euanus*
- *Lethrinus miniatus*
- *Mulloidichthys Flavolineatus*
- *Mulloidichthys vanicolensis*
- *Parupeneus ciliates*
- *Parupeneus multifasciatus*

- *Parupeneus pleurostigma*
- *Parupeneus spilurus*
- *Upeneichthys lineatus*
- *Upeneus francisi*
- *Monodactylus argenteus*
- *Parapriacanthus ransonneti*
- *Pempheris analis*
- *Girella cyanea*
- *Girella elevate*
- *Kyphosus bigibbus*
- *Kyphosus cinerascens*
- *Kyphosus sydneyanus*
- *Kyphosus vaigiensis*
- *Atypichthys latus*
- *Microcanthus strigatus*
- *Bathystethus cultratus*
- *Labracoglossa nitida*
- *Platax teiru*
- *Amphichaetodon howensis*
- *Chaetodon citrinellus*
- *chaetodon flavirostris*
- *Chaetodon lineolatus*
- *Chaetodon lunula*
- *Chaetodon melannotus*
- *Chaetodon mertensii*
- *Chaetodon pelewensis*
- *Chaetodon plebeius*
- *Chaetodon tricinctus*
- *Chaetodon trifascialis*
- *Chaetodon trifasciatus*
- *Chaetodon vagabundus*
- *Forcipiger flavissimus*
- *Heniochus Monoceros*
- *Centropyge bispinosus*
- *Centropyge tibicen*
- *Chaetodontoplus conspicillatus*
- *Evistias acutirostris*
- *Abudefduf sexfasciatus*
- *Abudefduf sordidus*
- *Abudefduf vaigiensis*
- *Abudefduf whitleyi*
- *Amphiprion latezonatus*
- *Chromis Flavomaculata*
- *Chromis fumea*
- *Chromis hypsilepis*
- *Chromis vanderbilti*
- *Chrysiptera glauca*
- *Chrysiptera notialis*
- *Neoglyphidodon polyacanthus*
- *Parma albo scapularis*
- *Parma polylepis*
- *Plectroglyphidodon*
- *Plectroglyphidodon johnstonianus*
- *Pomacentrus pavo*
- *Stegastesfasciolatus*
- *Stegastes gascoynei*
- *Teixeirichthys* sp.
- *Cirrhitus splendens*
- *Paracirrhites arcatus*
- *Paracirrhites forsteri*
- *Chironemus microlepis*
- *Aplodactylus etheridgii*
- *Cheilodactylus ephippium*
- *Cheilodactylus vestitus*
- *Nemadactylus macropterus*
- *Mugil cephalus*
- *Myxus elongatus*
- *Valamugil seheli*

- *Sphyraena acutipinnis*
- *Anampses elegans*
- *Bodianus perditio*
- *Bodianus unimaculatus*
- *Cheilio inermis*
- *Coris bulbifrons*
- *Coris picta*
- *Coris sandageri*
- *Cymolutes praetextatus*
- *Gomphosus varius*
- *Halichoeres margaritaceus*
- *Halichoeres trimaculatus*
- *Labroides dimidiatus*
- *Notolabrus inscriptus*
- *Novaculichthys taeniourus*
- *Pseudojuloides elongatus*
- *Pseudolabrus luculentus*
- *Stethojulis bandanensis*
- *Stethojulis maculatus*
- *Suezichthys arquatus*
- *Thalassoma amblycephalum*
- *Thalassoma hardwicke*
- *Thalassoma Jansenii*
- *Thalassoma lunare*
- *Thalassoma lutescens*
- *Thalassoma purpureum*
- *Thalassoma trilobatum*
- *Scarus rivulatus*
- *Limnichthys fasciatus*
- *Parapercis* sp.
- *Enneapterygius rufopilea*
- *Enneapterygius sp*
- *Norfolkia squamiceps*
- *Heteroclinus roseus*
- *Cirripectes alboapicalis*
- *Cirripectes castaneus*
- *Entomacrodus niuafoouensis*
- *Entomacrodus striatus*
- *Istiblennius dussumieri*
- *Istiblennius edentulus*
- *Parablennius serratolineatus*
- *Plagiotremus tapeinosoma*
- *Callionymus calcaratus*
- *Diplogrammus goramensis*
- *Bathygobius aeolosoma*
- *Eviota albolineata*
- *Eviota prasina*
- *Eviota smaragdus*
- *Eviota* sp.
- *Priolepis semidoliatus*
- *Vanderhorstia*
- *Acanthurus dllssumieri*
- *Acanthurus nlgrofuscus*
- *Acanthurus triostegus*
- *Naso annulatus*
- *Naso unicornis*
- *Prionurus maculatus*
- *Zebrasoma scopas*
- *Zanelus cornutus*
- *Sm·da australis*
- *Bothus mancus*
- *Bothus pantherinus*
- *Peltothtimphus latus*
- *Aseraggodes bahamondei*
- *Rhinecanthus rectangulus*

- *Suffiamen fraenatus*
- *Cantheschenia longipinnis*
- *Pervagor alternans*
- *Pervagor janthinosoma*
- *Lactoria diaphana*
- *Ostracion cubicus*
- *Canthigaster callisterna*
- *Torquigener altipinnis*
- *Diodon hystrix*

Threatened and Protected Fish Species

EPBC Act 1999 Listed bony fish which occur in the Temperate East Marine Region include:

- Eastern gemfish — eastern Australian population (*Rexea solandri*) - Conservation dependent
- Orange Roughy (*Hoplostethus atlanticus*)- Conservation dependent
- Black cod (*Epinephelus daemelii*) – Vulnerable

(DSEWPC 2012).

The Black rockcod (*E. daemelii*) is the only bony fish listed in the EPBC Act 1999 Protected Matters Search (**Appendix A**) which was undertaken for the Project. The species is listed as vulnerable, with "species or species habitat likely to occur within area". Black rockcod are usually found in caves, gutters and beneath bommies on rocky reefs, from near shore environments to depths of at least 50 m. Small juveniles are often found in coastal rock pools, and larger juveniles around rocky shores in estuaries. They are territorial and often occupy a particular cave for life (NSW DPI 2015).

3.3.1.2 Sharks

There have been reports of large shark populations around Norfolk Island from as far back as the early Polynesian settlement (1300-1500), where shark teeth have been discovered with artefacts found around the island. Records from European settlement on the island also recount many shark sightings around the island. Very little research has been conducted on sharks within the South Pacific, specifically around Norfolk Island, but Malcolm Francis documented that the "*range of habitats and water temperatures suggest that the shark fauna (around Norfolk Island) is likely to be relatively diverse… however relatively few shark species have been formally recorded from the Exclusive Economic Zone (EEZ) surrounding Norfolk Island*" (Francis, n.d.).

Important breeding, feeding and aggregation areas for sharks are found throughout the Temperate East Marine Region, including areas around Norfolk Island. Shark species identified in a study of fish species of Norfolk Island and surrounds are listed below (Francis 1993).

- Galapagos shark (*Carcharhinus galapagensis*)
- Grey reef shark (*Carcharhinus amblyrhynchos*)
- Smooth hammerhead shark (*Pshyrna zygaena)*
- Tiger shark (*Galeocerdo cuvier*)
- White shark (*Carcharodon carcharias*)

Galapagos sharks and reef sharks are commonly seen (daily) alongside the Kingston Pier, feeding on scraps of fish thrown into the water by fishermen. Tiger sharks are known to occur at Cascade on the northern side of the island and great whites at Headstone on the western side of the island (Source: local knowledge and field observations).

Threatened and Protected Shark Species

EPBC Act 1999 Listed shark species known to occur in the Temperate East Marine Region include:

- Grey nurse shark - east coast population (*Carcharias taurus*) - Critically endangered
- Longfin mako shark (*Isurus paucus*) - Migratory
- Porbeagle (*Lamna nasus*) - Migratory
- Shortfin mako shark (*Isurus oxyrinchus*) – Migratory
- Whale shark (*Rhincodon typus*) - Vulnerable, migratory
- White shark (*C. carcharias*) - Vulnerable, migratory

(DSEWPC 2012).

Listed shark species known to occur in the Temperate East Marine Region on an infrequent basis include:

- Green sawfish (*Pristis zijsron*) – Vulnerable
- School shark (*Galeorhinus galeus*) - Conservation dependent

(DSEWPC 2012).

The white shark (*C. carcharias*) is the only species of shark listed under the EPBC Act 1999 which is listed in the Protected Matters Search (**Appendix A**) for the Project (with “species or species habitat likely to occur within area”).

3.3.1.3 Rays

Rays in the Temperate East Marine Region are of great ecological importance due to their position at the top of the food chain (Keable 2007). Ray species identified in a study of fish species of Norfolk Island and surrounds are provided below (Francis 1993).

- Abbott’s moray (*Gymnothorax eurostus*)
- Grey moray (*Gymnothorax nubilus*)
- Griffin’s moray (*Gymnothorax obesus*)
- Lipspot moray (*Gymnothorax chilospilus*)
- Lord Howe Island moray (*Gymnothorax annasona*)
- Lowfin moray (*Gymnothorax porphyreus*)
- Mosaic moray (*Enchelycore ramosus*)
- New Zealand eagle ray (*Myliobatis tenuicaudatus*)
- Round ribbontail ray / bullray (*Taeniura meyeni*)
- Stingaree (*Urolophus* sp)

Round ribbon ray / bull ray (*T. meyeni*) are commonly sighted late in the afternoon in Kingston Harbour, particularly if boats have been fishing.

Threatened and Protected Ray Species

The Syngnathidae is a group of bony fishes which include seahorses, pipefishes, pipehorses and sea dragons. Australia has the highest recorded diversity of species, with about 25-37% of the world's populations occurring within Australian waters. Syngnathids are characterised by and have thick, external armor and a tubular snout.

Syngnathid species identified in a study of fish species of Norfolk Island and surrounds are given below (Francis 1993):

- Booth's pipefish (*Halicampus boothae*).

This species lives in rocks and coral reefs to depths of 30 m where it can grow to lengths of 17.5 cm (Dawson 1985).

3.3.1.4 Syngnathids

Threatened and Protected Syngnathid Species

All species of Syngnathids are listed and protected under the EPBC Act 1999.

Booth's pipefish (which is known from Norfolk Island) is listed in the EPBC Act 1999 Protected Matters Search for the Project (as a Listed Marine species and "species or species habitat may occur within area" (see **Appendix A**).

There are also a number of listed syngnathid species known to occur in the greater Temperate East Marine Region, however it is unclear whether these species inhabit the areas immediately surrounding Norfolk Island, as there are only limited studies available for the area. None of these species were listed in the EPBC Act 1999 Protected Matters Search for the Project.

- Big-belly seahorse (*Hippocampus abdominalis*) – Listed Marine
- Bullneck seahorse (*Hippocampus minotaur*) – Listed Marine
- Duncker's Pipehorse (*Solegnathus dunckeri*) – Listed Marine
- Hardwicke's pipefish (*Solegnathus hardwickii*) – Listed Marine
- Kellogg's seahorse (*Hippocampus kelloggi*) – Listed Marine
- Sad seahorse (*Hippocampus tristis*) – Listed Marine
- Weedy seadragon (*Phyllopteryx taeniolatus*) – Listed Marine

(DSEWPC 2012).

3.3.2 Marine Mammals (Whales and Dolphins)

Threatened and Protected Cetaceans (Whales, Dolphins and Porpoises)

Cetaceans (whales, dolphins and porpoises) are all are protected under the EPBC Act 1999 in the Australian Whale Sanctuary and, to some extent, beyond its outer limits. This includes the area of the Temperate East Marine Region.

3.3.2.1 Whales

The following 29 whale species listed under the EPBC Act are known to occur in the Temperate East Marine Region. Species and their conservation status are listed below:

- Andrew's beaked whale (*Mesoplodon bowdoini*) - Cetacean
- Antarctic minke whale (*Balaenoptera bonaerensis*) - Migratory, cetacean
- Arnoux's beaked whale (*Berardius arnuxii*) - Cetacean
- Blainville's beaked whale (*Mesoplodon densirostris*) - Cetacean
- Blue whale (*Balaenoptera musculus*) - Endangered, migratory, cetacean
- Bryde's whale (*Balaenoptera edeni*) - Migratory, cetacean
- Cuvier's beaked whale (*Ziphius cavirostris*) - Cetacean
- Dwarf minke whale (*Balaenoptera acutorostrata*) - Cetacean
- Dwarf sperm whale (*Kogia simus*) - Cetacean
- False killer whale (*Pseudorca crassidens*) - Cetacean
- Fin whale (*Balaenoptera physalus*) - Vulnerable, migratory, cetacean
- Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*) - Cetacean
- Gray's beaked whale (*Mesoplodon grayi*) - Cetacean
- Hector's beaked whale (*Mesoplodon hectori*) - Cetacean
- Humpback whale (*Megaptera novaeangliae*) - Vulnerable, migratory, cetacean
- Killer whale (*Orcinus orca*) - Migratory, cetacean
- Long-finned pilot whale (Globicephala melas) - Cetacean
- Melon-headed whale (*Peponocephala electra*) - Cetacean
- Pygmy killer whale (*Feresa attenuata*) - Cetacean
- Pygmy right whale (*Caperea marginata*) - Migratory, cetacean
- Pygmy sperm whale (Kogia breviceps) - Cetacean
- Sei whale (*Balaenoptera borealis*) - Vulnerable, migratory, cetacean
- Shepherd's beaked whale (*Tasmacetus shepherdi*) - Cetacean
- Short-finned pilot whale (*Globicephala macrorhynchus*) - Cetacean
- Southern bottlenose whale (*Hyperoodon planifrons*) - Cetacean
- Southern right whale (*Eubalaena australis*) - Endangered, migratory, cetacean

- Sperm whale (*Physeter macrocephalus*) - Migratory, cetacean
- Strap-toothed beaked whale (*Mesoplodon layardii*) - Cetacean
- True's beaked whale (*Mesoplodon mirus*) - Cetacean

(DSEWPC 2012).

The EPBC Act 1999 Protected Matters Search undertaken for the Project (**Appendix A**) lists the following 20 whales that have the potential to occur within the study area (i.e. within 10 km of the site).

- Antarctic minke whale - Species or species habitat likely to occur within area
- Blainville's beaked whale - Species or species habitat may occur within area
- Blue whale - Species or species habitat may occur within area
- Bryde's whale - Species or species habitat likely to occur within area
- Cuvier's beaked whale - Species or species habitat may occur within area
- Dwarf sperm whale - Species or species habitat may occur within area
- Fin whale - Species or species habitat likely to occur within area
- Gray's beaked whale - Species or species habitat may occur within area
- Humpback whale - Species or species habitat may occur within area
- Killer whale - Species or species habitat may occur within area
- Long-finned pilot whale - Species or species habitat may occur within area
- Melon-headed whale - Species or species habitat may occur within area
- Minke whale - Species or species habitat may occur within area
- Pygmy killer whale - Species or species habitat may occur within area
- Pygmy sperm whale - Species or species habitat may occur within area
- Sei whale - Species or species habitat likely to occur within area
- Short-finned pilot whale - Species or species habitat may occur within area
- Southern right whale - Species or species habitat may occur within area
- Sperm whale - Species or species habitat may occur within area
- Strap-toothed beaked whale - Species or species habitat may occur within area

3.3.2.2 Dolphins

As with whales above, all dolphins and porpoises are protected under the EPBC Act 1999. Twelve (12) species of dolphin are known to occur in the Temperate East Marine Region, and their conservation status under the EPBC Act 1999 is listed below:

- Bottlenose dolphin (*Tursiops truncatus*) - Cetacean
- Common dolphin (*Delphinus delphis*) - Cetacean
- Fraser's dolphin (*Lagenodelphis hosei*) - Cetacean
- Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) - Cetacean
- Indo-Pacific humpback dolphin (*Sousa chinensis*) - Migratory, cetacean
- Pantropical spotted dolphin (*Stenella attenuata*) - Cetacean
- Risso's dolphin (*Grampus griseus*) - Cetacean
- Rough-toothed dolphin (*Steno bredanensis*) - Cetacean
- Southern right whale dolphin (*Lissodelphis peronii*) - Cetacean
- Spinner dolphin (*Stenella longirostris*) - Cetacean
- Striped dolphin (*Stenella coeruleoalba*) - Cetacean
- Dusky dolphin (*Lagenorhynchus obscurus*) - Cetacean, migratory (may infrequently occur)

(DSEWPC 2012).

Eight of these dolphin species are listed in the EPBC Act 1999 Protected Matters Search for the Project (**Appendix A**) including:

- Bottlenose dolphin - Species or species habitat may occur within area
- Common dolphin - Species or species habitat may occur within area
- Fraser's dolphin - Species or species habitat may occur within area
- Long-snouted spinner dolphin - Species or species habitat may occur within area
- Pantropical spotted dolphin - Species or species habitat may occur within area
- Risso's dolphin - Species or species habitat may occur within area
- Rough-toothed dolphin - Species or species habitat may occur within area
- Striped dolphin - Species or species habitat may occur within area

3.3.2.3 Seals and Sea Lions

There are two species of seal and sea lion that are likely to be encountered in the Temperate East Marine Region, being the Australian fur seal (*Arctocephalus pusillus doriferus*) and New Zealand fur seal (*Arctocephalus forsteri*). There are no known breeding colonies within the Temperate East Marine Region, but it is likely that these species of seal traverse both state and Commonwealth waters (Keable 2007). Neither species was listed in the EPBC Act 1999 Protected Matters Search for the Project, (however both are listed under the EPBC Act), which may be a result of them being vagrants to this particular area. In any case, it is not expected that they would occur at the site except on very rare occasions.

3.3.3 Marine Reptiles (Turtles and Sea Snakes)

There are a number of marine reptile species found within the Temperate East Marine Region, with four species of marine turtle listed under the EPBC Act 1999 known to occur, and all listed as threatened and migratory. Green and loggerhead turtles are the most common marine turtles found in the Temperate East Marine Region, with nesting sites scattered across the NSW and Queensland coasts. Hawksbill and leatherback turtles are likely to be found foraging within the region.

According to the desktop review, the Green turtle is commonly seen around Norfolk Island. In recent years, Hawksbill and Loggerhead Turtles have also been recorded in the waters around Norfolk Island (Parsons Brinckerhoff 2009). A study undertaken in 2011 found that the Norfolk Island group is used for foraging by resident adult and juvenile green turtles (*Chelonia mydas*) and adult hawksbill turtles (*Eretmochelys imbricata*) (Pendoley & Christian 2011). It is also reported that literage crews regularly see adult green turtles off the Kingston Pier. This was confirmed by a turtle biologist who documented a green turtle observation off the Kingston Pier on 16 Jan 2006 during ultralight aerial surveys of the marine turtles around the island (pers obs, Pendoley and Ryan 2006). A mature hawksbill was also photographed in Cresswell Bay in 2005 (Pendoley 2009).

Threatened and Protected Reptiles

Twenty-five (25) listed marine reptile species (turtles and seasnakes) are known to occur within the Temperate East Marine Region as are listed below:

- Green turtle (*Chelonia mydas*) - Vulnerable, migratory, marine
- Hawksbill turtle (*Eretmochelys imbricata*) - Vulnerable, migratory, marine
- Leatherback turtle (*Dermochelys coriacea*) - Endangered, migratory, marine
- Loggerhead turtle (*Caretta caretta*) - Endangered, migratory, marine
- Beaked seasnake (*Enhydrina schistosa*) - Marine
- Black-ringed seasnake (*Hydrelaps darwiniensis*) - Marine
- Blue-lipped sea krait (*Laticauda laticaudata*) - Marine
- Colubrine sea krait (*Laticauda colubrine*) - Marine
- Dubois’ seasnake (*Aipysurus duboisii*) - Marine
- Elegant seasnake (*Hydrophis elegans*) - Marine
- Horned seasnake (*Acalyptophis peronii*) - Marine
- Laboute’s seasnake (*Hydrophis laboutei*) - Marine
- Little file snake (*Acrochordus granulatus*) - Marine
- Marbled or spine-tailed seasnake (*Aipysurus eydouxii*) - Marine
- Olive seasnake (*Aipysurus laevis*) – Marine
- Olive-headed seasnake (*Hydrophis major*) - Marine

- Plain-banded seasnake (*Hydrophis vorisi*) - Marine
- Small-headed seasnake (*Hydrophis mcdowelli*) - Marine
- Spectacled seasnake (*Hydrophis kingii*) - Marine
- Spotted seasnake (*Hydrophis ornatus*) - Marine
- Stokes' seasnake (*Astrotia stokesii*) - Marine
- Turtle-headed seasnake (*Emydocephalus annulatus*) - Marine
- White-bellied mangrove snake (*Fordonia leucobalia*) - Marine
- Yellow seasnake (*Hydrophis spiralis*) - Marine
- Yellow-bellied seasnake (*Pelamis platurus*) - Marine

(DSEWPC 2012).

Five (5) marine reptiles (all of which are turtles) are listed under the EPBC Act 1999 Protected Matters Search for the Project (**Appendix A**) with the potential to occur in the study area (including the flatback turtle which is not listed above) including:

- Loggerhead turtle - Species or species habitat likely to occur within area
- Green turtle - Species or species habitat likely to occur within area
- Leatherback turtle - Species or species habitat likely to occur within area
- Hawksbill turtle - Species or species habitat likely to occur within area
- Flatback turtle (*Natator depressus*) - Species or species habitat likely to occur within area

3.3.4 Marine Invertebrates

Marine invertebrates make up a large proportion of sea life in the Temperate East Marine Region and comprise the greatest majority of marine biodiversity. Marine invertebrates range in size from microscopic to several metres in length and may be solitary or colonial organisms (e.g. many ascidians, corals and sponges) (Ponder et al. 2002). No extensive marine invertebrate studies of Norfolk Island have been undertaken in recent years, limiting information available on marine invertebrates around the island. Some information is provided below.

3.3.4.1 Sessile Invertebrates (including Corals)

There is little available published data on the sessile invertebrates of Norfolk Island. A number of colonial ascidians occur around Norfolk Island, including the two-colour ascidian *Lissoclinum bistriatum*. Studies of bryozoans around the Norfolk Island Seamounts Area has not been undertaken, however, one study concluded that the bryozoan fauna found in the north of the island indicates that bryozoan species around the rest of the island were morphologically and taxonomically diverse (Cook et al. 2018)

Sponges within the Temperate Eastern Marine Region exist from inter-tidal to the deepest ocean zones, from shallow rocky and coral reefs, algal and seagrass beds, to caves, buried in rubble, or on sandy slopes (Keable 2007). Sponges exhibit very patchy special distributions within the region at large and small scales. In some cases, sponges form the dominant structural benthic component of a seafloor community and be practically absent nearby (Keable 2007).

The following sessile invertebrates were reported by Aurecon Australia (2011) as occurring in nearby Ball Bay based on a field survey and a desktop investigation of Christian and Marges 1995 and Coleman 1991.

- Two-colour ascidian - *Lissoclinum bistriatum*
- Dividing sponge - *Tethya fissurata*
- Jewel anemone - *Corynactis australis*
- Waratah anemone - *Actinia tenebrosa*
- Bubble tip anemone - *Entacmacea quadricolour*

Within the Temperate Eastern Marine Region, corals are present in a wide variety of marine environments, from northern tropical shallow waters down to the southern limit of Temperate Eastern Marine Region. Zooxanthellate corals can be found throughout the region within areas where temperature and calcium carbonate saturation limits are suitable and are limited in depth distribution by light availability and are usually found in depths of maximum 50 m of clear water (Keable 2007).

A survey of marine flora and fauna was conducted around Kingston Pier in 2005 and found that invertebrate species around the pier varied widely between the 'harbour' side and the lagoon side. The lagoon side showed a healthy selection of marine invertebrate species, including *Acanthartria lordhowensis* and several *Montipora* and *Goneastrea.* Colonies of zoanthids were also observed on the lagoon side of the pier (Marges 2005).

Benthic community composition was surveyed along a total of 40 transects at the Norfolk Island Commonwealth Marine Reserve (CMR) (Edgar et al. 2017). The Norfolk Island CMR was characterised by a benthic community of erect and tabular corals, a diverse algal assemblage, and a high proportion of anemones and zoanthids. Live coral cover was in the range of 19 to 25%. The key species of sea urchins dominating abundance records at the different locations were the main drivers of the differences between the reefs and the islands, caused by.

The Norfolk Island Natural Resource Management Plan (Parsons Brinkerhoff 2009) provides the following important observations regarding the corals of Norfolk Island:

"The inshore waters of Norfolk, Phillip and Nepean Islands support one of the southern-most coral assemblages in the world. The coral reef ecosystem at Norfolk is one of the few known examples of a transitional algae and coral assemblage (an unusual mix of tropical and temperate marine fauna and flora due to the alternating influence of warm and cool currents at the Islands) (Kuster 2001). The reefs are not actively accreting and are, therefore, not true coral reefs. The reefs occur as a thin veneer over the rock substrate and their rates of growth are slow in subtropical waters, therefore they are growing at around the same pace as their erosion and physical destruction (Kuster 2001 and Zann et al. 2001)".

"A survey on the reefs in 1999 found that the inshore benthic communities are dominated by relatively few species of subtropical hard corals co-existing with a high diversity of algae. The 57 species of scleractinian corals, in 27 genera in 11 families, comprises a unique association of tropical and temperate species of global biodiversity value. While species diversity on Norfolk was moderately high, six species accounted for almost half the coral coverage. These are mainly specialised subtropical species. The majority of the other species are uncommon to rare (Zann et al. 2001). These coral communities form part of a chain of reefs that may be essential in maintaining a supply of larvae dispersed from source reefs to the west, probably Lord Howe Island, Elizabeth and Middleton Reefs. The low diversity of coral species combined with marginal temperatures for coral growth at high latitudes indicates that the coral communities are vulnerable to disturbance (Kuster 2001)."

Previous studies around Norfolk Island show that the area supports an abundance of locally luxuriant assemblage of hermatypic corals (39 species) both within the Kingston Lagoon (i.e. the Slaughter Bay Lagoon) and elsewhere around the island (Pendoley 2011).

The following coral species were reported by Aurecon Australia (2011) as occurring in nearby Ball Bay on a reef growing on a rocky outcrop towards the north eastern headland. This reef has extensive hard coral cover (based on a desktop investigation of Christian and Marges 1995 and Coleman 1991).

- Cauliflower coral - *Pocillopora damicornis*
- Lord Howe Coral - *Acanthastrea lordhowensis*
- Brush coral - *Acropora hyacinthus*
- Lichen coral - *Porites lichen*
- Lesser star coral - *Goniastrea australensis*
- Uniform coral - *Montipora aequituberculata*
- *Platygyra favia acropora*
- Montipora sp.
- *Pocillopora damicornis*
- Porites sp.
- *Acropora hyacinthus*
- Acropora sp.
- Sarcophyton

The most accessible reefs within the Norfolk Island coral reef ecosystem include the Emily Bay and Slaughter Bay lagoonal reef, and neighbouring Cemetery Bay lagoonal reef. These reefs adjoin the Kingston lowland catchment and world heritage listed Kingston and Arthur's vale historic sites. The Slaughter Bay reef is most proximate to the proposed works area, located on the eastern side of Kingston Pier. Emily Bay and Slaughter Bay together form a ~0.18 km^2 intertidal lagoon (SIMS 2021).

Coral reefs are inherently sensitive, in addition, the Slaughter Bay and Emily Bay coral reefs are currently under particular stress as a result of an extensive coral bleaching event in 2020 (caused by unusually high sea surface temperatures) within the lagoonal reef, inshore pollution and declining water quality associated with high rainfall events and land-based run-off, and a subsequent coral disease outbreak on the reef. Each of these documented events (bleaching, land-based pollution, disease outbreaks) are known to be associated with declining coral reef health and phase-shifts from coral to algal dominated coral reef systems (SIMS 2021).

Extensive surveys of the coral reef benthic habitat were conducted by SIMS (2021) in Emily Bay and Slaughter Bay in March and November 2020, and video transects were collected by local residents in June and September 2020 to coincide with a substantial rain event causing flooding and sedimentation of the Emily Bay and Slaughter Bay lagoon. Site conditions were assessed with a combination of the following biophysical measurements: seawater temperature, salinity, tidal range, water flow speed and direction, seawater nutrient concentrations, and overall organic matter loads within reef sediments. In addition to these measurements, the quality and condition of the coral were assessed with an analysis of the bacterial diversity and community composition of key reef-building coral species (Acropora sp., Acropora plating, Montipora sp., Pocillopora sp. and Porites sp.) collected in Emily Bay.

Based on the coral reef health study undertaken by SIMS (2021), Figure 3-4 and Figure 3-5 provided on the following page have been developed by indicate the following:

- Areas with noteworthy coral diversity or unknown taxonomy.
- Proposed snorkel trails (dotted lines).
- Proposed Coral Preservation Areas for Emily Bay and Slaughter Bay (yellow, green).
- Cemetery Bay (pink and red) proposed as high conservation and management zone due to extensive coral cover.
- Map of suggested areas for scientific investigation of site rehabilitation in Slaughter and Emily Bay.
- Areas outlined for algae removal (green) and coral re-introduction following algal removal.
- Illustrative snorkel trail locations based on assessment of reef structure and management goals.
- Icons display noteworthy coral to be viewed along the trail and corals of cultural and/or ecological significance.

The entire Slaughter Bay ad Emily Bay are considered to be sensitive for the purposes of the EA and all associated monitoring plans.

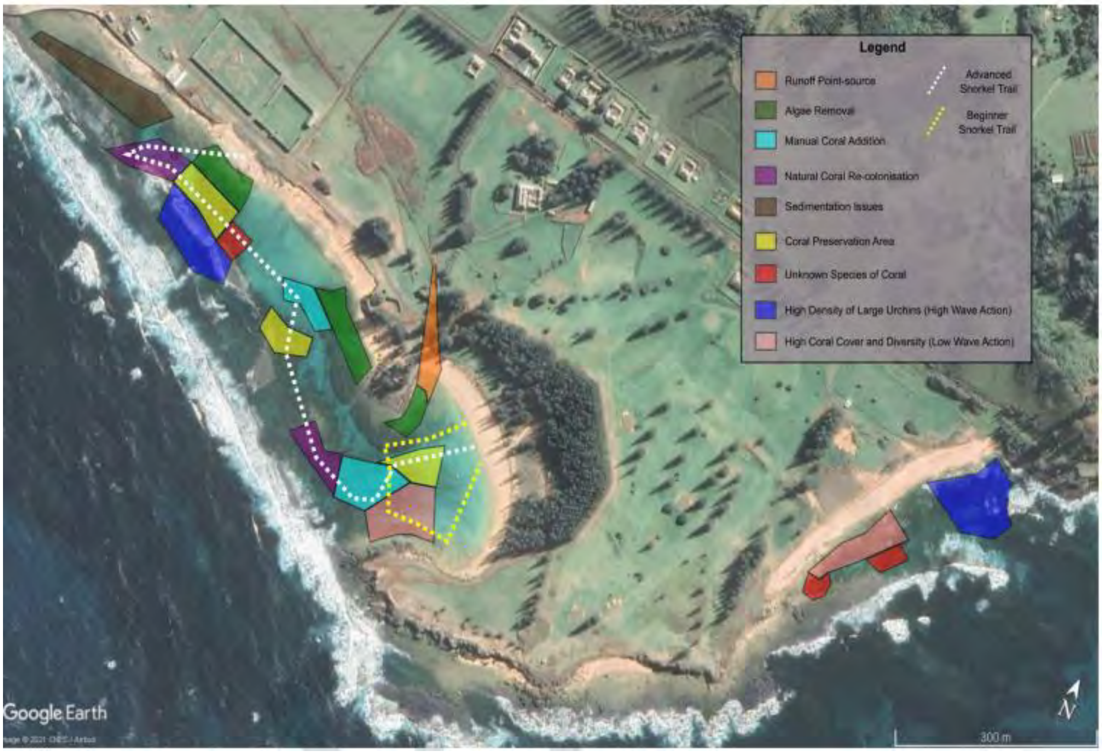


Figure 3-4 Emily Bay, Slaughter Bay and Cemetery Bay Site Orientation Summary (SIMS 2021).

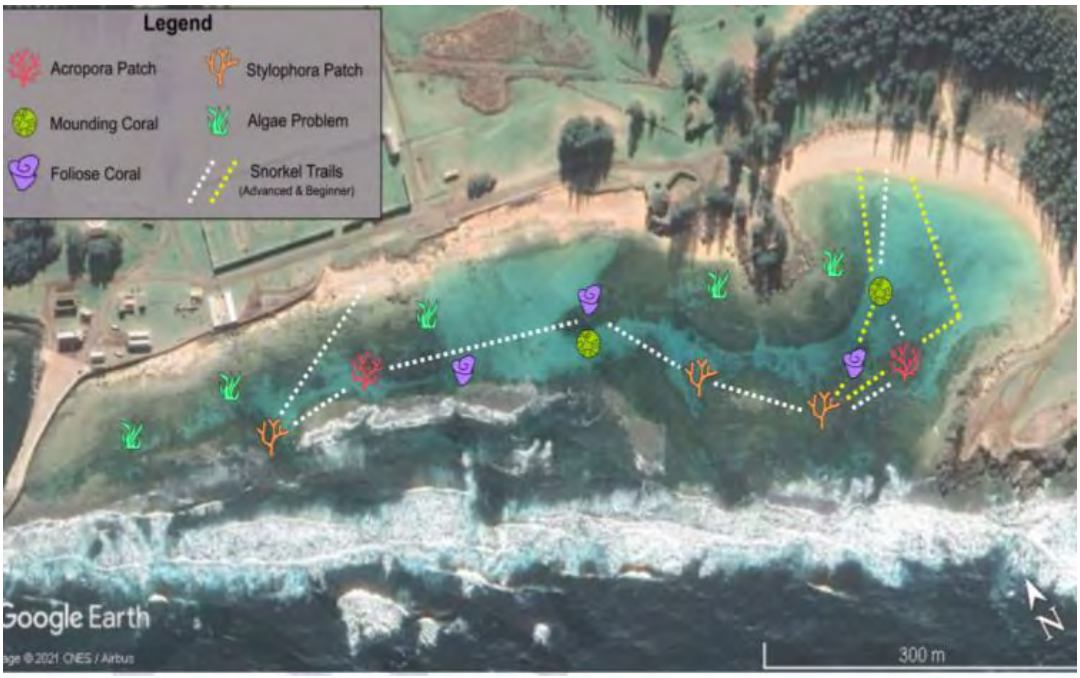


Figure 3-5 Proposed educational coral reef snorkel trail locations.

3.3.4.2 Mobile Invertebrates

Echinoderms are widely distributed in the Temperate East Marine region and can be split into five distinct classes. Sea stars or starfish (asteroids), sea cucumbers, brittle stars or basket stars, sea urchins, and feather stars. Echinoderms occupy a wide range of marine environments, from coral reefs to soft sediments. They are often the dominant organisms on the seafloor in both shallow and deepwater environments (Keable 2007). A large number of mobile invertebrates have been found on both sides of Kingston Pier on Norfolk Island, including the white tipped sea urchin *Tripneustes gratilla* and the brown urchin *Heliocidaris tuberculate,* as well several species of holothurian (Marges 2005). Several species of molluscs are found both sides of the Pier, including the popular edible mollusk *Nerita albicilla,* ('Hi Hi'). Some Sea Hare are also seasonally common in the Kingston area (Marges 2005).

Benthic community composition was surveyed along a total of 40 transects at the Norfolk Island Commonwealth Marine Reserve (CMR) (Edgar et al. 2017). Echinoderms dominated the invertebrate assemblage, in particular, the higher abundance of *Holothuria hilla* and *Thalamita* spp. Crustaceans and molluscs were also abundant and species-rich at Norfolk Island.

Crustaceans are a morphologically diverse of mobile invertebrates that occur in a broad range of marine environments within the Temperate East Marine Region, being found in both pelagic and benthic environments and from shallow to extreme depth waters. Small Rock Crabs are common on all sides of Kingston pier and in all inter-tidal areas of Norfolk Island.

The following mobile invertebrate species were reported by Aurecon Australia (2011) as occurring in Ball Bay based on a field survey and desktop investigation.

- Striped sea urchin - *Tripneustes gratilla*
- Tuberculate sea urchin - *Heliocidares tuberculata*
- Mathae's sea urchin, Rock-boring urchin - *Echinometra mathaei*
- Gracious sea urchin - *Tripneustes gratilla*
- Impatient sea cucumber - *Holothuria impatiens*
- Little sea star - *Patiriella exigua*
- White sea star - *Asterina alba*
- Dentate brittle star - *Ophiocoma dentate*
- Six-armed brittle star - *Ophiocomella sexradius*
- Forskal's side gilled slug - *Pleurobranchus forskali*
- Variegated shore crab - *Leptograpsus variegates*
- Little ghost crab - *Ocypode cordimana*
- Peduncle hermit crab - *Dardanus pedunculatus*
- Elegant xanthid crab - *Xanthias elegans*
- Red bait crab - *Plagusia chabrus*

- Little sea hare - *Aplysia parvula*
- Brazier's sea hare - *Dolabrifera brazieri*
- Milk-spot cowry - *Cypraea vitellus*
- False ear shell - *Gena sp.*
- *Nerita albicilla*
- Orange worm shell - *Vermetus sp.*
- Guam bubble shell - *Micromelo guamensis*
- Bristle worm - *Eurythoe complanata*
- Margined flatworm - *Callioplana marginata*
- Waratah anemone - *Actinia tenebrosa*
- Bubble tip anemone - *Entacmacea quadricolour*
- Hi Hi - *Nerita albicilla*
- Brazier's sea hare - *Dolabrifera brazieri*
- Impatient sea cucumber - *Holothuria impatiens*

3.3.5 Marine and Migratory Birds

The Temperate East Marine Region supports important breeding and foraging areas for seabirds; in particular, the Lord Howe Island and Norfolk Island groups are recognised both nationally and internationally as significant breeding sites (Dutson et al. 2009). Oceanographic features within the region like the EAC and Tasman Front drive sites of enhanced biological productivity, offering important foraging opportunities for both resident and migratory species (DEWHA 2009a). As significant consumers of marine resources, seabirds play an important functional role in marine ecosystems; for example, by transferring nutrients from pelagic and offshore regions to islands, reefs and coasts; and dispersing seeds and moving organic matter through the soil layers, particularly by burrow-nesting species (Congdon et al. 2007). There are many areas of the island that are important nesting habitat for these migratory birds, including the upper slopes and edges of the coastal cliff between Anson Bay and Duncombe Bay in the north of the island.

Nine species of sea birds (three noddies, two terns, a gannet, a tropic-bird and two species of petrel) breed on the island or its outliers. The Brown-headed or Providence Petrel was literally eaten out in the early days. Wedgetailed Petrels still nest on Norfolk in certain areas and the Red-tailed Tropic-bird nests on cliff edges. Sooty Terns (the so-called Whale Bird), *Sterna fuscata*, breeds on Phillip and Nepean Islands or on rock stacks like Red Stone, off the north coast of the main island. White Terns (*Gygis alba royana*) fly or hover in pairs near the cliff top. They make no proper nest, merely laying their eggs on the branches of Norfolk Island Pine supported only by a twig or nodule. White Terns seem to exist and occupy trees all around the coast with greatest concentrations near Creswell Bay, Rocky Point (near Ball Bay) and the northern slopes of Mt Bates (March and Pope 1967).

Threatened and Protected Marine and Migratory Birds

Migratory and marine birds are protected in Australia under the EPBC Act 1999. In total, 53 listed seabird species are known to occur in the Temperate East Marine Region as listed below.

<u>Listed seabirds known to occur in the Temperate East Marine Region</u>

<u>Albatrosses</u>

- Antipodean albatross (*Diomedea antipodensis*) - Vulnerable, migratory, marine
- Black-browed albatross (*Thalassarche melanophris*) - Vulnerable, migratory, marine
- Campbell albatross (*Thalassarche impavida*) - Vulnerable, migratory, marine
- Indian yellow-nosed albatross (*Thalassarche carteri*) - Vulnerable, migratory, marine
- Salvin's albatross (*Thalassarche salvini*) - Vulnerable, migratory, marine
- Wandering albatross (*Diomedea exulans*) - Vulnerable, migratory, marine
- White-capped albatross (*Thalassarche steadi*) - Vulnerable, migratory, marine

<u>Petrels and storm-petrels</u>

- Gould's petrel (*Pterodroma leucoptera*) - Endangered, migratory
- Southern giant-petrel (*Macronectes giganteus*) - Endangered, migratory, marine
- Northern giant-petrel (*Macronectes halli*) - Vulnerable, migratory, marine
- Providence petrel (*Pterodroma solandri*) - Migratory, marine
- Kermadec petrel (*Pterodroma neglecta*) - Vulnerable, marine
- Black-winged petrel (*Pterodroma nigripennis*) - Marine
- Great-winged petrel (*Pterodroma macroptera*) - Marine
- Black petrel (*Procellaria parkinsoni*) - Migratory, marine
- White-necked petrel (*Pterodroma cervicalis*) - Marine Yes
- Wilson's storm-petrel (*Oceanites oceanicus*) - Migratory, marine
- White-bellied storm-petrel (*Fregetta grallaria*) - Vulnerable, marine
- White-faced storm-petrel (*Pelagodroma marina*) - Marine

<u>Shearwaters</u>

- Flesh-footed shearwater (*Ardenna carneipes*) - Migratory, marine
- Short-tailed shearwater (*Ardenna tenuirostris*) - Migratory, marine
- Sooty shearwater (*Ardenna grisea*) - Migratory, marine

- Wedge-tailed shearwater (*Ardenna pacifica*) - Migratory, marine
- Little shearwater (*Puffinus assimilis*) - Marine

Penguins

- Little penguin (*Eudyptula minor*) - Marine

Terns and noddies

- Roseate tern (*Sterna dougallii*) - Migratory, marine
- White tern (*Gygis alba*) - Marine
- Crested tern (*Thalasseus bergii*) - Marine
- Sooty tern (*Onychoprion fuscata*) - Marine
- Grey ternlet (*Procelsterna cerulea*) - Marine
- Common noddy (*Anous stolidus*) - Migratory, marine
- Black noddy (*Anous minutus*) - Marine

Boobies

- Masked booby (*Sula dactylatra*) - Migratory, marine

Tropicbirds

- Red-tailed tropicbird (*Phaethon rubricauda*) - Marine

Listed seabird species known to occur in the Temperate East Marine Region on an infrequent basis

Albatrosses

- Amsterdam albatross (*Diomedea amsterdamensis*) - Endangered, migratory, marine
- Chatham albatross (*Thalassarche eremita*) - Endangered, migratory, marine
- Grey-headed albatross (*Thalassarche chrysostoma*) - Endangered, migratory, marine
- Northern royal albatross (*Diomedea sanfordi*) - Endangered, migratory, marine
- Tristan albatross (*Diomedea dabbenena*) - Endangered, migratory, marine
- Atlantic yellow-nosed albatross (*Thalassarche chlororhynchos*) - Vulnerable, migratory, marine
- Buller's albatross (*Thalassarche bulleri*) - Vulnerable, migratory, marine
- Shy albatross (*Thalassarche cauta*) - Vulnerable, migratory, marine
- Sooty albatross (*Phoebetria fusca*) - Vulnerable, migratory, marine
- Southern royal albatross (*Diomedea epomophora*) - Vulnerable, migratory, marine
- Light-mantled albatross (*Phoebetria palpebrata*) - Migratory, marine

Shearwaters

- Streaked shearwater (*Calonectris leucomelas*) - Migratory, marine

Terns and noddies

- Common tern (*Sterna hirundo*) - Migratory, marine
- Little tern (*Sternula albifrons*) - Migratory, marine
- Fairy tern (*Sternula nereis* formerly known as *Sterna nereis*) - Vulnerable, marine
- White-winged black tern (*Chlidonias leucopterus*) - Migratory, marine

Other

- Arctic jaeger (*Stercorarius parasiticus*) - Migratory, marine
- Brown skua (*Stercorarius antarcticus*) - Migratory, marine
- Pomarine jaeger (*Stercorarius pomarinus*) - Migratory, marine

The EPBC Act 1999 Protected Matters Search (**Appendix A**) lists 31 marine birds and 19 migratory birds with the potential to occur in the study area as listed in Table 3-1.

Table 3-1 Threatened marine and migratory birds with the potential to occur in the study area (EPBC Act 1999).

Common Name	Species Name	Status	Likelihood of Occurrence
Common Sandpiper	*Actitis hypoleucos*	Listed	Species or species habitat known to occur within area
Common Noddy	*Anous stolidus*	Listed, Migratory	Breeding known to occur within area
Sharp-tailed Sandpiper	*Calidris acuminata*	Listed	Species or species habitat known to occur within area
Red Knot	*Calidris canutus*	Endangered	Species or species habitat may occur within area
Pectoral Sandpiper	*Calidris melanotos*	Listed	Species or species habitat known to occur within area
Antipodean Albatross	*Diomedea antipodensis*	Vulnerable, Migratory	Species or species habitat may occur within area
Southern Royal Albatross	*Diomedea epomophora*	Vulnerable, Migratory	Species or species habitat may occur within area
Wandering Albatross	*Diomedea exulans*	Vulnerable, Migratory	Species or species habitat may occur within area
Gibson's Albatross	*Diomedea gibsoni*	Vulnerable	Species or species habitat may occur within area
Northern Royal Albatross	*Diomedea sanfordi*	Endangered, Migratory	Species or species habitat may occur within area

Lesser Frigatebird	*Fregata ariel*	Listed, Migratory	Species or species habitat known to occur within area
Great Frigatebird	*Fregata minor*	Listed	Species or species habitat known to occur within area
Bar-tailed Godwit	*Limosa lapponica*	Listed	Species or species habitat known to occur within area
Southern Giant Petrel	*Macronectes giganteus*	Endangered, Migratory	Species or species habitat may occur within area
Northern Giant Petrel	*Macronectes halli*	Vulnerable, Migratory	Species or species habitat may occur within area
Australasian Gannet	*Morus serrator*	Listed	Breeding known to occur within area
Eastern Curlew	*Numenius madagascariensis*	Critically Endangered	Species or species habitat known to occur within area
Red-tailed Tropicbird	*Phaethon rubricauda*	Listed, Migratory	Breeding known to occur within area
Grey Noddy	*Procelsterna cerulea*	Listed	Breeding known to occur within area
White-necked Petrel	*Pterodroma cervicalis*	Listed	Breeding known to occur within area
Black-winged Petrel	*Pterodroma nigripennis*	Listed	Breeding known to occur within area
Providence Petrel	*Pterodroma solandri*	Listed	Breeding known to occur within area
Little Shearwater	*Puffinus assimilis*	Listed	Breeding known to occur within area
Fleshy-footed Shearwater	*Puffinus carneipes*	Listed, Migratory	Species or species habitat known to occur within area
Sooty Shearwater	*Puffinus griseus*	Listed, Migratory	Species or species habitat may occur within area
Wedge-tailed Shearwater	*Puffinus pacificus*	Listed, Migratory	Breeding known to occur within area
Masked Booby	*Sula dactylatra*	Listed, Migratory	Breeding known to occur within area
Chatham Albatross	*Thalassarche eremita*	Endangered, Migratory	Species or species habitat may occur within area
Campbell Albatross, Campbell Black-browed Albatross	*Thalassarche impavida*	Vulnerable, Migratory	Species or species habitat may occur within area
Black-browed Albatross	*Thalassarche melanophris*	Vulnerable, Migratory	Species or species habitat may occur within area
Salvin's Albatross	*Thalassarche salvini*	Vulnerable, Migratory	Foraging, feeding or related behaviour likely to occur within area
White-capped Albatross	*Thalassarche steadi*	Vulnerable, Migratory	Foraging, feeding or related behaviour likely to occur within area

3.4 Marine Ecology Field Survey

3.4.1 Methods

Intertidal and inshore subtidal marine habitats adjacent to Kingston Pier were assessed using a combination of snorkel and diver-based surveys between Bumbora to the west and Emily Bay to the east with the primary focus on Kingston Pier and Slaughter Bay (see Figure 3-6). A permit for survey from inside the Marine Park was obtained from Parks Australia on the 17th February 2020. Surveys were undertaken between the 18th and 20th February 2020. All survey work was based on non-destructive methods and relied on photographic and visual assessment, no ecological samples were collected.

The foreshore and intertidal assessment were undertaken via site walkover and snorkelling, with photographs taken of the various habitats present and any fauna sighted. Key intertidal habitats inspected included rocky / sandy beach areas and intertidal rocky platforms.

Inshore subtidal habitat was surveyed by diver inspection, supplemented with underwater photography of common species and habitat. Key subtidal habitats inspected were primarily sandy seabed and subtidal rocky reef. Subtidal rocky reef to the west of Kingston Pier was primarily macroalgal dominated, whereas reef to the east and inside the lagoon (Slaughter Bay) was predominantly coral.

Figure 3-6 Aquatic (marine) ecology general survey areas at Kingston Pier harbour and Slaughter Bay Lagoon (Source: Nearmap, 2020).

3.4.2 Results

3.4.2.1 Kingston Pier Intertidal Habitat

Intertidal habitats adjacent to Kingston Pier are dominated by the artificial substrate created by the presence of the pier itself and dumped boulders to the west of the pier that protect the small beach which forms part of the original Landing Place 1788. The intertidal rock was generally devoid of any significant marine flora or fauna, except for small invertebrates like crabs and limpets (see Figure 3-7).

Figure 3-7 Intertidal habitat, Kingston Pier.

3.4.2.2 Kingston Pier Shallow Subtidal Habitat

The shallow subtidal habitat adjacent to Kingston Pier can be broadly divided into two distinct zones;

1. The existing channel that has been subject to previous disturbance and dredging (modified).
2. The surrounding seabed (unmodified).

Existing Channel

The seabed within the existing channel is primarily coarse sand and rubble overlying layers of rock (Figure 3-8). There is very little benthic fauna present on the areas of sand and a medium to moderate cover of macroalgae on the areas of rock. A variety of brown macroalgae and small encrusting and turfing species of red, green and brown algae varieties were also present.

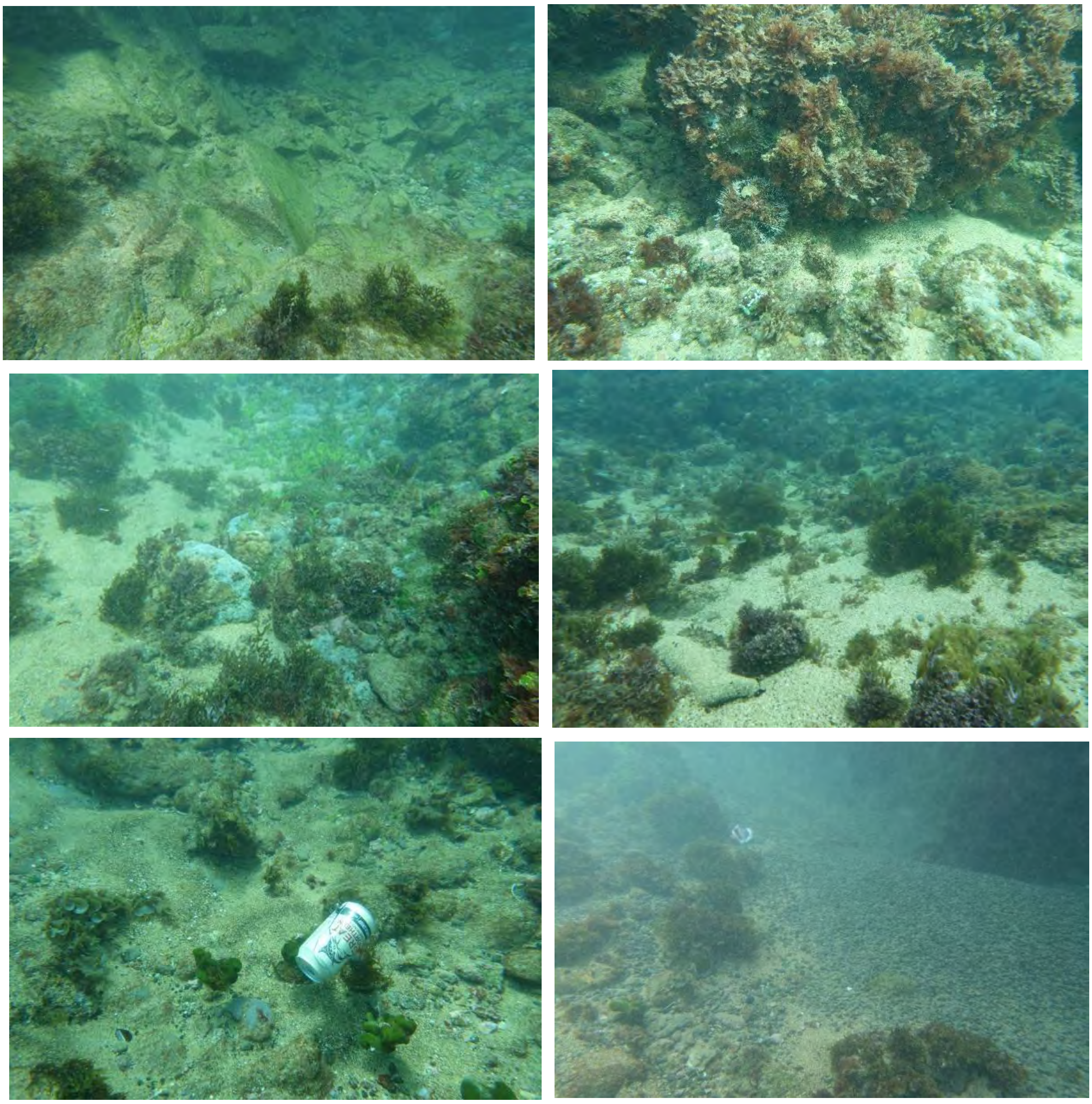


Figure 3-8 Subtidal habitat within existing channel, Kingston Pier.

Transitional Zone

The intermediate transitional zone is the area between the dredged channel and the natural seabed where there is some evidence of disturbance from previous dredging. The existing channel is relatively narrow, with outcrops of rock and ledges surrounding the area of seabed that has been deepened previously. The cover of macroalgae over these areas is much higher compared to the existing channel and there are more crevices and structure to the roof that is likely to provide niche habitat for a range of cryptic species including fish and invertebrates. There are also some smaller corals present, but they are generally uncommon. The corals present are low in percentage cover and are generally represented by a handful of taxa, primarily Acroporids. Images are shown in Figure 3-9.

Figure 3-9 Transitional zone between existing dredged channel and natural seabed, Kingston Pier.

Natural Subtidal Seabed

Beyond the transitional zone, the seabed grades into high rugosity, subtidal rocky reef where a higher diversity of macroalgae and corals are dominant. Larger and more well-established corals are present including *Acropora* spp., *Acanthastrea lordhowensis*, *Pocillopora damicornis*, *Porites* spp. and *Goniostrea australiensis.* Other invertebrates that were common include the white spined urchin *Tripneustes gratilla,* the tuberculate urchin, *Heliocidaris tuberculata* and the black spined urchin, *Centrostephanus rodgersii.* Bryozoans were also present, possibly the species *Cornuticella taurina.*

The percentage cover of macroalgae was also much higher with very little bare rock or sand visible. A patchy but moderate cover of the green alga, *Caulerpa racemosa* and the brown alga, *Dictyota* sp. was present together with a suite of other turfing and coralline species. Images of this area of natural subtidal rocky reef outside the existing channel are provided in Figure 3-10.

A variety of fish species were also present during the subtidal survey to the west of Kingston Pier including a school of trevally, *Pseudocaranx sp dentex* and smaller cryptic species. The Galapagos shark *Carcharhinus galapagensis*, was an opportunistic visitor to Kingston Pier, following boat charters into port and feeding on discarded fish catch. Images of some of the fish and invertebrates recorded at Kingston Pier are shown in Figure 3-11.

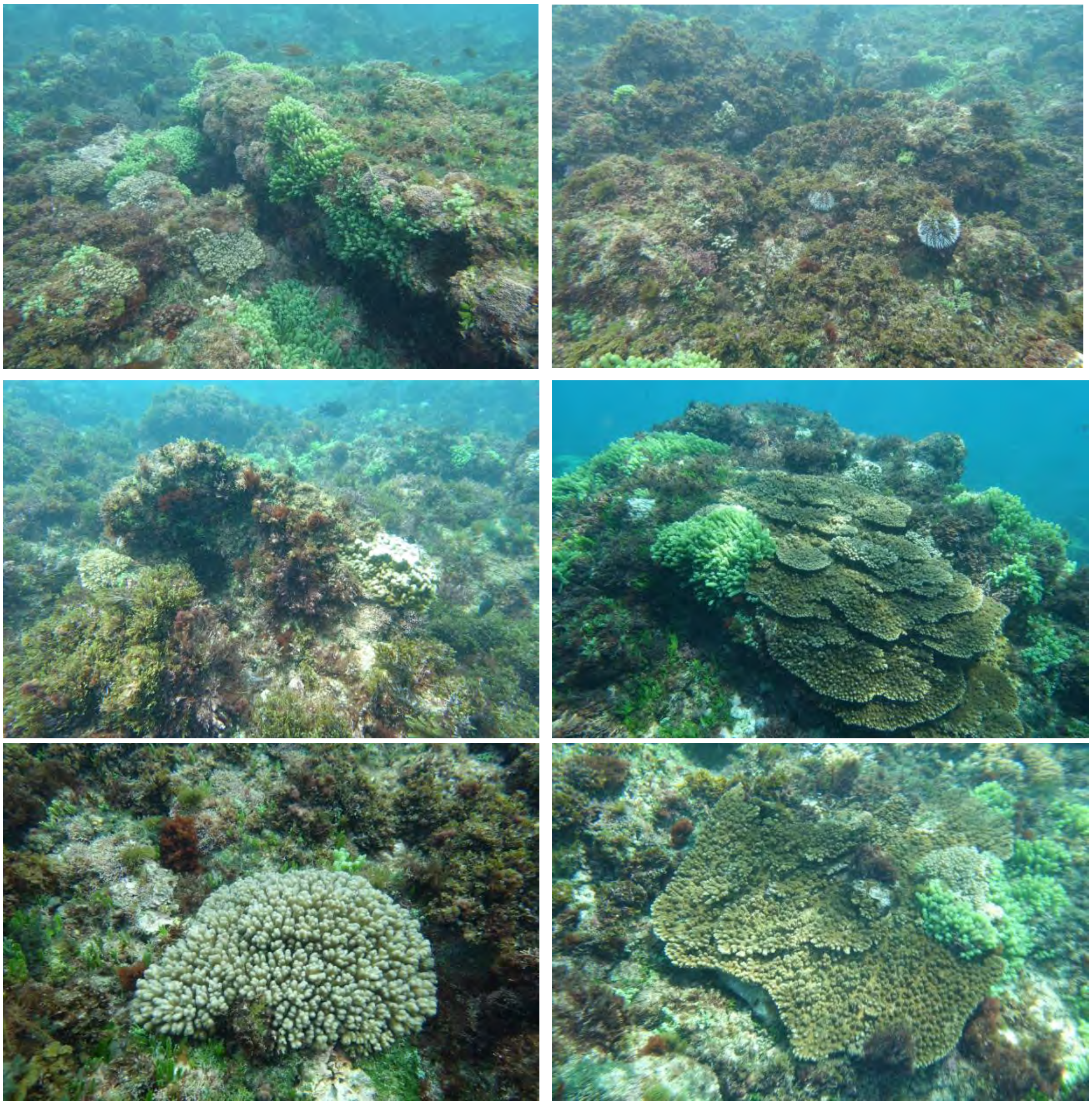


Figure 3-10 Subtidal rocky reef outside existing channel, west of Kingston Pier.

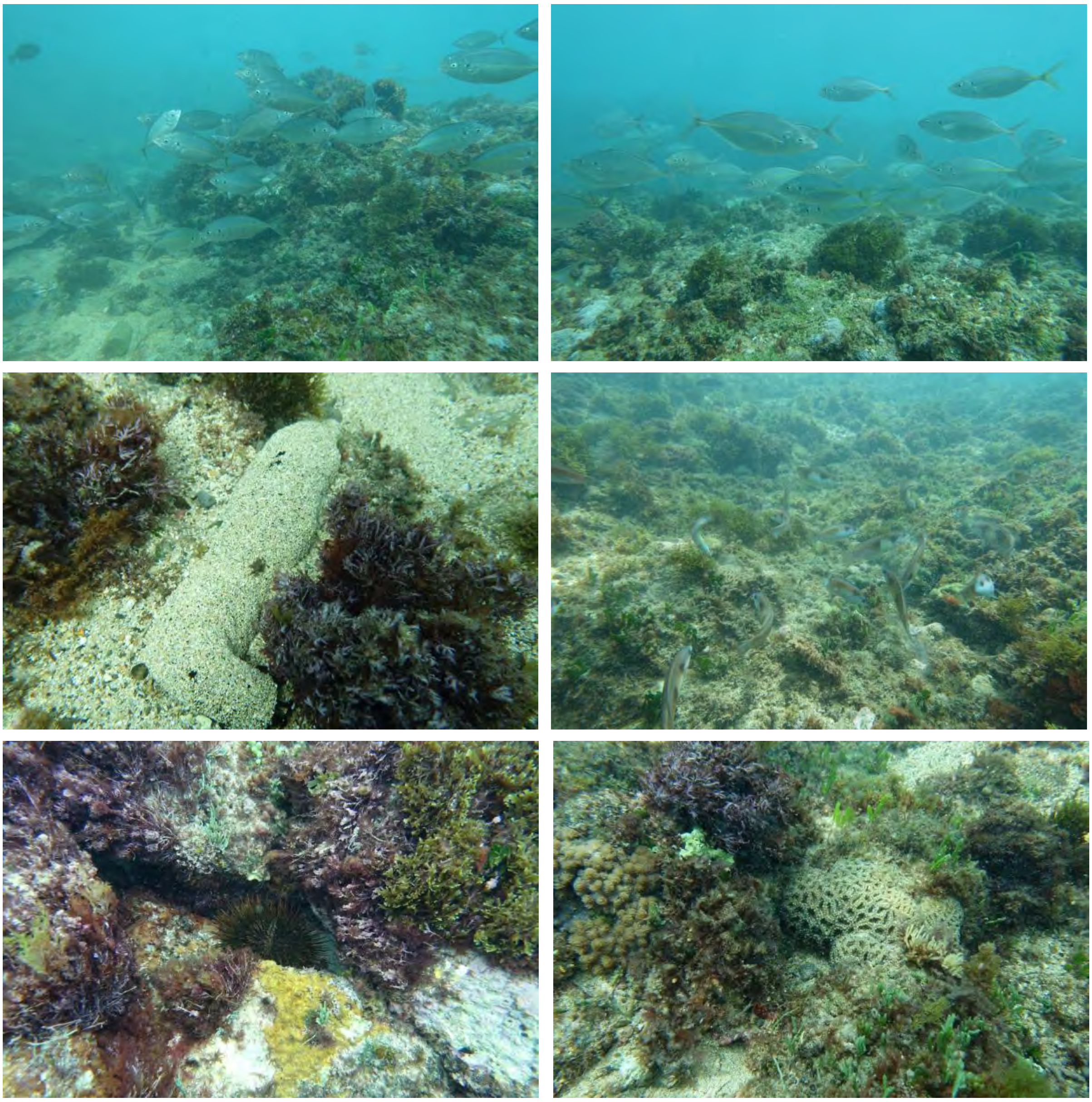


Figure 3-11 Fish and invertebrate species, Kingston Pier.

Bombora (Rocky Outcrop)

At the time of inspection of the Bombora, no fish or other pelagic species were noted. The substrate was dominated by a high percentage cover of macroalgae with minimal coral cover. Very little bare rock or sand was visible (see Figure 3-12).

Figure 3-12 Bombora at seaward end of channel, Kingston Pier.

3.4.2.3 Slaughter Bay Intertidal Habitat

The intertidal habitats in the lee of Kingston Pier primarily consist of bare rock with small rockpools close to the seawall that grade into a flat submerged rock platform. The rock is devoid of any fauna but is covered in very fine filamentous algae. The rock pools closer to the seawall are generally populated with small cryptic species of fish and invertebrates including small crabs and crustaceans. Molluscs were less common although the small black gastropod, *Nerita albicilla* was locally abundant. Images are shown in Figure 3-11.

Figure 3-13 Intertidal habitat, lee of Kingston Pier.

Walking eastward past the boatsheds toward Slaughter Bay, the rock platforms become interspersed with sections of sand that become increasingly larger before opening up into a continuous stretch of sandy beach, just past the end of the seawall. This section of beach provides an access point for snorkelers and surfers to access Slaughter Bay. Images are provided in Figure 3-14.

Figure 3-14 Intertidal habitat, east of Kingston Pier.

3.4.2.4 Slaughter Bay Shallow Subtidal Habitat

The lagoon at Slaughter Bay is shallow (2.5 m deep) and has a soft sandy bottom with scattered shells and coral rubble and is dominated by the algae species *Sargassum, Caulerpa, Cutleria, Helminthocladia, Galaxaura, Liagora* and members of the *Dictyotales*. On the outer reef edge there exists a community of *Codium, Caulerpa, Valonia, Dasycladus*, and more *Dictyotales*. The reef top has substantial mats of *Hormosira*, particularly in winter months (Millar 1999) (see Figure 3-15). Coral species noted were *Pocillopora damicornis*, *Goniostrea australiensis, Porites* sp. and some larger acroporids, most likely *Acropora glauca* and *Acropora hyacinthus*.

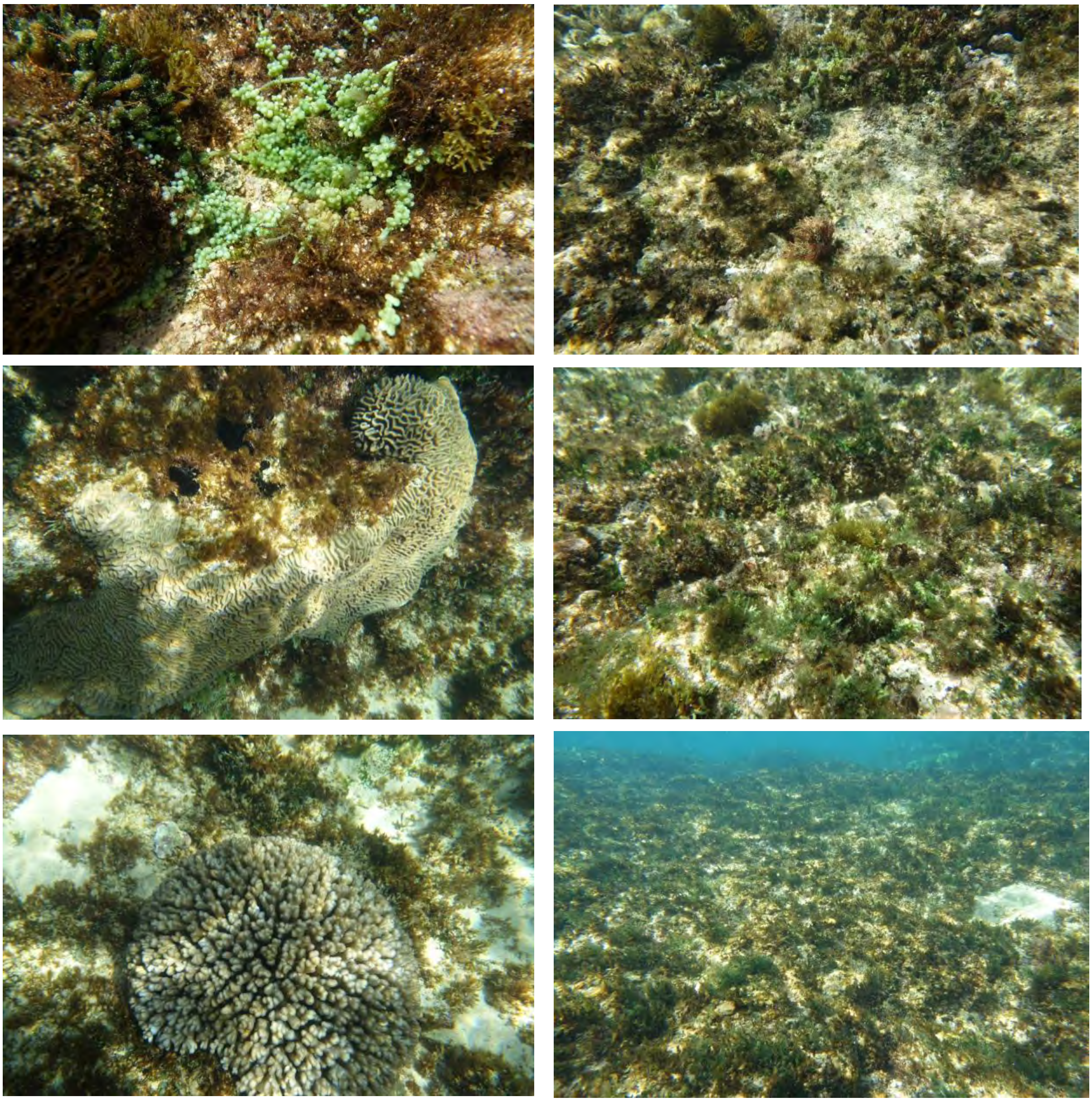


Figure 3-15 Shallow subtidal habitat, east of Kingston Pier.

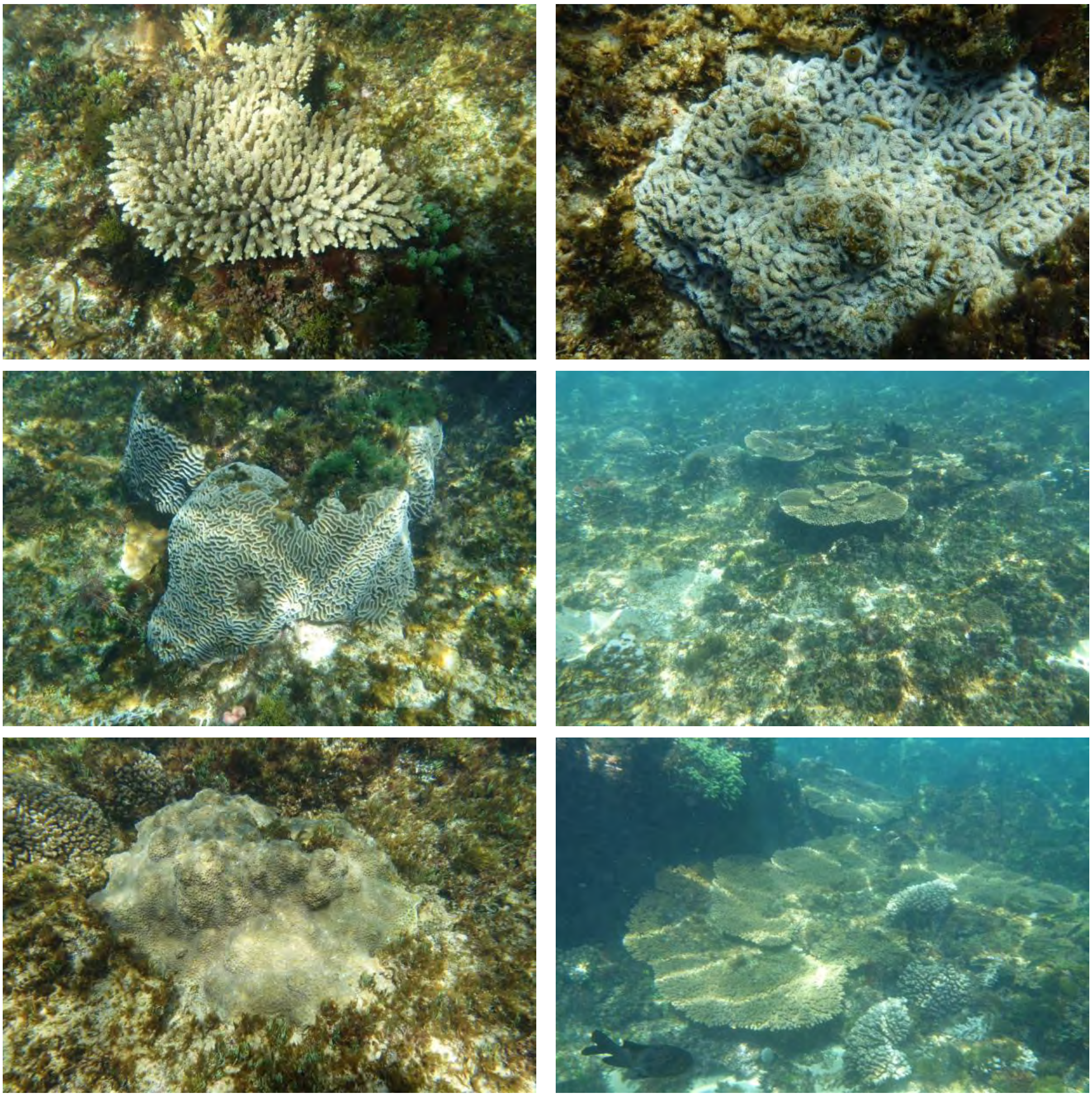


Figure 3-16 Corals of the Slaughter Bay lagoon, east of Kingston Pier.

The most common fish observed in the lagoon were the Banded Scalyfin, *Parma polylepis,* the Blackspot Sergeant, *Abudefduf sordidus,* Green Moon Wrasse, *Thalassoma lutescens,* Citron butterflyfish, *Chaetodon citrinellus* and the Black Rock Cod, *Epinephelus daemelii* (Figure 3-17).

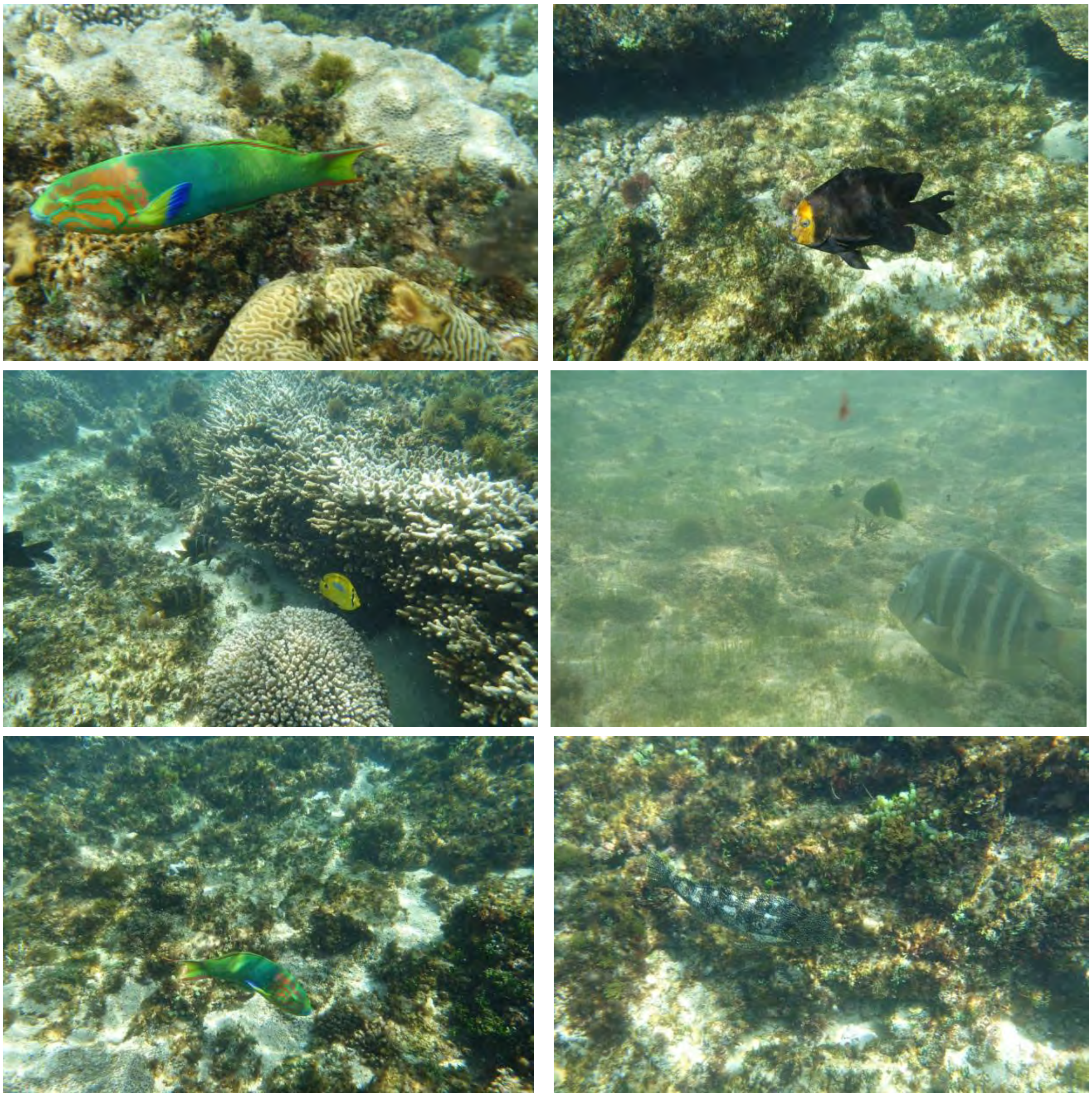


Figure 3-17 Fish of the Slaughter Bay lagoon, east of Kingston Pier.

The most common of the invertebrate species within the lagoon were the sea-urchins which included the white spined urchin *Tripneustes gratilla*, the black spined urchin, *Centrostephanus rodgersii* and the tuberculate urchin, *Heliocidaris tuberculata.* The holothurian, *Holothuria whitmaei* was also common over areas of sandy seabed. Images are shown in Figure 3-18.

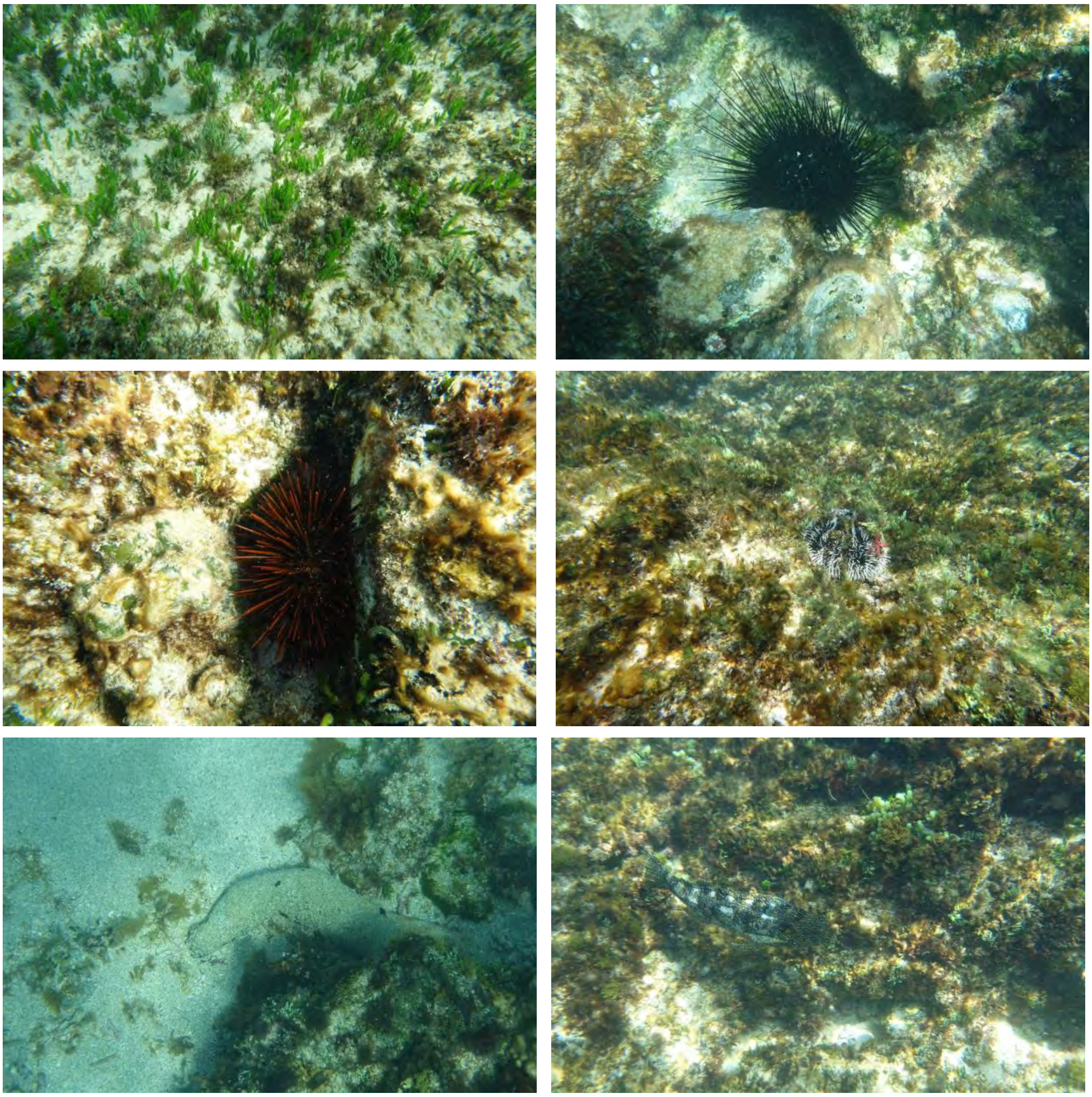


Figure 3-18 Invertebrates in Slaughter Bay lagoon, east of Kingston Pier.

4 Marine Water and Sediment Quality

4.1 Water Quality

4.1.1 Background Information

Three water body types are represented in the KAVHA – Emily Bay study area. Surface waters (creek and wetlands), groundwater and marine receiving waters (Emily Bay). The system was rated as 'slightly disturbed site' under the guidelines due to the unrestricted access by cattle, feral chickens, ducks and geese. Emily Bay, the receiving waters for the catchment, is rated as a 'site of high conservation value' due to the presence of EPBC Act 1999 listed species and habitats, the enclosed nature of the lagoon with restricted flushing and water exchange and the use of the quiet calm waters of the bay for recreation. A multitude of water quality investigations have been made for freshwater sites in the KAVHA catchment area as listed in Wilson (2017), however, no studies of marine water quality are readily available for reference.

In a letter to The Hon Gary Hardgrave (Administrator Norfolk Island, Commonwealth of Australia) in 2015, Pendoley reported the following water quality concerns for Emily Bay in regard to water entering the bay from the island:

- Large fresh water flows together with elevated nutrient levels have killed the coral in Emily Bay along a transect extending from the outfall, across the bay to Lone Pine and to the reef outlet channel. Personal observations over the past 50 years, together with anecdotal feedback from numerous island residents, indicate that the die-off of coral, increased algal growth, both on the floor of the bay and covering the dead coral habitat, plus the decrease in the number and diversity of small fish, has accelerated the past 5 years. We have serious concerns that this accelerated rate of decline will wipe out the entire Emily and Slaughter Bay lagoon within 5 – 10 years. Recovery of the ecosystem will be delayed by the lack of immigration of coral spawn from external reef systems (e.g. Lord Howe) due to the isolated nature of Norfolk Island.

- The Emily and Slaughter Bay lagoon supports the EPBC listed *Halicampus boothae* (Booths pipefish) and *Chelonia mydas* (green turtle). These species are at risk of disease, reduced health and habitat loss due to the water entering the bay and under the EPBC Act the responsible Governing Authority is obliged to protect these species and the ecosystems that support them

- While the existing sand plug in the creek has temporarily stopped water flowing from the creek into the bay, water continues to percolate through the sand and enter they bay in the intertidal zone near the mouth of the creek mouth in Emily Bay. The filtration action of the sand will remove solids but it will not remove the dissolved nutrients and pathogens which can cause a range of illnesses in people swimming in the bay.

- The pathogens in the Emily Bay outfall were measured by Dr Goldsmith between 2014 and 2015 are beyond the safe limits for human activity such as swimming, based on DoE Water Quality Guidelines. This is especially true after heavy rain washes human and animal waste from the catchment into the Kingston area. Commonwealth NHMRC Water quality standards for primary contact (e.g. swimming) require the water to contain little or no E. coli (<40 E. coli / 100ml) however sampling carried out in in June 2015 reported E. Coli levels in excess of

670/100 ml and Coliform counts in excess of 1860/100ml. The water entering Emily Bay is contaminated and a risk to human health.

The results of Wilson 2017 show that the water quality in KAVHA is degraded relative to the ANZECC Guidelines for Lowland rivers in South-East Australia. The unacceptably high nutrient load in the creek is indicative of what would be delivered to the enclosed, poorly flushed Emily Bay lagoon following a significant rainfall event. These nutrients accelerate the growth of primary producers, such as seagrass and algae, at the expense of coral.

The water quality analysis carried out across the KAVHA catchment by Norfolk Island Regional Council (Council), over the months of April to September 2017, have identified coliform concentrations that are substantially higher than the recommended E.coli/L levels set by the National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines and by ANZECC for primary contact and secondary contact (150 coliforms/100ml and 1000 coliforms/100ml respectively) (Wilson 2017).

4.1.2 ANZECC Guidelines

The ANZECC Water Quality Guidelines (2018) provide high-level guidance on the management context, ecological descriptions, biological indicator selection and other advice for five of Australia's six marine planning regions as well as for the Great Barrier Reef Marine Park (which represents the inshore portion of the Coral Sea Marine Region). The 2018 Default Guidelines for the Temperate East Marine Region are not currently available online, so the default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems (from the previous ANZECC 2000 Guidelines) for south-eastern Australian marine waters are provided in Table 4-1. Note that no default guidelines are provided for physical and chemical stressors for ''high conservation/ecological value systems'' (i.e. effectively unmodified or other highly-valued ecosystems, typically (but not always) occurring in national parks, conservation reserves or in remote and/or inaccessible locations) which the study area would be classified as. For these high conservation areas, ANZECC (2000) recommends the following in regard to levels of protection:

- No change beyond natural variability recommended, using ecologically conservative decision criteria for detecting change. Any relaxation of this objective should only occur where comprehensive biological effects and monitoring data clearly show that biodiversity would not be altered.
- Where reference condition is poorly characterised, actions to increase the power of detecting a change recommended.
- Precautionary approach taken for assessment of post-baseline data through trend analysis or feedback triggers.

Table 4-1 ANZECC (2000) Default Water Quality Guidelines for south-east Australian marine waters.

Parameter	Default Trigger Value
Temperature	NA
pH	8-8.4
Salinity	NA
Conductivity	NA
Turbidity	0.5-10 NTU
Dissolved Oxygen	90-110% saturation

4.1.3 Water Quality Sampling 2020

On the 19 and 20 February 2020 water quality profiling for a range of physico-chemical parameters was undertaken to obtain some basic background marine water quality data for the study area. Ten water quality sampling sites were sampled, located in the Kingston Harbour, Slaughter Bay, as well as four oceanic reference sites located east and west of Kingston Pier (see below and Figure 4-1).

1. Kingston Pier East
2. Kingston Pier - Seaward End
3. Kingston Pier West - Old Steps
4. Kingston Pier West - New Steps
5. Kingston Pier West - Bottom of Ramp / Fish Cleaning Table
6. Kingston Harbour (Middle)
7. Western Reference 1 - Offshore Flagstaff Hill
8. Western Reference 2 - Bumbora
9. Eastern Reference 1 - Slaughter Bay
10. Eastern Reference 2 - Emily Bay

Samples were taken at each site using a hand held water quality meter at the surface (1 m below surface), midwater (half water depth) and bottom (1 m off bottom) to measure the following parameters:

- Temperature (degrees Celsius)
- pH
- Dissolved Oxygen (mg/L)
- Salinity (ppt)
- Conductivity (ms/cm)
- Turbidity (NTU)

Field conditions including date, time, tidal state (ebb or flood), water depth, swell height and direction and wind strength and direction were also recorded.

Raw water quality results are provided in **Appendix B** and are summarised for each parameter in the tables in Section 4.1.3.1 to Section 4.1.3.5. There was very little difference in water quality data between the two sampling dates and between the surface, midwater and bottom sampling depths at each site. At some sites (i.e. eastern side of Kingston Pier and end of Kingston Pier), measurements were only taken from a single surface depth due to shallow water depths during sampling, which only allowed for one sample (these are denoted by NA in the tables).

Measurements obtained for temperature, conductivity, dissolved oxygen and pH at all sites and depths are typical of offshore marine waters and are in accordance with ANZECC (2000) where guidelines are available (see Table 4-1).

Turbidity was very low at all sites and at all depths sampled, with NTU values most often <1 NTU. Turbidity was only very slightly higher at sites located along the edge of the Pier compared to oceanic sites, most likely resulting from the resuspension of sandy seafloor sediments here with the moderate swells entering the harbour (which were present at the time of sampling). Turbidity measurements were not obtained from Kingston Pier West – Ramp on the 19/02/2020 and Kingston Pier End on the 20/02/2020 due to high swash/swell making readings inaccurate.

These turbidity values will be especially important in determining any site specific trigger values for construction monitoring of turbidity. Although measurements were only taken over two days, and while ANZECC (2000) provides default values of between 0.5-10 NTU, the turbidity site-specific values for this area of Norfolk Island are likely at the lower end of this range for the majority of the time.

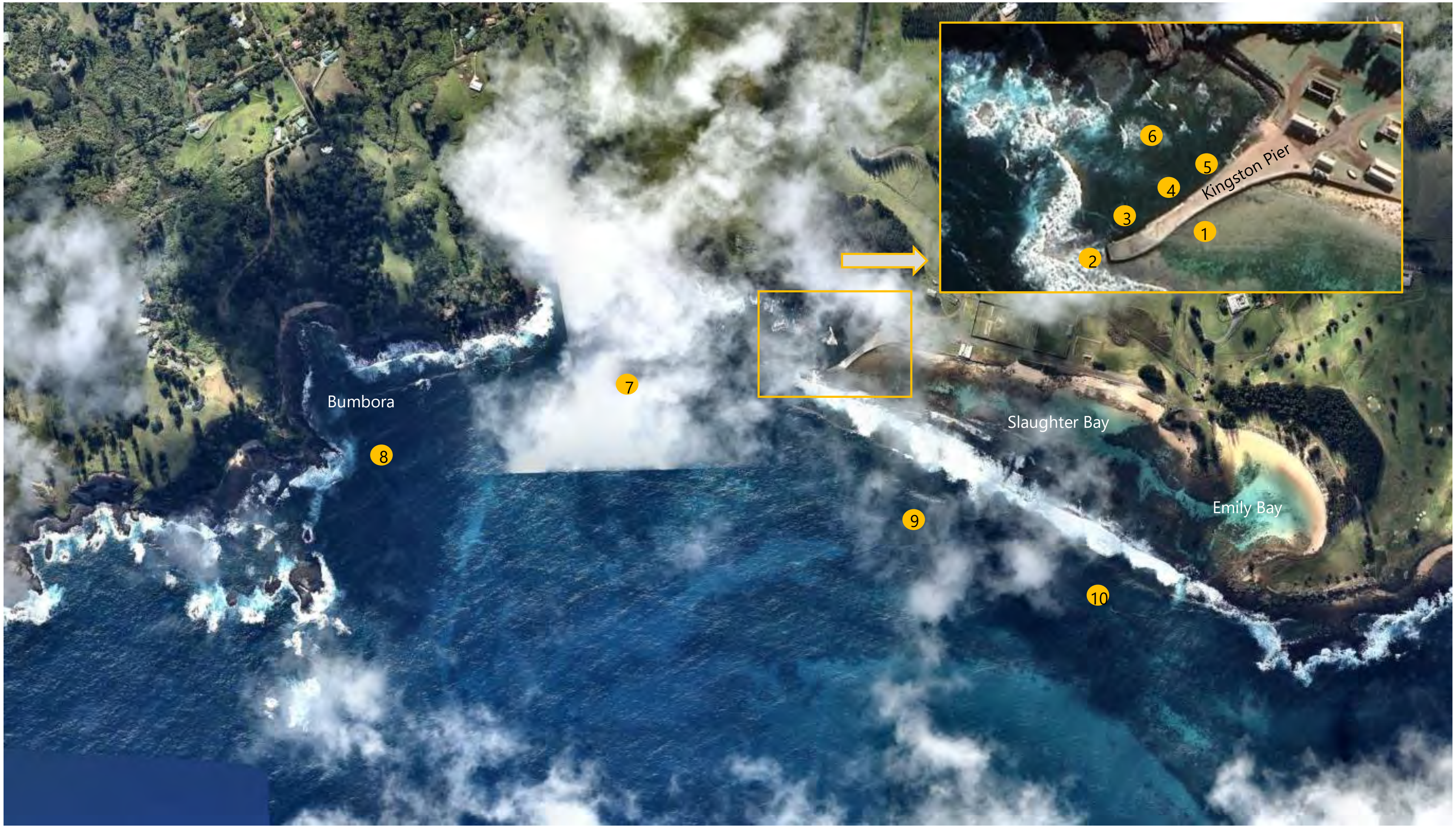


Figure 4-1 Location of water quality sampling sites 2020.

4.1.3.1 Temperate

Site	Location	Date	Temp (°C)	Temp (°C)	Temp (°C)
			Surface	Midwater	Bottom
1	Kingston Pier East	19/02/2020	24.8	NA	NA
2	Kingston Pier End	19/02/2020	24.8	NA	NA
3	Kingston Pier West - Old Steps	19/02/2020	24.8	24.8	24.8
4	Kingston Pier West - New Steps	19/02/2020	24.9	24.9	24.9
5	Kingston Pier West - Ramp	19/02/2020	24.9	24.9	24.9
6	Kingston Harbour (Middle)	19/02/2020	25.1	25.3	25.3
7	Western Reference - Offshore Flagstaff Hill	19/02/2020	25.1	25	25
8	Western Reference - Bumbora	19/02/2020	25.1	25.2	25.1
9	Eastern Reference - Slaughter Bay	19/02/2020	25.1	25	25
10	Eastern Reference - Emily Bay	20/02/2020	24.93	24.9	24.9
1	Kingston Pier East	20/02/2020	24.7	NA	NA
2	Kingston Pier End	20/02/2020	24.7	NA	NA
3	Kingston Pier West - Old Steps	20/02/2020	24.7	24.7	24.8
4	Kingston Pier West - New Steps	20/02/2020	24.7	24.7	24.7
5	Kingston Pier West - Ramp	20/02/2020	24.7	24.7	24.7
6	Kingston Harbour (Middle)	20/02/2020	24.8	24.9	24.9
7	Western Reference - Offshore Flagstaff Hill	20/02/2020	25	24.9	24.9
8	Western Reference - Bumbora	20/02/2020	25	25	24.9
9	Eastern Reference - Slaughter Bay	20/02/2020	24.9	25	24.9
10	Eastern Reference - Emily Bay	20/02/2020	24.9	24.9	24.9

4.1.3.2 Conductivity

Site	Location	Date	Conductivity (ms/cm)	Conductivity (ms/cm)	Conductivity (ms/cm)
			Surface	Midwater	Bottom
1	Kingston Pier East	19/02/2020	52.77	NA	NA
2	Kingston Pier End	19/02/2020	52.79	NA	NA
3	Kingston Pier West - Old Steps	19/02/2020	52.85	52.85	52.86
4	Kingston Pier West - New Steps	19/02/2020	52.89	52.89	52.89
5	Kingston Pier West - Ramp	19/02/2020	52.96	52.98	53
6	Kingston Harbour (Middle)	19/02/2020	53.33	53.35	53.36
7	Western Reference - Offshore Flagstaff Hill	19/02/2020	53.13	53.06	53.03
8	Western Reference - Bumbora	19/02/2020	53.24	53.22	53.2
9	Eastern Reference - Slaughter Bay	19/02/2020	53.19	53.06	53.05
10	Eastern Reference - Emily Bay	20/02/2020	53.01	52.96	52.96
1	Kingston Pier East	20/02/2020	52.61	NA	NA
2	Kingston Pier End	20/02/2020	52.65	NA	NA
3	Kingston Pier West - Old Steps	20/02/2020	52.77	52.79	52.79
4	Kingston Pier West - New Steps	20/02/2020	52.78	52.78	52.8
5	Kingston Pier West - Ramp	20/02/2020	52.8	52.8	52.8
6	Kingston Harbour (Middle)	20/02/2020	52.9	53	53.05
7	Western Reference - Offshore Flagstaff Hill	20/02/2020	53.01	52.94	52.92
8	Western Reference - Bumbora	20/02/2020	53.04	52.96	52.96
9	Eastern Reference - Slaughter Bay	20/02/2020	53.05	52.99	52.96
10	Eastern Reference - Emily Bay	20/02/2020	52.92	52.92	52.93

4.1.3.3 Dissolved Oxygen

Site	Location	Date	DO (mg/L) Surface	DO (mg/L) Midwater	DO (mg/L) Bottom
1	Kingston Pier East	19/02/2020	7.3	NA	NA
2	Kingston Pier End	19/02/2020	7.02	NA	NA
3	Kingston Pier West - Old Steps	19/02/2020	7.22	7.22	7.22
4	Kingston Pier West - New Steps	19/02/2020	7.24	7.27	7.27
5	Kingston Pier West - Ramp	19/02/2020	7.34	7.36	7.41
6	Kingston Harbour (Middle)	20/02/2020	7.13	7.36	7.54
7	Western Reference - Offshore Flagstaff Hill	19/02/2020	7.05	6.9	6.82
8	Western Reference - Bumbora	19/02/2020	7.57	7.58	7.65
9	Eastern Reference - Slaughter Bay	19/02/2020	7.17	7.07	7.09
10	Eastern Reference - Emily Bay	19/02/2020	6.8	6.82	6.8
1	Kingston Pier East	20/02/2020	6.88	NA	NA
2	Kingston Pier End	20/02/2020	6.86	NA	NA
3	Kingston Pier West - Old Steps	20/02/2020	6.64	6.61	6.53
4	Kingston Pier West - New Steps	20/02/2020	6.71	6.7	6.7
5	Kingston Pier West - Ramp	20/02/2020	6.82	6.82	6.81
6	Kingston Harbour (Middle)	20/02/2020	7.25	7.45	7.39
7	Western Reference - Offshore Flagstaff Hill	20/02/2020	7.6	6.59	6.62
8	Western Reference - Bumbora	20/02/2020	6.51	6.45	6.5
9	Eastern Reference - Slaughter Bay	20/02/2020	7.06	7.12	7.01
10	Eastern Reference - Emily Bay	20/02/2020	6.7	6.63	6.68

4.1.3.4 pH

Site	Location	Date	pH Surface	pH Midwater	pH Bottom
1	Kingston Pier East	19/02/2020	7.96	NA	NA
2	Kingston Pier End	19/02/2020	8	NA	NA
3	Kingston Pier West - Old Steps	19/02/2020	7.96	7.96	7.99
4	Kingston Pier West - New Steps	19/02/2020	7.97	7.97	7.97
5	Kingston Pier West - Ramp	19/02/2020	8	8	8
6	Kingston Harbour (Middle)	20/02/2020	8.1	8.1	8.11
7	Western Reference - Offshore Flagstaff Hill	19/02/2020	8.02	8	7.99
8	Western Reference - Bumbora	19/02/2020	8.06	8.06	8.06
9	Eastern Reference - Slaughter Bay	19/02/2020	8.05	8.03	8.02
10	Eastern Reference - Emily Bay	19/02/2020	8.03	8.03	8.03
1	Kingston Pier East	20/02/2020	8.05	NA	NA
2	Kingston Pier End	20/02/2020	8.04	NA	NA
3	Kingston Pier West - Old Steps	20/02/2020	8	8	7.99
4	Kingston Pier West - New Steps	20/02/2020	8	8	7.99
5	Kingston Pier West - Ramp	20/02/2020	8	8	8
6	Kingston Harbour (Middle)	20/02/2020	8.03	8.03	8.03
7	Western Reference - Offshore Flagstaff Hill	20/02/2020	8.13	8.05	8.02
8	Western Reference - Bumbora	20/02/2020	8.03	8.03	8.03
9	Eastern Reference - Slaughter Bay	20/02/2020	8.09	8.07	8.06
10	Eastern Reference - Emily Bay	20/02/2020	8.06	8.06	8.06

4.1.3.5 Turbidity

Site	Location	Date	Turbidity (NTU)	Turbidity (NTU)	Turbidity (NTU)
			Surface	Midwater	Bottom
1	Kingston Pier East	19/02/2020	0.6	NA	NA
2	Kingston Pier End	19/02/2020	1.5	NA	NA
3	Kingston Pier West - Old Steps	19/02/2020	0.87	0.85	0.85
4	Kingston Pier West - New Steps	19/02/2020	0.84	0.85	1.26
5	Kingston Pier West - Ramp	19/02/2020	Swash	Swash	Swash
6	Kingston Harbour (Middle)	20/02/2020	0.25	0.22	0.27
7	Western Reference - Offshore Flagstaff Hill	19/02/2020	0.25	0.37	0.36
8	Western Reference - Bumbora	19/02/2020	0.06	0.2	0.18
9	Eastern Reference - Slaughter Bay	19/02/2020	0.02	0.1	0.07
10	Eastern Reference - Emily Bay	19/02/2020	0.13	0.15	0.27
1	Kingston Pier East	20/02/2020	1.29	NA	NA
2	Kingston Pier End	20/02/2020	Swash	Swash	Swash
3	Kingston Pier West - Old Steps	20/02/2020	1.1	0.64	1.04
4	Kingston Pier West - New Steps	20/02/2020	0.58	0.53	0.84
5	Kingston Pier West - Ramp	20/02/2020	0.8	0.87	0.8
6	Kingston Harbour (Middle)	20/02/2020	0.08	0.13	0.1
7	Western Reference - Offshore Flagstaff Hill	20/02/2020	0.01	0.03	0.03
8	Western Reference - Bumbora	20/02/2020	0.07	0.06	0.2
9	Eastern Reference - Slaughter Bay	20/02/2020	0.01	0	0.06
10	Eastern Reference - Emily Bay	20/02/2020	0.17	0.39	0.51

* Swash = high swash or swell prevented accurate turbidity readings being obtained.

4.2 Sediment Quality

4.2.1 Historical Information

Very little information regarding the sediment quality at the study site is available except for a diver survey of the seabed which was undertaken in 2016 to improve understanding of the subsea conditions and assist with determining appropriate dredge methodologies (WorleyParsons 2016). During this survey, divers took four trial cores and two boulder-sized samples from the seabed. The material was reported to be generally very weak. The samples were generally able to be indented with a fingernail and easily broken-up by hand. It is therefore expected that the seabed would comprise rock of a low to very low strength profile.

Previous to this, the harbour adjacent to Kingston Pier was dredged in the early 1980's using a drag line. This resulted in an uneven seabed depth and the creation of channels. Furthermore, the drag line was only able to dredge successfully adjacent to the pier and left a poorly maintained section of channel at the entrance to the harbour, opposite the reef head (WorleyParsons 2016).

As the location is remote from known existing or historical sources of pollution and the material is subject to high wave energy, it is likely that material is uncontaminated.

4.2.2 Sediment Quality Assessment 2020

A sediment quality assessment was undertaken in 2020 for the Project. Prior to sampling a Sampling and Analysis Plan (SAP) for the Project was prepared by Advisian on behalf of the Department. The SAP was approved by DITRDC on 14 February 2020. A permit for collection of samples from inside the Marine Park was obtained from Parks Australia on 17 February 2020.

A sediment sampling program for the Kingston Pier Channel was carried out on 20 February 2020 in accordance with the approved SAP. Full sampling methods, sites and detailed results of the sediment sampling undertaken are provided in the Kingston Pier Channel Construction Sediment Quality Assessment (Advisian 2020). A summary of methods and results is provided below.

4.2.2.1 Methods

Consistent with the recommendations of the NAGD (for small dredging projects, up to 50,000 m^3), the entire dredge area was treated as a single site with six random sample locations selected within it. The dredge site was classified as "*probably clean*" as there was very little potential for contamination based on historical use of the site.

All sampling was undertaken in accordance with the NAGD protocols as described in the Sediment Quality Assessment. Samples were collected by divers using 100 mm diameter, 0.3 m long polycarbonate cores. Once each sample was collected, the cores were retrieved onto the vessel and emptied into a stainless-steel mixing bowl. A single core was sufficient at all locations except where a triplicate sample was collected.

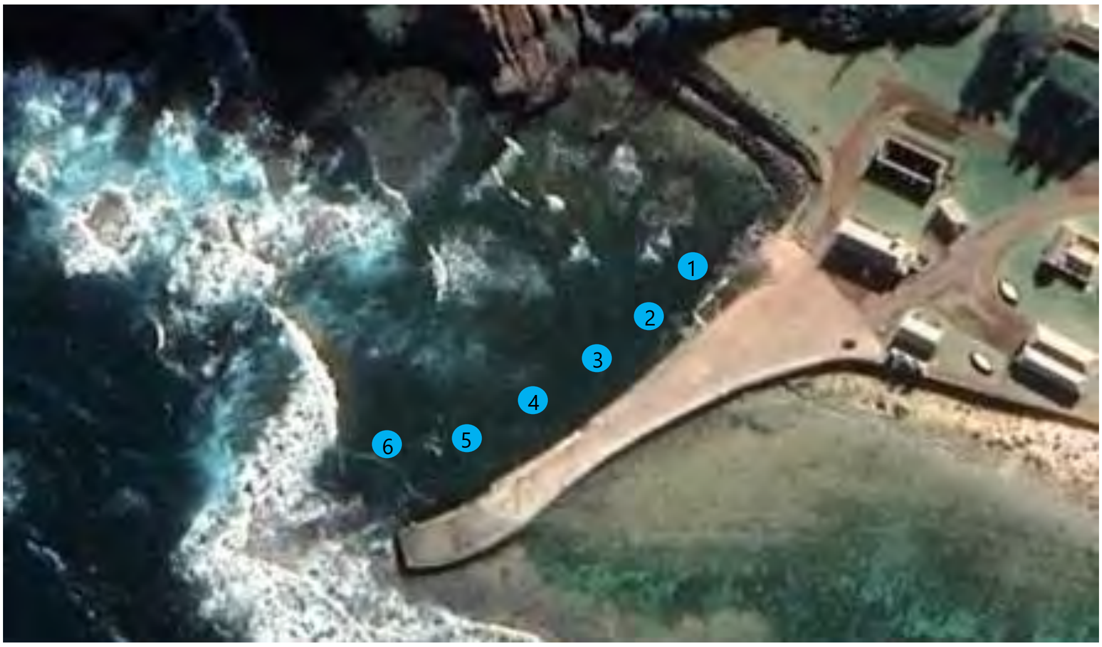


Figure 4-2 Location of sediment sampling sites 2020.

The Contaminants of Concern (COC) selected for testing were based on a suite of analytes that are typically measured in equivalent maritime locations. Samples were analysed for the parameters listed in Table 4-2.

Table 4-2 Parameters of interest and practical quantitation limits (PQLs) (Source: Table 1, DEWHA 2009)

Parameter	PQL
Moisture Content	0.1%
Particle Size Distribution *	
Total Organic Carbon *	0.1%
Organic Compounds	
Petroleum Hydrocarbons (TPHs)	100 mg/kg
Polycyclic Aromatic Hydrocarbons (PAHs)	5 µg/kg
Organotins (MBT, DBT, TBT)	1 µgSn/kg
Inorganic Compounds	
Antimony	1 mg/kg
Copper	1 mg/kg
Lead	1 mg/kg
Zinc	1 mg/kg
Chromium	1 mg/kg
Nickel	1 mg/kg
Cadmium	0.1 mg/kg
Mercury	0.01 mg/kg

* Analysis for total organic carbon (TOC) was included to allow for normalisation of organic contaminants (if present). Additionally, particle size distribution (PSD) was analysed in all samples to characterise the physical properties of the material.

4.2.2.2 Data Analysis

Contaminant levels for sediments were compared against the NAGD screening level concentrations listed in Appendix A, Table 2 of the NAGD to assess whether the material was suitable for unconfined sea disposal or if further testing was required (e.g. elutriate, bioavailability and/or direct toxicity assessment).

The comparison against guideline levels involves the comparison of mean contaminant concentrations at the 95% UCL of the mean. For the purposes of calculation of 95% UCLs, values below detection limits were set to half of the LOR in accordance with NAGD recommendations.

4.2.2.3 Results

Sediments tested consisted of coarse to medium grained sand with gravel with less than five percent fines (silt or clay), whereas samples of rock were composed of much higher proportions of clay and silt. The 95% upper confidence limit (UCL) of metal concentrations were below the National Assessment Guidelines for Dredging (NAGD; CoA 2009) low level screening guidelines for all contaminants of concern except for nickel. Organic contaminant concentrations including PAHs and TPHs were very low. Organotin concentrations including TBT were also very low and below the limits of reporting (LORs) for all samples tested. The 95% UCL for nickel exceeded the NAGD (2009) screening level, however the elevated levels in the dredge area may be due to naturally elevated ambient baseline levels, as sediments in Australia commonly have high levels of nickel. Overall, it was considered that the material located within the project area was suitable for onshore disposal and unconfined offshore disposal.

4.3 Dredge Plume Modelling

4.3.1 Aims

Advisian undertook a Dredge Plume Modelling Study (Advisian 2021b) to investigate the dispersion of sediments into the nearby marine area, as a result of the activities required for the Project. The purpose of the study was to inform the Environmental Assessment (EA) to obtain environmental approval for the project under the EPBC Act. The study investigated the potential risk of dispersion of sediments into the nearby lagoon and fringing reef area, as a result of the proposed dredging works.

The purpose of the modelling exercise was to understand:

- The potential distribution of sediment plumes that could be generated by the dredging.
- The intensity of the sediment plumes.
- Seasonal effects on the suspension of material and sedimentation patterns in the vicinity of the harbour, to support the environmental assessment.

The Dredge Plume Modelling exercise has informed the selection of a timeframe (or season) for undertaking the project activities to minimise the risk to the sensitive reef areas, as well as informing the daily operation of the dredging to minimise any impact.

4.3.2 Sediment Plume Influences

Sediment plumes can be generated by dredging activities, which for this Project would comprise a backhoe dredger mounted on a barge operating during daylight hours 5.5 days per week. The volume of material to be removed from the harbour is relatively small (up to 5,000 m^3) in the scheme of typical dredging projects and the disposal of the material is proposed to be onshore (as opposed to offshore sea disposal). The amount of sediment that can enter the water column as a result of the dredging depends on a number of factors that have been considered in the modelling, including:

- Schedule of activities (date and time).
- Location of the dredge plant.
- Dredging method.
- Spill volume (volume of material that is “spilled” into the water column during the dredging operation).
- Properties of the sediment material (density, proportion of fine silts, settling velocity of the sediment particles).
- Hydrodynamic conditions (waves, tidal and wind-driven currents).

When the sediment enters the water column at the site of the dredging, it is then dispersed by the action of waves, tidal and wind-driven currents, and can be carried away from the immediate project area.

4.3.3 Methods

The full range of conditions that could be experienced at the site, based on analysis of historical measurements of waves, winds and currents, was modelled to understand how far the sediment plume may travel from the dredging site, and whether there would be any settling of sediments outside the immediate project area as a result of the Project.

4.3.4 Scenarios

Eight separate scenarios were examined, to understand the full range of possible wave and current conditions that can occur during the dredging period and assess the full extent of dispersion and movement of the plumes away from the dredge site under the different conditions. The conditions examined included:

- **Scenario 1 (ambient wind, no waves)** - a baseline scenario simulated the dredge plume dispersion under ambient winds (or "everyday" wind speeds and directions) but without waves. This scenario provided a baseline for comparison between the other scenarios and to understand the sensitivity of the model without waves. This scenario does not represent real world conditions but does demonstrate the positive effect of waves containing a sediment plume
- **Scenario 2 (ambient wind, ambient waves)** - ambient winds from all directions and with ambient (or everyday) waves. <u>These are considered typical conditions that can be expected at the site and represent the most likely scenario that may occur during the dredging campaign</u>.
- **Scenario 3, 4, 5 and 6 (strong winds from the north, south, east and west respectively, no waves)** – these scenarios used an extreme (95th percentile) wind speed coming from the north, south, east and west and without including the impact of waves, and therefore are conservative. The purpose of these scenarios was to determine which wind directions could result in the plume moving toward the reef and lagoon areas, and to inform which wind directions should be tested with the inclusion of waves. From these scenarios, northerly and westerly winds were found to have the greatest potential for movement of sediments toward the lagoon area. The scenarios that modelled winds from the south and east demonstrated little to no potential for sediment to move towards the lagoon area and therefore were not investigated further.
- **Scenario 7 and 8 (strong winds from the north and west respectively, ambient waves)** – these scenarios investigated the effect of ambient waves on Scenarios 3 and 6, for northerly and westerly winds, thus representing a realistic "worst-case scenario" representation of real-world conditions during the dredging period.

Predictions of the sediment plume dispersion patterns have been extracted from the dredge dispersion model for the simulated scenarios. Results are presented for the entire simulation period as spatial plots of Suspended Sediment Concentration (SSC, also referred to as Total Suspended Solids: TSS) and sedimentation.

SSC is presented as milligrams per liter (mg/L). It is noted that at SSC concentrations below 10 mg/L, the plume would not be visible to a casual observer. The appearance of turbid water with varying concentrations of SSC is illustrated in Figure 4-3. Predictions of the sedimentation over the course of the dredging operation are presented as millimeters above seabed.

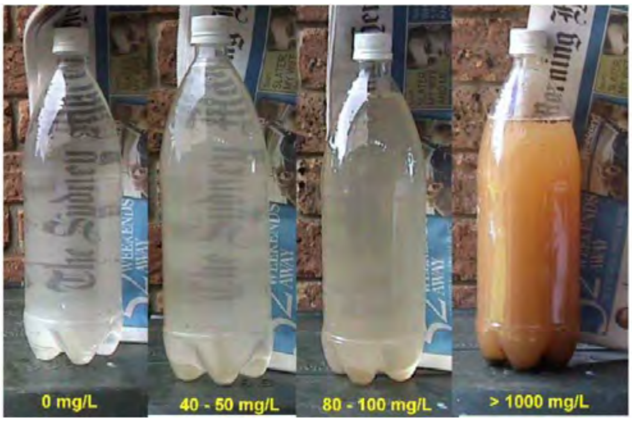


Figure 4-3 Visual representation of suspended sediment concentration.

Predictions of the suspended sediment dispersion and concentration over the course of the dredging operation have been illustrated in the model results on statistical analysis with the trigger values i.e. 80th percentile (i.e. SSC and sedimentation that would only be exceeded 20% of the time during the dredging) and 95th percentile (exceeded only 5% of the time during the dredging). It is recommended that such a visual representation is kept onsite during the construction period.

4.3.5 Results

The main findings of the dredge plume model are listed below with a summary in Table 4-3.

Scenario 1 (ambient wind, no waves)

With the proposed dredging method and time frame, the baseline scenario (under ambient wind without waves) has predicted that the dredge plume is retained within the Kingston harbour (up to 30 mg/L and 100 mg/L for the 80th and 95th percentile, respectively). For the 80th percentile, there is no plume detected for the lagoon and coral areas (Figure 4-4). For the 95th percentile, a limited level plume (less than 10 mg/L) was detected in the edge of north-west part of lagoon, away from the fringing reef area (Figure 4-5).

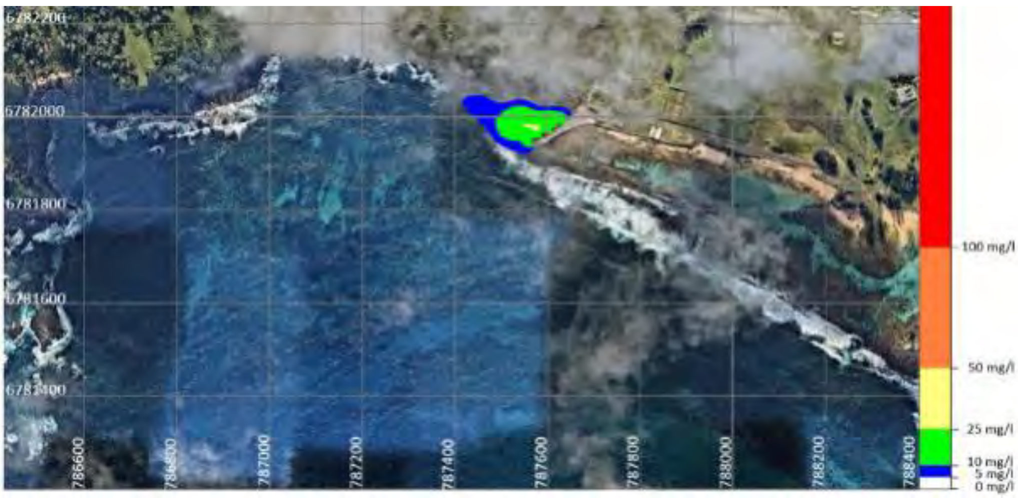


Figure 4-4 80th%ile Suspended sedimentation concentration distribution for Scenario 1 (ambient wind and no waves, wind rose for November shown).

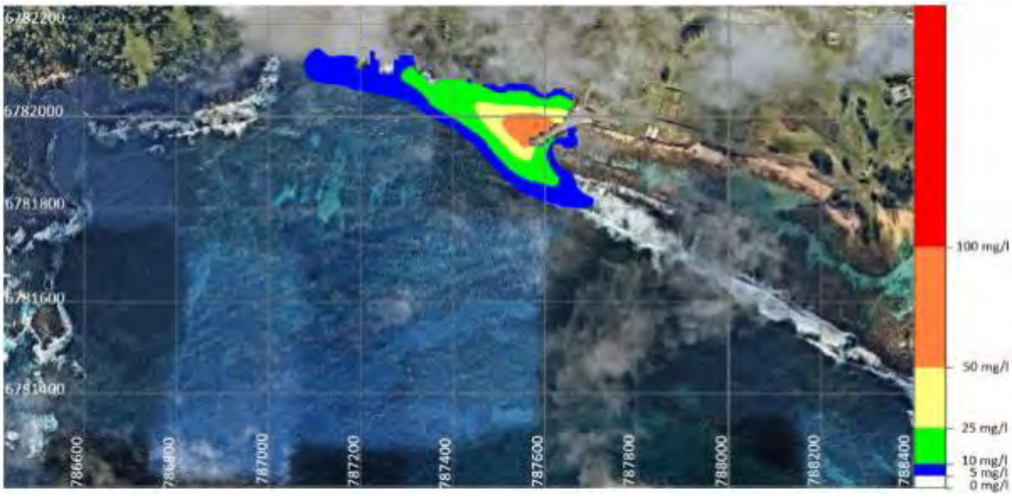


Figure 4-5 95th%ile Suspended sedimentation concentration distribution for Scenario 1 (ambient wind and no waves, wind rose for November shown).

Scenario 2 (ambient wind, ambient waves) (typical conditions - most likely scenario)

When ambient waves are included in the simulation (representing the real weather and hydrodynamic situation during the dredging operation (i.e. most likely scenario to occur during the dredging campaign) there is no plume detected for the lagoon and coral reef areas for both the 80th and 95th percentile (see (Figure 4-6 and Figure 4-7).

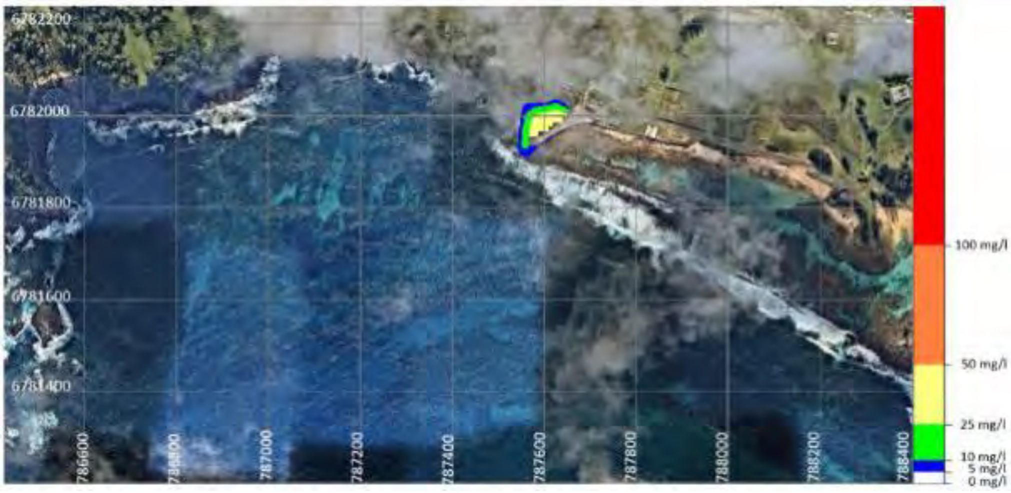


Figure 4-6 80th%ile Suspended sedimentation concentration distribution for Scenario 2, most likely scenario (ambient wind and waves).

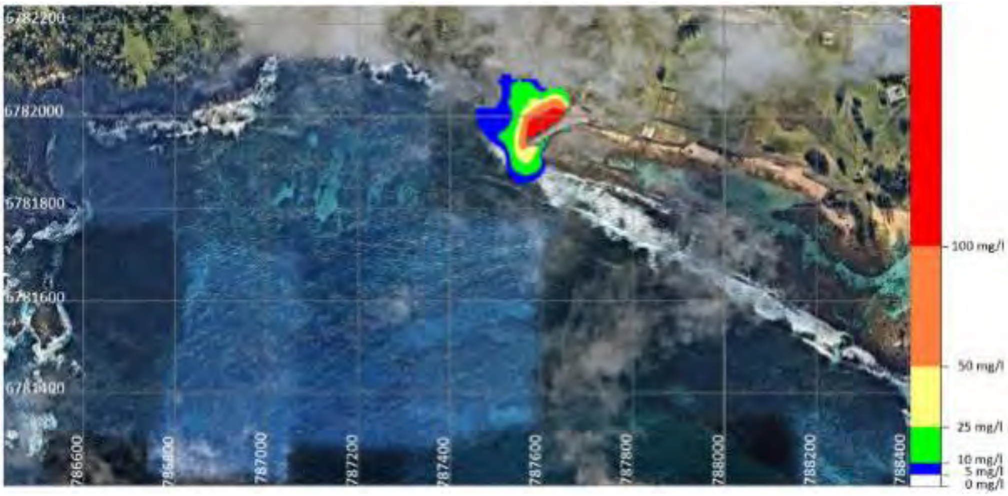


Figure 4-7 95th%ile Suspended sedimentation concentration distribution for Scenario 2, most likely scenario (ambient wind and waves).

Scenarios 4 and 5 (strong winds from south and east)

Under energetic meteorological conditions with strong winds from the south and east directions, the dredge plume model indicates no dredge plume detected for lagoon and reef areas for the 80th and 95th percentiles. The dredge plume is generally contained to the nearshore area west of the pier (see Figure 4-8 to Figure 4-11).

These modelled scenarios do not include the effects of waves they are thus conservative as the plume would be more contained under real world conditions. As such, these conservative results are considered acceptable to the Project and further refinement of these scenarios has not been undertaken.

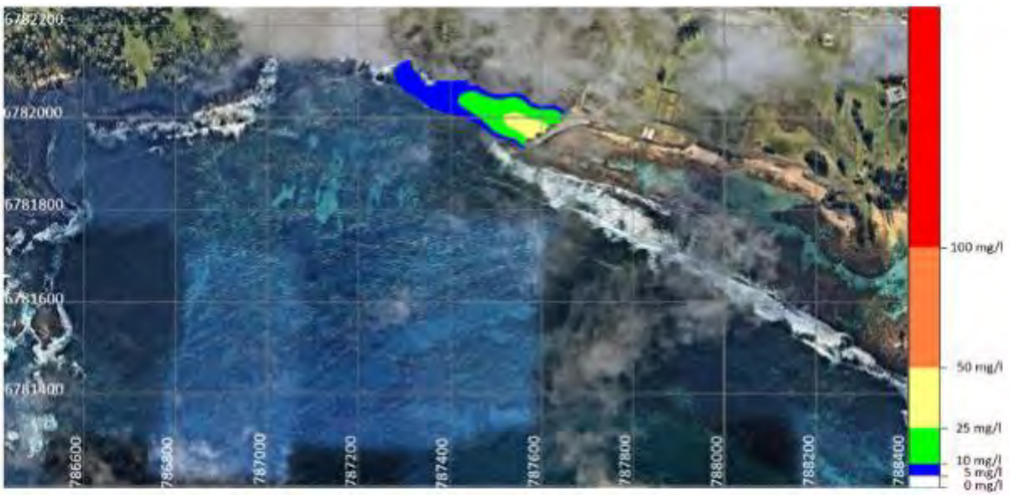


Figure 4-8 80th%ile Suspended sedimentation concentration distribution for Scenario 4 (strong south wind, no waves).

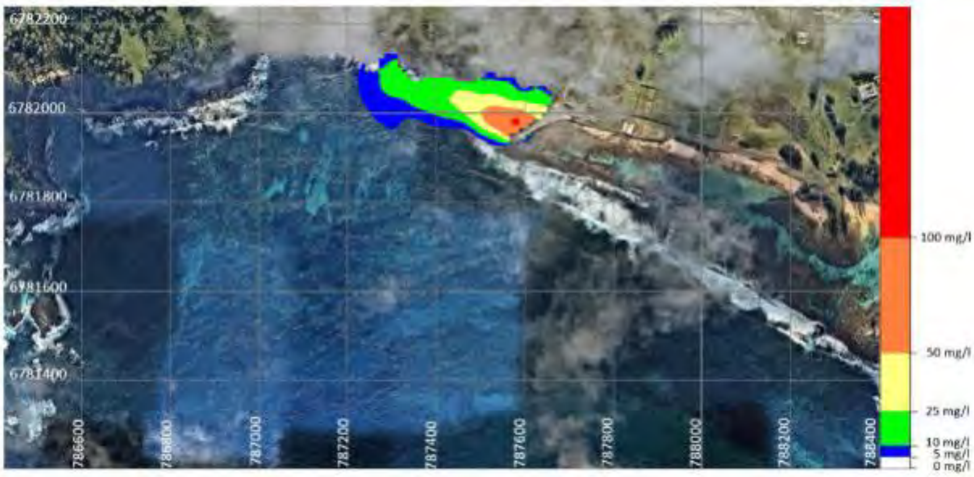


Figure 4-9 95th%ile Suspended sedimentation concentration distribution for Scenario 4 (strong south wind, no waves).

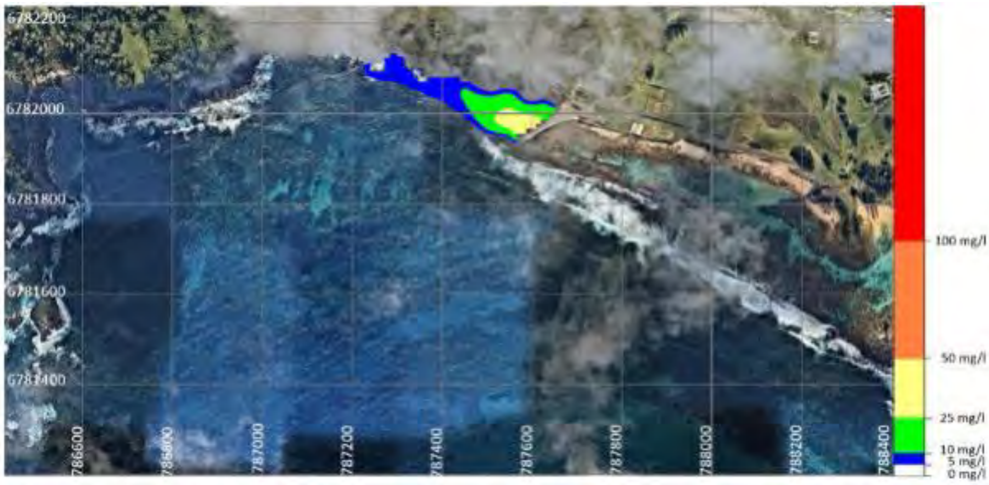


Figure 4-10 80th%ile Suspended sedimentation concentration distribution for Scenario 5 (strong east wind, no waves).

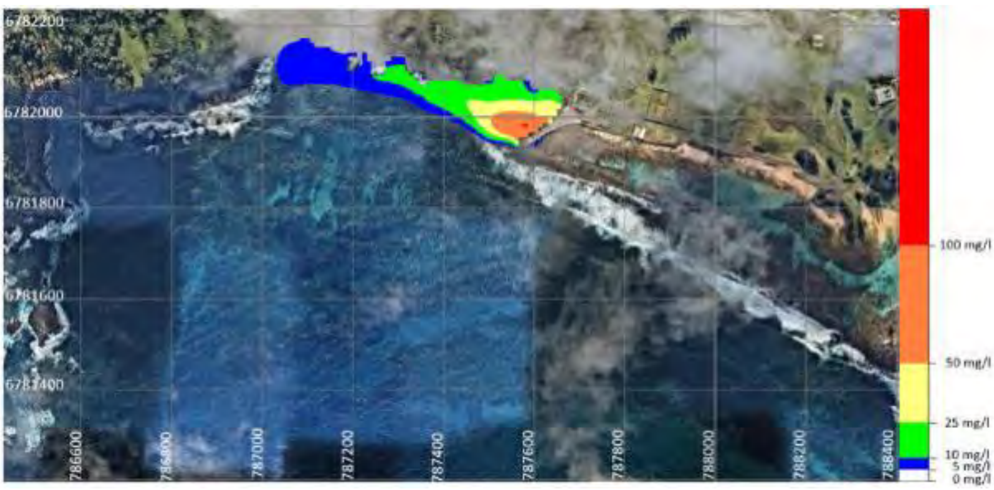


Figure 4-11 95th%ile Suspended sedimentation concentration distribution for Scenario 5 (strong east wind, no waves).

Scenarios 3 and 6 (strong winds from north and west)

Under energetic meteorological conditions with larger strong winds from the north and west directions there is a limited level of dredge plume (less than 10 mg/L) detected for lagoon and coral areas for the 80th percentile. For the 95th percentile, the dredge plume (up to 25 mg/L) was detected heading toward the lagoon and coral reef areas (i.e. the western end of Slaughter Bay). These scenarios are not realistic scenarios (as waves almost always occur at the site) and were run primarily to determine the sensitivity of the results to wind direction, i.e. to determine which wind directions could result in the plume moving toward the reef and lagoon areas so as to inform which wind directions should be tested with the inclusion of waves. As such, these modelled scenarios were refined and rerun as scenarios 7 and 8 to include ambient waves (see next section). Results from scenarios 3 and 6 are presented in the body of the Sediment Plume Modelling Report but have been superseded by scenarios 7 and 8 respectively.

Scenario 7 and 8 (strong winds from the north and west respectively, ambient waves)

When ambient waves are included in the simulation for 95th percentile northerly and westerly winds (representing a real "worst-case scenario" weather and hydrodynamic situation during the dredging operation), there is no plume detected for the lagoon and coral areas for both the 80th and 95th percentile. The inclusion of waves in the modelling is a more realistic scenario as Norfolk Island is almost always exposed to waves. Also, it is noted that winds from the east and north are more prevalent during the Spring and Summer months when the dredging is proposed (see Figure 4-12 to Figure 4-15).

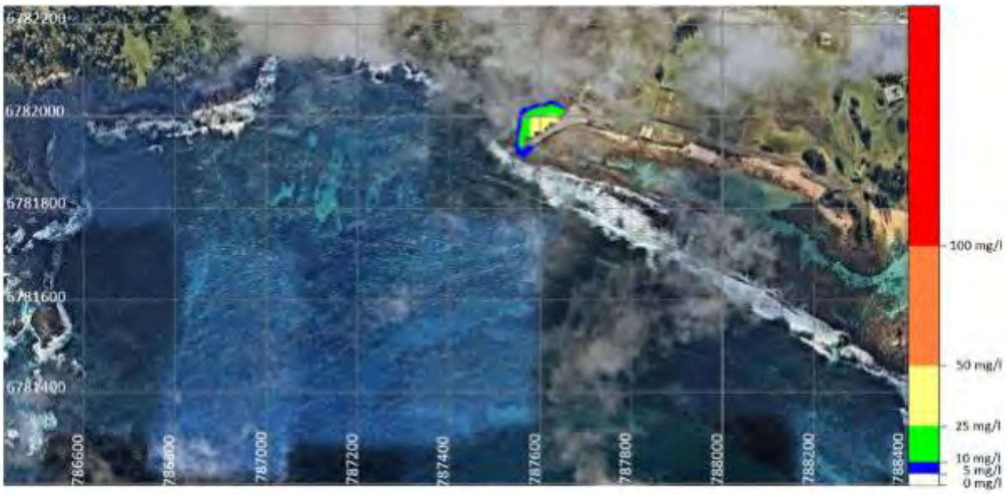


Figure 4-12 80th%ile Suspended sedimentation concentration distribution for Scenario 7 (strong north wind, ambient waves).

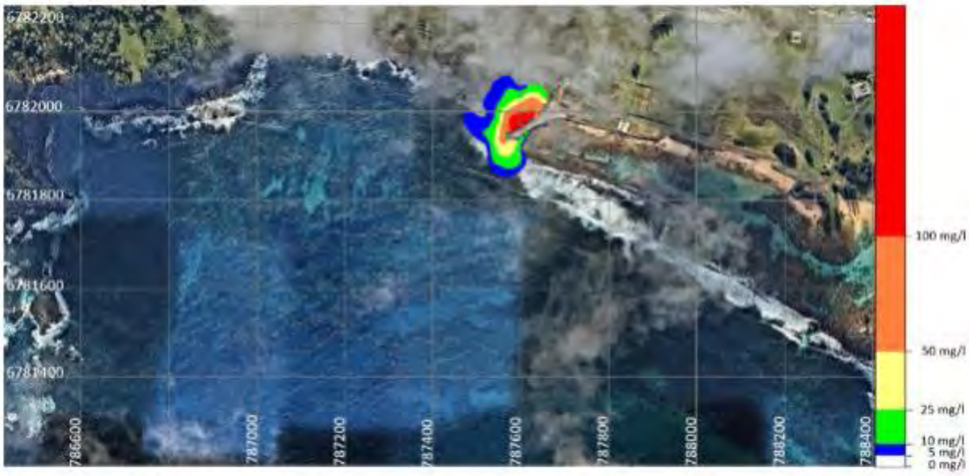


Figure 4-13 95th%ile Suspended sedimentation concentration distribution for Scenario 7 (strong north wind, ambient waves).

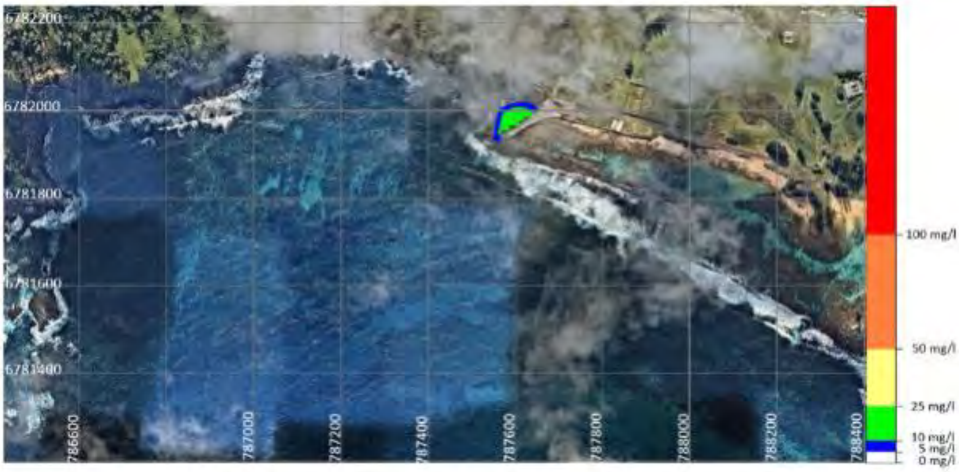


Figure 4-14 80th%ile Suspended sedimentation concentration distribution for Scenario 8 (strong west wind, ambient waves).

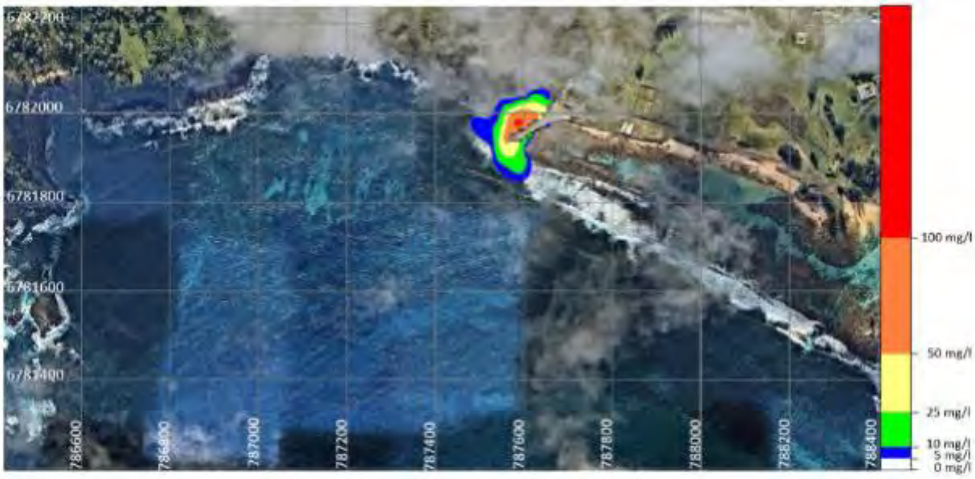


Figure 4-15 95th%ile Suspended sedimentation concentration distribution for Scenario 8 (strong west wind, ambient waves).

Sedimentation

The dredge plume model has predicted that sedimentation would be confined within the Kingston Harbour around the proposed dredging area. There is no sedimentation detected for the lagoon and coral reef areas in any scenarios. Figures presenting the sedimentation results are provided in the body of the Sediment Plume Modelling Report (Advisian 2021b).

Table 4-3 Summary of sediment plume modelling results.

Scenario	Result
Scenario 1 (baseline scenario with ambient wind, no waves)	Dredge plume is retained within the Kingston harbour (up to 30 mg/L and 100 mg/L for the 80th and 95th percentile, respectively). No plume detected in lagoon or coral reef areas.
Scenario 2 (typical conditions - most likely scenario; ambient wind, ambient waves)	No plume detected for the lagoon and coral reef areas for both the 80th and 95th percentile.
Scenarios 4 and 5 (strong winds from south and east)	No dredge plume detected for lagoon and reef areas for the 80th and 95th percentiles. The dredge plume is generally contained to the nearshore area west of the pier.
Scenarios 3 and 6 (strong winds from north and west – unrealistic scenario)	Limited level of dredge plume (less than 10 mg/L) detected for lagoon and coral areas for the 80th percentile. For the 95th percentile, the dredge plume (up to 25 mg/L) was detected heading toward the lagoon and coral reef areas (i.e. the western end of Slaughter Bay).
Scenario 7 and 8 (strong winds from the north and west respectively, ambient waves – real world 'worst case' scenario)	No plume detected for the lagoon and coral areas for both the 80th and 95th percentile.
Sedimentation	Sedimentation is confined within the Kingston Harbour around the proposed dredging area. No sedimentation detected for the lagoon and coral reef areas in any scenarios.

4.3.6 Conclusions

The modelling results have indicated that under real world conditions (i.e. the model runs that included waves) sediment plumes would not impact on the lagoon and coral areas to the east of the site, and sedimentation would not occur in these areas.

4.3.7 Recommendations

To ensure that the Environmental Quality Objectives for the lagoon and coral reef are met, the following recommendations are listed in the Sediment Plume Modelling Report (Advisian 2021b):

- **Dredging window:** Selection of a period of time, preferably between October and May, for the dredging operation to be undertaken to avoid the possible energetic meteorological conditions of which there will be a higher chance of strong wind from the northern and western sectors (noting the coral spawning season generally occurs from late January for a few months and would also look to be avoided).
- **Operation window:** Dredging should only take place during daylight hours with a break to unload spoil onshore per day for six days per week (half a day Saturday). No dredging activities are to take place during the night.
- **Water Quality Management Plan** - A Water Quality Management Plan is developed and implemented for the dredging works that outlines monitoring procedures and frequency, target limits, responsibilities, and mitigation measures (i.e. this document).

5 Terrestrial Environment

Terrestrial habitats in the study were described through a review of existing data and information collected during a site visit in February 2020.

5.1 Terrestrial Habitats

Norfolk Island is a weathered remnant of volcanoes on the Norfolk Ridge, linking New Zealand and New Caledonia. Pre-European vegetation of the island comprised subtropical rainforest which has largely been cleared, with the exception of Norfolk Island National Park in the north of the island (approximately 462 ha including Philip and Nepean Islands). The remainder of the island is now rural to rural-residential, with cattle grazing and crop production as some of the main terrestrial rural industries (Norfolk Island Region Threatened Species Recovery Plan 2010).

The terrestrial biota of Norfolk Island comprises approximately 556 vascular plant species (430 of these are introduced), 116 bird species (including 11 introduced and 66 vagrant species), 10 mammal species (all introduced) and many invertebrates and pathogens (Norfolk Island Region Threatened Species Recovery Plan 2010).

Norfolk Island is predominantly bounded by precipitous basaltic cliffs and tuff and is approximately 32 km in length. Surface water is restricted on the island, with no lakes and few wetlands. The three permanently flowing streams that exist are relatively small, but significant groundwater systems are known to occur. The soil is prone to mass movements, including soil creep and landslips, where vegetation cover has been degraded or lost after significant rain events (Norfolk Island Geology, Department of Agriculture, Water and the Environment 2020).

5.1.1 Terrestrial Protected Areas

5.1.1.1 National Parks and Nature Reserves

On Norfolk Island, there is one National Park in the north, and 11 smaller reserves located around the island, including the Norfolk Island Botanic Garden (Figure 5-1)(Norfolk Island National Park and Norfolk Island Botanic Garden Management Plan 2018-2029, 2018).

The Norfolk National Park was established in 1984 and is managed by the Commonwealth of Australia and is a protected area of 4.6 km^2 which serves as a sanctuary for several endangered flora and fauna species. The once dominant subtropical rainforests of Norfolk Island are now mainly restricted to the National Park, and extensive weed management is undertaken to protect the remaining rainforest areas. In addition to its natural values, the national park also includes historic and cultural values, as the park has been the site of several significant human events through time. The park provides educational, scientific, cultural and recreational opportunities for visitors and residents of the island. The Norfolk Island National Park will not be impacted in any way by the proposal.

Among the 11 reserves located on Norfolk Island, the Kingston Common Reserve and Bumbora Reserve occur within 1 km of the Kingston Pier (see Figure 5-1). The Kingston Common Reserve is an important historic site and vegetation within the reserve consists of kikuyu grass, rows of Norfolk Island Pines, white oaks and restricted instances of self-sown native flax have become established on the elevated foreshore north of the pier (Kingston Common Reserve Plan of Management 2003). The Kingston Common Reserve is adjacent to the Pier, but it is not expected that the proposed works would impact on any native vegetation communities within the reserve if all works (including any short term material stockpiling) are constrained to the existing roadways and the concrete Pier structure. Images of terrestrial vegetation in the Kingston Common Reserve are provided in Figure 5-3.

The Bumbora Reserve is a 5.5 ha area of secluded rocky beach with similar vegetation to the Kingston Common Reserve, except for kikuya grass, and with the addition of low herbaceous coastal vegetation fringing the beach (Bumbora Reserve Plan of Management 2003). Due to its location, this reserve will not be impacted in any way by the proposal.

Figure 5-1 Map of National Parks and Reserves on Norfolk Island (Norfolk Island National Park and Norfolk Island Botanic Garden Management Plan 2018-2029, 2018).

5.1.2 Matters of National Environmental Significance

Matters of National Environmental Significance (MNES) associated with terrestrial habitats as identified in the EPBC Act Protected Matters Search (**Appendix A**) are listed below. These MNES are those which are known to occur or have the potential to occur within a 10 km radius of the study site.

- 89 listed threatened species occur within the study area (77 are terrestrial).
- 41 listed migratory species occur within the study area (19 are terrestrial).

Other Matters listed under the EPBC Act 1999 and identified in the Protected Matters Search include:

- Commonwealth Land (the Norfolk Island National Park) occurs within the study area.
- No Critical Habitats occur within the study area.
- 3 Commonwealth Reserves (terrestrial reserves) occur within the study area:
  - Norfolk Island - Botanic Gardens.
  - Norfolk Island (Mt Pitt) - National Park (Commonwealth).
  - Norfolk Island (Phillip Island) - National Park (Commonwealth).

The only terrestrial MNES with the potential to be impacted by the Project are threatened and migratory species (see further detail in Section 5.2.2. All listed Commonwealth Land and Reserves listed above are outside the potential area of impact for the Project.

5.1.3 Critical Habitat

The EPBC Act 1999 Register of Critical Habitat was reviewed (Department of Agriculture, Water and the Environment 2020). Areas of Critical Habitat identified under the EPBC Act 1999 have been listed previously in Section 3.1.4. None of these areas of listed Critical Habitat occur within the study area and will not be impacted by the Project.

5.2 Terrestrial Fauna

5.2.1 General

Norfolk Island’s terrestrial fauna includes a mix of native and introduced species. March and Pope (1967) note the importance of Norfolk and Lord Howe Islands as stepping stones along what are the most likely migration routes for land dwelling organisms between Australia and New Caledonia, and New Zealand and Fiji.

There is a rich invertebrate fauna including assemblages of endemic land snails, cockroaches and beetles and an endemic cricket and centipede. There are also a number of introduced invertebrates such as the Argentine ant (*Linepithema humile*). Two native reptiles, the Lord Howe Island skink (*Oligosoma lichenigera*) and the Lord Howe Island gecko (*Christinus guentheri*) that are endemic to the Norfolk and Lord Howe Island groups. Neither is now found on the main island but both species occur on Phillip Island. The Asian house gecko (*Hemidactylus frenatus*) is a recent introduction to the main island (Director of National Parks 2008).

The only native land mammals that have been recorded on Norfolk Island are the Eastern free-tail bat (*Mormopterus norfolkensis*) and Gould's wattled bat (*Chalinolobus gouldii*). Only the latter has been seen in recent years. As in many other island ecosystems, introduced mammals have been responsible for significant environmental degradation. The Polynesian rat (*Rattus exulans*) was introduced by early Polynesian visitors prior to Cook's discovery of the island. The black rat (*Rattus rattus*) was possibly introduced from a ship wreck in 1942. There is a strong likelihood that the house mouse (*Mus musculus*) and the feral cat (*Felis catus*) were introduced during early settlement on the island. Early visitors also introduced goats and pigs.

Norfolk Island is notable for its endemic land birds. One hundred and two (102) species of birds have been recorded on Norfolk Island and adjacent islands in modern times. Norfolk Island is also a common resting place for migratory birds, some of which include the masked gannet, sooty tern, fairy tern and red-tailed tropic bird. Introduced birds, like the house sparry, European starling, and eastern rosella are common on the island (Birdwatching - Parks Australia, n.d). About twenty species of land birds breed on Norfolk Island and of these some six or so are merely geographical variants of species found in mainland Australia or in western Pacific Islands. They include an owl, a parakeet, a scarlet robin, a kingfisher a native starling and a fantail (March and Pope 1967). Analyses of Norfolk and Lord Howe bird populations made by various authors seem to reach the same general conclusions. namely, that in both faunas the most important element in the indigenous land species seems to have its origin in the New Caledonian area, with a secondary influence coming from New Zealand (March and Pope 1967).

Many migratory and vagrant sea birds also visit the island to nest on its steep cliffs. Many of the migratory seabirds visit Norfolk Island for the summer breeding season from October to May, others, like the Sooty Tern, arrive back on the island during the spring whale migration (Birdwatching - Parks Australia, n.d.). Many Forest birds are present on the island year-round and nest from September to December. A full list of Norfolk Island bird species, their preferred habitats and their seasonal occurrence at Norfolk Island can be found in the Norfolk Island Birdwatching Checklist (**Appendix B**).

5.2.2 Threatened and Protected Terrestrial Fauna

Appendix A (the EPBC Act Protected Matters Search) list all threatened and protected terrestrial fauna with the potential to occur within a 10 km radius of the study area as listed under the EPBC Act 1999. In summary, threatened and protected terrestrial fauna known to occur or with the potential to occur in the study area include:

- 24 Listed threatened species (birds)
- No mammals
- 5 snails
- 2 reptiles
- 6 migratory wetland species

These species along with their conservation status and likelihood of occurrence are listed below.

5.2.2.1 Birds

Threatened terrestrial bird species which are known to occur or have the potential to occur on Norfolk Island are listed in Table 5-1.

Table 5-1 Threatened bird species on Norfolk Island listed under the EPBC Act 1999.

Common Name	Species Name	Status	Likelihood of Occurrence
Red Knot	*Calidris canutus*	Endangered	Species or species habitat may occur within area
Norfolk Island Green Parrot	*Cyanoramphus cookii*	Endangered	Breeding known to occur within area
Antipodean Albatross	*Diomedea antipodensis*	Vulnerable	Species or species habitat may occur within area
Gibson's Albatross	*Diomedea antipodensis gibsoni*	Vulnerable	Species or species habitat may occur within area
Southern Royal Albatross	*Diomedea epomophora*	Vulnerable	Species or species habitat may occur within area
Wandering Albatross	*Diomedea exulans*	Vulnerable	Species or species habitat may occur within area
Northern Royal Albatross	*Diomedea sanfordi*	Endangered	Species or species habitat may occur within area
White-bellied Storm-Petrel	*Fregetta grallaria grallaria*	Vulnerable	Species or species habitat likely to occur within area
Western Alaskan Bar-tailed Godwit	*Limosa lapponica baueri*	Vulnerable	Species or species habitat may occur within area
Northern Siberian Bar-tailed Godwit	*Limosa lapponica menzbieri*	Vulnerable	Species or species habitat may occur within area
Southern Giant-Petrel	*Macronectes giganteus*	Endangered	Species or species habitat may occur within area
Northern Giant Petrel	*Macronectes halli*	Vulnerable	Species or species habitat may occur within area
Norfolk Island Boobook	*Ninox novaeseelandiae undulata*	Endangered	Breeding known to occur within area
Eastern Curlew, Far Eastern Curlew	*Numenius madagascariensis*	Critically Endangered	Species or species habitat known to occur within area
Golden Whistler	*Pachycephala pectoralis xanthoprocta*	Vulnerable	Species or species habitat known to occur within area
Norfolk Island Robin	*Petroica multicolor*	Vulnerable	Breeding likely to occur within area

Herald Petrel	*Pterodroma heraldica*	Critically Endangered	Species or species habitat may occur within area
Gould's Petrel	*Pterodroma leucoptera leucoptera*	Endangered	Species or species habitat may occur within area
Kermadec Petrel (western)	*Pterodroma neglecta neglecta*	Vulnerable	Breeding known to occur within area
White-capped Albatross	*Thalassarche cauta steadi*	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Chatham Albatross	*Thalassarche eremita*	Endangered	Species or species habitat may occur within area
Campbell Albatross	*Thalassarche impavida*	Vulnerable	Species or species habitat may occur within area
Black-browed Albatross	*Thalassarche melanophris*	Vulnerable	Species or species habitat may occur within area
Salvin's Albatross	*Thalassarche salvini*	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

5.2.2.2 Snails

Five threatened snails which are known to occur or have the potential to occur on Norfolk Island are listed in Table 5-2.

Table 5-2 Threatened terrestrial snail species on Norfolk Island listed under the EPBC Act 1999.

Common Name	Species Name	Status	Likelihood of Occurrence
Campbell's Helicarionid Land Snail	*Advena campbellii*	Critically Endangered	Species or species habitat known to occur within area
Gray's Helicarionid Land Snail	*Mathewsoconcha grayi ms*	Critically Endangered	Species or species habitat likely to occur within area
Phillip Island Helicarionid Land Snail	*Mathewsoconcha phillipii*	Critically Endangered	Species or species habitat likely to occur within area
Suter's Striped Glass-Snail	*Mathewsoconcha suteri*	Critically Endangered	Species or species habitat likely to occur within area
Stoddart's Helicarionid Land Snail	*Quintalia stoddartii*	Critically Endangered	Species or species habitat likely to occur within area

5.2.2.3 Reptiles

Two threatened reptiles which are known to occur or have the potential to occur on Norfolk Island are listed in Table 5-3.

Table 5-3 Threatened terrestrial reptile species on Norfolk Island listed under the EPBC Act 1999.

Common Name	Species Name	Status	Likelihood of Occurrence
Lord Howe Island Gecko	*Christinus guentheri*	Vulnerable	Species or species habitat likely to occur within area
Lord Howe Island Skink	*Oligosoma lichenigera*	Vulnerable	Species or species habitat likely to occur within area

5.2.2.4 Migratory Wetland Species

Migratory wetland species which are known to occur or have the potential to occur on Norfolk Island are listed in Table 5-4.

Table 5-4 Migratory wetland species on Norfolk Island listed under the EPBC Act 1999.

Common Name	Species Name	Status	Likelihood of Occurrence
Common Sandpiper	*Actitis hypoleucos*	Listed	Species or species habitat known to occur within area
Sharp-tailed Sandpiper	*Calidris acuminata*	Listed	Species or species habitat known to occur within area
Red Knot	*Calidris canutus*	Endangered	Species or species habitat may occur within area
Pectoral Sandpiper	*Calidris melanotos*	Listed	Species or species habitat known to occur within area
Bar-tailed Godwit	*Limosa lapponica*	Listed	Species or species habitat known to occur within area
Eastern Curlew, Far Eastern Curlew	*Numenius madagascariensis*	Critically Endangered	Species or species habitat known to occur within area

5.3 Terrestrial Plants

A number of threatened plant species are known to occur or have the potential occur on Norfolk Island as listed in Table 5-5.

Table 5-5 Threatened terrestrial plant species on Norfolk Island listed under the EPBC Act 1999.

Common Name	Species Name	Status	Likelihood of Occurrence
Norfolk Island Abutilon	*Abutilon julianae*	Critically Endangered	Species or species habitat known to occur within area
Chaff Tree, Soft-wood	*Achyranthes arborescens*	Critically Endangered	Species or species habitat known to occur within area

Phillip Island Chaffy Tree	*Achyranthes margaretarum*	Critically Endangered	Species or species habitat known to occur within area
Norfolk Island Water-fern	*Blechnum norfolkianum*	Endangered	Species or species habitat known to occur within area
Tree Nettle, Nettletree	*Boehmeria australis subsp. australis*	Critically Endangered	Species or species habitat known to occur within area
	Calystegia affinis	Critically Endangered	Species or species habitat known to occur within area
a creeper, Clematis	*Clematis dubia*	Critically Endangered	Species or species habitat known to occur within area
Coastal Coprosma	*Coprosma baueri*	Endangered	Species or species habitat known to occur within area
Mountain Coprosma	*Coprosma pilosa*	Endangered	Species or species habitat known to occur within area
Norfolk Island Cordyline	*Cordyline obtecta*	Vulnerable	Species or species habitat known to occur within area
Norfolk Island Orchid	*Dendrobium brachypus*	Endangered	Species or species habitat known to occur within area
Sharkwood	*Dysoxylum bijugum*	Vulnerable	Species or species habitat known to occur within area
Mountain Procris	*Elatostema montanum*	Critically Endangered	Species or species habitat known to occur within area
Phillip Island Wheat Grass	*Elymus multiflorus subsp. kingianus*	Critically Endangered	Species or species habitat likely to occur within area
Norfolk Island Euphorbia	*Euphorbia norfolkiana*	Critically Endangered	Species or species habitat known to occur within area
	Euphorbia obliqua	Vulnerable	Species or species habitat likely to occur within area
Phillip Island Hibiscus	*Hibiscus insularis*	Critically Endangered	Species or species habitat likely to occur within area
Downy Ground-fern, Brake Fern, Ground Fern	*Hypolepis dicksonioides*	Vulnerable	Species or species habitat likely to occur within area
Mistletoe	*Ileostylus micranthus*	Vulnerable	Species or species habitat known to occur within area
Shield-fern, Shieldfern	*Lastreopsis calanthe*	Endangered	Species or species habitat known to occur within area
King Fern, Para, Potato Fern	*Marattia salicina*	Endangered	Species or species habitat likely to occur within area

Shade Tree	*Melicope littoralis*	Vulnerable	Species or species habitat known to occur within area
Norfolk Island Mahoe	*Melicytus latifolius*	Critically Endangered	Species or species habitat known to occur within area
Whiteywood	*Melicytus ramiflorus subsp. Oblongifolius*	Vulnerable	Species or species habitat likely to occur within area
Narrow-leafed Mertya	*Meryta angustifolia*	Vulnerable	Species or species habitat known to occur within area
Shade Tree, Broad-leaved Meryta	*Meryta latifolia*	Critically Endangered	Species or species habitat likely to occur within area
Shrubby Creeper, Pohuehue	*Muehlenbeckia australis*	Endangered	Species or species habitat known to occur within area
Popwood, Sandalwood, Bastard Ironwood	*Myoporum obscurum*	Critically Endangered	Species or species habitat known to occur within area
Beech	*Myrsine ralstoniae*	Vulnerable	Species or species habitat known to occur within area
Pennantia	*Pennantia endlicheri*	Endangered	Species or species habitat known to occur within area
Norfolk Island Phreatia	*Phreatia limenophylax*	Critically Endangered	Species or species habitat known to occur within area
	Phreatia paleata	Endangered	Species or species habitat known to occur within area
Oleander	*Pittosporum bracteolatum*	Vulnerable	Species or species habitat known to occur within area
	Planchonella costata	Endangered	Species or species habitat known to occur within area
Middle Filmy Fern	*Polyphlebium endlicherianum*	Endangered	Species or species habitat known to occur within area
King's Brakefern	*Pteris kingiana*	Endangered	Species or species habitat likely to occur within area
Netted Brakefern	*Pteris zahlbruckneriana*	Endangered	Species or species habitat likely to occur within area
	Senecio australis	Vulnerable	Species or species habitat likely to occur within area
	Senecio evansianus	Endangered	Species or species habitat known to occur within area
	Senecio hooglandii	Vulnerable	Species or species habitat known to occur within area

Siah's Backbone, Sia's Backbone, Isaac Wood	*Streblus pendulinus*	Endangered	Species or species habitat known to occur within area
Minute Orchid, Ribbon-root Orchid	*Taeniophyllum norfolkianum*	Vulnerable	Species or species habitat likely to occur within area
Hanging Fork-fern	*Tmesipteris norfolkensis*	Vulnerable	Species or species habitat known to occur within area
Bastard Oak	*Ungeria floribunda*	Vulnerable	Species or species habitat known to occur within area
Kurrajong	*Wikstroemia australis*	Critically Endangered	Species or species habitat known to occur within area
Native Cucumber, Giant Cucumber	*Zehneria baueriana*	Endangered	Species or species habitat known to occur within area

5.4 Introduced Species

There are a high number of introduced species which occur on Norfolk Island, stemming from pre-European settlement, by Polynesian visitors who brought with them bananas, flax and the Polynesian Rat. Many other plants and animals were introduced following European settlement for production and amenity (Norfolk Island Quarantine Survey 2014). The impacts of invasive species range from negligible to extremely high, species that have entered and established and have the ability to spread aggressively can and have overwhelmed a large number of native species (Norfolk Island Region Threatened Species Recovery Plan 2010). Weeds reported in the EPBC Act 1999 Protected Matters Search are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are also reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. In the sections below, the birds, mammals, reptiles and plants introduced to Norfolk Island are listed.

5.4.1.1 Birds

Introduced bird species known to occur or with the potential to occur on Norfolk Island are listed in Table 5-6 below.

Table 5-6 Introduced bird species on Norfolk Island listed under the EPBC Act 1999.

Common Name	Species Name	Likelihood of Occurrence
Mallard	*Anas platyrhynchos*	Species or species habitat likely to occur within area
California Quail	*Callipepla californica*	Species or species habitat likely to occur within area
European Goldfinch	*Carduelis carduelis*	Species or species habitat likely to occur within area
European Greenfinch	*Carduelis chloris*	Species or species habitat likely to occur within area
Rock Pigeon	*Columba livia*	Species or species habitat likely to occur within area
Red Junglefowl	*Gallus gallus*	Species or species habitat likely to occur within area
House Sparrow	*Passer domesticus*	Species or species habitat likely to occur within area
Common Starling	*Sturnus vulgaris*	Species or species habitat likely to occur within area

Common Blackbird	*Turdus merula*	Species or species habitat likely to occur within area
Song Thrush	*Turdus philomelos*	Species or species habitat likely to occur within area

5.4.1.2 Mammals

Introduced mammals known to occur or with the potential to occur on Norfolk Island are listed in Table 5-7.

Table 5-7 Introduced mammals on Norfolk Island listed under the EPBC Act 1999.

Common Name	Species Name	Likelihood of Occurrence
Domestic Cat	*Felis catus*	Species or species habitat likely to occur within area
House Mouse	*Mus musculus*	Species or species habitat likely to occur within area
Pacific Rat	*Rattus exulans*	Species or species habitat likely to occur within area
Black Rat	*Rattus rattus*	Species or species habitat likely to occur within area

5.4.1.3 Reptiles

Introduced reptile species known to occur or with the potential to occur on Norfolk Island are listed in Table 5-8.

Table 5-8 Introduced reptiles on Norfolk Island listed under the EPBC Act 1999

Common Name	Species Name	Likelihood of Occurrence
Asian House Gecko	*Hemidactylus frenatus*	Species or species habitat likely to occur within area

5.4.1.4 Plants

Introduced plant species known to occur or with the potential to occur on Norfolk Island are listed in Table 5-9.

Table 5-9 Introduced plants on Norfolk Island listed under the EPBC Act 1999

Common Name	Species Name	Likelihood of Occurrence
Madeira Vine	*Anredera cordifolia*	Species or species habitat likely to occur within area
Climbing Asparagus-fern	*Asparagus plumosus*	Species or species habitat likely to occur within area
Water Hyacinth	*Eichhornia crassipes*	Species or species habitat likely to occur within area
Lantana	*Lantana camara*	Species or species habitat likely to occur within area
African Boxthorn, Boxthorn	*Lycium ferocissimum*	Species or species habitat likely to occur within area
Blackberry	*Rubus fruticosus aggregate*	Species or species habitat likely to occur within area

5.5 Terrestrial Ecology Field Survey

5.5.1 Kingston Pier Area

A general survey of terrestrial habitats occurring around the Kingston Pier area was undertaken in February 2020. Satellite imagery from January 2018 (Figure 5-2) clearly shows the proximity of the Pier to nearby areas of terrestrial vegetation. Vegetation near to the Kingston Pier was primarily comprised of grassed fields (including in Arthurs Vale) with several areas of planted Norfolk Island Pines along the nearby roadways (e.g. along Pier Street, Country Road and Quality Row), around several nearby KAVHA Buildings (e.g. Old Government House) and dominating the vegetation community of Flagstaff Hill. A high level of erosion was observed on the southern slope of Flagstaff Hill above the harbour. The seawall within the harbour and along the edge of Slaughter Bay was topped by planted grasses and the flowering coastal succulent pigface (*Carpobrotus glaucescens*). Lilies and reeds were present within and along the banks of the small canals and wetland areas located in Arthurs Vale to the west of Pier Street and the grassy fields to the east of Pier Street.

During consultation in February 2020, The Norfolk Island Flora and Fauna Group advised that the grassed area immediately adjacent to the harbour and in front of Old Government House covers original convict drains, and as such should not be disturbed during the proposed dredging activities, nor should the area be used as a temporary works or storage area in case of accidental damage occurring. It is not expected that any clearing or disturbance of native vegetation would need to occur for the proposed dredging works adjacent to Kingston Pier, and that all required land based access could be gained via existing roads and from the Pier itself. The general location of terrestrial habitats and other features are shown in Figure 5-2 and images of the terrestrial vegetation around the Kingston Pier with additional descriptive captions are provided in Figure 5-3.

Figure 5-2 Terrestrial vegetation in the vicinity of the study site (Zoom Imagery January 2018).


Norfolk Island Pines dominated the vegetation community of Flagstaff Hill to the west of the Pier. High levels of erosion were seen on the southern slopes leading to the ocean.


Grasses and pigface occurred around the top of the seawall immediately west of the Pier. Reports of old convict drains under this grassed area were made by Norfolk Island Flora and Fauna Group.


Grasses, pigface and other coastal flowers were also present at the base of the seawall to the east of the Kingston Pier.

Norfolk Island Pines, pigface and planted grass occurred around Old Government House, just north of the Pier and near the turning circle exiting out to Pier Street.

East of the Kingston Pier extensive areas of grass occurred around the KAVHA World Heritage Buildings. Some small areas of pigface and other small coastal flowers occurred around these buildings.

Norfolk Island Pines and grasslands fringed Pier Street, the main road leading to and from the Pier.

The valley looking eastwards from Pier Street with expansive grasslands and areas of lilies and reeds occurring within and along the small canals and wetland areas.

The valley (Arthurs Vale) looking west from Pier Street with grasslands, reeds and lilies (along the small canals and wetlands areas). Norfolk Island Pines on Flagstaff Hill can be seen in the background.

Figure 5-3 Terrestrial vegetation in the vicinity of the Kingston Pier.

6 Potential Construction Impacts

6.1 Marine and Terrestrial Habitats

The following sections outline the potential impacts of the Project on marine and terrestrial habitats which occur within the study area.

6.1.1 Protected Areas and Environmentally Sensitive Lands

Protected Areas

Marine

The study area is located within a Special Purpose Zone of the Norfolk Island Marine Park (see Section 3.1.2.1) and has the potential to impact both directly and indirectly on marine habitats and fauna within the boundaries of the Marine Park as discussed in the ensuing sections. "Dredging and disposal of dredged material" is an allowable activity within a Special Purpose Zone in the Temperate East Marine Region, subject to assessment and approval (refer to allowable activity tables at https://parksaustralia.gov.au/marine/pub/factsheets/factsheet-temperate-east-management-plan.pdf).

It is currently expected that disposal of excavated material will occur on land (refer to Section 2.6).

Terrestrial

The study area is located near to the Norfolk Island National Park, the Kingston Common Reserve and the Bumbora Reserve refer to Section 5.1.1.1).

The Project will not have any impact on the Norfolk Island National Park as it lies outside of the immediate Project boundaries and no proposed disposal sites are located within the National Park (refer to Section 5.1.1.1).

The Project will not have any impact on the Bumbora Reserve, which occurs to the west of Kingston, as this reserve lies outside of the Project boundaries and no proposed disposal sites are located within this Reserve (refer to Section 5.1.1.1).

The Kingston Common Reserve is an important historic site which occurs on the elevated foreshore immediately north of the Kingston Pier and is within the general works area (refer to Section 5.1.1.1). Due to its proximity, there is the potential for direct and/or indirect impacts on vegetation and fauna within the reserve. However, it is expected that these can largely be avoided if appropriate mitigation measures and no-go zones for construction vehicles and local materials stockpiling are adopted. No impacts during operation are expected.

Critical Habitat

No areas of Critical Habitat for marine or terrestrial species listed under the EPBC Act 1999 occur within the study area (see Sections 3.1.4 and 5.1.3). Therefore, no areas of Critical Habitat will be impacted by the Project.

Key Ecological Marine Features

Key Ecological Marine Features listed under the EPBC Act 1999 which occur within the study area include the Norfolk Ridge and the Tasman Front and eddy field (3.1.5). It is not expected that either of these would be impacted significantly by the Project.

6.1.2 Marine Habitats in the Study Area

Marine habitats located within the immediate construction footprint (Kingston Pier) and nearby areas (i.e. Slaughter Bay and Creswell Bay) were described using background data, including the results of previous surveys and the results of a marine field survey undertaken in February 2020.

Marine habitats located within the proposed excavation footprint at Kingston Pier consist largely of modified seabed that has been subject to previous disturbance and dredging and surrounding unmodified seabed that consists of coarse sand and rubble overlying layers of rock. Intertidal rocky reef fringes the rocky beach west and east of Kingston Pier. Artificial marine habitats including the rock revetment placed on the beach to the west of the Pier and the rock walls and timber supports that for part of Kingston pier itself.

Adjacent to Kingston Pier but outside of the immediate construction footprint, subtidal habitats are predominantly subtidal rocky reef which is inhabited by a large variety of macroalgae, together with a low percentage cover of coral species. The macroalgae and coral reef provide habitat for a range of fish and invertebrate species. It has been well documented that the broader marine ecosystem at Norfolk Island is not unique in terms of species present, however the coral reef ecosystem is one of the few known examples of a transitional algae and coral assemblage (an unusual mix of tropical and temperate marine fauna and flora due to the alternating influence of warm and cool currents at the Islands).

Potential construction related impacts on marine habitats and flora within the immediate construction footprint and greater Kingston Pier area can be summarised as follows (and are discussed in further detail following).

- Sedimentation of seafloor habitats including macroalgae and inshore subtidal reef from the settlement of sediments which may be generated during excavation of material and from the action of construction vessels. Within the immediate construction zone these impacts will not be able to be avoided, however, if appropriate safeguards are adopted then impacts outside of the immediate construction area can be mitigated under most oceanic / meteorological conditions (including the conditions which will likely be present during dredging), and therefore minimised.
- Short term reductions in light availability in the immediate construction area (or greater area if suspended sediment is not contained) through increased turbidity levels caused by excavation activity.
- Direct harm to the seafloor habitat and potentially small areas of marine vegetation (macroalgae) in the immediate construction area from pier refurbishment works.
- Direct harm to sediment seafloor habitats (macroalgae and corals) through the activities of construction vessels (e.g. anchoring during construction).
- Impacts of water pollution on marine habitats from vessel activities (e.g. accidental spills of fuels and oils and incorrect disposal of general and construction waste).

6.1.2.1 Impacts of Turbidity

Construction Area

Marine sediments may be mobilised within the immediate construction area by the act of excavating the seabed. If these remobilised sediments are not contained appropriately to prevent spread outside the immediate construction zone, they have the potential to cause sedimentation of nearby sensitive subtidal habitats including the macroalgae and corals that form part of the subtidal rocky reef. Minor disturbance and mobilisation of sediments at the construction site may also occur as a result of vessel movements (i.e. propeller wash) and vessel anchoring during construction activities, although, due to water depths within the most of footprint area (excluding inshore shallow areas), this is expected to be limited.

The preliminary construction methodology for the channel is based on the following three elements:

1. Removal of loose sediment material from the existing channel and cracks of calcarenite using a venturi suction pipe. The material will be lifted to the pier for screening of archaeological artefacts.
2. Removal of the calcarenite layer with a backhoe mounted on a jack-up barge and hand-tools near the pier. Skip bins would be filled with material and transported for material handling efficiency. The calcarenite rock would be screened for artefacts.
3. Removal of the tuff rock with a backhoe mounted on a jack-up barge and hand-tools near the pier. Screening of the artefacts is not expected to be required for the tuff material.

Some pier stabilisation works are also proposed but are unlikely to create turbid plumes.

Excavation of material using Venturi suction is unlikely to create elevated turbidity as most of the loose sediments on the existing seabed are very coarse (generally containing <5% fines). In contrast, excavation of the rock, in particular the tuff is likely to create localised plumes of turbidity as the rock has low strength and will crush from the force of the excavator. A proportion of the material on the seabed will escape from the backhoe (back into the water) as the excavator arm moves through the water column to place the excavated material onto the hardstand area on the pier or barge.

Potential damage associated with excavation and turbidity-generating activities are generally separated into direct and indirect effects. The direct effects include the removal of hard and soft substrate i.e. the excavation footprint. As disposal of excavated material is proposed to land, no impacts from marine disposal of material are anticipated.

The indirect effects are associated with mobilisation of sediments into the water column (i.e. turbidity or plume-generation) which are usually divided into chemical effects and physical effects. As the material from Kingston Pier is chemically clean, the assessment is focussed on the physical effects as they relate to increased turbidity and corresponding reductions in light availability.

Although a range of marine species around Kingston Pier have the potential to be impacted by turbidity generating activities, it is generally accepted that corals are amongst the most sensitive to disturbance and are therefore likely to be the most susceptible to changes in light.

Impacts from sediments on corals has been the subject of detailed review and assessment by Erfetmeijer et al. (2012) and more recently by Jones et al. (2017). As described by the latter, key proximal stressors affecting corals are: (1) light attenuation affecting photosynthesis (autotrophy), (2) high suspended sediment concentrations (SSCs) affecting feeding processes (heterotrophy) and, (3) sediment deposition resulting in smothering of corals and restricting solute exchange and light.

Light reduction is probably the most important of all sediment related effects on corals. Light decreases exponentially with depth due to a process of attenuation (extinction), i.e. the absorption and scatter of light by water molecules, particulate solids, and dissolved matter (Weinberg, 1976; Falkowski et al., 1990). Maximal growth and development of reef corals usually occurs down to 30% to 40% of subsurface irradiance (SI) and rarely is any significant reef formation found below 10% SI (Achituv and Dubinsky, 1990).

Tolerance limits of corals for total suspended matter (or suspended-sediment concentration) reported in the literature range from <10 mg/l in reef areas not subject to stresses from human activities to >100 mg/l in marginal reefs in turbid nearshore environments (Marshall and Orr 1931; Roy and Smith 1971; Mapstone et al. 1989; Hopley et al. 1993; Larcombe et al. 2001; Hoitink 2003; Sofonia and Anthony 2008) (Table 6-1). This wide range demonstrates that different coral species and corals in different geographic regions may respond differently to turbidity increases. Tolerance may also be a function of coral morphology as most soft corals and many massive coral species are relatively sensitive to turbidity while laminar, plating and tabular corals as well as some morphologically variable corals are relatively tolerant. The research completed by Jones et al. (2019) confirmed that sediment related metrics appeared to be more closely related to mortality in massive, primarily *Porites* spp., while light metrics were more strongly associated with mortality in branching colonies (*Acropora* spp. and *Pocilloporidae*).

Table 6-1 Some published critical thresholds of corals (reefs) for total suspended sediment (mg/L).

Description	Location	$mg\,L^{-1}$	References
Coral reefs	Great Barrier Reef (GBR), Australia	3.3	Bell (1990)
Coral reefs	Fanning lagoon, Florida, USA	10	Roy and Smith (1971)
Coral reefs	Caribbean	10	Rogers (1990)
Coral reefs	Papua New Guinea	15	Thomas et al. (2003)
Coral reefs	Florida, USA	20	Bogers and Gardner (2004)
Corals	Dominican Republic	20	Van der Klis and Bogers (2004)
Marginal reef environments	Banten Bay, Java, Indonesia	40	Hoitink (2003)
Marginal reef environments	Paluma Shoals, QLD Australia	40	Larcombe et al. (2001)
Nearshore fringing reefs	Magnetic Island, GBR, Australia	75–120	Mapstone et al. (1989)
Nearshore fringing reefs	Cape Tribulation, GBR, Australia	100–260	Hopley et al. (1993)
Seven resistant coral species	Florida, USA	165	Rice and Hunter (1992)

Water quality monitoring undertaken during the field program (February 2020) confirmed that background turbidity around Kingston Pier was usually between 0 NTU and 1 NTU confirming that water quality was high. Assuming a conversion of SSC=1.8 x NTU (Jones et al. 2019), this is equivalent to <2 mg/l. It is unclear what impact surface run-off from Flagstaff Hill and the surrounding catchment has (on Kingston Pier) during rainfall events but it can be assumed that water quality is generally high for most of the year but could be affected between May and August when rainfall is at its highest.

Given the ecological significance of the corals present and the ambient water quality, it is assumed that tolerance limits for turbidity would be in the lower range shown in Table 6-1. In assessing the potential impacts on corals that may be exposed to above ambient turbidity during the construction phase, consideration should also given to the proposed duration of the construction activities which are likely to be short (2-3 months) and periodic (occuring during daylight hours only).

6.1.2.2 Impacts of Sedimentation

While sedimentation is a major stressor that can lead to significant coral mortality, strong, isolated sediment pulses need not necessarily kill a reef. Many reefs, and certainly corals in most settings, can indeed survive repeated, even severe, sediment input (Browne et al. 2010). One of the most important factors mitigating against permanent damage is strong water motion, either by surge or by currents, that serves to re-suspend and remove the sediment from the corals, which would certainly be the case for the reefs to the west of Kingston Pier.

There is still a rather poor understanding of the relationship between sediment stress and the response of most corals. While meaningful sets of thresholds or criteria would ideally have to incorporate the intensity, duration and frequency of turbidity (or sedimentation) events generated by the dredging activities, actual values are difficult to determine with confidence and at present remain little more than estimates (Erftemeijer et al. 2012). Table 6-2 presents some published critical thresholds of corals reefs for sedimentation.

Table 6-2 Some published critical thresholds of coral reefs for sedimentation (mg cm^2/day).

Species/type of corals	Location	mg cm^{-2} day^{-1}	References
Coral reefs	Worldwide (moderate to severe)	10	Pastorok and Bilyard (1985)
Coral reefs	Caribbean	10	Rogers (1990)
Coral reefs	Caribbean	37	Pastorok and Bilyard (1985)
Coral reefs	Worldwide (catastrophic)	50	Pastorok and Bilyard (1985)
Coral reefs	Puerto Rico	90	Miller and Cruise (1995)
Coral reefs	Indo-Pacific	228	Pastorok and Bilyard (1985)
Most coral species	Worldwide	300	Bak and Elgershuizen (1976)

Overall, the increases in turbidity from activities including excavation and pier improvements are likely to be very short lived and highly localised if appropriate and conservative safeguards are employed to contain suspended sediments. They are not expected to result in any extended periods in the reduction of coral survival adjacent to Kingston Pier or in Slaughter Bay, nor are they expected to cause any significant impacts on sessile flora and fauna (e.g. through clogging of pores or filter feeding apparatus) in the areas of subtidal rocky reef. While recent sediment plume modelling (Advisian 2021) has shown that the likelihood of significant (or other) turbidity impacts within Slaughter Bay or Emily Bay is low during the majority of meteorological and oceanic conditions, including those most likely to be encountered during the proposed dredging, caution should be applied in the use of threshold limits for turbidity and sedimentation considering the sensitivity of corals in these areas.

6.1.2.3 Direct Disturbance to Seafloor Habitat

Direct disturbance of seafloor habitat during construction will occur through excavation and may also occur through the activities of construction vessels (e.g. via propeller wash or anchoring).

Excavation within the existing channel will remove existing areas of soft sediment habitat with the loss of epifauna which reside within it. There will also be loss of some areas of rocky substrate that have previously been disturbed which have little epibiotic cover (see Figure 3-8). Due to the coarse sediment present and the mobile nature of the sediments within the channel, there was no evidence of infauna in the sediment samples collected. Direct impacts from pier improvements on largely unvegetated soft sediment seafloor habitat and associated reef fauna are not considered to be significant in the context of impacts from the excavation activity. Any small scale and localised damage to macroalgae is not considered to be significant given the abundance of macroalgae (in better condition) inhabiting the nearby subtidal reefs both west and east of Kingston Pier.

The total area of seabed likely to be disturbed as a result of the preferred options are:

- Option 1 ~0.24 ha
- Option 1a ~0.29 ha
- Option 3 ~0.34 ha
- Option 3a ~0.29 ha

In all cases, most of the area likely to be directly impacted by excavation is within the existing channel and therefore has been previously disturbed. Whereas Option 1 involves mostly deepening of the existing channel, Option 3 also includes a small additional area of channel widening. Option 1a and 3a involve excavation within the existing channel as well as a small area of widening (which is less than proposed for Option 3). The channel widening will most likely impact small areas of rocky reef with some macroalgae and some isolated corals that are likely to be removed (see Figure 3-9).

Overall, the direct disturbance to the seabed associated with Option 1 is considered negligible as it will impact areas of seabed previously disturbed. The direct disturbance associated with Option 3 is also considered minor as the area of seabed impacted by widening of the existing channel is very small and less than 0.1 hectares. Similarly, the direct disturbance associated with Option 1a and 3a is also considered negligible, being intermediate to these other options.

6.1.2.4 Tolerance Limits

While meaningful sets of thresholds or criteria would ideally have to incorporate the intensity, duration and frequency of turbidity (or sedimentation) events generated by the dredging activities, actual values are difficult to determine with confidence (Erftemeijer et al 2012). This is particularly problematic with programs of the duration and extent proposed at Kingston Pier which are likely to result in small pulses of turbidity of short duration.

An example of thresholds previously used are provided in Table 6-3 and could be applied as a way of managing potential impacts from the proposed channel improvements.

Table 6-3 Suspended Sediment Thresholds for Corals (DHI 2010)

Zone	Suspended Sediment Threshold
Total Mortality	• Excess SSC >25mg/l for > 10% of the time OR • Excess SSC >10mg/l for >25% of the time
Partial Mortality	• Excess SSC >25mg/l for 2.5-10% of the time OR • Excess SSC >10mg/l for 10-25% of the time OR • Excess SSC >5mg/l for >25% of the time
Zone of Influence	• Excess SSC >25mg/l for 0.5-2.5% of the time OR • Excess SSC >10mg/l for 0.5-10% of the time OR • Excess SSC >5mg/l for 2.5-25% of the time
No Impact	• Excess SSC >25mg/l for <0.5% of the time OR • Excess SSC >10mg/l for <0.5% of the time OR • Excess SSC >5mg/l for <2.5% of the time

A combination of reactive (feedback) monitoring of water quality and coral health during dredging activities and spill-budget modelling of dredging plumes to guide decisions on when to modify (or even stop) dredging appears to be the most promising approach to effectively minimise negative impacts on corals and coral reefs (Erftemeijer et al. 2012).

6.1.2.5 Impacts on Water Quality / Pollution

Water quality impacts resulting from construction activities have the potential to impact on marine habitats and fauna. Water pollution is known to cause degradation to the quality of aquatic habitats, may alter the distribution and density of species, can increase levels of contaminants in the tissue of some species, which can then have impacts up the food chain, and reduce the relative abundance of top-order predators (DECCW 2009).

Potential sources of water pollution related to the construction phase of the Proposal include:

- Accidental spills and/or leaks of fuels and oils from construction vessels and equipment impacting on habitats and fauna.
- Incorrect disposal of general rubbish generated by Contractors into the waterway causing pollution of marine habitats / impacts on fauna.
- Incorrect disposal of construction waste (e.g. pieces of concrete, piles, timber, plastic and metallic objects) into the waterway causing pollution of marine habitats / impacts on fauna.

6.1.2.6 Impacts on Water Quality / Pollution

Water quality impacts resulting from construction activities have the potential to impact on marine habitats and fauna. Water pollution is known to cause degradation to the quality of aquatic habitats, may alter the distribution and density of species, can increase levels of contaminants in the tissue of some species, which can then have impacts up the food chain, and reduce the relative abundance of top-order predators (DECCW 2009). Reproductive physiology, mating systems, and organism life histories can also be impacted by water pollution and can combine with other factors to reduce population persistence (Dulvey et al. 2003).

Potential sources of water pollution related to the construction phase of the Project include:

- Accidental spills and/or leaks of fuels and oils from construction vessels and equipment impacting on habitats and fauna.
- Incorrect disposal of general rubbish generated by Contractors into the waterway causing pollution of marine habitats / impacts on fauna.
- Incorrect disposal of construction waste (e.g. pieces of concrete, piles, timber, plastic and metallic objects) into the waterway causing pollution of marine habitats / impacts on fauna.

6.1.3 Terrestrial Habitats in the Study Area

Terrestrial habitats in the vicinity of the immediate construction area consist of kikuya grassed areas around the KAVHA buildings, kikuya grassed fields and multiple stands of Norfolk Island Pines around buildings and along the roadside. As well as dominating Flagstaff Hill. Some small areas of coastal flowers (e.g. pigface) occur along the top and base of seawalls and there are a number of wetland / culvert areas with reeds and lilies which occur within Arthurs Vale (to the west of Pier Street) and in the expansive fields to the east of Pier Street.

While the vast majority of construction works will be marine based, some excavation related activities will need to occur onshore such as vehicle movements, transfer of excavated material from the harbour to the Pier for screening of material for artefacts, before transfer to trucks for transport to the disposal site, material stockpiling (dredge material and construction equipment) and other general construction activities.

Due to the availability of sealed roads and concrete areas of the Pier which can be nominated for use for such land based activities, in addition to fully sealed roads suitable for transport of excavated material to the selected disposal site, it is expected that direct impacts on terrestrial habitats can be avoided. The area of grass immediately north of the harbour cannot be used for any such stockpiling or other activities due to the reported presence of convict drains underneath which may be damaged during such activities. This grassed area should be flagged as a no-go zone.

All nominated preferred disposal sites are previously disturbed areas so no impacts on important flora or fauna communities are expected to occur.

6.2 Fauna

Potential direct and indirect impacts on marine fauna (including marine and migratory seabirds) are described below. Due to the proposed scope of works and location of works within and adjacent to Kingston Harbour, direct impacts on terrestrial fauna are very unlikely to occur but indirect impacts (such as from noise or lighting) may be similar in nature in some instances (and are noted where so).

6.2.1 Marine Vertebrates

Potential construction related impacts on marine vertebrate fauna (including marine and migratory seabirds) can be summarised as:

- Entanglement / Ingestion of Marine Debris
- Impacts of Floating Plant and Cable Strike
- Impacts of Water Pollution
- Lighting Impacts
- Noise Impacts

6.2.1.1 Entanglement / Ingestion of Marine Debris

Marine fauna (including fishes, reptiles, sharks and rays, marine mammals and marine/migratory birds) which utilise the study area have the potential to be adversely affected by marine debris which may be generated during construction and accidentally or deliberately disposed of into the local waterway. This risk is also possible for terrestrial fauna which occur near the marine study area (although this would be expected to be very uncommon).

"Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris" is listed as a Key Threatening Process under the EPBC Act 1999. There is an approved Threat Abatement Plan under the EPBC Act 1999 for *"Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris":* http://www.environment.gov.au/marine/publications/threat-abatement-plan-impacts-marine-debris-vertebrate-marine-life.

Harmful marine debris may include plastic garbage. Plastic materials are defined as bags, bottles, strapping bands, sheeting, synthetic ropes, synthetic fishing nets, floats, fibreglass, piping, insulation, paints and adhesives. There is the potential for plastic general waste and construction waste to be generated during construction. Disposal of plastics at sea is totally prohibited by the *International Convention* (DEH 2003).

Entanglement of fauna in marine debris can cause restricted mobility, starvation, infection, amputation, drowning and smothering. Ingestion of marine debris occurs when species confuse items such as plastic bags, rubber, balloons and confectionery wrappers with prey and ingest them, causing a physical blockage in the digestive system, leading to internal injuries.

Several studies have investigated the impact of marine debris on seals in Australian waters. A study of the New Zealand fur-seal, *A. forsteri*, on Kangaroo Island found 0.8% of the population suffers entanglements each year (Page et al. 2003). In Tasmanian waters from 1989-1993, 136 Australian fur-seals, *A. pusillus*, were observed with plastic neck collars (Pemberton et al. 1992). Observations of juvenile Australian fur-seals on Montague Island found entanglement around the neck by rope, strap or portions of trawl net on seven occasions (Shaughnessy et al. 2001).

Records of injured and dead marine wildlife kept by NSW NPWS and Taronga Zoo show a wide variety of marine vertebrates are impacted by entanglement in line, the presence of hooks in the mouth or gut, wounds caused by line or net and gastric impaction by plastic bodies (OEH 2011; Derraik 2002).

DEH (2003) lists the following marine fauna listed under the EPBC Act 1999 which are thought to be particularly vulnerable to ingestion or entanglement in marine debris:

- Loggerhead turtle (*C. caretta*) - endangered
- Southern right whale (*E. australis*) - endangered
- Blue whale (*B. musculus*) - endangered
- Leatherback turtle (*D. coriacea*) - vulnerable
- Hawksbill turtle (*E. imbricata*) - vulnerable
- Flatback turtle (*N. depressus*) - vulnerable
- Green turtle (*C. mydas*) - vulnerable
- Humpback whale (*M. novaeangliae*) - vulnerable
- Grey nurse shark (*C. taurus*) – vulnerable

While the potential impacts of marine debris on fauna can be fatal, this potential impact can also be quite easily mitigated. With appropriate waste management mitigation measures during construction, it is expected that the potential impact of marine debris on local marine fauna can be effectively mitigated.

6.2.1.2 Impacts of Construction Equipment and Cable Strike

The expected construction equipment required for the Project includes:

a. a venturi suction pipe

b. a jack-up barge

c. an appropriately sized backhoe

d. a hopper/flat barge and skip bins

e. a tug

f. sediment curtain / boom.

Any floating plant and/or pontoons to be used during construction will be required to be anchored or moored for the construction period. Anchoring gear typically has long cables which are necessary to achieve stability. This equipment has the potential to impact on marine fauna through noise impacts, vessel strike, liquids or solid material spills (all discussed further in ensuing sections) or cable strike. Cable strike is related to anchor cables that may stretch and slacken in the water column. Cables may strike marine fauna, causing slashing or other injuries, particularly larger fauna if swimming past. The risk of cable strike is generally greater for inquisitive young cetaceans and pinnipeds (seals) than for older animals, although all animals are susceptible to injuries from cable movement in the water column. The risk of cable strike is also greater at night when floating plant may be left on site with multiple anchors and/or moorings. The potential of risk from cable strike is related to the number of animals in the area, which in turn can be related to the time of year.

There is a low potential for larger mobile marine fauna (e.g. mammals, birds, sharks) to become entangled in loose components (e.g. lines) of or trapped (temporarily) within the confines of an erected silt curtain. As the mesh size of a silt curtain is very fine (i.e. designed to prevent movement of small sediment particles from one area to another) entanglement in the mesh of the curtain itself is not likely to occur (for small or large fauna). In addition, the curtain will remain off the seafloor at all times (i.e. allowing an area for smaller fauna to travel underneath).

6.2.1.3 Vessel Strike (Collision)

Vessel strike (i.e. vessels hitting marine fauna) has been reported to be a problem globally (Marsh et al. 2003). There is a clear relationship between the number of vessels within a given area and the incident of vessel strike. Vessel strike is of most concern for slower moving marine mammals such as whales. Vessel strike has the potential to cause injury and / or death depending on vessel size and speed and species involved. The 2011 Conservation Management Plan for Southern right whales concluded that from an east Australian coast population perspective, vessel collision risk was moderate (i.e. population recovery could be stalled or reduced).

Damaging vessel strike during the proposed dredging is unlikely to occur due to the low speeds that construction vessels would typically be travelling within the Kingston Harbour. However, if construction vessels are entering the site from oceanic waters they may be moving at faster speeds, in which case the potential for vessel strike would be greater. Vessel strike during any night time construction is most likely to occur if fauna are attracted to lights on vessels. However, any vessels undertaking construction works at night (noting that night time works are not proposed and would likely only occur in the case of emergency works being needed) are likely to be sedentary or moving very slowly so the potential impact of vessel strike from construction vessels at night is considered to be minor.

Overall, the increase in number of vessels potentially using the local area for the Project's construction will not be significant, so the risk of vessel strike is not considered to be significantly different to that which already exists in the local area.

6.2.1.4 Impacts of Water Pollution

There is the potential for hazardous substances (e.g. fuels, oils and other construction plant related fluids) to accidently enter the waterway through spills or leaks from construction vessels and other equipment (both marine and land based). Potential water pollution impacts may be related to construction vessel/vehicle management (i.e. fuel, bilge and on-board fuel tank and material lifting (crane) regulation) and over water work practices.

Water pollution has the potential to cause harm to a wide variety of marine fauna including sessile and mobile invertebrates, fish, reptiles, birds and marine mammals. Marine mammals have been reported swimming and feeding in or near an oil spill and some fish are attracted to oil because it looks like floating food. Birds can then be attracted to schools of fish and inadvertently become covered in or ingest fuels or oils.

Impacts of water pollution on marine fauna can potentially occur through two main routes being:

1. Ingestion; and
2. Substances such as oils sticking to their bodies, feathers or fur.

Sticky oils such as crude oil and bunker fuels and non-sticky oils such as refined petroleum products can affect wildlife. Refined petroleum products do not last as long in the marine environment as crude or bunker fuel and are not likely to stick to a bird or animal, but they are much more poisonous than crude oil or bunker fuel. Many of the impacts of oils on marine fauna are more commonly caused by refined oil products than crude oil and bunker fuels (AMSA 2016).

Oil in the environment or oil that is ingested can cause:

- Poisoning of wildlife higher up the food chain if they eat large amounts of other organisms that have taken oil into their tissues (i.e. fish and invertebrates).
- Interference with breeding by making animals too ill to breed, interfering with breeding behaviour (e.g. birds sitting on their eggs) or by reducing the number of eggs a bird will lay.
- Damage to the airways and lungs of marine mammals and turtles, congestion, pneumonia, emphysema and even death by breathing in droplets of oil, or oil fumes or gas.
- Damage to the eyes of marine mammals or turtle's, which can cause ulcers, conjunctivitis and blindness, making it difficult for them to find food, and sometimes causing starvation.
- Irritation or ulceration of skin, mouth or nasal cavities.
- Damage to and suppression of the immune system, sometimes causing secondary bacterial or fungal infections.
- Damage to red blood cells.
- Organ damage and failure such as a marine mammal's liver.
- Decrease in the thickness of egg shells.
- Stress.
- Damage to fish eggs, larvae and young fish.
- Contamination of beaches where turtles breed causing contamination of eggs, adult turtles or newly hatched turtles.
- Damage to estuaries, coral reefs, seagrass and mangrove habitats which are the breeding areas of many fish and crustaceans, interfering with their breeding.
- Tainting of fish, crustaceans, molluscs and algae.
- Interference with a baleen whale's feeding system by tar-like oil, as this type of whale feeds by skimming the surface and filtering out the water.
- Poisoning of young through the mother, as a dolphin calf can absorb oil through their mother's milk (AMSA 2016).

Oil that sticks to the bodies, feathers or fur of marina fauna (usually crude and bunker fuels) can cause the following issues:

- Hypothermia in fur seal pups as the insulation of their woolly fur (called lanugo) is reduced or destroyed. Adult fur seals have blubber and would not suffer from hypothermia if oiled.
- Hypothermia in birds (as the insulation and waterproofing properties of feathers is reduced or destroyed).
- Dolphins and whales do not have fur, so oil will not easily stick to them.
- Marine mammals such as fur seals become easy prey if oil sticks their flippers to their bodies, making it hard for them to escape predators.
- Birds becoming easy prey (as their feathers being matted by oil makes them less able to fly away from predators).
- Fur seal pups drown if oil sticks their flippers to their bodies.
- Birds may drown (because oiled feathers weigh more, and their sticky feathers cannot trap enough air between them to keep them buoyant).
- Marine mammals lose body weight when they cannot feed due to contamination of their environment by oil.
- Inflammation or infection in dugongs and difficulty eating due to oil sticking to the sensory hairs around their mouths.
- Disguise of scent that seal pups and mothers rely on to identify each other, leading to rejection, abandonment and starvation of seal pups.
- Damage to the insides of animals' bodies, for example by causing ulcers or bleeding in their stomachs if they ingest the oil by accident (AMSA 2016).

While the potential impacts of water pollution, including spills of fuels and oils, on marine fauna may be highly dangerous, it is expected that this potential impact can be mitigated or managed effectively with the use of appropriate mitigation measures associated with protecting water quality.

6.2.1.5 Lighting Impacts

Light emissions relating to construction will predominantly relate to the use of artificial lighting during night-time construction on vessels and equipment. While it is not expected that night time construction would be necessary, unforeseen night time emergency works are possible. Existing background night time lighting in the vicinity of the study area includes minimal lighting from nearby KAVHA buildings and minimal safety and navigation lighting on the Kingston Pier. Lit low density residential and rural areas also occur nearby (within kilometres of the site) but are not located in the immediate construction area. Lighting related to the proposed dredging activities and vessels will likely be visible, particularly during the evening and night from the coastline.

Artificial lighting has the potential to influence the behaviour of fauna, primarily by attraction, avoidance, disorientation or interruption to reproductive processes such as selection of oviposition sites (see review by Davies et al. 2014). The key receptors likely to be impacted by artificial lighting are coastal, marine and migratory birds, however; other marine fauna also have the potential to be impacted.

It is thought that anthropogenic light may increase foraging success in coastal environments. Becker et al. (2013) assessed the impacts of artificial lighting on estuarine fishes at a floating restaurant, which they suggest is analogous to other anthropogenic structures such as jetties or wharfs. Clear differences were evident in the abundance of fishes, whereby large-bodied predators increased in lit conditions, compared with dark environments, creating potentially unnatural top-down effects on fish populations within coastal and estuarine environments. Furthermore, parallels are drawn between foraging in decreasing light conditions with that of increased turbidity affecting fish community structure (e.g. see Utne-Palm 2001). Increased attraction of marine fauna (e.g. fish) to the construction area may occur in the short term as a result of activities which are undertaken during the evening/night.

Marine turtles, particularly reproducing females and hatchlings can be affected by artificial light, discouraging adult females from nesting in addition to disorienting hatchlings during their beach crawl to the ocean (EPA 2010; Davies *et al.* 2014). Recently, Pendoley and Kamrowski (2016) investigated the effects of lighting on sea-finding by flatback turtle (*Natator depressus*) and green turtle (*Chelonia mydas*) hatchlings at multiple distances at Barrow Island in Western Australia. They found that sea-finding of these hatchlings was disrupted by artificial lighting within 200 m, but not when more than 500 m. Subsequently, they suggest that industrial developments should be separated from nesting beaches by a buffer of 1.5 km, with installed lights appropriately shaded. While green, hawksbill and loggerhead turtles are expected to forage in the local waters on occasion, no nesting sites for marine turtles are known in the study area. Therefore, such impacts on nesting behaviour or success are not expected.

Potential impacts of lighting on coastal, marine and migratory birds are listed below:

- Artificial lighting, even at low levels, has the potential to influence the behaviour of avifauna.
- As ocean environments are essentially dark environments marine bird species not used to lit environments may be particularly attracted to artificial light sources, such as commercial ships and fishing vessels, lighthouses, coastal industrial areas (including ports and wharfs) and urban lighting (Lebbin et al. 2007; Merkel 2010; Miles et al. 2010; Watson et al. 2016).

- Behavioural impacts may include avoidance, disorientation or interruption to reproductive processes such as selection of oviposition sites (see review by Davies et al. 2014).
- As many shorebirds and marine birds are nocturnal, actively foraging at night, feeding behaviour may also be impacted by artificial lighting. For example, birds have been known to forage at night on insects which are attracted to artificial lights.
- Watson et al. (2016) reported more nocturnal flight calls of migratory birds over artificially lit areas with ground-level artificial lights. These species may have changed their original path to migrate over lit areas, flown at lower altitudes over lit areas, increased their call rate over lit areas, or remained longer over lit areas so detection of calls was higher.
- The effects of lighting are likely to be species specific, dependent on the role of light in the species physiology, reproduction and behaviour, and on the type of light.
- Birds (especially migratory species) can become disoriented in the presence of artificial light and many collisions, with vessels in particular, have resulted in mortality (Merkel 2010).
- Orienting from the sky may be problematic from artificial lighting, however, orienting in trees and near the ground in laminated areas was not as much of a problem (Lebbin et al. 2007).
- In order to reduce the impact of light on birds, a study of migrating bird species in the North Sea compared the impacts of white, red, blue and green light (Poot et al. 2008). Birds were found to be more disoriented and attracted to white and red artificial lighting (long-wavelength radiation), with little reaction to green lighting, and only minor observable effects on orientation under blue lighting (Wiltschko et al. 1993; Poot et al. 2008). This effect is more prominent on overcast nights (Poot et al. 2008). White light interferes with visual orientation on celestial cues, whereby birds become trapped in the beam, attracting them to the light (Poot et al. 2008).

As existing night time light sources at the study site are not substantial some behavioural impacts on marine fauna and birds during construction may be expected. However, there are several mitigations that can be adopted to reduce the impacts of artificial lighting during construction, and if adopted, lighting related impacts on marine fauna including coastal, marine and migratory birds are not expected to be significant.

6.2.1.6 Noise Impacts

Construction noise impacts related to the Proposal are likely to include:

- Vessel engine noise.
- Excavation noise.
- Piling Noise.

Given that the site is located within Kingston Harbour, and alongside the Kingston Pier, where recreational and commercial vessels regularly come and go, the impacts of construction vessel engine noise are not likely expected to be significant in relation to existing background noise from vessels. Once vessels and barges are in place, there will typically be limited movement.

Excavation and piling associated noise will be the main sources of underwater construction noise. Some piling is proposed for the Project (i.e. the legs of jack-up barge will be piled into the seabed and there is also a proposed piled channel marker). Piling typically emits the noise frequencies which are potentially most harmful to marine fauna.

There are several EPBC Act 1999 listed marine mammals which are known to occur in the coastal waters surrounding Norfolk Island which are sensitive to underwater noise (see Section 0).

The Underwater Piling Activities Noise Guidelines (Government of South Australia 2012) provides information regarding sensitivity of various species to underwater noise. Marine mammals are sensitive to the following frequencies:

- Baleen whales including Southern right whales, humpback whales and blue whales - may be sensitive to sound in the range of 7Hz to 22kHz;
- Toothed whales, including dolphins and killer whales - may be sensitive to sound in the range of 150 Hz to 160kHz; and
- Pinnipeds (seals and sea lions) - may be sensitive to higher frequencies in the range of 75 Hz to 30 kHz.

Impacts of noise on marine fauna may be classed as behavioural or physiological.

Behavioural Impacts

Behavioural related noise impacts on marine fauna may include:

- Behavioural responses to noise include changes in vocalisation, resting, diving and breathing patterns, changes in mother-infant spatial relationships, and avoidance of the noise source.

- Masking of biologically important sounds may interfere with communication and social interaction, and cause changes in behaviour as well.

Avoidance behaviour is most likely to occur for seals and for other mobile vertebrates present in the study area including fishes and marine reptiles (e.g. turtles).

The potential for noise to impact on a marine species is dependent on the ability of the species to hear the sound. Species hear sounds over different frequencies ranges, and the efficiency of sound detection varies markedly with frequency (refer to Table 6-4). Additionally, species behavioural responses to a detected sound may vary according to the sensitivity of the species to disturbance and what activities the animals are engaged in at the time.

Table 6-4 Estimated in water functional hearing range for various marine fauna.

Marine Species	Estimated Functional Hearing Range	Maximum Sensitivity Range or Peak sensitivity
Baleen Whales (i.e. Southern Right Whale; Humpback Whale; Blue Whale)	7 Hz to 22 kHz	-
Killer Whales	50 Hz to 100 kHz	~15 kHz
Dolphins and Porpoises (i.e. Common and Bottlenose Dolphins)	150 Hz to 180 kHz	16 kHz to 140 kHz
Pinnipeds (i.e. Fur-Seals and Little Penguins)	75 Hz to 75 kHz	700 Hz to 20 kHz

Source: Government of South Australia (2012)

Table 6-5 summarises noise exposure criteria for behavioural impacts. The noise exposure criteria are based on current interim criteria adopted by the US National Oceanic and Atmospheric Administration (NOAA 2011).

Table 6-5 Underwater noise exposure criteria for behavioural impacts (NOAA 2011).

Species	Behavioural Noise Exposure Criteria	
	Impact Piling	Vibro-driving
Cetaceans	SPL 160 dB re 1μPa	SPL 120 dB re 1μPa
Pinnipeds	SPL 160 dB re 1μPa	SPL 120 dB re 1μPa

Physiological Impacts

When the auditory system is exposed to a high level of sound for a specific duration, the sensory hair cells begin to fatigue and do not immediately return to their normal shape. This causes a reduction in the animal's hearing sensitivity, or an increase in hearing threshold. If noise exposure is below some critical sound energy level, hair cells will eventually return to their normal shape. This effect is called a temporary threshold shift (TTS) as the hearing loss is temporary. If the noise exposure exceeds the critical sound energy level, the hair cells become permanently damaged (the effect is called permanent threshold shift (PTS)) (PEL 2016). Table 6-6 summarises noise exposure criteria for physiological impacts. The SEL noise exposure criteria are M-weighted levels expressed in dB(M) re 1 µPa2·s.

Table 6-6 Underwater noise exposure criteria for physiological impacts (NOAA 2011).

Functional Hearing Group	Impact	Physiological Noise Exposure Criteria	
		Impact Piling	Vibro-Driving
Site Establishment Dredging	TTS	Peak 224 dB re 1μPa SEL 183 dB (M_{lf}) re 1μPa²·s	SPL 180 dB re 1μPa
	PTS	Peak 230 dB re 1μPa SEL 198 dB (M_{lf}) re 1μPa²·s	Peak 230 dB re 1μPa SEL 215 dB (M_{lf}) re 1μPa²·s
Mid-frequency cetaceans	TTS	Peak 224 dB re 1μPa SEL 183 dB (M_{mf}) re 1μPa²·s	SPL 180 dB re 1μPa
	PTS	Peak 230 dB re 1μPa SEL 198 dB (M_{mf}) re 1μPa²·s	Peak 230 dB re 1μPa SEL 215 dB (M_{mf}) re 1μPa²·s
High-frequency cetaceans	TTS	Peak 224 dB re 1μPa SEL 183 dB (M_{hf}) re 1μPa²·s	SPL 180 dB re 1μPa
	PTS	Peak 230 dB re 1μPa SEL 198 dB (M_{hf}) re 1μPa²·s	Peak 230 dB re 1μPa SEL 215 dB (M_{hf}) re 1μPa²·s
Pinnipeds	TTS	Peak 212 dB re 1μPa SEL 171 dB (M_{pw}) re 1μPa²·s	SPL 190 dB re 1μPa
	PTS	Peak 218 dB re 1μPa SEL 186 dB (M_{pw}) re 1μPa²·s	Peak 218 dB re 1μPa SEL 203 dB (M_{pw}) re 1μPa²·s

Notes: TTS = Temporary threshold shift, PTS = Permanent threshold shift
Mlf, Mmf, Mhf and Mpw are M-weighting functions depending on (flow) and (fhigh) (lower and upper functional hearing limits of each fauna group respectively.

Zones of Impact

The Underwater Piling Noise Guidelines provide 'zones of impact' for marine fauna including:

- Zone of audibility – Area within which marine mammal might hear the source noise but not show any significant behavioural response. The size of the zone of audibility is highly dependent on the ambient noise environment.
- Zone of responsiveness – Area within which the considered marine mammal might react behaviourally to the noise source. This zone can be smaller than the zone of audibility as marine mammals usually do not show significant behavioural responses to noises that are faint but audible.
- Zone of hearing injury – Area closest to the noise source where the noise levels may be high enough to cause a physiological impact such as TTS or PTS.

The zones of impact define the likely environmental footprint of a noise source and indicate how far away a noise source is expected to have an impact on a marine mammal species, either behaviourally or physiologically.

A number of mitigation measures will be adopted to reduce the potential impacts of underwater noise on marine fauna which are known to occur in the study area.

6.2.2 Marine Infauna

Any benthic marine infauna living within soft sediments within the proposed dredge footprint will be directly impacted. The direct impacts on benthic marine infauna are unable to be mitigated due to the nature of the Project. However, there is an abundance of similar habitat within the local area which is expected to support similar assemblages as those which will be lost, and this impact is not thought to be significant.

6.3 Invasive Marine Species

The introduction of invasive marine species to areas in which they do not yet occur has the potential to threaten local biodiversity, primary production and aquaculture through alteration of marine habitats, outcompeting or preying upon native species and fouling of marine infrastructure (NSW DPI 2008). Translocation of marine pests to areas in which they do not yet occur can also lead to the displacement of indigenous species, directly by predation and competitive exclusion, or indirectly by changing the physical and biological characteristics and structure of habitats (Williamson et al. 2002). The effects of exotic species on benthic communities can be long-term and are often irreversible (Currie and Parry 1999).

While the diversity of flora and fauna of Norfolk Island is low compared with Eastern Australia and New Caledonian reefs (due to Norfolk Island's extreme isolation) the mix of species is unique, and the island supports both endemic species and subtropical and Tasman Sea endemics. The Emily and Slaughter Bay lagoon system is also home to a number of EPBC Act 1999 listed species including juvenile green turtles and the Booths pipefish. As such, the introduction of invasive marine species to the island could have significant effects on local marine ecology.

The most likely method of introduction of invasive species to the local area during construction is via transport of organisms or their eggs / cysts attached to the hulls of construction vessels which are brought to site from mainland Australia or New Zealand, attached to construction equipment or in the ballast of vessels.

7 Potential Operational Impacts

The proposed operation of the site includes the following:

- Vessel operators such as commercial charter, fishing vessels and emergency responders as well as local launches and lighters would enter and exit the harbour adjacent to Kingston Pier through the newly augmented channel. Vessels would be guided by new channel navigation aids.
- The augmented channel would support greater use of Kingston Pier by various vessel operators, particularly as critical infrastructure for freight and cruise ship passengers.

Note that it is not likely that the increased use of the site by the vessels noted above compared to its current use would be substantial, especially on a day to day basis, so the operational impacts described below, compared to the current situation, are expected to be negligible.

7.1 Marine and Terrestrial Habitats

Potential operational impacts on marine and terrestrial habitats include potential water quality impacts from vessels using the facility (including the generation of marine debris) and the potential for recolonisation of marine habitat on the excavated seafloor over time.

7.1.1 Water Quality Impacts

Water quality impacts associated with operation are largely associated with vessel use. These potential impacts are similar to those of the operation phase (refer to 6.2.1.4) with some additional impacts. These are summarised below:

- Accidental spills of fuels, oils and other hazardous chemicals.
- Runoff from washing of the topsides of vessels leading to contamination of the local water column with potential pollutants such as oils, detergents, plastics etc.
- Illegal discharge of vessel holding tanks (sewage) – resulting in contamination of the water column in local area with pathogenic waste, potential impacts on local fauna and habitats from microbial organisms entering the waterway.
- Accidental spillages of bilge water, sewage and grey water.
- Increased levels of suspended sediments resulting from propeller wash from larger vessels disturbing sediments on the seabed on entry and exit - Potential for impacts associated sediments on nearby marine habitats.
- Pollution of the waterway with general waste.

Operational impacts of water quality on habitats compared to the current situation are expected to be negligible.

7.1.2 Marine Debris

Impacts of marine debris on habitats are mainly related to impacts on the fauna they support. The impacts of entanglement / ingestion of marine debris on marine and terrestrial fauna during construction have previously been addressed in Section 6.2.1.1. The potential impacts of marine debris during operation would be the same for the construction phase with the exception of construction related waste.

Operational impacts of marine debris on habitats compared to the current situation are expected to be negligible.

7.1.3 Recolonisation of the Excavated Seafloor

Once the excavation of the seafloor is completed, recolonization of the seabed will commence quickly. This has been well documented in many field based investigations where a range of species, typically from the surrounding environment will colonise available bare substrate. It is highly likely that the composition of the seafloor will revert to what is currently present in the existing channel. This includes a combination of coarse sand and rock including loose gravel substrate. The ability for infauna to recolonise the sand and macroalgal species to colonise rock will depend on the amount of turbulence on the seafloor caused by the prevailing wave action and current flow through the channel as well as the potential scouring caused by the boats and vessels using the pier. It is therefore likely that some areas of seabed, closest to the pier will remain devoid of marine growth, whilst other areas along the seaward edge of the channel will likely be recolonised by corals and macroalgae.

7.2 Fauna

Operational impacts of the Kingston Pier on marine fauna include entanglement / ingestion of marine debris, impacts of water pollution, lighting impacts, noise impacts and vessel strike.

7.2.1 Entanglement / Ingestion of Marine Debris

Operational related impacts associated with entanglement / ingestion of marine debris would be related to the accidental or deliberate release of general waste or operational parts of vessels using the facility. The impacts of entanglement / ingestion of marine debris on marine and terrestrial fauna have previously been addressed in Section 6.2.1.1.

Operational impacts of marine debris on fauna compared to the current situation are expected to be negligible.

7.2.2 Impacts of Water Pollution

Water pollution impacts on marine fauna associated with the operation of the floating breakwater are associated with vessel use (as discussed in Section 7.1.1) and marine debris (described above). The potential impacts of water pollution and marine debris on aquatic fauna have also been discussed in detail in the construction impacts section of this document (6.1.2.6 and 6.2.1.4).

Operational impacts of water pollution on fauna compared to the current situation are expected to be negligible.

7.2.3 Lighting Impacts

Operational related lighting impacts will include limited permanent lighting installed on the Pier and on newly installed navigation aids. The potential impacts of lighting on marine and terrestrial fauna during operation are as per the lighting impacts discussed for the construction phase (see Section 6.2.1.5).

Operational impacts of lighting on fauna compared to the current situation are expected to be quite negligible.

7.2.4 Noise Impacts

Noise impacts associated with the operation of the Pier which may impact marine or terrestrial fauna in the study area would be minimal and typically include vessel engine noise on approach and departure. Vessel related noise impacts are highly unlikely to have any significant impacts on marine fauna in the local area, especially considering that the area is already utilised by numerous commercial and recreational vessels.

Operational impacts of noise on fauna compared to the current situation are expected to be quite negligible.

7.2.5 Vessel Strike

The risk of vessel strike on marine fauna associated with the operation phase may include slightly increased movements of commercial charter, fishing vessels and emergency responders as well as local launches and lighters into Kingston Harbour to utilise the facility. However, the increased number of these vessels potentially accessing the Pier at any given time are expected to be low and insignificant. In addition, vessels would typically be travelling at low speeds coming into the Harbour and the risk of vessel strike is considered to be low.

Operational impacts of vessel strike on fauna compared to the current situation are expected to be negligible.

7.3 Invasive Marine Species

The potential impacts of invasive marine species on marine fauna are as per those described for the construction phase (refer to Section 6.3). The most likely method of introduction of invasive species to the local area during operation is via transport of organisms or their eggs / cysts attached to the hulls of vessels originating from mainland Australia or New Zealand or otherwise, or in the ballast of these vessels.

Operational impacts of invasive marine species on fauna compared to the current situation are expected to be negligible.

8 Mitigation Measures

A summary of the mitigation measures to be applied to manage or mitigate potential impacts of the Project (including during construction and operation) on the marine and terrestrial environment are summarised below.

8.1 Marine Water Quality

Mitigation measures to avoid or manage potential impacts on marine water quality during and after construction are provided in Table 8-1.

Table 8-1 Proposed mitigation measures – marine water quality.

Mitigation Measure	Responsibility	Phase
In calmer sea conditions (i.e. offshore wave height less than 1 m), which are suitable for deployment of a silt boom and curtain, this will be implemented around any active work areas that may disturb the seabed (e.g. when removing tuff material). The silt curtain will be suitable to accommodate the active coastal marine environment within Kingston Harbour. The silt curtain may be a robust floating system such as a flexible floating hose curtain, or a fixed silt curtain attached to barge. The installation of the silt curtain/boom may be progressive to contain areas of current works; however, before construction, a Plan of Deployment and Progression will be prepared to align with the schedule of works. The Plan will implement the following measures: ▪ Installation of the silt curtain/boom will occur before starting physical works. ▪ Installation will be undertaken during high tide periods from a boat. The device will be designed to rise and fall with the tide to prevent disturbance. ▪ The silt boom/curtain will extend from a minimum of 100 mm above the water line to 2.5 m below the water line (where water depth permits) before starting work. Note the bottom of the silt curtain is to be kept 0.5m from the bottom to prevent snagging. ▪ Inspection of the device will be undertaken on a daily basis after ebbing tides, with additional	Contractor	Pre-Construction and Construction

Mitigation Measure	Responsibility	Phase
inspection following storm events. Visual monitoring of turbidity inside and outside of the device will occur regularly during the day. ▪ Results of daily observations of the integrity of the silt curtain will be required to be recorded and maintained. Records will be required to be kept on the site and will be made available for inspection by persons authorised by the DITRDC. ▪ Decommissioning will be carried out by boat during a high tide period. ▪ Decommissioning will only be undertaken once construction activities are above seabed level (that is, no activities which disturb the seabed will occur without the silt curtain in place). Before removing the device, turbidity conditions within the silt curtain will be assessed both visually and by using a hand held water quality meter to confirm that turbidity levels (measured as NTU) inside and outside the device are similar. This will verify that sediment has settled, resulting in similar water turbidity within the work zone to that outside the curtain. The silt curtain will not be decommissioned until the water inside and outside correspond both visually and this is also confirmed using a hand held device.		
Bubble curtains comprise perforated air hoses anchored to the sea floor that shoot walls of air bubbles into the water column. The purpose of the bubble curtains is to form a barrier to underwater noise and deflect sediment debris from travelling past the bubble curtain. A bubble curtain will be implemented across the entrance channel in conjunction with a silt curtain/boom to assist in the control of the spread of suspended sediments. A bubble curtain will also have benefits in reducing noise impacts on marine fauna and does not restrict vessel navigation.	Contractor	Pre-Construction and Construction
A Baseline Water Quality Monitoring Program will be developed and implemented prior to construction. Site-specific trigger values for Water Quality Monitoring for turbidity and other potential contaminants of concern (including physico-chemical parameters and hydrocarbons) will be determined prior to construction through an appropriate Baseline Water Quality Monitoring Program over a suitable time period which	DITRDC or Contractor	Pre-Construction

Mitigation Measure	Responsibility	Phase
uses a combination of in-situ and lab-based testing. A Baseline Water Quality Report providing site-specific trigger values will be prepared.		
The Contractor will undertake Water Quality Monitoring during construction to identify any potential spills or deficient silt curtains or erosion and sediment controls. The requirements of Water Quality Monitoring will be outlined in the Construction Environmental Management Plan (CEMP) for the Project. Water Quality Monitoring will be implemented with other mitigation measures to manage potential impacts on the marine environment and aquatic ecology. This will include regular observations of the site for any visible indications of sediment plumes or pollution (for example, hydrocarbon spills or slicks) and also through collecting water quality data and samples (using a hand-held meter and via grab sampling for lab testing) at periodic intervals to ensure that turbidity and other parameters are within site-specific trigger values.	Contractor	Construction
A Spill Management Plan will be implemented during construction and will be communicated to all staff working on site. The Plan will include information on the following: • An emergency spill kit will be kept on site and maintained throughout the construction work and going forward. The spill kit will contain adequate quantities of material and will be suitable for the specific project application and site use. • All construction workers and regular users of Kingston Pier will be advised of the location of the spill kit and trained in its use. • Emergency contacts will be kept in an easily accessible location on vehicles, vessels, plant and site office. All workers will be advised of these contact details and procedures. • Procedures on vehicle, vessel and plant maintenance and inspection for fluid leaks will be implemented. • Vehicle wash-down and re-fuelling will not occur on site. • Refuelling of plant and equipment and storage of hazardous materials on land and on barges will occur within a double-bunded area.	Contractor	Construction

Mitigation Measure	Responsibility	Phase
If an incident (e.g. spill) occurs, the following incident responses will be implemented: • The Contract Manager will be notified as soon as practicable. • In the event of a maritime spill, the Spill Management Plan will be implemented.		
The number of jack-ups/anchor points during construction will be minimised where possible. The locations will be planned and selected to avoid areas of sensitive natural rocky reef habitats that have not yet been disturbed by historical excavation for the duration of construction.	Contractor	Construction
Work positioning barges and excavation of seafloor material during construction will be scheduled to occur during calm conditions wherever possible to prevent excessive and non-contained sedimentation and minimise any safety risks.	Contractor	Construction
A Soil and Water Management Plan (SWMP) will be prepared and implemented as part of a CEMP for the Project. The SWMP will identify all reasonably foreseeable risks relating to erosion, sediments and water pollution and describe how these risks will be addressed during construction. Erosion and sediment control measures will be implemented and maintained (in accordance with the *Landcom/Department of Housing Managing Urban Stormwater, Soils and Construction Guidelines* (the Blue Book)) to: • Prevent sediment moving off-site and sediment-laden water entering any water course, drainage lines, or drain inlets. • Reduce water velocity and capture sediment on site. • Minimise the amount of material transported from site to surrounding pavement surfaces. Divert clean water around the site.	Contractor	Pre-Construction and Construction
The Contractor, NIRC (Port Manager) and users of Kingston Pier will implement the following measures to minimise potential impacts on marine water quality, including (but not limited to): • All machinery and equipment will be maintained in good working order and regularly visually inspected for leaks.	Contractor, NIRC and Port Users	Construction and Operation

Mitigation Measure	Responsibility	Phase
• All construction equipment and vessels will be inspected by qualified personnel prior to the commencement of work to reduce the risk of hydrocarbon spills or leaks. • All visiting vessels will also adhere to the above two measures. • Portable toilets (if required) will be positioned securely within approved compound areas and emptied on a regular basis using a licenced service provider and human waste disposed of to a local sewerage treatment plant. • No sewage will be released into the local waterway from vessel holding tanks. • Non-toxic/biodegradable environmentally friendly/water-based chemicals will be used, where required. • The lowest volume of hydrocarbons (oil, grease, petrol and diesel) practicable will be stored on-site. • Chemical and fuel storage areas will be bunded and chemicals will be stored in accordance with the products Safety Data Sheet (SDS) and AS 1940 on board construction vessels and land-based construction areas only. • Vessels (self-propelled and unpowered) will have adequate on-board communication, containment, drainage, bunding and monitoring systems to prevent discharges of unauthorised effluents.		
The following recommendations are listed in the Dredge Plume Modelling Study (Advisian 2021) to reduce the potential impacts associated with remobilisation of sediments and associated water quality and ecological impacts: • Dredging window: To select a period between October and May for dredging operation to avoid the possible energetic meteorological conditions, with a higher chance of larger wind forcing from northern and western sectors (noting the coral spawning season generally occurs from late January for a few months and would also look to be avoided). • Operation window: The dredging operation is allowed only during the daylight time with a	Contractor	Construction

Mitigation Measure	Responsibility	Phase
break to unload spoil onshore per day for six days per week (half a day Saturday).		

8.2 Marine Sediment Quality

All practical measures are to be taken to minimise the disturbance of marine sediments and rock, exposure of potential contaminants and introduction of pollutants resulting from the Project. The proposed mitigation measures are outlined in Table 8-2.

Table 8-2 Proposed mitigation measures – sediment quality.

Mitigation Measure	Responsibility	Phase
The Contractor's spill containment, chemicals handling and emergency response procedures will be appropriate and adequate.	Contractor	Construction
The Contractor's procedures will describe processes for general waste handling and disposal.	Contractor	Construction
The NIRC as Port Manager will provide appropriate marine spill kits at Kingston Pier in case of accidental spills during operation.	NIRC	Operation

8.3 Marine Ecology

The proposed mitigation measures to avoid or minimise impacts to marine ecology are outlined in Table 8-3.

Table 8-3 Proposed mitigation measures – marine ecology.

Mitigation Measure	Responsibility	Phase
To minimise damage to sensitive marine habitats in the study area (i.e. intertidal and subtidal rocky reefs) and the fauna they support, all habitats beyond the approved marine footprint to be identified in the CEMP will remain no-go zones for the duration of construction. Marine no-go zones may be demarcated with floating buoys. No marine traffic or anchoring is permitted outside of the approved marine footprint. No vehicle movements, materials stockpiling, or other construction-related activities are permitted outside the approved land-based footprint during construction. During operation, vessels will stay within the designated channel area and not move over nearby shallow areas of sensitive marine habitat.	Contractor and Port Users	Construction and Operation
To minimise unnecessary damage to habitats and the fauna they support which occur within the construction	Contractor	Construction

Mitigation Measure	Responsibility	Phase
footprint during construction, the Contractor will limit any unnecessary and/or temporary construction (i.e. through selection of the most appropriate construction methods) and materials stockpiling and limit any anchoring which is required by vessels.		
All construction works will be undertaken by a suitably qualified, experienced and site-specific trained Contractor to reduce the risk of error and accidental environmental damage and flow-on effects on habitats and fauna in a safe manner.	Contractor	Construction
All sediment and erosion controls, marine water quality and waste management mitigation measures described in this EA will be implemented.	Contractor and the NIRC	Construction and Operation
To reduce the potential impacts of adverse marine water quality on marine habitats and the fauna they support during construction and operation, mitigation measures proposed for marine water quality impacts (refer to Section 8.1) will be implemented as well as the following additional measures: • Construction vessels will maintain their septic tanks and pumps so that they do not leak. No release of sewage into the waterway is allowed. • Both oil and sewage spill response kits will be readily available at Kingston Pier for use during construction and operation in the event of a spill. Regular users of Kingston Pier will be trained in their use.	Contractor and the NIRC	Construction and Operation
To enhance the potential for the Contractor to be able to assist in the protection of marine habitats and the fauna they support during construction, all personnel, in particular skippers, will be made aware of the areas of sensitive habitat within the study area during the general site induction, and of the potential impacts that construction works may have on these areas. Records of training will be retained.	Contractor	Construction
To reduce the spread of suspended sediments generated during excavation and the potential for sedimentation and/or smothering of nearby sensitive marine habitats and associated flora and fauna, silt curtains/booms and bubble curtains will be used around the immediate excavation area. Refer to Section 8.1.	Contractor	Construction

Mitigation Measure	Responsibility	Phase
Monitoring of water quality (particularly turbidity) during water-based construction activities with the potential to disturb the seafloor (i.e. during excavation and piling activities) will be undertaken and construction activities ceased if levels of suspended sediment become higher than site-specific trigger values developed for the Project (refer to Section 8.1).	Contractor	Construction
Surface level inspections for marine mammals or other large marine fauna entangled in the silt curtains must occur regularly (i.e. dedicated hourly visual observations should be maintained). If a marine mammal or other fauna is identified as being entangled in the silt curtain, the following procedures should be undertaken: • Immediate stop of all water based construction activities. • Contact appropriate environmental office to arrange for freeing of fauna. This may entail decommissioning of the curtain. • Water based construction activities will not commence until 30 minutes after marine mammal(s) have left the area.	Contractor	Construction
At the completion of construction, a seabed inspection (seabed clearance survey) and clean-up will occur to remove any construction waste and general debris from the seafloor. All waste will be removed and disposed of at a licenced facility.	Contractor	Post-Construction
To reduce the potential impacts of marine debris on fauna during construction and operation, the mitigation measures proposed for waste management in the main EA will be implemented.	Contractor	Construction and Operation
During operation, Kingston Pier and the channel navigation aid will be examined regularly to ensure that they are not in need of repair or have any loose parts that may fall into the waterway and cause harm to marine fauna.	NIRC	Operation
To reduce the potential for lighting-related impacts on marine fauna during construction the following measures will be implemented: • Limit the need for construction activities to be undertaken during the evening and night time to reduce the overall need for construction-	Contractor	Construction

Mitigation Measure	Responsibility	Phase
related artificial lighting (on vessels and the jack-up barge) and associated impacts. • Use downward-directed and dimmed lighting on Kingston Pier (ensuring that it is still in accordance with navigation requirements).		
If possible, the risk of overhead cable strike on marine fauna during construction will be minimised by placing any floating plant on a swing mooring, where space permits and it is deemed safe to do so rather than leaving plant in a fixed mooring configuration as the reliance on a single swing mooring line will minimise cable oscillation.	Contractor	Construction
The risk of vessel strike impacting on marine fauna, specifically marine mammals, during construction and operation will be reduced through the implementation of the following measures: • All vessels associated with construction will travel at speeds no higher than 10 knots in nearshore coastal waters. • Vessels will maintain a 300 m exclusion zone with any whales when travelling to and from site. • All construction personnel will be informed of these proposed measures. • Awareness of the presence of marine fauna in the local waterway by vessel operators so that they can adopt appropriate speeds and clearance when cetaceans are nearby. • Variable or zoned (time and place) speed limits for visiting vessels during operation, particularly in relation to peak marine mammal migrating periods.	Contractor and Port Users	Construction and Operation
To reduce the potential for noise-related impacts on marine fauna (specifically marine mammals) during piling work the following measures will be implemented: • Arrange piling and excavation work outside of the main marine mammal migration period, if feasible. • Implement the following piling operation procedures: o Piling and Excavation Operation Procedures:	Contractor	Construction

Mitigation Measure	Responsibility	Phase
a) *Pre-Start Observation:* Marine mammal observers will visually monitor observation and shut-down zones for whales for a minimum of 30 minutes before the commencement of piling and/or excavation. b) *Soft-Start Procedure:* If, after the 30 minute pre-start observation, no whale/s have been spotted within the observation or shutdown zone a soft start procedure will commence with a gradual increase in piling impact energy of no more than 50% of full impact energy for 10 minutes. The soft start procedure will be implemented after breaks in piling driving of 30 minutes or more. c) *Standby Procedure:* If a whale is spotted within the observation zone during the soft start procedure, the operator of the piling or excavation equipment will be placed on standby to shut-down the equipment and a trained crew member will continuously monitor the whale/s in sight at all times. d) *Normal Procedure:* If no whale/s has been sighted during the soft-start procedure, full impact piling or excavation may commence. • The use of bubble curtains around areas of excavation or piling will also be implemented to reduce noise impacts on marine fauna.		

Mitigation Measure	Responsibility	Phase
To reduce the potential for noise impacts on marine fauna (specifically marine mammals) during piling and/or excavation, the following Shut-Down requirements will be implemented: • Shut-Down requirements: a) If visibility is poor and the marine mammal observer is unable to clearly identify objects to the full observation zone distance, a vessel or aircraft search will be conducted, or the action postponed until visibility has improved. b) Piling and excavation are not permitted between 6.00 pm and 7.00 am. c) If any whales are spotted within the shut-down zone, piling or excavation will cease immediately or as soon as safe to do so until the whale/s has moved outside of the shut-down zone. d) All piling or excavation will cease for a minimum of 1 hour after the last sighting of a whale within the observation zone. Piling or excavation will recommence at the pre-start observation after the 1 hour shutdown has elapsed.	Contractor	Construction
All Contractors will undertake a Vessel Risk Assessment (VRA) prior to mobilisation to the site. The VRA may be undertaken by the vessel owner and/or operator. All vessels, floating plant and other marine-based construction equipment mobilised to the site from any place inside or outside of Australia will be subject to the VRA. The VRA will determine if a vessel inspection is required. The Contractor(s) will provide the VRA to the Principal four (4) weeks prior to mobilisation. The Contractor(s) will undertake an Invasive Marine Species (IMS) inspection of all vessels assessed in the VRA as uncertain or high risk for introduction of invasive marine species. The Contractor(s) will arrange for IMS inspections for all vessels considered high and/or uncertain risk prior to the commencement of construction either within seven days of mobilisation to the site (directly) or within 48 hours of entry to the harbour.	Contractor	Construction

Mitigation Measure	Responsibility	Phase
Any construction vessels mobilised from outside of Norfolk Island will be considered high risk and will be inspected. Construction vessels entering the site from international waters will be dry-docked and cleaned prior to entering the site. Following inspection, the Contractor(s) will submit a revised VRA and if the vessel is classified as low risk it will be permitted to enter the waterway and begin operations. The IMS inspection will be undertaken by appropriately qualified personnel with experience in biosecurity of marine vessels, floating plant and marine-based construction equipment. The Contractor(s) is responsible for arranging the IMS inspection by suitably qualified personnel.		
The antifouling of construction and visiting operational vessels will be maintained to avoid the attachment and potential translocation of invasive species into Norfolk Island waters.	Contractor and Port Users	Construction and Operation
Ballast water management will include the following measures: • Ballast water exchange by domestic vessels will be avoided. • Domestic vessels will manage ballast water in accordance with the Australian *Ballast Water Management Requirements* (Department of Agriculture and Water Resources 2016). Any ballast water exchange from international vessels will be undertaken in accordance with *the International Convention for the Control and Management of Ships' Ballast Water and Sediments* (BWM) (IMO 2016) – i.e. "whenever possible, conduct ballast water exchange at least 200 nautical miles from the nearest land and in water at least 200 metres in depth, taking into account Guidelines developed by IMO" and "in cases where the ship is unable to conduct ballast water exchange as above, this should be as far from the nearest land as possible, and in all cases at least 50 nautical miles from the nearest land and in water at least 200 metres in depth".	Contractor and Port Users	Construction and Operation
For all construction vessels and/or barges, piling or other equipment mobilised to the site from overseas, the processes of the Australian Government Department	Contractor	Construction

Mitigation Measure	Responsibility	Phase
of Agriculture for pre-arrival, arrival and inspection, and post-arrival will be followed.		
Monitoring and inspection and/or surveillance of all construction vessels and/or barges will be undertaken in accordance with the *Biosecurity Act 2015*. The Contractor will be responsible for understanding their obligations under the *Biosecurity Act 2015* in regard to monitoring, inspection and surveillance of construction vessels and/or barges.	Contractor	Construction

8.4 Terrestrial Ecology

Mitigation measures to avoid or minimise potential impacts on terrestrial ecology are outlined in Table 8-4.

Table 8-4 Proposed mitigation measures – terrestrial ecology.

Mitigation Measure	Responsibility	Phase
To minimise damage to sensitive terrestrial habitats in the study area (i.e. the terrestrial habitats of the Kingston Common Reserve) and the fauna they support, all habitats beyond the approved footprint will remain no-go zones for the duration of construction. No vehicle movements, materials stockpiling, or other construction-related activities are permitted outside the approved land-based footprint during construction. At all times, vehicles transporting construction-related materials, equipment or trailers pulling vessels will remain on the available sealed roadways and not on any grassed areas of the Kingston Common Reserve.	Contractor	Construction
To minimise unnecessary damage to habitats and the fauna they support which occur within the construction footprint during construction, the Contractor will limit any unnecessary and/or temporary construction (i.e. through selection of the most appropriate construction methods) and materials stockpiling.	Contractor	Construction
All construction works will be undertaken by a suitably qualified, experienced and site-specific trained Contractor to reduce the risk of error and accidental environmental damage and flow-on effects on habitats and fauna in a safe manner.	Contractor	Construction

Mitigation Measure	Responsibility	Phase
To reduce the potential for lighting-related impacts on terrestrial fauna during construction the following measures will be implemented: • Limit the need for construction activities to be undertaken during the evening and night time to reduce the overall need for construction-related artificial lighting (on vessels and the jack-up barge) and associated impacts. • Use downward-directed and dimmed lighting on Kingston Pier (ensuring that it is still in accordance with navigation requirements).	Contractor	Construction
All sediment and erosion controls, marine water quality and waste management mitigation measures described in this EA will be implemented.	Contractor and the NIRC	Construction and Operation

9 Assessment of Significance under the EPBC Act 1999 – Marine and Terrestrial Ecology

9.1 Significant Impact Guidelines

The EPBC Act 1999 Significant Impact Guidelines for threatened species and for endangered ecological communities (EECs) were reviewed and the Project was assessed in relation to these below (http://www.environment.gov.au/system/files/resources/42f84df4-720b-4dcf-b262-48679a3aba58/files/nes-guidelines_1.pdf).

9.1.1 Threatened, Migratory and Listed Marine Species

An action is likely to have a significant impact on a critically endangered, endangered or vulnerable species if there is a real chance or possibility that it will trigger one or more of the following nine impacts:

Impact 1. Lead to a long-term decrease in the size of a population or of an important population of a species.

The Project is not expected to lead to a long-term decrease in the size of a population, or of an important population of a species, listed under the EPBC Act. The location of the proposed construction activities adjacent to Kingston Pier is currently used by commercial and recreational vessels so is subject to regular low level disturbance. While there is the potential for listed species to occur here on occasion, the immediate construction area is not used regularly by any population of a species which would be impacted by the proposed works. Mobile marine fauna which are listed under the EPBC Act will either avoid or remove themselves from the immediate construction area during the works if they happen to be in the area during this work.

Impact 2. Reduce the area of occupancy of the species or of an important population.

The Project is not expected to reduce the area of occupancy of a species or important population as alternate nearby habitat is available. The location of the proposed construction activities adjacent to Kingston Pier is currently used by commercial and recreational vessels so is subject to regular low level disturbance. While there is the potential for listed species to occur here on occasion, the construction area is not an area of important habitat for any species or important populations listed under the Act.

Impact 3. Fragment an existing population or important population into two or more populations.

The Project is not expected to fragment any population into two or more populations. The proposed scope of works does not involve the construction of any structures which would result in the separation or fragmentation of a population. The project involves deepening of an existing channel and removal of an area of nearby subtidal rocky floor. The proposed works will not result in any significant change to the use of this area which may result in the fragmentation of a population.

Impact 4. Adversely affect habitat critical to the survival of a species.

No Critical Habitat listed under the EPBC Act occurs in the study area, so Critical Habitat will not be impacted by the Project.

Impact 5. Disrupt the breeding cycle of a population or of an important population.

The Project is not likely to disrupt the breeding cycle of a population or important population. The location of the proposed construction activities adjacent to Kingston Pier is currently used by commercial and recreational vessels so is subject to regular low level disturbance. While there is the potential for listed species to occur here on occasion, the construction area is not used as an important area for breeding for any listed marine species. Mobile marine fauna which are listed under the EPBC Act will either avoid or remove themselves from the immediate construction area during the works if they happen to be in the area during this work and there will be no significant change in use of the site after construction is completed.

Impact 6 - Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

The Project will remove or modify a small area of subtidal seafloor habitat. Most of the area likely to be directly impacted by excavation is within the existing channel and therefore has been previously disturbed. This area of seafloor typically has little epibiotic cover. Overall, direct disturbance to the seabed associated with Option 3a is considered negligible as it will impact areas of seabed previously disturbed and the area to be impacted by widening of the existing channel is relatively small. The nature of the habitat to be removed and the fact that this area will likely be recolonised to its current state over time means that it is not expected that habitat at the site will be destroyed, removed, isolated or decreased in quality to the extent that any species is likely to decline. Recolonisation of the subtidal rocky seafloor by microalgae would typically occur within a matter of weeks, with larger macroalgae then colonising the area within months. Sessile marine organisms such as corals, sponges and ascidians may also begin to occur within a year of completion of construction but are not currently common in this channel area due to the less complex existing habitat.

Impact 7. Result in invasive species that are harmful to a critically endangered, endangered or vulnerable species, becoming established in the species' habitat.

The Project will not result in the direct introduction of any invasive species that are harmful to a critically endangered, endangered or vulnerable species, becoming established in the species' habitat. While there is the potential for accidental introduction of species via ballast water and attached to the hulls of vessels, mitigation measures would be adopted to ensure that there is no potential for invasive species to be introduced to Norfolk Island during the construction or operation of the Project.

Impact 8. Introduce disease that may cause the species to decline.

The Project will not result in the direct introduction of a disease that may cause any marine species listed under the EPBC Act to decline. The project does not involve the transport of any living organisms (plants or animals) to the site which may result in the transfer of a disease from region to region. While there is the potential for plant or animal diseases to be accidently introduced, mitigation measures which are to be adopted to ensure that there is no potential for invasive species to be introduced to Norfolk Island will also act to ensure that no plant or animal diseases are introduced.

Impact 9. Interfere or interfere substantially (for vulnerable species) with the recovery of the species.

The Project will not interfere or interfere substantially (for vulnerable species) with the recovery of any threatened marine species as listed under the EPBC Act. The location of the proposed construction activities adjacent to Kingston Pier is currently used by commercial and recreational vessels so is already subject to regular low level disturbance. While there is the potential for listed species to occur here on occasion, the construction area is not used regularly by any listed species whose recovery would be interfered with by the proposed activity or resulting use of the site (which will not substantially change from its present use). Mobile marine fauna which are listed under the EPBC Act will either avoid or remove themselves from the immediate construction area during the works if they happen to be in the area during this work.

9.1.2 Threatened, Migratory and Listed Terrestrial Species

An action is likely to have a significant impact on a critically endangered, endangered or vulnerable terrestrial fauna species if there is a real chance or possibility that it will trigger one or more of the following nine impacts:

Impact 1. Lead to a long-term decrease in the size of a population or of an important population of a species.

The Project is not expected to lead to a long-term (or short-term) decrease in the size of any terrestrial population, or of an important population of a species, as listed under the EPBC Act. The proposed scope of works is largely confined to the marine environment and man-made structures adjacent to it, namely Kingston Pier and nearby local roads. Natural terrestrial habitats which may support such listed terrestrial species will not be impacted by the Project.

Impact 2. Reduce the area of occupancy of the species or of an important population.

The Project is not expected to reduce the area of occupancy of any terrestrial species or important population as listed under the EPBC Act. The proposed scope of works is largely confined to the marine environment and man-made structures adjacent to it, namely Kingston Pier and nearby local roads. Natural terrestrial habitats which may support such listed terrestrial species will not be impacted by the Project. Potential noise impacts may cause terrestrial fauna (e.g. birds inhabiting nearby Norfolk Island pine forests or grasslands) to temporarily avoid the area during works (although this is probably unlikely given that most noise generated would be underwater) and in this case they would be expected to return as soon as any short-term disturbance had ceased. Alternate nearby habitat is available for use by these species if this were the case.

Impact 3. Fragment an existing population or important population into two or more populations.

The Project would not fragment any existing terrestrial population or important population as listed under the EPBC Act into two or more populations. The proposed scope of works is largely confined to the marine environment and man-made structures adjacent to it, namely Kingston Pier and nearby local roads. Natural terrestrial habitats which may support such listed terrestrial species will not be impacted by the Project so there is no potential for fragmentation of populations to occur.

Impact 4. Adversely affect habitat critical to the survival of a species.

No areas of Critical Habitat for terrestrial species as listed under the EPBC Act occurs in the study area, so terrestrial Critical Habitat would not be impacted.

Impact 5. Disrupt the breeding cycle of a population or of an important population.

The Project is not likely to disrupt the breeding cycle of any terrestrial population or important population. The proposed scope of works is largely confined to the marine environment and man-made structures adjacent to it, namely Kingston Pier and nearby local roads. Natural terrestrial habitats which may support such listed terrestrial species will not be impacted by the Project so there is no potential for disruptions to the breeding cycles of important terrestrial populations to occur.

Impact 6 – Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

No terrestrial habitat at the site would be destroyed, removed, isolated or decreased in quality to the extent that any species is likely to decline as a result of the Project. The majority of works are water-based and any land-based work would be undertaken over existing roads, the concrete surface of Kingston Pier and at an already disturbed land-based disposal site.

Impact 7. Result in invasive species that are harmful to a critically endangered, endangered or vulnerable species becoming established in the species' habitat.

The Project will not result in the direct introduction of any invasive terrestrial species. While there is the potential for the accidental introduction of species via land-based construction equipment, mitigation measures would be adopted to ensure that there is no potential for invasive species to be introduced to Norfolk Island during the construction or operation of the Project. In addition, local biosecurity laws and measures which are adopted at the airport will ensure that invasive species are not introduced by any persons associated with the Project entering Norfolk Island via this method.

Impact 8. Introduce disease that may cause the species to decline.

The Project will not result in the direct introduction of disease that may cause listed terrestrial species to decline. The project does not involve the transport of any living organisms (plants or animals) to the site which may result in the transfer of a disease from region to region. While there is the potential for plant or animal diseases to be accidently introduced, mitigation measures which are to be adopted to ensure that there is no potential for invasive species to be introduced to Norfolk Island will also act to ensure that no plant or animal diseases are introduced. In addition, local biosecurity laws and measures which are adopted at the airport will ensure that plant or animal diseases are not introduced by any persons associated with the Project entering Norfolk Island via this method.

Impact 9. Interfere or interfere substantially (for vulnerable species) with the recovery of the species.

The Project will not interfere with the recovery of any threatened terrestrial species listed under the EPBC Act. The proposed scope of works is largely confined to the marine environment and man-made structures adjacent to it, namely Kingston Pier and nearby local roads. Natural terrestrial habitats which may support such listed terrestrial species will not be impacted by the Project.

9.1.3 Endangered Ecological Communities

No Endangered Ecological Communities listed under the EPBC Act occur within the study area and will not be impacted by the Project. Further assessment has not been undertaken.

9.2 Overall Assessment of Significance

As no significant impact on any threatened species or EECs listed under the EPBC Act are expected to occur, no additional assessment in the form of an Environmental Impact Statement is considered to be required.

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Appendix A EPBC Act 1999 Protected Matters Search

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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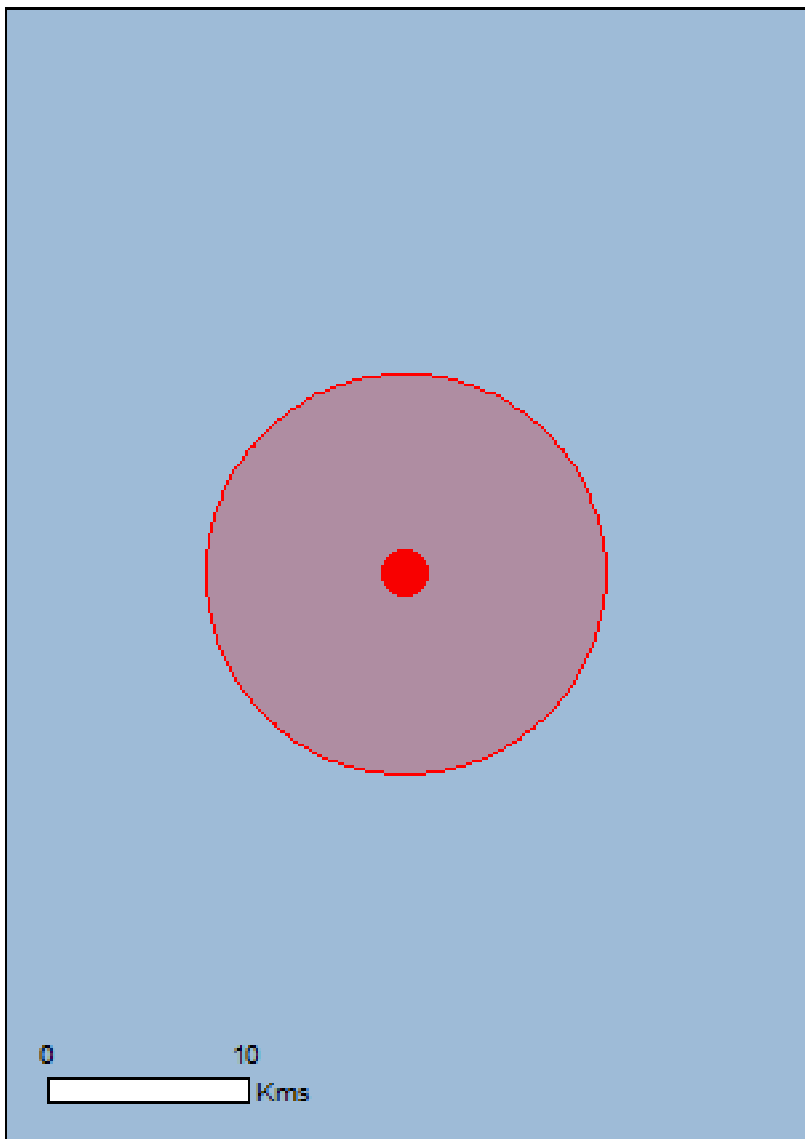

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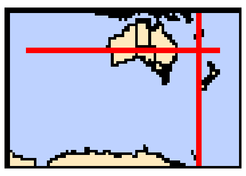

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	2
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	89
Listed Migratory Species:	41

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	1
Commonwealth Heritage Places:	6
Listed Marine Species:	38
Whales and Other Cetaceans:	28
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	3
Australian Marine Parks:	1

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	21
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	2

Details

Matters of National Environmental Significance

World Heritage Properties

[Resource Information]

Name	State	Status
Australian Convict Sites (Kingston and Arthurs Vale Historic Area)	EXT	Declared property

National Heritage Properties

[Resource Information]

Name	State	Status
Historic		
HMS Sirius Shipwreck	EXT	Listed place
Kingston and Arthurs Vale Historic Area	EXT	Listed place

Commonwealth Marine Area

[Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions

[Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
Temperate East

Listed Threatened Species

[Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Cyanoramphus cookii Norfolk Island Green Parrot, Tasman Parakeet, Norfolk Island Parakeet [67046]	Endangered	Breeding known to occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Species or species habitat may occur within area
Diomedea antipodensis gibsoni Gibson's Albatross [82270]	Vulnerable	Species or species habitat may occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area

Name	Status	Type of Presence
Fregetta grallaria grallaria White-bellied Storm-Petrel (Tasman Sea), White-bellied Storm-Petrel (Australasian) [64438]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat may occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Ninox novaeseelandiae undulata Norfolk Island Boobook, Southern Boobook (Norfolk Island) [26188]	Endangered	Breeding known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pachycephala pectoralis xanthoprocta Golden Whistler (Norfolk Island) [64444]	Vulnerable	Species or species habitat known to occur within area
Petroica multicolor Norfolk Island Robin, Pacific Robin [604]	Vulnerable	Breeding likely to occur within area
Pterodroma heraldica Herald Petrel [66973]	Critically Endangered	Species or species habitat may occur within area
Pterodroma leucoptera leucoptera Gould's Petrel, Australian Gould's Petrel [26033]	Endangered	Species or species habitat may occur within area
Pterodroma neglecta neglecta Kermadec Petrel (western) [64450]	Vulnerable	Breeding known to occur within area
Thalassarche cauta steadi White-capped Albatross [82344]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Fish		
Epinephelus daemelii Black Rockcod, Black Cod, Saddled Rockcod [68449]	Vulnerable	Species or species habitat likely to occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
Other		
Advena campbellii Campbell's Helicarionid Land Snail [81250]	Critically Endangered	Species or species habitat known to occur within area
Mathewsoconcha grayi ms Gray's Helicarionid Land Snail [81852]	Critically Endangered	Species or species habitat likely to occur within area
Mathewsoconcha phillipii Phillip Island Helicarionid Land Snail [81252]	Critically Endangered	Species or species habitat likely to occur within area
Mathewsoconcha suteri a helicarionid land snail [81851]	Critically Endangered	Species or species habitat likely to occur within area
Quintalia stoddartii Stoddart's Helicarionid Land Snail [81253]	Critically Endangered	Species or species habitat likely to occur within area
Plants		
Abutilon julianae Norfolk Island Abutilon [27797]	Critically Endangered	Species or species habitat known to occur within area
Achyranthes arborescens Chaff Tree, Soft-wood [65879]	Critically Endangered	Species or species habitat known to occur within area
Achyranthes margaretarum Phillip Island Chaffy Tree [68426]	Critically Endangered	Species or species habitat known to occur within area
Blechnum norfolkianum Norfolk Island Water-fern [65885]	Endangered	Species or species habitat known to occur within area
Boehmeria australis subsp. australis Tree Nettle, Nettletree [83309]	Critically Endangered	Species or species habitat known to occur within area
Calystegia affinis [48909]	Critically Endangered	Species or species habitat known to occur within area
Clematis dubia a creeper, Clematis [22035]	Critically Endangered	Species or species habitat known to occur within area
Coprosma baueri Coastal Coprosma [37851]	Endangered	Species or species habitat known to occur within area

Name	Status	Type of Presence
Coprosma pilosa Mountain Coprosma [37884]	Endangered	Species or species habitat known to occur within area
Cordyline obtecta Ti [65878]	Vulnerable	Species or species habitat known to occur within area
Dendrobium brachypus Norfolk Island Orchid [2592]	Endangered	Species or species habitat known to occur within area
Dysoxylum bijugum Sharkwood, a tree [65892]	Vulnerable	Species or species habitat known to occur within area
Elatostema montanum Mountain Procris [33862]	Critically Endangered	Species or species habitat known to occur within area
Elymus multiflorus subsp. kingianus Phillip Island Wheat Grass [82413]	Critically Endangered	Species or species habitat likely to occur within area
Euphorbia norfolkiana Norfolk Island Euphorbia [65887]	Critically Endangered	Species or species habitat known to occur within area
Euphorbia obliqua a herb [44385]	Vulnerable	Species or species habitat likely to occur within area
Hibiscus insularis Phillip Island Hibiscus [30614]	Critically Endangered	Species or species habitat likely to occur within area
Hypolepis dicksonioides Downy Ground-fern, Brake Fern, Ground Fern [10243]	Vulnerable	Species or species habitat likely to occur within area
Ileostylus micranthus Mistletoe [65891]	Vulnerable	Species or species habitat known to occur within area
Lastreopsis calantha Shield-fern, Shieldfern [65884]	Endangered	Species or species habitat known to occur within area
Marattia salicina King Fern, Para, Potato Fern [16197]	Endangered	Species or species habitat likely to occur within area
Melicope littoralis Shade Tree [22042]	Vulnerable	Species or species habitat known to occur within area
Melicytus latifolius Norfolk Island Mahoe [56677]	Critically Endangered	Species or species habitat known to occur within area
Melicytus ramiflorus subsp. oblongifolius Whiteywood, a tree [56680]	Vulnerable	Species or species habitat likely to occur within area
Meryta angustifolia a tree [65881]	Vulnerable	Species or species habitat known to occur within area
Meryta latifolia Shade Tree, Broad-leaved Meryta [65882]	Critically Endangered	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Muehlenbeckia australis Shrubby Creeper, Pohuehue [68510]	Endangered	Species or species habitat known to occur within area
Myoporum obscurum Popwood, Sandalwood, Bastard Ironwood [50255]	Critically Endangered	Species or species habitat known to occur within area
Myrsine ralstoniae Beech [83889]	Vulnerable	Species or species habitat known to occur within area
Pennantia endlicheri Pennantia [65890]	Endangered	Species or species habitat known to occur within area
Phreatia limenophylax Norfolk Island Phreatia [9239]	Critically Endangered	Species or species habitat known to occur within area
Phreatia paleata an orchid [20193]	Endangered	Species or species habitat known to occur within area
Pittosporum bracteolatum Oleander [47181]	Vulnerable	Species or species habitat known to occur within area
Planchonella costata [30944]	Endangered	Species or species habitat known to occur within area
Polyphlebium endlicherianum Middle Filmy Fern [87494]	Endangered	Species or species habitat known to occur within area
Pteris kingiana King's Brakefern [35183]	Endangered	Species or species habitat likely to occur within area
Pteris zahlbruckneriana Netted Brakefern [65893]	Endangered	Species or species habitat likely to occur within area
Senecio australis a daisy [40250]	Vulnerable	Species or species habitat likely to occur within area
Senecio evansianus a daisy [55340]	Endangered	Species or species habitat known to occur within area
Senecio hooglandii a daisy [55346]	Vulnerable	Species or species habitat known to occur within area
Streblus pendulinus Siah's Backbone, Sia's Backbone, Isaac Wood [21618]	Endangered	Species or species habitat known to occur within area
Taeniophyllum norfolkianum Minute Orchid, Ribbon-root Orchid [82347]	Vulnerable	Species or species habitat likely to occur within area
Tmesipteris norfolkensis Hanging Fork-fern [65895]	Vulnerable	Species or species habitat known to occur within area
Ungeria floribunda Bastard Oak [41714]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Wikstroemia australis Kurrajong [42074]	Critically Endangered	Species or species habitat known to occur within area
Zehneria baueriana Native Cucumber, Giant Cucumber [39253]	Endangered	Species or species habitat known to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Christinus guentheri Lord Howe Island Gecko, Lord Howe Island Southern Gecko [59250]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Oligosoma lichenigera Lord Howe Island Skink [82034]	Vulnerable	Species or species habitat likely to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat likely to occur within area

Listed Migratory Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat known to occur within area
Ardenna grisea Sooty Shearwater [82651]		Species or species habitat may occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Species or species habitat may occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land - Norfolk Island National Park

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Nepean Island Reserve	EXT	Listed place
Phillip Island	EXT	Listed place
Selwyn Reserve (2003 boundary)	EXT	Listed place
Historic		
Arched Building, Longridge	EXT	Listed place
HMS Sirius Shipwreck	EXT	Listed place
Kingston and Arthurs Vale Commonwealth Tenure Area	EXT	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Species or species habitat may occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Diomedea gibsoni Gibson's Albatross [64466]	Vulnerable*	Species or species habitat may occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Morus serrator Australasian Gannet [1020]		Breeding known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Procelsterna cerulea Grey Noddy, Grey Ternlet [64378]		Breeding known to occur within area
Pterodroma cervicalis White-necked Petrel [59642]		Breeding known to occur within area
Pterodroma nigripennis Black-winged Petrel [1038]		Breeding known to occur within area
Pterodroma solandri Providence Petrel [1040]		Breeding known to occur within area
Puffinus assimilis Little Shearwater [59363]		Breeding known to occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Species or species habitat known to occur within area
Puffinus griseus Sooty Shearwater [1024]		Species or species habitat may occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area

Name	Threatened	Type of Presence
Fish		
Halicampus boothae Booth's Pipefish [66218]		Species or species habitat may occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Globicephala melas Long-finned Pilot Whale [59282]		Species or species habitat may occur within

Name	Status	Type of Presence
		area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon grayi Gray's Beaked Whale, Scamperdown Whale [75]		Species or species habitat may occur within area
Mesoplodon layardii Strap-toothed Beaked Whale, Strap-toothed Whale, Layard's Beaked Whale [25556]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Commonwealth ReservesTerrestrial [Resource Information]

Name	State	Type
Norfolk Island	EXT	Botanic Gardens
Norfolk Island (Mt Pitt)	EXT	National Park (Commonwealth)
Norfolk Island (Phillip Island)	EXT	National Park (Commonwealth)

Australian Marine Parks [Resource Information]

Name	Label
Norfolk	Special Purpose Zone (Norfolk) (IUCN

Extra Information

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Anas platyrhynchos Mallard [974]		Species or species habitat likely to occur within area
Callipepla californica California Quail [59451]		Species or species habitat likely to occur within area
Carduelis carduelis European Goldfinch [403]		Species or species habitat likely to occur within area
Carduelis chloris European Greenfinch [404]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Gallus gallus Red Junglefowl, Domestic Fowl [917]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Turdus merula Common Blackbird, Eurasian Blackbird [596]		Species or species habitat likely to occur within area
Turdus philomelos Song Thrush [597]		Species or species habitat likely to occur within area
Mammals		

Name	Status	Type of Presence
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Rattus exulans Pacific Rat, Polynesian Rat [79]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Plants		
Anredera cordifolia Madeira Vine, Jalap, Lamb's-tail, Mignonette Vine, Anredera, Gulf Madeiravine, Heartleaf Madeiravine, Potato Vine [2643]		Species or species habitat likely to occur within area
Asparagus plumosus Climbing Asparagus-fern [48993]		Species or species habitat likely to occur within area
Eichhornia crassipes Water Hyacinth, Water Orchid, Nile Lily [13466]		Species or species habitat likely to occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Lycium ferocissimum African Boxthorn, Boxthorn [19235]		Species or species habitat likely to occur within area
Rubus fruticosus aggregate Blackberry, European Blackberry [68406]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Norfolk Ridge	Temperate east
Tasman Front and eddy field	Temperate east

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-29.0417 168.0108

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Appendix B Norfolk Island Bird List

Bird Checklist for Norfolk Island

Forest birds

Common Name	Local Name	Scientific Name	Where	When	Seen
Green parrot (E, N)		*Cyanoramphus cookii*	Forest	All year	
Grey gerygone (N)	Hummingbird	*Gerygone modesta*	All habitats	All year	
Golden whistler (V, N)	Tamey	*Pachycephala pectoralis xanthoprocta*	Forest	All year	
Scarlet robin (V, E)		*Petroica multicolor multicolor*	Forest	All year	
Grey fantail (N)		*Rhipidura fuliginosa pelzelni*	Forest	All year	
White-breasted white-eye (X)	Grinnell	*Zosterops albogularis*	Forest		
Silvereye	Grinnell	*Zosterops lateralis*	Forest, gardens	All year	
Long-billed white-eye (N)	Grinnell	*Zosterops tenuirostris*	Forest	All year	
Sacred kingfisher (N)	Nuffka	*Halcyon sancta*	All habitats	All year	
Norfolk Island boobook owl (E, N)	Morepork	*Ninox novaeseelandiae undulata*	Forest	All year	
Shining bronze-cuckoo	Greenback	*Chrysococcyx lucidus*	Forest	Summer	
Welcome swallow		*Hirundo neoxena*	Open areas	Winter	
Long-tailed cuckoo		*Eudyanamis taitensis*	Forest	Winter-spring	
Emerald dove		*Chalcophaps indica*	Forest, gardens	All year	
Australian kestrel	Sparrow-hawk	*Falco cenchroides*	Pasture, cliffs and forest edges	All year	
European goldfinch *		*Carduelis carduelis*	Open areas, gardens	All year	
European greenfinch *		*Carduelis chloris*	Open areas, gardens	All year	
House sparrow *		*Passer domesticus*	Open areas, gardens	All year	
Common starling *		*Sturnus vulgaris*	Open areas, gardens	All year	
European blackbird *		*Turdus merula*	All habitats	All year	
Song thrush *		*Turdus philomelos*	All habitats	All year	
Feral pigeon *		*Columba livia*	Open areas, gardens	All year	
Feral chicken *	Fowl / chook	*Gallus gallus*	All habitats	All year	
California quail *		*Lophortyx californicus*	All habitats	All year	
Crimson rosella *	Red parrot	*Platycercus elegans*	All habitats	All year	

Waterbirds

Common Name	Local Name	Scientific Name	Where	When	Seen
Mallard *		*Anas platyrhynchos*	Wetlands, dams	All year	
Pacific black duck	Duck	*Anas superciliosa*	Wetlands, dams	All year	
Feral goose *		*Anser domesticus*	Wetlands, dams	All year	
White-faced heron	Crane	*Ardea novaehollandiae*	Pastures, reef	All year	
Purple swamphen	Tarler bird	*Porphyrio porphyrio*	Wetlands, thick vegetation	All year	
Spotless crake	Little tarler bird	*Porzana tabuensis*	Wetlands	All year	
Buff-banded rail	Little tarler bird	*Rallus philippensis*	Wetlands	All year	
Great cormorant		*Phalacrocorax carbo*	Wetlands, coastal	Winter	
Little pied cormorant		*Phalacrocorax melanoleucos*	Wetlands, coastal	Winter	
Little black cormorant		*Phalacrocorax sulcrirostris*	Wetlands, coastal	Winter	

Legend: (E) = endangered; (V) = vulnerable; (X) = extinct; (N) = endemic to Norfolk Island; * = introduced

Seabirds

Common Name	Local Name	Scientific Name	Where	When	Seen
Grey ternlet	Patro	*Procelsterna albivittata*	Off-shore Islands	All year	
White-capped noddy	Titerack	*Anous minutus*	Off-shore Islands	All year, some migrate	
White tern		*Gygis alba*	Forest	All year, some migrate	
Red-tailed tropic bird		*Phaethon rubricauda roseotincta*	Coastal cliffs & off-shore Islands	All year, some migrate	
Masked booby	Garnet	*Sula dactylatra fullagari*	Off-shore Islands	All year, some migrate	
Common noddy	Noddy	*Anous stolidus*	Off-shore Islands	Spring - autumn	
Australasian gannet	Garnet	*Morus serrator*	Off-shore Islands	Spring - autumn	
Wedge-tail shearwater	Ghostbird	*Puffinus pacificus*	Coastal cliffs	Spring - autumn	
Sooty tern	Whale bird	*Sterna fuscata*	Off-shore Islands	Spring - autumn	
Little shearwater		*Puffinus assimilis*	Coastal cliffs & off-shore Islands	Spring - autumn	
Ruddy turnstone		*Arenaria interpres*	Coastal and reef	Summer	
Bar-tailed godwit		*Limosa lapponica*	Wetlands and coastal	Summer	
Black-tailed godwit		*Limosa limosa*	Wetlands and coastal	Summer	
Whimbrel		*Numenius phaeopus*	Wetlands and coastal	Summer	
Lesser golden plover		*Pluvialis dominica*	Pasture	Summer	
Pacific golden plover		*Pluvias fulva*	Pasture	Summer	
Black-winged petrel		*Pterodroma nigripennis*	Coastal	Summer	
Greenshank		*Tringa nebularia*	Wetlands and coastal	Summer	
White-necked petrel		*Pterodroma cervicalis*	Phillip Island	Summer - autumn	
Kermadec petrel (V)		*Pterodroma neglecta*	Phillip Island	Summer - autumn	
Double-banded plover		*Charadrius bicinctus*	Coastal and reef	Winter	
Providence petrel		*Pterodroma solandri*	Phillip Island	Winter	
Lesser frigatebird		*Fregata ariel*	Coastal	All year	
Greater frigatebird		*Fregata minor*	Coastal	All year	

Birdwatchers notes:

Legend: (E) = endangered; (V) = vulnerable; (X) = extinct; (N) = endemic to Norfolk Island; * = introduced

Occasional visitors / vagrants

Common Name	Scientific Name	Habitat
Brown goshawk	*Accipiter fasciatus*	All habitats
White-throated needletail	*Hirundapus caudacutus*	All habitats
Fork-tailed swift	*Apus pacificus*	All habitats
Barn owl	*Tyto alba*	All habitats
Masked lapwing	*Vanellus miles*	All habitats
Hardhead	*Aythya australis*	Wetlands, coastal
Cattle egret	*Bubulcus ibis*	Pasture, wetlands
Pallid cuckoo	*Cuculus pallidus*	Forest
Rose-crowned fruit-dove	*Ptilinopus regina*	Forest
Dollarbird	*Eurystomus orientalis*	Forest and gardens
Cape petrel	*Daption capense*	Coastal
Gould's petrel	*Pterodroma leucoptera*	Coastal
Short-tailed shearwater	*Puffinus tenuirostris*	Coastal
Townsend's shearwater	*Puffinus auricularis*	Coastal
Flesh-footed shearwater	*Puffinus carneipes*	Coastal
Wandering albatross	*Diomedea exulans*	Coastal
White-fronted tern	*Sterna striata*	Coastal
Brown booby	*Sula leucogaster*	Coastal
Silver gull	*Larus novaehollandiae*	Coastal
Kelp gull	*Larus dominicanus*	Coastal
Southern giant petrel	*Macronectes giganteus*	Coastal
White-winged tern	*Chlidonias leucopterus*	Coastal
Laysan albatross	*Phoebastria immutabilis*	Coastal
White-tailed tropicbird	*Phaethon lepturus*	Coastal
Terek sandpiper	*Xenus cinereus*	Wetlands and coastal
Eurasian coot	*Fulica atra*	Wetlands, coastal
Latham's snipe	*Gallinago hardwickii*	Wetlands, coastal
South Island pied oystercatcher	*Haematopus ostralegus finschi*	Wetlands, coastal
Grey-tailed tattler	*Heteroscelus brevipes*	Wetlands, coastal
Wandering tattler	*Heteroscelus incanus*	Wetlands, coastal

Common Name	Scientific Name	Habitat
Eastern curlew	*Numenius phaeopus*	Wetlands, coastal
Australasian grebe	*Tachybaptus novaehollandiae*	Wetlands, coastal
Australian pelican	*Pelecanus conspicillatus*	Wetlands, coastal
Bristle-thighed curlew	*Numenius tahitiensis*	Wetlands, coastal
Great cormorant	*Phalacrocorax carbo*	Wetlands, coastal
Little black cormorant	*Phalacrocorax sulcirostris*	Wetlands, coastal
Marsh sandpiper	*Tringa stagnatilis*	Wetlands, coastal
Little pied cormorant	*Microcarbo melanoleucos*	Wetlands, coastal
Curlew sandpiper	*Calidris ferruginea*	Wetlands, coastal
Hudsonian godwit	*Limosa haemastica*	Wetlands, coastal
Black-winged stilt	*Himantopus himantopus*	Wetlands, coastal
Sharp-tailed sandpiper	*Calidris acuminata*	Wetlands, coastal
Red knot	*Calidris canutus*	Wetlands, coastal
Common sandpiper	*Actitis hypoleucos*	Wetlands, coastal
Red-necked stint	*Calidris ruficolis*	Wetlands, coastal
Brown skua	*Catharacta skua*	Wetlands, coastal
Mongolian plover	*Charadrius mongolus*	Wetlands, coastal
Marsh harrier	*Circus aeruginosus*	Wetlands, coastal
Black swan	*Cygnus atratus*	Wetlands
Australian shelduck	*Tadorna tadornoides*	Wetlands
Sacrid ibis	*Threskiornis bernieri*	Wetlands
White Ibis	*Threskiornis molluca*	Wetlands
Plumed whistling duck	*Dendrocygna eytoni*	Wetlands
Pacific heron	*Ardea pacifica*	Wetlands
Little egret	*Egretta garzetta*	Wetlands
Intermediate egret	*Egretta intermedia*	Wetlands
Yellow-billed spoonbill	*Platalea flavipes*	Wetlands
Royal spoonbill	*Platalea regia*	Wetlands
Great egret	*Ardea alba*	Wetlands

Kingston Pier Channel Construction

Sediment Quality Assessment

Department of Infrastructure, Transport, Regional Development and Communications (DITRDC)

28 July 2020

311015-00061

Advisian
Worley Group

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PROJECT 311015-00061: Kingston Pier Channel Construction - Sediment Quality Assessment

Rev	Description	Author	Review	Advisian approval	Revision date	Client approval	Approval date
A	Draft for internal review	H. Houridis	K. Newton	B. Morgan	16/4/2020		
B	Draft for client review	K. Newton	DITRDC				
O	Final submitted to client	K. Newton	H. Houridis	H. Houridis	1 July 2020		
O_v2	Final 2 submitted to client	Katie Lom K. Newton	H. Houridis	H. Houridis	28 July 2020		

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Executive summary

The Department of Infrastructure, Transport, Regional Development and Communications (DITRDC) has commissioned Advisian to design and deliver a Detailed Design for the Kingston Pier Channel Construction Project (Project). Part of the Project includes augmentation of the seabed adjacent to Kingston Pier to improve navigation, safety and accessibility to Norfolk Island.

This study was undertaken to assess the physical and chemical properties of the marine sediments around Kingston Pier and to determine whether the construction material is suitable for unconfined ocean disposal. The assessment was undertaken in accordance with the National Assessment Guidelines for Dredging (NAGD; CoA 2009).

Sediments were sampled by divers on the 20th February 2020. Sediments were tested by the NATA accredited laboratory ALS Environmental and consisted of coarse to medium grained sand with gravel with less than five percent fines (silt or clay), whereas samples of rock were composed of much higher proportions of clay and silt. The 95% UCL of metal concentrations were below the NAGD low level screening guidelines for all contaminants of concern except for nickel. Organic contaminant concentrations including PAHs and petroleum hydrocarbons were very low. Organotin concentrations including TBT were also very low and below the limits of reporting (LORs) for all samples tested.

Although the 95% UCL for nickel exceeded the NAGD screening level, the elevated levels in the dredging area may be due to naturally elevated ambient baseline levels, as sediments in mainland Australia commonly have high levels of nickel.

Overall, it was concluded that the dredge material located within the project area was suitable for unconfined offshore disposal and would also be suitable for land-based disposal.

1 Introduction

Advisian has been commissioned by the Department of Infrastructure, Transport, Regional Development and Communications (DITRDC) to develop and deliver a Detailed Design for the Kingston Pier Channel Construction Project (Project). Part of the Project includes augmentation of the seabed adjacent to Kingston Pier to improve navigation, safety and accessibility to Norfolk Island.

The investigations of the channel bed required an assessment of the physical and chemical properties of the marine sediments (including rock) to be dredged as required for the Project. This report summarises the outcomes of implementing the sediment sampling and analysis plan (SAP) to assess the suitability of the construction material for unconfined ocean disposal.

The SAP was prepared by Advisian in accordance with the requirements of the National Assessment Guidelines for Dredging (NAGD; CoA 2009) and will form part of the submission to the Department of Environment (DoE) if a sea dumping permit is required.

1.1 Background

The Australian Government Department of Infrastructure and Regional Development (DIRD) engaged WorleyParsons in 2016 to undertake an appreciation of dredging options adjacent to Kingston Pier, Norfolk Island. Stakeholder feedback had highlighted safety concerns regarding inadequate under-keel clearance during low tides (Advisian 2016). The report (WorleyParsons 2016) provided 3 options for improving channel dimensions adjacent to the Pier, of which Option 3 is preferred.

The key features of the Project include:

- Augmentation of approximately 5,000 cubic metres (m^3) of in-situ material at the existing channel bed at Kingston Pier to enable the deepening and widening of the existing channel to between approximately -2.7 metres to -3.2 metres (m) Mean Sea Level (MSL). The seabed material (including loose sediment, calcarenite rock and tuff rock) has been assumed to bulk out by 10% once onshore, resulting in a volume of up to 5,500 m^3.
- Dewatering of spoil.
- Transport and placement of spoil to the land-based disposal site at the Old Cascade Quarry.
- Installation of a channel navigation aid.
- Stabilisation of the existing steel sheet pile wall at Kingston Pier.
- Remediation of the rock revetment adjacent to Kingston Pier and the Slaughter Bay seawall.

The seabed adjacent to the Pier appears to be predominantly rock and/or reef, with scarce sandy patches.

1.2 Objectives

The aim of the sampling program was to assess the physical and chemical properties of the marine sediments and assess the suitability of the dredge material for unconfined ocean disposal.

2 Historical Information

Very little information is available from the site except for a diver survey of the seabed which was undertaken in 2016 to improve understanding of the subsea conditions and assist with determining appropriate dredge methodologies (WorleyParsons 2016). The divers took four trial cores and two boulder-sized samples from the seabed. The material was reported to be generally very weak. The samples were generally able to be indented with a fingernail and easily broken-up by hand. It is therefore expected that the seabed would comprise rock of a low to very low strength profile.

Previous to this, the harbour adjacent to Kingston Pier was dredged in the early 1980's using a drag line. This resulted in an uneven seabed depth and the creation of channels. Furthermore, the drag line was only able to dredge successfully adjacent to the Pier and left a poorly maintained section of channel at the entrance to the harbour, opposite the reef head (WorleyParsons 2016).

As the location is remote from known existing or historical sources of pollution and the material is subject to high wave energy, it is likely that material is uncontaminated.

3 Sampling and Analysis

A sampling and analysis plan (SAP) for the project was prepared by Advisian on behalf of the Department. The SAP was approved by DITRDC on the 14th February 2020. A permit for collection of samples from inside the Marine Park was obtained from Parks Australia on the 17th February 2020. The sampling design implemented during the 2020 survey was in accordance with the approved SAP (Advisian 2019).

3.1 Sampling Design and Rationale

3.2 Rationale

The sampling program followed the following criteria:

- It was representative of the whole of the dredged area (i.e. there are sufficient sampling locations to provide a reasonable geographic coverage of the area to be dredged);
- The selected sample locations were representative of the bulk of the unconsolidated material to be dredged.

The Contaminants of Concern (COC) selected for testing were based on a suite of analytes that are typically measured in equivalent maritime locations.

Consistent with the recommendations of the NAGD (for small dredging projects, up to 50,000 m^3), the entire dredge area was treated as a single site with random sample locations selected within it. The dredge site was classified as "*probably clean*" as there was very little potential for contamination based on historical use of the site.

It is important to note that the NAGD (CoA 2009) indicates that sediments which meet the following criteria may not require further chemical testing:

(a) Dredged material composed predominantly of gravel, sand or rock, or any other naturally occurring bottom material with particle sizes larger than silt, but only where this material is found in areas of high current or wave energy where the seabed consists of shifting gravel and sandbars, or

(b) The site from which the material is to be taken is sufficiently far removed from known existing and historical sources of pollution to provide reasonable assurance that the material has not been contaminated and the material is substantially the same as the substrate at the disposal site.

Irrespective, chemical testing was undertaken so that sediments could be retrieved and tested for a range of parameters such as particle size density and other physicochemical parameters that can be used to inform the environmental impact assessment and to develop a dredging methodology.

3.3 Timing

Sediment sampling was undertaken on the 20th February 2020.

3.4 Sample Locations

The number of sampling locations recommended was six as set out in Table 6 of the NAGD. Samples were randomly collected from the proposed dredging area as shown in Figure 3-1.

Figure 3-1 Sediment sampling locations, Kingston Pier, 20 February 2020.

3.5 Contaminants of Concern

Samples were analysed for the following analytes:

- Trace metals (Cu, Pb, Zn, Cr, Ni, Cd, Hg, As, Ag and Sb);
- Polycyclic aromatic hydrocarbons (PAHs);
- Total petroleum hydrocarbons (TPH); and
- Organotins (MBT, DBT, TBT).

Analysis for total organic carbon (TOC) was also included to allow for normalisation of organic contaminants (if present). Additionally, particle size distribution (PSD) was analysed in all samples to characterise the physical properties of the material.

3.6 Sampling Procedure

All sampling was undertaken in accordance with the NAGD protocols as described below.

Samples were collected by divers using 100 mm diameter, 0.3 m long diver cores. Once each sample was collected, the cores were retrieved onto the vessel and emptied into a stainless-steel mixing bowl. A single core was sufficient at all locations except where a triplicate sample was collected.

3.6.1 Field Sampling Protocols

Samples were collected by scientific diver with an experienced sediment quality specialist processing the samples. The sampling procedure implemented is summarised below:

(a) A Safe Work Method Statement and Dive Plan were developed for the field works, in accordance with WHS requirements and company policy. These were reviewed by Advisian and DITCRD staff prior to works being undertaken.

(b) Positioning of the vessel was done by cross-checking the position of the vessel relative to the pier and proposed dredge area. The diver then entered the water and retrieved the sample from the seabed. When the minimal sampling depth could not be achieved, sampling at an alternative location (usually within 5 m of the original location) was attempted until a sample could be collected.

(c) All locations within the areas designated for dredging were sampled to a depth of 10-20 cm, as much of the area was underlain by harder rock that was representative of the underlying geological material.

(d) Once a sample was retrieved, the sample was photographed and included in Appendix B.

(e) Once grabs from each sampling location were photographed, the sample was homogenised by placing the sample into a bowl and briefly mixed with a clean spoon rinsed in clean, fresh seawater.

(f) Sediment was then placed directly into pre-treated (solvent washed, acid rinsed glass jars with Teflon lined lids) laboratory supplied jars and air tight zip lock bags. All sediment designated for contaminant testing was placed in glass jars, whereas samples designated for PSD assessment were placed in zip lock bags. For organic analyses, sediment was placed into jars with zero headspace to prevent volatilisation.

(g) All processing of sediment samples was undertaken on the vessel (at sea). QA samples were also collected in accordance with the requirements of NAGD. New gloves were used for each sample to avoid potential cross-contamination and all sampling equipment was cleaned using fresh seawater: Seawater was also available to allow the rapid washdown of working areas between sampling locations.

(h) Sample containers were appropriately labelled (using indelible ink to write the sample location number and date on both the label and lid of the container) and stored in a cooler box. At the end of the field day, the samples were frozen before being dispatched in person by Advisian personnel to the analytical laboratory (in Melbourne) on return from Norfolk Island. All samples were accompanied by appropriate Chain of Custody forms.

3.7 Laboratory Methodology

3.7.1 Whole Sediment Analyses

All sediment samples recovered were submitted to a National Association of Testing Authorities (NATA) accredited laboratory (capable of meeting the practical quantitation limits) in accordance with Chain of Custody documentation. All samples were analysed by ALS Environmental (ALS) using the practical quantitation limits (also referred to as limits of reporting (LORs)) set out in Table 1, Appendix A of the NAGD) and as listed in Table 3-1.

Table 3-1 Practical quantitation limits (PQL) (Source: Table 1, DEWHA 2009).

Parameter	PQL
Moisture Content	0.1%
Total Organic Carbon	0.1%
Organic Compounds	
Petroleum Hydrocarbons (TPH)	100 mg/kg
Polycyclic Aromatic Hydrocarbons (PAHs)	5 µg/kg
Organotins (MBT, DBT, TBT)	1 µgSn/kg
Inorganic Compounds	
Antimony	1 mg/kg
Copper	1 mg/kg
Lead	1 mg/kg
Zinc	1 mg/kg
Chromium	1 mg/kg
Nickel	1 mg/kg
Cadmium	0.1 mg/kg
Mercury	0.01 mg/kg

3.8 Quality Control

Quality control during field sampling was ensured by:

- Using suitably qualified environmental staff experienced in sediment sampling, field supervision and sediment logging.
- Chain of Custody forms identifying (for each sample) the sampler, nature of the sample, collection date and time, analyses to be performed and sample preservation method.
- Using a survey vessel that was thoroughly inspected and washed down.
- Samples being contained in appropriately cleaned, pre-treated and labelled sample containers.

- Samples being kept cool (4°C) after sampling and during transport, stored in eskies with pre-frozen ice bricks.
- Transportation of samples under Chain of Custody documentation.
- All sampling equipment, including mixing bowls etc. was decontaminated between sampling locations via a decontamination procedure involving a wash with ambient seawater and successive rinsing with fresh seawater.
- Samples submitted to NATA accredited laboratories (ALS) capable of meeting the practical quantitation limits.
- Internal laboratory QA/QC procedures included laboratory blanks, matrix spikes, surrogates and replicate analysis was undertaken and reported.
- Sample holding times were within the prescribed times as set out in Appendix 7 of the NAGD.

Consistent with NAGD requirements, the following quality control measures were also implemented:

- Collection of a field triplicate from one location, to determine the variability of the sediment physical and chemical characteristics; and
- Collection of field duplicate (one sample split into two containers: primary sample, intra-laboratory duplicate) from one location to assess variation within the laboratory associated with sub-sample handling.

Laboratory results and certificates from the quality testing of sediments are presented in Appendix C together with the Chain of Custody documentation.

3.8.1 Laboratory QA/QC

Consistent with NAGD requirements, the following quality control measures were implemented:

- The analytical laboratory complied with the laboratory and quality assurance procedures specified in Appendix A and Appendix F of the NAGD.
- The laboratory quality assurance program included analysis of the following quality control samples in each batch (10–20 samples). This was in addition to its own internal procedures to ensure analytical procedures were conducted properly and produced reliable results:

Validation of the analytical data obtained was undertaken in accordance with Appendix F of the NAGD to confirm it was of appropriate quality for assessing the dredge material's suitability for sea disposal. This validation included consideration of results for blanks, standards and spikes, and replicate and duplicate samples. Relative percent differences (RPDs) and relative standard deviations (RSDs) between quality control duplicate and triplicate samples have been compared against relevant criteria.

3.9 Data Analysis

Contaminant levels for sediments were compared against the NAGD screening level concentrations listed in Appendix A, Table 2 of the NAGD to assess whether the material was suitable for unconfined sea disposal or if further testing was required (e.g. elutriate, bioavailability and/or direct toxicity assessment).

The comparison against guideline levels involves the comparison of mean contaminant concentrations at the 95% UCL of the mean. For the purposes of calculation of 95% UCLs, values below detection limits were set to half of the LOR in accordance with NAGD recommendations.

4 Results

Contaminant levels for sediments were compared against the NAGD screening level concentrations listed in Appendix A, Table 2 of the NAGD.

The upper 95 percent confidence limit of the mean (95 percent UCL) was used to determine compliance with the Screening Levels. For the purposes of calculation of 95% UCLs, values below Practical Quantification Limit (PCL) were set to half of the PQL in accordance with NAGD recommendations.

Tabulated results are presented in Appendix A and photographs of sediments recovered have been presented in Appendix B. Chain of Custody documentation together with laboratory certificates are provided in Appendix C. PSD laboratory results are provided in Appendix D.

4.1 Contaminant Testing

4.1.1 Metals

Total metal concentrations were generally low across all sites. Shaded yellow cells in Table 4-1 indicate an exceedance above NADG screening level. Exceedances were recorded only for nickel at three of the six sites. All other metals were found to be below their respective NAGD screening levels.

Table 4-1 Concentrations of Metals in Sediments from Kingston Pier, (mg/kg), February 2020

	NAGD Screening Value	KP1	KP2	KP3	KP4	KP5	KP6
Antimony	**2**	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Arsenic	**20**	8.17	9.6	5.4	8.05	6.91	6.24
Cadmium	**1.5**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	**80**	22.4	32	8.7	19.8	9.6	11.4
Copper	**65**	8.8	9.7	1.4	6.1	2	1.8
Lead	**50**	3.2	4	1.5	2.6	1.1	<1
Mercury	**0.15**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	**21**	43.9	43.4	9.5	28.3	13.2	9.8
Zinc	**200**	33.2	26.7	4.8	16.3	6.5	4.9

The nickel (Ni) screening level was exceeded at KP1, KP2 and KP4. The 95% UCL concentration calculated was also above the NAGD screening level of 21 mg/kg at 38.03 mg/kg (Table 4-2).

Table 4-2 95%UCL concentrations of Metals in Sediments from Kingston Pier, (mg/kg), February 2020.

	NAGD Screening Value	NAGD High Value	95%UCL
Antimony	**2**	**25**	<0.1
Arsenic	**20**	**70**	8.6
Cadmium	**1.5**	**10**	<0.1
Chromium	**80**	**370**	24.8
Copper	**65**	**270**	8.0
Lead	**50**	**220**	3.3
Mercury	**0.15**	**1**	<0.01
Nickel	**21**	**52**	38.0
Zinc	**200**	**410**	25.5

4.1.2 Organic Contaminants

No TBT or organotins were detected in any of the samples tested. All concentrations were less than the limits of reporting.

Total petroleum hydrocarbons (TPH) were present in all samples tested but were present in very low concentrations. Hydrocarbons present were in the C15 to C36 range and were generally highest at the two sites closes to the landing (KP1 and KP2). All concentrations were less than the screening level of 550 mg/kg (Table 4-3).

Table 4-3 Concentrations of TPH in Sediments from Kingston Pier, (mg/kg), February 2020.

	KP1	KP2	KP3	KP4	KP5	KP6
TPH C6-C9	<3	<3	<3	<3	<3	<3
TPH C10 - C14	<3	<3	<3	<3	<3	<3
TPH C15 - C28	32	45	16	19	14	10
TPH C29 - C36	17	84	11	18	7	6
Sum of C10 - C36	49	129	27	37	21	16
Normalised to 1% TOC	**104**	**478**	**135**	**168**	**105**	**80**

Similarly, polycyclic aromatic hydrocarbons (PAH) concentrations were very low and were only detected in sediments from KP1. All other PAH concentrations were less than the limits of reporting. The normalised concentration of PAH from KP1 was 105 µg/kg compared to the screening level of 10,000 µg/kg.

4.2 Physical Characteristics

All sediments retrieved from the seabed were medium to coarse grained sand with minimal fines present. This is also reflected in the total organic carbon (TOC) results which were generally less than 0.3% except at KP1 where the TOC concentration was 0.47%.

4.2.1 Particle Size Distribution of Sediments

All the samples collected were also tested for particle size distributions (PSD). PSD data was collected into the seven standard categories as described below:

- Gravel (2000 – 10000 µm);
- Course Sand (500 – 2000 µm);
- Medium sand (300-500 µm);
- Fine sand (60 -300 µm);
- Silt (2 – 60 µm); and
- Clay (1 – 2 µm);

Sediments located within the dredge area are predominantly sand and gravel with a small proportion of clay (Figure 4-1). Sediment particle size was generally consistent between sample locations.

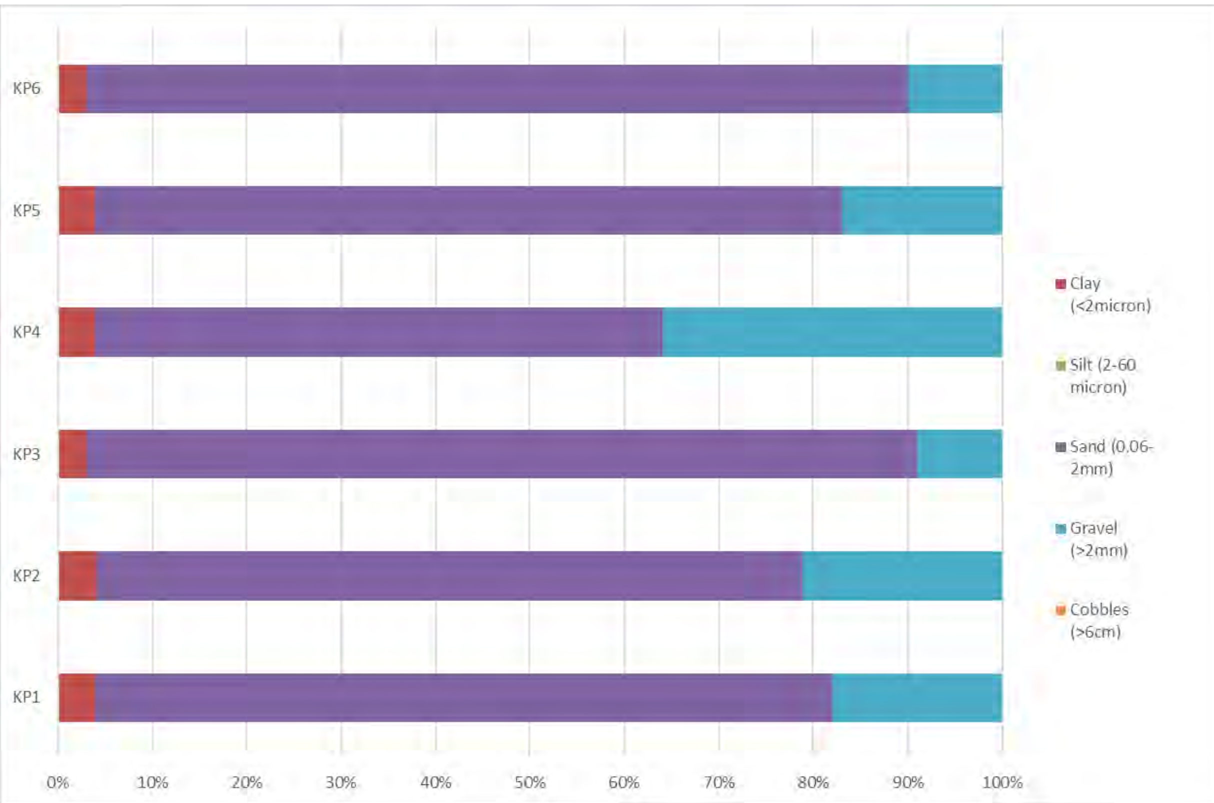


Figure 4-1 Particle size distribution of sediment samples, Kinston Pier, February 2020.

4.2.2 Particle Size Distribution of Rock

Two samples of rock were also subject to PSD testing by crushing the rock. Results are summarised in Figure 4-2 and show that the greatest proportion of the rock consists of consolidated silt and clay with a much smaller proportion of sand.

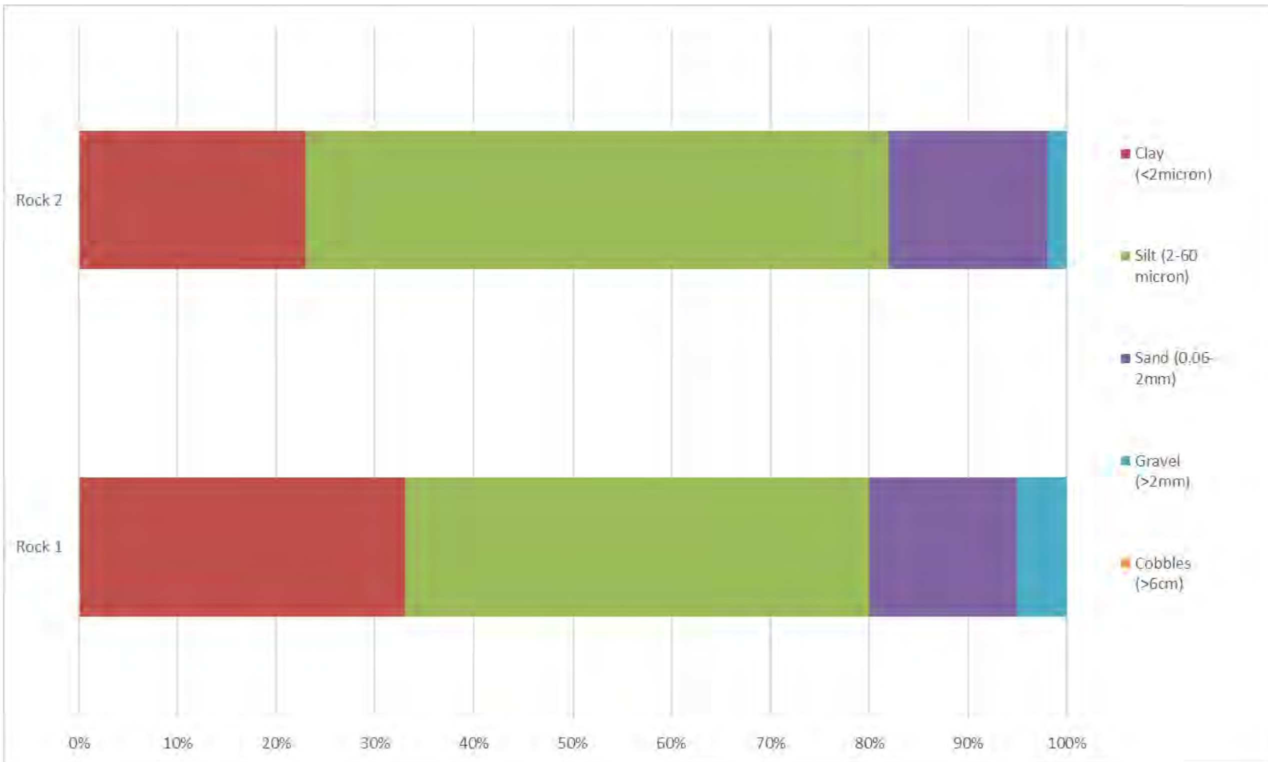


Figure 4-2 Particle size distribution of rock samples, Kinston Pier, February 2020

A complete set of results are included in Appendix D.

5 Quality Assurance and Data Validation

Quality assurance (QA) procedures, including a field quality control (QC) program, are important to validate the data presented in this report by indicating conformances and non-conformances. Quality assurance results have been tabulated and presented in Appendix C and discussed in the following sections.

5.1 Field QA/QC Samples

As part of the field QA/QC procedure a number of QA/QC samples were collected as required in the NAGD. These included one set of triplicates and one set of duplicate samples from KP1 and KP2 respectively, in accordance with NAGD requirements.

Results from the field triplicates and the intra-lab duplicates are shown in Table 5-1. Field triplicate data was consistent between samples (cores) with percentage differences well below 50% in any of the samples or analytes tested. This confirms that there was minimal variability in the chemical characteristics of the sediments within locations.

Table 5-1 Field Duplicate and Field Triplicate Data, Kingston Pier Sediments, February 2020.

	Field Duplicate		RPD (%)	Field Triplicate			RSD (%)
	QA3	KP2		QA1	QA2	KP1	
Antimony	0.25	0.25	0.0	0.25	0.25	0.25	0.0
Arsenic	9.37	9.55	1.9	7.15	8.61	8.17	9.4
Cadmium	0.05	0.05	0.0	0.05	0.05	0.05	0.0
Chromium	27.90	32.00	13.7	21.3	25.4	22.4	9.2
Copper	10.10	9.70	4.0	5.1	9.9	8.8	31.7
Lead	4.20	4.00	4.9	2.9	3.4	3.2	7.9
Mercury	0.01	0.01	0.0	0.01	0.01	0.01	0.0
Nickel	56.40	43.40	26.1	38.6	33.8	43.9	13.0
Zinc	24.90	26.70	7.0	20.2	21.9	33.2	28.2

Results from the intra-lab duplicates were also consistent with percentage differences less than 35%.

Advisian considers that overall the QA/QC completed on the field investigation to be adequate and the analytical data suitable for interpretive purposes.

5.2 Laboratory QA/QC

The laboratory also conducted QA/QC sampling for the samples in accordance with the NAGD requirements and these results are presented in Appendix C. All samples were analysed within holding times and no duplicate or blank value outliers were detected. The laboratory duplicates were also within the expected range of values with RPD values within recommended limits.

5.2.1 QA/QC Results Summary

Analytical data validation is the process of assessing whether data are in compliance with method requirements and project specifications. The primary objectives of this process are to ensure that data of known quality are reported and to identify if the data can be used to fulfil the overall project data quality objectives.

The adopted data validation guidelines are based upon data validation guidance documents published by the US Environmental Protection Authority (US EPA). The process involves the checking of analytical procedure compliance and an assessment of the accuracy and precision of analytical data from a range of quality control measurements, generated from both the field sampling and laboratory analytical programs.

A summary of the data quality objective outcomes is provided in Table 5-2.

Table 5-2 Summary of Data Quality Objective Outcomes.

Data Quality Objective	Parameter	Objective Achieved
Precision	Intra-laboratory field replicate samples	Yes
	Laboratory replicate samples	Yes
	Laboratory method blank samples	Yes
Accuracy	Laboratory matrix spike samples	Yes
	Laboratory control samples	Yes
Representativeness	Sampling program appropriate for investigation	Yes
	Sampling, handling, storage and transport appropriate for sample media	Yes
	Trip blank samples	Yes
	Samples extracted and analysed within holding times	Yes
Comparability	Standard operating procedures used for sample collection, handling and decontamination	Yes
	Standard analytical methods used for all analyses	Yes
	Consistent field conditions, field staff and laboratory analysis	Yes
	Appropriate and consistent limits of reporting	Yes
Completeness	Complete set of samples collected, and analyses requested	Yes
	Frequency of laboratory QA/QC samples adequate	Yes
	Field description and Chain of Custody appropriately completed	Yes
	Appropriate documentation for analysis	Yes

6 Conclusions

The 95% UCL of metal concentrations were below the NAGD low level screening guidelines for all contaminants of concern with exception of nickel. Organic contaminant concentrations including PAHs and petroleum hydrocarbons were very low. Organotin concentrations, including TBT, were also very low and below the limits of reporting (LORs) for all samples tested.

Although the 95% UCL for nickel exceeded the NAGD screening level, the elevated levels in the dredging area may be due to naturally elevated ambient baseline levels as sediments in mainland Australia commonly have high levels of nickel.

It is therefore concluded that the proposed dredge material located within the project area is considered suitable for unconfined offshore disposal and would also be suitable for land-based disposal.

Appendix A
Analytical Results

Analytical Parameters		Units	Detection Limit	NAGD Screening Level	NAGD High Values	Surface Sediments KP1 0.0-0.5m	KP2 0.0-0.5m	KP3 0.0-0.5m	KP4 0.0-0.5m	KP5 0.0-0.5m	KP6 0.0-0.5m
Metals											
	Antimony	mg/kg	0.5	2	25	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Arsenic	mg/kg	1	20	70	8.17	9.6	5.4	8.05	6.91	6.24
	Cadmium	mg/kg	0.1	1.5	10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Chromium	mg/kg	1	80	370	22.4	32	8.7	19.8	9.6	11.4
	Copper	mg/kg	1	65	270	8.8	9.7	1.4	6.1	2	1.8
	Lead	mg/kg	1	50	220	3.2	4	1.5	2.6	1.1	<1
	Mercury	mg/kg	0.01	0.15	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nickel	mg/kg	1	21	52	**43.9**	**43.4**	9.5	28.3	13.2	9.8
	Zinc	mg/kg	1	200	410	33.2	26.7	4.8	16.3	6.5	4.9
Organotins											
	Monobutyltin	µgSn/kg	1			<1	<1	<1	<1	<1	<1
	Dibutyltin	µgSn/kg	1			<1	<1	<1	<1	<1	<1
	Tributyltin	µgSn/kg	0.5	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Normalised to 1% TOC	µgSn/kg	0.5	9.00	70.00	**<0.5**	**<0.5**	**<0.5**	**<0.5**	**<0.5**	**<0.5**
TRH	**Total Recoverable Hydrocarbons**										
	TRH C6-C10	mg/kg				<3	<3	<3	<3	<3	<3
	TRH C10-C16	mg/kg	3			<3	3	<3	<3	<3	<3
	TRH C16-C34	mg/kg	3			43	97	22	29	18	14
	TRH C34-C40	mg/kg	3			15	97	12	24	8	6
	TRH C10-C40 (Sum)	mg/kg	3			58	197	34	53	26	20
TPH											
	TPH C6-C9	mg/kg				<3	<3	<3	<3	<3	<3
	TPH C10 - C14	mg/kg	3	-	-	<3	<3	<3	<3	<3	<3
	TPH C15 - C28	mg/kg	3	-	-	32	45	16	19	14	10
	TPH C29 - C36	mg/kg	5	-	-	17	84	11	18	7	6
	Sum of C10 - C36	mg/kg	3	-	-	49	129	27	37	21	16
	Normalised to 1% TOC	mg/kg	3	550	-	**104.3**	**478**	**135**	**168**	**105**	**80**
PAH											
	Naphthalene	µg/kg	5			<5	<5	<5	<5	<5	<5
	2-Methylnaphthalene	µg/kg	5			<5	<5	<5	<5	<5	<5
	Acenaphthylene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Acenaphthene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Fluorene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Phenanthrene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Anthracene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Fluoranthene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Pyrene	µg/kg	4			5	<4	<4	<4	<4	<4
	Benx(a)anthracene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Chrysene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Benzo(b+J)fluoranthene	µg/kg	4			5	<4	<4	<4	<4	<4
	Benzo(k)fluoranthene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Benzo€pyrene	µg/kg	4			5	<4	<4	<4	<4	<4
	Benzo(a)pyrene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Preylene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Benzo(g,h,i)preylene	µg/kg	4			6	<4	<4	<4	<4	<4
	Dibenz(a,h)anthracene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Indeno(1,2,3,cd)pyrene	µg/kg	4			<4	<4	<4	<4	<4	<4
	Coronene	µg/kg	5			<5	<5	<5	<5	<5	<5
	Sum of PAHs	µg/kg	4			21	<4	<4	<4	<4	<4
	Sum of PAHs (normalised)	µg/kg		10000		**105**	**<4**	**<4**	**<4**	**<4**	**<4**
Moist/TOC											
	Moisture content	%	0.1	-	-	30.1	36.0	27.1	26.1	24.6	28.3
	Total organic carbon	%	0.02	-	-	0.47	0.27	0.17	0.22	0.14	0.15

Appendix B
Sample Images

Sample Name	Characteristics	Photo
KP1	Location: Kingston Pier Depth: 0-0.3m Colour: brown Type: coarse sand Odour: nil	
KP2	Location: Kingston Pier Depth: 0-0.3m Colour: brown Type: coarse sand Odour: nil	
KP3	Location: Kingston Pier Depth: 0-0.3m Colour: brown Type: coarse sand and gravel Odour: nil	

KP4	Location: Kingston Pier Depth: 0-0.3m Colour: brown Type: coarse sand, gravel Odour: nil	
KP5	Location: Kingston Pier Depth: 0-0.3m Colour: brown Type: coarse sand Odour: nil	
KP6	Location: Kingston Pier Depth: 0-0.3m Colour: brown Type: coarse sand Odour: nil	

Appendix C
Laboratory Certificates

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EM2003018**	Page	: 1 of 10
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: HARRY HOURIDIS	Contact	: Customer Services EM
Address	: Level 13 333 Collins Street, Melbourne Victoria 3000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: ----	Telephone	: +61-3-8549 9600
Project	: 311015-00061	Date Samples Received	: 24-Feb-2020 10:00
Order number	: ----	Date Analysis Commenced	: 26-Feb-2020
C-O-C number	: ----	Issue Date	: 11-Mar-2020 13:38
Sampler	: Harry Houridis		
Site	: ----		
Quote number	: ME/094/20		
No. of samples received	: 11		
No. of samples analysed	: 11		

ilac-MRA NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Aleksandar Vujkovic	Laboratory Technician	Newcastle - Inorganics, Mayfield West, NSW
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Edwandy Fadjar	Organic Coordinator	Sydney Inorganics, Smithfield, NSW
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW
Minh Wills	2IC Organic Chemist	Brisbane Organics, Stafford, QLD
Peter Keyte	Technical Manager - Air	Newcastle - Inorganics, Mayfield West, NSW

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP132B-SD : Poor duplicate precision due to sample heterogeneity. Confirmed by re-extraction and re-analysis.
- EA150H: Soil particle density results fell outside the scope of AS1289.3.6.3 for sample EM2003018-010. Results should be scrutinised accordingly.

Analytical Results

Sub-Matrix: MARINE SEDIMENT (Matrix: SOIL)			Client sample ID	KP1	KP2	KP3	KP4	KP5
			Client sampling date / time	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00
Compound	CAS Number	LOR	Unit	EM2003018-001	EM2003018-002	EM2003018-003	EM2003018-004	EM2003018-005
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	30.1	36.0	27.1	26.1	24.6
EA150: Particle Sizing								
+75µm	----	1	%	95	94	96	95	96
+150µm	----	1	%	95	94	96	94	96
+300µm	----	1	%	93	89	95	90	94
+425µm	----	1	%	80	74	93	78	90
+600µm	----	1	%	53	50	87	65	81
+1180µm	----	1	%	22	24	17	40	37
+2.36mm	----	1	%	16	19	5	34	8
+4.75mm	----	1	%	15	17	3	30	<1
+9.5mm	----	1	%	8	5	1	19	<1
+19.0mm	----	1	%	<1	<1	1	4	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	4	4	3	4	4
Silt (2-60 µm)	----	1	%	<1	1	<1	<1	<1
Sand (0.06-2.00 mm)	----	1	%	78	74	88	60	79
Gravel (>2mm)	----	1	%	18	21	9	36	17
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.77	2.77	2.78	2.79	2.75
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	8.17	9.55	5.40	8.05	6.91
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	22.4	32.0	8.7	19.8	9.6
Copper	7440-50-8	1.0	mg/kg	8.8	9.7	1.4	6.1	2.0
Lead	7439-92-1	1.0	mg/kg	3.2	4.0	1.5	2.6	1.1
Nickel	7440-02-0	1.0	mg/kg	43.9	43.4	9.5	28.3	13.2
Zinc	7440-66-6	1.0	mg/kg	33.2	26.7	4.8	16.3	6.5
EG035T: Total Recoverable Mercury by FIMS (Low Level)								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EP003: Total Organic Carbon (TOC) in Soil								

Analytical Results

Sub-Matrix: MARINE SEDIMENT (Matrix: SOIL)			Client sample ID	KP1	KP2	KP3	KP4	KP5
			Client sampling date / time	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00
Compound	*CAS Number*	*LOR*	*Unit*	EM2003018-001	EM2003018-002	EM2003018-003	EM2003018-004	EM2003018-005
				Result	Result	Result	Result	Result
EP003: Total Organic Carbon (TOC) in Soil - Continued								
Total Organic Carbon	----	0.02	%	**0.47**	**0.27**	**0.17**	**0.22**	**0.14**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	**3**	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	**43**	**97**	**22**	**29**	**18**
>C34 - C40 Fraction	----	5	mg/kg	**15**	**97**	**12**	**24**	**8**
>C10 - C40 Fraction (sum)	----	3	mg/kg	**58**	**197**	**34**	**53**	**26**
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	**3**	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**32**	**45**	**16**	**19**	**14**
C29 - C36 Fraction	----	5	mg/kg	**17**	**84**	**11**	**18**	**7**
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**49**	**129**	**27**	**37**	**21**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP132B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	5	µg/kg	<5	<5	<5	<5	<5
2-Methylnaphthalene	91-57-6	5	µg/kg	<5	<5	<5	<5	<5

Analytical Results

Sub-Matrix: **MARINE SEDIMENT**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	KP1	KP2	KP3	KP4	KP5
Client sampling date / time				20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00
				EM2003018-001	EM2003018-002	EM2003018-003	EM2003018-004	EM2003018-005
				Result	Result	Result	Result	Result
EP132B: Polynuclear Aromatic Hydrocarbons - Continued								
Acenaphthylene	208-96-8	4	µg/kg	<4	<4	<4	<4	<4
Acenaphthene	83-32-9	4	µg/kg	<4	<4	<4	<4	<4
Fluorene	86-73-7	4	µg/kg	<4	<4	<4	<4	<4
Phenanthrene	85-01-8	4	µg/kg	<4	<4	<4	<4	<4
Anthracene	120-12-7	4	µg/kg	<4	<4	<4	<4	<4
Fluoranthene	206-44-0	4	µg/kg	<4	<4	<4	<4	<4
Pyrene	129-00-0	4	µg/kg	5	<4	<4	<4	<4
Benz(a)anthracene	56-55-3	4	µg/kg	<4	<4	<4	<4	<4
Chrysene	218-01-9	4	µg/kg	<4	<4	<4	<4	<4
Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	5	<4	<4	<4	<4
Benzo(k)fluoranthene	207-08-9	4	µg/kg	<4	<4	<4	<4	<4
Benzo(e)pyrene	192-97-2	4	µg/kg	5	<4	<4	<4	<4
Benzo(a)pyrene	50-32-8	4	µg/kg	<4	<4	<4	<4	<4
Perylene	198-55-0	4	µg/kg	<4	<4	<4	<4	<4
Benzo(g.h.i)perylene	191-24-2	4	µg/kg	6	<4	<4	<4	<4
Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<4	<4	<4	<4	<4
Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<4	<4	<4	<4	<4
Coronene	191-07-1	5	µg/kg	<5	<5	<5	<5	<5
^ Sum of PAHs	----	4	µg/kg	21	<4	<4	<4	<4
^ Benzo(a)pyrene TEQ (zero)	----	4	µg/kg	<4	<4	<4	<4	<4
^ Benzo(a)pyrene TEQ (half LOR)	----	4	µg/kg	5	5	5	5	5
^ Benzo(a)pyrene TEQ (LOR)	----	4	µg/kg	10	10	10	10	10
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	93.5	112	99.5	124	107
Toluene-D8	2037-26-5	0.2	%	89.9	107	95.8	120	103
4-Bromofluorobenzene	460-00-4	0.2	%	92.9	112	97.4	124	106
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	106	109	112	105	103
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	109	82.7	78.5	91.1	72.3
Anthracene-d10	1719-06-8	10	%	106	84.0	84.3	85.0	82.3
4-Terphenyl-d14	1718-51-0	10	%	122	84.8	89.1	77.5	85.8

Analytical Results

Sub-Matrix: MARINE SEDIMENT (Matrix: SOIL)			Client sample ID	KP6	QA1	QA2	QA3	----
			Client sampling date / time	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	----
Compound	CAS Number	LOR	Unit	EM2003018-006	EM2003018-007	EM2003018-008	EM2003018-009	--------
				Result	Result	Result	Result	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	28.3	28.7	33.4	30.8	----
EA150: Particle Sizing								
+75µm	----	1	%	97	----	----	----	----
+150µm	----	1	%	97	----	----	----	----
+300µm	----	1	%	96	----	----	----	----
+425µm	----	1	%	93	----	----	----	----
+600µm	----	1	%	77	----	----	----	----
+1180µm	----	1	%	17	----	----	----	----
+2.36mm	----	1	%	7	----	----	----	----
+4.75mm	----	1	%	5	----	----	----	----
+9.5mm	----	1	%	3	----	----	----	----
+19.0mm	----	1	%	3	----	----	----	----
+37.5mm	----	1	%	<1	----	----	----	----
+75.0mm	----	1	%	<1	----	----	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	3	----	----	----	----
Silt (2-60 µm)	----	1	%	<1	----	----	----	----
Sand (0.06-2.00 mm)	----	1	%	87	----	----	----	----
Gravel (>2mm)	----	1	%	10	----	----	----	----
Cobbles (>6cm)	----	1	%	<1	----	----	----	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.78	----	----	----	----
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	----
Arsenic	7440-38-2	1.00	mg/kg	6.24	7.15	8.61	9.37	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----
Chromium	7440-47-3	1.0	mg/kg	11.4	21.3	25.4	27.9	----
Copper	7440-50-8	1.0	mg/kg	1.8	5.1	9.9	10.1	----
Lead	7439-92-1	1.0	mg/kg	<1.0	2.9	3.4	4.2	----
Nickel	7440-02-0	1.0	mg/kg	9.8	38.6	33.8	56.4	----
Zinc	7440-66-6	1.0	mg/kg	4.9	20.2	21.9	24.9	----
EG035T: Total Recoverable Mercury by FIMS (Low Level)								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
EP003: Total Organic Carbon (TOC) in Soil								

Analytical Results

Sub-Matrix: MARINE SEDIMENT (Matrix: SOIL)			Client sample ID	KP6	QA1	QA2	QA3	----
			Client sampling date / time	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	----
Compound	CAS Number	LOR	Unit	EM2003018-006	EM2003018-007	EM2003018-008	EM2003018-009	--------
				Result	Result	Result	Result	----
EP003: Total Organic Carbon (TOC) in Soil - Continued								
Total Organic Carbon	----	0.02	%	**0.15**	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	----	----	----	----
>C16 - C34 Fraction	----	3	mg/kg	**14**	----	----	----	----
>C34 - C40 Fraction	----	5	mg/kg	**6**	----	----	----	----
>C10 - C40 Fraction (sum)	----	3	mg/kg	**20**	----	----	----	----
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	----	----	----	----
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	----	----	----	----
C10 - C14 Fraction	----	3	mg/kg	<3	----	----	----	----
C15 - C28 Fraction	----	3	mg/kg	**10**	----	----	----	----
C29 - C36 Fraction	----	5	mg/kg	**6**	----	----	----	----
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**16**	----	----	----	----
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	----	----	----	----
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	----	----	----	----
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	----	----	----	----
Toluene	108-88-3	0.2	mg/kg	<0.2	----	----	----	----
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	----	----	----	----
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	----	----	----	----
^ Total Xylenes	----	0.5	mg/kg	<0.5	----	----	----	----
^ Sum of BTEX	----	0.2	mg/kg	<0.2	----	----	----	----
Naphthalene	91-20-3	0.2	mg/kg	<0.2	----	----	----	----
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	----	----	----	----
Dibutyltin	1002-53-5	1	µgSn/kg	<1	----	----	----	----
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	----	----	----	----
EP132B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	5	µg/kg	<5	----	----	----	----
2-Methylnaphthalene	91-57-6	5	µg/kg	<5	----	----	----	----

Analytical Results

Sub-Matrix: MARINE SEDIMENT (Matrix: SOIL)			Client sample ID	KP6	QA1	QA2	QA3	----
			Client sampling date / time	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	20-Feb-2020 00:00	----
Compound	CAS Number	LOR	Unit	EM2003018-006	EM2003018-007	EM2003018-008	EM2003018-009	--------
				Result	Result	Result	Result	----
EP132B: Polynuclear Aromatic Hydrocarbons - Continued								
Acenaphthylene	208-96-8	4	µg/kg	<4	----	----	----	----
Acenaphthene	83-32-9	4	µg/kg	<4	----	----	----	----
Fluorene	86-73-7	4	µg/kg	<4	----	----	----	----
Phenanthrene	85-01-8	4	µg/kg	<4	----	----	----	----
Anthracene	120-12-7	4	µg/kg	<4	----	----	----	----
Fluoranthene	206-44-0	4	µg/kg	<4	----	----	----	----
Pyrene	129-00-0	4	µg/kg	<4	----	----	----	----
Benz(a)anthracene	56-55-3	4	µg/kg	<4	----	----	----	----
Chrysene	218-01-9	4	µg/kg	<4	----	----	----	----
Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	<4	----	----	----	----
Benzo(k)fluoranthene	207-08-9	4	µg/kg	<4	----	----	----	----
Benzo(e)pyrene	192-97-2	4	µg/kg	<4	----	----	----	----
Benzo(a)pyrene	50-32-8	4	µg/kg	<4	----	----	----	----
Perylene	198-55-0	4	µg/kg	<4	----	----	----	----
Benzo(g.h.i)perylene	191-24-2	4	µg/kg	<4	----	----	----	----
Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<4	----	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<4	----	----	----	----
Coronene	191-07-1	5	µg/kg	<5	----	----	----	----
^ Sum of PAHs	----	4	µg/kg	<4	----	----	----	----
^ Benzo(a)pyrene TEQ (zero)	----	4	µg/kg	<4	----	----	----	----
^ Benzo(a)pyrene TEQ (half LOR)	----	4	µg/kg	**5**	----	----	----	----
^ Benzo(a)pyrene TEQ (LOR)	----	4	µg/kg	**10**	----	----	----	----
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**90.0**	----	----	----	----
Toluene-D8	2037-26-5	0.2	%	**88.8**	----	----	----	----
4-Bromofluorobenzene	460-00-4	0.2	%	**95.4**	----	----	----	----
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**117**	----	----	----	----
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	**74.0**	----	----	----	----
Anthracene-d10	1719-06-8	10	%	**82.4**	----	----	----	----
4-Terphenyl-d14	1718-51-0	10	%	**80.3**	----	----	----	----

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	Hold	Rock 1, PSD	----	----	----
			Client sampling date / time	20-Feb-2020 00:00	20-Feb-2020 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EM2003018-010	EM2003018-011	--------	--------	--------
				Result	Result	----	----	----
EA150: Particle Sizing								
+75µm	----	1	%	17	12	----	----	----
+150µm	----	1	%	11	8	----	----	----
+300µm	----	1	%	9	6	----	----	----
+425µm	----	1	%	8	5	----	----	----
+600µm	----	1	%	8	4	----	----	----
+1180µm	----	1	%	7	3	----	----	----
+2.36mm	----	1	%	4	1	----	----	----
+4.75mm	----	1	%	<1	<1	----	----	----
+9.5mm	----	1	%	<1	<1	----	----	----
+19.0mm	----	1	%	<1	<1	----	----	----
+37.5mm	----	1	%	<1	<1	----	----	----
+75.0mm	----	1	%	<1	<1	----	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	33	23	----	----	----
Silt (2-60 µm)	----	1	%	47	59	----	----	----
Sand (0.06-2.00 mm)	----	1	%	15	16	----	----	----
Gravel (>2mm)	----	1	%	5	2	----	----	----
Cobbles (>6cm)	----	1	%	<1	<1	----	----	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.41	2.45	----	----	----
Supplementary Information								
ø Supplementary Report	----	-	-	See Attached	See Attached	----	----	----

Surrogate Control Limits

Sub-Matrix: **MARINE SEDIMENT**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	67	137
Toluene-D8	2037-26-5	74	134
4-Bromofluorobenzene	460-00-4	73	137
EP090S: Organotin Surrogate			
Tripropyltin	----	35	130
EP132T: Base/Neutral Extractable Surrogates			
2-Fluorobiphenyl	321-60-8	55	135
Anthracene-d10	1719-06-8	70	136
4-Terphenyl-d14	1718-51-0	57	127

QUALITY CONTROL REPORT

Work Order	: **EM2003018**	Page	: 1 of 8
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: HARRY HOURIDIS	Contact	: Customer Services EM
Address	: Level 13 333 Collins Street, Melbourne Victoria 3000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: ----	Telephone	: +61-3-8549 9600
Project	: 311015-00061	Date Samples Received	: 24-Feb-2020
Order number	: ----	Date Analysis Commenced	: 26-Feb-2020
C-O-C number	: ----	Issue Date	: 11-Mar-2020
Sampler	: Harry Houridis		
Site	: ----		
Quote number	: ME/094/20		
No. of samples received	: 11		
No. of samples analysed	: 11		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Aleksandar Vujkovic	Laboratory Technician	Newcastle - Inorganics, Mayfield West, NSW
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Edwandy Fadjar	Organic Coordinator	Sydney Inorganics, Smithfield, NSW
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW
Minh Wills	2IC Organic Chemist	Brisbane Organics, Stafford, QLD
Peter Keyte	Technical Manager - Air	Newcastle - Inorganics, Mayfield West, NSW

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **SOIL**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EG035T: Total Recoverable Mercury by FIMS (Low Level) (QC Lot: 2888417)									
EM2003018-001	KP1	EG035T-LL: Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	0.00	No Limit
ES2006534-004	Anonymous	EG035T-LL: Mercury	7439-97-6	0.01	mg/kg	0.04	0.03	0.00	No Limit
EA055: Moisture Content (Dried @ 105-110°C) (QC Lot: 2888421)									
EM2003018-003	KP3	EA055: Moisture Content	----	0.1	%	27.1	31.2	14.0	0% - 20%
ES2007136-001	Anonymous	EA055: Moisture Content	----	0.1	%	20.4	18.8	7.84	0% - 20%
EG020-SD: Total Metals in Sediments by ICPMS (QC Lot: 2888416)									
EM2003018-001	KP1	EG020-SD: Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	0.00	No Limit
		EG020-SD: Antimony	7440-36-0	0.5	mg/kg	<0.50	<0.50	0.00	No Limit
		EG020-SD: Arsenic	7440-38-2	1	mg/kg	8.17	9.02	9.90	No Limit
		EG020-SD: Chromium	7440-47-3	1	mg/kg	22.4	19.0	16.3	0% - 20%
		EG020-SD: Copper	7440-50-8	1	mg/kg	8.8	6.9	24.4	No Limit
		EG020-SD: Lead	7439-92-1	1	mg/kg	3.2	3.5	11.0	No Limit
		EG020-SD: Nickel	7440-02-0	1	mg/kg	43.9	44.2	0.690	0% - 20%
		EG020-SD: Zinc	7440-66-6	1	mg/kg	33.2	32.9	0.952	0% - 20%
ES2006534-004	Anonymous	EG020-SD: Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	0.00	No Limit
		EG020-SD: Antimony	7440-36-0	0.5	mg/kg	<0.50	<0.50	0.00	No Limit
		EG020-SD: Arsenic	7440-38-2	1	mg/kg	1.76	1.49	16.6	No Limit
		EG020-SD: Chromium	7440-47-3	1	mg/kg	11.4	9.5	18.4	0% - 50%
		EG020-SD: Copper	7440-50-8	1	mg/kg	11.8	8.9	27.8	0% - 50%
		EG020-SD: Lead	7439-92-1	1	mg/kg	18.7	14.7	24.2	0% - 50%
		EG020-SD: Nickel	7440-02-0	1	mg/kg	5.0	4.2	16.8	No Limit
		EG020-SD: Zinc	7440-66-6	1	mg/kg	27.3	22.7	18.4	0% - 20%
EP003: Total Organic Carbon (TOC) in Soil (QC Lot: 2892274)									
EB2005587-001	Anonymous	EP003: Total Organic Carbon	----	0.02	%	0.79	0.78	0.00	0% - 20%

Sub-Matrix: **SOIL**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EP003: Total Organic Carbon (TOC) in Soil (QC Lot: 2892274) - continued									
EM2003088-003	Anonymous	EP003: Total Organic Carbon	----	0.02	%	0.14	0.11	23.9	No Limit
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QC Lot: 2880671)									
EM2003018-001	KP1	EP071-SD: C10 - C14 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: C15 - C28 Fraction	----	3	mg/kg	32	30	7.22	0% - 50%
		EP071-SD: C10 - C36 Fraction (sum)	----	3	mg/kg	49	46	6.32	0% - 50%
		EP071-SD: C29 - C36 Fraction	----	5	mg/kg	17	16	7.76	No Limit
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QC Lot: 2881089)									
EM2003018-001	KP1	EP080-SD: C6 - C9 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QC Lot: 2880671)									
EM2003018-001	KP1	EP071-SD: >C10 - C16 Fraction	----	3	mg/kg	<3	<3	0.00	No Limit
		EP071-SD: >C16 - C34 Fraction	----	3	mg/kg	43	40	7.69	0% - 50%
		EP071-SD: >C10 - C40 Fraction (sum)	----	3	mg/kg	58	55	5.31	0% - 50%
		EP071-SD: >C34 - C40 Fraction	----	5	mg/kg	15	15	0.00	No Limit
EP080-SD: BTEXN (QC Lot: 2881089)									
EM2003018-001	KP1	EP080-SD: Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
		EP080-SD: ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	0.00	No Limit
EP090: Organotin Compounds (QC Lot: 2881357)									
EM2003018-001	KP1	EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	0.00	No Limit
		EP090: Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	0.00	No Limit
		EP090: Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	0.00	No Limit
EP132B: Polynuclear Aromatic Hydrocarbons (QC Lot: 2880672)									
EM2003018-001	KP1	EP132B-SD: Acenaphthylene	208-96-8	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Acenaphthene	83-32-9	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Fluorene	86-73-7	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Phenanthrene	85-01-8	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Anthracene	120-12-7	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Fluoranthene	206-44-0	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Pyrene	129-00-0	4	µg/kg	5	<4	23.8	No Limit
		EP132B-SD: Benz(a)anthracene	56-55-3	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Chrysene	218-01-9	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	5	<4	31.4	No Limit
		EP132B-SD: Benzo(k)fluoranthene	207-08-9	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Benzo(e)pyrene	192-97-2	4	µg/kg	5	<4	29.4	No Limit
		EP132B-SD: Benzo(a)pyrene	50-32-8	4	µg/kg	<4	<4	0.00	No Limit

Sub-Matrix: **SOIL**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EP132B: Polynuclear Aromatic Hydrocarbons (QC Lot: 2880672) - continued									
EM2003018-001	KP1	EP132B-SD: Perylene	198-55-0	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Benzo(g.h.i)perylene	191-24-2	4	µg/kg	6	<4	36.8	No Limit
		EP132B-SD: Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<4	<4	0.00	No Limit
		EP132B-SD: Sum of PAHs	----	4	µg/kg	21	<4	136	No Limit
		EP132B-SD: Naphthalene	91-20-3	5	µg/kg	<5	<5	0.00	No Limit
		EP132B-SD: 2-Methylnaphthalene	91-57-6	5	µg/kg	<5	<5	0.00	No Limit
		EP132B-SD: Coronene	191-07-1	5	µg/kg	<5	<5	0.00	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG035T: Total Recoverable Mercury by FIMS (Low Level) (QCLot: 2888417)								
EG035T-LL: Mercury	7439-97-6	0.01	mg/kg	<0.01	0.257 mg/kg	81.9	72.0	116
EG020-SD: Total Metals in Sediments by ICPMS (QCLot: 2888416)								
EG020-SD: Antimony	7440-36-0	0.5	mg/kg	<0.50	4.6 mg/kg	75.7	70.0	130
EG020-SD: Arsenic	7440-38-2	1	mg/kg	<1.00	21.7 mg/kg	88.6	80.0	139
EG020-SD: Cadmium	7440-43-9	0.1	mg/kg	<0.1	4.64 mg/kg	92.8	83.0	127
EG020-SD: Chromium	7440-47-3	1	mg/kg	<1.0	43.9 mg/kg	78.3	73.0	130
EG020-SD: Copper	7440-50-8	1	mg/kg	<1.0	32 mg/kg	107	76.0	130
EG020-SD: Lead	7439-92-1	1	mg/kg	<1.0	40 mg/kg	89.0	74.0	130
EG020-SD: Nickel	7440-02-0	1	mg/kg	<1.0	55 mg/kg	90.0	83.0	130
EG020-SD: Zinc	7440-66-6	1	mg/kg	<1.0	60.8 mg/kg	92.3	82.0	137
EP003: Total Organic Carbon (TOC) in Soil (QCLot: 2892274)								
EP003: Total Organic Carbon	----	0.02	%	<0.02	0.44 %	96.6	70.0	130
				<0.02	0.48 %	111	70.0	130
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 2880671)								
EP071-SD: C10 - C14 Fraction	----	3	mg/kg	<3	5 mg/kg	98.4	78.0	118
EP071-SD: C15 - C28 Fraction	----	3	mg/kg	<3	7.5 mg/kg	90.8	84.0	118
EP071-SD: C29 - C36 Fraction	----	5	mg/kg	<5	5 mg/kg	89.0	73.0	119
EP071-SD: C10 - C36 Fraction (sum)	----	3	mg/kg	<3	----	----	----	----
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 2881089)								
EP080-SD: C6 - C9 Fraction	----	3	mg/kg	<3	6.2 mg/kg	66.3	61.0	133
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons (QCLot: 2880671)								
EP071-SD: >C10 - C16 Fraction	----	3	mg/kg	<3	6.25 mg/kg	100	70.0	130
EP071-SD: >C16 - C34 Fraction	----	3	mg/kg	<3	8.75 mg/kg	87.2	74.0	138
EP071-SD: >C34 - C40 Fraction	----	5	mg/kg	<5	3.75 mg/kg	82.6	63.0	131
EP071-SD: >C10 - C40 Fraction (sum)	----	3	mg/kg	<3	----	----	----	----
EP080-SD: BTEXN (QCLot: 2881089)								
EP080-SD: Benzene	71-43-2	0.2	mg/kg	<0.2	0.2 mg/kg	85.5	66.0	122
EP080-SD: Toluene	108-88-3	0.2	mg/kg	<0.2	0.2 mg/kg	91.9	70.0	130
EP080-SD: Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	0.2 mg/kg	97.4	66.0	126
EP080-SD: meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	0.4 mg/kg	92.4	59.0	129
EP080-SD: ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	0.2 mg/kg	97.4	66.0	126
EP090: Organotin Compounds (QCLot: 2881357)								

Sub-Matrix: **SOIL**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
				Result	Concentration	LCS	Low	High
EP090: Organotin Compounds (QCLot: 2881357) - continued								
EP090: Monobutyltin	78763-54-9	1	µgSn/kg	<1	1.25 µgSn/kg	114	36.0	128
EP090: Dibutyltin	1002-53-5	1	µgSn/kg	<1	1.25 µgSn/kg	130	42.0	132
EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	1.25 µgSn/kg	117	52.0	139
EP132B: Polynuclear Aromatic Hydrocarbons (QCLot: 2880672)								
EP132B-SD: Naphthalene	91-20-3	5	µg/kg	<5	25 µg/kg	84.0	63.0	129
EP132B-SD: 2-Methylnaphthalene	91-57-6	5	µg/kg	<5	25 µg/kg	78.5	64.0	128
EP132B-SD: Acenaphthylene	208-96-8	4	µg/kg	<4	25 µg/kg	78.2	65.0	129
EP132B-SD: Acenaphthene	83-32-9	4	µg/kg	<4	25 µg/kg	82.2	68.0	132
EP132B-SD: Fluorene	86-73-7	4	µg/kg	<4	25 µg/kg	83.8	68.0	124
EP132B-SD: Phenanthrene	85-01-8	4	µg/kg	<4	25 µg/kg	81.2	64.0	134
EP132B-SD: Anthracene	120-12-7	4	µg/kg	<4	25 µg/kg	79.0	65.0	131
EP132B-SD: Fluoranthene	206-44-0	4	µg/kg	<4	25 µg/kg	81.8	64.0	130
EP132B-SD: Pyrene	129-00-0	4	µg/kg	<4	25 µg/kg	89.2	67.0	133
EP132B-SD: Benz(a)anthracene	56-55-3	4	µg/kg	<4	25 µg/kg	79.4	62.0	130
EP132B-SD: Chrysene	218-01-9	4	µg/kg	<4	25 µg/kg	80.0	65.0	133
EP132B-SD: Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	<4	25 µg/kg	83.9	68.0	120
EP132B-SD: Benzo(k)fluoranthene	207-08-9	4	µg/kg	<4	25 µg/kg	81.9	61.0	133
EP132B-SD: Benzo(e)pyrene	192-97-2	4	µg/kg	<4	25 µg/kg	78.3	63.0	127
EP132B-SD: Benzo(a)pyrene	50-32-8	4	µg/kg	<4	25 µg/kg	81.6	66.0	118
EP132B-SD: Perylene	198-55-0	4	µg/kg	<4	25 µg/kg	108	69.0	119
EP132B-SD: Benzo(g.h.i)perylene	191-24-2	4	µg/kg	<4	25 µg/kg	87.2	66.0	120
EP132B-SD: Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<4	25 µg/kg	86.5	64.0	122
EP132B-SD: Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<4	25 µg/kg	82.7	64.0	120
EP132B-SD: Coronene	191-07-1	5	µg/kg	<5	25 µg/kg	87.6	68.0	136
EP132B-SD: Sum of PAHs	----	4	µg/kg	<4	----	----	----	----

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
				Concentration	MS	Low	High
EG035T: Total Recoverable Mercury by FIMS (Low Level) (QCLot: 2888417)							
EM2003018-001	KP1	EG035T-LL: Mercury	7439-97-6	0.05 mg/kg	87.1	70.0	130
EG020-SD: Total Metals in Sediments by ICPMS (QCLot: 2888416)							
EM2003018-002	KP2	EG020-SD: Arsenic	7440-38-2	50 mg/kg	92.6	70.0	130

Sub-Matrix: **SOIL**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
EG020-SD: Total Metals in Sediments by ICPMS (QCLot: 2888416) - continued							
EM2003018-002	KP2	EG020-SD: Cadmium	7440-43-9	50 mg/kg	91.9	70.0	130
		EG020-SD: Chromium	7440-47-3	50 mg/kg	101	70.0	130
		EG020-SD: Copper	7440-50-8	250 mg/kg	92.1	70.0	130
		EG020-SD: Lead	7439-92-1	250 mg/kg	90.6	70.0	130
		EG020-SD: Nickel	7440-02-0	50 mg/kg	113	70.0	130
		EG020-SD: Zinc	7440-66-6	250 mg/kg	90.6	70.0	130
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 2880671)							
EM2003018-001	KP1	EP071-SD: C10 - C14 Fraction	----	14 mg/kg	115	70.0	130
		EP071-SD: C15 - C28 Fraction	----	59 mg/kg	130	70.0	130
		EP071-SD: C29 - C36 Fraction	----	42 mg/kg	116	70.0	130
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 2881089)							
EM2003018-001	KP1	EP080-SD: C6 - C9 Fraction	----	6.5 mg/kg	105	70.0	130
EP080-SD: BTEXN (QCLot: 2881089)							
EM2003018-001	KP1	EP080-SD: Benzene	71-43-2	0.5 mg/kg	101	70.0	130
		EP080-SD: Toluene	108-88-3	0.5 mg/kg	102	70.0	130
		EP080-SD: Ethylbenzene	100-41-4	0.5 mg/kg	106	70.0	130
		EP080-SD: meta- & para-Xylene	108-38-3 106-42-3	0.5 mg/kg	103	70.0	130
		EP080-SD: ortho-Xylene	95-47-6	0.5 mg/kg	106	70.0	130
EP090: Organotin Compounds (QCLot: 2881357)							
EM2003018-002	KP2	EP090: Monobutyltin	78763-54-9	1.25 µgSn/kg	67.6	20.0	130
		EP090: Dibutyltin	1002-53-5	1.25 µgSn/kg	118	20.0	130
		EP090: Tributyltin	56573-85-4	1.25 µgSn/kg	95.1	20.0	130
EP132B: Polynuclear Aromatic Hydrocarbons (QCLot: 2880672)							
EM2003018-001	KP1	EP132B-SD: Naphthalene	91-20-3	25 µg/kg	103	70.0	130
		EP132B-SD: 2-Methylnaphthalene	91-57-6	25 µg/kg	104	70.0	130
		EP132B-SD: Acenaphthylene	208-96-8	25 µg/kg	105	70.0	130
		EP132B-SD: Acenaphthene	83-32-9	25 µg/kg	103	70.0	130
		EP132B-SD: Fluorene	86-73-7	25 µg/kg	111	70.0	130
		EP132B-SD: Phenanthrene	85-01-8	25 µg/kg	130	70.0	130
		EP132B-SD: Anthracene	120-12-7	25 µg/kg	109	70.0	130
		EP132B-SD: Fluoranthene	206-44-0	25 µg/kg	130	70.0	130
		EP132B-SD: Pyrene	129-00-0	25 µg/kg	127	70.0	130
		EP132B-SD: Benz(a)anthracene	56-55-3	25 µg/kg	90.3	70.0	130
		EP132B-SD: Chrysene	218-01-9	25 µg/kg	98.3	70.0	130
		EP132B-SD: Benzo(b+j)fluoranthene	205-99-2 205-82-3	25 µg/kg	90.1	70.0	130
		EP132B-SD: Benzo(k)fluoranthene	207-08-9	25 µg/kg	88.3	70.0	130

Sub-Matrix: **SOIL**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report: Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	Recovery Limits (%) High
EP132B: Polynuclear Aromatic Hydrocarbons (QCLot: 2880672) - continued							
EM2003018-001	KP1	EP132B-SD: Benzo(e)pyrene	192-97-2	25 µg/kg	72.9	70.0	130
		EP132B-SD: Benzo(a)pyrene	50-32-8	25 µg/kg	89.8	70.0	130
		EP132B-SD: Perylene	198-55-0	25 µg/kg	128	70.0	130
		EP132B-SD: Benzo(g.h.i)perylene	191-24-2	25 µg/kg	89.3	70.0	130
		EP132B-SD: Dibenz(a.h)anthracene	53-70-3	25 µg/kg	91.6	70.0	130
		EP132B-SD: Indeno(1.2.3.cd)pyrene	193-39-5	25 µg/kg	93.3	70.0	130
		EP132B-SD: Coronene	191-07-1	25 µg/kg	97.1	70.0	130

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **EM2003018**	Page	: 1 of 7
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: HARRY HOURIDIS	Telephone	: +61-3-8549 9600
Project	: 311015-00061	Date Samples Received	: 24-Feb-2020
Site	: ----	Issue Date	: 11-Mar-2020
Sampler	: Harry Houridis	No. of samples received	: 11
Order number	: ----	No. of samples analysed	: 11

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method		*Sample Date*	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)			*Date extracted*	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EA055: Moisture Content (Dried @ 105-110°C)								
Soil Glass Jar - Unpreserved (EA055)								
KP1,	KP2,	**20-Feb-2020**	**----**	----	----	**02-Mar-2020**	05-Mar-2020	✓
KP3,	KP4,							
KP5,	KP6,							
QA1,	QA2,							
QA3								
EA150: Particle Sizing								
Snap Lock Bag - Friable Asbestos/PSD Bag (EA150H)								
KP1,	KP2,	**20-Feb-2020**	**----**	----	----	**02-Mar-2020**	18-Aug-2020	✓
KP3,	KP4,							
KP5,	KP6							
Snap Lock Bag - Friable Asbestos/PSD Bag (EA150H)								
Hold,	Rock 1, PSD	**20-Feb-2020**	**----**	----	----	**05-Mar-2020**	18-Aug-2020	✓
EA150: Soil Classification based on Particle Size								
Snap Lock Bag - Friable Asbestos/PSD Bag (EA150H)								
KP1,	KP2,	**20-Feb-2020**	**----**	----	----	**02-Mar-2020**	18-Aug-2020	✓
KP3,	KP4,							
KP5,	KP6							
Snap Lock Bag - Friable Asbestos/PSD Bag (EA150H)								
Hold,	Rock 1, PSD	**20-Feb-2020**	**----**	----	----	**05-Mar-2020**	18-Aug-2020	✓
EA152: Soil Particle Density								
Snap Lock Bag - Friable Asbestos/PSD Bag (EA152)								
KP1,	KP2,	**20-Feb-2020**	**----**	----	----	**02-Mar-2020**	18-Aug-2020	✓
KP3,	KP4,							
KP5,	KP6							
Snap Lock Bag - Friable Asbestos/PSD Bag (EA152)								
Hold,	Rock 1, PSD	**20-Feb-2020**	**----**	----	----	**05-Mar-2020**	18-Aug-2020	✓

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation: Date extracted	Due for extraction	Evaluation	Analysis: Date analysed	Due for analysis	Evaluation
EG020-SD: Total Metals in Sediments by ICPMS								
Soil Glass Jar - Unpreserved (EG020-SD)								
KP1,	KP2,	**20-Feb-2020**	**02-Mar-2020**	18-Aug-2020	✓	**02-Mar-2020**	18-Aug-2020	✓
KP3,	KP4,							
KP5,	KP6,							
QA1,	QA2,							
QA3								
EG035T: Total Recoverable Mercury by FIMS (Low Level)								
Soil Glass Jar - Unpreserved (EG035T-LL)								
KP1,	KP2,	**20-Feb-2020**	**02-Mar-2020**	19-Mar-2020	✓	**03-Mar-2020**	19-Mar-2020	✓
KP3,	KP4,							
KP5,	KP6,							
QA1,	QA2,							
QA3								
EP003: Total Organic Carbon (TOC) in Soil								
Soil Glass Jar - Unpreserved (EP003)								
KP1,	KP2,	**20-Feb-2020**	**04-Mar-2020**	19-Mar-2020	✓	**04-Mar-2020**	19-Mar-2020	✓
KP3,	KP4,							
KP5,	KP6							
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
Soil Glass Jar - Unpreserved (EP071-SD)								
KP1,	KP2,	**20-Feb-2020**	**26-Feb-2020**	05-Mar-2020	✓	**28-Feb-2020**	06-Apr-2020	✓
KP3,	KP4,							
KP5,	KP6							
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
Soil Glass Jar - Unpreserved (EP071-SD)								
KP1,	KP2,	**20-Feb-2020**	**26-Feb-2020**	05-Mar-2020	✓	**28-Feb-2020**	06-Apr-2020	✓
KP3,	KP4,							
KP5,	KP6							
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
Soil Glass Jar - Unpreserved (EP080-SD)								
KP1,	KP2,	**20-Feb-2020**	**26-Feb-2020**	05-Mar-2020	✓	**28-Feb-2020**	05-Mar-2020	✓
KP3,	KP4,							
KP5,	KP6							
EP080-SD: BTEXN								
Soil Glass Jar - Unpreserved (EP080-SD)								
KP1,	KP2,	**20-Feb-2020**	**26-Feb-2020**	05-Mar-2020	✓	**28-Feb-2020**	05-Mar-2020	✓
KP3,	KP4,							
KP5,	KP6							

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EP090: Organotin Compounds								
Soil Glass Jar - Unpreserved (EP090)								
KP1,	KP2,	**20-Feb-2020**	**26-Feb-2020**	05-Mar-2020	✓	**28-Feb-2020**	06-Apr-2020	✓
KP3,	KP4,							
KP5,	KP6							
EP132B: Polynuclear Aromatic Hydrocarbons								
Soil Glass Jar - Unpreserved (EP132B-SD)								
KP1,	KP2,	**20-Feb-2020**	**26-Feb-2020**	05-Mar-2020	✓	**02-Mar-2020**	06-Apr-2020	✓
KP3,	KP4,							
KP5,	KP6							

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **SOIL**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Moisture Content	EA055	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Organotin Analysis	EP090	1	6	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
PAHs in Sediments by GCMS(SIM)	EP132B-SD	1	6	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS (Low Level)	EG035T-LL	2	16	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals in Sediments by ICPMS	EG020-SD	2	16	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP003	2	12	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fraction	EP071-SD	1	6	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	1	6	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Organotin Analysis	EP090	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
PAHs in Sediments by GCMS(SIM)	EP132B-SD	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS (Low Level)	EG035T-LL	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals in Sediments by ICPMS	EG020-SD	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP003	2	12	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fraction	EP071-SD	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Organotin Analysis	EP090	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
PAHs in Sediments by GCMS(SIM)	EP132B-SD	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS (Low Level)	EG035T-LL	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals in Sediments by ICPMS	EG020-SD	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP003	1	12	**8.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fraction	EP071-SD	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Organotin Analysis	EP090	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
PAHs in Sediments by GCMS(SIM)	EP132B-SD	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS (Low Level)	EG035T-LL	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals in Sediments by ICPMS	EG020-SD	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TPH - Semivolatile Fraction	EP071-SD	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH Volatiles/BTEX in Sediments	EP080-SD	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
Moisture Content	EA055	SOIL	In house: A gravimetric procedure based on weight loss over a 12 hour drying period at 105-110 degrees C. This method is compliant with NEPM (2013) Schedule B(3) Section 6.1 and Table 1 (14 day holding time).
Particle Size Analysis by Hydrometer	EA150H	SOIL	Particle Size Analysis by Hydrometer according to AS1289.3.6.3 - 2003
Soil Particle Density	EA152	SOIL	Soil Particle Density by AS 1289.3.5.1-2006 : Methods of testing soils for engineering purposes - Soil classification tests - Determination of the soil particle density of a soil - Standard method
Settling Rate by Hydrometer	* EA157H	SOIL	Settling Rate calculation from Hydrometer analysis according to AS1289.3.6.3 - 2003
Total Metals in Sediments by ICPMS	EG020-SD	SOIL	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector. Analyte list and LORs per NODG.
Total Mercury by FIMS (Low Level)	EG035T-LL	SOIL	In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection ($SnCl_2$)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. Mercury in solids are determined following an appropriate acid digestion. Ionic mercury is reduced online to atomic mercury vapour by $SnCl_2$ which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3)
Total Organic Carbon	EP003	SOIL	In house C-IR17. Dried and pulverised sample is reacted with acid to remove inorganic Carbonates, then combusted in a furnace in the presence of strong oxidants / catalysts. The evolved (Organic) Carbon (as CO_2) is automatically measured by infra-red detector.
TPH - Semivolatile Fraction	EP071-SD	SOIL	In house: Referenced to USEPA SW 846 - 8270D. Extracts are analysed by Capillary GC/FID and quantification is by comparison against an established 5 point calibration curve. This method is compliant with NEPM (2013) Schedule B(3) (Method 504)
TRH Volatiles/BTEX in Sediments	EP080-SD	SOIL	In house: Referenced to USEPA SW 846 - 8260B Extracts are analysed by Purge and Trap, Capillary GC/MS. Quantification is by comparison against an established 5 point calibration curve.
Organotin Analysis	EP090	SOIL	In house: Referenced to USEPA SW 846 - 8270D Prepared sample extracts are analysed by GC/MS coupled with high volume injection, and quanitified against an established calibration curve.
PAHs in Sediments by GCMS(SIM)	EP132B-SD	SOIL	In house: Referenced to USEPA 8270D GCMS Capillary column, SIM mode using large volume programmed temperature vaporisation injection.

Preparation Methods	Method	Matrix	Method Descriptions
Hot Block Digest for metals in soils sediments and sludges	EN69	SOIL	In house: Referenced to USEPA 200.2. Hot Block Acid Digestion 1.0g of sample is heated with Nitric and Hydrochloric acids, then cooled. Peroxide is added and samples heated and cooled again before being filtered and bulked to volume for analysis. Digest is appropriate for determination of selected metals in sludge, sediments, and soils. This method is compliant with NEPM (2013) Schedule B(3) (Method 202)
Dry and Pulverise (up to 100g)	GEO30	SOIL	#
Methanolic Extraction of Soils for Purge and Trap	ORG16	SOIL	In house: Referenced to USEPA SW 846 - 5030A. 5g of solid is shaken with surrogate and 10mL methanol prior to analysis by Purge and Trap - GC/MS.

Preparation Methods	Method	Matrix	Method Descriptions
Tumbler Extraction of Solids for LVI (Non-concentrating)	ORG17D	SOIL	In house: 10g of sample, Na2SO4 and surrogate are extracted with 50mL 1:1 DCM/Acetone by end over end tumbling. An aliquot is concentrated by nitrogen blowdown to a reduced volume for analysis if required.
Organotin Sample Preparation	ORG35	SOIL	In house: 20g sample is spiked with surrogate and leached in a methanol:acetic acid:UHP water mix and vacuum filtered. Reagents and solvents are added to the sample and the mixture tumbled. The butyltin compounds are simultaneously derivatised and extracted. The extract is further extracted with petroleum ether. The resultant extracts are combined and concentrated for analysis.

CHAIN OF CUSTODY

ALS Laboratory: please tick →

CLIENT: Advisian (make invoice to WorleyParsons please)	TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g.. Ultra Trace Organics)	☒ Standard TAT (List due date): ☐ Non Standard or urgent TAT (List due date):	FOR LABORATORY USE ONLY (Circle)
OFFICE: Melbourne 311015-00061			Custody Seal Intact? Yes No N/A
PROJECT: Kingston Pier Channel Project PROJECT NO.:	ALS QUOTE NO.: ME/094/20	COC SEQUENCE NUMBER (Circle)	Free ice / frozen ice bricks present upon receipt? Yes No N/A
ORDER NUMBER: NA PURCHASE ORDER NO.: NA	COUNTRY OF ORIGIN: Australia	COC: 1 2 3 4 5 6 7	Random Sample Temperature on Receipt: °C
PROJECT MANAGER: Harry Houridis CONTACT PH: 0412 969 630		OF: 1 2 3 4 5 6 7	Other comment:
SAMPLER: Harry Houridis SAMPLER MOBILE: 0412 969 630	RELINQUISHED BY: Katie Newton	RECEIVED BY:	RELINQUISHED BY: / RECEIVED BY: [illegible] (ML)
COC Emailed to ALS? No EDD FORMAT (or default):	DATE/TIME:	DATE/TIME:	DATE/TIME: / DATE/TIME: 24/2, 10:00
Email Reports to: harry.houridis@advisian.com, katie.newton@advisian.com			
Email Invoice to (will default to PM if no other addresses are listed): harry.houridis@advisian.com			

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: Marine Sediments

ALS USE ONLY	SAMPLE DETAILS MATRIX: Solid(S) Water(W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).								Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL BOTTLES	METALS +HG	TRH	PAH	TOC	ORGANOTIN	EA150H (PSD)		SPOCAS	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
1	KP1	20/02/2020	S	Frozen	2G+1B	✓	✓	✓	✓	✓	✓			Marine Sediments
2	KP2	20/02/2020	S	"	2G+1B	✓	✓	✓	✓	✓	✓		TBC - Please Call.	
3	KP3	20/02/2020	S	"	2G+1B	✓	✓	✓	✓	✓	✓			
4	KP4	20/02/2020	S	"	2G+1B	✓	✓	✓	✓	✓	✓			
5	KP5	20/02/2020	S	"	2G+1B	✓	✓	✓	✓	✓	✓			
6	KP6	20/02/2020	S	"	2G+1B	✓	✓	✓	✓	✓	✓			
7	QA1	20/02/2020	S	"	2G	✓								
8	QA2	20/02/2020	S	"	2G	✓								
9	QA3	20/02/2020	S	"	2G	✓								
Extra Samples,														
10	Hold.													
11.	Rock 1, PSD				TOTAL									

Environmental Division
Melbourne
Work Order Reference
EM2003018

SH
25/2

Telephone : + 61-3-8549 9600

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag; LI = Lugols Iodine Preserved Bottles; STT = Sterile Sodium Thiosulfate Preserved Bottles.

CHAIN OF CUSTODY

ALS Laboratory: *please tick →*

CLIENT: Advisian (make invoice to WorleyParsons please)	TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g.. Ultra Trace Organics)	☒ Standard TAT (List due date): ☐ Non Standard or urgent TAT (List due date):
OFFICE: Melbourne 311015-00061		
PROJECT: Kingston Pier Channel Project PROJECT NO.:	ALS QUOTE NO.: ME/094/20	COC SEQUENCE NUMBER (Circle)
ORDER NUMBER: NA PURCHASE ORDER NO.: NA	COUNTRY OF ORIGIN: Australia	COC: 1 2 3 4 5 6 7
PROJECT MANAGER: Harry Houridis CONTACT PH: 0412 969 630		OF: 1 2 3 4 5 6 7

FOR LABORATORY USE ONLY (Circle)

Custody Seal Intact?	Yes	No	N/A
Free ice / frozen ice bricks present upon receipt?	Yes	No	N/A
Random Sample Temperature on Receipt:	°C		
Other comment:			

SAMPLER: Harry Houridis SAMPLER MOBILE: 0412 969 630	RELINQUISHED BY: Katie Newton	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY: Maria (ME)
COC Emailed to ALS? No EDD FORMAT (or default):	DATE/TIME:	DATE/TIME:	DATE/TIME:	DATE/TIME: 24/2, 10:00
Email Reports to: harry.houridis@advisian.com, katie.newton@advisian.com				
Email Invoice to (will default to PM if no other addresses are listed): harry.houridis@advisian.com				

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: Marine Sediments

ALS USE ONLY	SAMPLE DETAILS MATRIX: Solid(S) Water(W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).								Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL BOTTLES	METALS + HG	TRH	PAH	TOC	ORGANOTIN	EA150H (PSD)		SPOCAS	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
1	KP1	20/02/2020	S	Frozen	2G+1B	✓	✓	✓	✓	✓	~~✓~~			Marine Sediments
2	KP2	20/02/2020	S	"	2G+1B	✓	✓	✓	✓	✓	✓		TBC - Please Call.	
3	KP3	20/02/2020	S	"	2G+1B	✓	✓	✓	✓	✓	✓			
4	KP4	20/02/2020	S	"	2G+1B	✓	✓	✓	✓	✓	✓			
5	KP5	20/02/2020	S	"	2G+1B	✓	✓	✓	✓	✓	✓			
6	KP6	20/02/2020	S	"	2G+1B	✓	✓	✓	✓	✓	✓			
7	QA1	20/02/2020	S	"	2G	✓								
8	QA2	20/02/2020	S	"	2G	✓								
9	QA3	20/02/2020	S	"	2G	✓								
Extra Samples,														
10	Hold.													
11.	Rock 1, PSD				TOTAL									

Environmental Division
Melbourne
Work Order Reference
EM2003018

SH 25/2

Telephone : + 61-3-8549 9600

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag; LI = Lugols Iodine Preserved Bottles; STT = Sterile Sodium Thiosulfate Preserved Bottles.

SH 25/2

Scott Huett

From: Houridis, Harry (Melbourne) <harry.houridis@advisian.com>
Sent: Wednesday, 26 February 2020 10:25 AM
To: Hannah White
Cc: Newton, Katie (Newcastle)
Subject: [EXTERNAL] - RE: EM2003018 - 311015-00061

CAUTION: This email originated from outside of ALS. Do not click links or open attachments unless you recognize the sender and are sure content is relevant to you.

Hi Hannah

The invoice will need to be made out to Advisian. You can email me the invoice and I will forward on or you can send to Ben Morgran who will approve the ALS invoice (details below). Please quote the project code on the COC in your invoice.

Ben Morgan
L17, 141 Walker Street | North Sydney NSW 2060
M 0411316002 **E** ben.morgan@advisian.com

Yes, please analyse KP1 for PSD, don't worry about the SPOCAS testing.

With the two rock samples, can you get the lab to crush the rock and then test it for PSD as well please. The rock is not too hard, it should crumble under pressure.

Harry

From: Hannah White <hannah.white@ALSGlobal.com>
Sent: Tuesday, 25 February 2020 3:46 PM
To: Houridis, Harry (Melbourne) <harry.houridis@advisian.com>
Cc: Newton, Katie (Newcastle) <katie.newton@advisian.com>
Subject: EM2003018 - 311015-00061[External Sender]

**** [EXTERNAL SENDER] Do not click links or open attachments unless you recognize the sender. ****

Good afternoon Harry and Katie,

Our sample receipt team had a couple of questions about the batch we received yesterday, that we were hoping you could provide some clarity on:

- The COC (attached) implies we are to invoice Worley Parsons, but to email the invoice to Harry. We have to log the work order under the account allocated to the person paying the invoice, as they are considered owners of the results once they are released. In this way, if we were to log the batch under the Advisian account, Advisian would be invoiced and be considered owners of the results. Could you please confirm who we need to address the invoice to, and therefore which account to log under?
- Could you please confirm if you would like for us to analyse PSD on sample KP1? The COC is ambiguous, but in the interim we are proceeding as if PSD is requested.
- We are presuming the TBC refers to potential SPOCAS analysis. As none of the samples were received frozen, the singular bags we received for samples #001-006 have been allocated to the PSD analysis. Please let us know if this is incorrect.

We also received two extra samples (1x snap lock bag each):

Sample	Sub-Matrix	Status	Date	Highly Impacted	Name
010	ROCK	Hold	20/02/2020	☐	Hold
011	ROCK	Hold	20/02/2020	☐	Rock 1, PSD

If any analysis is required on these samples please let me know.

Thank you

Regards,

Hannah White
Client Services Officer, Environmental
Melbourne

T +61 3 8549 9600 D +61 3 8549 9608
Hannah.White@ALSglobal.com
2-4 Westall Rd
Springvale VIC 3171
AUSTRALIA

Appendix D
PSD Results

Certificate of Analysis

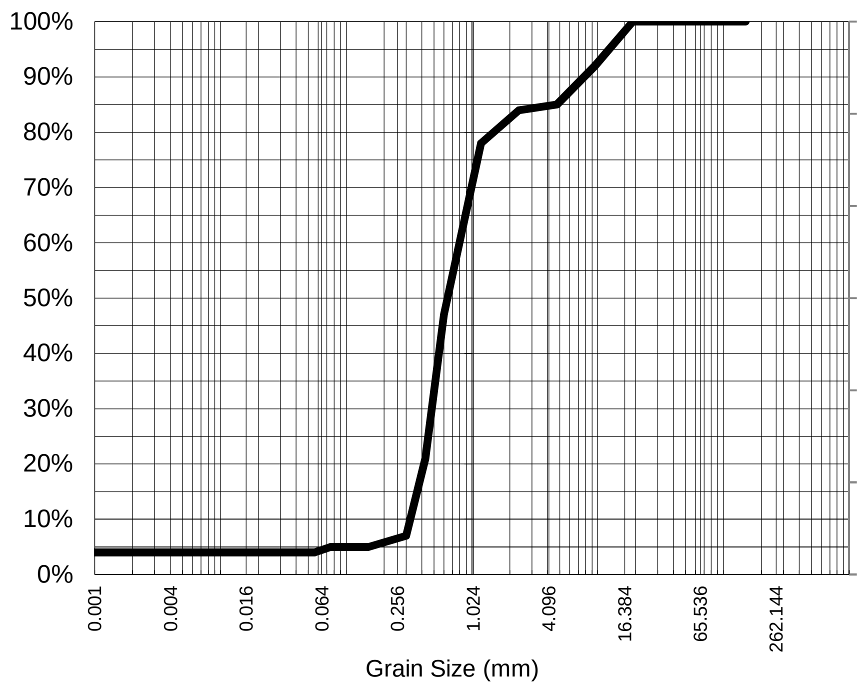
ALS Laboratory Group Pty Ltd
5/585 Maitland Road
Mayfield West, NSW 2304
pH 02 4014 2500
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	HARRY HOURIDIS	**DATE REPORTED:**	2-Mar-2020
COMPANY:	ADVISIAN PTY LTD	**DATE RECEIVED:**	24-Feb-2020
ADDRESS:	Level 13 333 Collins Street, Melbourne Victoria 3000	**REPORT NO:**	EM2003018-001 / PSD
PROJECT:	311015-00061	**SAMPLE ID:**	KP1

Particle Size Distribution



Particle Size (mm)	% Passing
19.0	100%
9.50	92%
4.75	85%
2.36	84%
1.18	78%
0.600	47%
0.425	21%
0.300	7%
0.150	5%
0.075	5%
Particle Size (microns)	
56	4%
39	4%
28	4%
20	4%
14	4%
10	4%
7	4%
5	4%
1	4%

Median Particle Size (mm)*	0.656

Analysis Notes

Samples analysed as received.

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments: AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly

Analysed: 27-Feb-20

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: SAND, SHELL

Dispersion Method Shaker

Test Method: AS1289.3.6.1/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.77

NATA Accreditation: 825 Site: Newcastle
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WORLD RECOGNISED ACCREDITATION

Peter Keyte
Technical Manager Air
Authorised Signatory

Template Version PKV8.0 180919

Certificate of Analysis

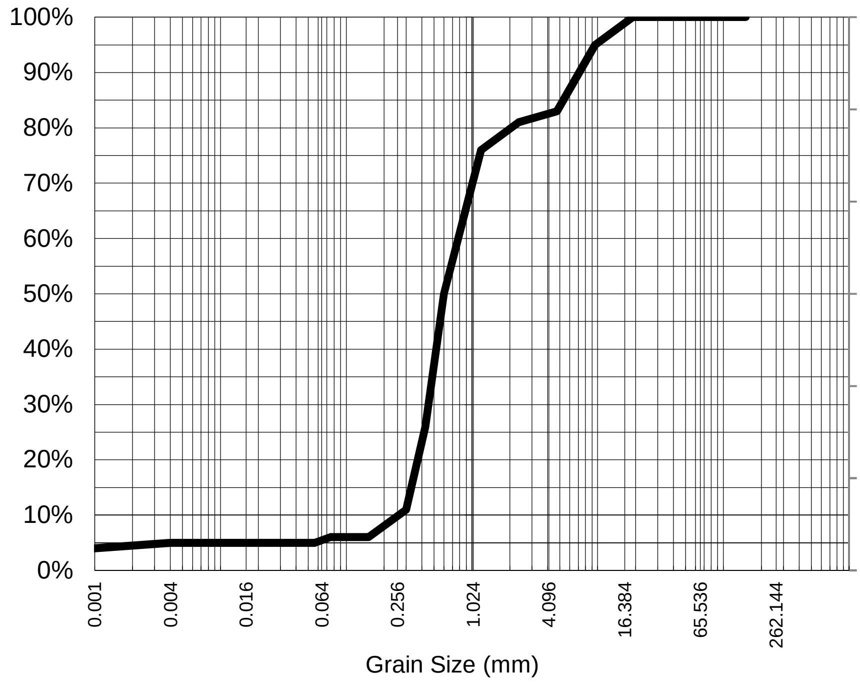
ALS Laboratory Group Pty Ltd
5/585 Maitland Road
Mayfield West, NSW 2304
pH 02 4014 2500
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	HARRY HOURIDIS	**DATE REPORTED:**	2-Mar-2020
COMPANY:	ADVISIAN PTY LTD	**DATE RECEIVED:**	24-Feb-2020
ADDRESS:	Level 13 333 Collins Street, Melbourne Victoria 3000	**REPORT NO:**	EM2003018-002 / PSD
PROJECT:	311015-00061	**SAMPLE ID:**	KP2

Particle Size Distribution



Particle Size (mm)	% Passing
19.0	100%
9.50	95%
4.75	83%
2.36	81%
1.18	76%
0.600	50%
0.425	26%
0.300	11%
0.150	6%
0.075	6%
Particle Size (microns)	
56	5%
39	5%
28	5%
20	5%
14	5%
10	5%
7	5%
5	5%
1	4%

Median Particle Size (mm)*	0.600

Analysis Notes

Samples analysed as received.

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments: AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly

Analysed: 27-Feb-20

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: SAND, SHELL

Dispersion Method Shaker

Test Method: AS1289.3.6.1/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.77

NATA Accreditation: 825 Site: Newcastle
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Authorised Signatory

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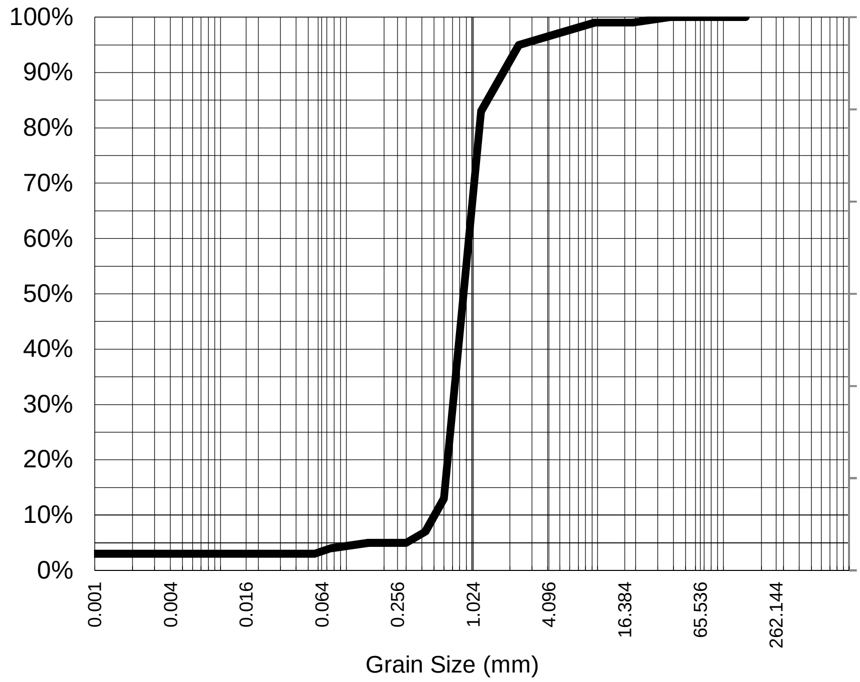
Mayfield West, NSW 2304
pH 02 4014 2500
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	HARRY HOURIDIS	**DATE REPORTED:**	2-Mar-2020
COMPANY:	ADVISIAN PTY LTD	**DATE RECEIVED:**	24-Feb-2020
ADDRESS:	Level 13 333 Collins Street, Melbourne Victoria 3000	**REPORT NO:**	EM2003018-003 / PSD
PROJECT:	311015-00061	**SAMPLE ID:**	KP3

Particle Size Distribution



Particle Size (mm)	% Passing
37.5	100%
19.0	99%
9.50	99%
4.75	97%
2.36	95%
1.18	83%
0.600	13%
0.425	7%
0.300	5%
0.150	5%
0.075	4%
Particle Size (microns)	
56	3%
39	3%
28	3%
20	3%
14	3%
10	3%
7	3%
5	3%
1	3%

Median Particle Size (mm)*	0.907

Analysis Notes

Samples analysed as received.

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments: AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly

Analysed: 27-Feb-20

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: SAND, SHELL

Dispersion Method Shaker

Test Method: AS1289.3.6.1/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.78

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Peter Keyte
Technical Manager Air
Authorised Signatory

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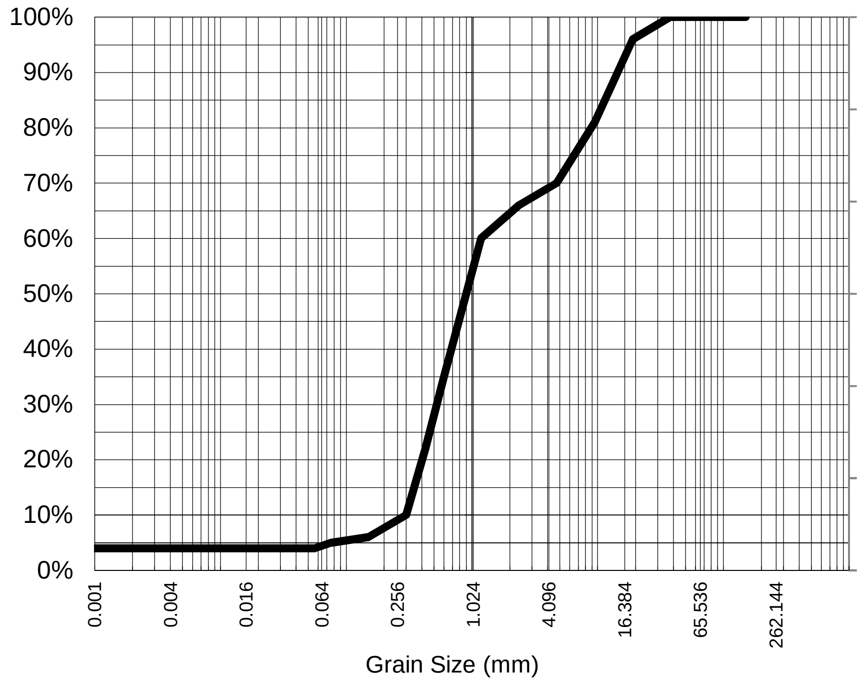
pH 02 4014 2500
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	HARRY HOURIDIS	**DATE REPORTED:**	2-Mar-2020
COMPANY:	ADVISIAN PTY LTD	**DATE RECEIVED:**	24-Feb-2020
ADDRESS:	Level 13 333 Collins Street, Melbourne Victoria 3000	**REPORT NO:**	EM2003018-004 / PSD
PROJECT:	311015-00061	**SAMPLE ID:**	KP4

Particle Size Distribution



Particle Size (mm)	% Passing
37.5	100%
19.0	96%
9.50	81%
4.75	70%
2.36	66%
1.18	60%
0.600	35%
0.425	22%
0.300	10%
0.150	6%
0.075	5%
Particle Size (microns)	
56	4%
39	4%
28	4%
20	4%
14	4%
10	4%
7	4%
5	4%
1	4%

Median Particle Size (mm)*	0.948

Analysis Notes

Samples analysed as received.

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments: AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly

Analysed: 27-Feb-20

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: SAND, SHELL

Dispersion Method Shaker

Test Method: AS1289.3.6.1/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.79

NATA Accreditation: 825 Site: Newcastle
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Peter Keyte
Technical Manager Air
Authorised Signatory

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Mayfield West, NSW 2304
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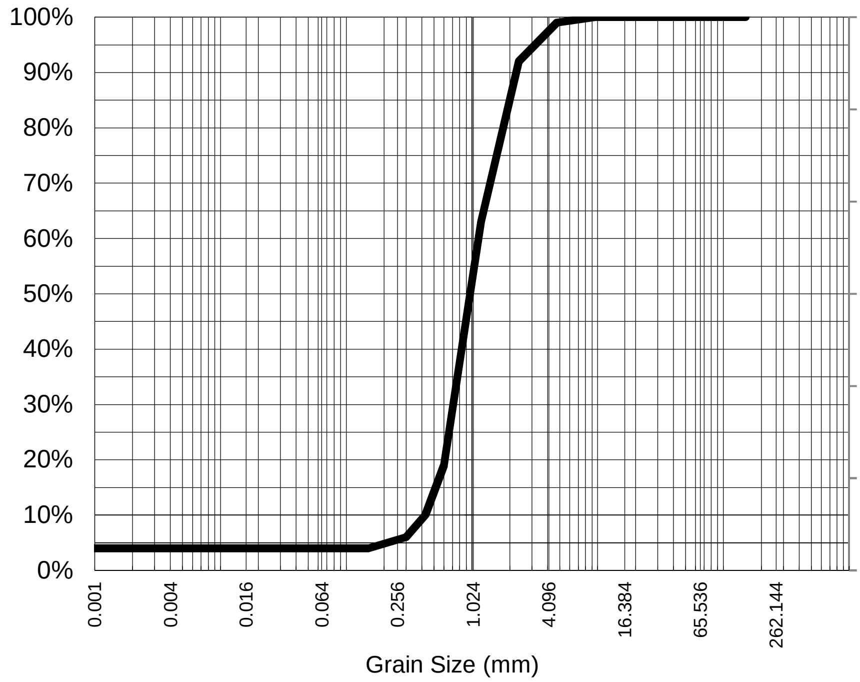
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	HARRY HOURIDIS	**DATE REPORTED:**	2-Mar-2020
COMPANY:	ADVISIAN PTY LTD	**DATE RECEIVED:**	24-Feb-2020
ADDRESS:	Level 13 333 Collins Street, Melbourne Victoria 3000	**REPORT NO:**	EM2003018-005 / PSD
PROJECT:	311015-00061	**SAMPLE ID:**	KP5

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	99%
2.36	92%
1.18	63%
0.600	19%
0.425	10%
0.300	6%
0.150	4%
0.075	4%
Particle Size (microns)	
56	4%
39	4%
28	4%
20	4%
14	4%
10	4%
7	4%
5	4%
1	4%

Median Particle Size (mm)*	1.009

Analysis Notes

Samples analysed as received.

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments: AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly

Analysed: 27-Feb-20

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: SAND, SHELL

Dispersion Method Shaker

Test Method: AS1289.3.6.1/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.75

NATA Accreditation: 825 Site: Newcastle
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WORLD RECOGNISED ACCREDITATION

Peter Keyte
Technical Manager Air
Authorised Signatory

Certificate of Analysis

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5/585 Maitland Road
Mayfield West, NSW 2304
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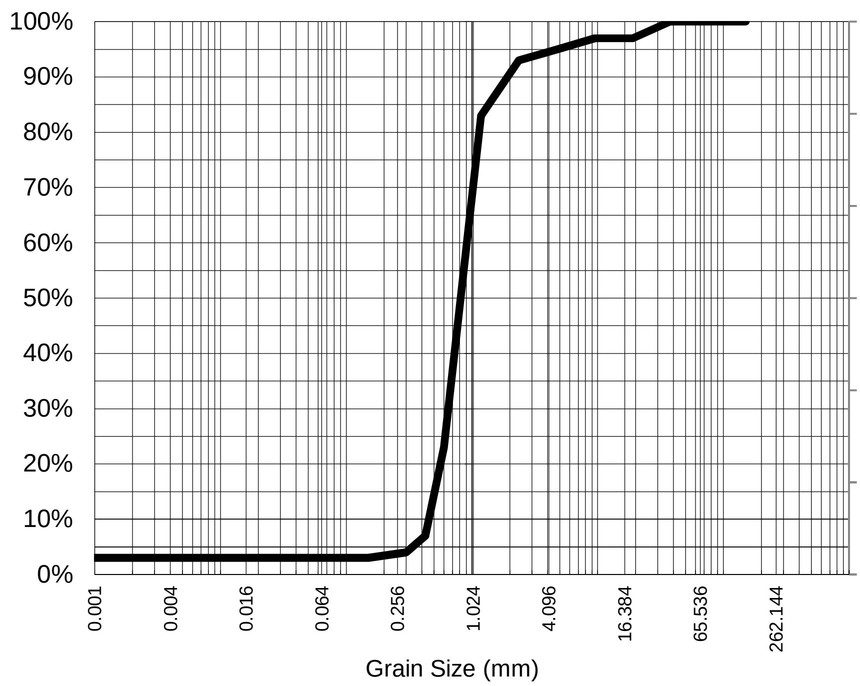
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	HARRY HOURIDIS	**DATE REPORTED:**	2-Mar-2020
COMPANY:	ADVISIAN PTY LTD	**DATE RECEIVED:**	24-Feb-2020
ADDRESS:	Level 13 333 Collins Street, Melbourne Victoria 3000	**REPORT NO:**	EM2003018-006 / PSD
PROJECT:	311015-00061	**SAMPLE ID:**	KP6

Particle Size Distribution



Particle Size (mm)	% Passing
37.5	100%
19.0	97%
9.50	97%
4.75	95%
2.36	93%
1.18	83%
0.600	23%
0.425	7%
0.300	4%
0.150	3%
0.075	3%
Particle Size (microns)	
56	3%
39	3%
28	3%
20	3%
14	3%
10	3%
7	3%
5	3%
1	3%

Median Particle Size (mm)*	0.861

Analysis Notes

Samples analysed as received.

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments: AS1289.3.6.3 states that hydrometer analysis is not applicable for samples containing <10% fines (<75um). Results should be assessed accordingly

Analysed: 27-Feb-20

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: SAND, SHELL

Dispersion Method Shaker

Test Method: AS1289.3.6.1/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.78

NATA Accreditation: 825 Site: Newcastle
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NATA
WORLD RECOGNISED ACCREDITATION

Peter Keyte
Technical Manager Air
Authorised Signatory

Certificate of Analysis

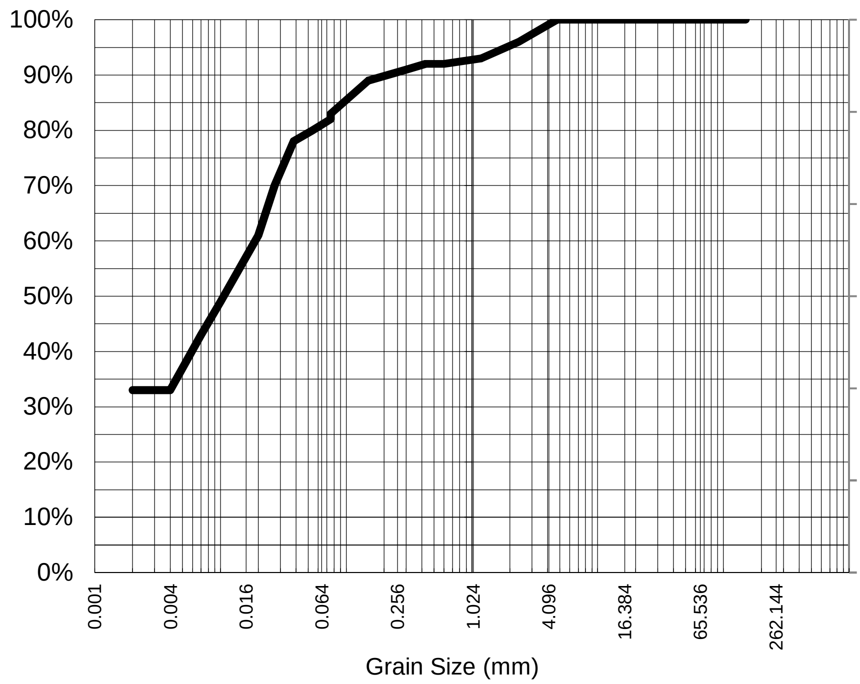
ALS Laboratory Group Pty Ltd
5/585 Maitland Road
Mayfield West, NSW 2304
pH 02 4014 2500
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	HARRY HOURIDIS	**DATE REPORTED:**	5-Mar-2020
COMPANY:	ADVISIAN PTY LTD	**DATE RECEIVED:**	24-Feb-2020
ADDRESS:	Level 13 333 Collins Street, Melb	**REPORT NO:**	EM2003018-010 / PSD
PROJECT:	311015-00061	**SAMPLE ID:**	Hold

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	96%
1.18	93%
0.600	92%
0.425	92%
0.300	91%
0.150	89%
0.075	83%
Particle Size (microns)	
54	80%
38	78%
27	70%
20	61%
15	56%
10	49%
7	43%
5	37%
2	33%

Median Particle Size (mm)*	0.011

Analysis Notes

Samples analysed as received.

**** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results***

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:		**Analysed:**	2-Mar-20
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:	FINES, SAND	**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.2/AS1289.3.6.3		
Soil Particle Density (<2.36mm)	2.41 (2.45)*		

NATA Accreditation: 825 Site: Newcastle
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NATA
WORLD RECOGNISED ACCREDITATION

Aleksandar Vujkovic
Laboratory Supervisor
Authorised Signatory

Template Version PKV8.0 180919

Certificate of Analysis

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ALS Environmental

Newcastle, NSW

CLIENT: HARRY HOURIDIS

DATE REPORTED: 5-Mar-2020

COMPANY: ADVISIAN PTY LTD

DATE RECEIVED: 24-Feb-2020

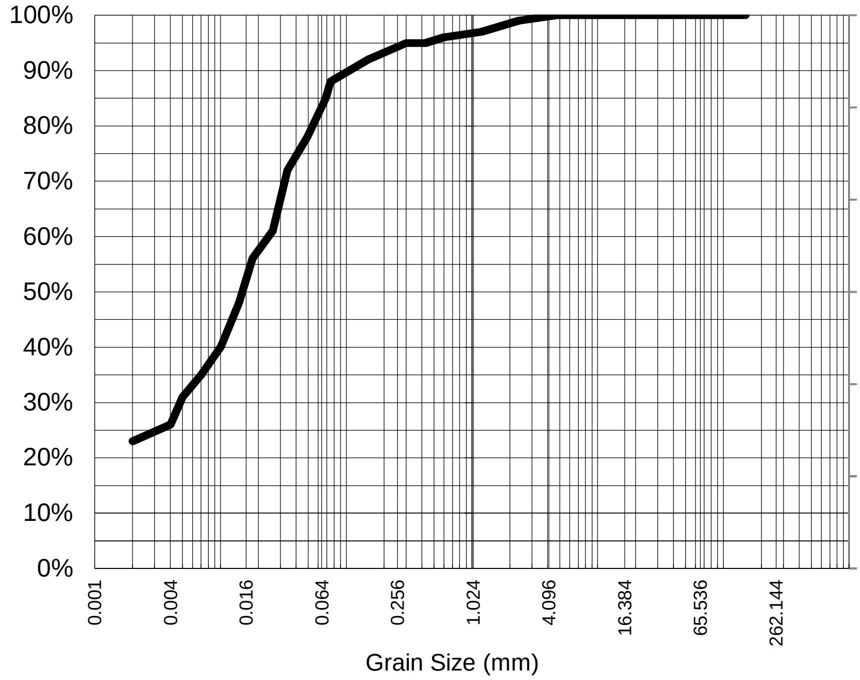
ADDRESS: Level 13 333 Collins Street, Melb

REPORT NO: EM2003018-011 / PSD

PROJECT: 311015-00061

SAMPLE ID: Rock 1, PSD

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	97%
0.600	96%
0.425	95%
0.300	95%
0.150	92%
0.075	88%
Particle Size (microns)	
49	78%
34	72%
26	61%
18	56%
14	48%
10	40%
7	35%
5	31%
2	23%

Median Particle Size (mm)*	0.015

Analysis Notes

Samples analysed as received.

**** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results***

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 2-Mar-20

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: FINES, SAND

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) 2.45

NATA Accreditation: 825 Site: Newcastle
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WORLD RECOGNISED ACCREDITATION

Aleksandar Vujkovic
Laboratory Supervisor
Authorised Signatory

Certificate of Analysis

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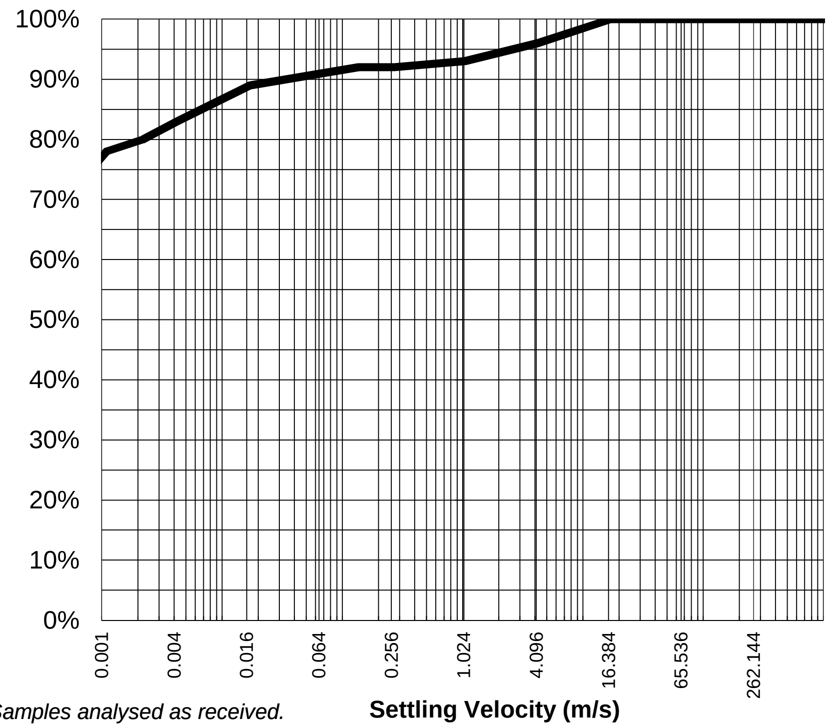
ALS Environmental

Newcastle, NSW

CLIENT:	HARRY HOURIDIS	**DATE REPORTED:**	11-Mar-2020
COMPANY:	ADVISIAN PTY LTD	**DATE RECEIVED:**	24-Feb-2020
ADDRESS:	Level 13 333 Collins Street, Melbc Victoria 3000 Melbourne	**REPORT NUMBER:**	EM2003018-010 / SR
PROJECT:	311015-00061	**SAMPLE ID:**	Hold



Particle Size	Percent Passing	Settling Velocity	Time to Settle 100cm
mm	**%**	**m/s**	**min**
4.75	100%	17	9.8E-04
2.36	96%	4.2	4.0E-03
1.18	93%	1.1	1.6E-02
0.600	92%	0.27	6.1E-02
0.425	92%	0.14	1.2E-01
0.300	91%	0.068	2.4E-01
0.150	89%	0.017	9.8E-01
0.075	83%	0.004	3.9E+00
µm			
54	80%	2.2E-03	7.591
38	78%	1.1E-03	15.183
27	71%	5.5E-04	30.366
19	62%	2.7E-04	60.731
10	51%	8.0E-05	207.74
5	38%	2.2E-05	762.94
2	35%	1.8E-06	9155.32

Samples analysed as received.

** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Time for 50% to Settle 100cm	237.42
Time for 90% to Settle 100cm	>1440
Settling Rate at 50% settled (m/s)	0.00
Settling Rate at 90% settled (m/s)	<0.0005

Analysis Notes

Sample Description: FINES, SAND

Test Method: AS1289.3.6.1/AS1289.3.6.3

Analysed: 2-Mar-20

Loss on Pretreatment NA

Dispersion Method Shaker

Limit of Reporting: 1%

Hydrometer Type ASTM E100

Aleksandar Vujkovic
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CLIENT: HARRY HOURIDIS

DATE REPORTED: 11-Mar-2020

COMPANY: ADVISIAN PTY LTD

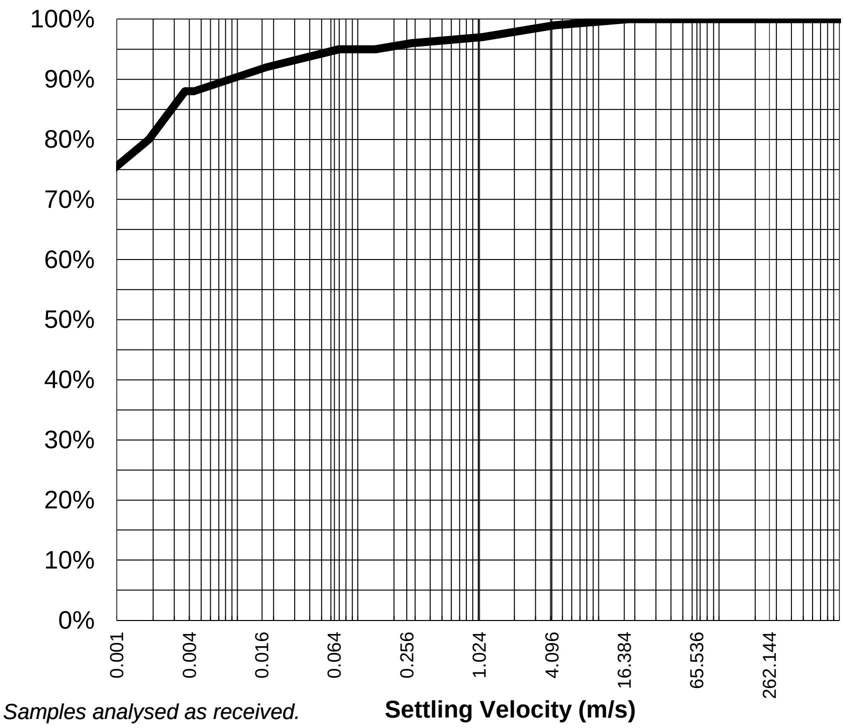
DATE RECEIVED: 24-Feb-2020

ADDRESS: Level 13 333 Collins Street, Melbc
Victoria 3000
Melbourne

REPORT NUMBER: EM2003018-011 / SR

PROJECT: 311015-00061

SAMPLE ID: Hold



Particle Size	Percent Passing	Settling Velocity	Time to Settle 100cm
mm	**%**	**m/s**	**min**
4.75	100%	18	9.5E-04
2.36	99%	4.3	3.8E-03
1.18	97%	1.1	1.5E-02
0.600	96%	0.28	6.0E-02
0.425	95%	0.14	1.2E-01
0.300	95%	0.070	2.4E-01
0.150	92%	0.018	9.5E-01
0.075	88%	0.004	3.8E+00
µm			
49	80%	1.8E-03	9.036
34	75%	9.2E-04	18.072
26	63%	5.1E-04	32.646
18	58%	2.6E-04	65.293
10	43%	7.5E-05	221.45
5	34%	2.1E-05	808.02
1	26%	1.7E-06	9696.20

Samples analysed as received.

** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Analysis Notes

Time for 50% to Settle 100cm	124.57
Time for 90% to Settle 100cm	>1440
Settling Rate at 50% settled (m/s)	0.00
Settling Rate at 90% settled (m/s)	<0.0005

Sample Description: FINES, SAND

Test Method: AS1289.3.6.1/AS1289.3.6.3

Analysed: 2-Mar-20

Loss on Pretreatment NA

Dispersion Method Shaker

Limit of Reporting: 1%

Hydrometer Type ASTM E100

Aleksandar Vujkovic
Laboratory Supervisor
Authorised Signatory

Kingston Pier Channel Construction Project

Wave Modelling

Department of Infrastructure, Transport, Regional Development and Communications (DITRDC)

1 July 2020

311015-00061

advisian.com

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PROJECT 311015-00061 – MA-RP-0005: Kingston Pier Channel Construction Project – Wave Modelling

Rev	Description	Author	Review	Advisian approval	Revision date	Client approval	Approval date
A	Draft for Internal Review	C. Adamantidis	B. Morgan	Initial. Surname	16 April 2020	Initial. Surname	Approval date
B	Draft for Internal Review	C. Adamantidis	A. Nielsen	B. Morgan	20 April 2020		
C	Draft for Customer Review	C. Adamantidis	A. Nielsen	B. Morgan	24 April 2020		
D	Draft for Customer Review	C. Adamantidis	A. Nielsen	B. Morgan	29 June 2020		
0	Final	C. Adamantidis	A. Nielsen	B. Morgan	1 July 2020		

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Appendices

Table list

Figure list

Acronyms and abbreviations

Acronym/abbreviation	Definition
Hs	Significant wave height; average height of the highest one-third of waves in a wave train
Tp	Peak wave period; the inverse of the frequency at which the wave energy spectrum peaks
SWAN	Simulating Waves Nearshore; offshore to nearshore wave transformation model
NOAA	National Oceanic and Atmospheric Administration
AWAC	Acoustic Wave And Current data collection instrument
MSL	Mean Sea Level
WW3	Wave Watch III Global Wind and Wave model, administered by the National Oceanic and Atmospheric Administration
SW	Spectral Wave
DHI	Danish Hydraulics Institute
Mike21	A hydrodynamic modelling program simulating waves and currents.
2D(H)	Two-dimensional numerical modelling scheme in the horizontal plane
ARI	Average Recurrence Interval
HHWSS	Higher High Water Springs Solstice, close to maximum highest astronomical tide level.
MSL	Mean Sea Level, close to the water level at mid-tide.

1 Introduction

Kingston is the capital of Norfolk Island and is Australia's second oldest town behind Sydney. The Kingston Pier is located on the south side of the Island and is one of two piers on the island, the other being Cascade Pier. Break-bulk cargo is transhipped from cargo ships moored offshore using launches and lighters. Cargo is lifted out of lighters at the pier using either a shore mounted crane or mobile crane. Limited water depth is available adjacent to Kingston Pier at lower tides and presents a safety risk for users due to inadequate under-keel clearance.

The Project involves the investigation, design, planning approval, construction documentation, procurement services and input during the construction stage for constructing a deeper approach channel and berth pocket at the Kingston Pier.

The location of Kingston Pier in relation to Norfolk Island is shown in Figure 1-1.

Figure 1-1 – Location of Kingston Pier within Norfolk Island

This report presents a wave modelling investigation which aims to provide stakeholders, regulators and the Department with confidence that the impacts of the proposed works on coastal processes (in particular wave climate) are understood. As deepening the channel has the potential to increase wave climate on the shoreline and at the berth, the objective of the wave modelling investigation is to understand this potential impact for various channel configuration options, with a view toward configuring the channel so as to minimise the impact.

Advisian has undertaken hydrodynamic numerical wave modelling using the SWAN software package to establish the near shore wave climate (at the channel entrance) for various recurrence intervals. The modelling was initially proposed to be based on a 2D scheme outside of the harbour and channel, with a 1D profile wave transformation model (SBEACH) to be used within the harbour. However, Advisian have created a sufficiently fine 2D SWAN model grid within the harbour that schematises the important processes, including wave setup, as well as providing the advantage of being able to visualise the wave climate in two dimensions over the harbour in more detail than is possible from using the 1D model scheme. For this reason, the SWAN model has been applied over the entire area.

The transformations of waves as they enter the channel and harbour for six channel configuration options have been investigated as shown in Figure 1-2**.**

Figure 1-2 - Schematic of wave transformation paths that would be investigated following establishment of the nearshore wave climate.

2 Offshore Wave Climate

The offshore wave climate of Norfolk Island has been developed by WorleyParsons (2008) as part of the Norfolk Island Port Study.

The offshore wave climate was developed based on the output from two different wave models:

- A wave hindcast model for the South Pacific Ocean run for the 10 year period between March 1997 to February 2007
- Wave parameters extracted from the National Oceanic and Atmospheric Administration's (NOAA) Wavewatch3 (WW3) Global model for the period from March 1997 to February 2006.

WorleyParsons' model of the South Pacific Ocean used DHI's Mike21 Spectral Wave (SW) model for flexible meshes. Mike21 SW allows for the simulation of growth, dissipation and transformation of wind-generated waves and swell in offshore and coastal areas. It includes nonlinear wave-wave interaction, dissipation due to white capping, bottom friction, depth induced wave breaking, and refraction and shoaling due to depth variation.

The NOAA's WW3 model provides output of wind and wave parameters across the globe. The model resolution is 1 degree (approximately 111 km) in the north south direction and 1.25 degrees (approximately 139 km) in the east west direction. Parameters are output at 3 hourly time intervals.

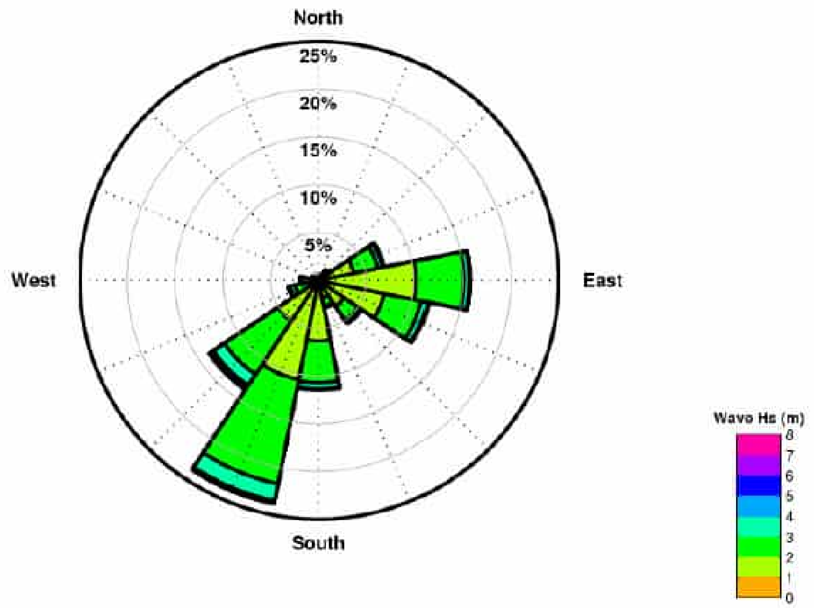
Model output data was obtained for the period from February 1997 to September 2006. Data from the period from March 1997 to February 2006 was used to produce the wave climate summaries presented in this report to ensure the record contained equal numbers of each month, necessary due to seasonal variability in the metocean conditions.

The offshore wave climate at Norfolk Island is summarised in Figure 2-1 and Figure 2-2.

In addition to the above wave climate analysis, WorleyParsons (2008) estimated the Directional extreme waves for the 1, 50 and 100 year return periods for Norfolk Island based on analysis of a variety of data sources (modelled, satellite and visual observation wave data). These are shown in Table 2-1.

The offshore wave climate developed by WorleyParsons (2008) was applied as boundary conditions for the nearshore SWAN wave modelling.

Wave Height and Direction Rose, 29216 Records, 01–Mar–1997 to 28–Feb–2007 21:00:00



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Location: Norfolk Island [167.95000 , −29.03000]
Data period: 01−Mar−1997 to 28−Feb−2007 21:00:00
Data source: Mike21 SW Model
Data summary: All Records
Number of Records: 29216

Joint Frequency Table (%) Showing Hs Against Direction for the Period 01–Mar–1997 to 28–Feb–2007 21:00:00

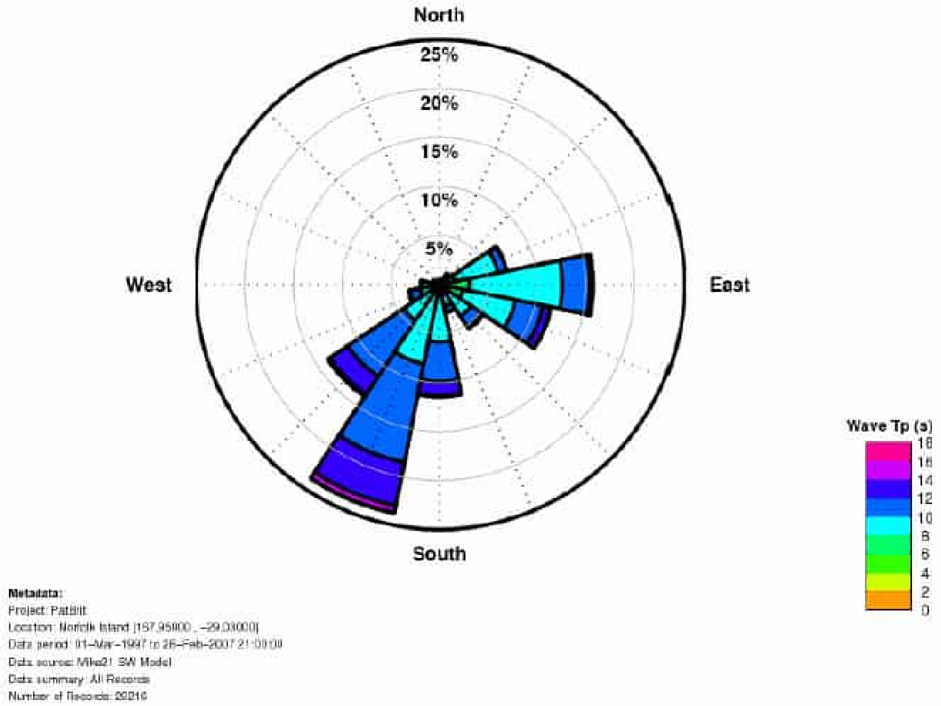
N=29216	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0–0.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0.5–1	–	–	0.01	0.03	0.18	0.04	0.01	0.02	0.07	0.01	0.02	–	–	–	–	–	0.41	0.41
1–1.5	–	0.08	0.09	1.08	3.63	2.32	1.08	0.60	1.95	2.36	1.12	0.20	0.21	0.08	0.01	*	14.82	15.23
1.5–2	0.01	0.07	0.25	2.67	6.37	4.64	2.13	1.19	4.30	8.19	3.93	0.65	0.46	0.21	0.10	0.01	35.18	50.41
2–2.5	*	0.14	0.49	1.72	3.32	2.74	1.33	0.69	2.99	7.03	4.07	0.91	0.56	0.16	0.13	0.05	26.36	76.77
2.5–3	0.01	0.12	0.31	0.81	1.55	1.18	0.46	0.23	1.38	4.08	2.67	0.71	0.36	0.17	0.11	0.02	14.17	90.94
3–3.5	*	0.06	0.12	0.34	0.42	0.47	0.23	0.10	0.47	1.35	0.93	0.30	0.16	0.06	0.04	*	5.04	95.98
3.5–4	*	0.02	0.07	0.17	0.16	0.17	0.13	0.05	0.19	0.47	0.47	0.25	0.06	0.02	0.02	*	2.27	98.25
4–4.5	*	–	*	0.09	0.08	0.05	0.02	0.02	0.02	0.17	0.20	0.13	0.08	0.03	0.01	–	0.91	99.16
4.5–5	–	–	*	0.07	0.01	0.03	0.02	*	0.03	0.09	0.14	0.06	0.03	0.02	*	–	0.50	99.67
5–5.5	–	–	–	0.01	–	*	–	*	0.01	0.04	0.10	*	*	*	–	–	0.18	99.85
5.5–6	–	–	–	–	*	*	–	*	–	*	0.04	*	*	–	0.01	–	0.08	99.93
6–6.5	–	–	–	–	–	*	–	–	–	*	0.03	–	–	–	–	–	0.04	99.97
6.5–7	–	–	–	–	*	–	–	–	–	–	0.01	–	–	–	–	–	0.02	99.99
7–7.5	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	*	99.99
7.5–8	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	*	100.00
Total	0.04	0.50	1.35	6.99	15.73	11.67	5.41	2.92	11.43	23.80	13.74	3.22	1.93	0.76	0.43	0.10		
Cumul.	0.04	0.54	1.89	8.87	24.60	36.27	41.68	44.60	56.03	79.82	93.57	96.78	98.71	99.47	99.90	100.00		

* denotes values less than 0.01%   – denotes no records in bin

Metadata:
Project: PatBrit
Location: Norfolk Island [167.95000 , −29.03000]
Data period: 01−Mar−1997 to 28−Feb−2007 21:00:00
Data source: Mike21 SW Model
Data summary: All Records
Number of Records: 29216

Figure 2-1 – Offshore wave climate of Norfolk Island – Significant Wave Height, Direction and Joint Frequency Table (WorleyParsons 2008)

Wave Period and Direction Rose, 29216 Records, 01–Mar–1997 to 28–Feb–2007 21:00:00



Joint Frequency Table (%) Showing Hs Against Tp for the Period 01–Mar–1997 to 28–Feb–2007 21:00:00

N=29216	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	Total	Cumul.
0–0.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0.5–1	–	–	–	–	–	–	0.03	0.15	0.08	0.10	0.05	–	–	–	–	–	–	–	0.41	0.41
1–1.5	–	–	–	–	0.01	0.17	0.85	2.39	5.62	4.06	1.12	0.36	0.15	0.05	0.05	*	–	–	14.82	15.23
1.5–2	–	–	–	–	*	0.24	1.78	3.47	7.49	10.68	7.42	2.73	0.92	0.34	0.07	0.02	0.02	–	35.18	50.41
2–2.5	–	–	–	–	–	0.03	0.83	2.65	3.79	5.13	5.92	4.96	2.21	0.63	0.10	0.08	0.03	–	26.36	76.77
2.5–3	–	–	–	–	–	–	0.11	1.16	2.11	2.13	2.46	2.94	2.00	0.90	0.26	0.08	0.01	–	14.17	90.94
3–3.5	–	–	–	–	–	–	*	0.21	0.81	0.76	0.76	0.85	0.80	0.66	0.17	0.02	–	–	5.04	95.98
3.5–4	–	–	–	–	–	–	–	0.01	0.28	0.43	0.41	0.41	0.41	0.19	0.10	0.02	–	–	2.27	98.25
4–4.5	–	–	–	–	–	–	–	–	0.04	0.23	0.20	0.19	0.15	0.05	0.05	*	–	–	0.91	99.16
4.5–5	–	–	–	–	–	–	–	–	*	0.07	0.08	0.12	0.12	0.07	0.05	–	–	–	0.50	99.67
5–5.5	–	–	–	–	–	–	–	–	–	*	0.01	0.05	0.08	0.03	*	*	–	–	0.18	99.85
5.5–6	–	–	–	–	–	–	–	–	–	*	*	0.01	0.03	*	0.01	*	–	–	0.08	99.93
6–6.5	–	–	–	–	–	–	–	–	–	–	–	*	0.02	–	0.01	0.01	–	–	0.04	99.97
6.5–7	–	–	–	–	–	–	–	–	–	–	*	*	–	*	*	–	–	–	0.02	99.99
7–7.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	*	99.99
7.5–8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	*	100.00
Total	–	–	–	–	0.01	0.44	3.61	10.04	20.24	23.58	18.44	12.63	6.89	2.92	0.89	0.24	0.06	–		
Cumul.	–	–	–	–	0.01	0.46	4.07	14.11	34.34	57.92	76.36	88.99	95.89	98.81	99.70	99.94	100.00	100.00		

* denotes values less than 0.01%   – denotes no records in bin

Metadata:
Project: PatBrit
Location: Norfolk Island [167.95000 , –29.03000]
Data period: 01–Mar–1997 to 28–Feb–2007 21:00:00
Data source: Mike21 SW Model
Data summary: All Records
Number of Records: 29216

Figure 2-2 – Significant Wave Height vs. Peak Wave Period, offshore Norfolk Island (WorleyParsons 2008)

Table 2-1 – Directional offshore extreme waves and directions estimated for Norfolk Island (WorleyParsons 2008)

Site: Norfolk Island
Location: 29°02'00"S, 167°57'00"E Water depth: Deep Water
Region: Western Pacific

The following are the extremes likely to be reached, or exceeded, once on average every 1 year, every 50 years and every 100 years respectively from the direction sector indicated at the above location. The values do not take into account the sheltering effects of Norfolk Island itself.

Return Period	Direction from							
	N	NE	E	SE	S	SW	W	NW
1-year								
Significant wave height (m)	4.1	4.3	5.6	4.8	5.0	7.1	6.2	4.5
Peak energy period (s)	8.9	9.0	10.4	10.2	11.9	13.4	11.5	9.3
50-year								
Significant wave height (m)	5.7	5.9	7.8	6.7	6.9	9.8	8.5	6.2
Peak energy period (s)	10.4	10.6	12.2	12.0	13.7	15.8	13.5	10.9
100-year								
Significant wave height (m)	6.0	6.2	8.1	7.0	7.2	10.3	9.0	6.5
Peak energy period (s)	10.7	10.9	12.5	12.3	14.3	16.2	13.9	11.2

NB The above data are intended for conceptual design and are based on a broad scale study of the meterology and oceanography of the area.

3 Nearshore Wave Climate

3.1 Introduction

The nearshore wave climate at Kingston Pier was developed using an offshore to nearshore wave transformation model, SWAN.

SWAN is a third-generation phase-averaged two-dimensional (horizontal – 2D(H)) wind wave model and is capable of simulating a range of physical processes such as:

- Wave generation by wind
- Shoaling
- Wave setup
- Refraction due to current and depth
- Diffraction
- Three and four wave interactions
- Wave dissipation due to white capping, bottom friction, and depth induced breaking.

Wave diffraction around Phillip and Nepean Islands is expected to be an important process in the transformation of offshore waves to the site. While diffraction is not able to be modelled explicitly in phase averaged wave models such as SWAN, which has been applied to this study, recent advances include diffraction by utilising a phase-decoupled refraction-diffraction approximation. This approach has been shown to give realistic approximations to wave diffraction around large obstacles such as headlands as is considered here. The diffraction approximation has been applied to the SWAN modelling described in this section.

The methodology for developing the nearshore wave climate was applied as follows:

- Import Royal Australian Navy bathymetry data already available to build the SWAN spectral wave model all around Norfolk Island
- Create fine nested 2D SWAN model grid around Kingston Pier harbour area
- Run the model for various average reccurrence interval events to establish the nearshore wave climate
- Note as nearshore wave measurements do not exist, all modelling is uncalibrated, which is acceptable for a preliminary assessment. Collection of wave data by deploying instruments over say 3 months would provide more confidence with the numerical modelling.

3.2 Model Setup

The SWAN model was set up as a series of nested model computational grids, as follows:

- An outer grid encompassing the entire island out to deep water, 25 km x 40 km with a grid resolution of 200 m
- A second level nested grid encompassing the southern coastline of Norfolk Island and Phillip Island 15 km x 10 km with a resolution of 100 m
- A third level nested grid encompassing the area surrounding Kingston Pier, 4.5 km x 4.5 km, with a grid resolution of 10 m

- A fourth level fine nested grid covering Kingston Pier and harbour in detail, 2150 x 1500 m, with a grid resolution of 5 m.

The model domain and bathymetry for the outer grid of the model is shown in Figure 3-1, with detail in the area of interest shown in Figure 3-2.

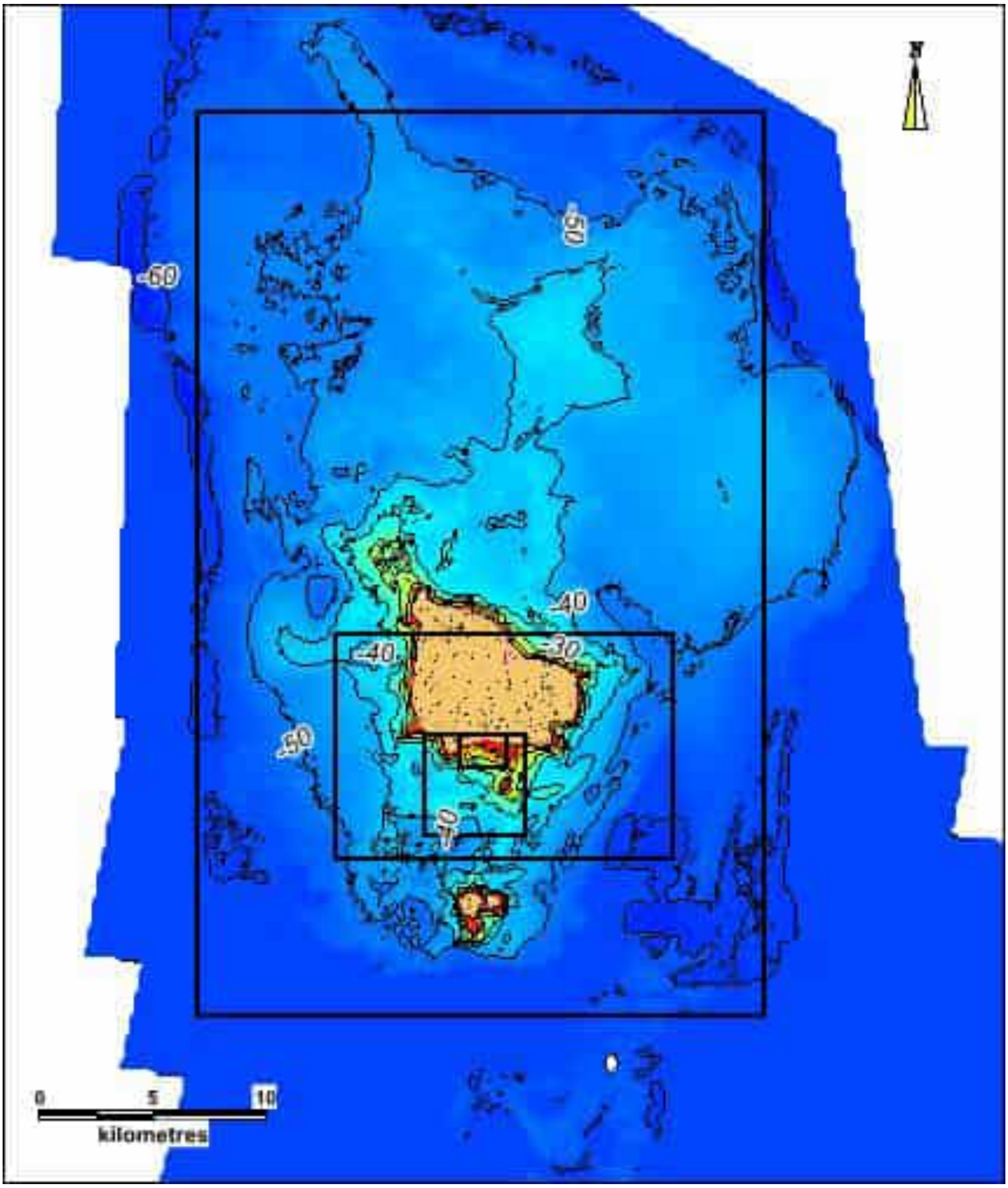


Figure 3-1 – Model domain and bathymetry

3.2.1 Model Bathymetry

The Kingston Pier is located seaward of a shallow rock shelf that is exposed at lower tide levels and provides some sheltering of waves for vessels in the lee. The existing entrance channel is over rocky reef with sea bed levels ranging from around -2.4 to -3.4 m MSL offshore and adjacent to the rock shelf. Landward of the rock shelf and next to the pier seabed levels are around -0.7 to -1.5m MSL. Seabed levels have been sourced from a hydrographic survey undertaken by Don Taylor on 1 December 2006 and the Royal Australian Navy in 28 October 2010. A more recent survey of the area is proposed although as the seabed is rocky reef, the Don Taylor survey is still considered valid.

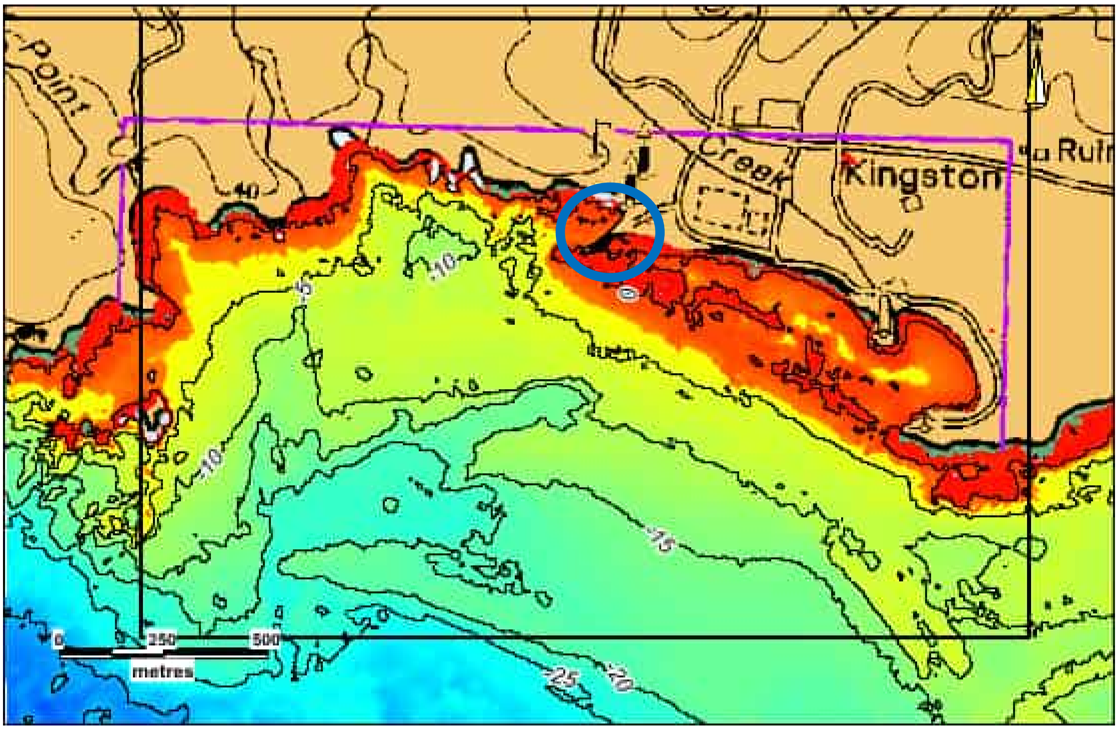


Figure 3-2 – Detail of bathymetry at Kingston Pier

3.2.2 Model Validation

No site-specific validation of the wave transformation model was possible due to a lack of suitable nearshore and offshore wave measurements. However, Nielsen and Adamantidis (2003) have validated successfully the SWAN numerical algorithms for the NSW coast *via* a comparison of numerical results with a comprehensive field data set obtained at Broken Bay, north of Sydney. As the only opportunity to calibrate the model lies in varying the bathymetric boundary conditions, if the bathymetry is known and schematised at an appropriate resolution then the model can be expected to give realistic results.

3.2.3 Boundary Conditions

The boundary conditions applied to the model were derived from the offshore wave climate described in Section 2.

The focus of the project is to improve operational conditions by increasing the depth of harbour, although it is considered the pier is not safe and unable to be used when the waves reaching the loading/unloading face of the pier are greater than 1 m. The limiting wave height value of 1 m was confirmed with stakeholders and adopted as a design criterion (Advisian, 2020). It is considered that the 1 m wave height would occur frequently at the site, especially at high tide. For this reason, offshore boundary conditions for the model were derived based on median conditions from Section 2, as well as the 1 year ARI storm event, for the most common wave directions obtained from Figure 2-1. The unique set of offshore boundary conditions including significant wave height, peak wave period and offshore wave directions used for the modelling is shown in Table 3-1.

3.2.4 Adopted Water Levels

For the 1 year ARI runs, the Higher High Water Springs Solstice (HHWSS) water level (0.9 m MSL) was applied to the model. For the median conditions runs, the Mean Higher Water level (0.65 m MSL) was applied. The higher water level was used to capture wave transformation into the harbour over the extensive reef system present at the mouth of the harbour.

Table 3-1 – Offshore wave cases run through SWAN model

Case No.	Offshore wave direction °TN	Significant Wave Height Hs (m)	Peak Wave Period Tp (s)	Case Description
1	270 (W)	6.2	11.5	1 year ARI westerly offshore waves
2	225 (SW)	7.1	13.4	1 year ARI south-westerly offshore waves
3	180 (S)	5.0	11.9	1 year ARI southerly offshore waves
4	135 (SE)	4.8	10.2	1 year ARI south-easterly offshore waves
5	90 (E)	5.6	10.4	1 year ARI easterly offshore waves
6	225 (SW)	2.0	10.0	Median conditions, south-west offshore waves
7	202.5 (SSW)	2.0	10.0	Median conditions, SSW offshore waves
8	180 (S)	2.0	10.0	Median conditions, S offshore waves
9	90 (E)	2.0	10.0	Median conditions, E offshore waves

3.3 Existing Nearshore Wave Climate

The existing wave climate at the pier for the various offshore cases in Table 3-1 is illustrated in Appendix A, Figures A-1 to A-9.

The wave climate parameters were derived from the model at points A to H as identified in Figure 3-3. The significant wave height and wave direction derived from the model at points A to H for model cases 1 to 9 is provided in Table 3-2. From Table 3-2 it can be seen that the highest waves occur in the harbour when offshore wave direction is from the southwest, as the existing reef at the end of the pier results in wave breaking for the more easterly wave approach directions. The southwest direction also coincides with the most common offshore wave approach sector. The existing significant wave heights for the southwest offshore waves for the 1 year ARI and median conditions are shown in Figure 3-4 and Figure 3-5.

Figure 3-3 – Points of interest for wave climate comparison

Table 3-2 – Significant wave height Hs (m) at point of interest for each case run

Case	A	B	C	D	E	F	G	H
1 (W)	3.17	2.32	1.52	0.67	0.35	0.44	0.47	0.67
2 (SW)	3.61	2.75	1.72	0.79	0.41	0.50	0.59	0.83
3 (S)	2.70	2.29	1.11	0.14	0.26	0.27	0.43	0.72
4 (SE)	2.11	2.04	1.03	0.43	0.22	0.31	0.30	0.59
5 (E)	1.55	1.54	0.70	0.29	0.15	0.23	0.21	0.44
6 (SW)	2.13	1.66	1.11	0.46	0.24	0.31	0.27	0.41
7 (SSW)	1.79	1.48	0.98	0.40	0.21	0.29	0.25	0.38
8 (S)	1.17	1.06	0.48	0.02	0.09	0.11	0.15	0.30
9 (E)	0.69	0.69	0.31	0.12	0.06	0.10	0.08	0.14

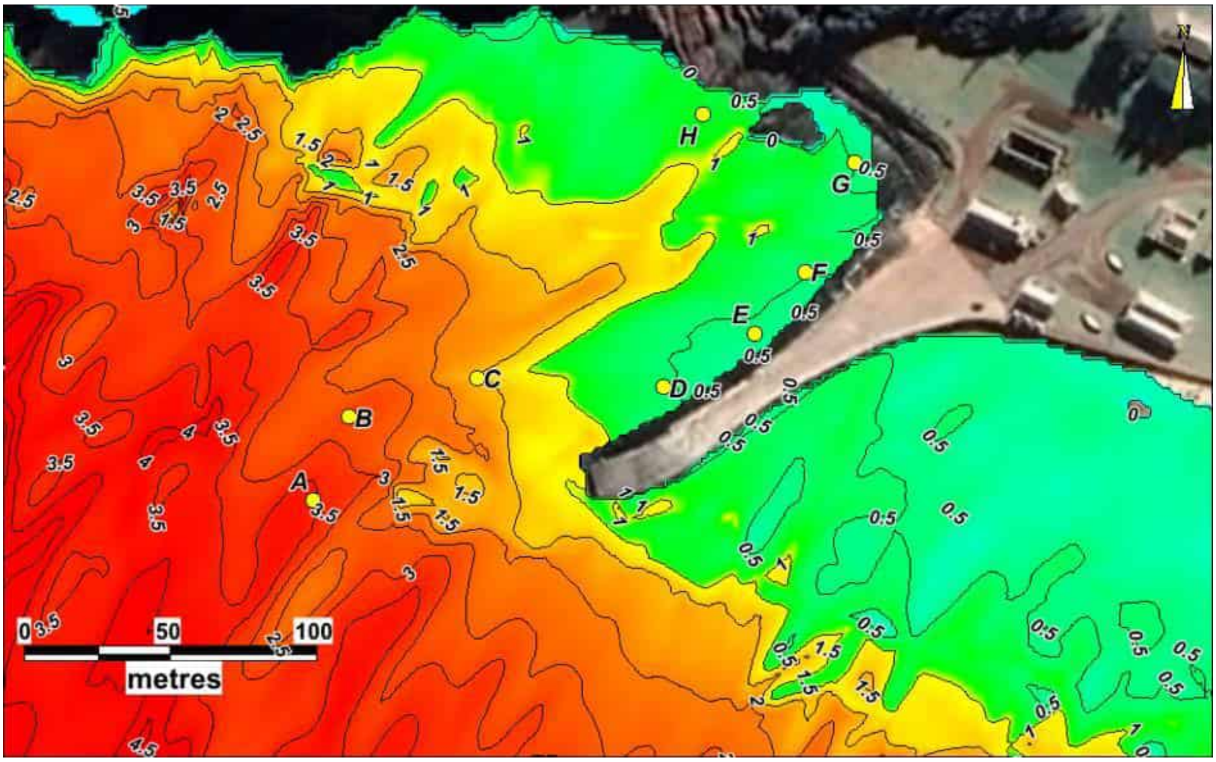


Figure 3-4 – Significant wave height (m), SW offshore waves, 1 year ARI (Case 2)

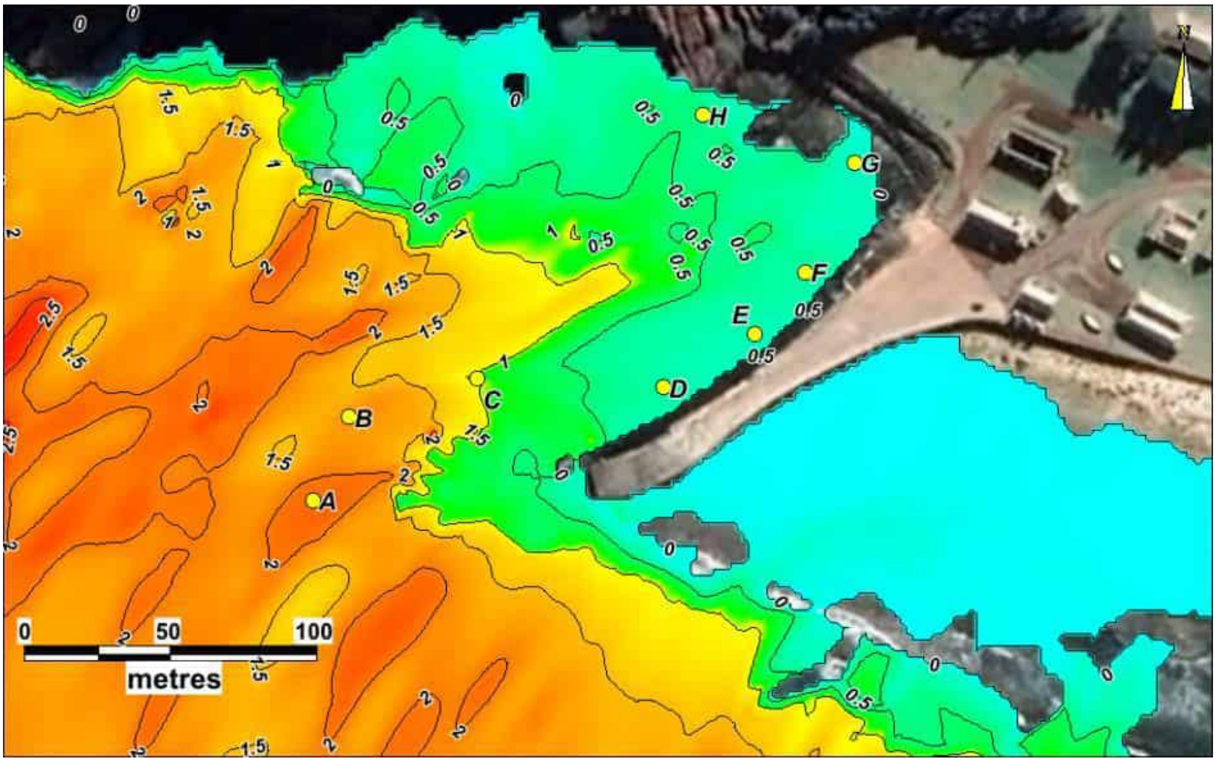


Figure 3-5 – Significant wave height (m), SW offshore waves, median conditions (Case 6)

3.4 Kingston Pier Channel Construction Options

The following four channel construction options were initially modelled to assess their impact on wave climate within the harbour and surrounds:

- Option 1 – Channel width 20 m, Channel elevation min. -2.7 m MSL, turning circle 18 m
- Option 2 – Channel width 26.5 m, Channel elevation min. -2.7 m MSL, turning circle 24 m
- Option 3 – Channel width 20 m, Channel elevation min. -3.2 m MSL, turning circle 27 m
- Option 4 – Channel width 32.5 m, Channel elevation min. -3.2 m MSL, turning circle 36 m.

The four options are shown in Figure 3-6 to Figure 3-9. Of note is that each option preserves the existing rock shelf at the entrance to the channel.

Two additional options have been considered following consultation with stakeholders. Key information provided by the Fishing Association and Lighterage stakeholder groups has been progressed on the basis that they are both frequent users of the channel, have intimate knowledge of the channel conditions and can provide unique and invaluable insights based on their experiences. This information has been developed in Options 1a and 3a. These options are variations of Options 1 and 3, which incorporate a channel width and turning circle in front of the berth face of 22.5 m that is intermediate between Options 1 and 3, with Option 1a maintaining a depth of -2.7 m MSL and Option 3a maintaining a depth of -3.2 m MSL. These options are shown diagrammatically below in Figure 3-10 and Figure 3-11.

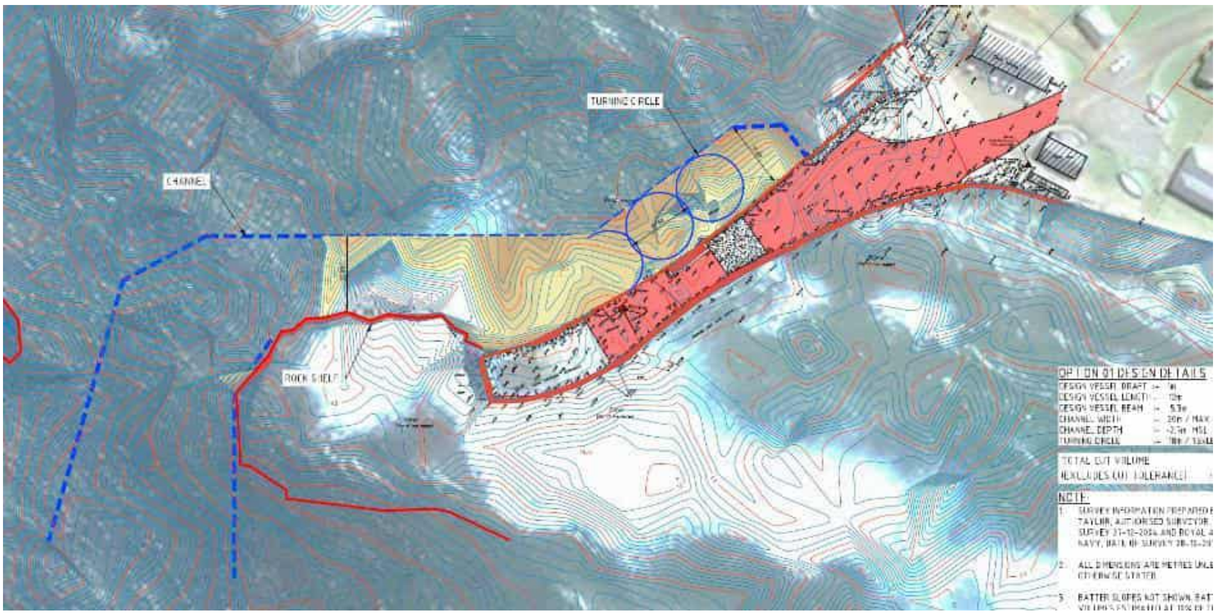


Figure 3-6 – Option 1 Channel configuration

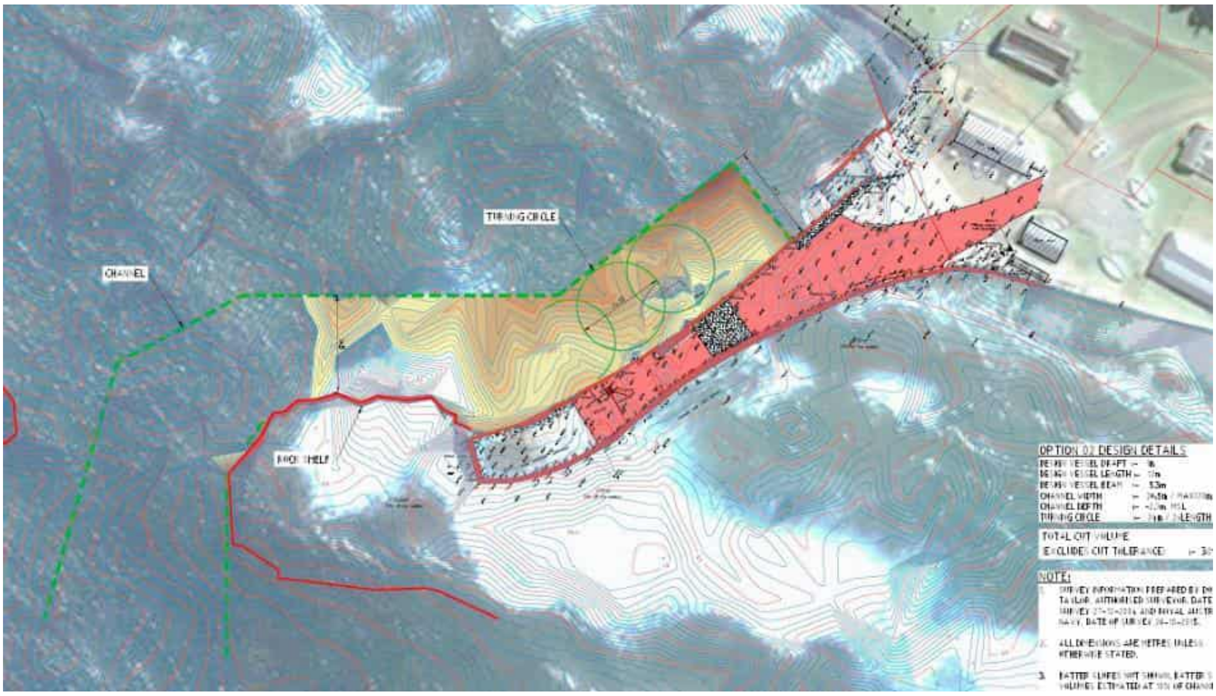


Figure 3-7 – Option 2 channel configuration

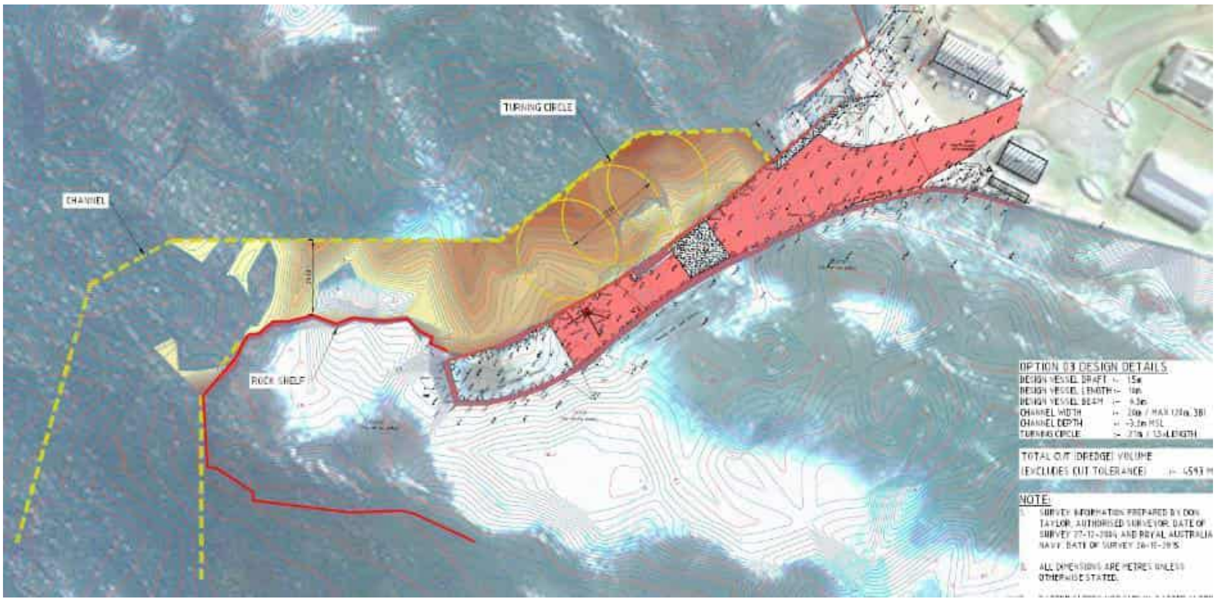


Figure 3-8 – Option 3 channel configuration

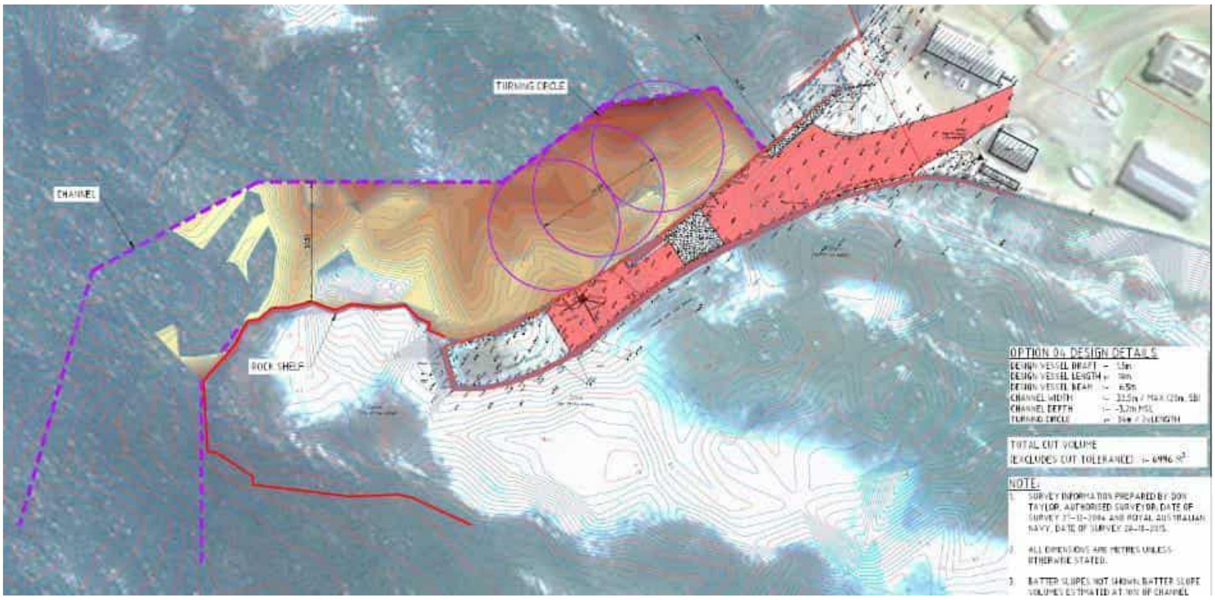


Figure 3-9 – Option 4 Channel configuration

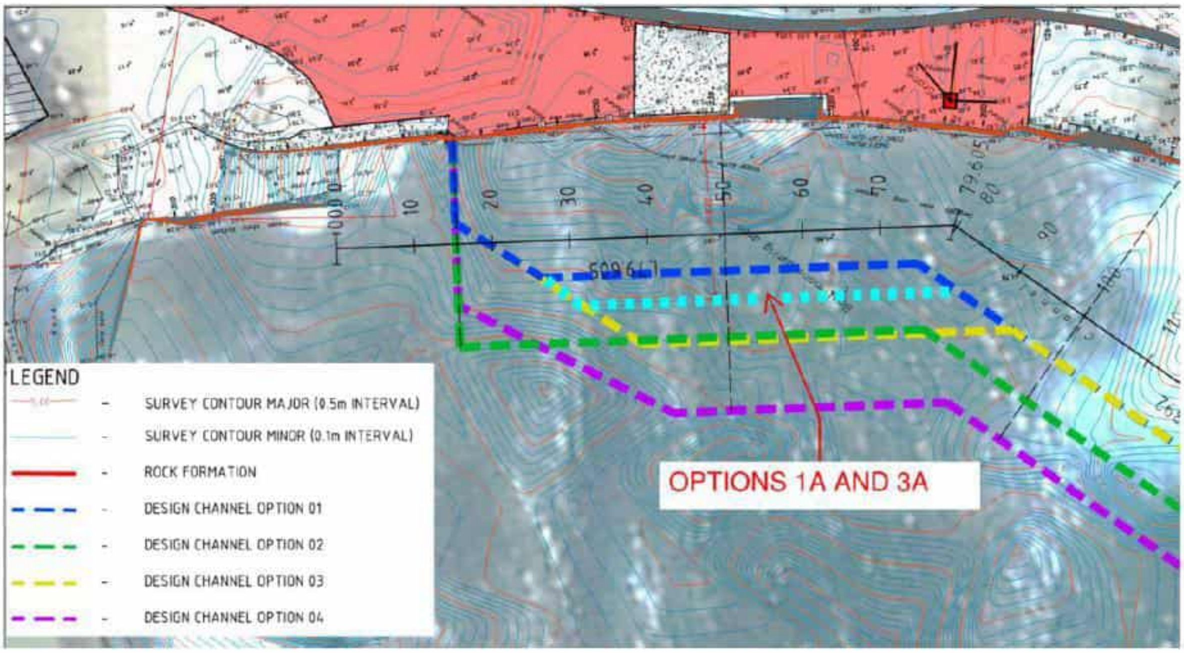


Figure 3-10 – Option 1A and 3A channel alignment compared with channel alignment of Options 1 to 4 (Plan View)

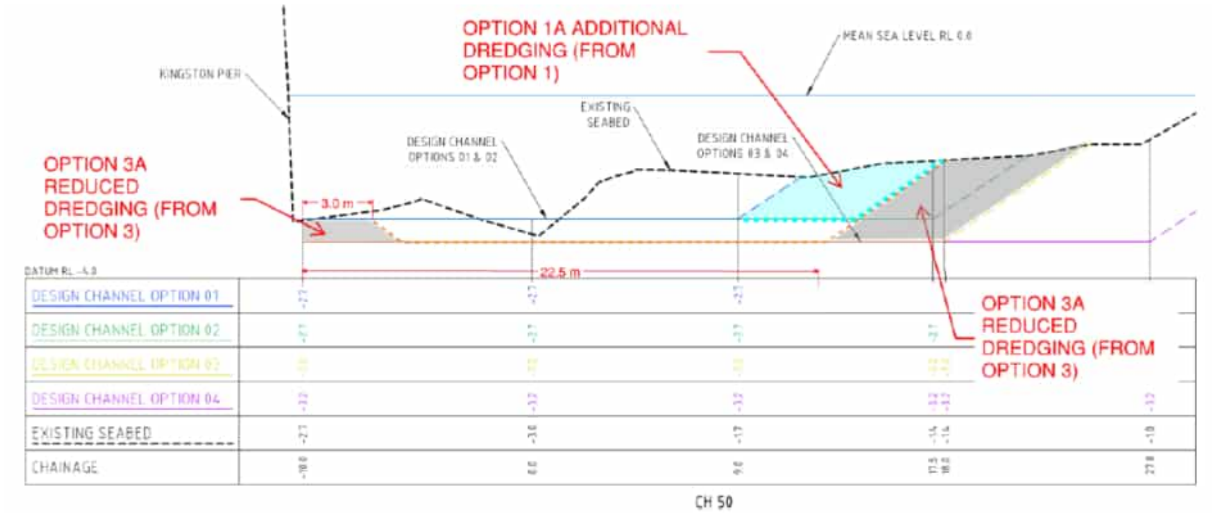


Figure 3-11 – Option 1A and 3A compared with Options 1 to 4 (section view)

3.5 Model Results

The model was run for the six channel configuration options above, for the south-west offshore waves (representing the worst-case for wave penetration into the harbour, Cases 2 and 6 from Table 3-1).

The changes in significant wave height over the harbour area are shown in Figure 3-12 to Figure 3-23, for each of the channel configuration options modelled. The results for significant wave height and percentage change at each of the locations A to H from Figure 3-3 are provided in Table A-1 to A-4 in Appendix A and compared with the existing significant wave heights at those locations.

3.5.1 Option 1

The change in significant wave height for Option 1, for the 1 year ARI (south-west offshore waves, Case 2), is shown in Figure 3-12. Wave height is generally decreased within the channel area but increased to the north and west of the channel.

For the median wave conditions for Option 1, in relation to median south-west offshore waves, the change in significant wave height is shown in Figure 3-13. For this case also, the wave height within the channel area is generally decreased by around 0.1m, but there is a slight focussing of wave energy near Point D, with an increase in significant wave height of around 0.1 m.

Table A-1 to A-4 in Appendix A show the modelled significant wave heights and percentage change in wave height when compared with existing conditions, for Case 2 and Case 6. For Option 1, these indicate that the significant wave height would decrease within the channel for the 1 year ARI condition, but increase by 24% to the north and by 6% in the area in front of the foreshore revetment to the west of the pier. Under median conditions, however, there is a 21% increase in wave height at Point D, but a decrease elsewhere within the harbour. There are increases at Point C to the north of the channel, and a slight increase of 12% in the area in front of the foreshore revetment to the west of the pier.

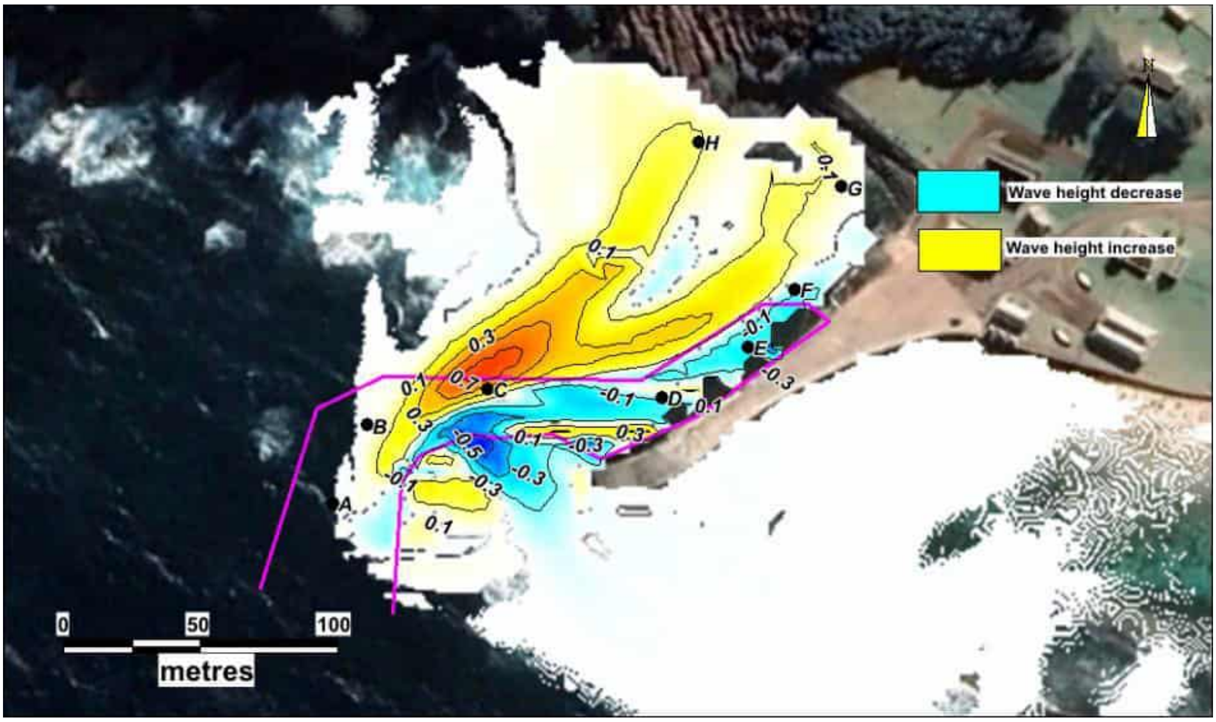


Figure 3-12 – Change in significant wave height (m), Option 1, Case 2 (SW offshore waves, 1y ARI)

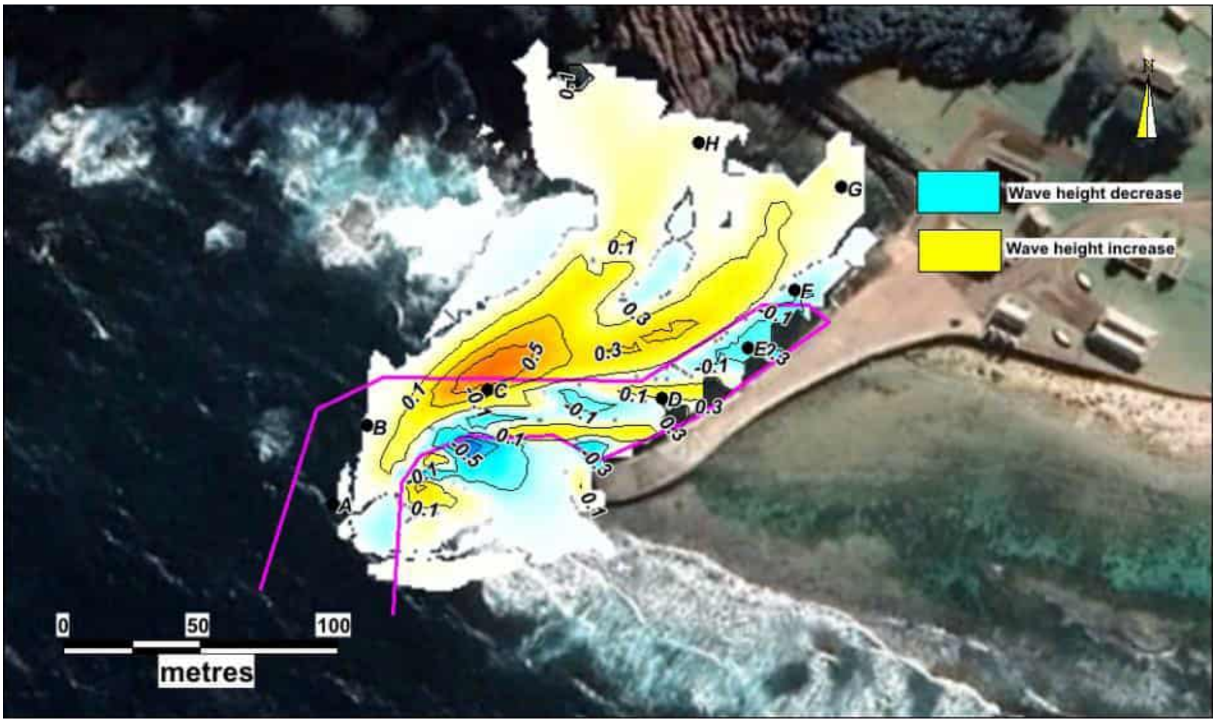


Figure 3-13 – Change in significant wave height (m), Option 1, Case 6 (SW offshore waves, median conditions)

3.5.2 Option 2

The change in significant wave height for Option 2, for the 1 year ARI (south-west offshore waves, Case 2), is shown in Figure 3-14. Under this option, there is an area of wave focussing that occurs near the berth at Point E and the surrounding area. Wave height is generally increased to the north and west of the channel.

For the median wave conditions for Option 2, in relation to median south-west offshore waves, the change in significant wave height is shown in Figure 3-15. For this case also, the wave height within the channel area is generally increased by around 0.1m, with wave focusing occurring along the berth near Point E.

Table A-1 to A-4 in Appendix A show the modelled significant wave heights and percentage change in wave height when compared with existing conditions, for Case 2 and Case 6. For Option 2, these indicate that the significant wave height would increase at the berth (Point E) by around 50% for the 1 year ARI, and up to 100% for median conditions. There would be a slight decrease in significant wave height in the area in front of the foreshore revetment to the west of the pier.

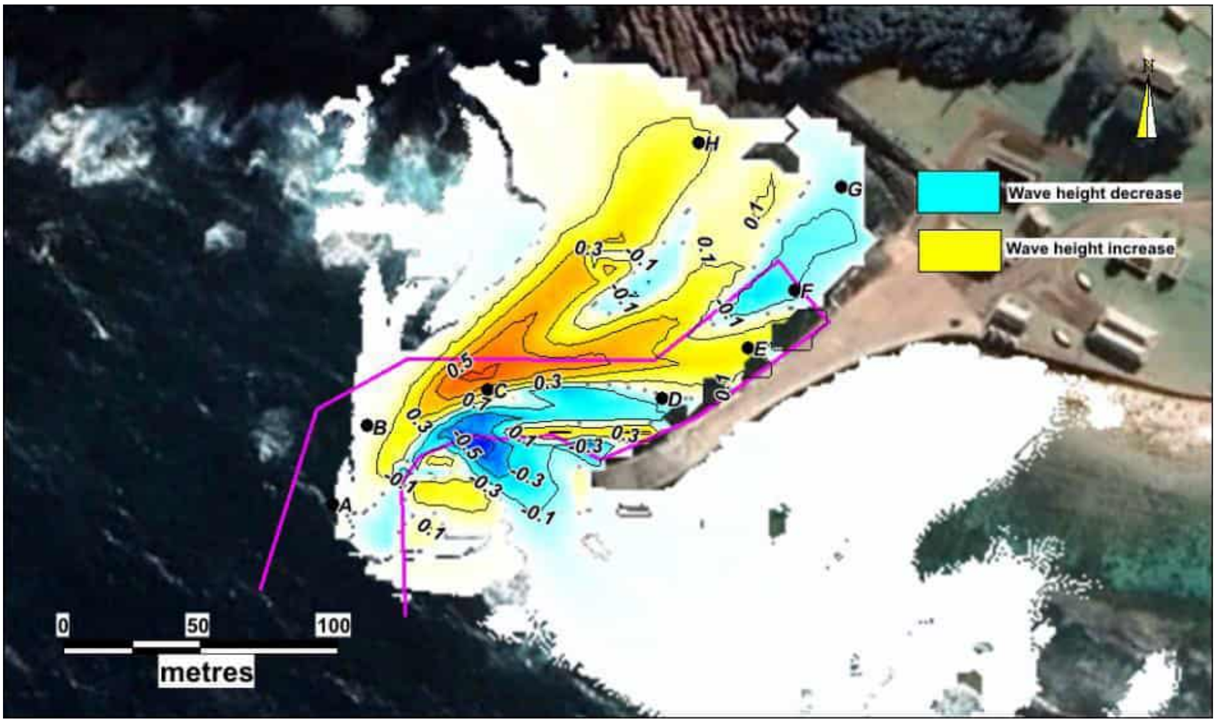


Figure 3-14 – Change in significant wave height (m), Option 2, Case 2 (SW offshore waves, 1 year ARI)

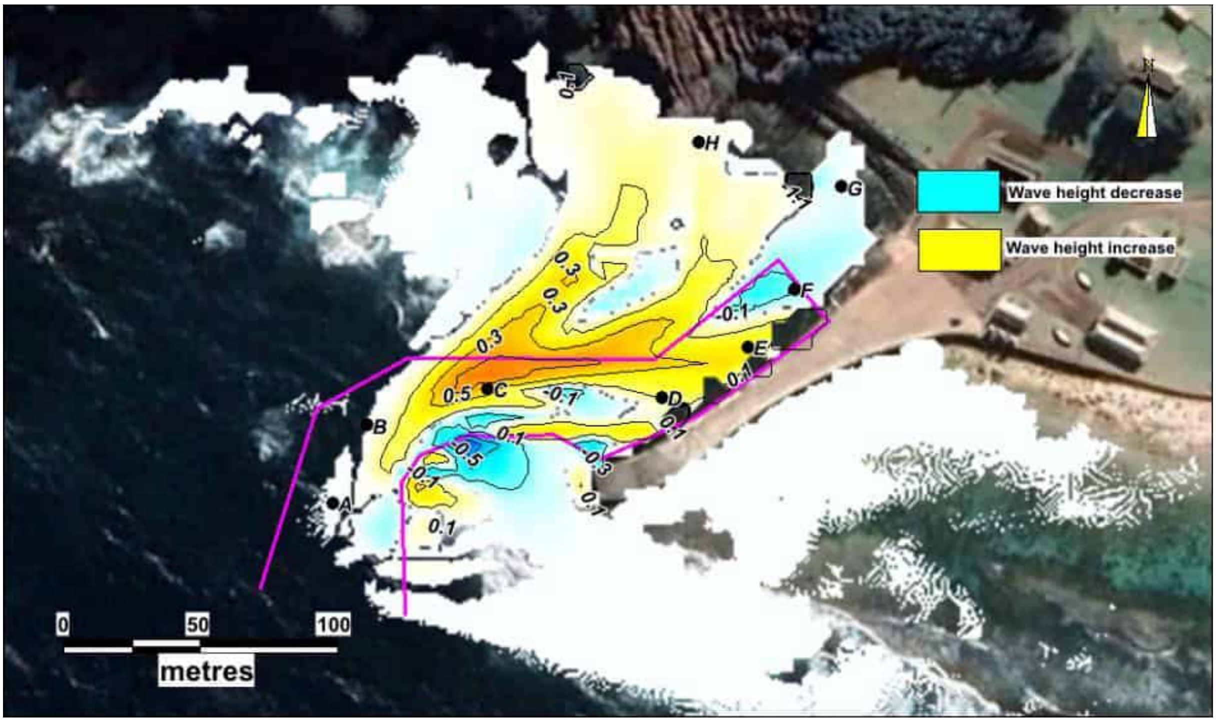


Figure 3-15 – Change in significant wave height (m), Option 2, Case 6 (SW offshore waves, median conditions)

3.5.3 Option 3

The change in significant wave height for Option 3, for the 1 year ARI (south-west offshore waves, Case 2), is shown in Figure 3-16. Wave height is generally decreased within the channel area but increased to the north and west of the channel.

For the median wave conditions for Option 3, in relation to median south-west offshore waves, the change in significant wave height is shown in Figure 3-17. For this case also, the wave height within the channel area is generally decreased by around 0.1 m. There is also a decrease in significant wave height of 0.1 m in the area in front of the foreshore revetment near Point G. There are increases in the area north of the channel.

Table A-1 to A-4 in Appendix A show the modelled significant wave heights and percentage change in wave height when compared with existing conditions, for Case 2 and Case 6. For Option 3, these indicate that the significant wave height would decrease within the channel for the 1 year ARI condition by around 30%, and decrease by 40% for the median condition.

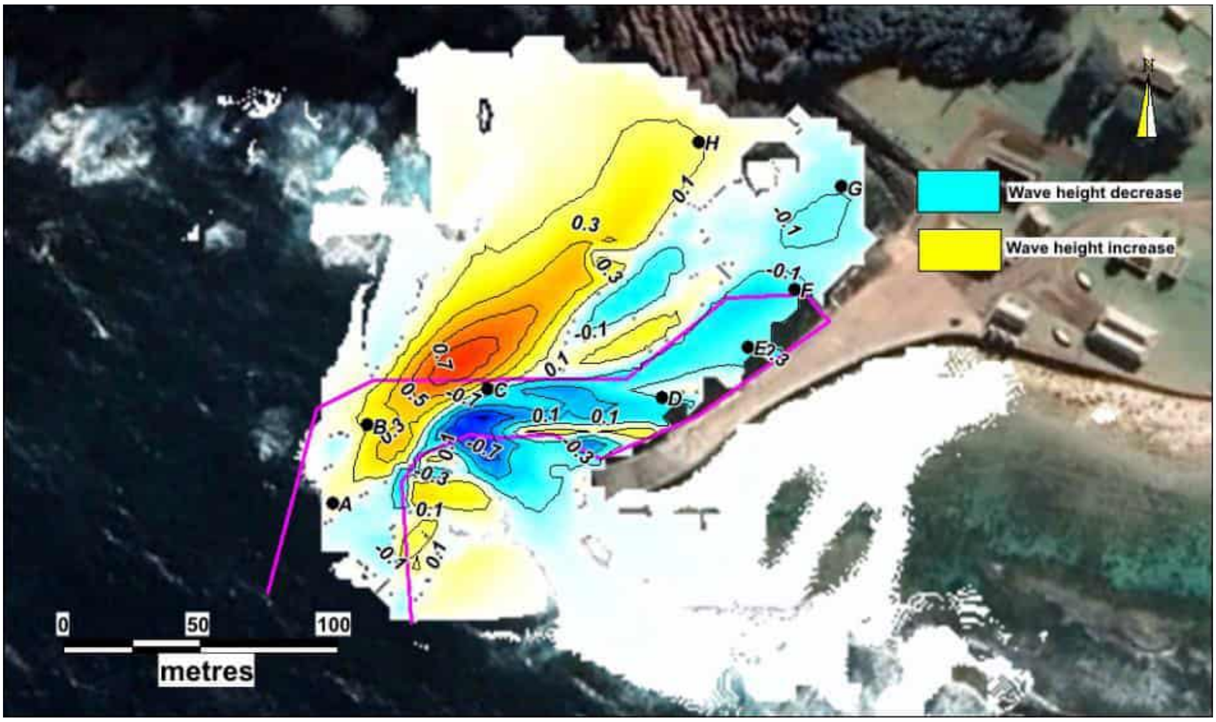


Figure 3-16 – Change in significant wave height (m), Option 3, Case 2 (SW offshore waves, 1 year ARI)

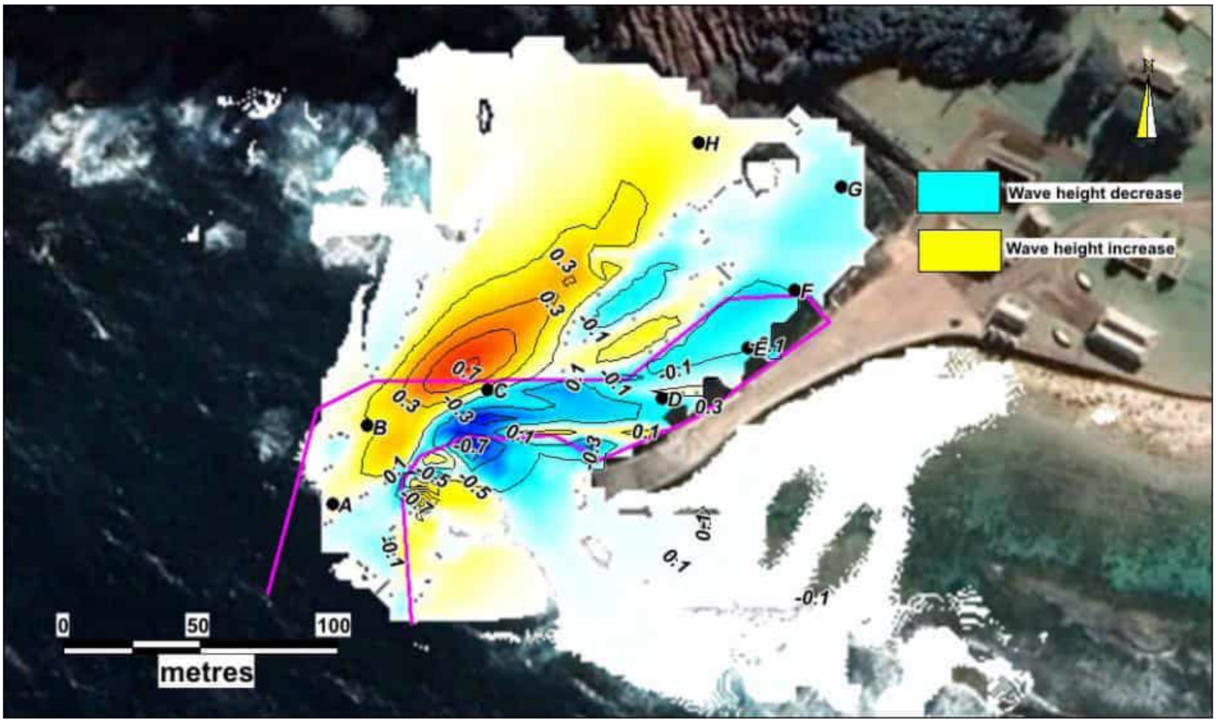


Figure 3-17 – Change in significant wave height (m), Option 3, Case 6 (SW offshore waves, median conditions)

3.5.4 Option 4

The change in significant wave height for Option 4, for the 1 year ARI (south-west offshore waves, Case 2), is shown in Figure 3-18. Under this option, there is an area of wave focussing that occurs near the berth at Point E and the surrounding area. Wave height is generally increased to the north and west of the channel but also within the boundary of the channel as shown in Figure 3-18.

For the median wave conditions for Option 4, in relation to median south-west offshore waves, the change in significant wave height is shown in Figure 3-19. For this case also, the wave height within the channel area is generally increased by around 0.1 m, with wave focusing occurring along the berth near Point E.

Table A-1 to A-4 in Appendix A show the modelled significant wave heights and percentage change in wave height when compared with existing conditions, for Case 2 and Case 6. For Option 4, these indicate that the significant wave height would increase at the berth (Point E) by 40% for the 1 year ARI, and up to 80% for median conditions. There would be a slight decrease in significant wave height in the area in front of the foreshore revetment to the west of the pier.

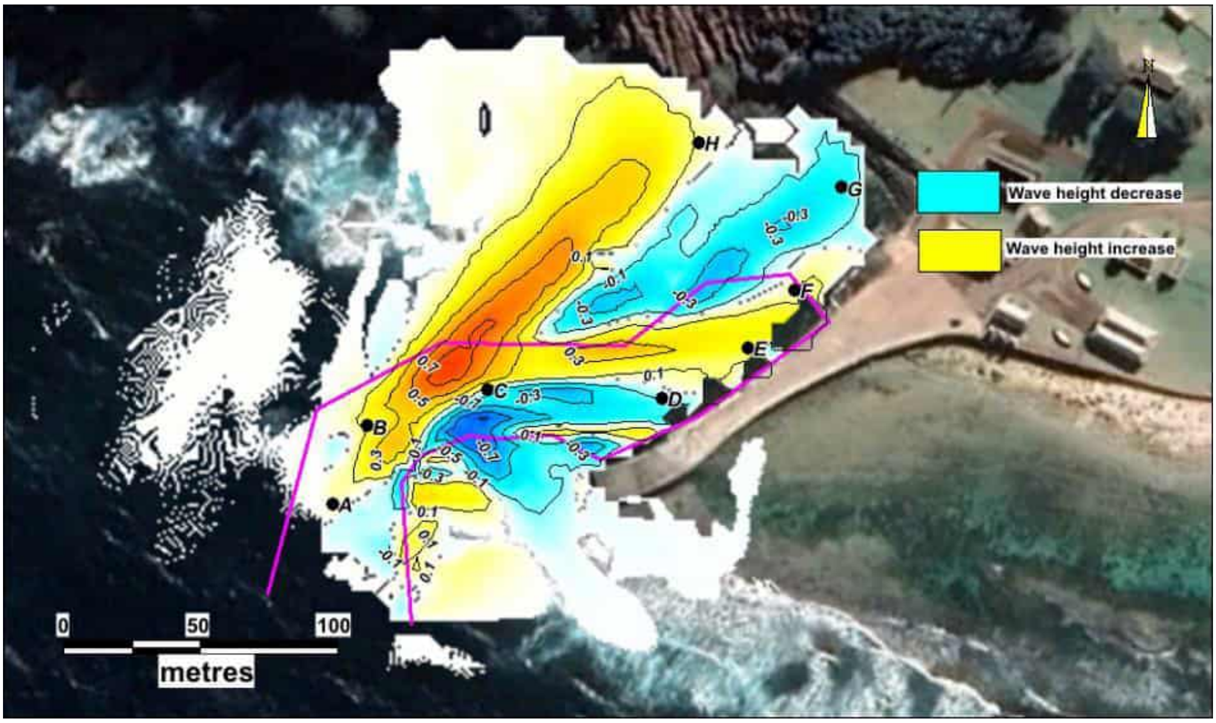


Figure 3-18 – Change in significant wave height (m), Option 4, Case 2 (SW offshore waves, 1 year ARI)

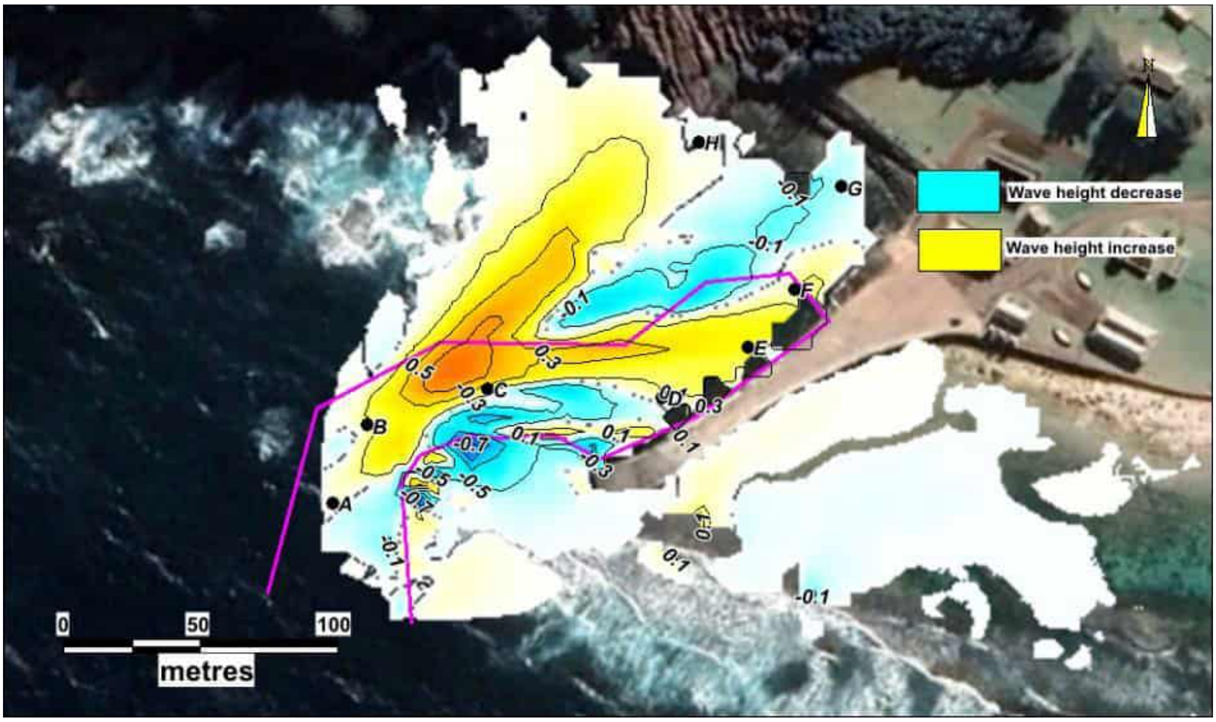


Figure 3-19 – Change in significant wave height (m), Option 4, Case 6 (SW offshore waves, median conditions)

3.5.5 Option 1a

The change in significant wave height for Option 1a, for the 1 year ARI (south-west offshore waves, Case 2), is shown in Figure 3-20. Wave height is generally decreased within the channel area but increased to the north and west of the channel.

For the median wave conditions for Option 1a, in relation to median south-west offshore waves, the change in significant wave height is shown in Figure 3-21. For this case also, the wave height within the channel area is generally decreased by around 0.1m, however, there is a localised focusing of wave energy near Point D, with an increase in significant wave height of around 0.1 m. The focusing around Point D is more pronounced than that observed under Option 1, but less pronounced than Options 2 and 4.

Table A-1 to A-4 in Appendix A show the modelled significant wave heights and percentage change in wave height when compared with existing conditions, for Case 2 and Case 6. For Option 1a, these indicate that the significant wave height would generally decrease within the channel for the 1 year ARI condition, with a decrease of 5% at Point D and 34% at Point E, and a decrease of 4% in front of the foreshore revetment to the west of the pier, but increase by 24% to the north. Under median conditions, there is a 20% increase in wave height at Point D, but a decrease elsewhere within the harbour. There are increases at Point C to the north of the channel, but there is a slight decrease of 4% in the area in front of the foreshore revetment to the west of the pier.

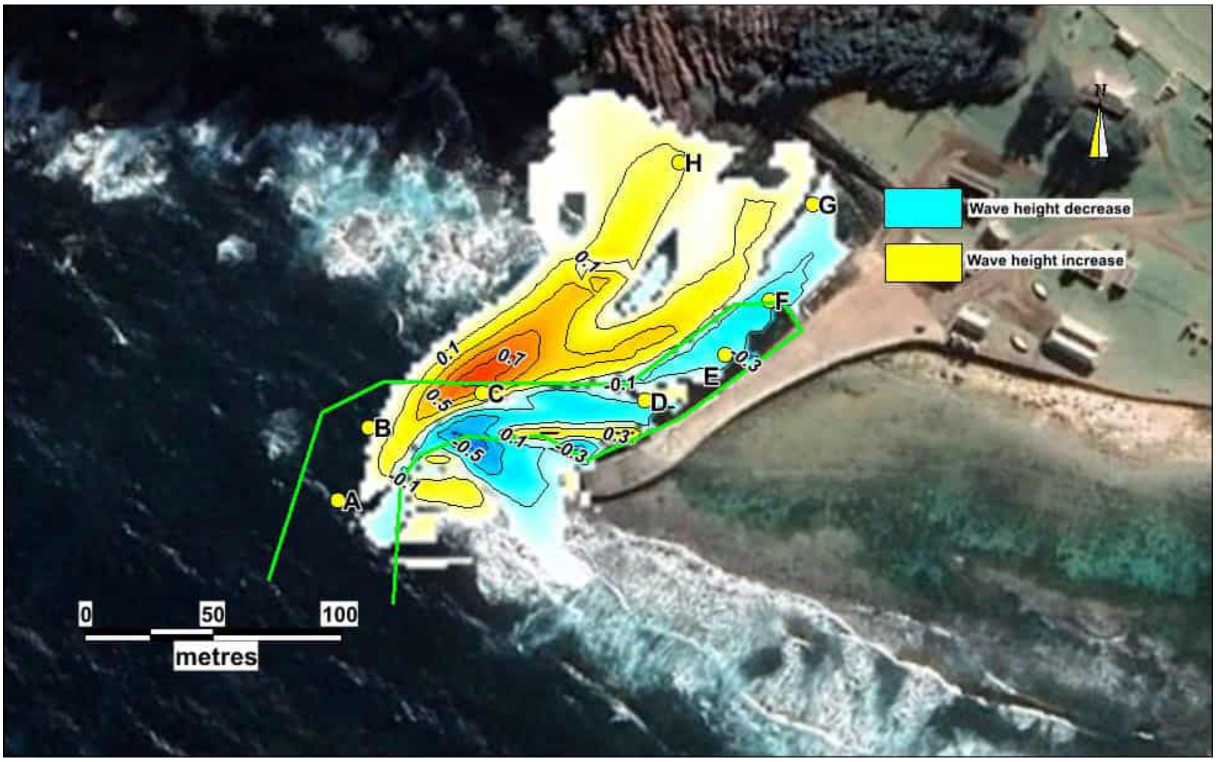


Figure 3-20 - Change in significant wave height (m), Option 1a, Case 2 (SW offshore waves, 1 year ARI)

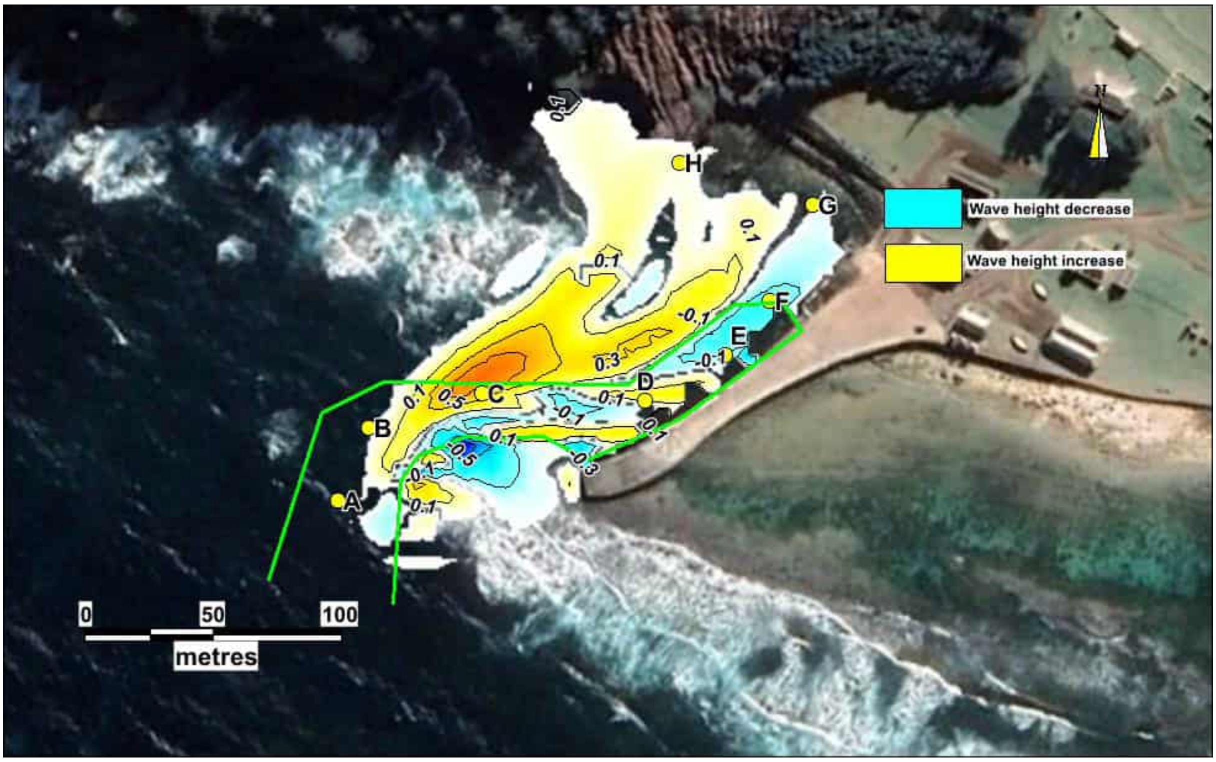


Figure 3-21 - Change in significant wave height (m), Option 1a, Case 6 (SW offshore waves, median conditions)

3.5.6 Option 3a

The change in significant wave height for Option 3a, for the 1 year ARI (south-west offshore waves, Case 2), is shown in Figure 3-22. Wave height is generally decreased within the channel area but increased to the north and west of the channel.

For the median wave conditions for Option 3a, in relation to median south-west offshore waves, the change in significant wave height is shown in Figure 3-23. For this case also, the wave height within the channel area is generally decreased by around 0.1 m. However, a slight focusing of wave energy is observed near Point D, with an increase in significant wave height of around 0,.04 m. There is also a decrease in significant wave height of 0.02 m in the area in front of the foreshore revetment near Point G. There are increases in the area north of the channel.

Table A-1 to A-4 in Appendix A show the modelled significant wave heights and percentage change in wave height when compared with existing conditions, for Case 2 and Case 6. For Option 3a, these indicate that the significant wave height would decrease within the channel at Point D for the 1 year ARI condition by around 12%, but would increase by 9% at Point D for the median condition. There would be large reductions in significant wave height at Point E and Point F under 1 year ARI as well as median conditions.

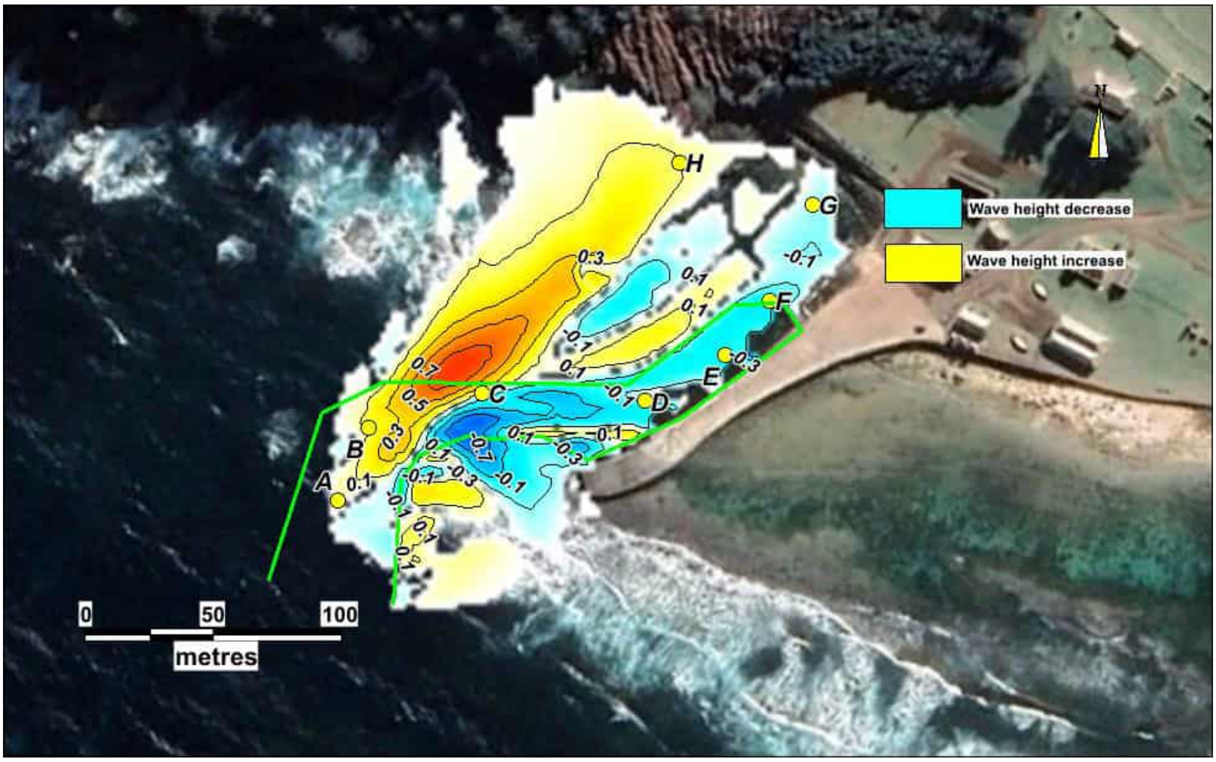


Figure 3-22 - Change in significant wave height (m), Option 3a, Case 2 (SW offshore waves, 1Y ARI conditions)

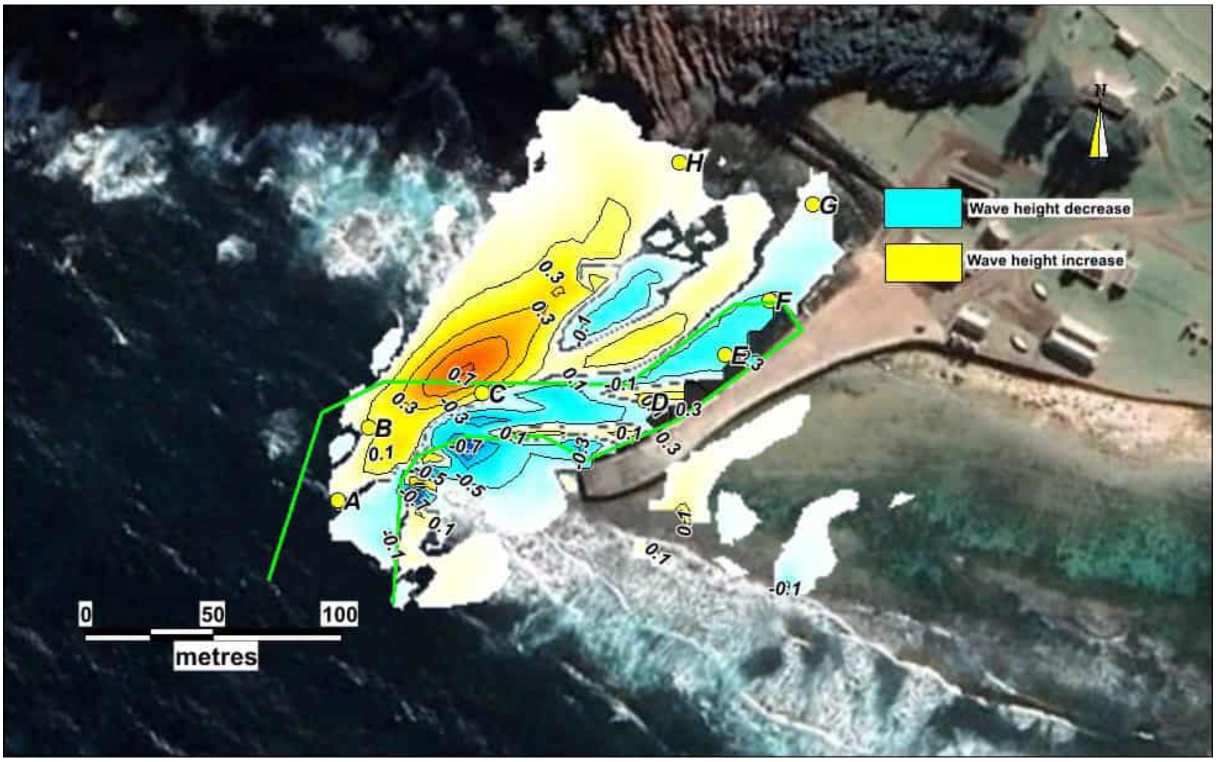


Figure 3-23 – Change in significant wave height (m), Option 3a, Case 6 (SW offshore waves, median conditions)

4 Discussion

The wave model results for median "day-to-day" conditions and the 1 year ARI storm event indicate that the existing wave climate in the harbour is such that operations at the pier are impacted (Kingston and Cascade Piers combined are generally usable 70% of the time).

However, the proposed works, particularly for Options 1 and 3, result in a general decrease in significant wave height within the berth area when compared with existing conditions, due in part to the retention of the rock reef and bombora at the entrance to the harbour as well as the orientation of the channel with respect to the incoming waves, which are subject to severe refraction and diffraction and can only approach the site from a limited range of directions. Additional wave energy does enter the harbour under the wider channel Options 2 and 4 and impacts on the pier at Points D and E, this can be seen clearly in Figure 3-14, Figure 3-15, Figure 3-18 and Figure 3-19. There is some slight focusing of wave energy at the berth at Point D under Option 1 and Option 1a in median conditions, but a general decrease elsewhere in the channel. Option 3a and Option 3 both resulted in a general decrease of similar magnitude within the berth area when compared with existing conditions.

4.1 Option 1

As shown in Figure 3-12 and Figure 3-13, wave height for Option 1 is generally decreased within the channel area but increased to the north and west of the channel, for both 1 year ARI and median offshore wave conditions. There is a small area of wave focussing under median conditions at Point D within the berth.

There is an increase in significant wave height at the foreshore revetment of around 10% predicted under Option 1. However, the orientation and shape of the channel for this Option results in refraction of much of the wave energy toward the north, away from the berth area under this option.

4.2 Option 2

As shown in Figure 3-14 and Figure 3-15, there is wave focussing predicted to occur at the berth, for both 1 year ARI and median offshore wave conditions. While there is generally the same pattern of wave refraction seen in Option 1, with wave energy refracted away from the channel toward the north, the wider channel geometry appears to have led to a larger portion of wave energy refracting back into the channel from the north, possibly due to features within the bathymetry in the area north of the channel.

4.3 Option 3

As shown in Figure 3-16 and Figure 3-17, wave height for Option 3 is generally decreased within the channel area but increased to the north and west of the channel, for both 1 year ARI and median offshore wave conditions.

There is also a decrease in significant wave height at the foreshore revetment of around 10% predicted under Option 3. As per Option 1, the orientation and shape of the channel for this Option results in refraction of much of the wave energy toward the north, away from the berth area under this option, for both the 1 year ARI and median wave conditions.

4.4 Option 4

As shown in Figure 3-18 and Figure 3-19, there is wave focussing predicted to occur at the berth, for both 1 year ARI and median offshore wave conditions. While there is generally the same pattern of wave refraction seen in Option 1, with wave energy refracted away from the channel toward the north, the wider channel geometry appears to have led to a larger portion of wave energy refracting back into the channel from the north, possibly due to features within the bathymetry in the area north of the channel.

4.5 Option 1a

As shown in Figure 3-20 and Figure 3-21, wave height for Option 1 is generally decreased within the channel area but increased to the north and west of the channel, for both 1 year ARI and median offshore wave conditions. There is a small area of wave focusing under median conditions at Point D within the berth.

There is a decrease in significant wave height at the foreshore revetment of around 4% predicted under Option 1a. While the orientation and shape of the channel for this Option results in refraction of some of the wave energy toward the north, away from the berth area under this option, there is similar focusing of wave energy occurring at the berth under median conditions, when compared with Option 1.

4.6 Option 3a

As shown in Figure 3-22 and Figure 3-23, wave height for Option 3a is generally decreased within the channel area but increased to the north and west of the channel, for both 1 year ARI and median offshore wave conditions. There is a small area of wave focusing under median conditions at Point D within the berth under median conditions.

There is also a decrease in significant wave height at the foreshore revetment of around 10% predicted under Option 3a in 1 year ARI conditions. As per Option 1, the orientation and shape of the channel for this Option results in refraction of much of the wave energy toward the north, away from the berth area under this option, for both the 1 year ARI and median wave conditions, albeit with some focusing of wave energy at the berth near Point D under median wave conditions.

4.7 Summary

Of the options modelled, Options that have narrower channel widths resulted in a decrease in the amount of wave energy entering the harbour, possibly due to severe wave refraction within the deepened channel. However, Options 2 and 4 did result in an increase in wave energy entering the harbour (with wave height increases of up to 100%), possibly due to the different geometry of the wider channel for these options allowing more energy to enter the harbour, or refraction around the bathymetric features of the area north of and adjacent to the channel.

The results indicate that the channel geometry (i.e. width and orientation) has more influence on the wave energy entering the harbour than does the channel bed elevation (i.e. Option 1 had a similar impact to Option 3, and Option 2 had a similar impact to Option 4).

Option 3 provided the most beneficial impact on wave height with reductions within the berth area and for the foreshore revetment, whereas Option 1 did result in a 10% wave height increase at the foreshore revetment and a small area of wave focusing under median wave conditions (though generally, a reduction in the harbour area). Options 2 and 4 resulted in significant wave height increases at the berth. Options 1a and 3a resulted in slight wave focusing at the berth near Point D under median conditions, and were generally similar to Options 1 and 3. Lower wave heights were achieved within the harbour area for Options 1a and 3a than for Options 2 and 4. Both Options 1a and 3a resulted in a slight decrease in significant wave height at the revetment.

While the results indicate some changes in wave energy as a result of the proposals, the changes are not expected to impact significantly on the existing foreshore erosion protection structures compared with existing conditions. However, it would be prudent to review the design and undertake an inspection of the rock revetment with respect to the predicted incident wave conditions to ascertain whether an upgrade would be warranted.

5 Conclusion and Recommendations

This report has presented a wave modelling investigation of the Kingston Pier and six options for the proposed channel upgrade works, to determine whether there is a risk that the works could increase wave heights in the channel by allowing more wave energy to enter the harbour.

The investigation developed a SWAN spectral wave model of Norfolk Island and the site in detail, with the model constructed at a fine enough resolution to be able to resolve changes in wave climate due to the proposed channel upgrade works. The model can be used to resolve wave climate at any site around Norfolk Island.

The model was run for existing conditions for median offshore swell waves from the full range of directions that could impact the site, as well as for the 1 year ARI wave conditions from a range of directions, for a high tide condition. It was found that under existing conditions, waves can penetrate into the harbour, although much of the wave energy is dissipated on a rocky reef at the entrance to the harbour. Of the six options modelled, Options 1, 1a, 3 and 3a appear to result generally in a decrease in the significant wave heights within the harbour area. Options 1a, 3 and 3a result in a slight decrease in significant wave height at the foreshore revetment, while Option 1 results in a small increase in wave height at the revetment.

The SWAN wave modelling presented in this report includes the important processes of wave refraction and wave setup which has provided a good comparative assessment of the impact of the various channel upgrade options. Boussinesq wave modelling, which resolves the wave phases and models wave reflections (e.g. from the pier face), would provide a more detailed picture of the wave climate within the berth.

6 References

Advisian (2020) "Kingston Pier Channel Construction Project: Basis of Design" Report 311015-00061 – MA-RP-0003 for Department of Infrastructure, Transport, Regional Development and Communications (DITRDC), March.

Nielsen, A. F. and Adamantidis, C. A. (2003) "A Field Validation of the SWAN Wave Transformation Program" Proc. Coasts and Ports Australasian Conference 2003.

WorleyParsons (2008) "Norfolk Island Wave Climate Study – Feasibility Stage" Report 5928.01, October.

Appendix A
Model Results

A.1 Model Results – Points A to H

The red values in the tables indicate an increase in significant wave height when compared with existing conditions, and the green values indicate a decrease.

Table 6-1 – Significant Wave Height (m) at Points A to H, 1 year ARI, SW offshore wave conditions (Case 2)

Case	A	B	C	D	E	F	G	H
2 (existing)	3.61	2.75	1.72	0.79	0.41	0.50	0.59	0.83
2 (Option 1)	3.61	2.76	2.13	0.75	0.23	0.43	0.63	0.94
2 (Option 2)	3.61	2.76	2.12	0.77	0.63	0.38	0.52	0.96
2 (Option 3)	3.66	2.90	1.78	0.70	0.29	0.35	0.50	0.94
2 (Option 4)	3.66	2.90	1.78	0.71	0.60	0.57	0.39	0.92
2 (Option 1a)	3.61	2.76	2.13	0.75	0.27	0.28	0.57	0.94
2 (Option 3a)	3.65	2.90	1.78	0.70	0.22	0.30	0.53	0.93

Table 6-2 – % Change in Significant Wave Height (m) at Points A to H, 1 year ARI, SW offshore wave conditions (Case 2)

Case	A	B	C	D	E	F	G	H
2 (existing)	3.61	2.75	1.72	0.79	0.41	0.50	0.59	0.83
2 (Option 1)	0%	0%	24%	-5%	-45%	-13%	6%	13%
2 (Option 2)	0%	0%	23%	-3%	53%	-23%	-12%	15%
2 (Option 3)	1%	5%	3%	-12%	-31%	-29%	-16%	13%
2 (Option 4)	1%	5%	3%	-10%	47%	14%	-34%	10%
2 (Option 1a)	0%	0%	24%	-5%	-34%	-44%	-4%	14%
2 (Option 3a)	1%	5%	4%	-12%	-45%	-40%	-11%	12%

Table 6-3 – Significant wave height (m) at Points A to H, median SW offshore wave conditions, (Case 6)

Case	A	B	C	D	E	F	G	H
6 (existing)	2.13	1.66	1.11	0.46	0.24	0.31	0.27	0.41
6 (Option 1)	2.13	1.67	1.53	0.56	0.11	0.25	0.30	0.43
6 (Option 2)	2.13	1.67	1.52	0.57	0.48	0.23	0.26	0.44
6 (Option 3)	2.15	1.74	1.32	0.50	0.14	0.22	0.24	0.43
6 (Option 4)	2.15	1.74	1.32	0.52	0.45	0.39	0.22	0.40
6 (Option 1a)	2.13	1.67	1.53	0.56	0.15	0.17	0.26	0.44
6 (Option 3a)	2.15	1.74	1.32	0.50	0.09	0.19	0.25	0.43

Table 6-4 – % Change in Significant wave height (m) at Points A to H, median SW offshore wave conditions, (Case 6)

Case	A	B	C	D	E	F	G	H
6 (existing)	2.13	1.66	1.11	0.46	0.24	0.31	0.27	0.41
6 (Option 1)	0%	0%	38%	21%	-53%	-19%	12%	7%
6 (Option 2)	0%	0%	37%	24%	97%	-28%	-2%	8%
6 (Option 3)	1%	5%	18%	8%	-43%	-30%	-9%	5%
6 (Option 4)	1%	5%	18%	12%	84%	23%	-19%	-2%
6 (Option 1a)	0%	1%	38%	21%	-36%	-46%	-4%	7%
6 (Option 3a)	1%	5%	19%	9%	-62%	-40%	-8%	4%

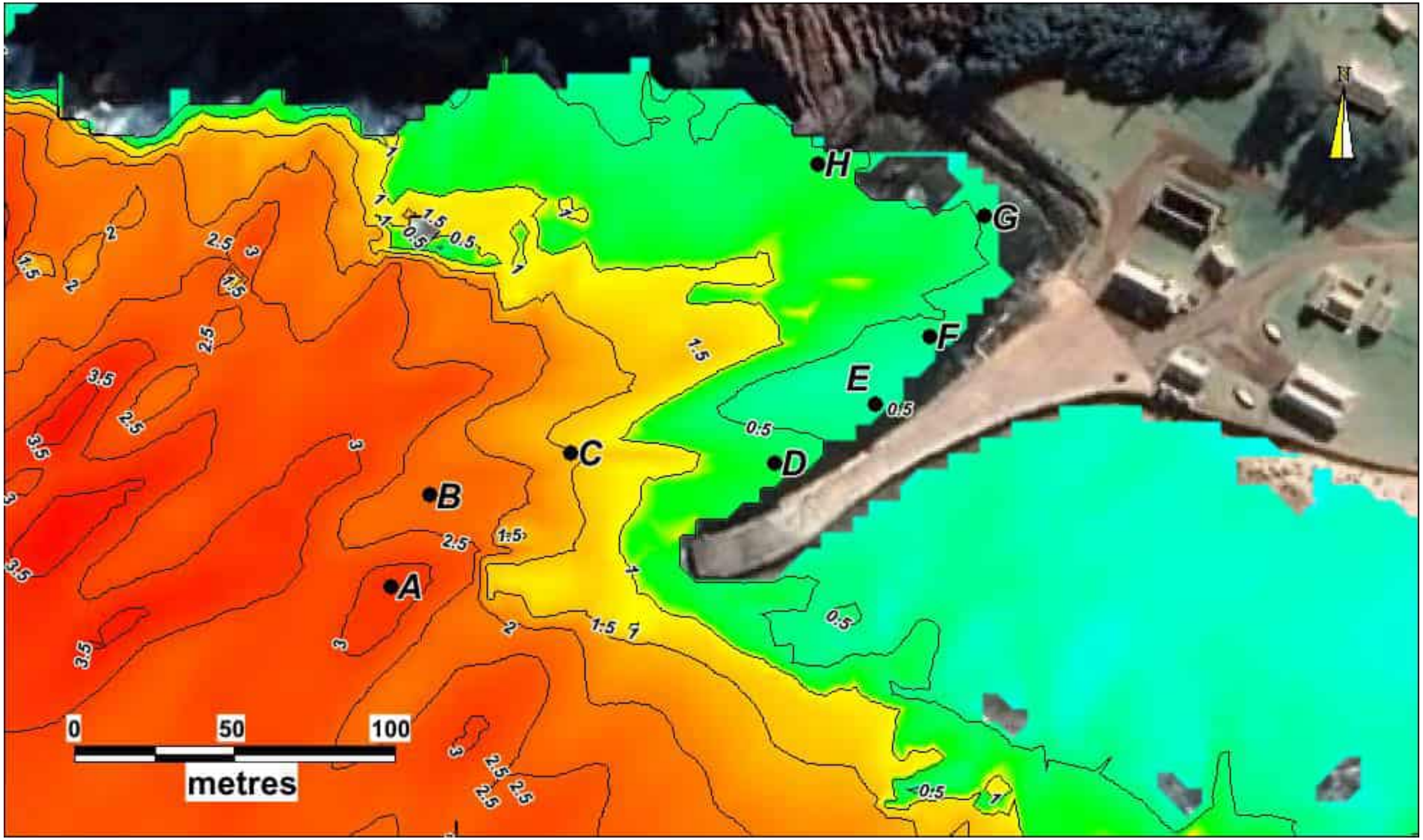


Figure A-1 – Existing significant wave height (m), Kingston Pier, Case 1 (1 year ARI, westerly waves)

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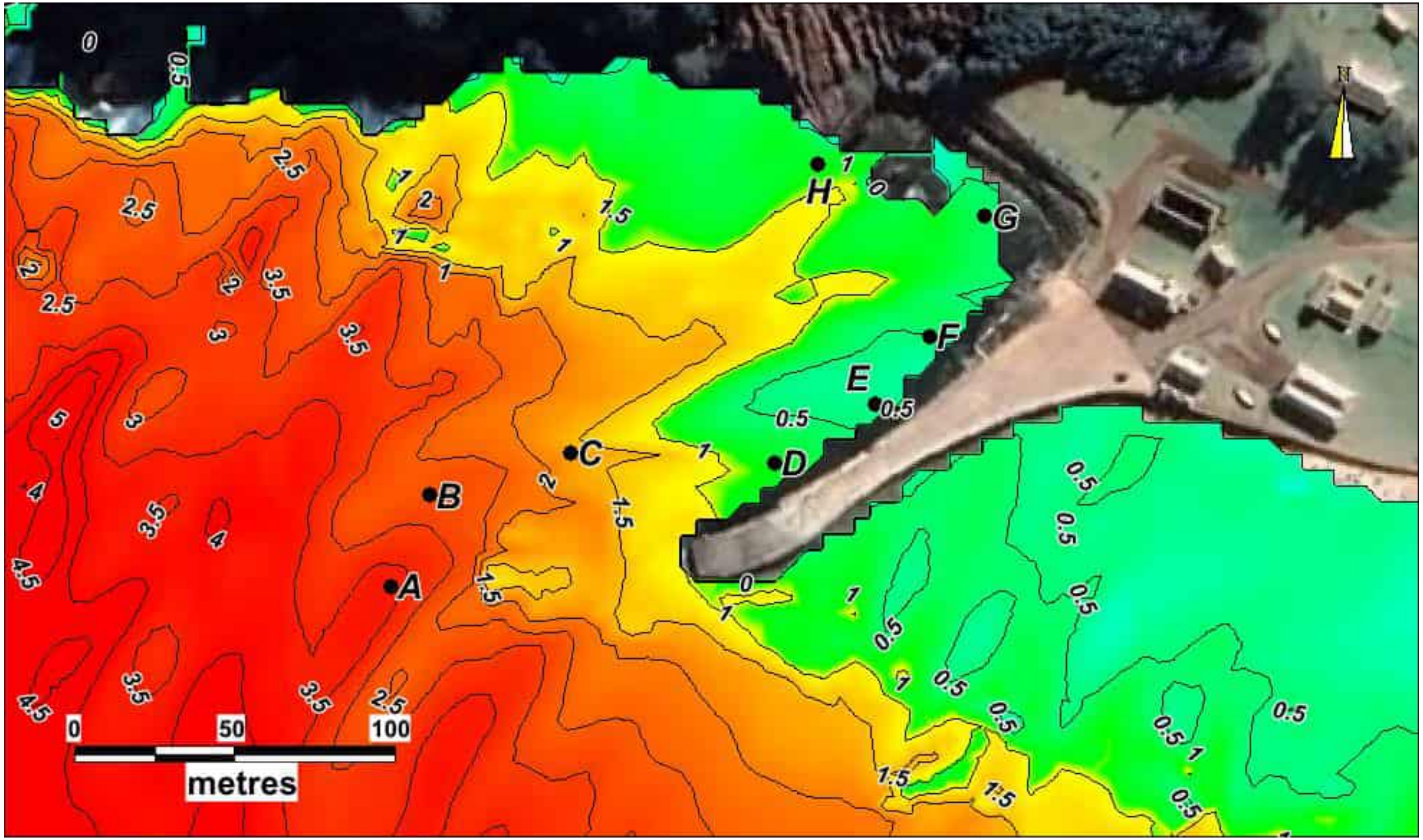

Figure A-2 – Existing significant wave height (m), Kingston Pier, Case 2 (1 year ARI, south-westerly waves)

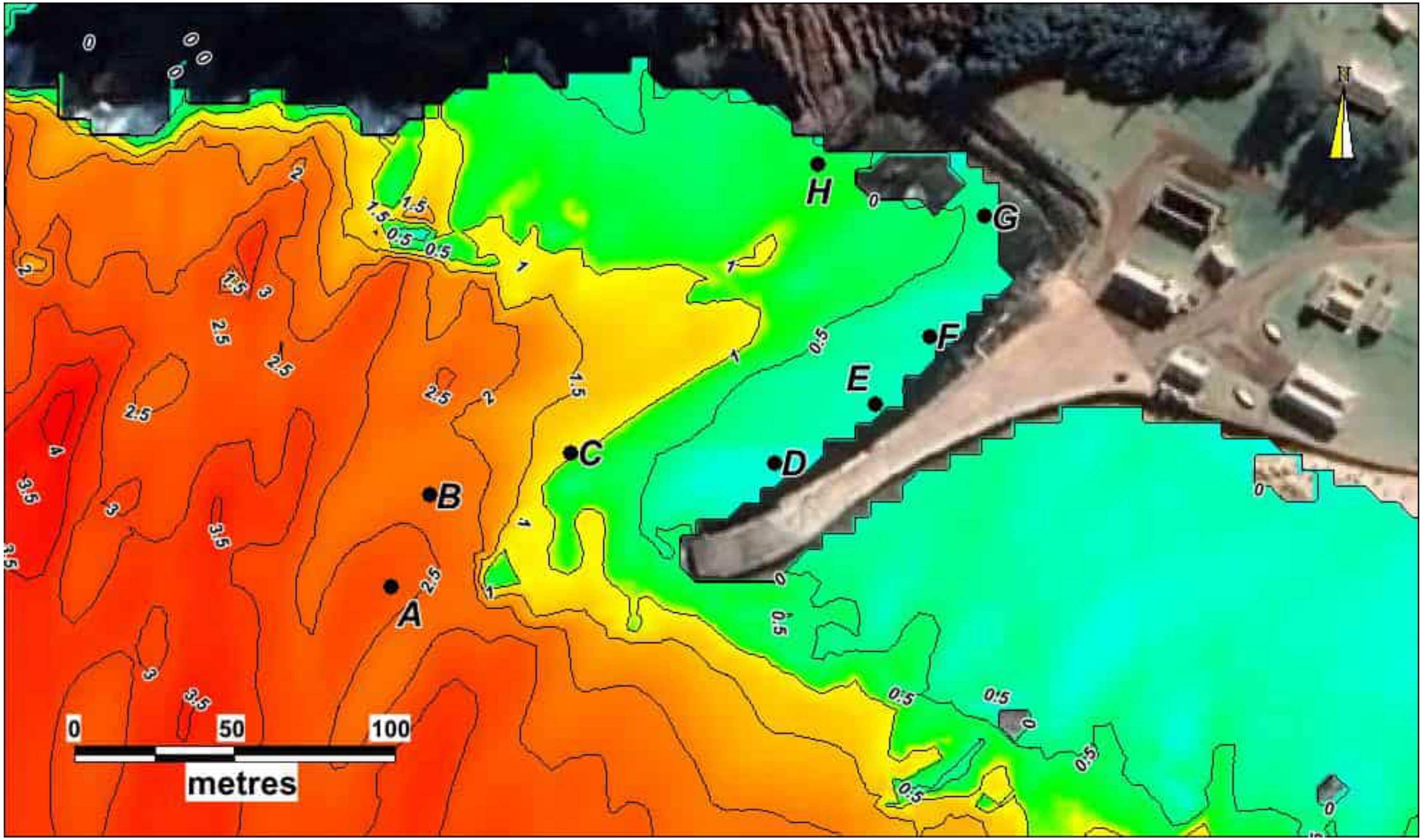

Figure A-3 – Existing significant wave height (m), Kingston Pier, Case 3 (1 year ARI, southerly waves)

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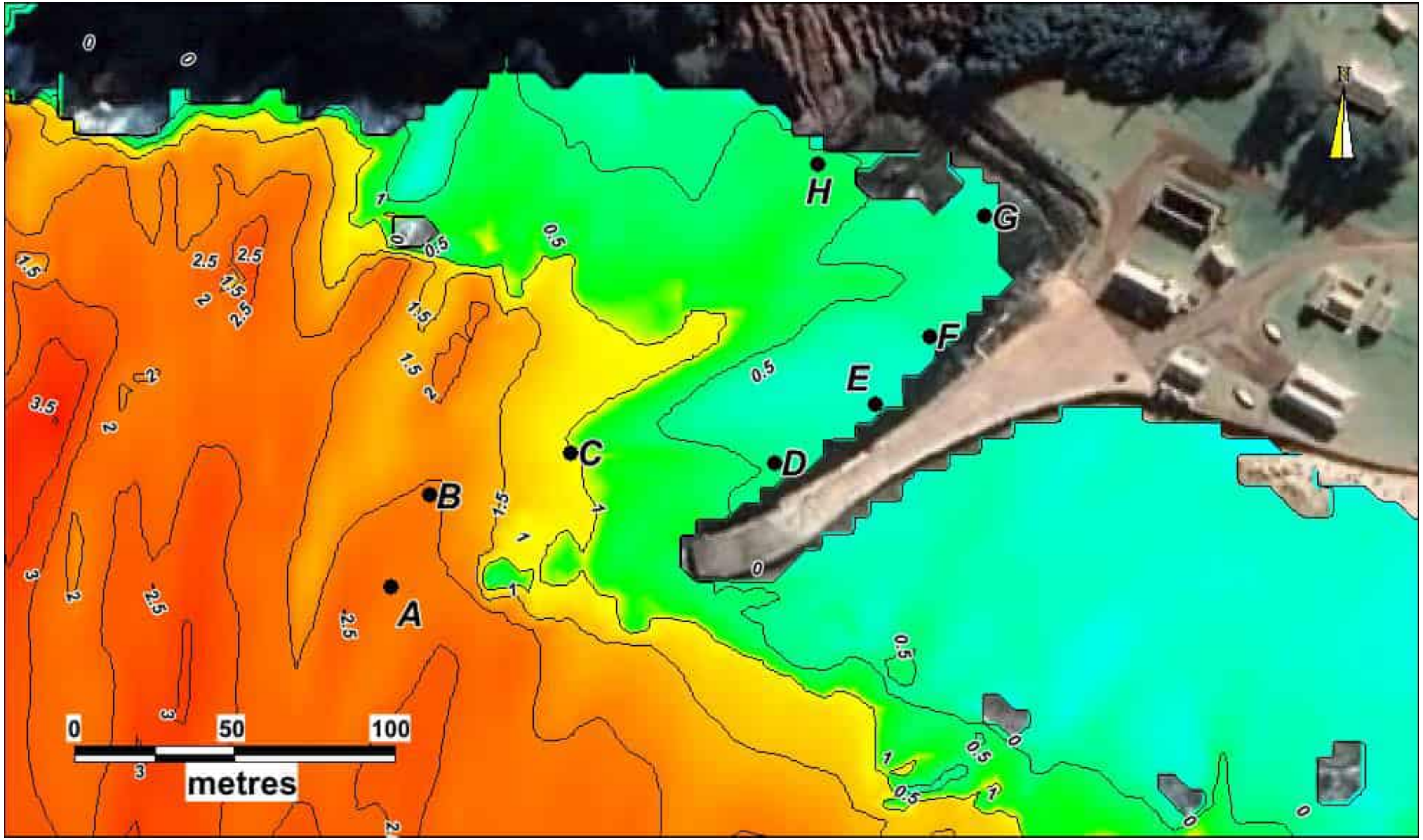


Figure A-4 – Existing significant wave height (m), Kingston Pier, Case 4 (1 year ARI, south-easterly waves)

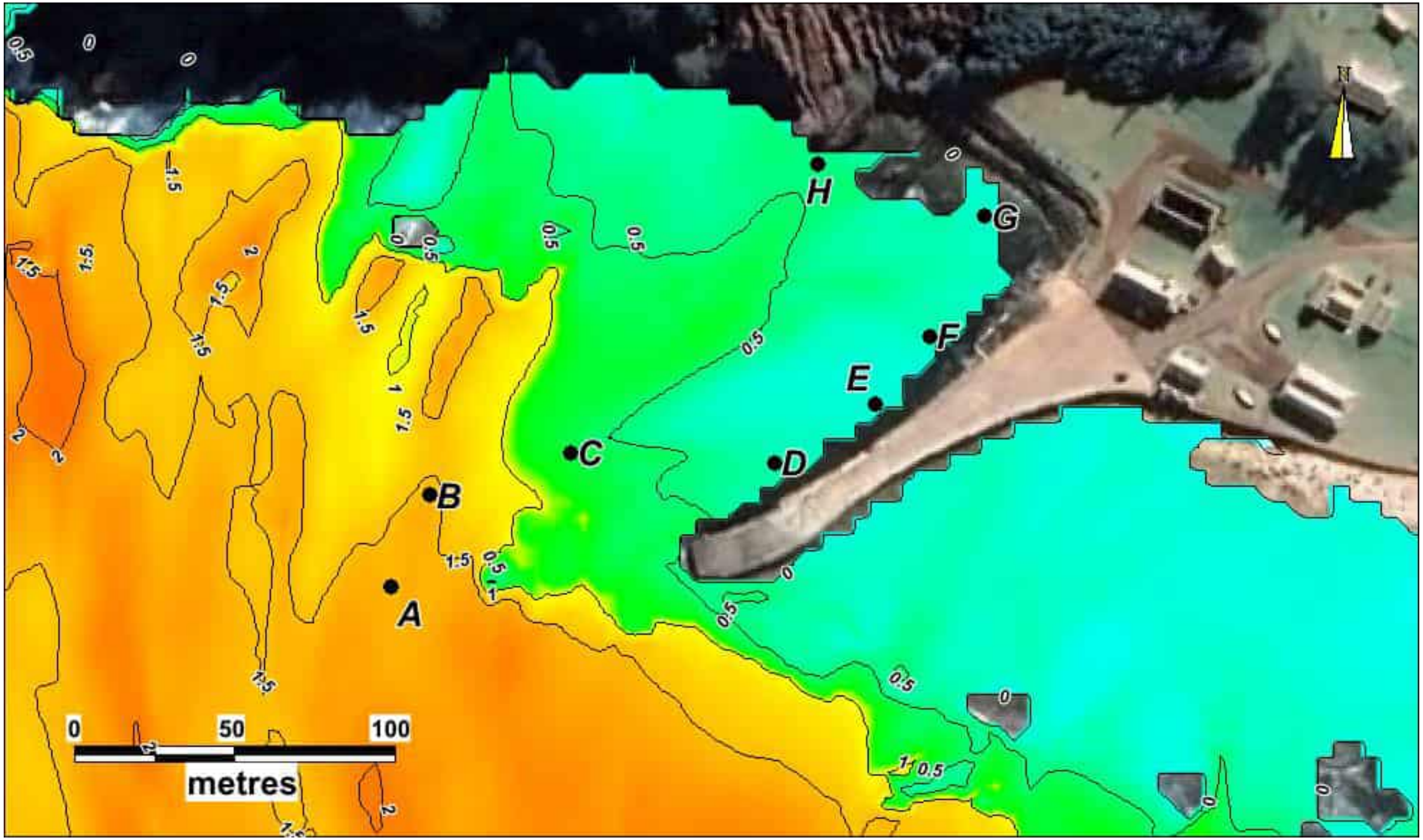


Figure A-5 – Existing significant wave height (m), Kingston Pier, Case 5 (1 year ARI, easterly waves)

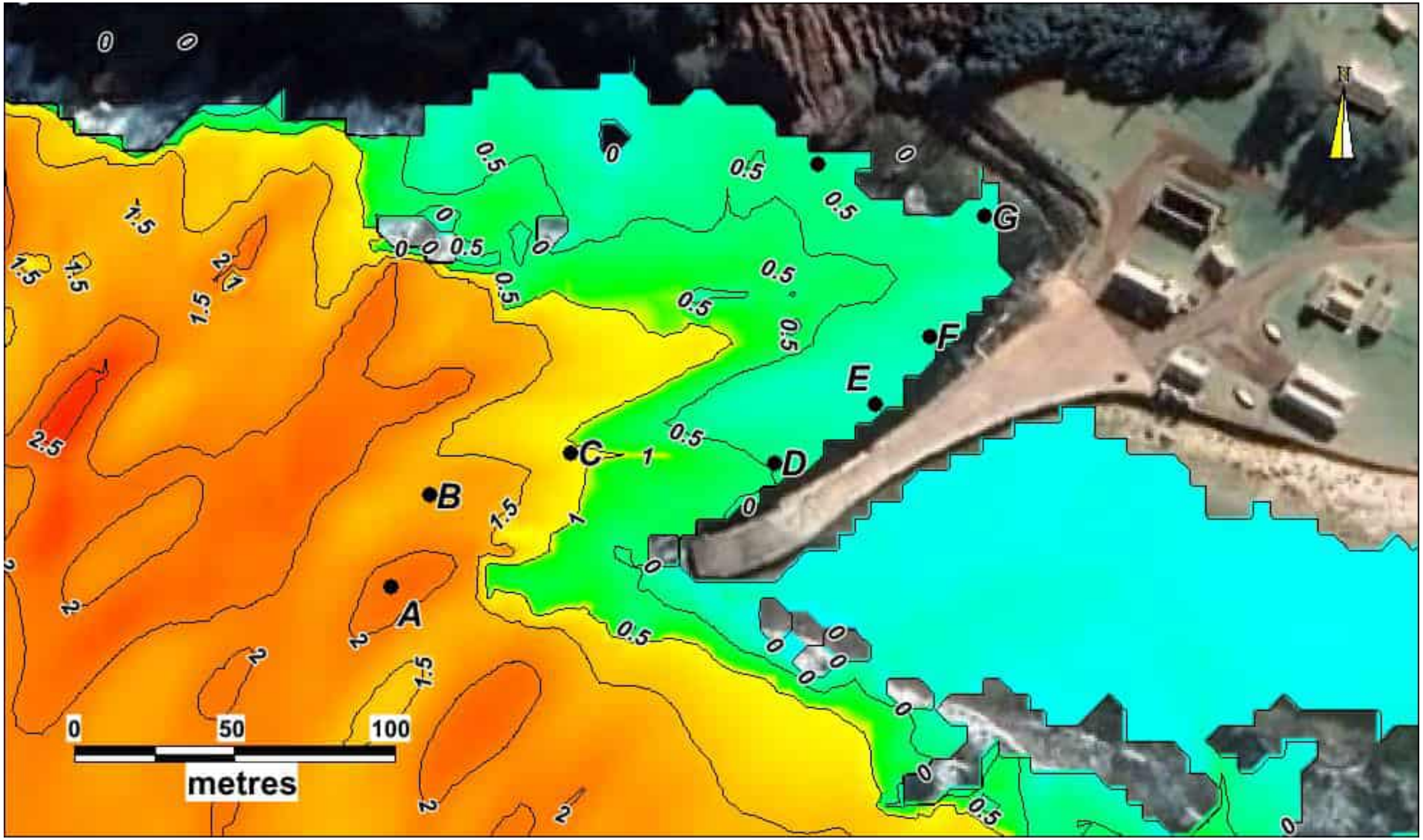


Figure A-6 – Existing significant wave height (m), Kingston Pier, Case 6 (median south-westerly waves)

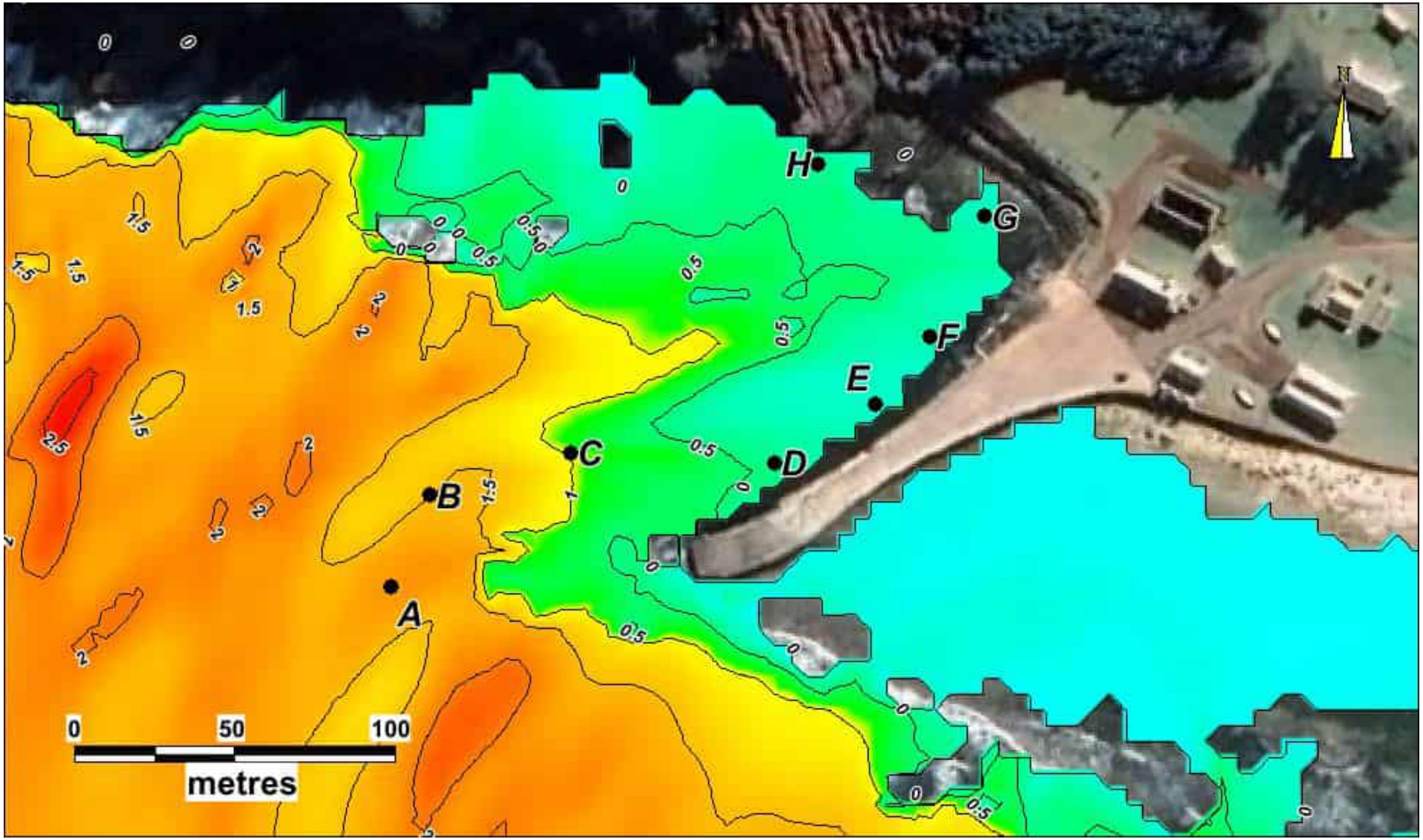


Figure A-7 – Existing significant wave height (m), Kingston Pier, Case 7 (median south-south-westerly waves)

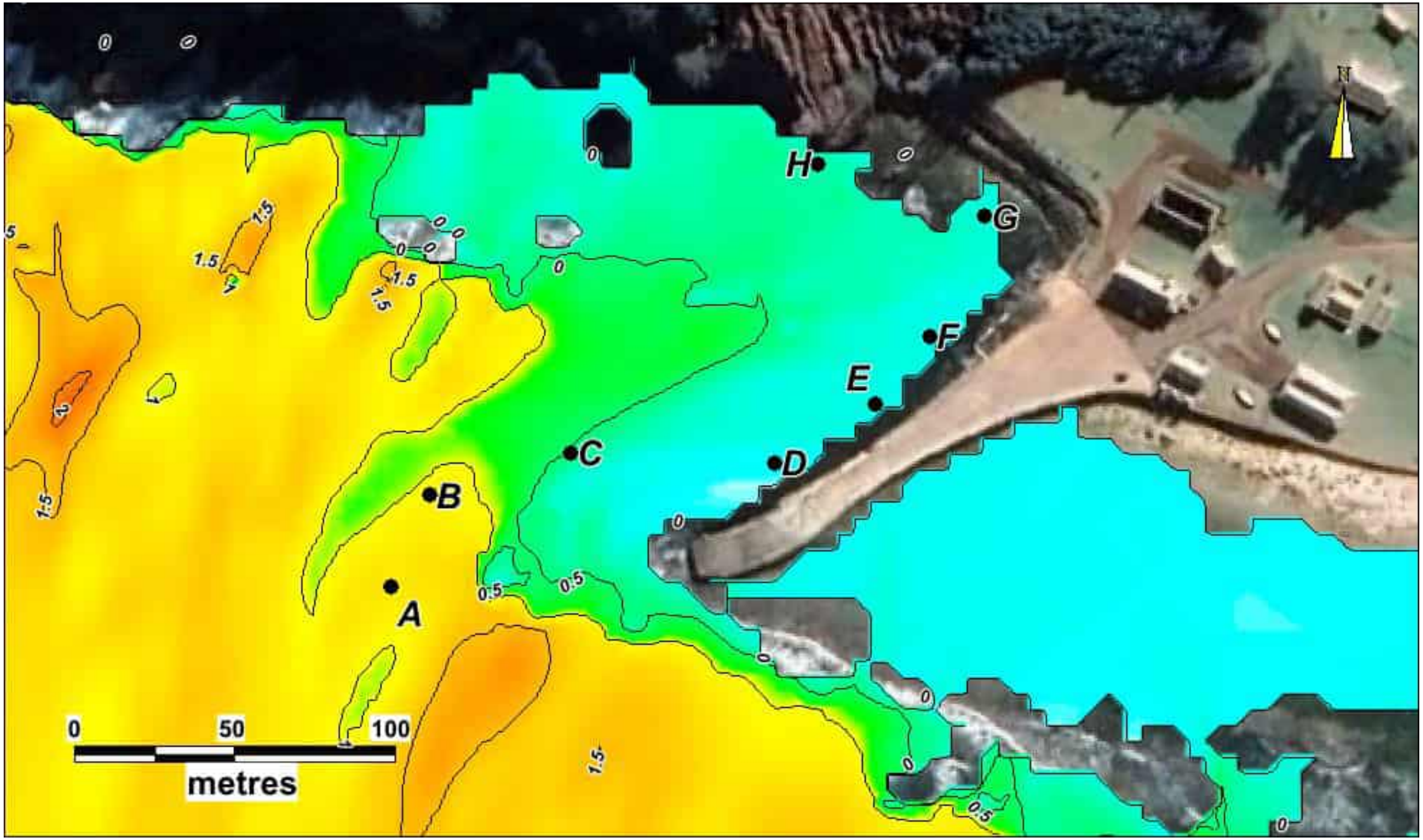


Figure A-8 – Existing significant wave height (m), Kingston Pier, Case 8 (median southerly waves)

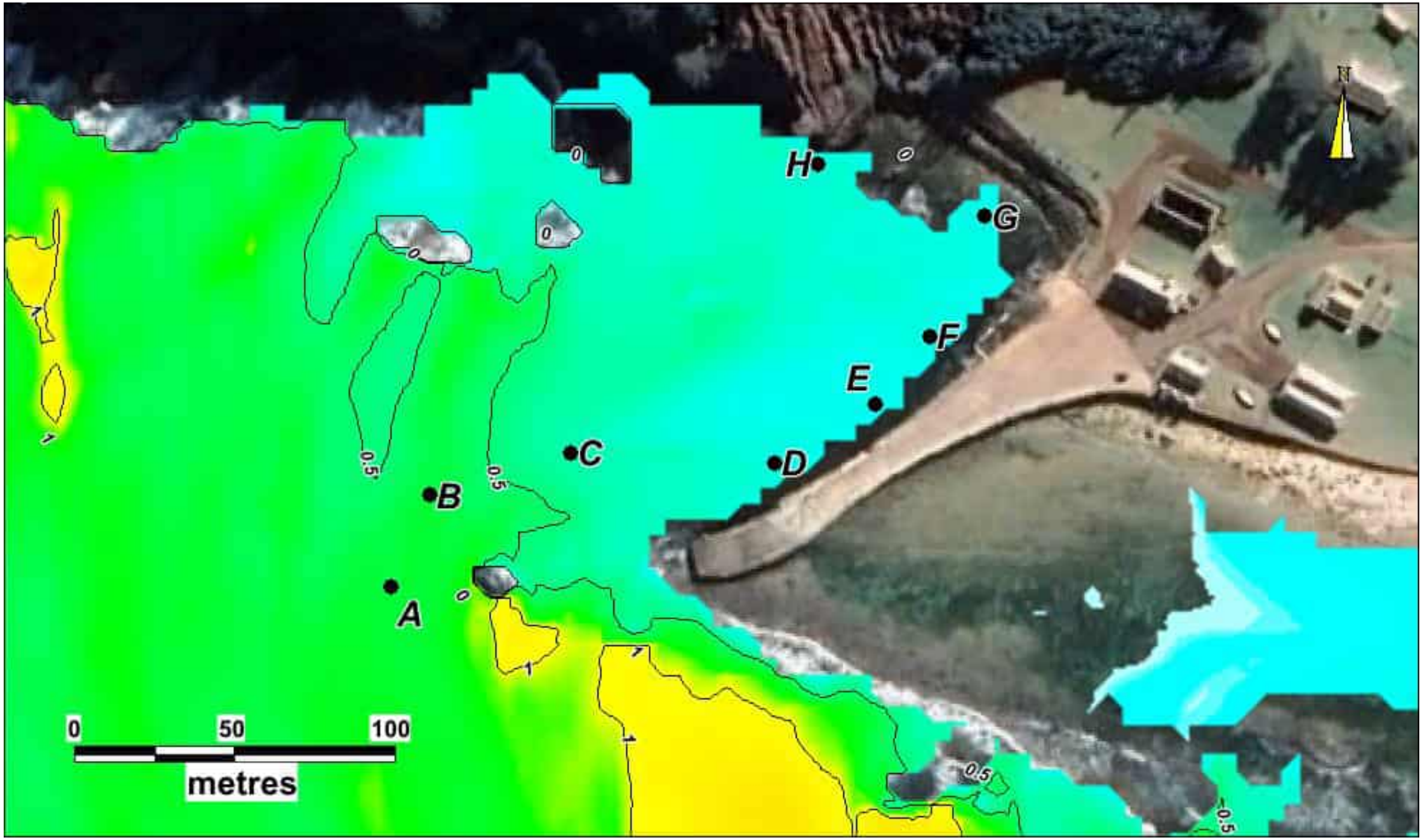
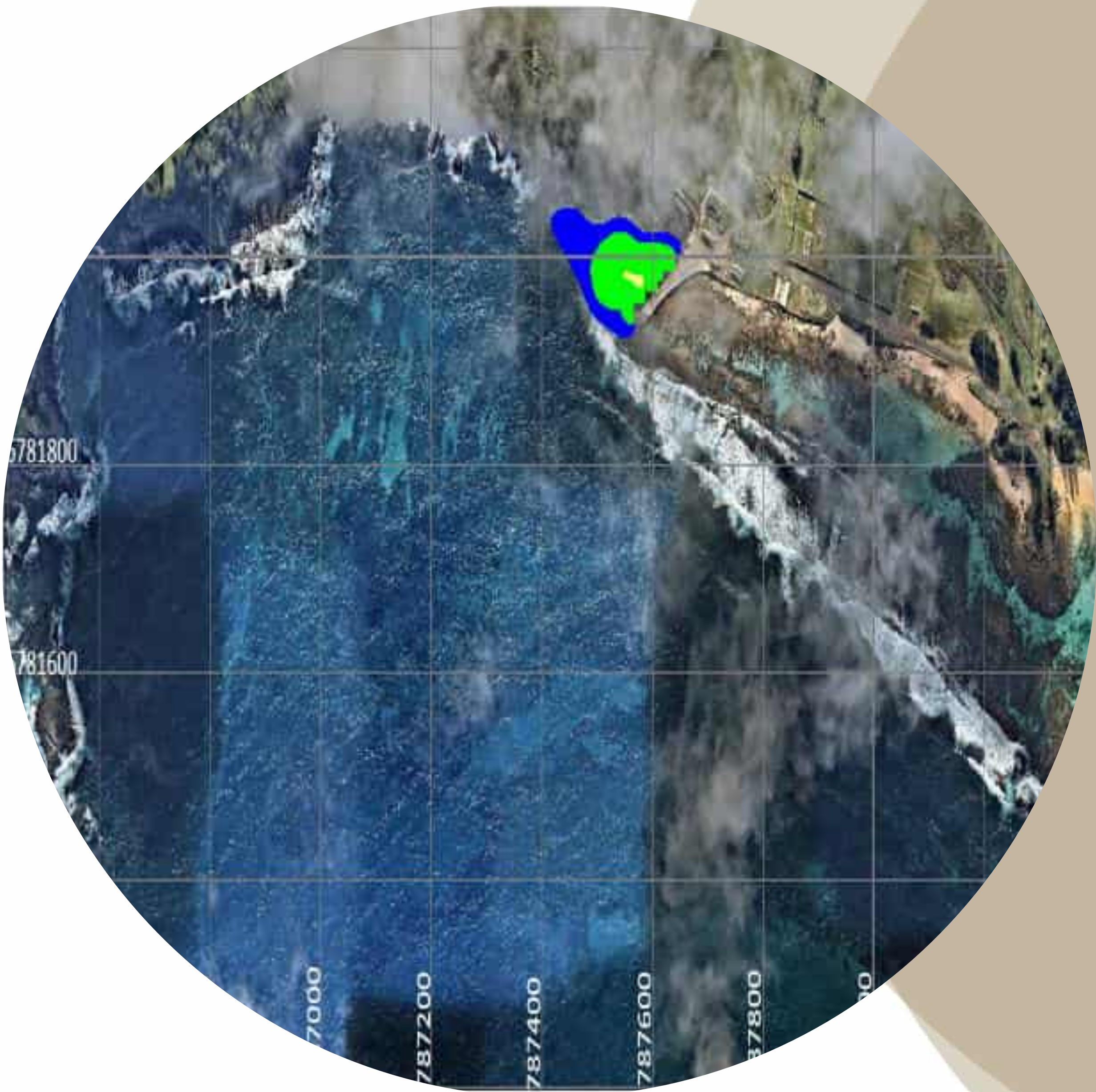


Figure A-9 – Existing significant wave height (m), Kingston Pier, Case 9 (median easterly waves)



Kingston Pier Channel Construction

Preliminary Dredge Plume Modelling

Department of Infrastructure, Transport, Regional Development and Communications

28 July 2021

311015-00061

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PROJECT 311015-00061 - CS-Rep-0001: Kingston Pier Channel Construction - Preliminary Dredge Plume Modelling

Rev	Description	Author	Review	Advisian approval	Revision date	Client approval	Approval date
A	Internal review	J Jiang	J Owen-Conway	B Morgan	01.04.21		Approval date
B	Issued for client review	J Jiang	B Morgan/C Adamantidis	B Morgan	09.04.21		
C	Issued as Final	C Adamantidis	B Morgan	B Morgan	12.05.21		
D	Re-Issued as Final	C. Adamantidis	B Morgan	B MorganB	28.07.21		

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Executive summary

Advisian has undertaken a Dredge Plume Modelling study to investigate the dispersion of sediments into the nearby marine area, as a result of the activities required for the Kingston Pier Channel Construction Project for Kingston Pier Harbour. The purpose of the study is to inform the Environmental Assessment to obtain environmental approval for the project under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The study has investigated the potential risk of dispersion of sediments into the nearby lagoon and fringing reef area, as a result of the dredging works for the deepening of the harbour.

The purpose of the modelling exercise was to understand:

- the potential distribution of sediment plumes that could be generated by the dredging
- the intensity of the sediment plumes
- seasonal effects on the suspension of material and sedimentation patterns in the vicinity of the harbour, to support the environmental assessment (EA).

Sediment plumes can be generated by dredging activities, which for this project would comprise a backhoe dredger mounted on a barge operating during daylight hours 5.5 days per week. The volume of material to be removed from the harbour is relatively small (up to 5,000 m^3) in the scheme of typical dredging projects and the disposal of the material is proposed to be onshore (as opposed to offshore sea disposal). The amount of sediment that can enter the water column as a result of the dredging depends on a number of factors that have been considered in the modelling, including:

- schedule of activities (date and time);
- location of the dredge plant;
- dredging method;
- spill volume (volume of material that is "spilled" into the water column during the dredging operation);
- properties of the sediment material (density, proportion of fine silts, settling velocity of the sediment particles); and,
- hydrodynamic conditions (waves, tidal and wind-driven currents).

When the sediment enters the water column at the site of the dredging, it is then dispersed by the action of waves, tidal and wind-driven currents, and can be carried away from the immediate project area. The full range of conditions that could be experienced at the site, based on analysis of historical measurements of waves, winds and currents, has been modelled to understand how far the sediment plume may travel from the dredging site, and whether there would be any settling of sediments outside the immediate project area as a result of the project. This exercise has informed the selection of a timeframe (or season) for undertaking the project activities to minimise the risk to the sensitive reef areas, as well as informing the daily operation of the dredging to minimise any impact.

Eight separate scenarios were examined, to understand the full range of possible wave and current conditions that can occur during the dredging period, and assess the full extent of dispersion and movement of the plumes away from the dredge site under the different conditions. The conditions examined included:

- **Scenario 1 (ambient wind, no waves)**- a baseline scenario simulated the dredge plume dispersion under *ambient* winds (or "everyday" wind speeds and directions) but without waves. This scenario provided a baseline for comparison between the other scenarios and to understand the sensitivity of the model without waves. This scenario does not represent real world conditions but does demonstrate the positive effect of waves containing a sediment plume

- **Scenario 2 (ambient wind, ambient waves)**- ambient winds from all directions and with *ambient* (or everyday) waves. These are considered typical conditions that can be expected at the site and represent the most likely scenario that may occur during the dredging campaign.

- **Scenario 3, 4, 5 and 6 (strong winds from the north, south, east and west respectively, no waves)** – these scenarios used an extreme (95th percentile) wind speed coming from the north, south, east and west and without including the impact of waves ,and therefore are conservative. The purpose of these scenarios was to determine which wind directions could result in the plume moving toward the reef and lagoon areas, and to inform which wind directions should be tested with the inclusion of waves. From these scenarios. northerly and westerly winds were found to have the greatest potential for movement of sediments toward the lagoon area The scenarios that modelled winds from the south and east demonstrated little to no potential for sediment to move towards the lagoon area and therefore were not investigated further.

- **Scenario 7 and 8 (strong winds from the north and west respectively, ambient waves)** – these scenarios investigated the effect of *ambient* waves on Scenarios 3 and 6, for northerly and westerly winds, thus representing a realistic "worst-case scenario" representation of real-world conditions during the dredging period.

Note that dredging is unlikely to occur when wave conditions are greater than ambient, and are therefore not necessary to be modelled. Further, as application of ambient wave conditions in Scenarios 7 and 8 has been shown based on the results of the modelling to reduce the extent of the plume, for wave conditions greater than ambient the dispersion of the plume and hence the extent of the plume would be reduced further and no sedimentation would occur.

Predictions of the sediment plume dispersion patterns have been extracted from the dredge dispersion model for the simulated scenarios. Results are presented for the entire simulation period as spatial plots of suspended sediment concentration (SSC, also referred to as Total Suspended Solids) and sedimentation.

SSC is presented as milligrams per liter. It is noted that at SSC concentrations below 10 mg/L, the plume would not be visible to a casual observer. The appearance of turbid water with varying concentrations of SSC is illustrated in Figure E1. Predictions of the sedimentation over the course of the dredging operation are presented as millimeters above seabed.

Figure E1 Visual representation of suspended sediment concentration

Predictions of the suspended sediment dispersion and concentration over the course of the dredging operation have been illustrated in the model results on statistical analysis with the trigger values i.e. *80th percentile* (i.e. suspended sediment concentrations and sedimentation that would only be exceeded 20% of the time during the dredging campaign) and *95th percentile* (exceeded only 5% of the time during the dredging campaign).

The main findings of the dredge plume model are listed below.

Scenario 1 (Figures E2 and E3)

With the proposed dredging method and time frame, the baseline scenario (under ambient wind without waves) has predicted that the dredge plume is retained within the Kingston harbour (up to 30mg/L and 100mg/L for the 80th and 95th percentile, respectively). For the 80th percentile, there is no plume detected for lagoon and coral areas. For 95th percentile, a limited level plume (less than 10 mg/L) was detected by the model in the edge of north-west part of lagoon, away from the fringing reef area.

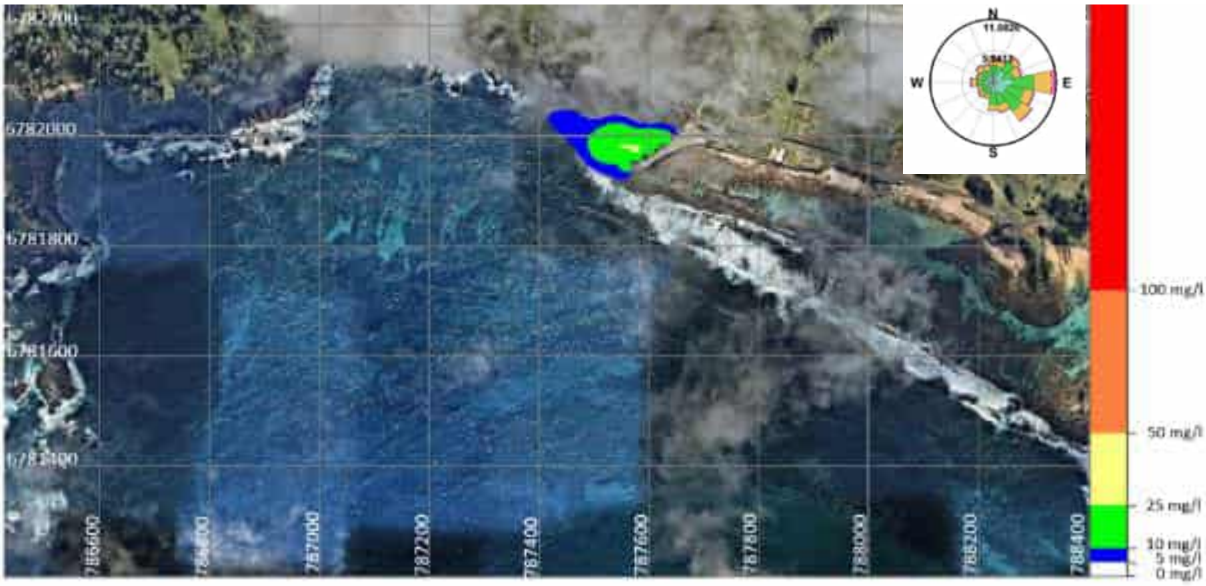

Figure E2 80th%ile Suspended sedimentation concentration distribution for Scenario 1 (ambient wind and no waves, wind rose for November shown)

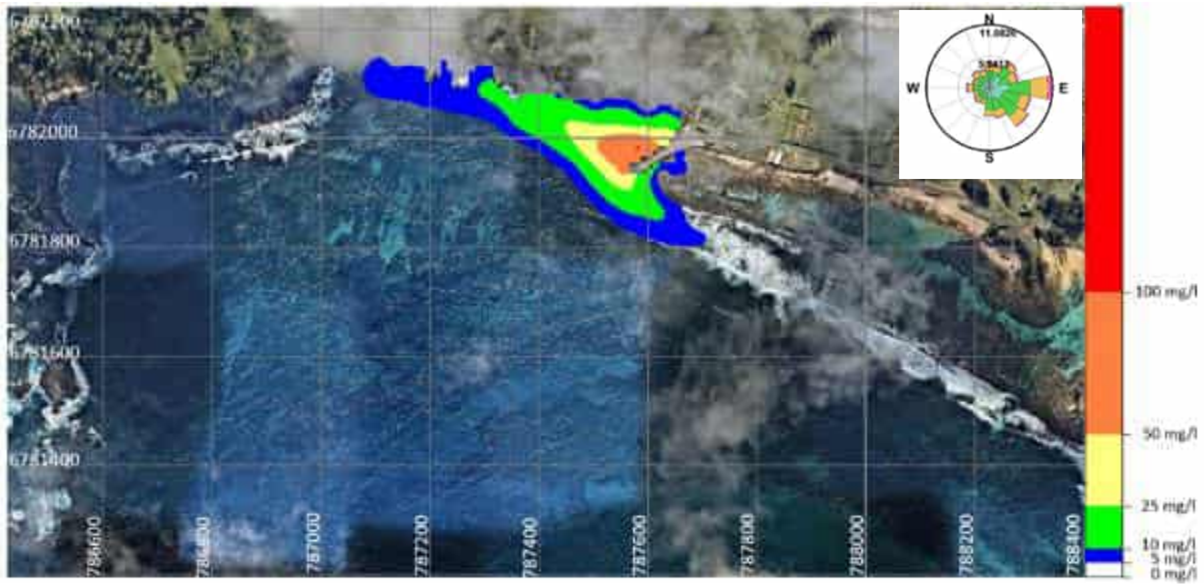

Figure E3 95th%ile Suspended sedimentation concentration distribution for Scenario 1 (ambient wind and no waves, wind rose for November shown)

Scenario 2 (Figures E4 and E5)

When ambient waves are included in the simulation (representing the real weather and hydrodynamic situation during the dredging operation, (i.e. most likely scenario to occur during the dredging campaign), there is no plume detected for lagoon and coral reef areas for both 80th and 95th percentile.

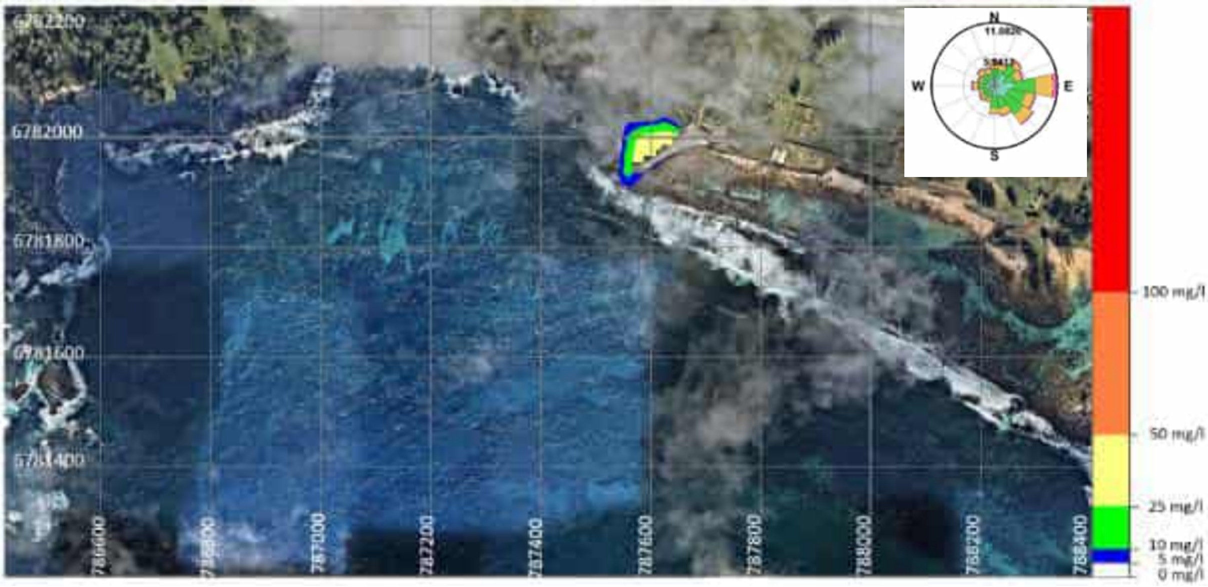

Figure E4 80th%ile Suspended sedimentation concentration distribution for Scenario 2, most likely scenario (ambient wind and waves)

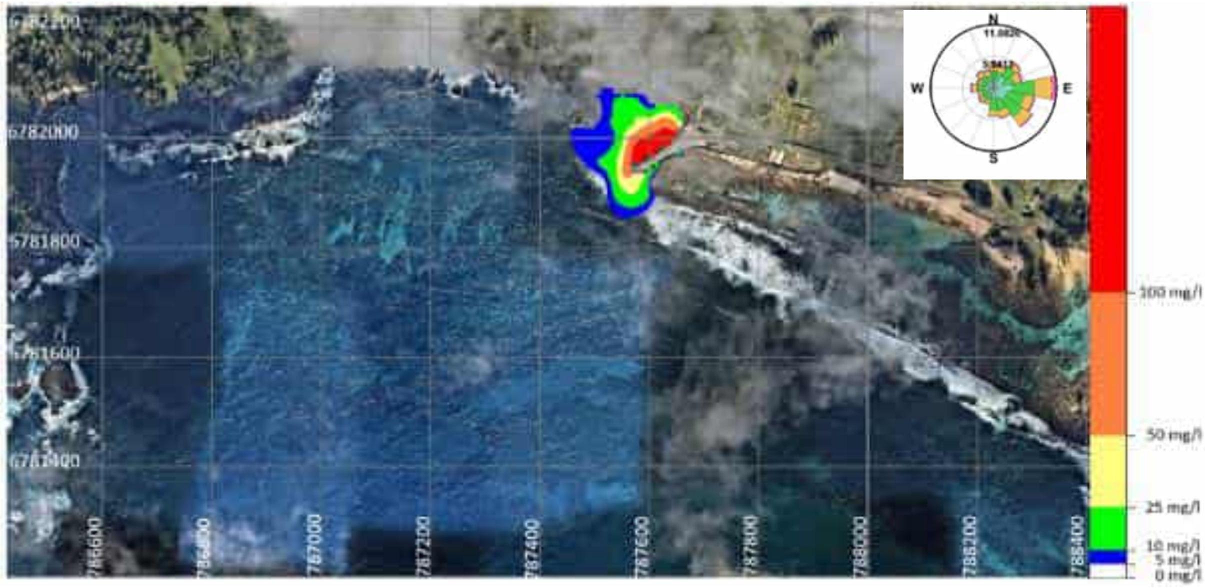

Figure E5 95th%ile Suspended sedimentation concentration distribution for Scenario 2, most likely scenario (ambient wind and waves)

Scenarios 4 and 5 (Figures E6 to E9)

Under energetic meteorological conditions with strong winds from the south and east directions, the dredge plume model indicates no dredge plume detected for lagoon and reef areas for the 80th and 95th percentiles. The dredge plume is generally contained to the nearshore area west of the pier. These modelled scenarios do not include the effects of waves they are thus conservative as the plume would be more contained under real world conditions. As such, these conservative results are considered acceptable to the Project and further refinement of these scenarios has not been undertaken.

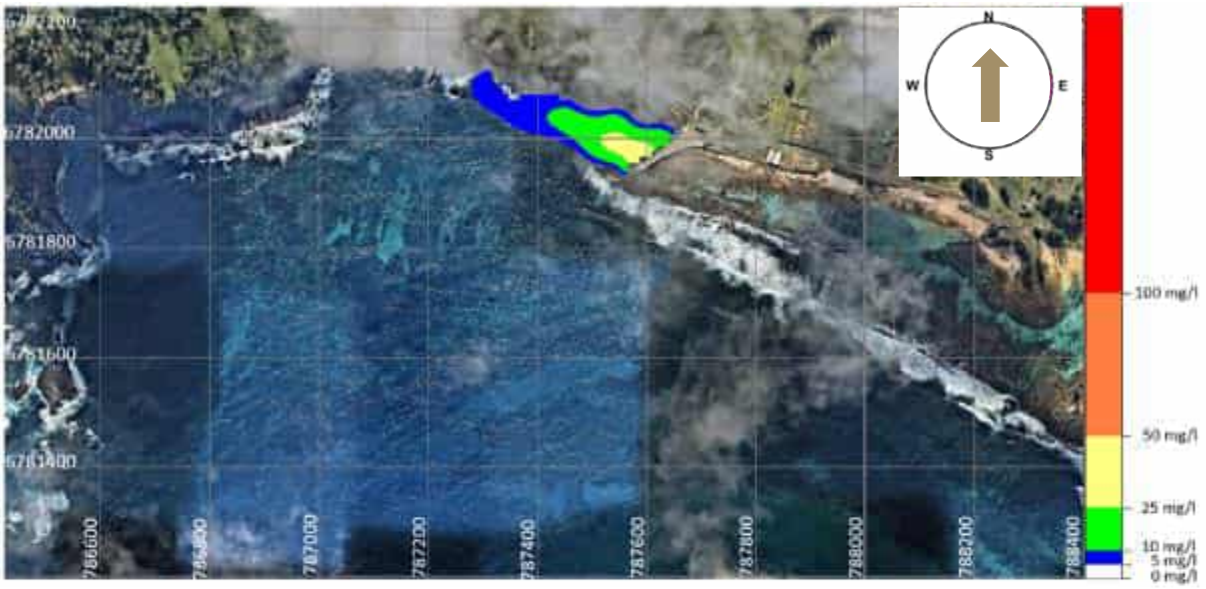

Figure E6 80th%ile Suspended sedimentation concentration distribution for Scenario 4 (strong south wind, no waves)

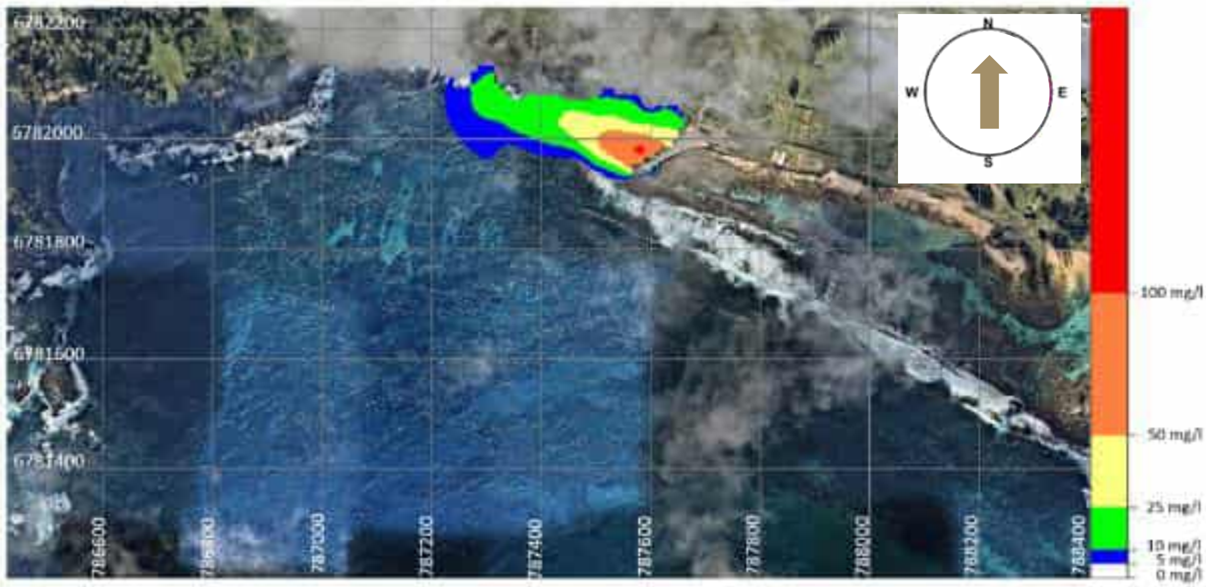

Figure E7 95th%ile Suspended sedimentation concentration distribution for Scenario 4 (strong south wind, no waves)

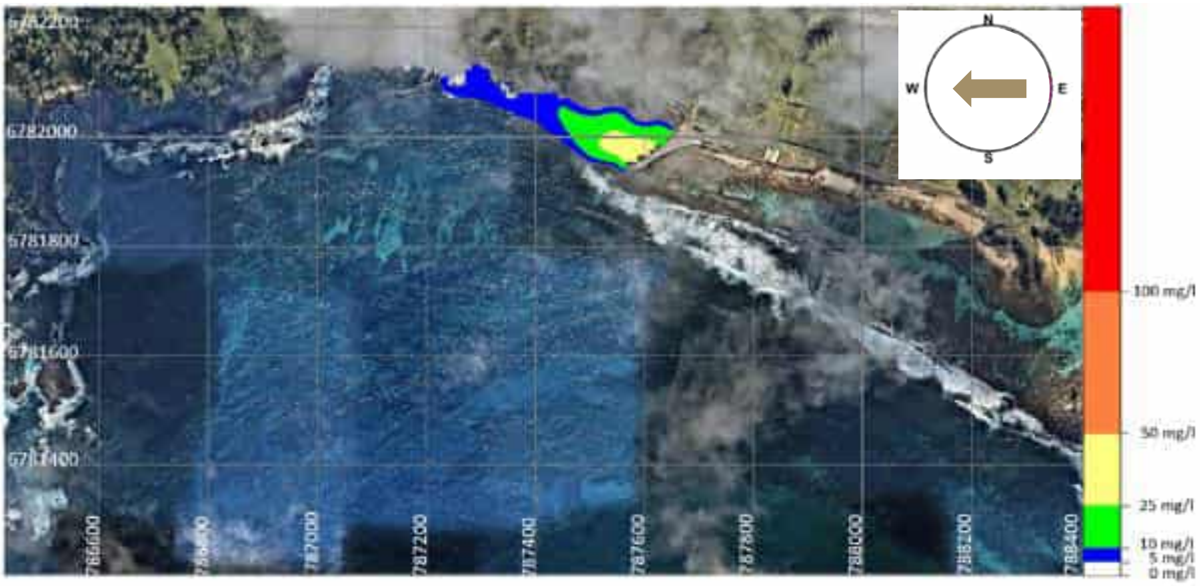

Figure E8 80th%ile Suspended sedimentation concentration distribution for Scenario 5 (strong east wind, no waves)

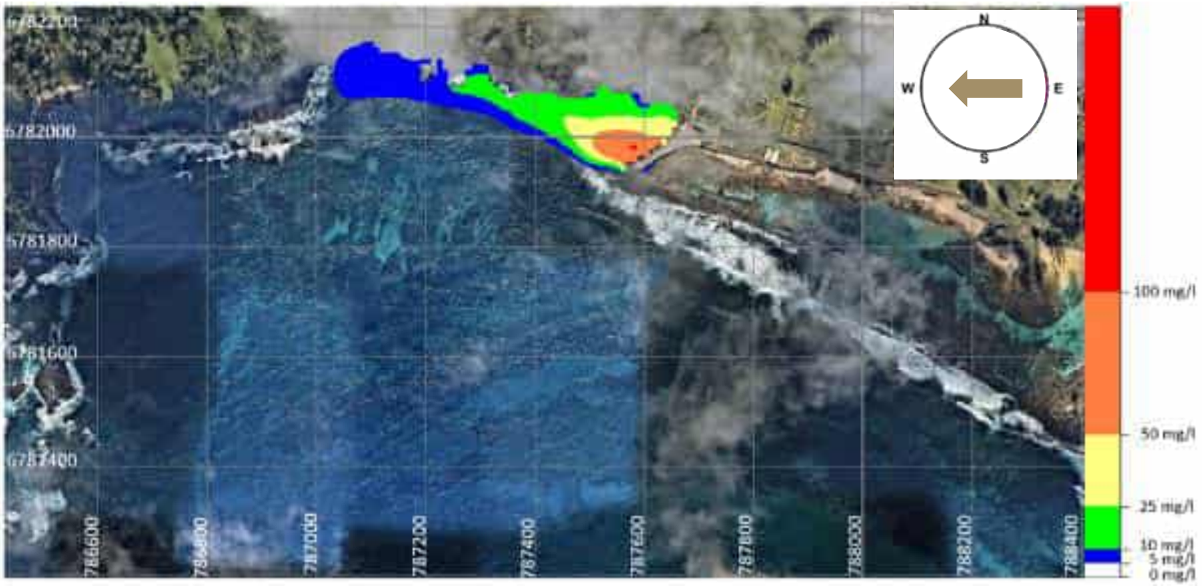

Figure E9 95th%ile Suspended sedimentation concentration distribution for Scenario 5 (strong east wind, no waves)

Scenarios 3 and 6

Under energetic meteorological conditions with larger strong winds from the north and west directions , there is a limited level of dredge plume (less than 10 mg/L) detected for lagoon and coral areas for the 80th percentile. For the 95th percentile, the dredge plume (up to 25 mg/L) was detected heading toward the lagoon and coral reef areas (ie the western end of Slaughter Bay). These scenarios are not realistic scenarios (as waves almost always occur at the site) and were run primarily to determine the sensitivity of the results to wind direction, i.e. to determine which wind directions could result in the plume moving toward the reef and lagoon areas so as to inform which wind directions should be tested with the inclusion of waves. As such, these modelled scenarios were refined and rerun as scenarios 7 and 8 to include ambient waves (see next section). Results from scenarios 3 are 6 are presented in the body of the report but have been superseded by scenarios 7 and 8 respectively.

Scenarios 7 – 8 (Figures E10 – E13)

When ambient waves are included in the simulation for 95th percentile northerly and westerly winds (representing a real "worst-case scenario" weather and hydrodynamic situation during the dredging operation), there is no plume detected for the lagoon and coral areas for both 80th and 95th percentile. The inclusion of waves in the modelling is a more realistic scenario as Norfolk Island is almost always exposed to waves. Also, it is noted that winds from the east and north are more prevalent during the Spring and Summer months when the dredging is proposed.

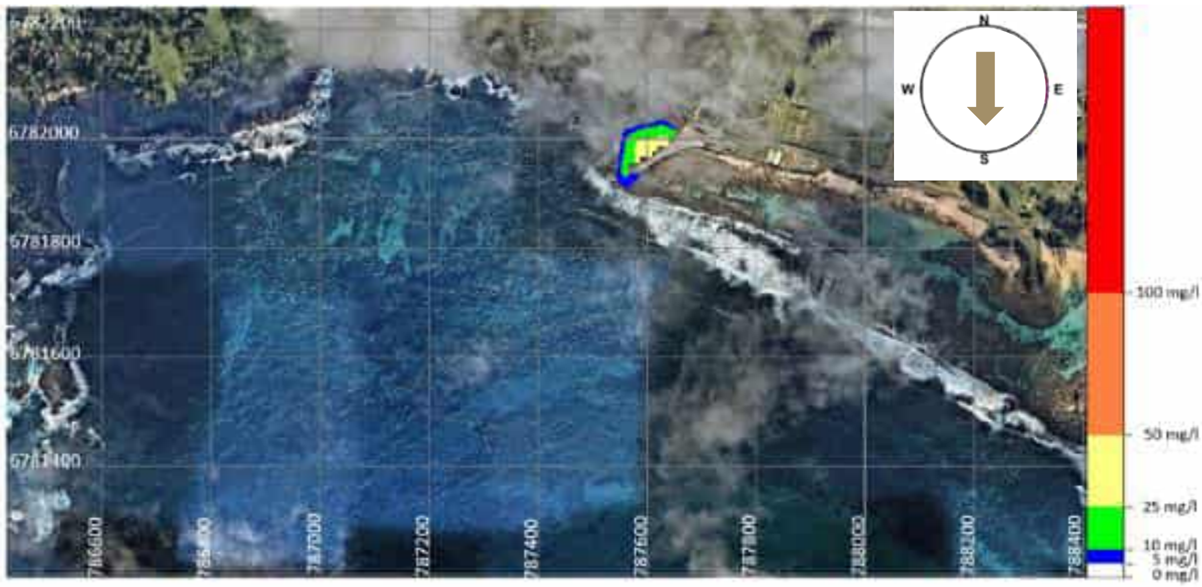

Figure E10 80th%ile Suspended sedimentation concentration distribution for Scenario 7 (strong north wind, ambient waves)

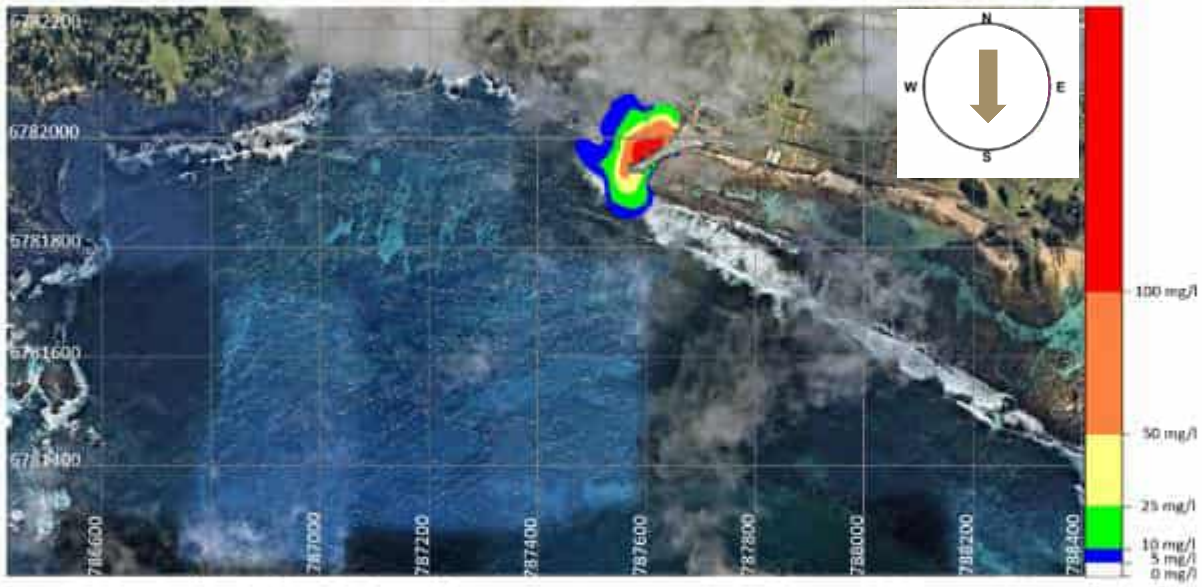

Figure E11 95th%ile Suspended sedimentation concentration distribution for Scenario 7 (strong north wind, ambient waves)

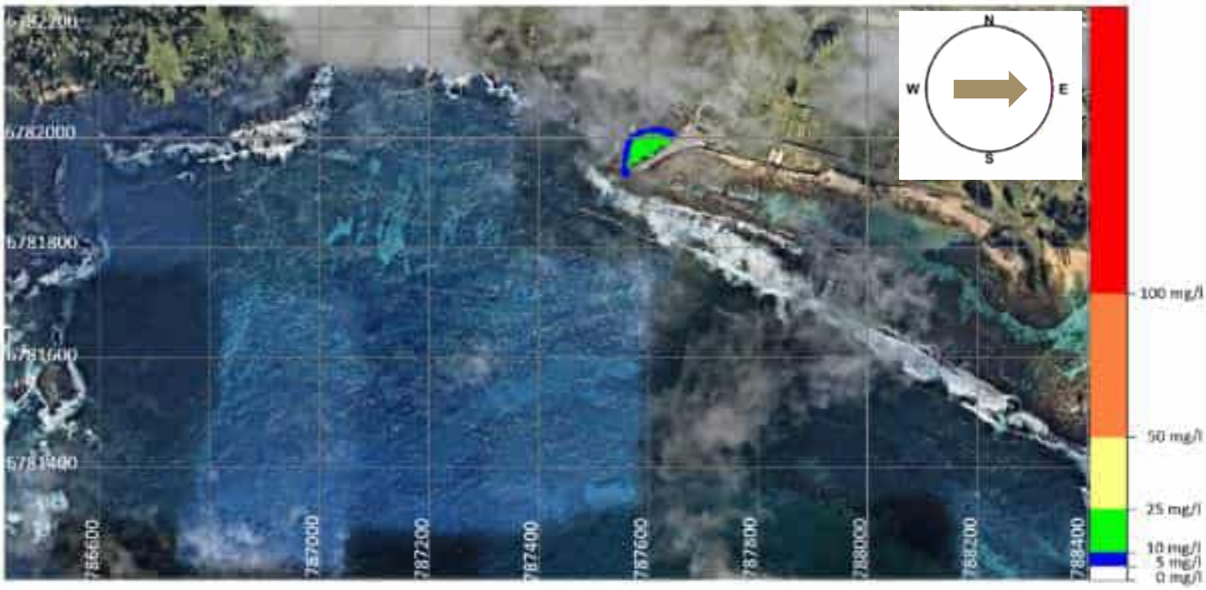

Figure E12 80th%ile Suspended sedimentation concentration distribution for Scenario 8 (strong west wind, ambient waves)

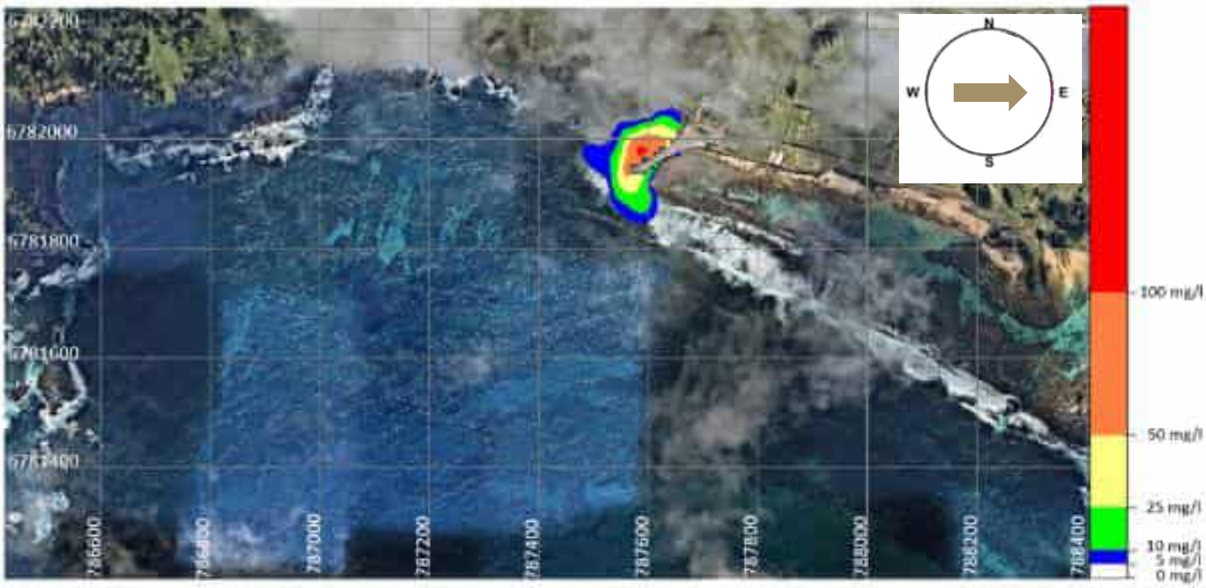

Figure E13 95th%ile Suspended sedimentation concentration distribution for Scenario 8 (strong west wind, ambient waves)

The dredge plume model has predicted that sedimentation would be confined within the Kingston harbour around the proposed dredging area. There is no sedimentation detected for the lagoon and coral reef areas in any scenarios. Figures presenting the sedimentation results are provided in the body of the report.

In conclusion, the modelling results indicated that under real world conditions (ie the model runs that included waves) sediment plumes would not impact on the lagoon and coral areas to the east of the site, and sedimentation would also not occur in these areas.

To ensure that the Environmental Quality Objectives for the lagoon and coral reef are met, the following recommendations are listed:

- Dredging window: Selection of a period of time, preferably between October and May, for the dredging operation to be undertaken to avoid the possible energetic meteorological conditions of which there will be a higher chance of strong wind from the northern and western sectors (noting the coral spawning season generally occurs from late January for a few months and would also look to be avoided). Monthly wind roses are presented in Figure E14
- Operation window: The dredging operation should only take place during the daylight time with a break to unload spoil onshore per day for six days per week (half a day Saturday). No dredging activities are to take place during the night.
- Management Plan - A Water Quality Management Plan is developed and implemented for the dredging works that outlines monitoring procedures and frequency, target limits, responsibilities, and mitigation measures.

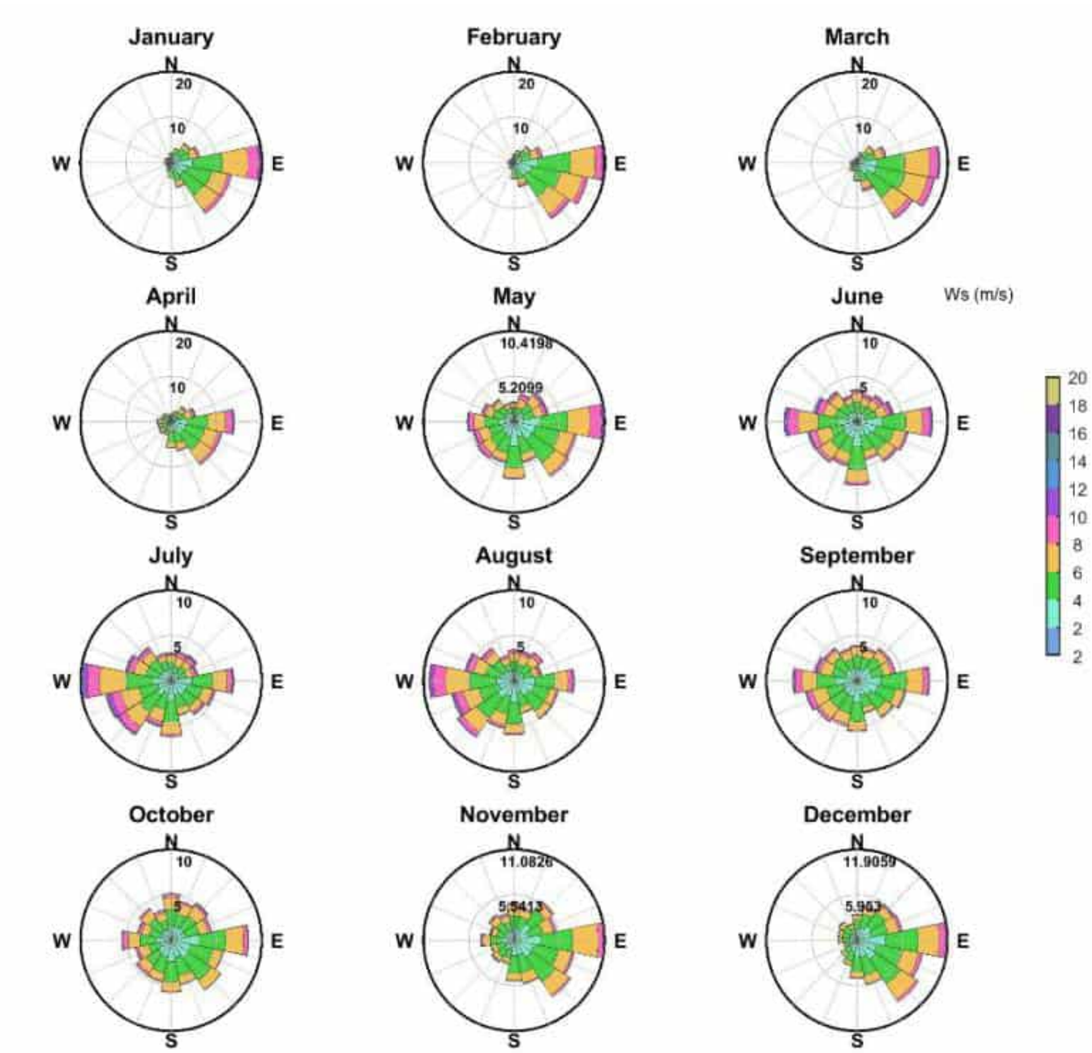

Figure E14 Wind rose plots by month (1940 to 2009

Acronyms and abbreviations

Acronym/abbreviation	Definition
3D	Three Dimensional
ADI	Alternating Direction Implicit
BD	Bulk Density of the Dredged or Infilled Material
CSD	Cutter Suction Dredger
EA	Environmental Assessment
EQO	Environmental Quality Objectives
EMMP	Environmental Monitoring and Management Plan
GDA	Global Data Assimilation
GMT	Greenwich time
MGA	Map Grid of Australia
MSL	Mean Sea Level
MT	Mud Transport
NOAA	National Ocean and Atmospheric Administration
PF	Percentage of fine sediment ($d \leq 63\mu m$)
RMS	Root Mean Square
S_f	Spill of fines
SR	Spill rate
SW	Spectral Wave
SSC	Suspended Sediment Concentration
TSHD	Trailing Suction Hopper Dredger
TSS	Total Suspended Solids
UKFWR	UK Foundation for Water Research
WQMP	Water Quality Management Plan

1 INTRODUCTION

1.1 Background

For the purpose of obtaining environmental approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the Kingston Pier Channel Construction Project for Kingston Pier harbour (outlined in Figure 1-1), Advisian has undertaken a Dredge Plume Modelling study to investigate the dispersion of sediments into the nearby marine area, as a result of the activities required for the construction project.

The purpose of the modelling exercise was to understand the distributions and intensities of suspended sediment plumes and sedimentation that the proposed dredging program could potentially generate. The study also investigated potential seasonal effects on the suspended material and sedimentation patterns to support the environmental assessment (EA).

Figure 1-1 – Location of Kingston Pier within Norfolk Island. Harbour area indicatively outlined

1.2 Scope of work

The volume of material to be removed from the harbour is relatively small (up to 5,000 m^3) in the scheme of typical dredging projects and the disposal of the material is proposed to be onshore (as opposed to offshore sea disposal). As such, Advisian proposed the following scope of work for the preliminary investigations of dredge plume dispersal in this study.

- To develop a hydrodynamic model of Kingston Harbour and the surrounding lagoons and fringing reef areas as identified in Figure 1-2, to assess the dispersal and fate of dredged material into the surrounding environment, as well as the potential for dredge spoil material to settle on the surrounding seabed and reef areas.
- To investigate combined tidal and wind-driven currents during ambient and energetic meteorological conditions, occurring during the proposed dredging activity, e.g. a backhoe dredger mounted on a barge. To run the dredge plume modelling on the range of hydrodynamic conditions based on the above investigation.
- To analyse the dredge plume model results on particular statistical trigger values e.g. 80th percentile concentrations of suspended sediments and sedimentation, 95th percentile concentrations of suspended sediments and sedimentation within the study area.

Figure 1-2 Identified coral reef sites and proposed educational coral reef snorkel trail locations (Parks Australia, 2020)

1.3 Study datum

Water depths and levels presented in this report are referenced to mean sea level (MSL), unless otherwise stated, and are in units of metres.

Geographical positions are provided in the Map Grid of Australia (MGA) coordinate system, zone 58, based on Geocentric Datum of Australia (GDA 94) Geodetic Datum, unless stated otherwise.

All units are in standard SI units unless otherwise stated, with all bearings and directions provided in degrees True North.

Time varying inputs (e.g. tide and wind forcing) are referenced to Kingston local time (-1130 Greenwich time (GMT)).

2 DREDGE PLUME MODEL SETUP

2.1 Modelling strategy

The numerical model provides a critical input to the Water Quality Management Plan (WQMP) defined within the EA which is a key supporting document to obtain environmental approval for the project.

The sediment plume model is run to provide sediment spill forecast results. These results quantify the movement and fate of material suspended in the water column during dredging activities related to the project, allowing comparison against defined environmental quality objectives (EQOs) for approval and, in the event of exceedance, provides information for relevant mitigation measures to be proposed.

The dredge plume model incorporates several modelling elements including physical site data, engineering and metocean inputs. Figure 2-1 illustrates the integration of the various elements employed in the modelling process and their relation to the Environmental Assessment (EA).

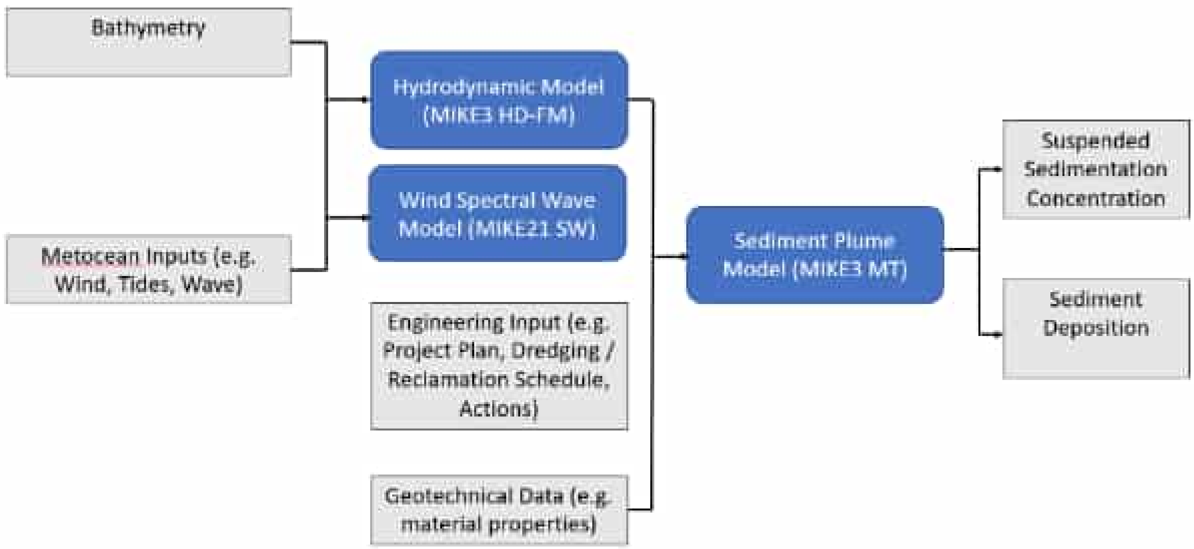

Figure 2-1 Schematic of the sediment plume modelling process

The items, which follow the principles for modelling mentioned in the guideline documents A Framework for Marine and Estuarine Model Specification in the UK (UKFWR, 1993), Guidelines the Use of Hydrodynamic Numerical Modelling for Dredging Projects in the Great Barrier Reef Marine Park (GBRMPA, 2012) and Guideline on dredge plume modelling for environmental impact assessment (WAMSI,2020), are described in detail below:

- A three-dimensional (3D) model shall be adopted for dredge plume modelling, for which it is important to consider two key aspects of the plume advection and diffusion problem:
    1. 3D hydrodynamic processes that influence the horizontal circulation (establishing the pathway from source to receptor); and

2. 3D sediment transport processes that influence the vertical structure, mixing, deposition and resuspension in the passive plume (affecting pressure at receptor).

- A model domain size which is sufficient to encompass the total area affected by the sediment plumes, including not only the initial extent of the sediment plume and deposition, but also areas affected following the reworking of sediments, which occurs through re-suspension and subsequent transport.
- The model must account for particle-size specific sinking, sedimentation and re-suspension of sediments given the range of hydrodynamic conditions for the area.
- The model should accommodate the initial sediment plume generated by spill from the defined water layer and also should capture the plume movement and dispersion within the water column.
- The effects of sediment cohesion (i.e. clumping) on sinking rates of fine particles and the effects of sedimentation history, burial and armouring on re-suspension rates must be accounted for.

Other necessary inputs are specific to the construction project and relate to the dredging and infilling operations. Details of the dredge vessel to be utilised, transport and disposal plans for the removed material, schedule and production rates are all necessary inputs for the model.

Advisian has developed a Kingston Hydrodynamic Model and Dredge Plume Models to suit the above required principles for the project by incorporating site specific data. The model set up is discussed in Section 2.2 to Section 2.8.

2.2 Model description

The dispersion, transport and deposition of sediment from the dredging works are being simulated with Advisian's Kingston Dredge Plume model.

2.2.1 Coupled model approach

The dredge plume model applies the MIKE3 coupled flexible mesh hydrodynamic modelling system to simulate the plume dispersion process. A 3D modelling framework has been adopted to represent both horizontal and vertical circulation.

MIKE3 suite is particularly appropriate to simulate sediment plume dispersion in this instance, due to its ability to:

- Allow a large domain with high resolution to be achievable in a single model;
- Include representation of wetting and drying, as well as coral effects on bottom friction;
- Dynamically change the flow regime in response to changes in sedimentation and resuspension during the construction;
- Account for plume stratification within the water column depending upon construction processes and equipment used during dredging and infilling; and
- Facilitate and assist in visual impact assessment of the plume footprint given its ability to capture surface plume dispersion.

The hydrodynamic model provides water level variations and flows in response to a variety of forcing functions in the region. This is coupled with a dredge plume model to simulate the dispersion, transport and deposition of the sediment plume.

2.2.2 Hydrodynamic model

MIKE3 Hydrodynamic (HD) is the base module for Kingston Hydrodynamic Model. The MIKE3 HD numerically solves the 3D incompressible Reynolds averaged Navier-Stokes equations subject to the assumptions of Boussinesq and of hydrostatic pressure. Thus, the model consists of continuity, momentum, temperature, heat exchange, salinity and density equations and it is closed by a turbulent closure scheme. The free surface is taken into account using a sigma-coordinate transformation. Wetting and drying effects in intertidal areas are also accounted for in the model, which is particularly important to this study given the extent of intertidal reef with the study area.

The turbulence is modelled using an eddy viscosity concept, which involves a common practical strategy to ignore the small-scale vortices (or eddies) in the fluid motion and to calculate a large-scale motion with an effective viscosity, called the "eddy viscosity", which characterises the transport and dissipation of energy in the smaller-scale flow. The eddy viscosity is often described separately for the vertical and the horizontal transport.

The discretization in the solution domain is solved using an unstructured mesh applying a cell-centred finite volume method. The spatial domain is discretised by a subdivision of the continuum into non-overlapping cells/elements.

The hydrodynamics module of MIKE 3 makes use of the so-called Alternating Direction Implicit (ADI) technique to integrate the equations for mass and momentum conservation in the space-time domain.

In the 3D model, the vertical mesh is based on either sigma coordinates or combined sigma/z-level coordinates. The most important advantage using sigma coordinates is their ability to accurately represent the bathymetry and provide consistent resolution near the bed.

The model runs in barotropic mode, meaning that currents due to temperature and salinity variations are excluded from the model. It is considered that within the main region of interest, barotropic effects (wind and water level varying) would dominate. The main driving mechanisms are tide and wind forcing. The wave forcing was included for the dredge plume model as sensitivity runs to investigate the wave effects on the plume movement and sedimentation.

2.2.3 Wave model

For this dredge plume study, the wave model was coupled with the dredge plume model to determine wave-induced re-suspension and transport of sediments. Associated wave conditions over the dredge plume dispersion area will be relatively low, due to the limited water depth. However, these waves will still affect sedimentation and re-suspension over shallow areas within the harbour and lagoon area and, as such, are a necessary input to the dredge plume model. In addition, the waves also affect the local hydrodynamic conditions with wave induced currents because of wave breaking.

The Advisian local wave model applies the MIKE21 Spectral Wave (SW) software. MIKE21 SW is a third-generation spectral wind-wave model based on unstructured meshes, which is particularly useful as it allows areas of interest to be refined in great detail whilst minimising computational demand. The model enables full time domain simulations, which are important for the present development site. MIKE21 SW allows for the simulation of growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas and near shore with a limited fetch.

The fully spectral formulation is based on the wave action conservation equation, where the directional-frequency wave action spectrum is the dependent variable. Specifically, MIKE21 SW includes the following physical phenomena:

- wave growth by action of wind;
- non-linear wave-wave interaction;
- dissipation due to white-capping;
- dissipation due to bottom friction;
- dissipation due to depth-induced wave breaking;
- refraction and shoaling due to depth variations;
- wave-current interaction; and
- effect of time-varying water depth.

2.2.4 Dredge plume model

Advisian has developed the Kingston Dredge Plume model which utilises the MIKE3 Mud Transport (MT) multi fraction cohesive sediment transport module.

The MIKE3 MT module describes erosion, transport and deposition of mud or sand/mud mixtures under the action of currents, wind and waves. The bed is described as layered and characterised by the density and critical shear strength for erosion. For the sediment plume study, a one-layer approach has been applied to represent sedimentation from the plume due to the spill.

The MIKE3 MT module, which calculates the combined transport of cohesive sediments (silt/clay; with grain size diameter $\leq 63\mu m$) and non-cohesive sediments (sand; diameter $> 63\mu m$), is basically a solution of the advection dispersion equation.

2.2.5 Model extent

As the MIKE3 MT model is dynamically coupled with the hydrodynamic model (MIKE3 HD) and wave model (MIKE21 SW), the dredge plume model adopts the same model domain as that used in the hydrodynamic and wave model.

The coupled model domain (Figure 2-2) spans approximately 25 km covering Norfolk Island and Philip Island with the extension to water depth to approximately 30m (north) and 70m (south). The deeper water depth around the boundaries of west, south and east within the domain allows an accurate representation of the tides and wave offshore from deeper to shallow area within the model.

Figure 2-2 Model extent – domain area outlined in red

2.2.6 Model bathymetry

The model bathymetry is based on local and regional nautical charts supplemented with available site-specific bathymetric survey data, as detailed in Table 2-1. The resulting model bathymetry in the vicinity of the Kingston harbour is shown in Figure 2-3.

The model uses an unstructured computational mesh which allows for higher resolution around areas of specific interest, or with complex bathymetries or morphologies. For this project the mesh was refined in the area immediately offshore of and within harbour and lagoon areas. Computational length scales of the mesh elements ranged from approximately 90 m at the nearshore off the harbour down to 15 m for harbour and lagoon areas.

A sigma layer system was adopted (Figure 2-4), whereby the same number of vertical layers is present at each point of the computational domain irrespective of water depth. The sigma layers were set with surface and bottom layer spanning 20% of the local water depth each and the middle layer uses 60%. Three layers were considered appropriate to resolve the 3D hydrodynamics both offshore and near the project site.

Table 2-1 Dredge plume model bathymetric data sources

Source	Description	Survey Date
UK Admiralty	Local and regional Nautical Charts	various
Don Taylor	Local survey data	1 December 2006
the Royal Australian Navy	Local and regional Survey data	28 October 2010
Advisian	Local survey data	26 August 2020

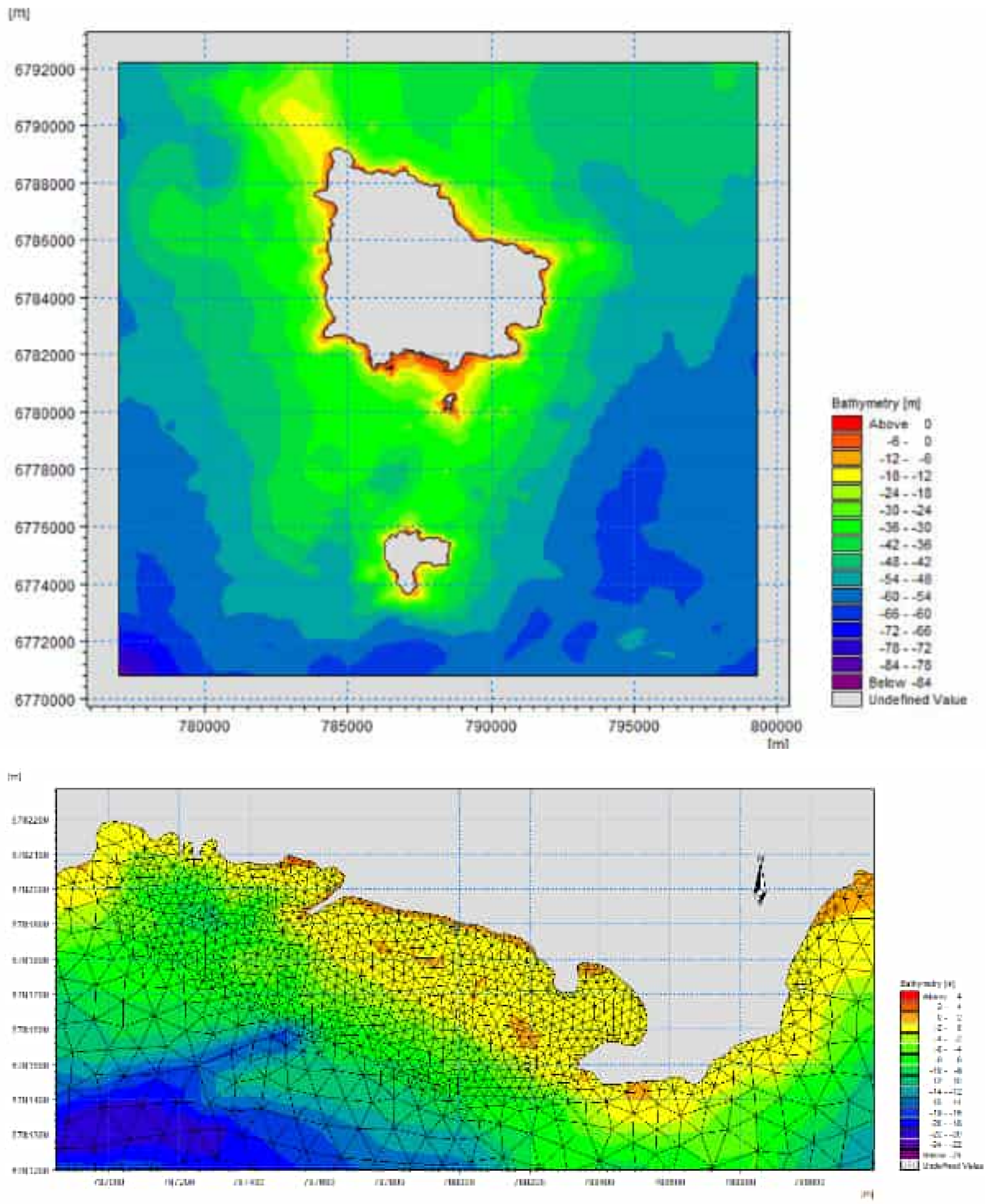

Figure 2-3 Model bathymetry (as of 01 February 2021) Top figure: whole model domain Bottom figure: zooming in with mesh for the Kingston harbour and lagoon area

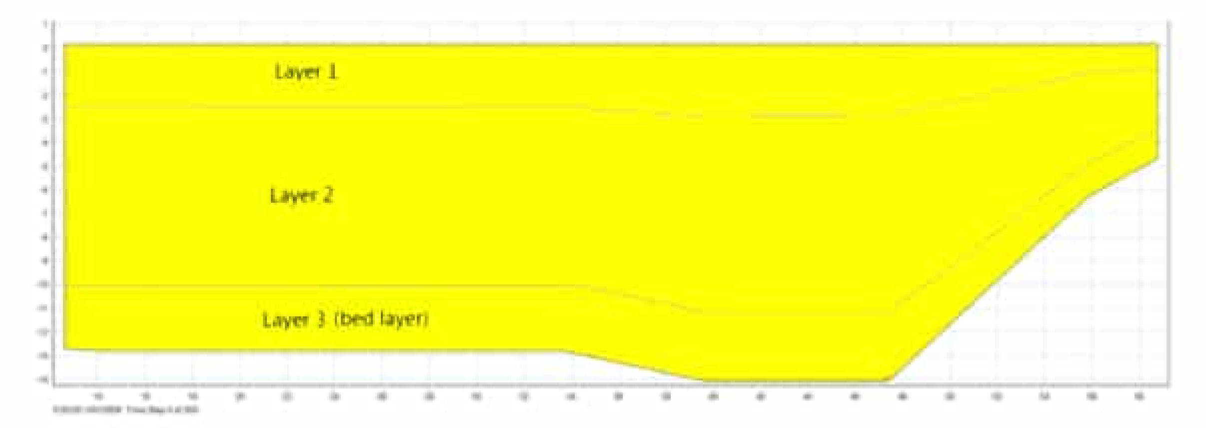

Figure 2-4 Illustration of vertical sigma layer approach with 3 vertical layers

2.3 Forcing mechanisms

2.3.1 Hydrodynamic driving forces

Hydrodynamic driving forces can be attributed to tidal or non-tidal processes. Compared to the tidal and wind forcing, the hydrology of the adjacent watershed (e.g. river discharge) plays a minor role in ambient currents. The local meteorological conditions, primarily winds are expected to contribute to surface currents, with these effects having more influence during slack and neap tide periods. Clearly, in addition to wind forcing the other main hydrodynamic force driving water circulation in the area is tidal forcing.

2.3.1.1 Wind forcing

A total of 70 years of wind data (1940 to 2009) at Kingston was analysed to present the statistical wind speeds (Table A-1 Appendix A). Higher wind speeds are expected to result in transport of the sediment plumes further away from the dredging source, so are therefore considered to be "worst-case scenarios" for the impact of the dredging operation. For this reason, the available wind data of 2008, which had higher median wind speeds than most other years in the record, was selected for model simulation. This approach was considered to represent a conservative scenario for testing, under which the dredge plume would move more quickly toward the coral lagoon.

Further statistical investigation results for the wind speeds in 2008 are summarised in Table 2-2, in which the wind speed for western sector (45°) shows higher wind speeds than the other sectors (north, south and east). The modelling used the 95th percentile winds (those winds exceeded only 5% of the time), to provide a likely "worst-case scenario" for the speed and distance of movement of the sediment plumes away from the dredging site. These wind speeds which represent different sectors were used for model sensitivity runs (Section 2.9) to investigate the wind effect on the plume movements.

Table 2-2 Wind statistical analysis for 2008

Period (2008)	Median Wind Speed (m/s)	80th percentile Wind Speed (m/s)	95th percentile Wind Speed (m/s)
Northern Sector (337.5 °<= Wdir <= 22.5 °)	1.00	5.11	7.69
Southern Sector (157.5 °<= Wdir <= 202.5 °)	4.11	6.19	7.69
Eastern Sector (67.5 ° <= Wdir <= 112.5 °)	4.61	6.69	8.69
Western Sector (247.5 °<= Wdir <= 292.5 °)	4.61	7.19	9.31
All sectors (360 °)	5.11	7.69	9.81

Figure 2-5 shows an investigation of the 70 years of wind data and presents the wind rose plots for each month. Generally during the months between November and April, the dominant wind is from eastern sector, swinging between north-eastern and southerly directions. During the months of June, July and August, the dominant wind occurs from the west sector, even though a relatively large percentage of wind come from other sectors. September and October are basically transfer months between these two dominant winds. More detailed wind rose plots and statistics for monthly and seasonally plots are presented in Appendix A.

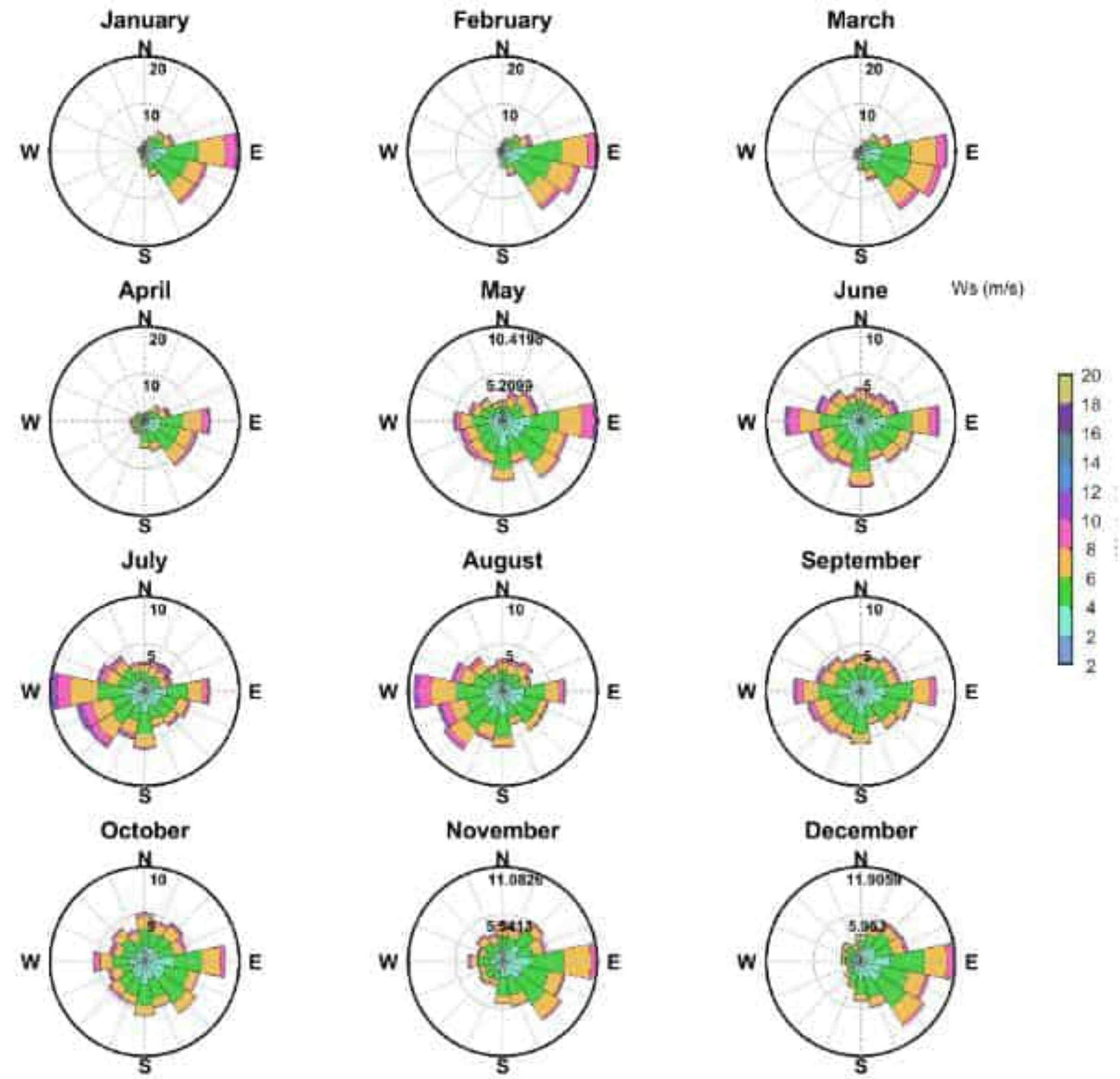

Figure 2-5 Wind rose plots for each month (1940 to 2009)

2.3.1.2 Tidal forcing

Tidal forcing was included in the model by imposing predicted tidal levels on all the open boundaries. The predicted tidal levels are site specific and vary in time and along each boundary line. At the points along the boundary where water is flowing into the model domain, the flow is forced perpendicular to the boundary orientation; at points where the water is flowing out of the model domain, the flow direction is extrapolated from the nearest points inside the model domain.

Tidal levels at the model boundaries have been predicted from global tide model data incorporated in the MIKE 21 Toolbox. The global tide model data includes the major diurnal (K1, O1, P1 and Q1) and semidiurnal tidal constituents (M2, S2, N2 and K2) with a spatial resolution of 0.25° × 0.25° based on TOPEX/Poseidon altimetry.

The annual (Sa) and semi-annual (Ssa) constituents, based on tidal predictions at Kingston tidal station (AHS, 2015), were also included to account for seasonal changes in Mean Sea Level.

2.4 Wave forcing

The wave forcing was generated using the local wave model, which the offshore wave conditions were sourced from WWIII model run by National Ocean and Atmospheric Administration (NOAA). The offshore waves extracted at the location (Longitude 167.5E, Latitude -29.5S shown in Figure 2-7) nearest to Kingston.

To include local wind wave component for wave forcing, the local wind was input to the local wave model for the study. The waves from 2008-9 were used in combination with the 2008 winds (which were higher than the wind speeds for most other years in the record), as the waves are not statistically independent of the winds, and to provide a realistic assessment of the actual (worst-case) conditions that would have occurred at the site.

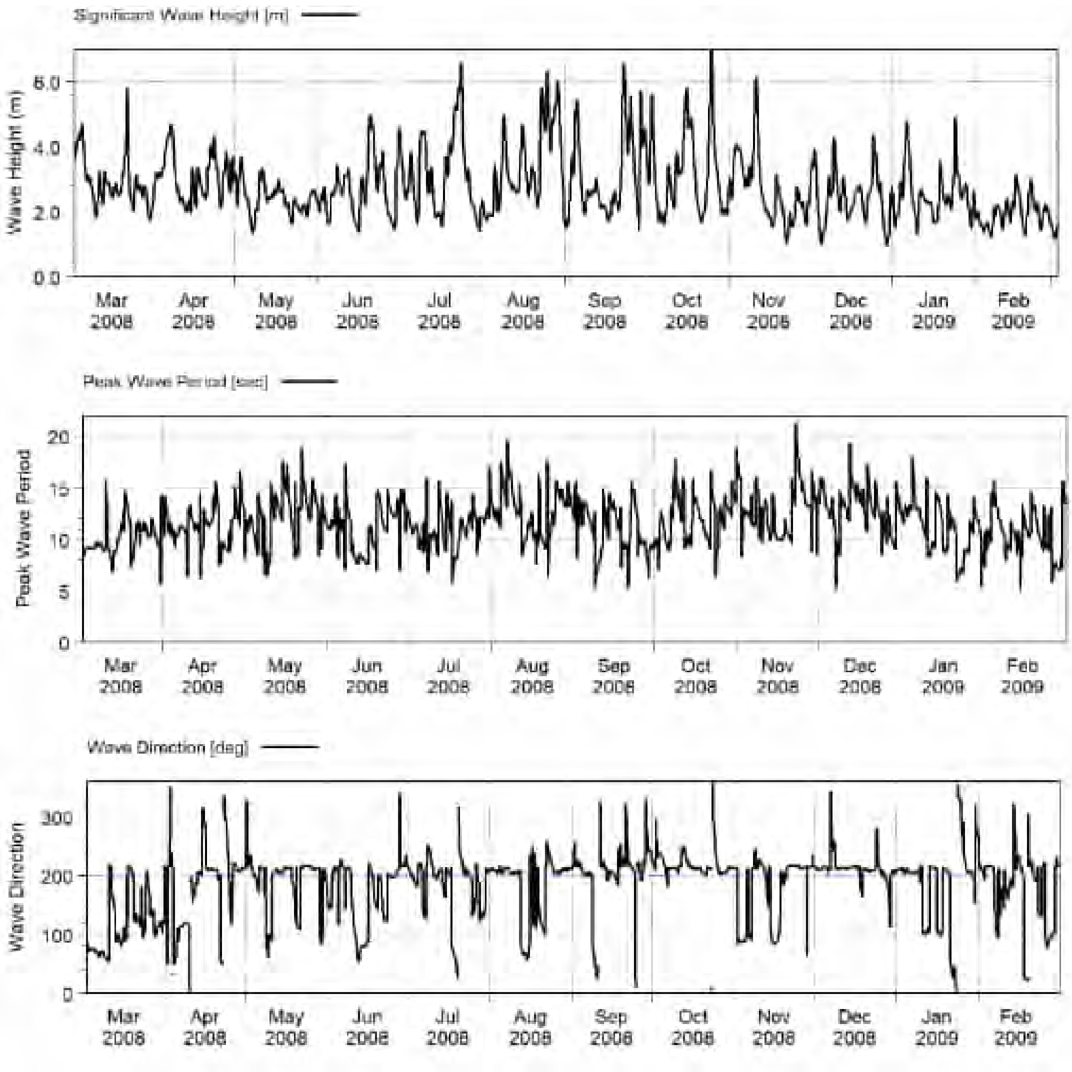

Figure 2-6 Offshore waves extracted from WWIII input to local wave model

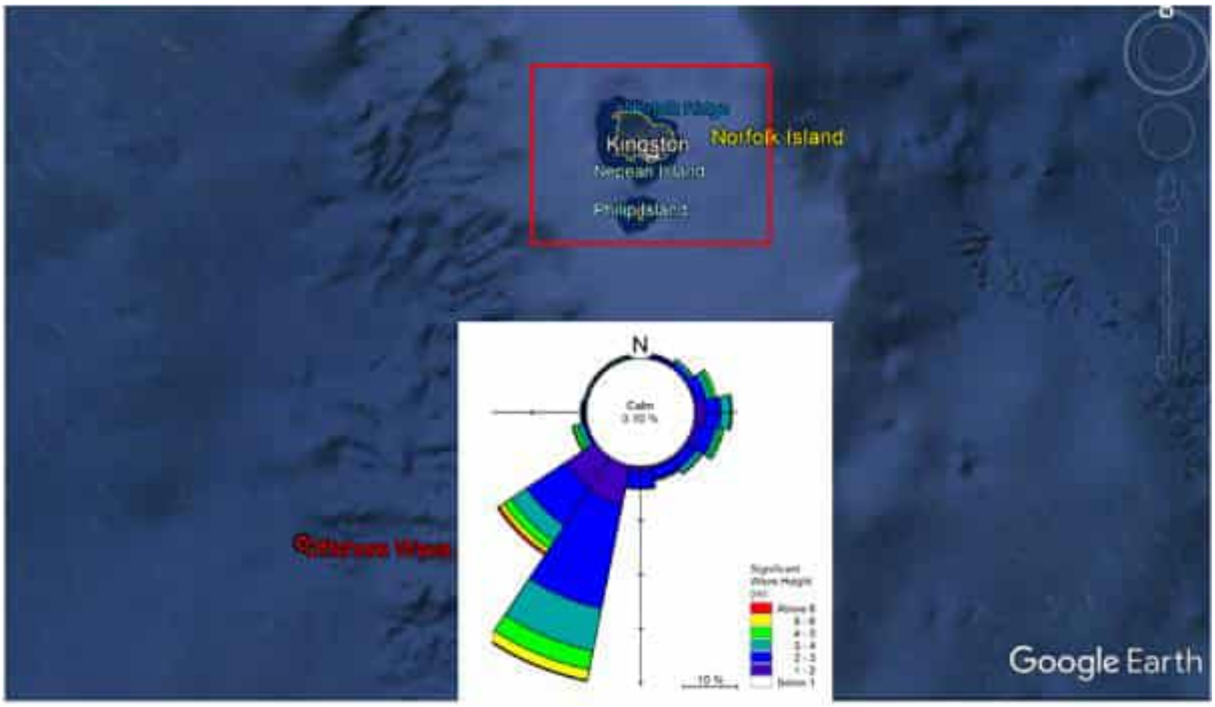

Figure 2-7 Offshore wave location and its wave rose plot

Figure 2-8 presents a snapshot of wave vector plot. The wave time series conditions were presented in Figure 2-9, in which the wave was extracted at a nearshore point (787386E, 6781888N) close to the harbour.

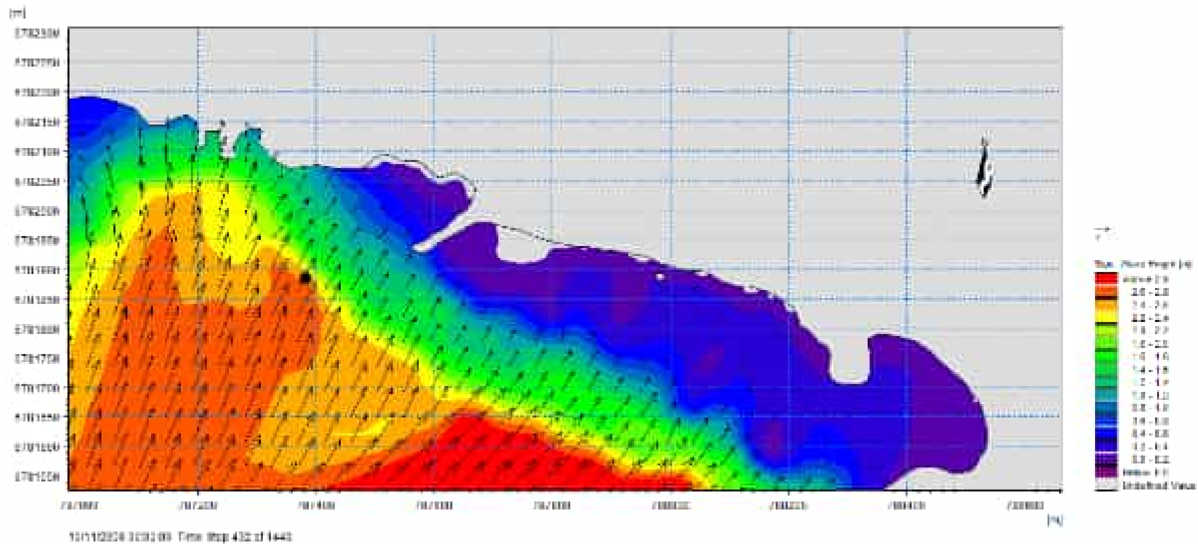

Figure 2-8 snapshot wave vector plots distribution (extracted location highlighted in a black dot)

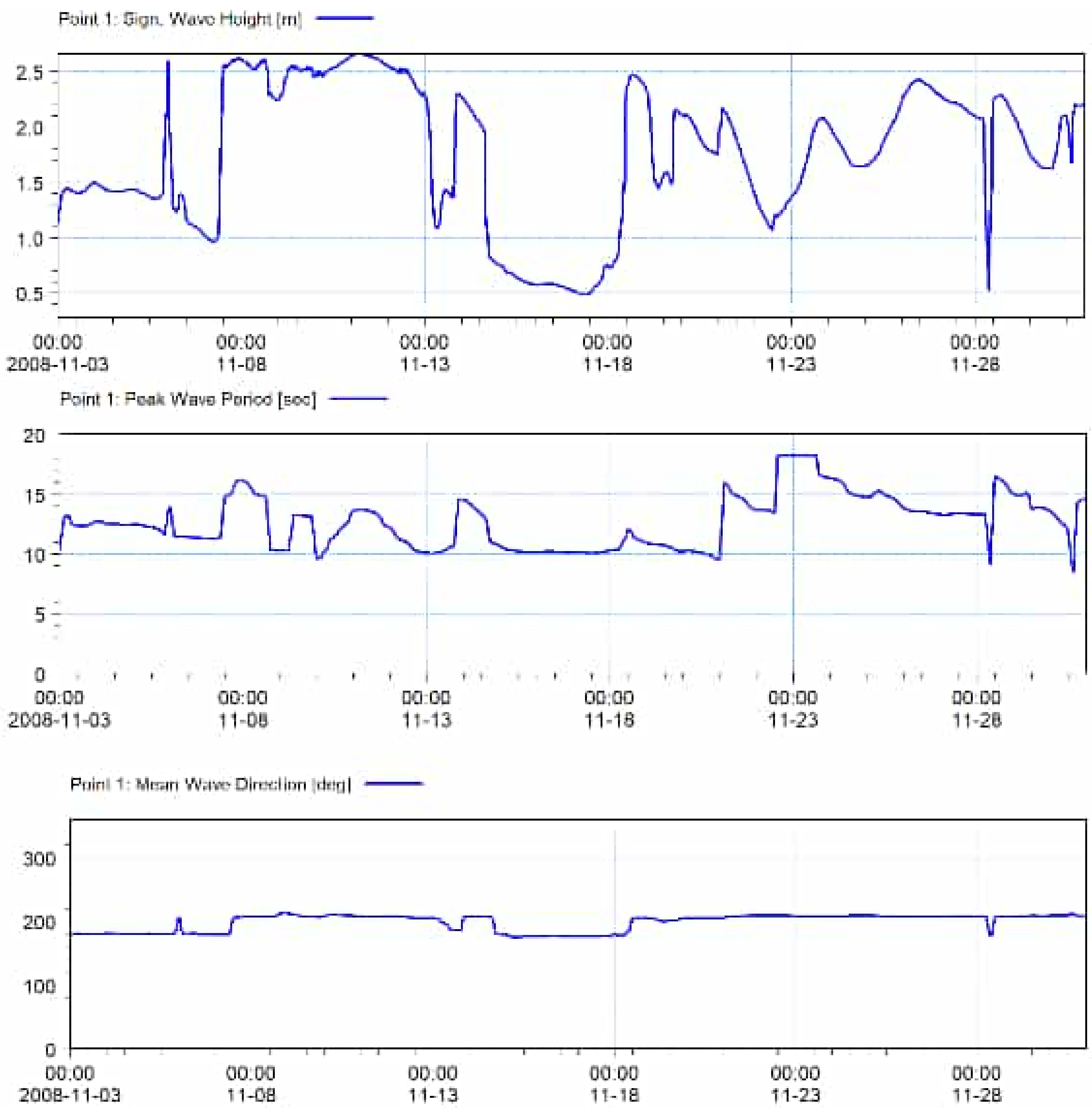

Figure 2-9 wave time series conditions extracted at a nearshore point close to harbour

2.5 Geotechnical data

Baseline geotechnical characteristics of sediments to be dredged have been determined from a series of site surveys.

2.5.1 Bulk density and percentage of fines

Laboratory analysis of pre-construction works samples were available to provide a baseline bulk density and percentage of fines value for each type of material for input to the initial plume modelling.

As a worst case for the dredge plume modelling approach, the bulk density (2.2 T/m^3) for Tuff material was adopted in this study. The percentage of 15% fines of material was used for the dredging operations and 10% of fines was used for overflow for Tuff material to be placed on barge.

2.5.2 Baseline Settling Velocity

Settling velocities were also predicted through analysis of the available pre-construction sediment samples. Two samples were used for Owen tube testing reported on 11 March 2020 (Appendix B).

For the present study, a total of five fractions based on the Owen tube testing results were adopted to represent different settling velocities of the suspended sediment inputs. The proportions of the five components used in the model are summarised in Table 2-3. It is noted that the settling velocity and the five fraction values are required to be confirmed with more site sample results during the dredging over the construction of the project.

Table 2-3 Percentage of settling material distribution and associated settling velocities used for model input

Material type	Description	% Contribution to total spill volume	Settling velocity (mm/s)
Fraction 1 (fine fines)	Regularly transported large distances, generally will not settle out and contributing largely to suspended sediment migration	47.0	0.06
Fraction 2 (medium fines)	Can be transported large distances during spring tide, prime cause of remote sedimentation	20.0	0.3
Fraction 3 (fines)	Settles outside of the work area and can easily re-suspend under wave and current action	13.0	0.7
Fraction 4 (coarse fines)	Settles quickly outside of the work area	5.5	3.0
Fraction 5 (fine sands)	Settles quickly within and outside the work area	14.5	7.0

2.6 Engineering inputs

2.6.1 Dredging and spill information

Engineering information was assumed as input to the models, and included:

- Schedule of activities (date and time);
- Duration;
- Location;
- Dredging method; and
- Spill volume.

This data has been incorporated in the dredge plume model as a series of source files, as described in Section 2.7.3.

It is proposed that dredging operations would be undertaken primarily with a long reach excavator mounted on a jack-up barge, or divers with hand-tools in areas that possess potential archaeological significance (only relevant to the sediment layer).

The duration of sediment dredging is estimated to be two (2) weeks at an assumed production rate of 40 m^3/day. The duration of calcarenite and tuff dredging is estimated to be a total of five (5) weeks at an assumed production rate of 180 m^3/day and 600 m^3/day respectively. An additional seven (7) weeks have been allowed in the construction program to account for weather delays. Spoil bins would be placed on the jack-up barge and lifted to the pier as they are filled during dredging.

A workweek is defined as 55-hours over six days – dredging during daylight hours. The dredging program is proposed to take place in the spring/early summer months between October to January to avoid dredging during the coral spawning period starting in late January.

2.6.2 Spill rates

The spill rate (SR) is defined as the fraction of fine material that remains in the water column as an initial suspended sediment immediately after a spill (either from dredging or infilling operations).

Spill rates from different sources have been extensively investigated in the past. Anchor Environmental (2003) reviewed studies and site measurements of resuspended sediments due to dredging operations. They concluded that spill rates for mechanical dredges ranged from 0.18 % to 10.11 %, with an average rate of 2.06 % while the Suspended Sediment Concentration (SSC) near the dredge (up to 98 m distance) ranged from 6 mg/L to 475 mg/L with an average of 240 mg/L.

Similarly, published spill rates for hydraulic dredges ranged from 0.00 % to 5.14 % of the production rate with an averaged 0.73 % spill rate (Anchor Environmental 2003, Hayes and Wu 2001), whereas initial SSC (within 59 m of the dredger) presented values from 4 mg/L to 311 mg/L.

J Jiang, H Han and A Karunarathna (2019) presented a sediment plume hindcast model of dredging activities which was supported by dredge plume modelling practices for Environmental Monitoring Management Programs (EMMP) projects. They investigated spill rates (shown in Table 2-4) on different dredging and infilling operations with the site measurements. The model using these rates was verified with both direct SSC measurements of the sediment plume and via sediment flux transects through the plume. Photographic examples of various dredging operations and equipment are provided in Figure 2-10.

Table 2-4 Spill rates for dredging and infilling operations

Operation description	Material type	Spill water layer	Spill rate (%)
Trailing Suction Hopper Dredger (TSHD)	Silt/clay	Bottom	7%
Cutter Suction Dredger (CSD)	Silt/clay	Bottom	2%
Grab Dredger	Silt/clay	Surface	2.5%
Overflow	Silt/clay	Surface	Associated with TSS
Barge propeller wash	Silt/clay	Bottom	5%

Operation description	Material type	Spill water layer	Spill rate (%)
Pipe discharge	Silt/clay	Surface	2%
Barge/Hopper Dumping	Silt/clay	Bottom	6%
Grab Dredger Dumping	Silt/clay	Bottom	6%
Any type of operations	Sand		25%

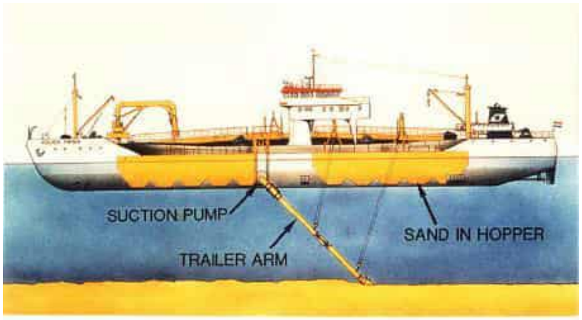	
Trailer-suction hopper dredge (https://oceanandairtechnology.wordpress.com/2013/06/11/trailing-suction-hopper-dredger/)	Cutter-suction dredge (https://www.ship-technology.com/projects/damen-csd-500/)
	
Grab-dredger (https://www.dredgepoint.org/dredging-database/equipment/christiaan-p)	Split-hopper barge (https://www.sanddredger.com/TransportBarge/split-hopper-barge.html)

Figure 2-10 - Example dredging equipment and operations

For the present study, a smaller jack-up barge with max capability to load 50t of spoil and weight of bins has been proposed for the dredge operation. For this dredger, a spill rate of 2.5% (Grab Dredger shown in Table 2-4) was assumed for the preliminary dredge plume modelling study. The dredged material will be temporarily placed on a >400t flat top barge which allows overflow during the dredging operation. Without total suspended solids (TSS) value assumption made for the overflow, a relative spill rate of 1% was assumed input to the model.

It is noted that the sediment flux measurement (field data) is suggested to be utilised to confirm the spill rates during the course of the project.

2.6.3 Spill mass

The dredging and infilling operations have been modelled in terms of dredging time and location with the material being introduced as a Spill Mass. A source file was created for each spill event as proposed worst events for the construction of the project.

- Spill event one: spill due to dredger- dredging operation is proposed for two trips per daytime (120 minutes site dredging and 90 minutes discharge on land for one trip). It operates for 6 days per week lasting for four weeks to remove a total of 5,000 m^3 seabed material.
- Spill event two: spill due to overflow – This spill is associated with dredging operation, i.e. overflow lasting for 120 minutes for each trip.

The general formula for calculating a Spill Mass is:

$$\text{Spill Mass [Kg]} = V\,[m^3] \times PF\,[\%] \times SR\,[\%] \times BD\,[Kg/m^3] \qquad (2\text{-}1)$$

where:

- SR is the spill rate;
- V is the volume of dredged or infilled material;
- PF the percentage of fine sediment with grain size diameter ≤ 63μm in the dredged or infilled material; and
- BD the bulk density of the dredged or infilled material.

2.7 Key model parameters

2.7.1 Bed resistance

The roughness height is input into the model to reflect the bottom resistance. Due to the high accuracy requirements of the present study, it has been necessary to develop a detailed roughness height map of the study area with the basic depth relationship shown in Table 2-5. The equivalent Manning Number is estimated by using relationship:

$$M = \frac{25.4}{{k_s}^{1/6}} \qquad (2\text{-}7)$$

The spatial bed resistance map used in the model is shown Figure 2-11.

Table 2-5 Roughness Height applied for the model

Description	Roughness Height (m)	Manning Number Equivalent ($m^{1/3}/s$)
<15 m water depth	0.03	45
15 m to 30 m water depth	0.07	40
30 m to 80 m water depth	0.15	35
>80 m water depth	0.25	32
Wetland (intertidal, lagoon and reef area)	0.30	20

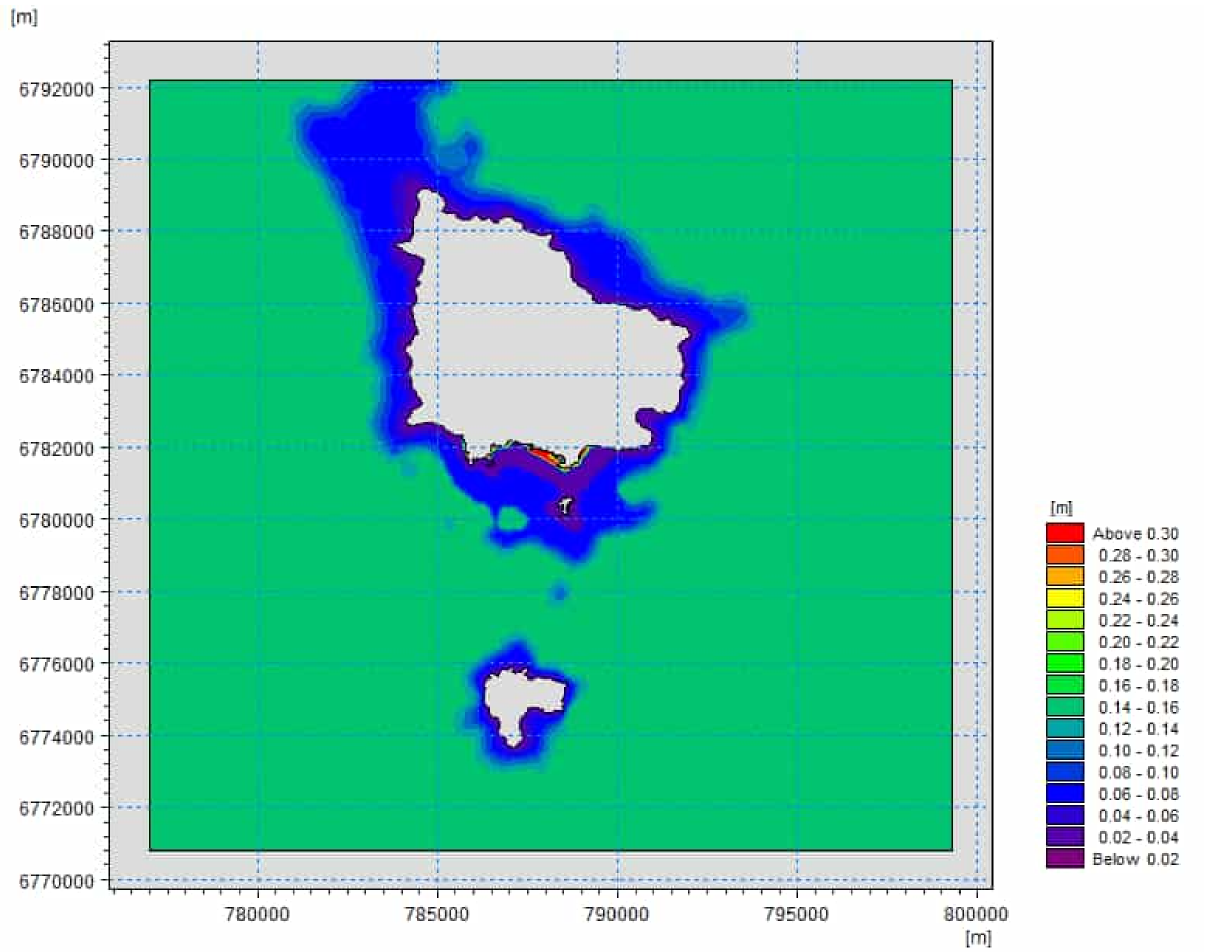

Figure 2-11 Spatial roughness height map

2.7.2 Settling parameters in water column

The initial settling velocity was derived from the Owen Tube analysis. The proportions of the five components used in the model are summarised in Table 2-3.

Flocculation is an important process enhancing the settling velocity of suspended matter by allowing the individual particles to stick together and form larger aggregates which in turn influence the settling velocity of the suspended matter.

The present model has taken into account the flocculation process for all five fractions (Table 2-3), which is believed to have cohesive properties, in which the settling velocity calculation is expressed as:

$$w_s = w_0 \left[\frac{c_{total}}{\rho_{sediment}}\right]^{\gamma} \tag{2-2}$$

Where w_s is the settling velocity in m/s, w_0 the settling velocity coefficient in m/s, $\rho_{sediment}$ the dry fine sediment density, c_{total} the total concentration of sediment and γ the power constant with a default value as 1.

If sediment concentration increases further, the flocculation will eventually interact with the hydrodynamics such that flocculation during settling may cause an upward flow of the liquid that they displace. This would result in hindered settling leading to a reduction in settling velocity. The start of the flocculation and hindered concentrations are 0.01 kg/m^{3}and 10 kg/m^3, respectively. Table 2-6 summarises the settling parameters used in the model.

Table 2-6 Settling parameters in the water column

Fractions	Concentration for flocculation (kg/m^3)	Concentration for hindered setting (kg/ m^3)	Density of Dry Fine Particle (kg/m^3)	Settling velocity coefficient (m/s)	Corresponding to settling velocity range (mm/s)
F1	0.01	10	2650	10.6	0.06
F2	0.01	10	2650	63.6	0.3
F3	0.01	10	2650	185.5	0.7
F4	0.01	10	2650	662.5	3.0
F5	0.01	10	2650	1855	7.0

2.7.3 Sediment deposition

In the dredge plume model, the deposition rate is formulated as a function of the settling velocity, the near-bed concentration and the actual critical bed shear stress for deposition. The settling velocity in this formula depends on two key parameters, namely the grain size and an estimation of the level of flocculation, with larger grain sizes (i.e. those associated with sands) containing much higher settling velocities than finer materials. As such, sands are more readily deposited in the model than the fine silt and clay materials, which tend to remain suspended and transport greater distances in the model.

For the present study, a range of (0.1 N/m^2 to 0.3 N/m^2) critical bed shear stress for deposition was employed to reflect the five sediment fractions, and the shear stress adopted is consistent with recommendations for dredge dispersion studies in areas of similar seabed characteristics (J. Jiang 2011).

2.7.4 Erosion rate

The erosion rate depends on the seabed properties; that is, whether the seabed is dense and consolidated or soft and only partly consolidated. In the present model, the bed (due to the sedimentation from spilled plume) is assumed to be one layer, with material deposited and re-suspended solely from the construction works. This enabled the impact of the proposed dredging works to be isolated in the analysis. The layer contains the material which is re-suspended and subsequently settled during each tidal cycle. A critical shear stress is usually set to determine whether the deposition material is re-suspended or not. The criterion for erosion occurs when driving forces exceed sediment stabilising forces.

Estimates of critical shear stress are presented in Table 2-7, based on investigations by Partheniades, (1965) and Parchure & Mehta, (1985). For the present modelling study, the critical shear stress was set to the value of 0.6 N/m^2 for coral reef area and 0.3 N/m^2 for the remaining area, which assumes partly consolidated mud and is a conservative approach.

Table 2-7 Critical shear stress for sediment erosion

Sediment type	Density (kg/m^3)	Typical critical shear stress (N/m^2)
Mobile fluid mud	180	0.05 – 0.1
Partly consolidated mud	450	0.2 – 0.4
Hard mud	600+	0.6 – 2.0

Note: The sediment type indicated in Table 2-7 are reflective of the material for sedimentation from the spilled plume, rather than refer to the existing seabed material.

2.8 Model calibration

Model performance was preliminary assessed for hydrodynamic model calibration. A comparison of the modelled water levels with those predicted at Norfolk Island tidal station, generated through harmonic analysis of constituents quoted in Australia tidal table (AHS, 2015). The comparisons shown in Figure 2-12 indicates an excellent agreement between the model simulation results at the site for both the phase and amplitude comparisons.

The hydrodynamic model performance criteria is specified in UK Foundation for Water Research FR0374 (UKFWR), as follows for tidal elevation:

- Root Mean Square (RMS) error to within +-0.3m at the head on spring tide or alternatively;
- RMS error < 15% on spring tide amplitude (0.26m for this study).

Quantitative performance of the model simulation results (RMS error) of 0.10m was achieved, which is less than that the criteria of 0.26m for the study, indicating the high performance of hydrodynamic model.

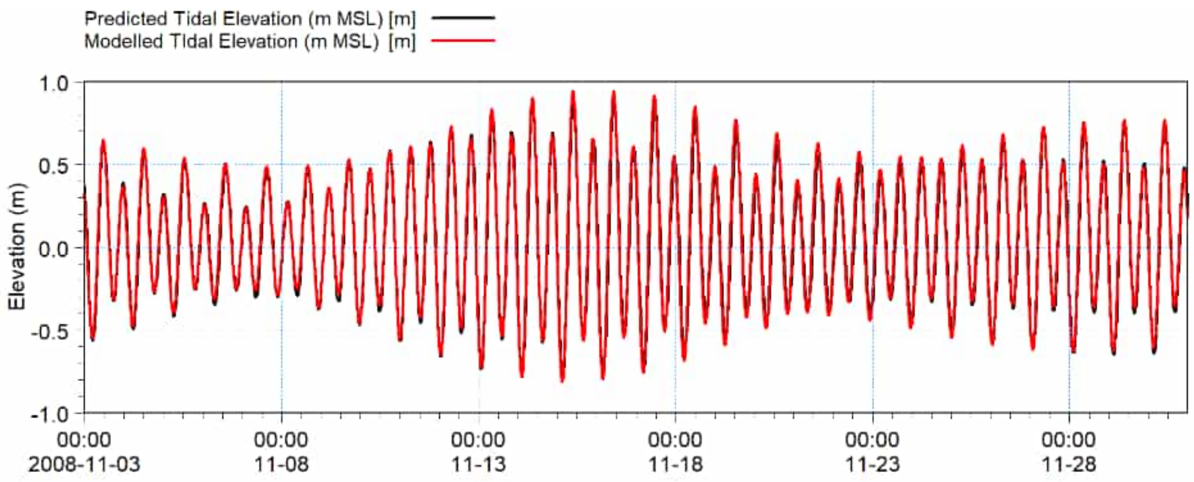

Figure 2-12 Comparison of predicted water level variation at Kingston tidal station with modelled results

2.9 Simulation scenarios

Given that the starting dredging date had not been ascertained at the time of this report, the model was designed to simulate the dredging process from November for a period for four weeks, which is the expected period of dredging operation. Based on analysis of wind data from Kingston for the period from 1940 to 2009, the dominant wind direction during November is from the eastern sector.

In order to reflect the potential wind effects on the plume movement, four sectors of wind directions (north, east, south and west), were selected with a high constant wind forcing (95th Percentile wind speed) for the sediment plume model simulation, to ascertain the potential dominant worst-case wind directions for impacts on the sensitive receptor areas.

In order to reflect the potential wave effects on the plume movement, ambient waves as described in Section 2.4 were included on selected simulation scenarios.

Running a simulation scenario without waves is not considered realistic (as Norfolk Island is almost always exposed to swell waves) but it does provide a conservative bookend to the model results. Furthermore, by running the model with and without ambient wave forcing demonstrates the model sensitivity to the added wave effects on the plume mixing process. If benign sediment plume and deposition outcomes result from a specific scenario without waves, there is no reason to investigate the scenario further. If any potential sediment plume and/or deposition impacts are indicated by a particular model simulation, then the effects of waves are included to provide a more realistic simulation outcome. Note that dredging is unlikely to occur when wave conditions are greater than ambient, and are therefore not necessary to be modelled.

The list of modelled scenarios is presented in Table 2-8.

Table 2-8 Model simulaton scenarios

Scenarios	Season	Dredging and spill time frame.	Wind	wave	purpose
1	Nov	3 Nov to 1 Dec. (4 weeks) for a total of 5,000 m3 dredged material	Ambient wind	Without wave	Baseline
2	Nov	3 Nov to 1 Dec. (4 weeks) for a total of 5,000 m3 dredged material	Ambient wind	With ambient wave	to check wave effect on baseline
3	Nov	3 Nov to 1 Dec. (4 weeks) for a total of 5,000 m3 dredged material	95th Percentile wind speed (7.7 m/s) under N direction	Without wave	to check north wind effect on baseline
4	Nov	3 Nov to 1 Dec. (4 weeks) for a total of 5,000 m3 dredged material	95th Percentile wind speed (7.7 m/s) under S direction	Without wave	to check south wind effect on baseline
5	Nov	3 Nov to 1 Dec. (4 weeks) for a total of 5,000 m3 dredged material	95th Percentile wind speed (8.7 m/s) under E direction	Without wave	to check east wind effect on baseline
6	Nov	3 Nov to 1 Dec. (4 weeks) for a total of 5,000 m3 dredged material	95th Percentile wind speed (9.3 m/s) under W direction	Without wave	to check west wind effect on baseline
7	Nov	3 Nov to 1 Dec. (4 weeks) for a total of 5,000 m3 dredged material	95th Percentile wind speed (7.7 m/s) under N direction	Swell wave associated with time frame, ambient wave	to check wave effect on north wind scenario
8	Nov	3 Nov to 1 Dec. (4 weeks) for a total of 5,000 m3 dredged material	95th wind speed (9.3 m/s) under W direction	Swell wave associated with time frame, ambient wave	to check wave effect on west wind scenario

3 Dredge plume model results

3.1 Introduction

Predictions of the sediment plume dispersion patterns have been extracted from the dredge dispersion model for the simulated scenarios.

Results are presented for the entire simulation period as spatial plots of suspended sediment concentration (SSC) and sedimentation.

The spatial images of percentiles were selected as the most appropriate means of presenting the results as they clearly indicate the scale and magnitude of the dredging operation's environmental footprint. The results represent concentrations above background levels, that is, the background SSC and sedimentation rates were not included in the analysis.

3.1.1 Suspended sediment concentration

Predictions of the suspended sediment dispersion and concentration over the course of the dredging operation have been illustrated in the model results, which presents the 80th and 95th percentile SSC concentrations. These maps were derived using the integrated depth-averaged SSC values as they were the most conducive to the overall level of light loss in the water column which was of particular concern to corals and aquatic biota in the affected waters.

In the context of the results presented in this report, the percentiles represent the percentage of time during the dredging at which SSC levels are predicted to be below the given thresholds. For example, the 80th percentile is the SSC value below which 80% of the model predicted SSC values may be found. It is important to note that each model grid point will be associated with a different distribution of SSC values with time. Thus, a spatial plot of percentiles is a composite plot and does not represent a SSC distribution predicted to occur at a particular point in time.

It is noted that at SSC concentrations below 10 mg/L above background, the plume would not be visible to a casual observer. The appearance of turbid water with varying concentrations of TSS is illustrated in Figure 3-1.

The term SSC has been used in this report instead of total suspended sediment concentration as background values were not included in the model results. As such, SSC is defined here as the suspended sediment concentration, throughout the water column, resulting from the dredging associated with the project.

Figure 3-1 - Visual representation of suspended sediment concentration

3.1.2 Sedimentation

Predictions of the sedimentation over the course of the dredging operation have been illustrated as the model results, which present the 80th and 95th percentile sedimentation values above seabed. These maps were derived using the seabed change purely due to dredging operation, which was of particular concern to corals and aquatic biota in the affected waters. The density of the initial sedimentation material due to the dredging applied 400 kg/m^2 for sedimentation thickness calculation. With time, as a result of soil consolidation, this density value is expected to increase. Therefore, the sedimentation values presented in this report provides conservative sedimentation values.

In the context of the results presented in this report, the percentiles represent the percentage of time during the dredging at which sedimentation levels are predicted to be below the given thresholds. For example, the 80th percentile is the sedimentation value below which 80% of the model predicted sedimentation values may be found (i.e. sedimentation would only be greater than the 80th percentile value for 20% of the time during the dredging campaign). It is important to note that each model grid point will be associated with a different distribution of SSC values with time. Thus, a spatial plot of percentiles is a composite plot and does not represent a sedimentation value predicted to occur at a particular point in time.

The term sedimentation has been used in this report instead of total accretion/erosion as background values were not included in the model results. As such, sedimentation is defined here as the resulting from the dredging associated with the Project.

3.2 Scenario 1

Scenario 1 as a baseline scenario simulated the dredge plume dispersion under ambient winds without waves.

Figure 3-2 and Figure 3-3 detail the 80th and 95th percentile SSC concentrations, respectively. The dredge plume was retained within the Kingston harbour (up to 30mg/L and 100mg/L for the 80th and 95th percentile, respectively). For the 80th percentile, there is no plume detected for lagoon and coral areas. For 95th percentile, a limited level plume (less than 10 mg/L) was detected by the model in the north-west part of the lagoon, away from the edge of coral reef.

Figure 3-4 and Figure 3-5 presents the 80th and 95th percentile sedimentation, respectively. The sedimentation plots show the sedimentation (up to 33mm and 50mm for the 80th and 95th percentile, respectively) confined within the Kingston harbour dredge area. There is no sedimentation detected for the lagoon and coral areas.

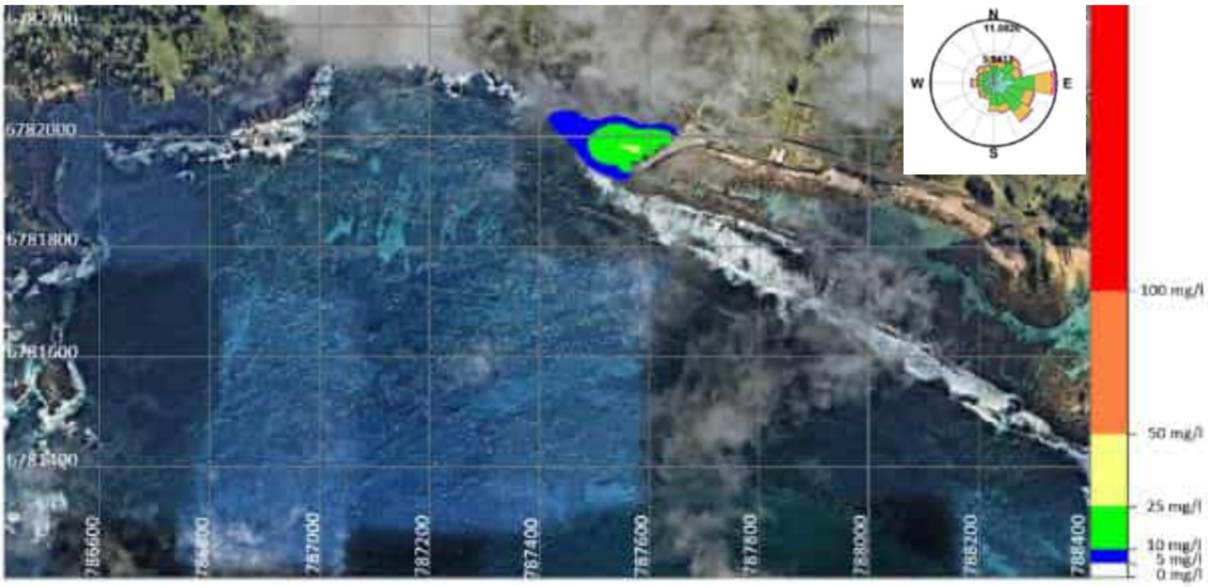

Figure 3-2 80th%ile Suspended sedimentation concentration distribution for Scenario 1 (ambient wind, wind rose for November shown)

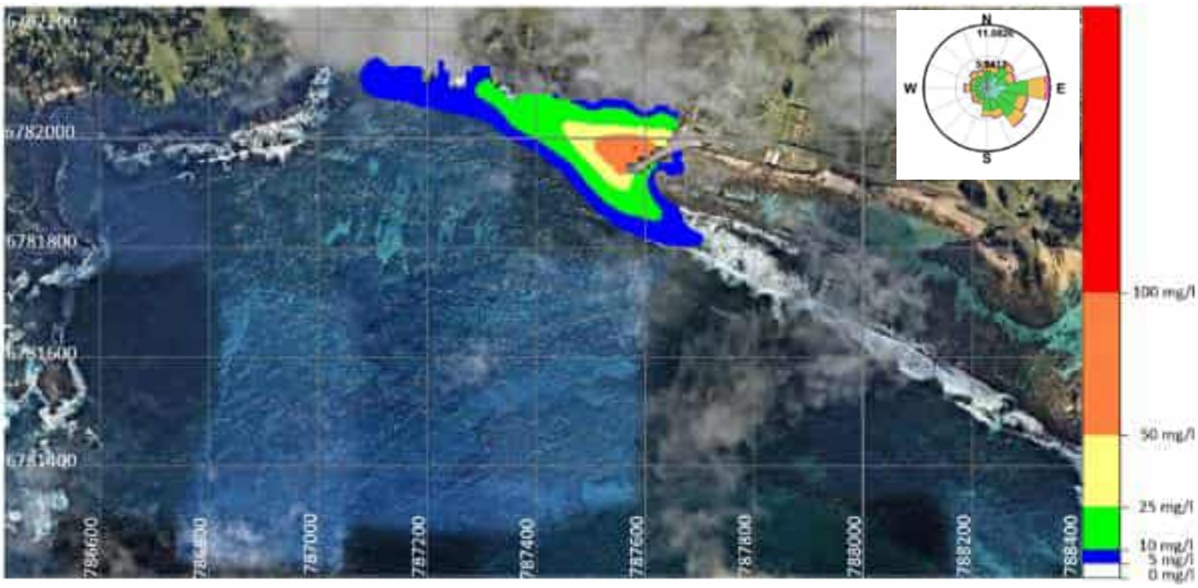

Figure 3-3 95th%ile Suspended sedimentation concentration distribution for Scenario 1 (ambient wind, wind rose for November shown)

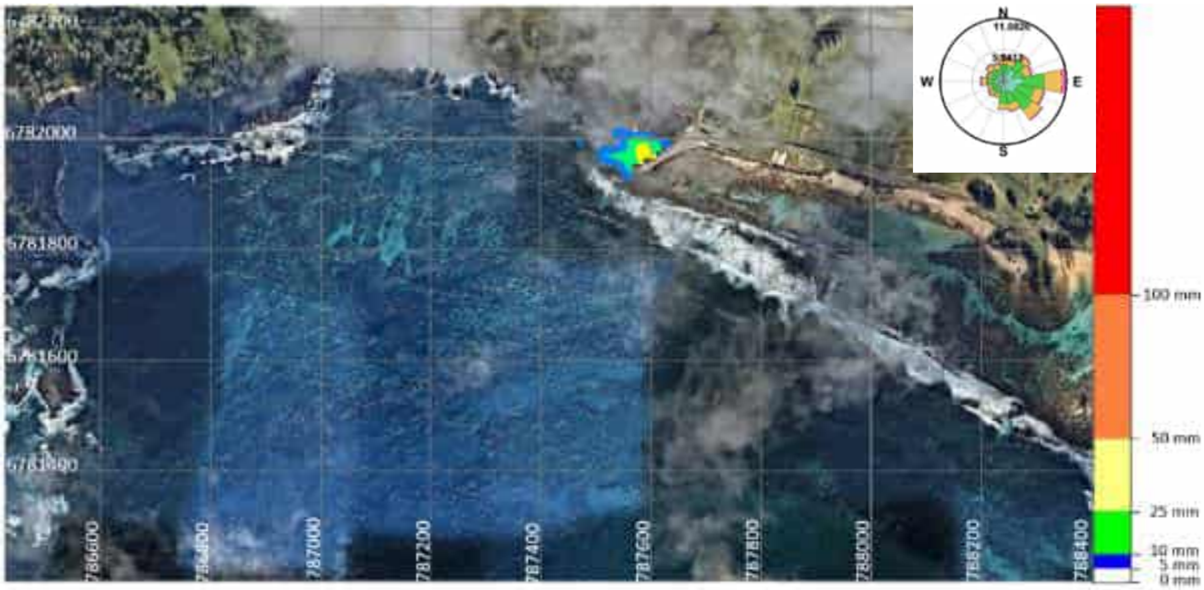

Figure 3-4 80th%ile Sedimentation thickness distribution for Scenario 1 (ambient wind, wind rose for November shown)

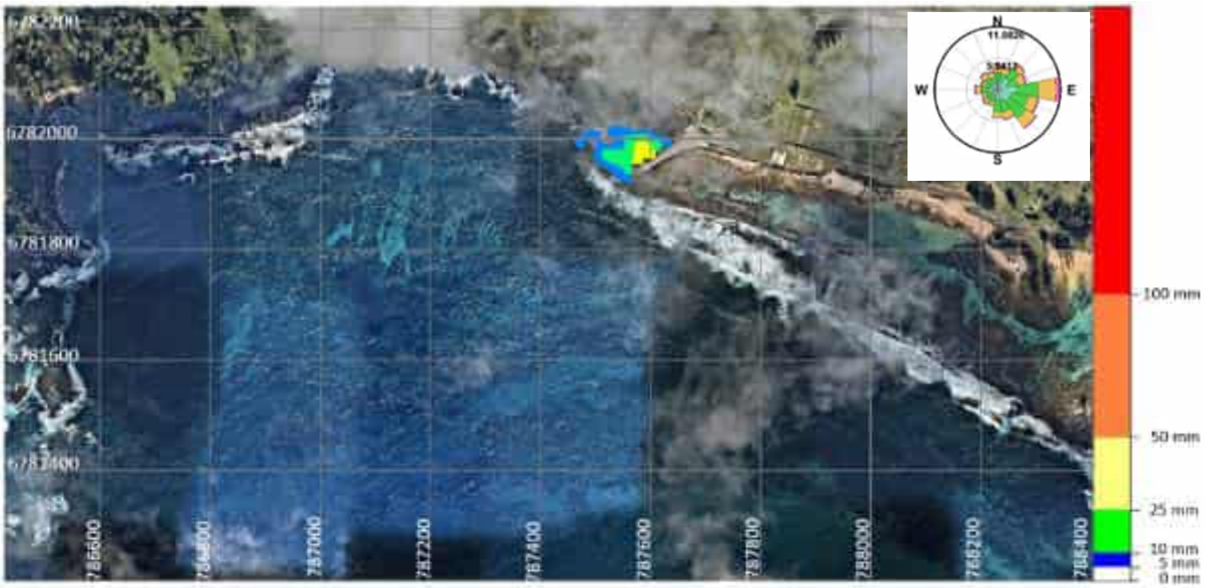

Figure 3-5 95th%ile Sedimentation thickness distribution for Scenario 1 (ambient wind, wind rose for November shown)

3.3 Scenario 2

Scenario 2 simulated the dredge plume dispersion under ambient winds from all directions with ambient waves. These are considered typical conditions.

Figure 3-6 and Figure 3-7 detail the 80th and 95th percentile SSC concentrations, respectively. The dredge plume was retained within the Kingston harbour (up to 50mg/L and 150mg/L for the 80th and 95th percentile, respectively). For both of 80th percentile and 95th percentile, there is no plume detected for the lagoon and coral areas. Compared to the scenario without the ambient waves (Baseline scenario), the wave forcing has resuspended the sedimentation material back to the water column, and therefore it increased the SSC concentration levels through enhancing the mixing process through the water column.

Figure 3-8 and Figure 3-9 presents the 80th and 95th percentile sedimentation, respectively. The sedimentation plots show negligible sedimentation (less than 5mm for 80th and 95th percentile, respectively.) within the Kingston harbour dredge area. There is no sedimentation detected for the lagoon and coral areas.

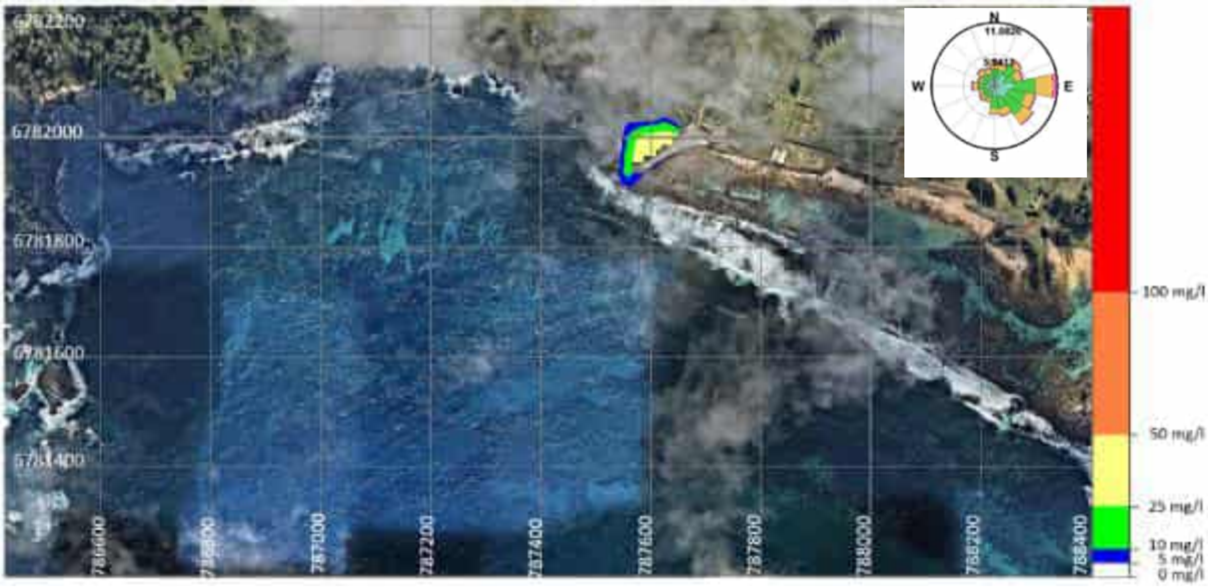

Figure 3-6 80th%ile Suspended sedimentation concentration distribution for Scenario 2 (ambient wind and waves, wind rose for November shown)

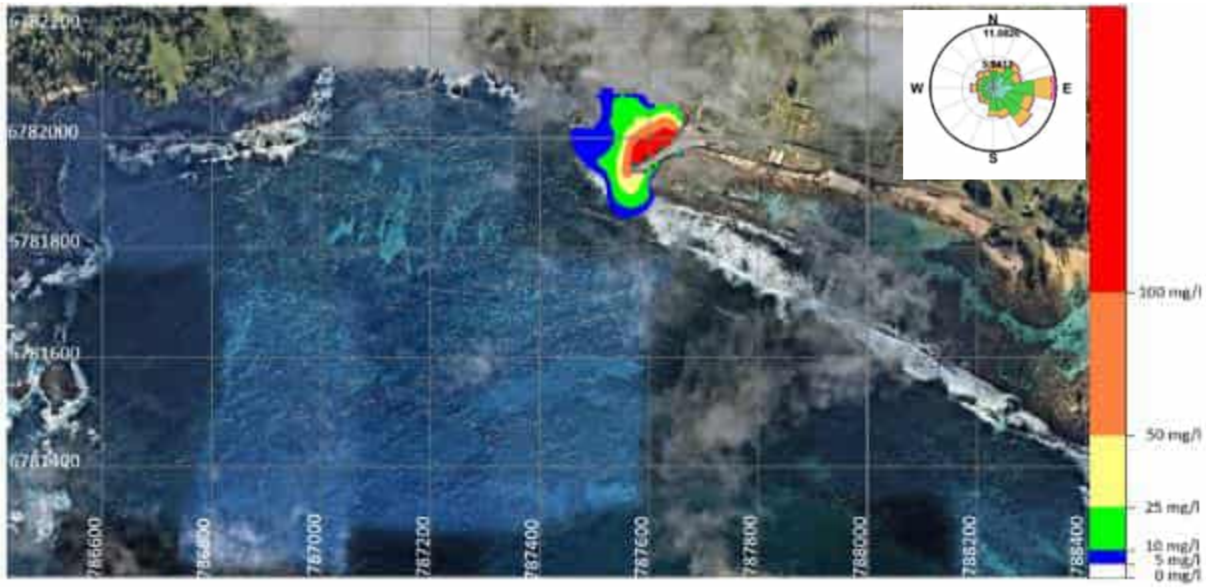

Figure 3-7 95th%ile Suspended sedimentation concentration distribution for Scenario 2 (ambient wind and waves, wind rose for November shown)

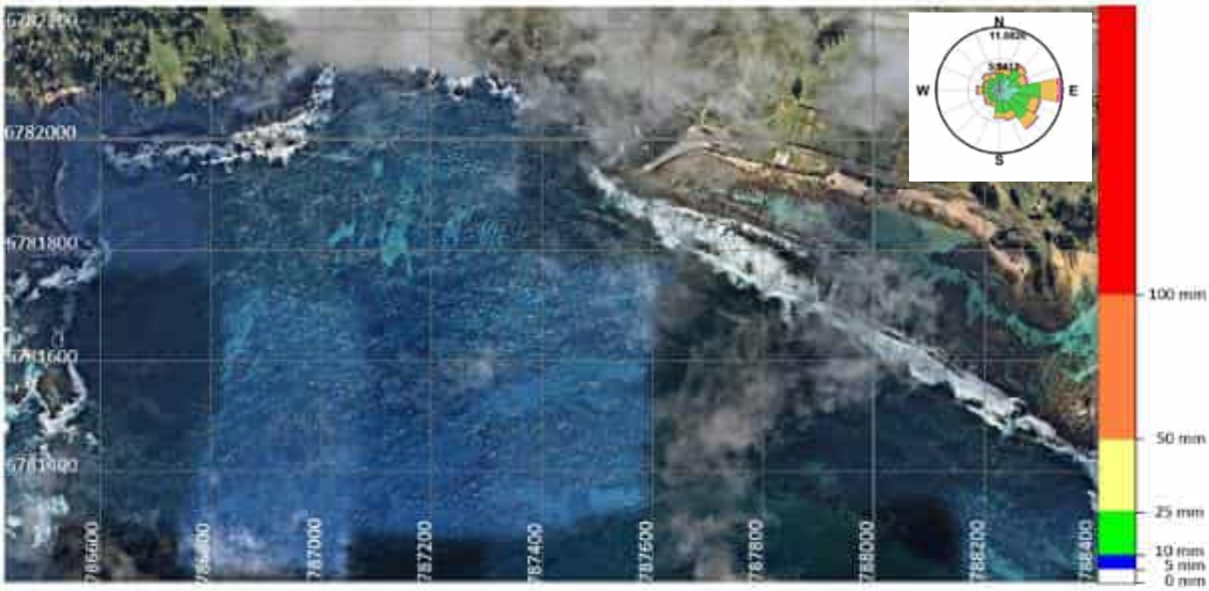

Figure 3-8 80th%ile Sedimentation thickness distribution for Scenario 2 (ambient wind and waves, wind rose for November shown)

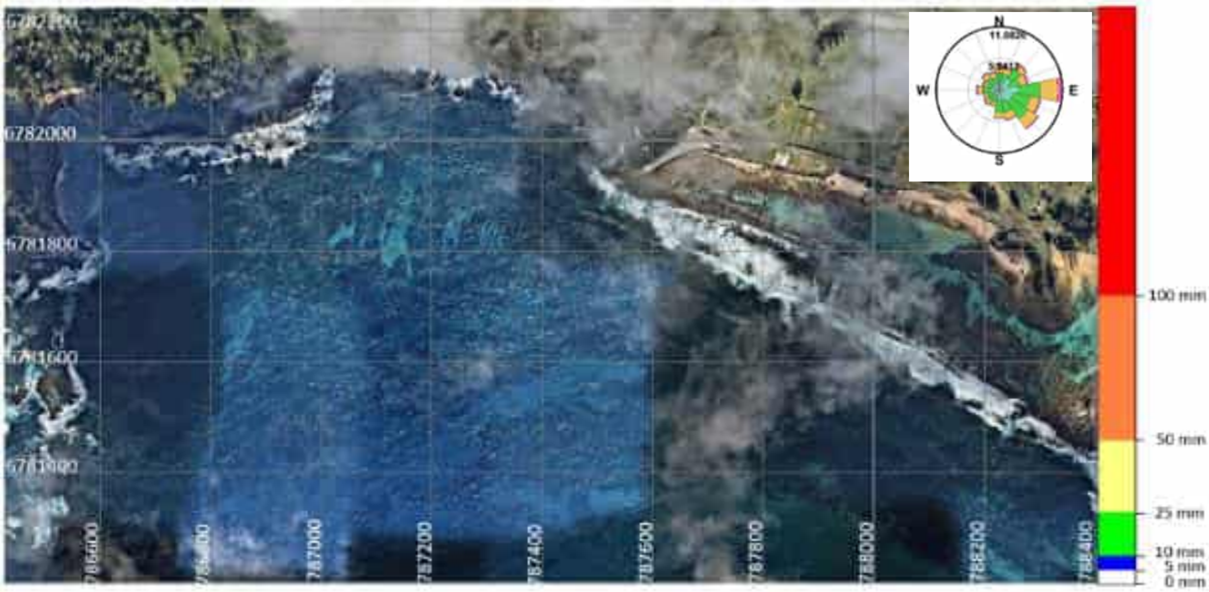

Figure 3-9 95th%ile Sedimentation thickness distribution for Scenario 2 (ambient wind and waves, wind rose for November shown)

3.4 Scenario 3

Scenario 3 simulated the dredge plume dispersion using 95th percentile wind speed coming from a northern direction and without waves. This scenario was investigated for the north wind effect on the baseline scenario.

Figure 3-10 and Figure 3-11 detail the 80th and 95th percentile SSC concentrations, respectively. The dredge plume within the Kingston harbour was detected up to 25mg/L and 110mg/L for the 80th and 95th percentile, respectively. For the 80th percentile, there is negligible dredge plume (less than 5 mg/L) detected for lagoon and coral areas. For the 95th percentile, the dredge plume (up to 25 mg/L) was detected heading to the lagoon and coral reef area, however for most of the lagoon area, this plume is invisible (less than 10 mg/L). Compared to the scenario with the ambient winds (Baseline scenario), the wind from the northern sector is predicted to move the plume, heading to the lagoon area.

Figure 3-12 and Figure 3-13 presents the 80th and 95th percentile sedimentation, respectively. The sedimentation plots show the sedimentation (up to 50mm and 75mm for the 80th and 95th percentile, respectively) confined within the Kingston harbour dredge area. There is no sedimentation detected for the lagoon and coral areas. Compared to the scenario with the ambient winds (Baseline scenario), the wind from the northern sector is predicted to have no impact on sedimentation patterns.

<u>Note this scenario is conservative, and was rerun with ambient waves (refer Scenario 7 in Section3.8) to demonstrate a more realistic conditions.</u>

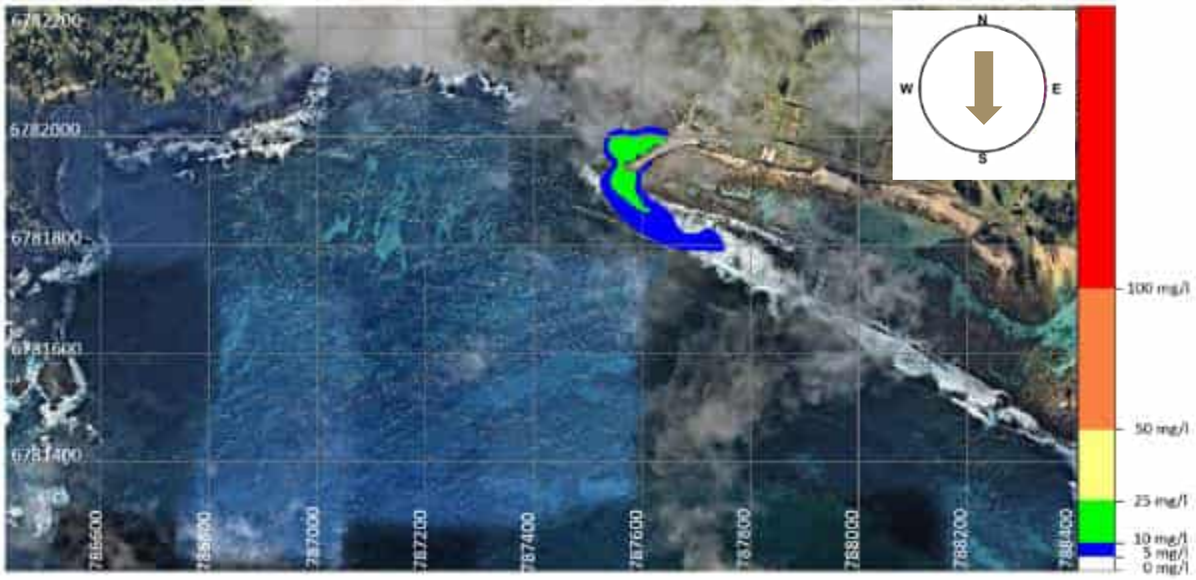

Figure 3-10 80th%ile Suspended sedimentation concentration distribution for Scenario 3 (northerly wind, no waves)

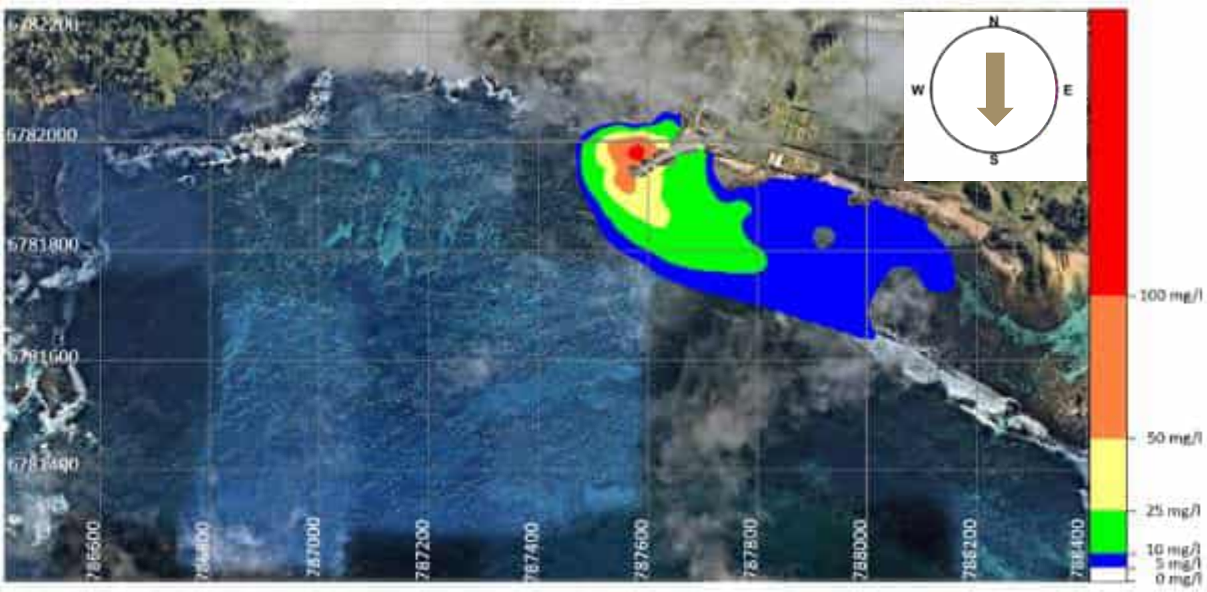

Figure 3-11 95th%ile Suspended sedimentation concentration distribution for Scenario 3 (northerly wind, no waves)

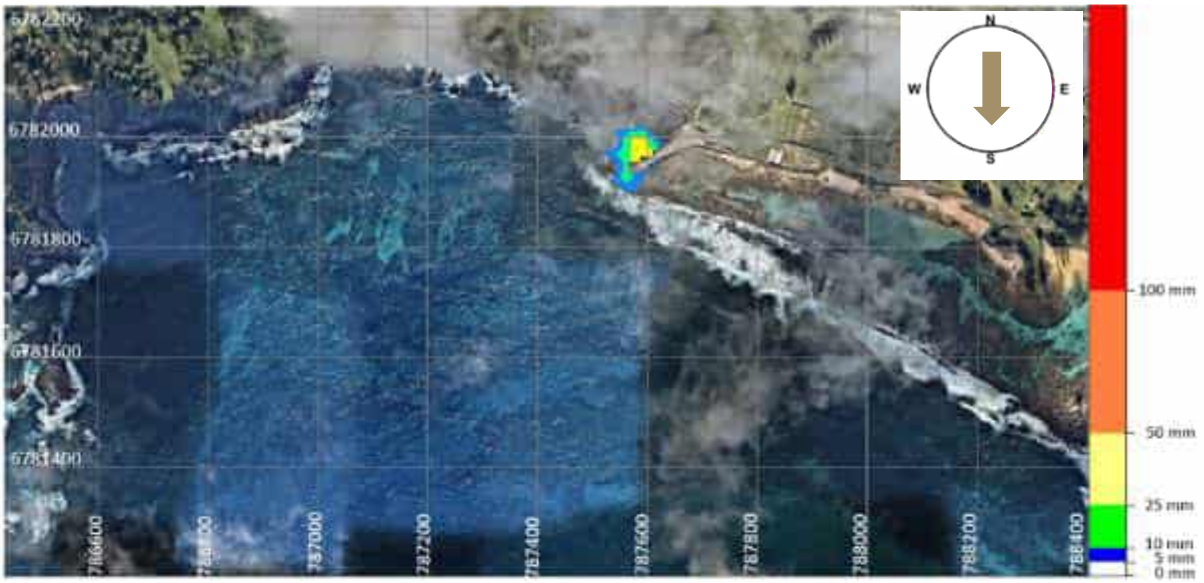

Figure 3-12 80th%ile Sedimentation thickness distribution for Scenario 3 (northerly wind, no waves)

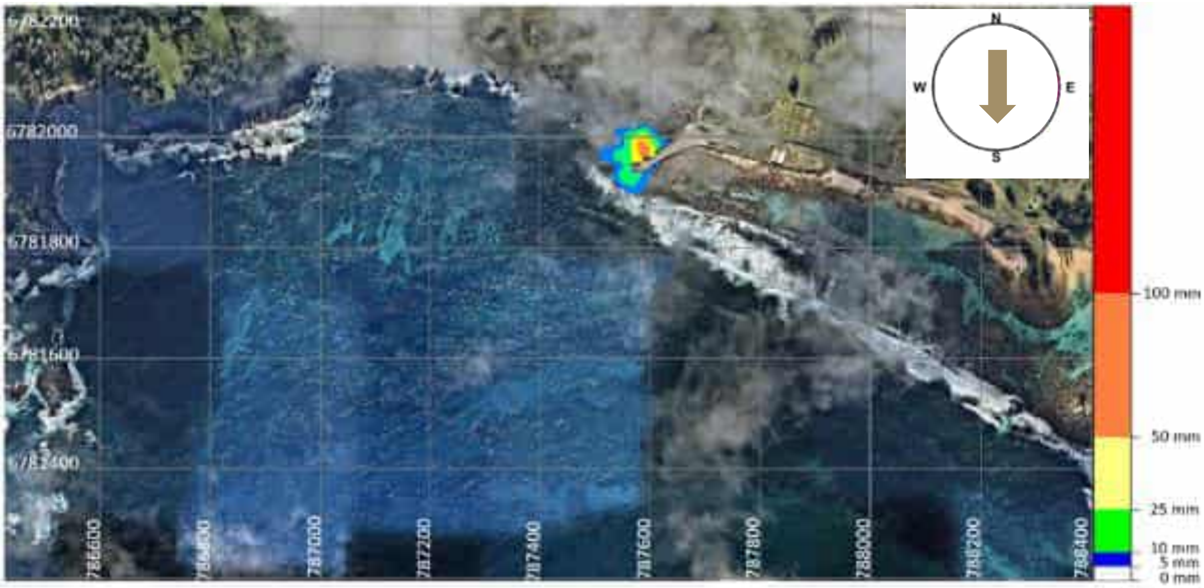

Figure 3-13 95th%ile Sedimentation thickness distribution for Scenario 3 (northerly wind, no waves)

3.5 Scenario 4

Scenario 4 simulated the dredge plume dispersion using 95th percentile wind speed coming from a southern direction and without waves. This scenario investigated for the south wind effect on the baseline scenario.

Figure 3-14 and Figure 3-15 detail the 80th and 95th percentile SSC concentrations, respectively. The dredge plume within the Kingston harbour was detected up to 40mg/L and 120mg/L for the 80th and 95th percentile, respectively. For both the 80th and 95th percentile, there is no dredge plume detected for the lagoon and coral areas. Compared to the scenario with the ambient winds (Baseline scenario), the wind from the southern sector is predicted to move the plume toward the north-eastern direction away from the lagoon area.

Figure 3-16 and Figure 3-17 presents the 80th and 95th percentile sedimentation, respectively. The sedimentation plots show the sedimentation (up to 40mm and 45mm for the 80th and 95th percentile, respectively) narrowed within the Kingston harbour dredge area. There is no sedimentation detected for lagoon and coral areas. Compared to the scenario with the ambient winds (Baseline scenario), the wind from the southern sector is predicted to not impact on sedimentation patterns.

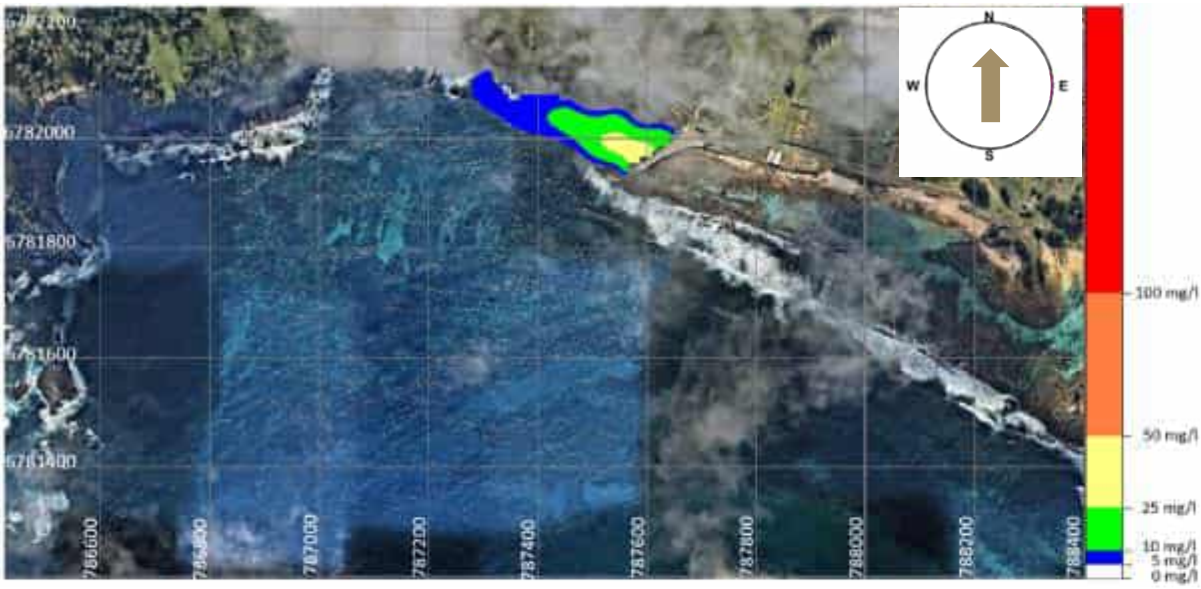

Figure 3-14 80th%ile Suspended sedimentation concentration distribution for Scenario 4 (southerly wind, no waves)

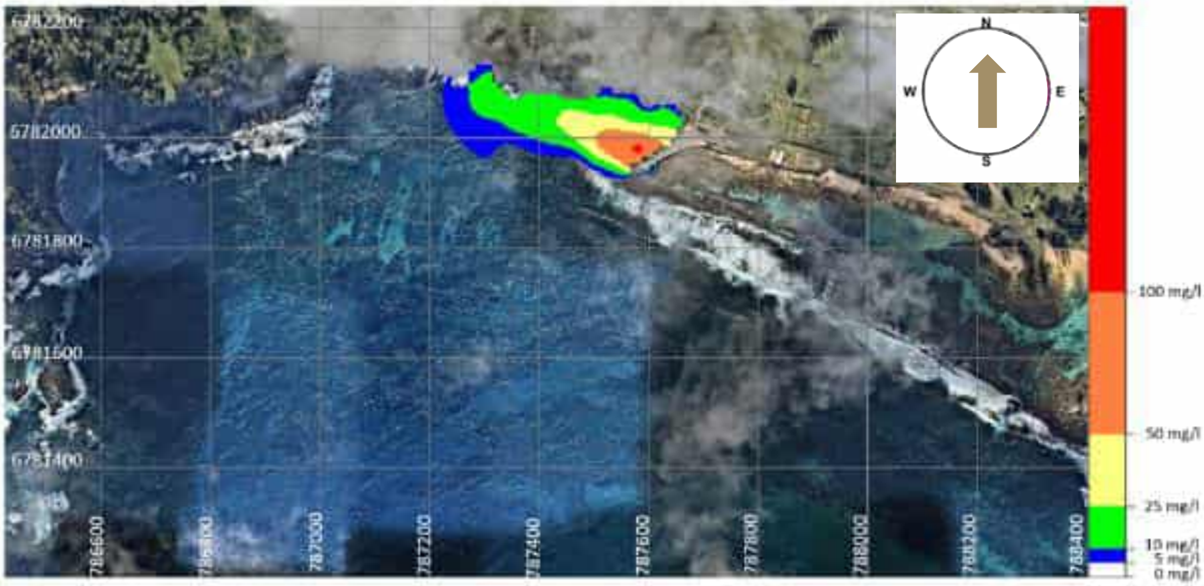

Figure 3-15 95th%ile Suspended sedimentation concentration distribution for Scenario 4 (southerly wind, no waves)

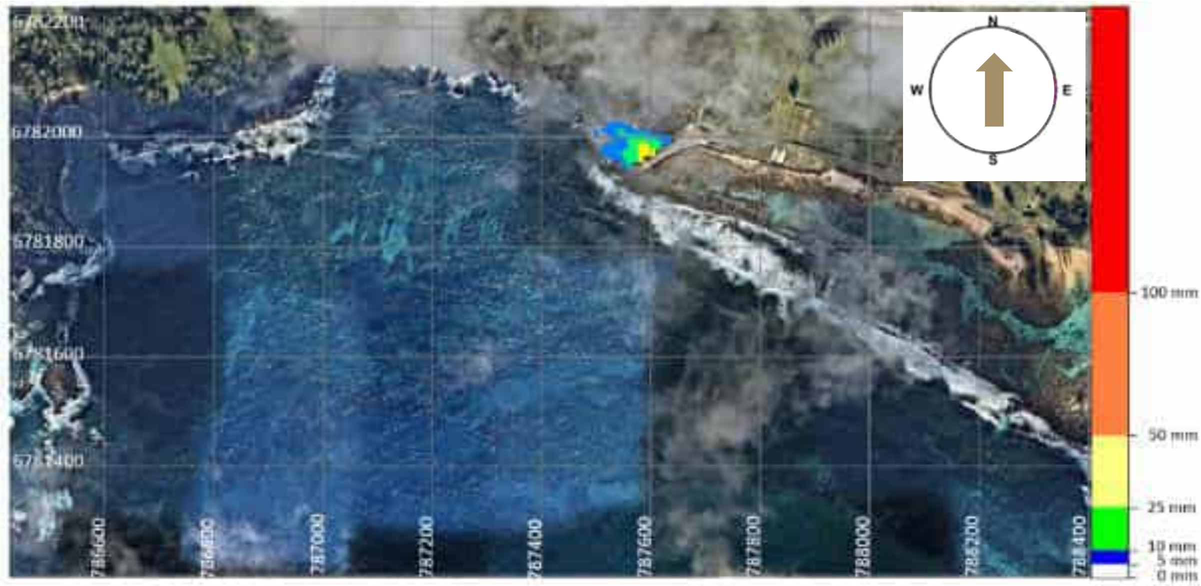

Figure 3-16 80th%ile Sedimentation thickness distribution for Scenario 4 (southerly wind, no waves)

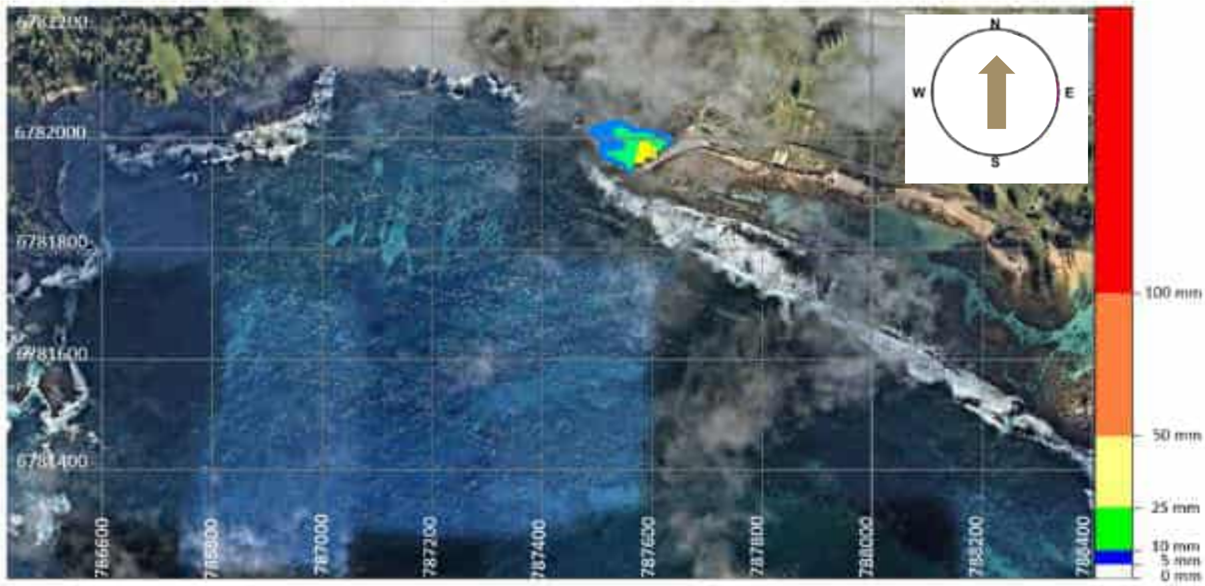

Figure 3-17 95th%ile Sedimentation thickness distribution for Scenario 4 (southerly wind, no waves)

3.6 Scenario 5

Scenario 5 simulated the dredge plume dispersion using 95th percentile wind speed coming from an eastern direction without waves. This scenario investigated the east wind effect on the baseline scenario.

Figure 3-18 and Figure 3-19 detail the 80th and 95th percentile SSC concentrations, respectively. The dredge plume within the Kingston harbour was detected up to 45mg/L and 100mg/L for the 80th and 95th percentile, respectively. For both the 80th and 95th percentile, there is no dredge plume detected for the lagoon and coral areas. Compared to the scenario with the ambient winds (Baseline scenario), the wind from the eastern sector is predicted to move the plume toward the west along the shoreline and away from the lagoon area.

Figure 3-20 and Figure 3-21 presents the 80th and 95th percentile sedimentation, respectively. The sedimentation plots show the sedimentation (up to 40mm and 50mm for the 80th and 95th percentile, respectively) confined within the Kingston harbour dredge area. There is no sedimentation detected for the lagoon and coral areas. Compared to the scenario with the ambient winds (Baseline scenario), the wind from the eastern sector is predicted to have no impact on sedimentation patterns.

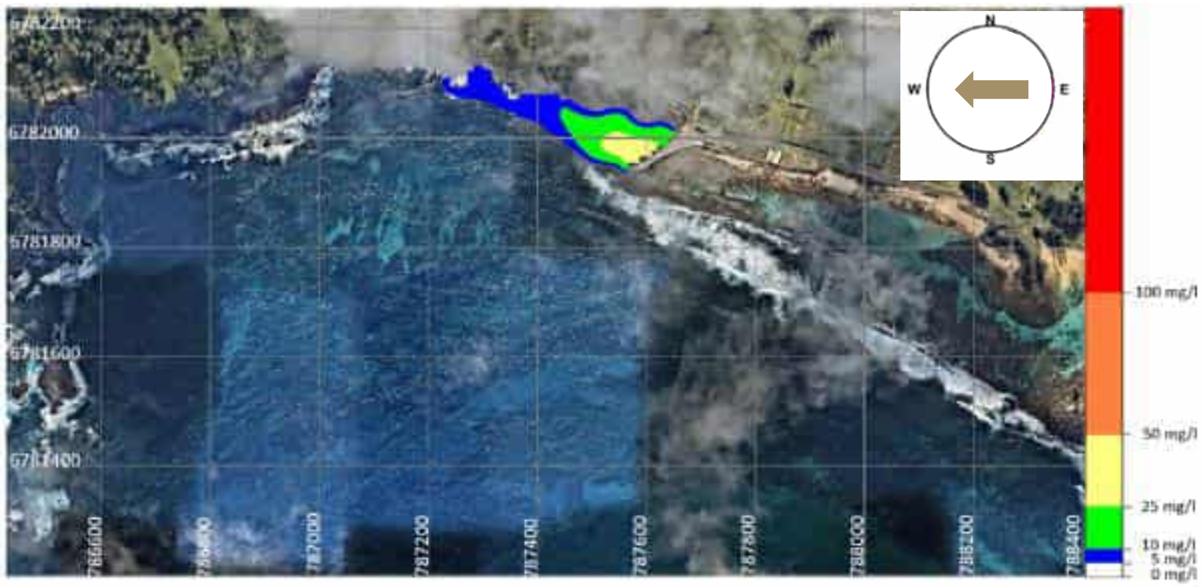

Figure 3-18 80th%ile Suspended sedimentation concentration distribution for Scenario 5 (easterly wind, no waves)

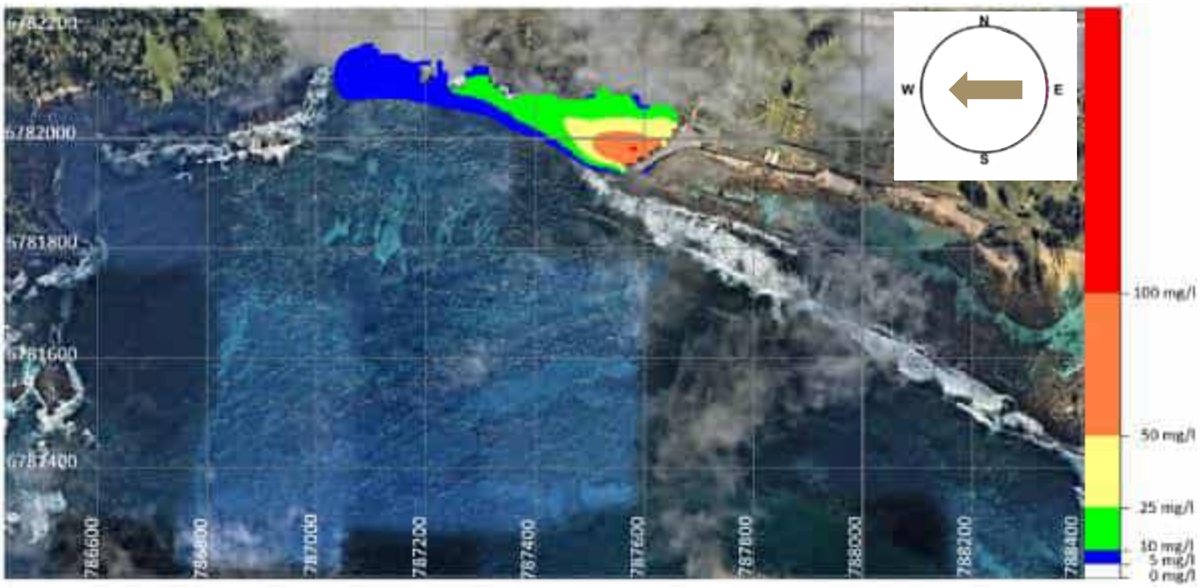

Figure 3-19 95th%ile Suspended sedimentation concentration distribution for Scenario 5 (easterly wind, no waves)

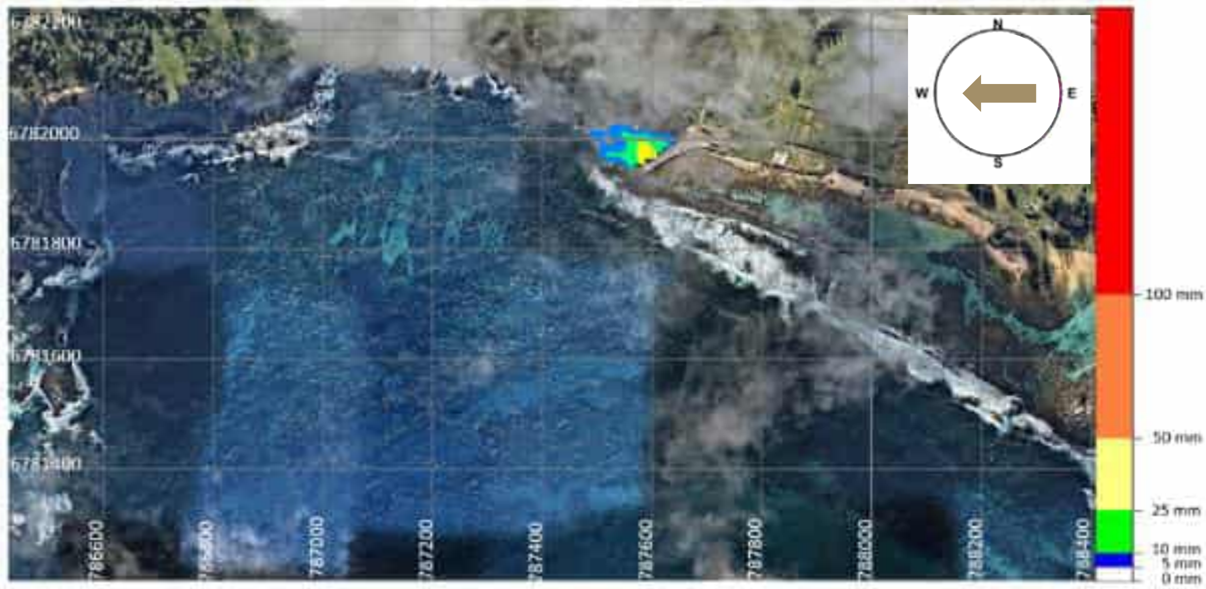

Figure 3-20 80th%ile Sedimentation thickness distribution for Scenario 5 (easterly wind, no waves)

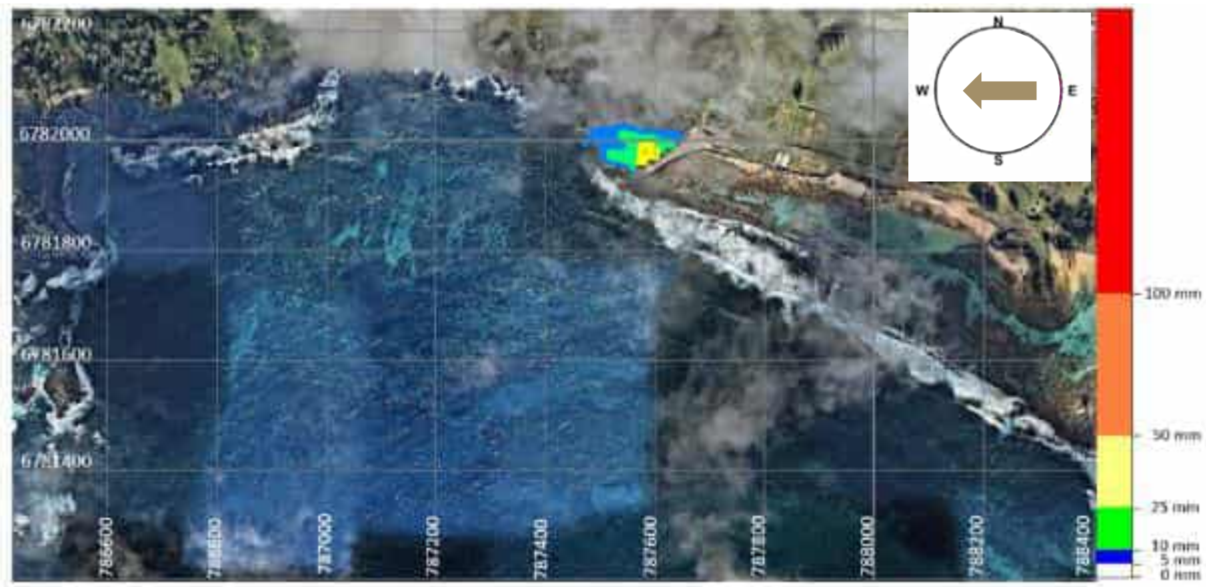

Figure 3-21 95th%ile Sedimentation thickness distribution for Scenario 5 (easterly wind, no waves)

3.7 Scenario 6

Scenario 6 simulated the dredge plume dispersion using 95th percentile wind speed coming from a western direction without waves. This scenario investigated for the west wind effect on the baseline scenario.

Figure 3-22 and Figure 3-23 detail the 80th and 95th percentile SSC concentrations, respectively. The dredge plume within the Kingston harbour was detected up to 20mg/L and 70mg/L for the 80th and 95th percentile, respectively. For the 80th percentile, there is negligible dredge plume (less than 5 mg/L) detected for the lagoon and coral areas. For the 95th percentile, the dredge plume (up to 25 mg/L) was detected heading toward the lagoon and coral reef areas, however, for most of the area of the lagoon, this plume is invisible (less than 10 mg/L). Compared to the scenario with the ambient winds (Baseline scenario), the wind from the western sector is predicted to move the plume heading to lagoon area.

Figure 3-24 and Figure 3-25 presents the 80th and 95th percentile sedimentation, respectively. The sedimentation plots show the sedimentation (up to 30mm and 35mm for the 80th and 95th percentile, respectively) confined within the Kingston harbour dredge area. There is no sedimentation detected for the lagoon and coral areas. Compared to the scenario with the ambient winds (Baseline scenario), the wind from the western sector is predicted to have no impact on sedimentation patterns.

Note this scenario is conservative, and was rerun with ambient waves (refer Scenario 8 in Section 3.9) to demonstrate a more realistic conditions.

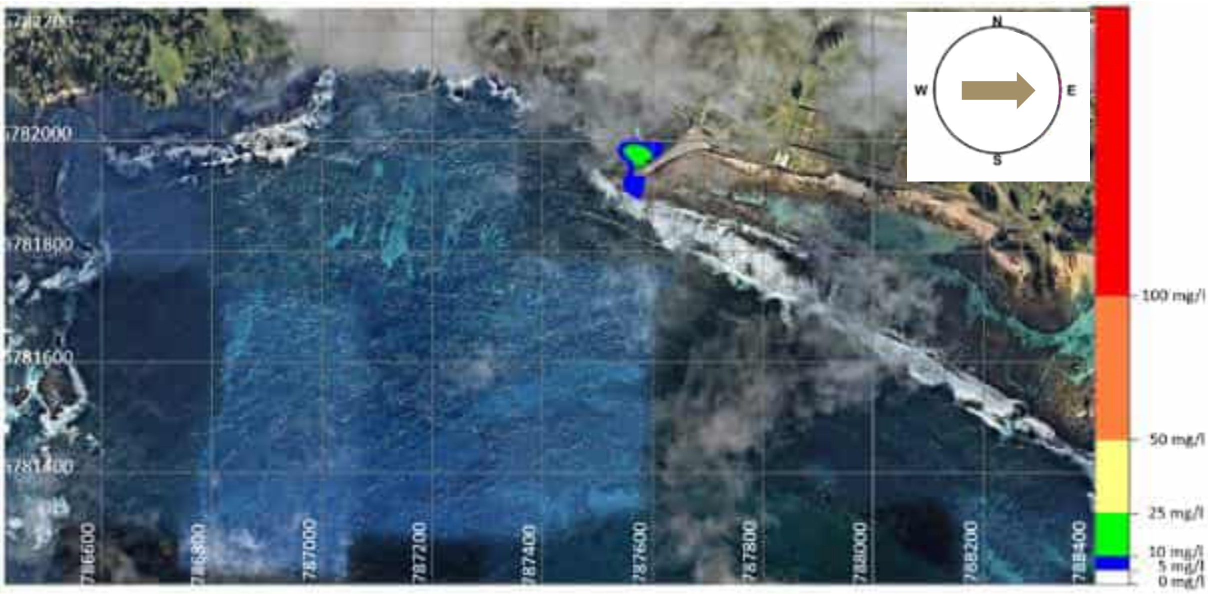

Figure 3-22 80th%ile Suspended sedimentation concentration distribution for Scenario 6 (westerly wind, no waves)

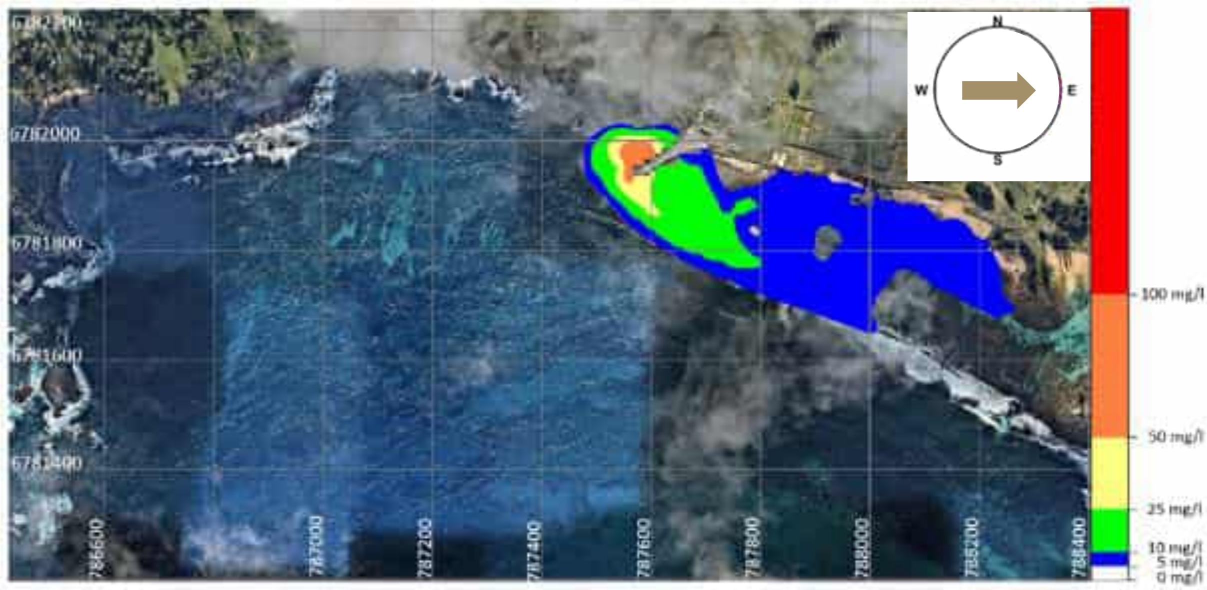

Figure 3-23 95th%ile Suspended sedimentation concentration distribution for Scenario 6 (westerly wind, no waves)

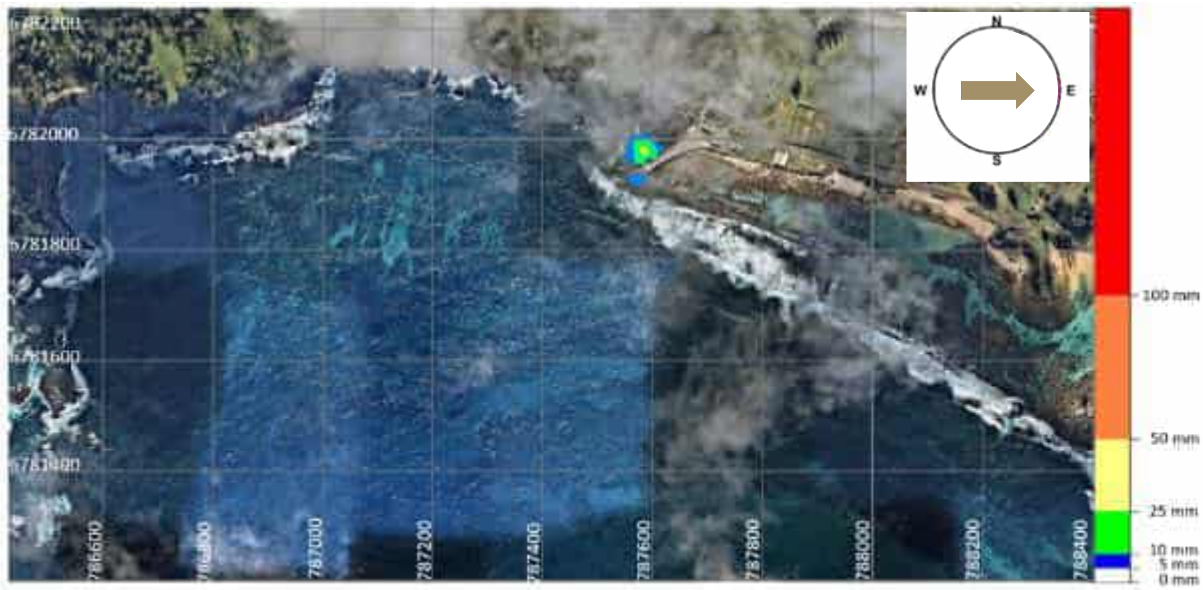

Figure 3-24 80th%ile Sedimentation thickness distribution for Scenario 6 (westerly wind, no waves)

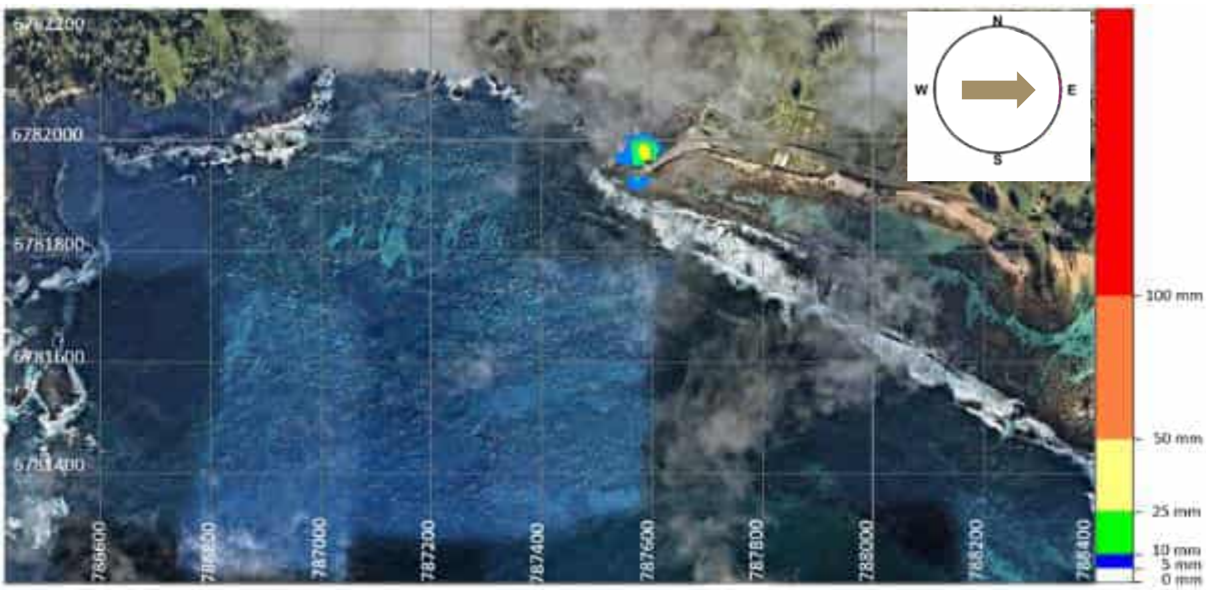

Figure 3-25 95th%ile Sedimentation thickness distribution for Scenario 6 (westerly wind, no waves)

3.8 Scenario 7

Scenario 7 simulated the dredge plume dispersion using 95th percentile wind speed coming from a northern direction with ambient waves. This scenario investigated the effect of waves on Scenario 3, thus representing a more realistic representation of real-world conditions during the dredging period.

Figure 3-26 and Figure 3-27 detail the 80th and 95th percentile SSC concentrations, respectively. The dredge plume within the Kingston harbour was detected up to 30mg/L and 120mg/L for the 80th and 95th percentile, respectively. For both the 80th and 95th percentile, there is no dredge plume detected for the lagoon and coral areas. Compared to the scenario without the ambient waves (Scenario 3), the waves provided a benefit to reduce the plume intensity via mixing with more ambient waters. The plume with the ambient waves is predicted to be retained within Kingston harbour.

Figure 3-28 and Figure 3-29 presents the 80th and 95th percentile sedimentation, respectively. The sedimentation plots show the negligible sedimentation (less than 5mm for 80th and for 95th percentile, respectively) within the Kingston harbour dredge area. There is no sedimentation detected for the lagoon and coral areas. Compared to the scenario without the ambient waves (Scenario 3), the ambient waves scenario has predicted negligible sedimentation, due to wave-induced stirring of bed sediments.

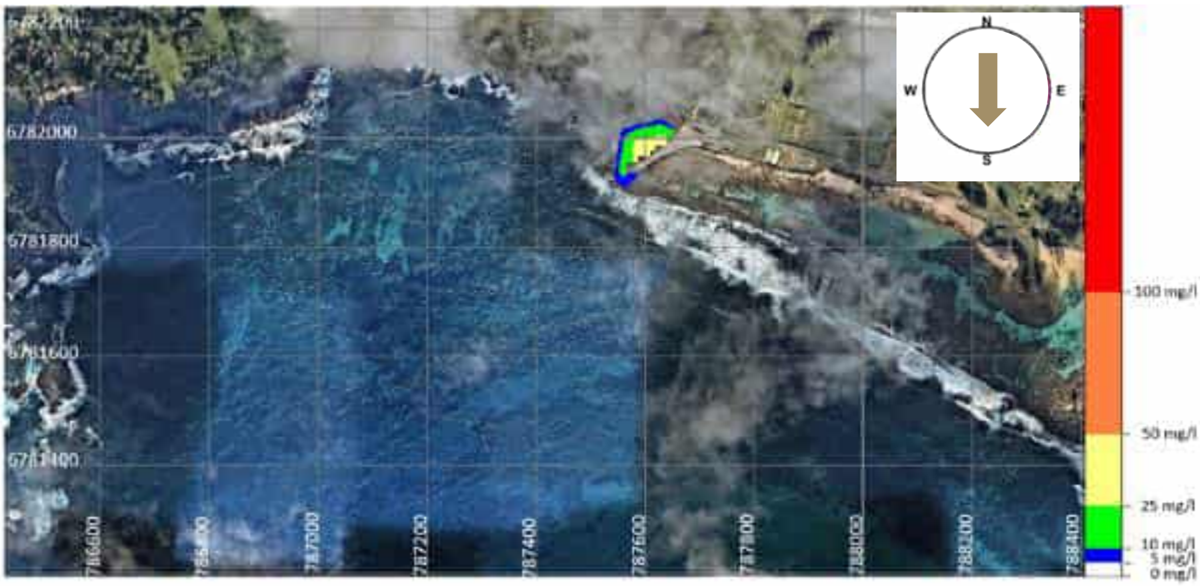

Figure 3-26 80th%ile Suspended sedimentation concentration distribution for Scenario 7 (northerly wind, ambient waves)

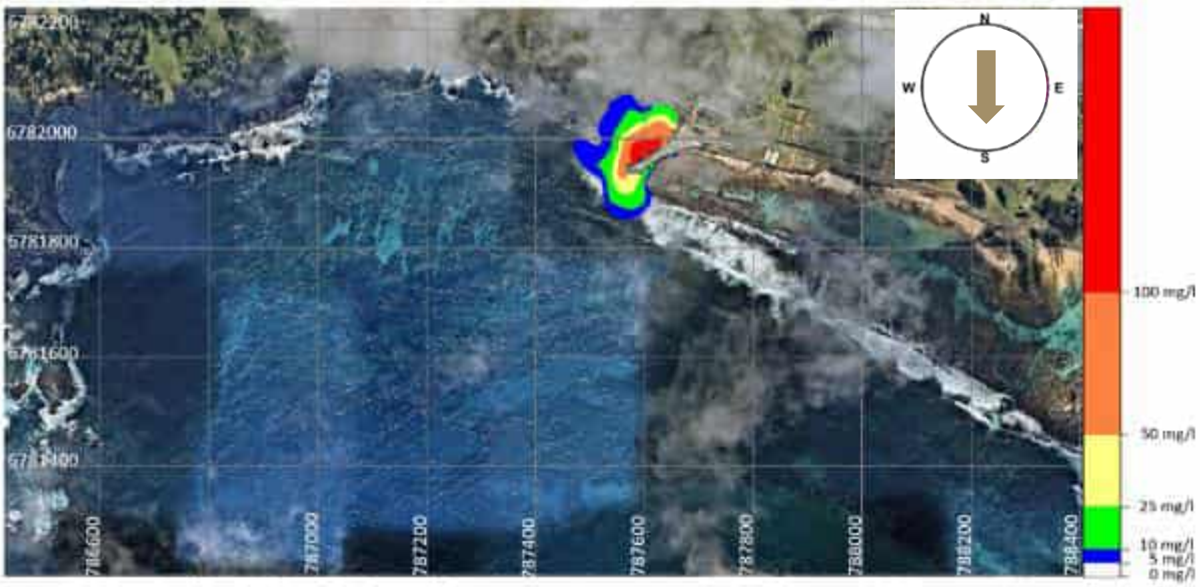

Figure 3-27 95th%ile Suspended sedimentation concentration distribution for Scenario 7 (northerly wind, ambient waves)

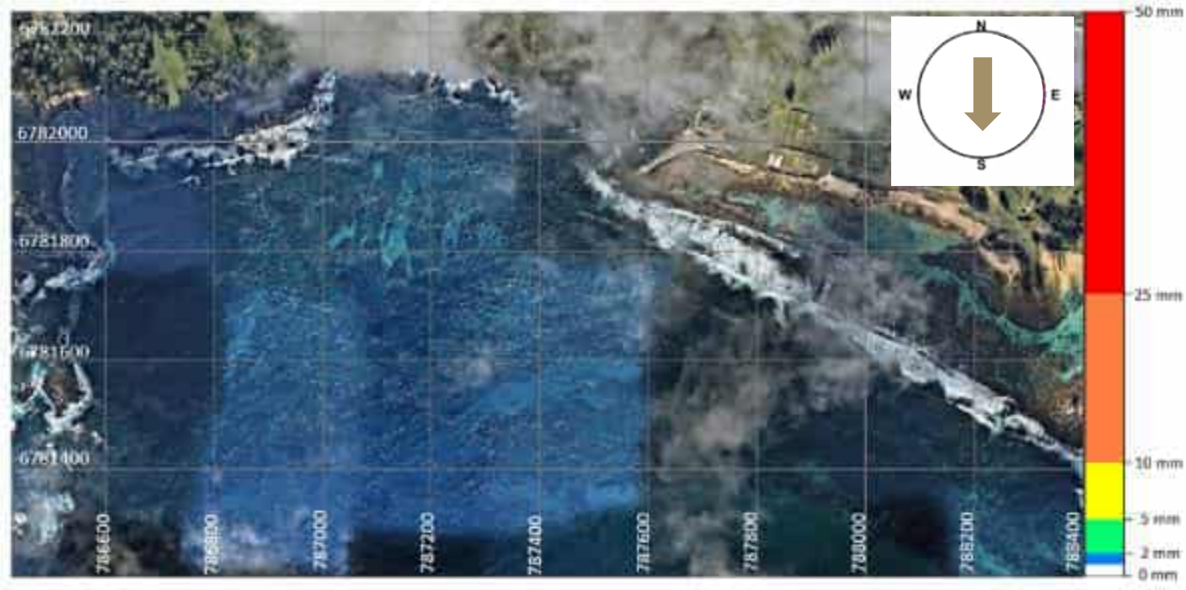

Figure 3-28 80th%ile Sedimentation thickness distribution for Scenario 7 (northerly wind, ambient waves)

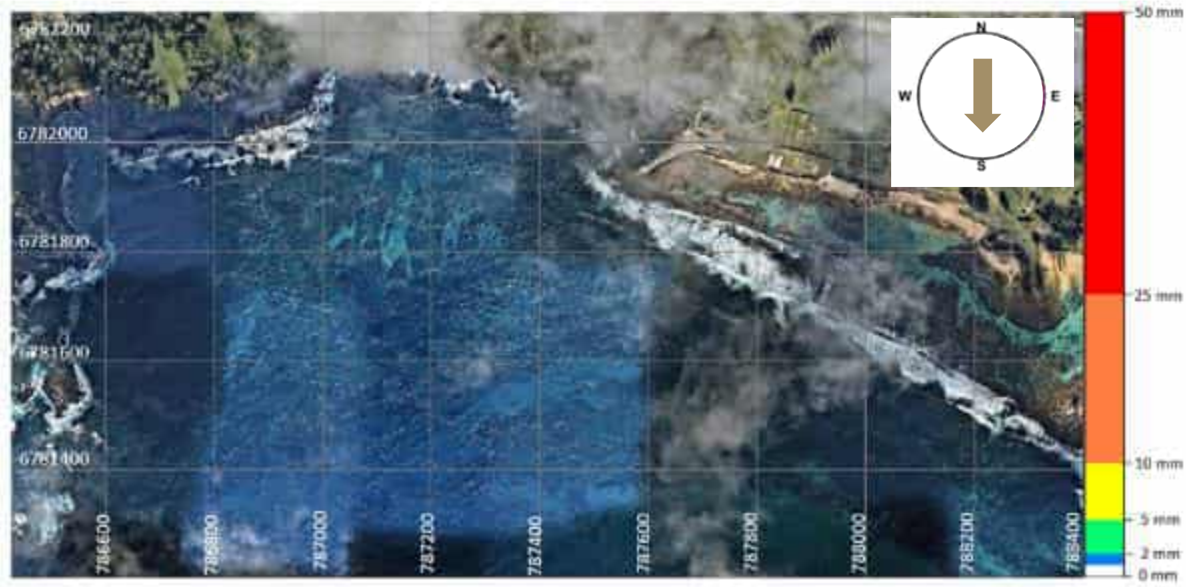

Figure 3-29 95th%ile Sedimentation thickness distribution for Scenario 7 (northerly wind, ambient waves)

3.9 Scenario 8

Scenario 8 simulated the dredge plume dispersion using 95th percentile wind speed coming from west direction with ambient waves. This scenario investigated the effect of waves on Scenario 6, thus representing a more realistic representation of real-world conditions during the dredging period.

Figure 3-30 and Figure 3-31 detail the 80th and 95th percentile SSC concentrations, respectively. The dredge plume within the Kingston harbour was detected up to 17mg/L and 110mg/L for the 80th and 95th percentile, respectively. Under both 80th and 95th percentile, there is no dredge plume detected for the lagoon and coral areas. Compared to the scenario without the ambient waves (Scenario 6), the waves reduce the plume intensity via mixing with more ambient waters. The plume with ambient waves is predicted to be retained within Kingston harbour.

Figure 3-32 and Figure 3-33 presents the 80th and 95th percentile sedimentation, respectively. The sedimentation plots show the negligible sedimentation (less than 5mm for both 80th and 95th percentile) within the Kingston harbour dredge area. There is no sedimentation detected for lagoon and coral areas. Compared to the scenario without the ambient waves (Scenario 6), the ambient waves scenario has predicted negligible sedimentation, due to wave-induced stirring of bed sediments.

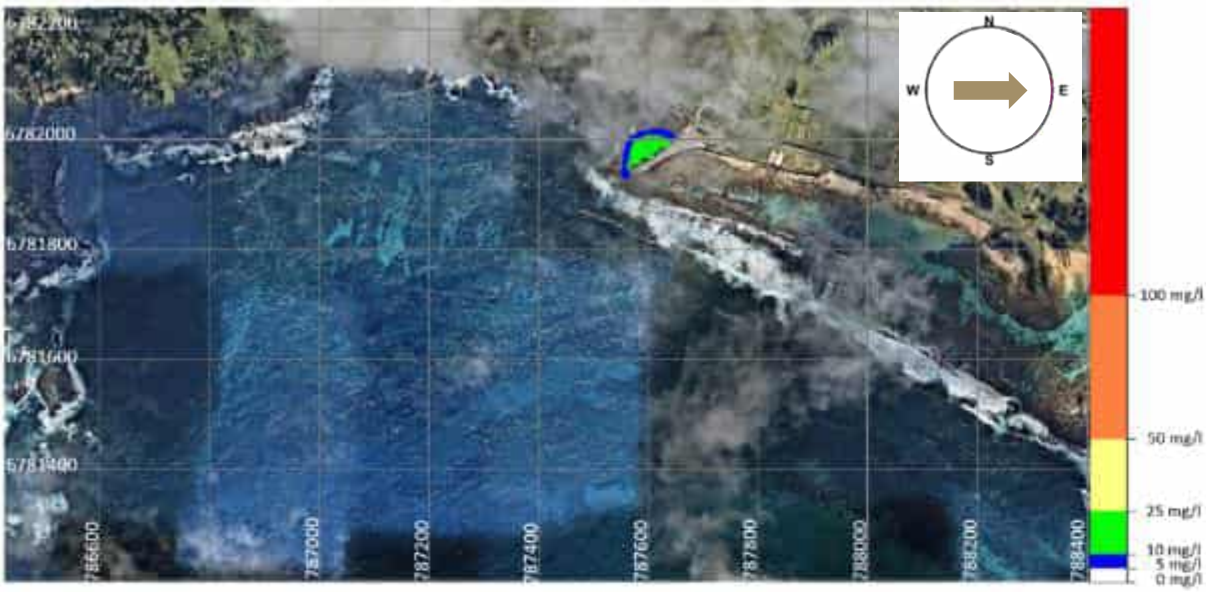

Figure 3-30 80th%ile Suspended sedimentation concentration distribution for Scenario 8 (westerly wind, ambient waves)

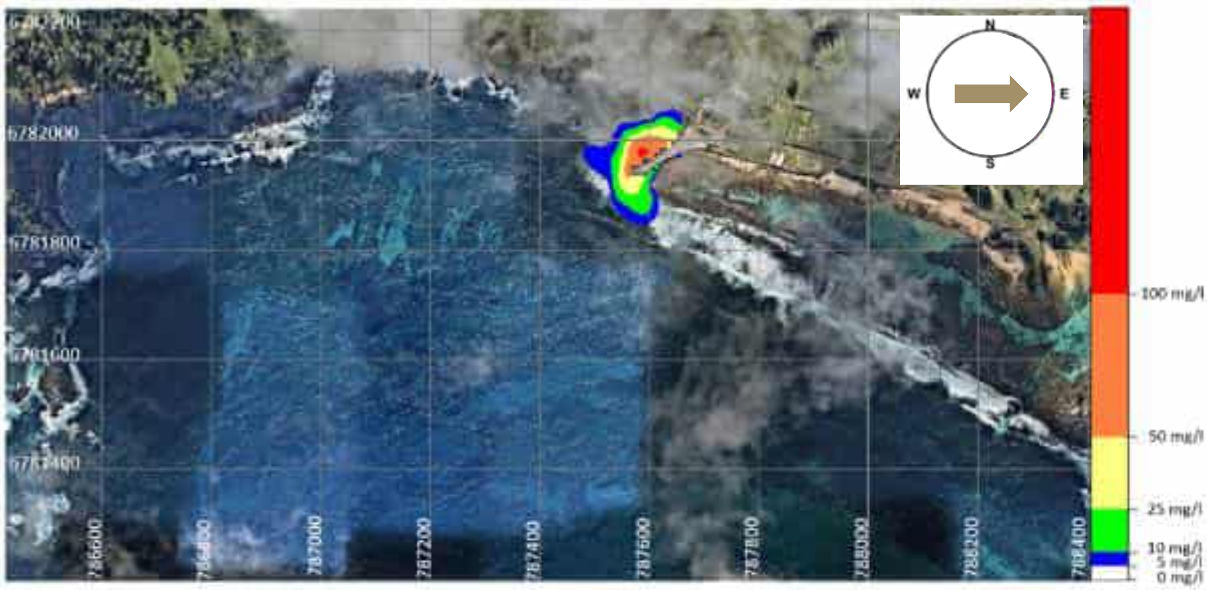

Figure 3-31 95th%ile Suspended sedimentation concentration distribution for Scenario 8 (westerly wind, ambient waves)

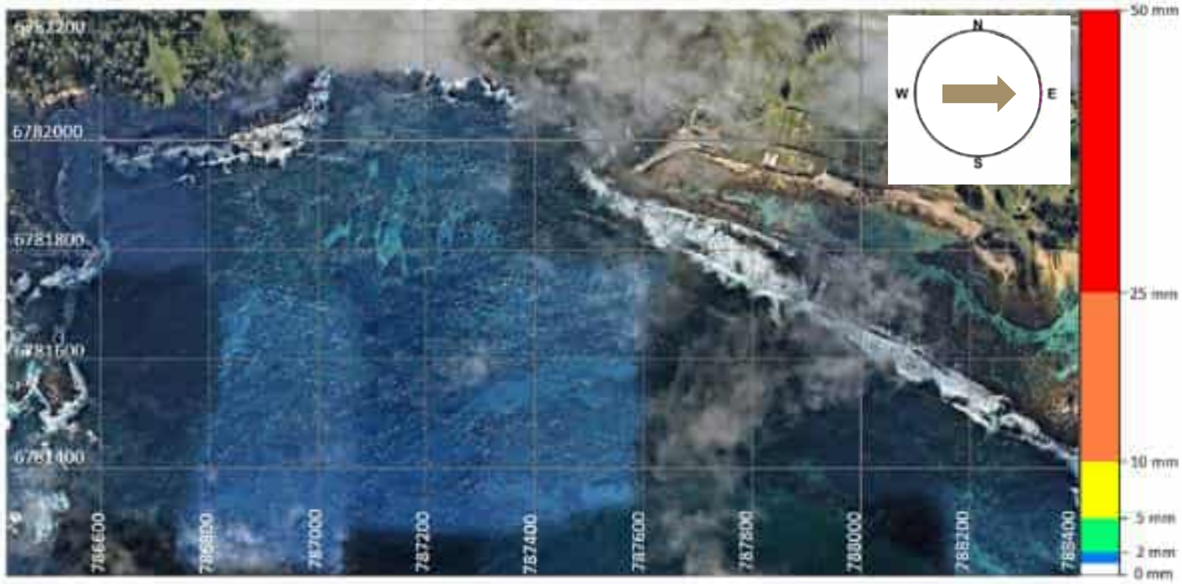

Figure 3-32 80th%ile Sedimentation thickness distribution for Scenario 8 (westerly wind, ambient waves)

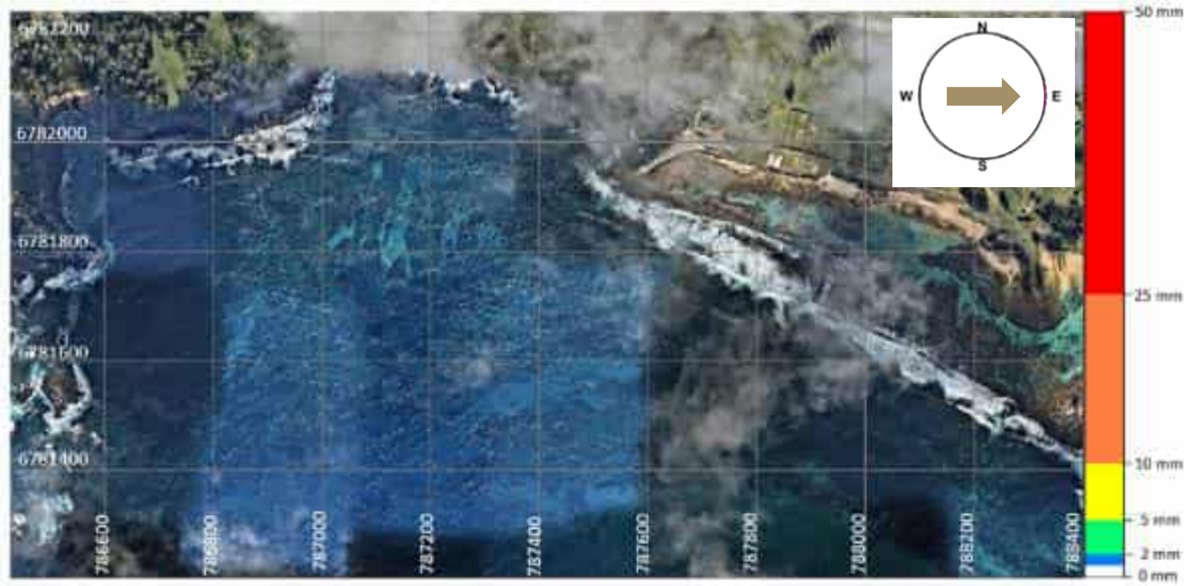

Figure 3-33 95th%ile Sedimentation thickness distribution for Scenario 8 (westerly wind, ambient waves)

3.10 Summary

The sediment plume modelling results are summarised in Table 3-1.

Table 3-1 - Summary of sediment plume modelling results.

Scenario	Result
Scenario 1 (baseline scenario with ambient wind, no waves)	Dredge plume is retained within the Kingston harbour (up to 30 mg/L and 100 mg/L for the 80th and 95th percentile, respectively). No plume detected in lagoon or coral reef areas.
Scenario 2 (typical conditions - most likely scenario; ambient wind, ambient waves)	No plume detected for the lagoon and coral reef areas for both the 80th and 95th percentile.
Scenarios 4 and 5 (strong winds from south and east)	No dredge plume detected for lagoon and reef areas for the 80th and 95th percentiles. The dredge plume is generally contained to the nearshore area west of the pier.
Scenarios 3 and 6 (strong winds from north and west – unrealistic scenario)	Limited level of dredge plume (less than 10 mg/L) detected for lagoon and coral areas for the 80th percentile. For the 95th percentile, the dredge plume (up to 25 mg/L) was detected heading toward the lagoon and coral reef areas (i.e. the western end of Slaughter Bay).
Scenario 7 and 8 (strong winds from the north and west respectively, ambient waves – real world 'worst case' scenario)	No plume detected for the lagoon and coral areas for both the 80th and 95th percentile.
Sedimentation	Sedimentation is confined within the Kingston Harbour around the proposed dredging area. No sedimentation detected for the lagoon and coral reef areas in any scenarios.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Advisian has undertaken a Dredge Plume Modelling study to investigate the dispersion of sediments into the nearby marine area, as a result of the activities required for the Kingston Pier Channel Construction Project for Kingston Pier Harbour. The purpose of the study is to inform the Environmental Assessment to obtain environmental approval for the project under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The study has investigated the potential risk of dispersion of sediments into the nearby lagoon and fringing reef area, as a result of the dredging works for the deepening of the harbour.

The purpose of the modelling exercise was to understand:

- the potential distribution of sediment plumes that could be generated by the dredging
- the intensity of the sediment plumes
- seasonal effects on the suspension of material and sedimentation patterns in the vicinity of the harbour, to support the environmental assessment (EA).

Eight separate scenarios were examined, to understand the full range of possible wave and current conditions that can occur during the dredging period, and assess the full extent of dispersion and movement of the plumes away from the dredge site under the different conditions.

Modelling results indicated that under real world conditions (ie the model runs that included waves) sediment plumes would not impact on the lagoon and coral areas to the east of the site, and sedimentation would also not occur in these areas.

4.2 Recommendations

To ensure that the Environmental Quality Objectives for the lagoon and coral reef are met, the following recommendations are listed:

- Dredging window: Selection of a period of time, preferably between October and May, for the dredging operation to be undertaken to avoid the possible energetic meteorological conditions of which there will be a higher chance of larger wind forcing from the northern and western sectors (noting the coral spawning season generally occurs from late January for a few months and would also look to be avoided).
- Operation window: The dredging operation should only take place during the daylight time with a break to unload spoil onshore per day for six days per week (half a day Saturday). No dredging activities are to take place during the night.
- Management Plan - A Water Quality Management Plan is developed and implemented for the dredging works that outlines monitoring procedures and frequency, target limits, responsibilities, and mitigation measures.

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Appendix A
Wind Analysis

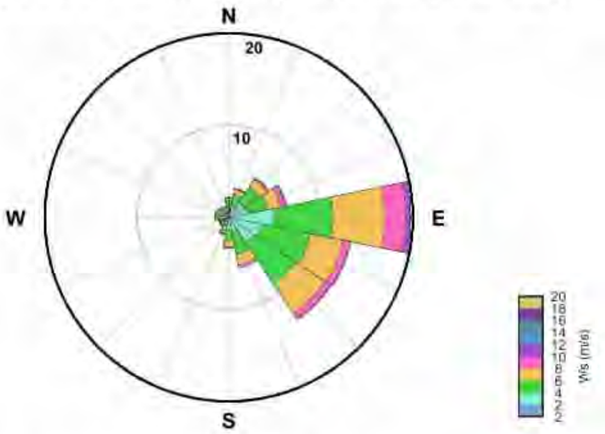
Table A-1 Wind statistical analysis

Period	Median Wind Speed (m/s)	80th percentile Wind Speed (m/s)	95th percentile Wind Speed (m/s)
Total	4.11	6.19	8.19
1939 (not a full year)	1.50	2.96	6.69
1940	2.61	4.61	9.31
1941	2.61	4.61	9.31
1942	2.61	4.61	6.69
1943	4.61	6.69	9.31
1944	4.61	6.69	9.31
1945	4.11	6.19	9.31
1946	3.61	6.19	8.19
1947	3.61	6.19	8.81
1948	4.11	6.69	9.31
1949	4.11	7.19	10.31
1950	4.11	6.19	8.19
1951	3.61	6.19	8.19
1952	4.11	6.19	8.81
1953	3.61	6.19	7.69
1954	3.11	5.11	7.19
1955	4.11	6.19	8.19
1956	3.61	6.19	7.69
1957	4.11	6.19	7.69
1958	3.61	6.19	8.19
1959	4.61	6.19	8.19
1960	4.11	6.19	8.19
1961	4.11	6.19	7.69

1962	5.11	6.69	8.19
1963	5.11	6.19	7.19
1964	4.11	6.19	8.81
1965	4.61	6.69	8.19
1966	4.11	6.19	8.19
1967	5.11	7.19	9.31
1968	5.11	7.19	8.81
1969	4.11	6.19	8.19
1970	4.11	5.69	7.69
1971	4.61	7.19	9.31
1972	4.11	6.19	8.19
1973	3.61	6.19	7.69
1974	4.61	7.19	9.31
1975	4.11	6.69	8.81
1976	4.11	6.19	8.19
1977	4.11	6.19	8.19
1978	5.11	7.69	10.31
1979	4.11	6.19	8.19
1980	3.61	5.69	7.69
1981	3.11	6.19	8.19
1982	3.11	6.19	7.69
1983	3.61	5.69	7.69
1984	4.11	6.19	8.19
1985	4.61	7.19	9.11
1986	4.11	6.19	8.19
1987	3.61	6.19	7.69
1988	4.11	7.19	9.31

1989	4.11	6.69	8.81
1990	3.61	6.19	8.19
1991	3.11	5.11	7.19
1992	3.61	6.19	8.19
1993	3.11	5.11	7.19
1994	4.11	6.19	7.69
1995	3.61	5.69	7.69
1996	4.11	6.19	7.89
1997	4.11	6.19	8.19
1998	4.61	6.69	8.69
1999	4.61	6.69	8.69
2000	4.61	6.19	8.19
2001	4.61	6.69	8.69
2002	4.61	6.69	8.69
2003	5.11	7.19	9.31
2004	4.61	6.69	8.69
2005	5.11	7.19	8.69
2006	5.11	6.69	8.69
2007	5.11	7.19	8.69
2008	5.11	7.69	9.81
2009 (not a full year)	5.69	7.69	9.31

Wind Speed Rose for Kingston Pier, January



JFT (%) of Wind Speed against Direction for January (1940 to 2009)

N=16009	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17.38	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82.62
2-4	1.11	1.24	2.01	2.06	4.86	3.71	3.27	1.61	1.33	0.89	0.57	0.60	0.74	0.54	0.60	0.57	25.71	82.62
4-6	0.73	1.32	1.95	2.29	6.41	5.39	5.47	2.52	1.24	0.62	0.39	0.29	0.48	0.59	0.56	0.46	30.73	56.91
6-8	0.24	0.53	0.99	1.33	5.64	3.55	3.79	1.17	0.60	0.28	0.14	0.16	0.21	0.33	0.16	0.16	19.31	26.19
8-10	0.06	0.09	0.18	0.56	2.31	0.78	0.74	0.32	0.14	0.08	0.05	0.06	0.04	0.06	0.08	*	5.54	6.87
10-12	0.03	0.02	0.04	0.13	0.48	0.08	0.08	0.01	0.01	0.06	*	*	0.02	*	-	0.02	0.98	1.34
12-14	-	0.03	0.02	0.02	0.08	0.02	0.03	0.01	0.01	0.02	0.03	*	*	*	-	*	0.29	0.36
14-16	*	-	*	*	-	-	-	*	0.02	-	0.01	*	-	-	-	-	0.06	0.07
16-18	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	*	*
18-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	2.18	3.23	5.20	6.39	19.78	13.52	13.38	5.65	3.36	1.94	1.21	1.14	1.49	1.53	1.39	1.23		
Total **	3.27	4.32	6.28	7.47	20.87	14.61	14.47	6.73	4.45	3.03	2.29	2.22	2.57	2.62	2.48	2.31		
Cumul.	3.27	7.59	13.87	21.35	42.21	56.82	71.29	78.02	82.47	85.50	87.79	90.01	92.59	95.21	97.69	100.00		

* denotes values less than 0.01% - denotes no records in bin

** includes calm winds which are evenly distributed amongst the directional bins

Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: January (01-Jan-1940 to 31-Jan-2009)
Data source: Wind Station 200288
Data summary: January
Number of Records: 16009
Missing data (%): 0.14
Calm (% < 2.00m/s): 17.38

Key Data Statistics:
Max Wind Speed: 18.00 m/s
Mean Wind Speed: 4.25 m/s
StdDev. Wind Speed: 2.50 m/s

Advisian

Figure A-1 Wind rose plot and joint frequency table of January

Advisian

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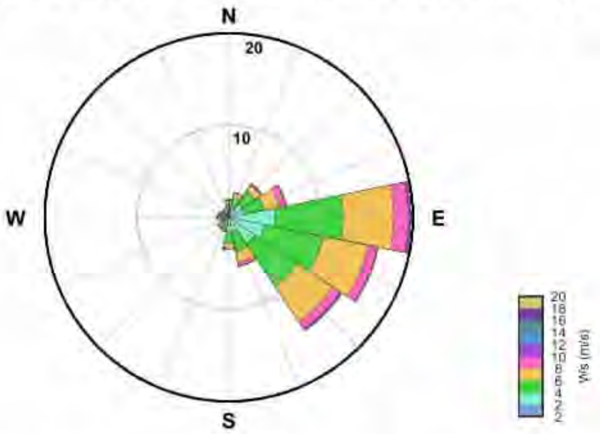
Wind Speed Rose for Kingston Pier, February



JFT (%) of Wind Speed against Direction for February (1940 to 2009)

N=14994	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15.65	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	84.35
2-4	0.77	1.08	1.81	1.77	5.03	3.98	3.42	1.65	1.47	0.80	0.70	0.43	0.51	0.45	0.34	0.39	24.58	84.35
4-6	0.65	1.03	1.60	2.12	7.39	6.51	5.61	2.11	1.37	0.50	0.55	0.32	0.46	0.39	0.37	0.37	31.35	59.77
6-8	0.37	0.56	0.80	1.64	5.47	4.97	4.58	1.22	0.54	0.23	0.19	0.15	0.25	0.23	0.16	0.25	21.63	28.42
8-10	0.13	0.13	0.12	0.74	1.58	0.97	0.97	0.39	0.14	0.05	0.04	0.04	0.08	0.05	0.04	0.05	5.52	6.79
10-12	0.02	0.02	0.04	0.11	0.24	0.13	0.15	0.05	0.05	*	*	*	0.03	0.02	0.03	*	0.92	1.26
12-14	-	-	0.03	0.01	0.06	0.02	0.07	0.03	-	*	-	-	-	*	*	0.01	0.25	0.34
14-16	-	-	0.02	-	0.02	*	0.02	*	-	-	-	-	-	-	-	-	0.07	0.09
16-18	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	0.01	0.01
18-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	1.95	2.82	4.41	6.39	19.79	16.58	14.83	5.47	3.57	1.60	1.48	0.95	1.34	1.14	0.94	1.09		
Total **	2.92	3.80	5.39	7.37	20.77	17.56	15.80	6.45	4.55	2.58	2.46	1.93	2.32	2.12	1.92	2.07		
Cumul.	2.92	6.72	12.11	19.48	40.25	57.80	73.61	80.06	84.61	87.18	89.65	91.57	93.89	96.01	97.93	100.00		

* denotes values less than 0.01% - denotes no records in bin

** includes calm winds which are evenly distributed amongst the directional bins

Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: February (01-Feb-1940 to 28-Feb-2009)
Data source: Wind Station 200288
Data summary: February
Number of Records: 14994
Missing data (%): 0.27
Calm (% < 2.00m/s): 15.65

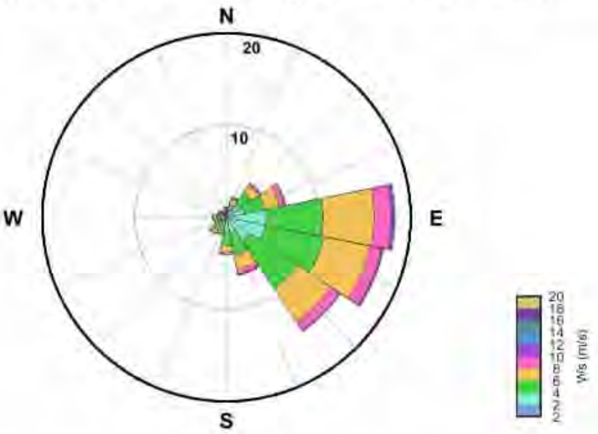
Key Data Statistics:
Max Wind Speed: 17.50 m/s
Mean Wind Speed: 4.39 m/s
StdDev. Wind Speed: 2.46 m/s

Advisian

Figure A-2 Wind rose plot and joint frequency table of February

Advisian
Worley Group

Wind Speed Rose for Kingston Pier, March



JFT (%) of Wind Speed against Direction for March (1940 to 2009)

N=16443	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.47	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85.53
2-4	0.49	0.84	1.66	1.92	4.29	4.31	3.08	1.73	1.57	0.79	0.94	0.57	0.58	0.43	0.34	0.34	23.88	85.53
4-6	0.37	0.66	1.62	2.27	6.17	6.47	6.18	2.49	1.52	0.73	0.76	0.44	0.53	0.32	0.31	0.17	31.00	61.65
6-8	0.18	0.55	0.97	1.66	5.54	5.08	4.36	1.58	0.71	0.35	0.42	0.30	0.30	0.15	0.13	0.16	22.44	30.65
8-10	0.08	0.16	0.26	0.58	1.83	1.30	1.11	0.44	0.22	0.10	0.08	0.07	0.13	0.10	0.09	0.04	6.60	8.21
10-12	0.03	0.03	0.02	0.10	0.30	0.16	0.14	0.12	0.04	*	-	-	0.04	0.01	0.04	0.02	1.05	1.60
12-14	0.04	0.01	*	0.03	0.12	0.06	*	0.05	*	-	-	-	0.01	0.02	0.01	*	0.37	0.55
14-16	-	0.01	0.02	-	0.03	0.01	-	0.02	*	-	-	-	-	0.02	-	*	0.13	0.18
16-18	-	-	-	*	-	*	0.02	*	-	-	-	-	-	-	*	*	0.05	0.05
18-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	1.19	2.27	4.55	6.56	18.28	17.41	14.90	6.44	4.06	1.97	2.21	1.38	1.59	1.05	0.93	0.74		
Total **	2.09	3.18	5.46	7.47	19.19	18.31	15.80	7.34	4.97	2.87	3.11	2.29	2.49	1.95	1.83	1.65		
Cumul.	2.09	5.27	10.73	18.19	37.38	55.69	71.49	78.84	83.81	86.68	89.79	92.07	94.57	96.52	98.35	100.00		

* denotes values less than 0.01% - denotes no records in bin
** includes calm winds which are evenly distributed amongst the directional bins

Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: March (01-Mar-1940 to 31-Mar-2009)
Data source: Wind Station 200288
Data summary: March
Number of Records: 16443
Missing data (%): 0.18
Calm (% < 2.00m/s): 14.47

Key Data Statistics:
Max Wind Speed: 18.00 m/s
Mean Wind Speed: 4.54 m/s
StdDev. Wind Speed: 2.52 m/s

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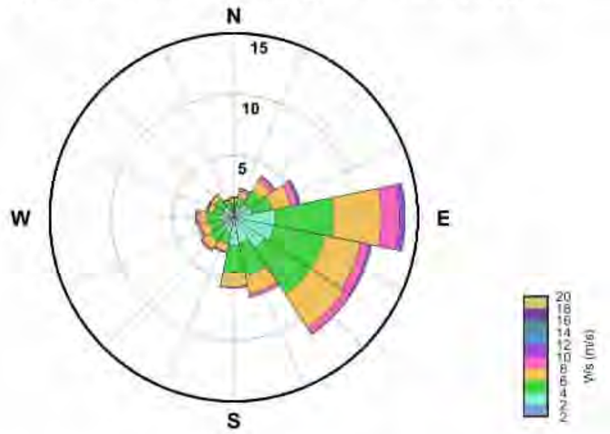
Figure A-3 Wind rose plot and joint frequency table of March

Advisian

Wind Speed Rose for Kingston Pier, April



JFT (%) of Wind Speed against Direction for April (1939 to 2009)

N=16071	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.42	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	81.58
2-4	0.66	0.81	1.37	1.53	3.37	3.38	3.06	2.12	2.29	1.15	1.28	0.96	1.09	0.90	1.02	0.66	25.65	81.58
4-6	0.53	0.75	1.28	1.65	4.76	4.18	4.49	2.69	2.19	1.02	1.11	1.09	1.17	0.79	0.82	0.54	29.05	55.93
6-8	0.35	0.61	0.98	1.54	3.87	2.97	3.25	1.52	1.14	0.65	0.69	0.66	0.56	0.46	0.39	0.21	19.83	26.88
8-10	0.12	0.20	0.31	0.57	1.49	0.71	0.62	0.31	0.12	0.11	0.17	0.24	0.24	0.09	0.02	0.09	5.44	7.04
10-12	0.03	0.03	0.10	0.15	0.41	0.18	0.05	*	0.01	0.04	0.03	0.01	0.06	0.05	0.02	0.04	1.22	1.60
12-14	0.02	0.01	0.04	0.08	0.07	0.04	-	*	*	-	*	*	*	0.03	*	*	0.34	0.39
14-16	-	*	*	-	*	-	-	-	*	0.01	-	-	-	*	-	-	0.04	0.04
16-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	1.72	2.42	4.08	5.51	13.97	11.46	11.46	6.65	5.78	2.97	3.29	2.97	3.13	2.33	2.28	1.54		
Total **	2.87	3.57	5.24	6.67	15.12	12.62	12.62	7.80	6.93	4.12	4.44	4.12	4.28	3.48	3.43	2.69		
Cumul.	2.87	6.45	11.68	18.35	33.47	46.09	58.70	66.50	73.43	77.56	82.00	86.12	90.40	93.88	97.31	100.00		

* denotes values less than 0.01% - denotes no records in bin

** includes calm winds which are evenly distributed amongst the directional bins

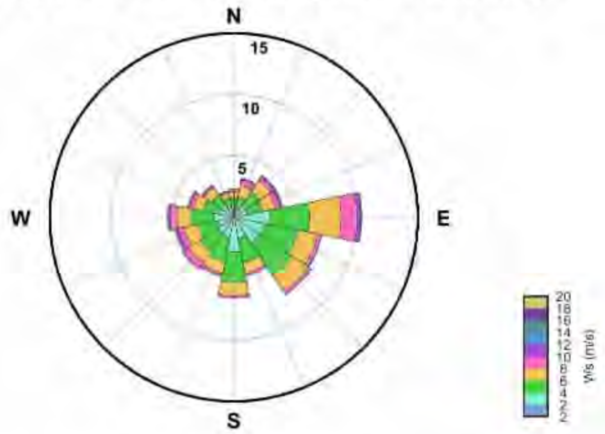
Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: April (06-Apr-1939 to 30-Apr-2009)
Data source: Wind Station 200288
Data summary: April
Number of Records: 16071
Missing data (%): 0.35
Calm (% < 2.00m/s): 18.42

Key Data Statistics:
Max Wind Speed: 15.39 m/s
Mean Wind Speed: 4.24 m/s
StdDev. Wind Speed: 2.54 m/s

Advisian

Figure A-4 Wind rose plot and joint frequency table of April

Wind Speed Rose for Kingston Pier, May



JFT (%) of Wind Speed against Direction for May (1939 to 2009)

N=16648	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20.14	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	79.86
2-4	0.86	0.72	1.26	1.14	2.93	2.55	2.46	1.80	2.82	1.69	1.57	1.30	1.67	1.16	1.23	0.95	26.11	79.86
4-6	0.75	0.95	1.24	1.25	3.24	2.81	3.23	1.99	2.49	2.01	1.73	1.64	1.78	1.38	0.95	0.67	28.12	53.75
6-8	0.49	0.98	1.11	1.04	2.57	1.61	1.58	0.81	1.07	0.90	1.08	1.19	1.16	0.81	0.72	0.43	17.55	25.63
8-10	0.17	0.48	0.32	0.39	1.32	0.30	0.28	0.19	0.16	0.22	0.55	0.45	0.58	0.33	0.17	0.13	6.04	8.08
10-12	0.02	0.13	0.11	0.17	0.28	0.03	0.04	0.02	0.02	0.04	0.13	0.25	0.16	0.15	0.05	0.01	1.63	2.05
12-14	0.01	0.02	0.04	0.04	0.06	0.02	-	0.01	*	-	0.01	0.02	0.05	0.01	0.03	*	0.34	0.42
14-16	-	-	*	0.02	0.02	-	-	-	*	-	-	-	-	-	*	-	0.06	0.08
16-18	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	*	0.02
18-20	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	*	0.01
>20	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	*	*
subTot.	2.31	3.26	4.10	4.05	10.42	7.31	7.60	4.83	6.58	4.85	5.08	4.86	5.40	3.84	3.16	2.20		
Total **	3.57	4.52	5.35	5.31	11.68	8.57	8.85	6.09	7.84	6.11	6.34	6.12	6.66	5.10	4.42	3.46		
Cumul.	3.57	8.09	13.45	18.76	30.43	39.00	47.86	53.95	61.78	67.90	74.23	80.35	87.01	92.12	96.54	100.00		

* denotes values less than 0.01% - denotes no records in bin

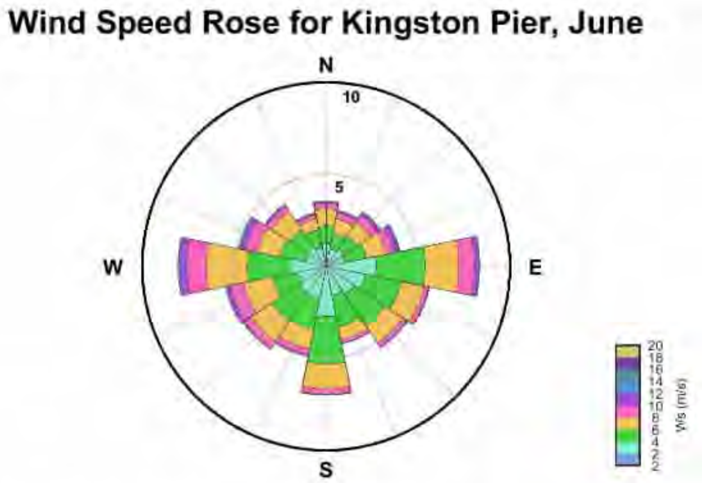
** includes calm winds which are evenly distributed amongst the directional bins

Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: May (01-May-1939 to 31-May-2009)
Data source: Wind Station 200288
Data summary: May
Number of Records: 16648
Missing data (%): 0.27
Calm (% < 2.00m/s): 20.14

Key Data Statistics:
Max Wind Speed: 20.61 m/s
Mean Wind Speed: 4.16 m/s
StdDev. Wind Speed: 2.63 m/s

Advisian

Figure A-5 Wind rose plot and joint frequency table of May



JFT (%) of Wind Speed against Direction for June (1939 to 2008)

N=15844	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19.07	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80.93
2-4	1.25	0.96	1.16	1.03	2.71	2.16	1.82	1.61	2.73	1.81	1.73	1.55	1.99	1.14	1.22	1.05	25.93	80.93
4-6	0.96	0.87	0.86	1.20	2.66	2.00	2.03	1.73	2.57	1.66	1.80	1.42	2.29	1.42	1.15	0.98	25.62	55.00
6-8	0.90	0.81	0.87	1.08	1.85	1.28	1.18	0.72	1.34	1.11	1.38	1.59	2.21	1.23	1.22	0.61	19.36	29.37
8-10	0.30	0.33	0.45	0.45	0.85	0.24	0.24	0.20	0.30	0.34	0.44	0.75	1.06	0.68	0.32	0.23	7.17	10.01
10-12	0.09	0.11	0.18	0.25	0.21	0.03	0.08	0.03	0.04	0.06	0.05	0.18	0.35	0.23	0.09	0.06	2.06	2.85
12-14	0.03	0.02	0.05	0.06	0.07	0.04	-	*	0.01	-	0.01	0.08	0.11	0.13	0.03	0.03	0.66	0.78
14-16	0.01	-	*	0.03	-	-	-	-	-	-	0.01	-	0.03	0.02	-	-	0.10	0.13
16-18	-	-	-	-	-	-	-	-	-	-	-	*	-	-	0.01	-	0.02	0.03
18-20	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	*	*
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	3.54	3.10	3.57	4.10	8.35	5.74	5.34	4.29	7.01	4.98	5.43	5.57	8.04	4.86	4.05	2.96		
Total **	4.73	4.30	4.76	5.29	9.54	6.93	6.53	5.48	8.20	6.17	6.62	6.76	9.23	6.05	5.24	4.15		
Cumul.	4.73	9.03	13.79	19.08	28.62	35.56	42.09	47.58	55.77	61.95	68.57	75.33	84.56	90.61	95.85	100.00		

* denotes values less than 0.01% - denotes no records in bin

** includes calm winds which are evenly distributed amongst the directional bins

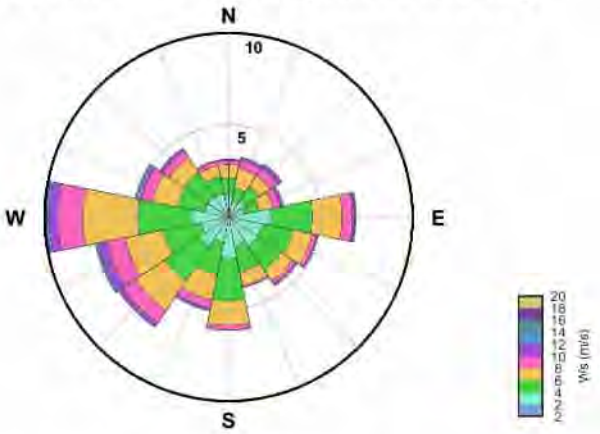
Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: June (01-Jun-1939 to 30-Jun-2008)
Data source: Wind Station 200288
Data summary: June
Number of Records: 15844
Missing data (%): 0.17
Calm (% < 2.00m/s): 19.07

Key Data Statistics:
Max Wind Speed: 18.50 m/s
Mean Wind Speed: 4.35 m/s
StdDev. Wind Speed: 2.76 m/s

Advisian

Figure A-6 Wind rose plot and joint frequency table of June

Wind Speed Rose for Kingston Pier, July



JFT (%) of Wind Speed against Direction for July (1939 to 2008)

N=16503	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.11	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	81.89
2-4	1.20	0.81	1.12	0.88	2.29	1.87	1.89	1.61	2.26	1.41	1.90	1.52	2.03	1.32	1.34	1.29	24.73	81.89
4-6	0.92	0.82	0.87	0.83	2.25	1.70	1.53	1.44	2.29	1.81	2.25	2.11	2.89	1.51	1.55	0.96	25.72	57.16
6-8	0.73	1.06	0.71	0.74	1.62	1.06	0.75	0.74	1.33	1.37	1.92	2.09	2.99	1.38	0.99	0.59	20.06	31.44
8-10	0.22	0.44	0.50	0.38	0.57	0.24	0.23	0.10	0.26	0.40	0.83	1.01	1.37	0.60	0.42	0.25	7.80	11.38
10-12	0.07	0.15	0.16	0.14	0.13	0.05	0.10	0.02	0.01	0.16	0.23	0.48	0.46	0.24	0.18	0.04	2.62	3.58
12-14	0.01	0.02	0.09	0.05	0.02	0.02	*	-	*	0.04	0.05	0.12	0.15	0.09	0.02	*	0.69	0.96
14-16	-	0.02	0.02	0.01	0.05	-	-	-	-	0.01	0.02	0.01	0.04	0.02	*	-	0.20	0.27
16-18	-	-	-	-	0.01	-	-	-	-	*	-	0.04	*	*	-	-	0.07	0.07
18-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	3.15	3.32	3.47	3.03	6.93	4.95	4.50	3.91	6.15	5.20	7.20	7.37	9.92	5.15	4.51	3.14		
Total **	4.28	4.45	4.60	4.16	8.06	6.08	5.63	5.04	7.28	6.33	8.33	8.51	11.06	6.28	5.64	4.27		
Cumul.	4.28	8.72	13.32	17.49	25.55	31.63	37.26	42.30	49.58	55.91	64.24	72.75	83.80	90.09	95.73	100.00		

* denotes values less than 0.01%   - denotes no records in bin

** includes calm winds which are evenly distributed amongst the directional bins

Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: July (01-Jul-1939 to 31-Jul-2008)
Data source: Wind Station 200288
Data summary: July
Number of Records: 16503
Missing data (%): 0.41
Calm (% < 2.00m/s): 18.11

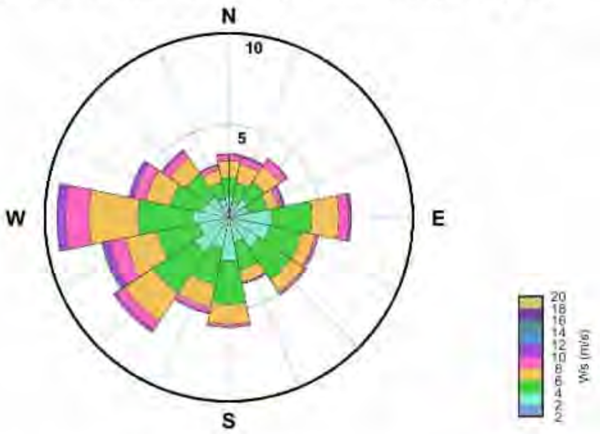
Key Data Statistics:
Max Wind Speed: 18.00 m/s
Mean Wind Speed: 4.51 m/s
StdDev. Wind Speed: 2.84 m/s

Figure A-7 Wind rose plot and joint frequency table of July

Advisian

Worley Group

Wind Speed Rose for Kingston Pier, August



JFT (%) of Wind Speed against Direction for August (1939 to 2008)

N=16215	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17.72	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82.28
2-4	1.15	0.83	1.22	1.09	2.31	2.27	1.98	1.39	2.37	1.73	2.24	1.66	1.91	1.47	1.32	1.03	25.98	82.28
4-6	1.05	1.08	1.10	1.03	2.19	1.76	2.07	1.50	2.36	1.98	2.68	2.31	3.00	1.76	1.50	0.91	28.26	56.30
6-8	0.87	1.04	0.98	0.61	1.46	0.73	0.82	0.68	1.06	1.23	1.87	1.75	2.67	1.34	1.03	0.68	18.81	28.04
8-10	0.34	0.35	0.46	0.26	0.52	0.16	0.14	0.06	0.16	0.33	0.57	0.90	1.29	0.69	0.45	0.25	6.92	9.22
10-12	0.04	0.08	0.07	0.09	0.14	0.03	0.04	0.04	0.02	0.07	0.14	0.32	0.43	0.23	0.11	0.04	1.90	2.30
12-14	-	0.04	*	0.02	0.03	-	*	0.01	-	*	0.01	0.08	0.06	0.05	0.01	0.01	0.35	0.40
14-16	-	-	-	*	*	-	*	-	-	-	-	0.02	-	-	-	-	0.04	0.06
16-18	-	-	-	*	-	-	-	-	-	-	*	*	-	-	-	-	0.02	0.02
18-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	3.46	3.42	3.84	3.10	6.66	4.95	5.05	3.68	5.98	5.35	7.52	7.03	9.36	5.53	4.42	2.92		
Total **	4.56	4.53	4.95	4.21	7.77	6.06	6.16	4.79	7.09	6.46	8.63	8.14	10.47	6.64	5.53	4.03		
Cumul.	4.56	9.09	14.04	18.25	26.01	32.07	38.23	43.02	50.11	56.57	65.20	73.33	83.80	90.44	95.97	100.00		

* denotes values less than 0.01%   - denotes no records in bin

** includes calm winds which are evenly distributed amongst the directional bins

Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: August (01-Aug-1939 to 31-Aug-2008)
Data source: Wind Station 200288
Data summary: August
Number of Records: 16215
Missing data (%): 0.24
Calm (% < 2.00m/s): 17.72

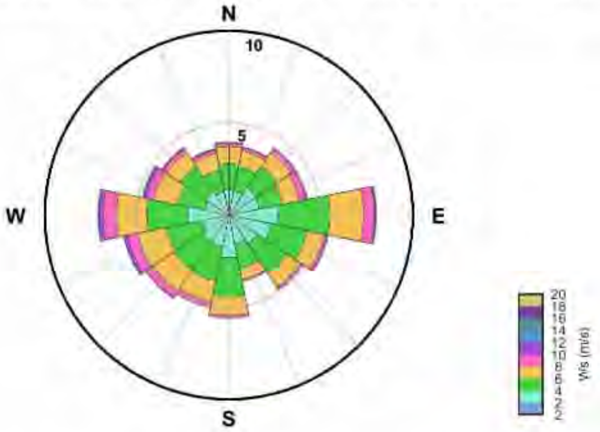
Key Data Statistics:
Max Wind Speed: 18.00 m/s
Mean Wind Speed: 4.34 m/s
StdDev. Wind Speed: 2.63 m/s

Advisian

Figure A-8 Wind rose plot and joint frequency table of August

Advisian

Wind Speed Rose for Kingston Pier, September



JFT (%) of Wind Speed against Direction for September (1939 to 2008)

N=15650	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19.54	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80.46
2-4	1.40	1.32	1.80	1.69	2.65	2.35	1.85	1.58	2.30	1.75	1.69	1.47	2.23	1.32	1.50	1.28	28.19	80.46
4-6	1.40	1.37	1.37	1.28	2.83	1.99	1.94	1.37	2.14	1.89	1.90	1.99	2.22	1.52	1.67	1.21	28.07	52.27
6-8	0.92	0.86	0.90	0.94	1.83	0.94	0.90	0.60	0.99	1.17	1.35	1.60	1.64	1.31	0.90	0.91	17.77	24.20
8-10	0.19	0.18	0.24	0.39	0.57	0.16	0.13	0.09	0.13	0.31	0.44	0.55	0.74	0.39	0.26	0.21	4.98	6.42
10-12	0.04	0.05	0.04	0.05	0.08	0.05	0.04	0.01	0.01	*	0.05	0.17	0.21	0.19	0.07	0.05	1.13	1.44
12-14	0.01	-	0.01	-	0.03	0.01	-	*	-	-	*	0.03	0.08	0.06	0.01	0.01	0.28	0.31
14-16	-	-	-	-	*	-	-	-	-	-	-	*	-	*	*	*	0.03	0.04
16-18	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	*	*
18-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	3.96	3.78	4.37	4.35	8.01	5.50	4.87	3.67	5.58	5.13	5.44	5.82	7.12	4.80	4.41	3.67		
Total **	5.18	5.00	5.59	5.57	9.23	6.72	6.09	4.89	6.80	6.35	6.66	7.04	8.34	6.02	5.63	4.90		
Cumul.	5.18	10.18	15.77	21.34	30.57	37.29	43.38	48.27	55.07	61.42	68.07	75.12	83.46	89.47	95.10	100.00		

* denotes values less than 0.01% - denotes no records in bin

** includes calm winds which are evenly distributed amongst the directional bins

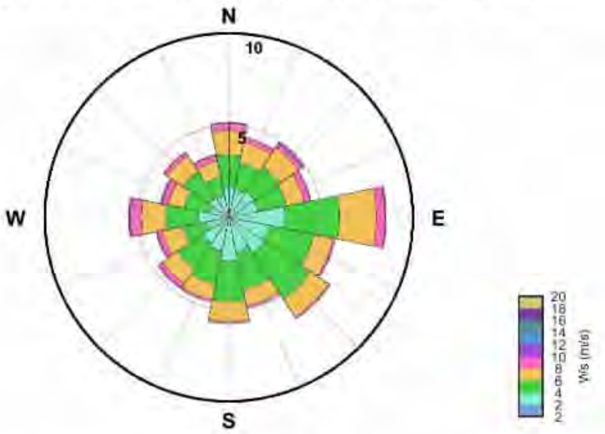
Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: September (01-Sep-1939 to 30-Sep-2008)
Data source: Wind Station 200288
Data summary: September
Number of Records: 15650
Missing data (%): 0.34
Calm (% < 2.00m/s): 19.54

Key Data Statistics:
Max Wind Speed: 17.00 m/s
Mean Wind Speed: 4.06 m/s
StdDev. Wind Speed: 2.51 m/s

Advisian

Figure A-9 Wind rose plot and joint frequency table of September

Wind Speed Rose for Kingston Pier, October



JFT (%) of Wind Speed against Direction for October (1939 to 2008)

N=16111	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.62	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	81.38
2-4	1.63	1.55	1.67	1.61	3.03	2.24	2.34	1.93	2.39	1.87	1.72	1.22	1.68	1.04	1.28	1.19	28.40	81.38
4-6	1.77	1.45	1.62	1.57	2.98	2.47	2.99	2.05	2.19	1.82	1.62	1.30	1.72	1.44	1.69	1.05	29.73	52.98
6-8	1.30	1.14	1.25	0.99	1.99	1.05	1.19	0.91	1.07	0.86	0.99	1.15	1.34	0.87	1.03	0.88	18.04	23.25
8-10	0.40	0.26	0.25	0.35	0.48	0.12	0.09	0.17	0.11	0.15	0.30	0.28	0.59	0.35	0.22	0.32	4.42	5.21
10-12	0.05	0.03	0.12	0.04	0.07	0.02	*	-	*	*	0.03	0.06	0.09	0.09	0.03	0.02	0.66	0.79
12-14	*	-	0.02	-	-	-	-	-	-	-	0.01	0.01	0.03	0.02	*	0.01	0.12	0.12
14-16	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	*	*
16-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	5.16	4.43	4.94	4.55	8.55	5.90	6.62	5.06	5.77	4.71	4.67	4.03	5.45	3.80	4.26	3.48		
Total **	6.32	5.59	6.10	5.72	9.72	7.06	7.79	6.23	6.93	5.87	5.83	5.19	6.62	4.97	5.43	4.64		
Cumul.	6.32	11.91	18.02	23.73	33.45	40.51	48.30	54.53	61.46	67.33	73.16	78.35	84.97	89.93	95.36	100.00		

* denotes values less than 0.01% - denotes no records in bin

** includes calm winds which are evenly distributed amongst the directional bins

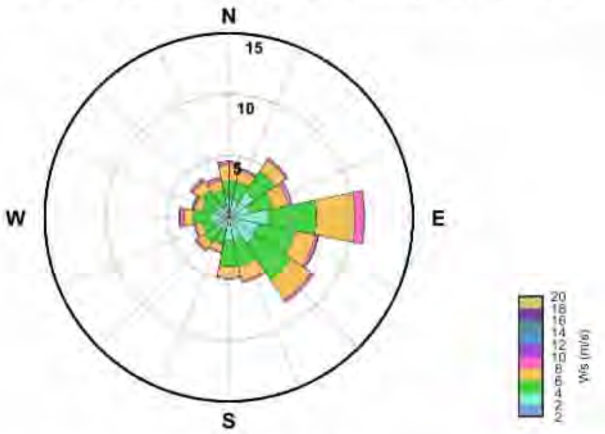
Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: October (01-Oct-1939 to 31-Oct-2008)
Data source: Wind Station 200288
Data summary: October
Number of Records: 16111
Missing data (%): 0.09
Calm (% < 2.00m/s): 18.62

Key Data Statistics:
Max Wind Speed: 15.39 m/s
Mean Wind Speed: 4.05 m/s
StdDev. Wind Speed: 2.38 m/s

Advisian

Figure A-10 Wind rose plot and joint frequency table of October

Wind Speed Rose for Kingston Pier, November



JFT (%) of Wind Speed against Direction for November (1939 to 2008)

N=15973	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19.29	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80.71
2-4	1.55	1.42	2.48	1.78	3.22	2.46	2.53	1.86	1.89	1.10	1.27	1.12	1.50	1.12	1.27	1.03	27.57	80.71
4-6	1.44	1.55	2.05	1.85	3.93	3.06	3.59	2.22	2.11	1.12	1.20	1.07	1.40	1.09	1.36	1.21	30.23	53.14
6-8	1.27	0.90	1.03	1.27	3.13	1.65	1.94	1.20	0.90	0.66	0.63	0.59	0.78	0.64	0.91	0.82	18.34	22.90
8-10	0.29	0.18	0.20	0.35	0.76	0.24	0.23	0.14	0.11	0.11	0.19	0.12	0.26	0.12	0.20	0.29	3.80	4.56
10-12	0.03	0.05	0.03	0.02	0.04	0.05	0.04	*	0.01	-	0.03	0.03	0.09	0.07	0.04	0.04	0.58	0.76
12-14	-	-	-	-	*	0.03	*	-	-	-	*	-	0.04	0.04	*	*	0.14	0.19
14-16	*	-	*	-	-	*	-	-	-	-	-	-	*	0.01	-	-	0.04	0.04
16-18	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	*	*
18-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	4.58	4.09	5.80	5.27	11.08	7.50	8.33	5.43	5.01	2.99	3.32	2.92	4.09	3.09	3.79	3.40		
Total **	5.79	5.30	7.00	6.48	12.29	8.70	9.54	6.64	6.22	4.20	4.53	4.13	5.29	4.30	5.00	4.60		
Cumul.	5.79	11.09	18.09	24.57	36.86	45.56	55.10	61.74	67.96	72.15	76.68	80.81	86.10	90.40	95.40	100.00		

* denotes values less than 0.01% - denotes no records in bin

** includes calm winds which are evenly distributed amongst the directional bins

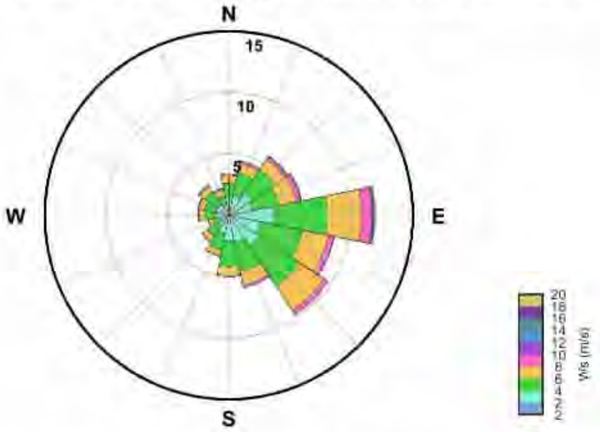
Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: November (01-Nov-1939 to 30-Nov-2008)
Data source: Wind Station 200288
Data summary: November
Number of Records: 15973
Missing data (%): 0.13
Calm (% < 2.00m/s): 19.29

Key Data Statistics:
Max Wind Speed: 17.50 m/s
Mean Wind Speed: 4.01 m/s
StdDev. Wind Speed: 2.38 m/s

Advisian

Figure A-11 Wind rose plot and joint frequency table of November

Wind Speed Rose for Kingston Pier, December



JFT (%) of Wind Speed against Direction for December (1939 to 2008)

N=16309	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-2 (Calm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20.44	100.00
2-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	79.56
2-4	1.40	1.69	2.26	1.96	3.73	2.64	3.02	2.25	2.08	1.51	1.12	0.69	1.13	1.09	1.10	0.78	28.46	79.56
4-6	1.23	1.84	2.20	2.17	4.30	3.50	3.89	2.43	2.08	1.39	0.96	0.67	0.82	0.93	1.21	0.82	30.42	51.10
6-8	0.64	0.77	1.04	1.46	2.78	2.14	2.43	1.13	0.72	0.45	0.49	0.35	0.44	0.47	0.55	0.55	16.41	20.67
8-10	0.11	0.20	0.23	0.38	0.81	0.44	0.40	0.18	0.12	0.06	0.07	0.04	0.10	0.09	0.12	0.09	3.44	4.26
10-12	0.02	0.04	0.07	0.07	0.16	0.08	*	0.02	*	-	-	*	0.02	0.01	0.02	0.04	0.58	0.82
12-14	*	-	0.04	0.01	0.06	-	-	*	*	-	-	*	0.02	-	-	-	0.15	0.25
14-16	-	-	*	*	0.03	-	-	-	-	-	-	*	-	-	-	-	0.05	0.09
16-18	-	-	-	*	0.01	-	-	-	-	-	-	-	-	-	-	-	0.02	0.04
18-20	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-	-	-	0.02	0.02
>20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
subTot.	3.41	4.54	5.83	6.07	11.91	8.80	9.74	6.01	5.02	3.41	2.65	1.77	2.53	2.60	3.00	2.28		
Total **	4.69	5.82	7.11	7.34	13.18	10.08	11.02	7.29	6.29	4.69	3.92	3.05	3.81	3.87	4.27	3.56		
Cumul.	4.69	10.51	17.62	24.96	38.15	48.22	59.24	66.53	72.82	77.51	81.44	84.48	88.29	92.16	96.44	100.00		

* denotes values less than 0.01% - denotes no records in bin

** includes calm winds which are evenly distributed amongst the directional bins

Data Information:
Project: 311015-00061
Location: Kingston Pier
Data period: December (01-Dec-1939 to 31-Dec-2008)
Data source: Wind Station 200288
Data summary: December
Number of Records: 16309
Missing data (%): 0.14
Calm (% < 2.00m/s): 20.44

Key Data Statistics:
Max Wind Speed: 19.00 m/s
Mean Wind Speed: 3.88 m/s
StdDev. Wind Speed: 2.38 m/s

Advisian

Figure A-12 Wind rose plot and joint frequency table of December

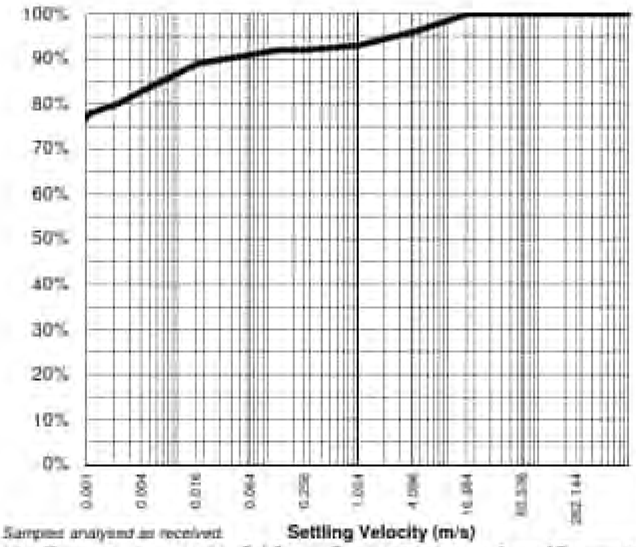
Appendix B
Owen Tube Testing Results

ALS Laboratory Group Pty Ltd
5/585 Maitland Road
Mayfield West, NSW 2304
pH 02 4014 2500
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	HARRY HOURIDIS	**DATE REPORTED:**	11-Mar-2020
COMPANY:	ADVISIAN PTY LTD	**DATE RECEIVED:**	24-Feb-2020
ADDRESS:	Level 13 333 Collins Street, Melbc Victoria 3000 Melbourne	**REPORT NUMBER:**	EM2003018-010 / SR
PROJECT:	311015-00061	**SAMPLE ID:**	Hold



Samples analysed as received.
¹ Soil Particle Density results fall outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results.

Particle Size	Percent Passing	Settling Velocity	Time to Settle 100cm
mm	%	m/s	min
4.75	100%	17	9.8E-04
2.36	96%	4.2	4.0E-03
1.18	92%	1.1	1.5E-02
0.600	92%	0.27	6.1E-02
0.425	92%	0.14	1.2E-01
0.300	91%	0.068	2.4E-01
0.150	89%	0.017	9.8E-01
0.075	83%	0.004	3.9E+00
µm			
54	80%	2.2E-03	7.591
38	78%	1.1E-03	15.183
27	71%	5.5E-04	30.366
19	62%	2.7E-04	60.731
10	51%	8.0E-05	207.74
5	38%	2.2E-05	782.94
2	35%	1.8E-06	6155.32

Analysis Notes

Time for 50% to Settle 100cm	237.42
Time for 90% to Settle 100cm	>1440
Settling Rate at 50% settled (m/s)	0.00
Settling Rate at 90% settled (m/s)	<0.0009

Sample Description: FINES, SAND

Test Method: AS1289.3.6.1/AS1289.3.6.3

Loss on Pretreatment NA

Limit of Reporting: 1%

Analysed: 2-Mar-20

Dispersion Method Shaker

Hydrometer Type ASTM E100

Aleksandar Vujkovic
Laboratory Supervisor
Authorised Signatory

Figure B-1 Owen tube results (percentage weight (%) vs Settling Velocity (mm/s) for Sample 1

Advisian

Worley Group

Certificate of Analysis

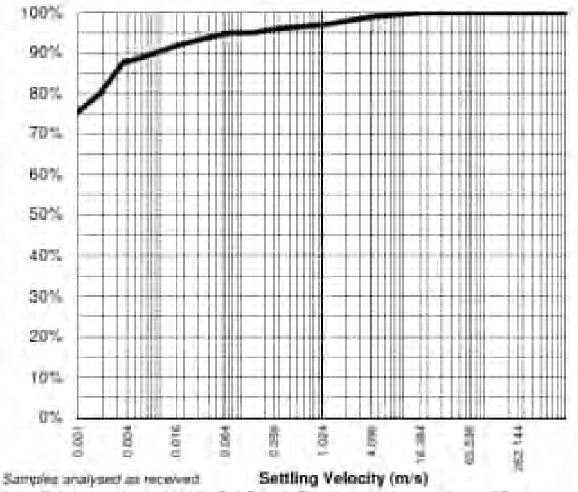
ALS Laboratory Group Pty Ltd
5/585 Maitland Road
Mayfield West, NSW 2304
pH 02 4014 2500
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

ALS

CLIENT:	HARRY HOURIDIS	**DATE REPORTED:**	11-Mar-2020
COMPANY:	ADVISIAN PTY LTD	**DATE RECEIVED:**	24-Feb-2020
ADDRESS:	Level 13 333 Collins Street, Melbc Victoria 3000 Melbourne	**REPORT NUMBER:**	EM2003018-011 / SR
PROJECT:	311015-00061	**SAMPLE ID:**	Hold



Particle Size	Percent Passing	Settling Velocity	Time to Settle 100cm
mm	%	m/s	min
4.75	100%	18	9.5E-04
2.36	99%	4.3	3.6E-03
1.18	97%	1.1	1.5E-02
0.600	96%	0.28	6.0E-02
0.425	95%	0.14	1.2E-01
0.300	95%	0.070	2.4E-01
0.150	92%	0.018	9.5E-01
0.075	88%	0.004	3.8E+00
µm			
49	80%	1.8E-03	9.036
34	75%	9.2E-04	18.072
25	63%	5.1E-04	32.646
18	58%	2.6E-04	65.293
10	43%	7.5E-05	221.45
5	34%	2.1E-05	808.02
1	29%	1.7E-06	9896.20

Time for 50% to Settle 100cm	124.57
Time for 90% to Settle 100cm	>1440
Settling Rate at 50% settled (m/s)	0.00
Settling Rate at 90% settled (m/s)	<0.0005

Samples analysed as received

* *Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Analysis Notes

Sample Description: FINES, SAND

Test Method: AS1289.3.6.1/AS1289.3.6.3

Loss on Pretreatment NA

Limit of Reporting: 1%

Analysed: 2-Mar-20

Dispersion Method Shaker

Hydrometer Type ASTM E100

Aleksandar Vujkovic
Laboratory Supervisor
Authorised Signatory

Template Version PR-Mar-151120

Page 1 of 1

Figure B-2 Owen tube results (percentage weight (%) vs Settling Velocity (mm/s) for Sample 2

Sydney 46 Gale Road
Maroubra, NSW, 2035

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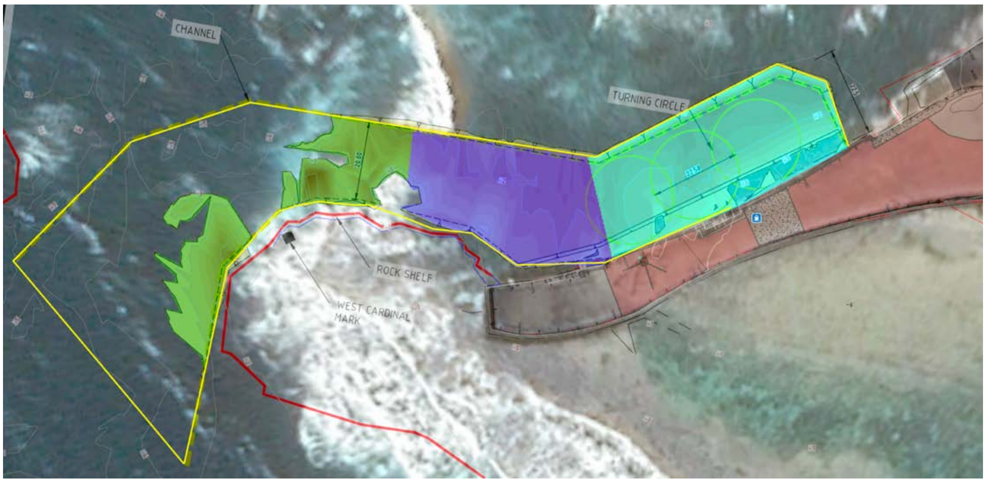
Murwillumbah, NSW
P.O. Box 42 Condong, 2484

General Inquiries +61 2 9568 5800
www.cosmosarch.com

A.B.N. 83 082 211 498

Kingston Pier Channel Construction Project



Underwater Archaeology Management Plan

Draft – V0.1

Kingston
Norfolk Island
Australian External Territory

November 2022

Kingston Pier Channel Construction Project Underwater Archaeology Management Plan (KPUAMP)

DRAFT V0.1

Prepared for:

Advisian

By:

Jane Mitchell

Cos Coroneos

November 2022

Cosmos Archaeology Job Number J22/10

Cover image:

Option 3a overlaid with locations of cultural sensitivity. Light blue is low cultural heritage sensitivity (Sector A), dark blue is high cultural heritage sensitivity (Sector B), and green is tested only through video survey and therefore considered have medium cultural heritage sensitivity (Sector C). Yellow outline is navigation channel.

Revision	Description	Date	Originator	Reviewer	Approver
V0	Draft KPUAMP	14/10/2022	JM, CC	CC	CC
V0.1	Incorporated C. Homann comments	18/11/2022	JM	CC	CC

TABLE OF CONTENTS

Abbreviations

ADAS	Australian Diver Accreditation Scheme
AR	Artefact Registrar
AUCHD	Australasian Underwater Cultural Heritage Database
AZMP	Archaeology Zoning and Management Plan
BP	Before Present
CE	Common Era
DAWE	Department of Agriculture, Water and the Environment
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DITRDC	Department of Infrastructure, Transport, Regional Development and Communications
DITRDCA	Department of Infrastructure, Transport, Regional Development, Communications and the Arts
ED	Excavation Director
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
KAVHA	Kingston and Arthur's Vale Historic Area
KPUAMP	Kingston Pier Underwater Archaeology Management Plan
MSL	Mean Sea Level
OH&S	Occupational Health & Safety
PDS	Professional Diving Services
Regulations	*Environment Protection and Biodiversity Conservation Regulations 2000*
SCUBA	Self-Contained Underwater Breathing Apparatus
SoHI	Statement of Heritage Impact
TT	Test Trench
UCHA	*Underwater Cultural Heritage Act 2018* (Commonwealth)

1 INTRODUCTION

1.1 Background

The Commonwealth Department of Infrastructure, Transport, Regional Development, Communications, and the Arts (DITRDCA) is proposing to improve the shipping capabilities of Kingston Pier, Norfolk Island. This will involve deepening the approach and berthing areas of the Kingston Pier to provide safer access for vessels at all tides.

Advisian prepared an environmental assessment for the proposed works and Cosmos Archaeology Pty Ltd prepared the Statement of Heritage Impact (SoHI) for the underwater cultural heritage.[1] The SoHI found that the identified underwater archaeological resource within the construction envelope is interwoven with the cultural heritage values of World Heritage listed Kingston and Arthur's Vale Historic Area. These values state that archaeological remains pre-dating the transfer of Norfolk Island's governance to Australia (1897) as being of critical cultural heritage significance while material cultural relating to WWII defence works, tourism, use of earlier structures and modifications is of secondary significance. As part of the SoHI, a non-disturbance archaeological dive inspection was undertaken to determine the presence of any culturally significance artefacts.

The dive inspection in February 2020 did not identify any culturally significant artefacts, however it was assessed that culturally significant artefacts could be concentrated and buried within gullies, gutters, cracks and fissures within the calcarenite and possibly volcanic tuff substrate that would be removed by the proposed works and as such a test excavation was recommended.

The underwater archaeological test excavation was undertaken in November 2020 adjacent to Kingston Pier. The purpose of the test excavation was to obtain a better understanding of the extent, frequency, variety, condition and significance of the underwater cultural resource.[2] Four test trenches were excavated over seven days recovering 1,442 artefacts, the overwhelming majority being from the 20th and 21st century. Twenty-three artefacts were assessed as being potentially 19th century or earlier. These artefacts are in the possession of KAVHA, the remainder (1,399 artefacts) were discarded after cataloguing.

The test excavation upheld the idea that the proposed seabed removal without acceptable mitigation, could have a significant impact because it will permanently remove, destroy, damage or substantially disturb a portion of an underwater archaeological resource assessed to have critical cultural heritage significance values in relation to World Heritage listed KAVHA. In fact, this resource could be considered to be unique to KAVHA in that there is no other location elsewhere within and without KAVHA which formed a constant and longstanding cultural nexus between the land and the sea. The Commonwealth *Underwater Cultural Heritage Act 2018* automatically protects remains of shipwrecks of 75 years old and it is probable that the proposed works will disturb such remains.

To mitigate the impact of the proposed works on the cultural heritage significance of the underwater archaeological remains a limited archaeological excavation prior to the works commencing and a monitoring programme throughout the works is required. For the mitigation to be successful a well-prepared plan covering all aspects of the archaeological investigation, from its focus, the recovery, recording, management and publicising of the artefacts as well as the data collected, this plan would be called the Kingston Pier Underwater Archaeological Management Plan (KPUAMP).

Cosmos Archaeology has been engaged by Advision to prepare the KPUAMP.

---

[1] **Cosmos Archaeology Pty Ltd, June 2020,** *Kingston Pier Channel Construction Project: Statement of Heritage Impact,* prepared for Advision.
[2] **Cosmos Archaeology, Pty Ltd, April 2021**, *Kingston Pier Channel Construction Project: Underwater Archaeological Test Excavation Report,* prepared for Advision.

1.2 Objective of underwater archaeology management plan

The objective of the KPUAMP is to preserve and promote the significance of the underwater archaeological resource. The KPUAMP comprise five key parts which are:

- *Focus*
- *Recovery*
- *Record*
- *Manage*
- *Publicise*

This draft report will address the first two parts – Focus and Recovery. The remaining parts will be addressed in a subsequent draft.

Focus (also known as a **Research Design)** refers to establishing the direction of the underwater archaeological excavation by identifying and prioritising the significant elements of the resource as well as positing questions that the resource could answer in relation to the understanding of the cultural development of KAVHA and Norfolk Island, maritime infrastructure related sites and site formation processes in general.

Establishing a focus for the mitigation guides the approach and methodologies for the remaining key parts. Having a clear focus will provide a reference point for decision making in the event that unexpected finds and/or situations arise during the implementation of the KPUAMP.

Recovery refers to the removal of artefacts from within the proposed project envelope in a manner that minimises any loss of contextual (and therefore significant) information. Artefact recovery would take the form of a combination of diver-based activities as well as monitoring and sampling of removed seabed.

Record refers to how the artefacts are documented, that is, descriptions, photographs, bagging and tagging. All artefacts will be recorded to a standard level so as to create an inventory of finds.

The KPUAMP will detail such things as the information that will be recorded for each artefact, methods of recording, how the information will be catalogued, processed and stored (paper forms, photo labelling, databases, etc..), recording sequence, where recording will take place, photography standards, roles and responsibilities of those undertaking the recording. Consideration could be given to retaining samples of non-cultural material such as marine animal bones or corals that could be used for other scientific studies.

Manage refers to how the artefact collection is to be treated with respect to storage, conservation or de-accessioning. In the first instance all artefacts recovered will need to remain in sea water, which would need to be changed regularly, until such time as their status in curation is determined.

The KPUAMP will contain an artefact retention policy which will guide the archaeologists as to which artefacts are to be retained and those which could be de-accessioned after recording has been completed. What is meant by de-accessioning is that such designated artefacts leave the controls set by the KPUAMP and are in effect discarded. Broadly speaking the artefacts that would be retained would be those associated with the critical significance values of the resource – those which can be dated to the 18th and 19th centuries.

Those artefacts that would be de-accessioned would be recent 21st century objects while those artefacts from the 20th century would be retained or discarded on account of their association with the secondary significance values and/or their inherent rarity.

The artefact retention policy worked well during the test excavation and it is proposed that the same policy be retained for the KPUAMP.

The KPUAMP will detail the locations where retained artefacts will be stored pending the commencement of conservation treatment. It will also detail the process for determining which retained artefacts are prioritised for conservation based on factors such as rarity or representativeness of objects displayed in the Island's museums, or their relevance to planned exhibitions.

It is possible that the volume of artefacts retained could exceed existing wet storage capacity and/or initial conservation budgets. An option to be considered in the KPUAMP would be the in-water storage or reburial of the artefacts. The creation and management of underwater repositories for artefacts recovered from a marine environment, is either being undertaken or considered by agencies responsible for the management of underwater cultural heritage.

For artefacts to be reburied successfully they require to be returned to a similar environment from which they were recovered. For example, if recovered from a gravelly seabed at 3 m of water and is subject to surge, a similar environment should be sought. This usually means that they should not be re-buried far from where they were found. The artefacts should also be buried at a depth to effect anaerobic conditions, which can dramatically slow down fabric degradation. Wrapping the artefacts in geofabric facilitates the creation of an anaerobic environment. The KPUAMP would examine suitable locations for an underwater repository taking into consideration the security of the artefacts. What is meant by security is safeguarding a buried cache from disturbance from surge and from theft.

The KPUAMP will also contain basic protocols for monitoring the collection prior to and during conservation treatment, as well as addressing budget estimates for conservation and curation. Most critically the KPUAMP will detail the roles and responsibilities of the dredging contractors, the archaeologists, the Commonwealth and the KAVHA Authority, including a well-defined chain of custody for the management of the artefacts.

Publicise refers to the dissemination of the conduct and findings of the archaeological investigations. This includes the preparation of a comprehensive technical excavation report with specialist reports as required as well as associated project records such as images, videos, databases, mapping. Also, to be prepared would be a shorter and well-illustrated 'plain English' report.

The KPUAMP will outline options for further promotion in the form of displays, video, publications and other multi-media that would be addressed in an Interpretation Plan that would be prepared after the archaeological excavation and cataloguing has been completed. In addition, the KPUAMP will include a construction environmental sub-plan documenting procedures to negate impacts on the environment such as the controls placed on reducing turbidity or fuel spills.

The KPUAMP will need to be prepared in consultation with key stakeholders from the Norfolk Island Council, community, KAVHA and the Commonwealth. It is the intention that the KPUAMP forms part of the conditions of approval required under the Underwater Cultural Heritage and EPBC Acts.

1.3 Study area

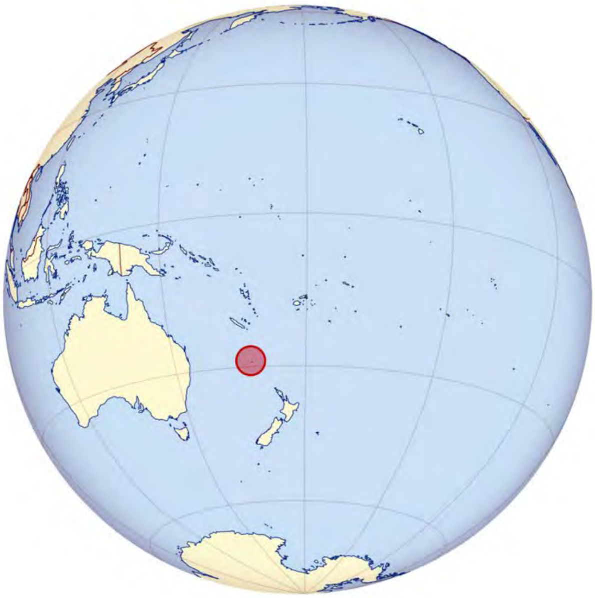


Figure 1: Location of Norfolk Island.
(Source: Mapworld).

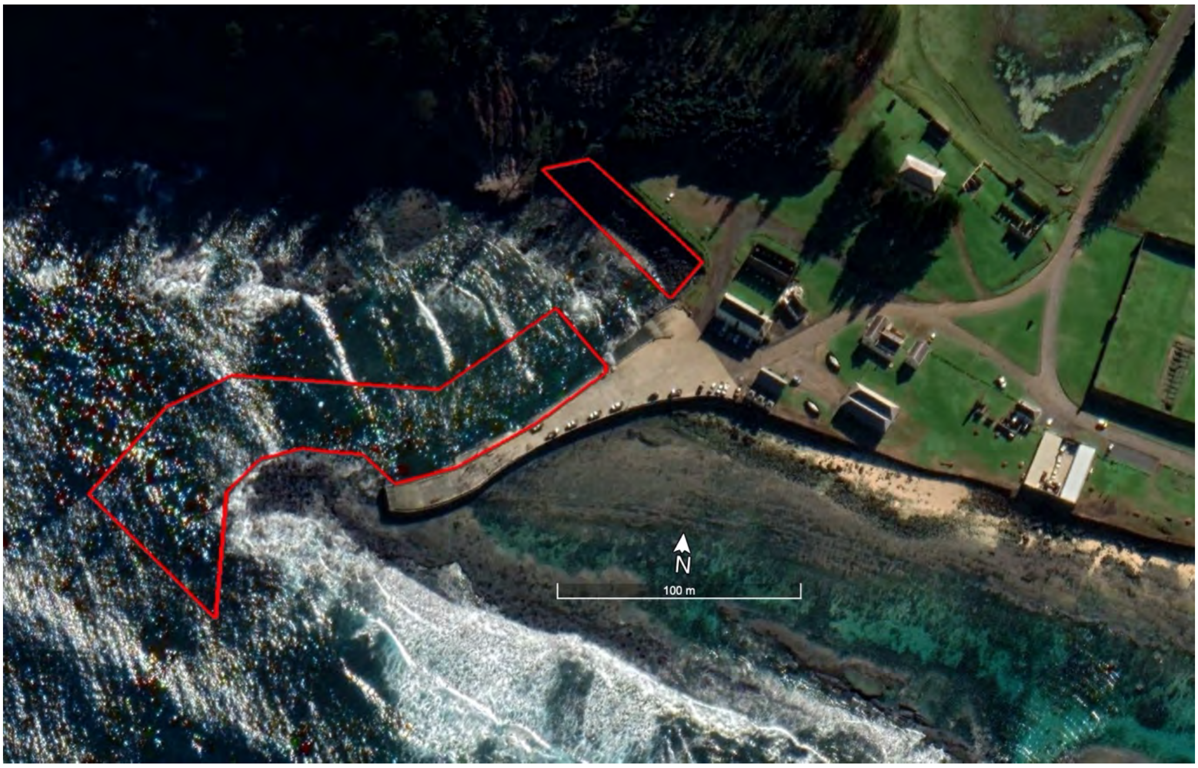


Figure 2: Footprint of the proposed navigation channel for the Kingston Pier Upgrade and the Rock Revetment works (red outline) which forms the study area for the KUAMP. (Base image: Google Earth).

2 PROPOSED WORKS

2.1 Proposed Dredging Works

The dredging works for the Kingston Pier Channel Project involves the removal of approximately 4000 m^3 to 5000 m^3 of the seabed material adjacent to the western side of Kingston Pier to design levels of 3.2 m below mean sea level. The actual quantity of material to be removed shall be determined from the pre-dredging survey levels and quantity of dredge tolerance used. All dredged material shall be brought onshore for disposal.

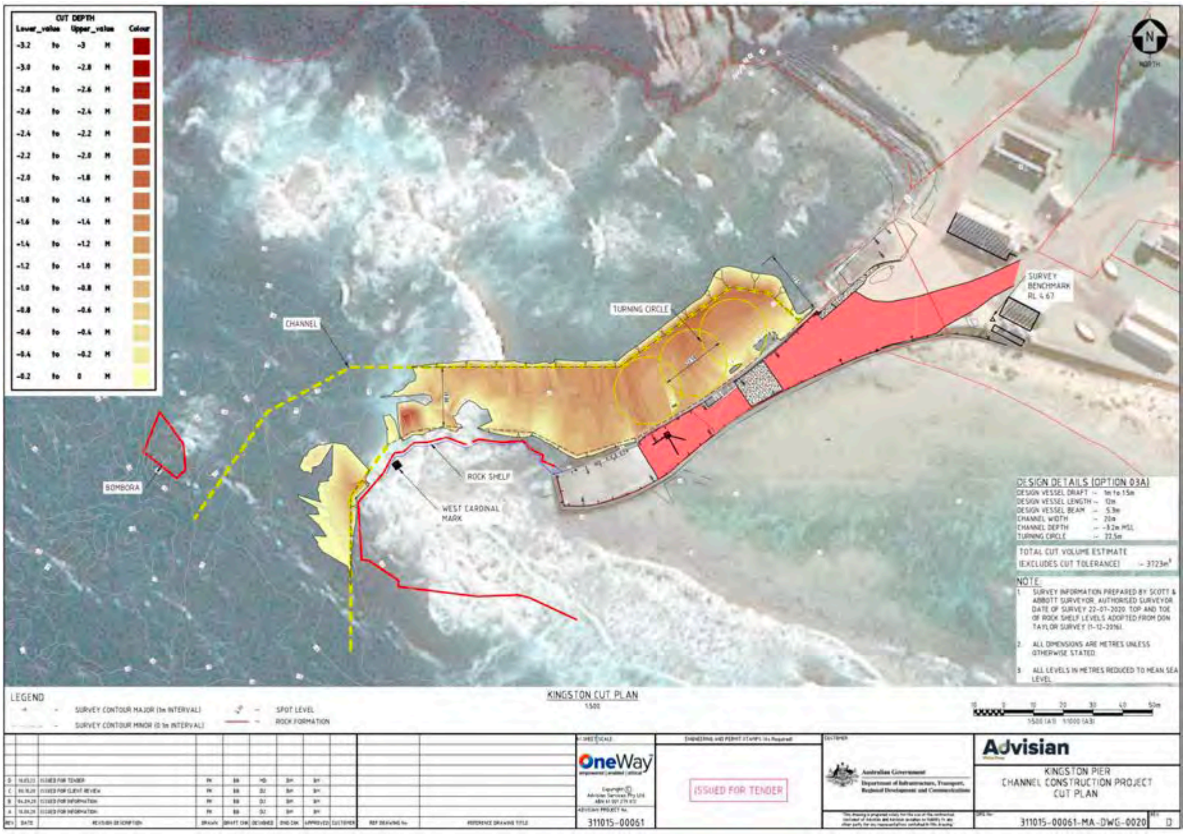


Figure 3: Cut plan (Option 3A) Kingston Pier Channel Construction Project. Plan supplied by Advisian.

2.1.1 Removal of the sediment layer

The sediment layer within the dredge footprint covers an area of around 3,750 m^2 with an average thickness of 0.1 mm equating to an estimate of 375 m^2 of material to be removed.

2.1.2 Removal of the calcarenite layer

There is up to 1,600 m^2 of calcarenite material to be removed within the dredge footprint. Calcarenite does not exist in the area of the existing channel adjacent to the Pier that was deepened with a dragline in the 1980s and may not over all of the remaining seabed within the dredge footprint.

2.2 Pier Stabilisation Works

The stabilisation of Kingston Pier includes the following:

- Concrete plugging and grouting up cavities behind the existing sheet pile wall to form a gravity retaining wall system (Figure 4);
- Welding the existing sheet piles to distribute stress across the entire wall;
- Forming a concrete toe in front of the existing sheet pile wall below the seabed to prevent future undermining.

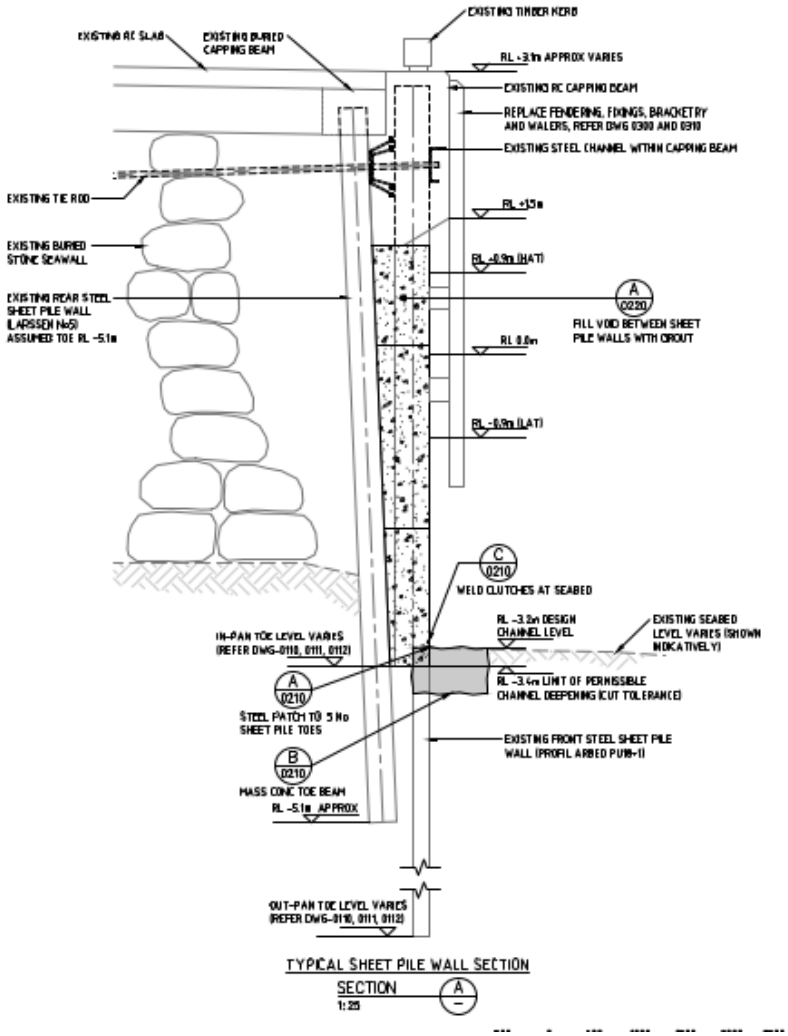


Figure 4 : Cross section showing proposed Pier Stabilisation Works

The KUAMP will assess the potential impacts of the works on the underwater archaeological resource adjacent to the Pier. It does not assess any impacts to the heritage values of the Pier structure.

Any archaeological remains on or under the seabed adjacent to the Pier could potentially be destroyed by the installation of the concrete toe in front of the existing sheet pile wall. The seabed immediately in front of the existing sheet piling wall has been dredged in recent years and the test excavation in 2020 found many artefacts of which the overwhelming majority were of modern manufacture. As such the impact to the underwater archaeological resource will be negligible.

3 HISTORICAL OVERVIEW

The following is a brief historical summary of key historical events with a particular focus on events around Sydney Bay and KAHVA on the southern edge of Norfolk Island.

3.1 Polynesian settlement c. 1150 – 1450

Kingston and Arthur's Vale Historic Area (KAVHA) was initially inhabited by Polynesian settlers from c. 1150 to c. 1450 AD, likely during a single phase of occupation. They appear to have migrated from either New Zealand or the Cook Islands-Society Islands area of East Polynesia, during an expansion to the west. Evidence of this settlement era was the discovery of bananas growing in Arthur's Vale in 1788, human remains and stone artefacts (Figure 5).[3] The Norfolk Museum holds a collection of Polynesian artefacts from KAHVA.

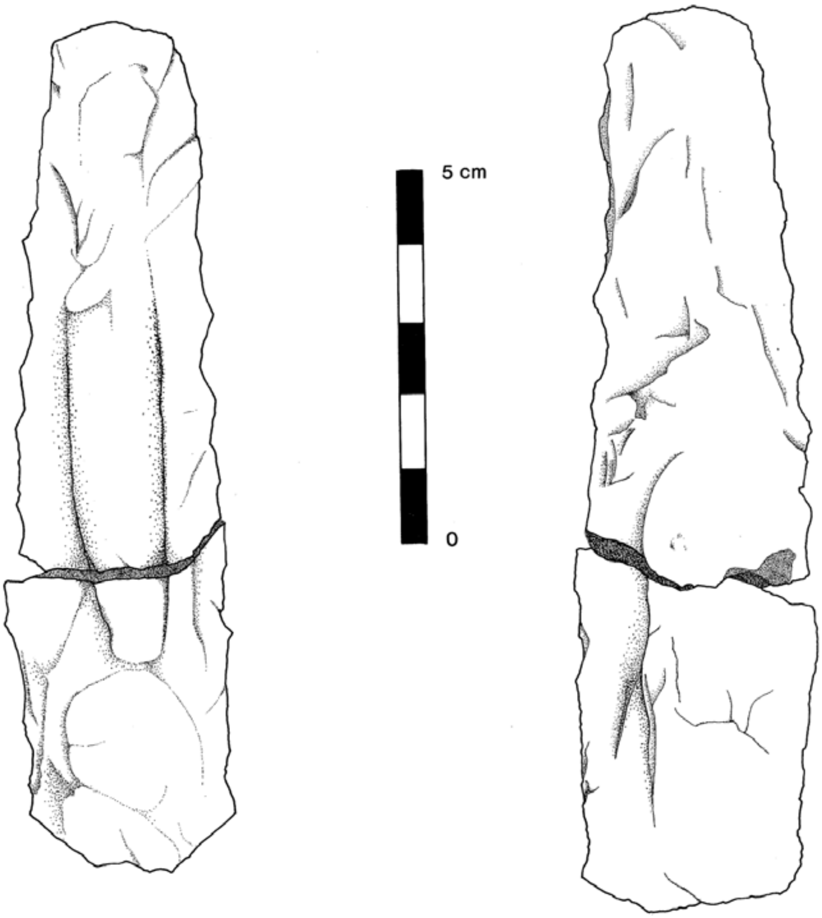


Figure 5: An example of a Norfolk Island stone artefact: Stone tool #4 found by B. Tofts underwater near Kingston/Cemetery Bay, Norfolk Island.[4]

[3] **Jean Rice Architect, Context Pty Ltd, and GML Heritage Pty Ltd. 2016**. *Kingston and Arthur's Vale Historic Area: Heritage Management Plan*, p. 24.
[4] **Specht, J, 1993,** Additional evidence for pre-1788 visits by Pacific Islanders to Norfolk Island, South-West Pacific, in Records of the Australian Museum (1993) Supplement 17, p. 152.

3.2 1st (Colonial) settlement 1788 - 1814

The first instance of Europeans sighting the future landing site on Norfolk Island was by Captain Cook and the crew of HMS *Resolution* on 10th October 1774. The island was at that stage uninhabited and on 11th October, Cook landed on the northeast side of the island with two boats, along with his officers, to undertake a quick exploration and survey of the island. Cook and his crew took floral and faunal samples, noting the similarities of plants and animals to those in New Zealand.[5]

On the morning of 12th October, the landing party returned to the *Resolution* and set sail for New Zealand. As they rounded the southern side of Norfolk Island, Cook recorded the first observation of what would become known as the Landing Place at Kingston:

> *Next morning at sunrise, we made sail, stretching to S.S.W., and weathered the island; on the south side of which lie two isles… On this, as also on the S.E. side, is a sandy beach; whereas most of the other shores are bounded by rocky cliffs… A bank of coral sand, mixed with shells, on which we found from nineteen to thirty-five or forty fathoms water, surrounds the isle, and extends, especially to the South, seven leagues off.*[6]

The first European settlement of Norfolk Island was established five weeks after the arrival of the First Fleet at Botany Bay in 1788. Instructions given to Captain Arthur Phillip from King George III instructed him to establish a settlement on Norfolk to "secure" the island for England and to "prevent it being occupied by the subjects of any other European Power." To accomplish this end, Philip Gidley King was appointed by Phillip as superintendent and commandant of Norfolk Island. King embarked with a group of 20, including four military officers, four civil officers, and fifteen convicts.[7] The site chosen by King for settlement was the same southern site described by Cook 15 years earlier, which had fresh water, flat ground and a place to land boats.[8] More people arrived in the following two years to help relieve starvation and overcrowding on the mainland (Figure 6).

By the early 1800s the Island was no longer needed as a penal colony had been set up in Van Diemen's Land, and the settlement was steadily reduced over the years. Rough seas and suitable landing sites posed difficulties in supplying provisions and communications and the settlement on the mainland was becoming more established. By 1810 the population had decreased to 117 and in 1813 plans were put in place for the abandonment of the Island. It was finally deserted in February 1814.

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[5] **M. Hoare**, **1999**, Norfolk Island: A Revised and Enlarged History 1774-1998, p.4.
[6] **Cook**, 12th October 1774, from A Voyage Towards the South Pole and Round the World, Vol.2.
[7] Op. Cit., **M. Hoare**, **1999**, p.7.
[8] Op. Cit., **Jean Rice Architect, Context Pty Ltd, and GML Heritage Pty Ltd. 2016**, p. 24.

Figure 6: View of the Town Sydney on Norfolk Island c. 1792.[9]

3.2.1 First settlement shipwrecks

The shipwreck that had the most impact on the fledgling first Norfolk Island settlement was the wrecking of HMS *Sirius.* In March 1790, HMS *Sirius* was sent to Norfolk with a contingent of supplies, convicts and marines to relieve the overcrowding at Sydney Cove. On Friday March 19th, Captain John Hunter steered HMS *Sirius* in for Sydney Bay (Kingston) between the main Island and Nepean Island.

On 19th March 1790, HMS *Sirius* and HMS *Supply* sailed close to shore to unload supplies. A strong western current pushed both vessels towards Point Ross, forcing them to make sail and attempt to leave the bay. HMS *Supply* was successful but HMS *Sirius* lost control and momentum as it turned into the wind. The small bower anchor was dropped but the vessel struck the reef stern first before the anchor cable could check it.

The vessel held this position for several days, during which people and supplies were rescued (Figure 7). On March 28th, high winds snapped the anchor chain, and the vessel was turned shoreward and thrown more than its own length nearer to shore. The vessel remained here until it fully disintegrated almost two years later.

Along with HMS *Sirius*, two smaller boats are also recorded as having wrecked during this time:

- **1788** – a boat was wrecked at the end of the reef while assisting another boat to deliver provisions from HMS *Supply.* Three out of four crew on the boat drowned.[10]
- **1790** – a cutter belonging to HMS *Sirius* was wrecked while transporting supplies and convicts from the *Justinian* and *Surprise* onto shore. Two seamen, one convict man, three convict women and one child were drowned.[11]

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[9] **King, P., Gidley 1861** View of the Town Sydney on Norfolk Island [picture]. [ca. 1792], available at https://viewer.slv.vic.gov.au/?entity=IE1500270&mode=browse, accessed 18 December 2020.
[10] Op. Cit., **Bradley, 1802**, p. 123.
[11] Op. Cit., **Bradley, 1802**, pp. 210-211.

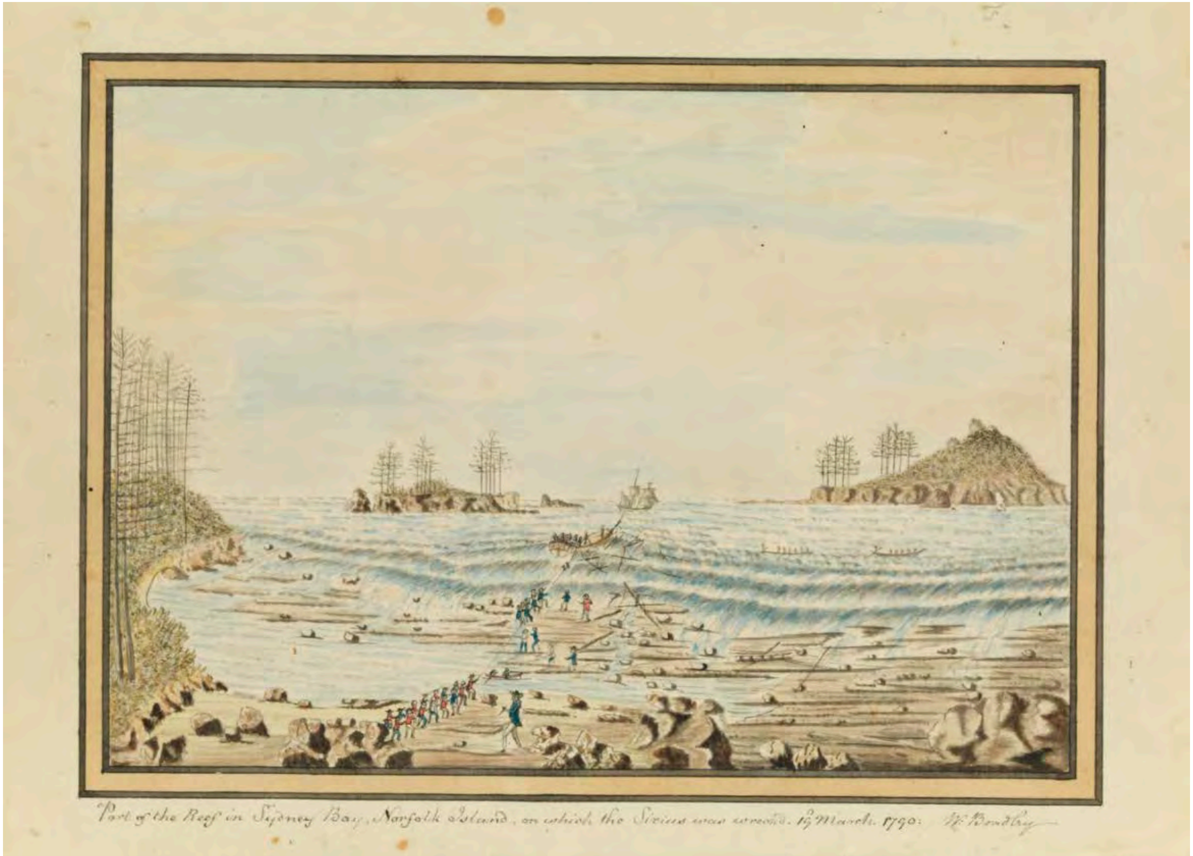

Figure 7: Wreck of HMS* Sirius *drawn by William Bradley.[12]

3.3 2nd (Penal) settlement 1825 - 1855

In July 1824 the Governor of New South Wales, General Sir Thomas Brisbane, was instructed to reopen Norfolk Island as a penal settlement on the principles of a ‘great hulk or penitentiary’ as a means of secondary punishment. Norfolk Island was re-established as a convict settlement in 1825, and quickly built a reputation as one of the harshest in all of the British Empire. Uprisings and escape attempts were common. Ambitious building works and large-scale clearing for agriculture began (Figure 8 and Figure 9).[13]

[12] Op. Cit., **Bradley, 1802**, p. 195.
[13] **Parks Australia, 2020,** *Norfolk Island National Park History,* available at https://parksaustralia.gov.au/norfolk/discover/history/#:~:text=Early%20settlement&text=The%20island%20was%20settled%20by,flax%20as%20good%20for%20sails, accessed 12 Decmber 2020.

Figure 8: Plan of the settlement and Garrison Farm c 1829 and left detail of Landing Place. [14]

By 1833, there were 600 convicts and 130 troops. An official report of the time described convicts working in building and agriculture from dawn to dusk. Convicts were given land to produce food and responsible positions in return for good behaviour.[15]

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[14] **Wakefield, C, May 1829,** *Plan of the settlement and Garrison Farm* NRS 13859 Map 6321, NSW State Archives and Records.
[15] Op. Cit., **Jean Rice Architect, Context Pty Ltd, and GML Heritage Pty Ltd. 2016**, p. 26.

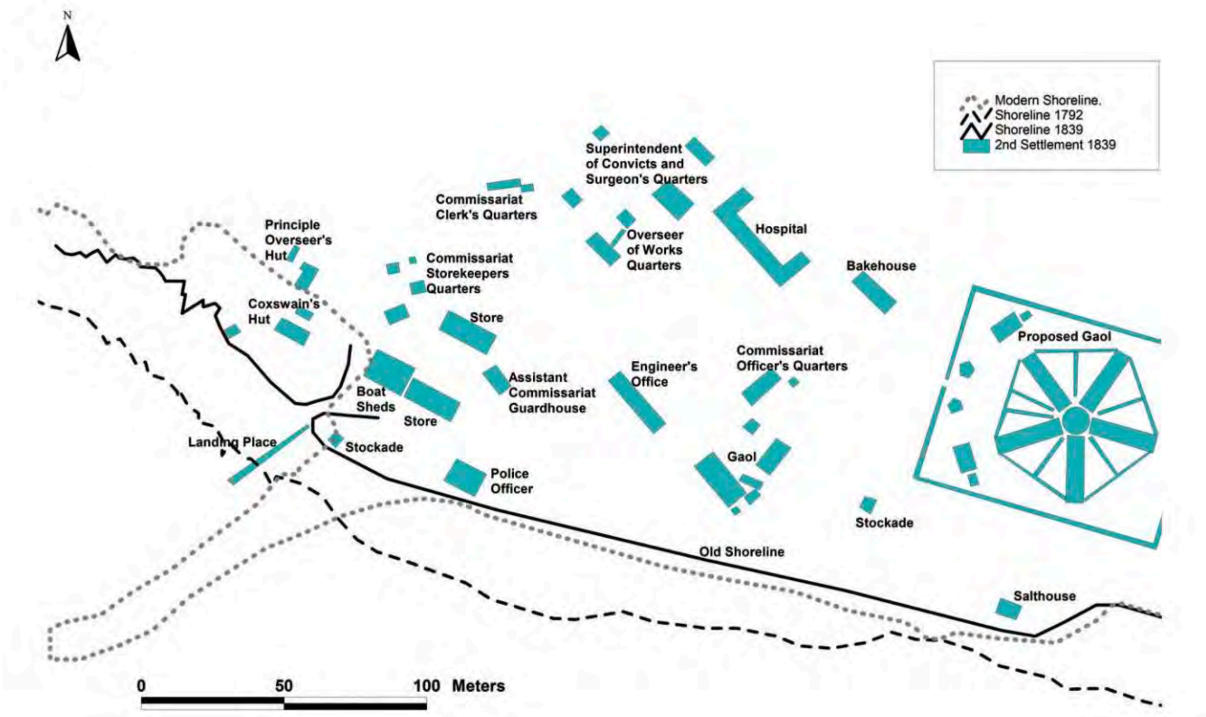

Figure 9: Kingston (second settlement). Based on H. W. Lugard 1839, Plan of the Settlement, Norfolk Island. Tasmanian archives, Plan PWD 266/1/1940.[16]

In 1847, Britain's Secretary of State for the Colonies ordered the Governor of New South Wales to abolish the settlement of Norfolk Island and the settlement on Norfolk was slowly wound down. The majority of convicts were transferred to Tasmania by mid-1856, apart from a small group who overlapped with the arrival of the Pitcairners and helped familiarise them with the local landscape.[17]

3.3.1 Construction of Kingston Pier 1839

Construction of the Kingston Pier began in 1839 to improve the port facilities. The Pier was designed by Royal Engineers, chiefly Lt. Henry Lugard and RG Hamilton, and was constructed during low tide on the western edge of the reef (Figure 10). It was built using large stone blocks as foundation, fastened together with metal clamps. The upper courses were built out of cut stone keyed together using perpendicular stone blocks.[18] The rough conditions prevented the full construction of the intended length, as the stone foundations were continually washed away. Construction of the Pier was halted almost 50 metres from the end of the reef.[19] A timber slipway constructed at the Landing Place in the 1830s was replaced in 1853 with a stone slipway for launching boats, and sea walls were constructed on the shoreline on either side of the Pier.[20]

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[16] **Gibbs, M., B. Duncan and R. Varman, 2017,** The free and unfree settlements of Norfolk Island: an overview of archaeological research, in Australian Archaeology 83:3, p. 88.
[17] Op. Cit., **Gibbs, M., B. Duncan and R. Varman, 2017**, p. 90.
[18] **Baskerville, B., 2013**, "Kingston Pier and Landing Place", *HistoryMatrix.* https://historymatrix.wordpress.com/2013/07/07/kingston-Pier-and-landing-place/ Accessed 15 April 2020.
[19] **Van Pel 1959**, "Report on the Fisheries of Norfolk Island", Report prepared for the South Pacific Commission. p.34.
[20] Op. Cit. **Baskerville, 2013**.

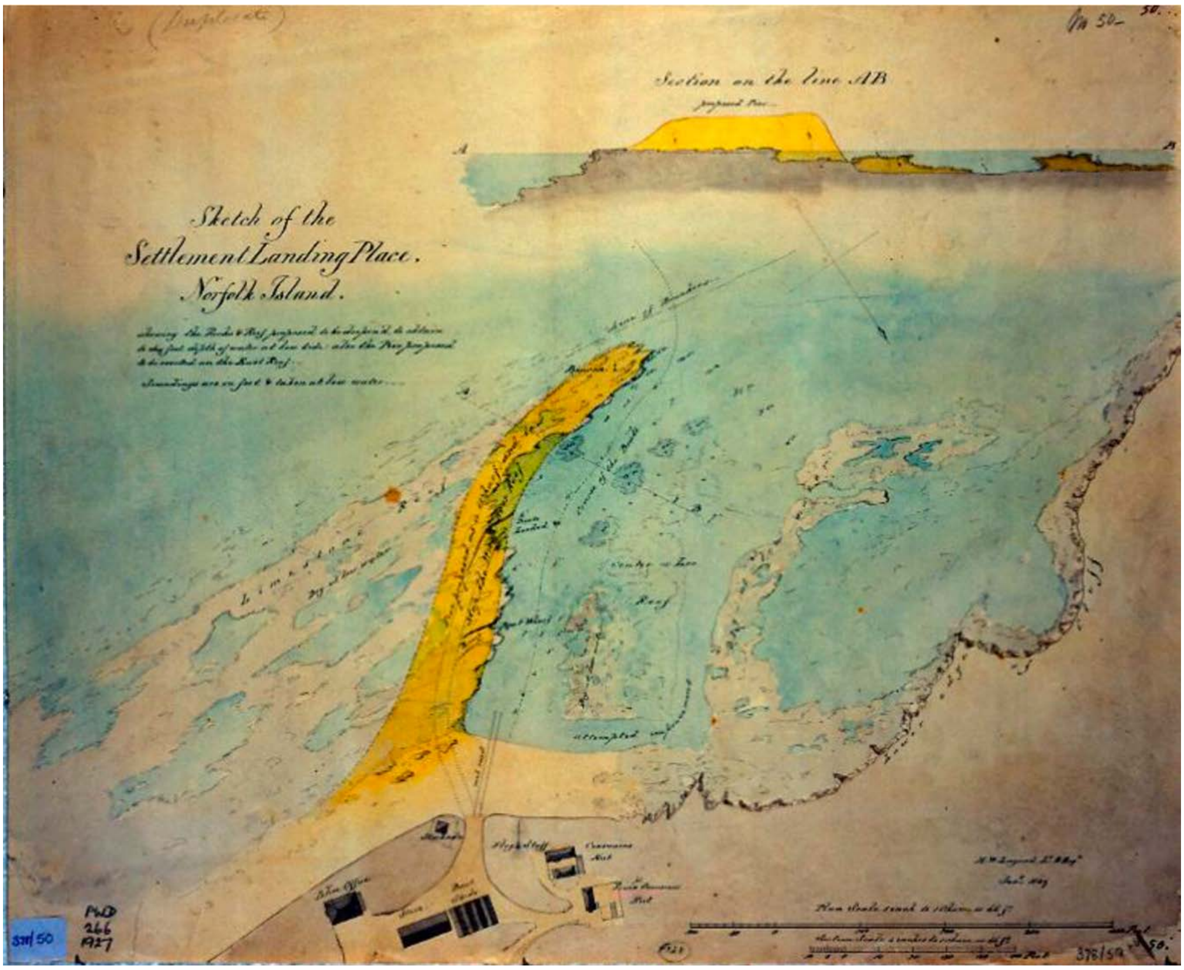

Figure 10: An un-dated sketch of Kingston Pier showing the structure overlaying the western edge of the fringing reef that stretches across Slaughter Bay.[21]

Unloading cargo operated under similar methods as it had before the construction of the Pier. Large ships would anchor well south of Norfolk Island and send goods and people on small boats to the Pier. Cargo would then be removed from the boats via crane, where it would be placed into horse-drawn carts and delivered (Figure 11). The location of ship anchorage is indicated in contemporary charts as being roughly halfway between Norfolk and Phillip Islands (Figure 12).

[21] **Hogan, R. November 2011**, Kingston Pier Refurbishment, Norfolk Island. Paper presented at the 16th Engineering Heritage Australia Conference, Hobart November 2011, photo 4.

Figure 11: Kingston Pier, c.1910, cargo ship anchored in background, lighters unloading cargo via crane onto horse-drawn carts. [22]

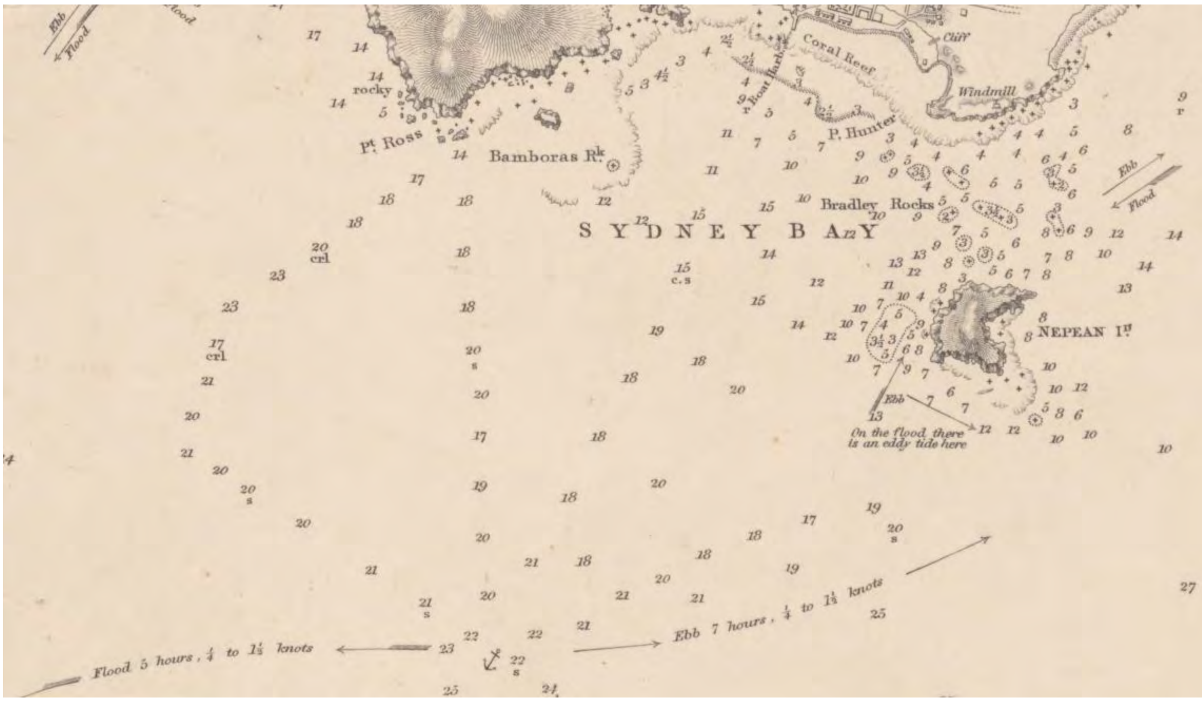

Figure 12: 1855 chart showing ship anchorage (indicated by anchor) approximately 3 km southwest of Kingston. [23]

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[22] **Anon, 1910**, Kingston Pier, horses on the landing, Crankmill, boat store ruins and a ship at a distance, Norfolk Island, approximately 1910, https://trove.nla.gov.au/work/237389426 accessed 16 April 2020.
[23] **Hydrographic Department, Great Britain, 1856**, *Pacific Ocean. Norfolk and Philip Islands,* viewed 16 April 2020 http://nla.gov.au/nla.obj-231292577

3.3.2 Second settlement shipwrecks

3.3.2.1 Friendship (1835)

Friendship was an 88 ton wooden hulled schooner. The vessel had three decks, measured 58 feet (17.68m) in length, 19 feet (5.79m) wide and had a draft of 10 feet (3.05m). *Friendship* was built by J. White in Barnstable England in 1824 and had been chartered by Henry Bull of Sydney to convey himself and his family to Tahiti to establish a sugar plantation. The commander of the vessel, Captain Harrison, was part owner in the venture as well.

Friendship attempted to reach the moorings south of Kingston harbor but was unable to due to due to a strong SW breeze. As the wind picked up, the vessel was forced to pull anchor and sail through the channel between Nepean and Norfolk Islands.

On Saturday, 16th May, *Friendship* was successful in reaching the mooring. However, the wind was still blowing from the SW and the mooring was precarious. Norfolk Island's Commandant, Major Anderson, sent a whale boat to the vessel in case of accident as *Friendship* had lost its only boat on the passage around Nepean Island.

At daylight on Sunday morning, it was seen that *Friendship* was drifting towards the breakers and the shallow reef, on a lee shore (blowing towards land) wind and heavy surf. The drift was caused by a faulty mooring buoy, which had been installed the previous year in July 1834.

The crew struggled to keep the vessel off the reef by raising the sails, but as the vessel came directly across from the Commissariat Store, they struck the reef and lost the vessel's rudder and came to a spot directly opposite the landing place (presumably where the Pier now exists).

The masts were then cut away from the vessel to form a bridge and hawser to facilitate rescue. At this point the tide was still low enough for a large number of prisoners on the beach to wade out to the stranded vessel and rescue the 50 passengers, crew, and prisoners aboard. To affect this rescue, the prisoners carried a whale boat over the reef and alongside the *Friendship* to rescue its passengers.

Over the next two days, prisoners were engaged in salvaging as much cargo and personal effects as could be managed.[24]

The location of wrecking is an extremely high energy environment, and it is realistic to assume that the majority of the vessel was broken up with wreckage washed towards shore.

3.3.2.2 Mary Hamilton (1873)

Mary Hamilton was a 218 ton wooden hulled whaling barque built by Barr & Shearer in Ardrossan, Scotland in 1857. The vessel was registered in Melbourne upon its arrival in 1872 and was fitted out for whaling purposes. On 1st August 1872, *Mary Hamilton* left Melbourne under the command of Captain Barker for a 12-month sperm whaling expedition with a crew of 21 sailors. After returning to Sydney for repairs to replace the bowsprit, the vessel set sail on 9th December and reached Norfolk Island on 19th April 1873.

Boats were sent ashore at Cascade in Norfolk Island to gather wood, water and other supplies. On 6th May, the *Mary Hamilton* circled around the south of Norfolk Island to send a boat to Kingston to pick up Captain Glover, who had made his way across the island for business purposes. At approximately 2pm, *Mary Hamilton* struck a submerged rock to the

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[24] **Anon, 1835** 'Domestic and Miscellaneous Intelligence.', *The Australian (Sydney, NSW: 1824 - 1848)*, 21 August, p. 2, available at http://nla.gov.au/nla.news-article42008860, viewed 15 Apr 2020.

southeast of Nepean Island, just south of Kingston. The wrecking event comes from accounts given by both the Captain and the First Mate, Mr. D.W. Glover.[25]

Glover, in command, recorded feeling a slight bump, and noticing sheets of copper coming off the keel of the vessel. Upon checking the hold, it was determined that the vessel was quickly taking on water and would soon sink.

When Captain Barker boarded the vessel at 5:30 pm, it was determined that the best course of action would be to unload the vessel's cargo to a nearby schooner, *Ivanhoe,* and make preparations to beach the sinking vessel near Kingston Pier.

In the morning of the 7th May, *Mary Hamilton* was beached at the Landing Place. Over the next seven days supplies and parts were salvaged from the beached vessel until waves eventually broke the vessel in half. It was noted by the Captain that the surf and tides were relatively mild, with little heavy surf and spring tides, which assisted in the salvage operation.

3.3.2.3 Bittern (1868)

Bittern was a 40-ton timber hulled cutter, registered in Auckland, and involved in the trade of timber and livestock between Auckland, Norfolk Island, and Noumea. The vessel was built in 1865 in Mahurangi, New Zealand, and measured 53.4 feet (16.28 m) long and 17.6 feet (5.36 m) wide.

Bittern arrived at Norfolk Island on 13th July 1868 from Noumea, after delivering a load of cattle and sheep for that port. On 16th July, the vessel anchored at Cascade Bay and delivered a portion of its cargo. During the night, the wind shifted to the north and *Bittern* left its anchorage to avoid being blown onto shore. The crew moved the vessel to the south side of the island, making anchorage off Kingston on the 18th July and finished unloading the vessel's cargo.

The wrecking was recorded in contemporary newspapers as occurring on the 19th May: [26]

At approximately 7:00 am, the wind suddenly shifted to the southeast, bringing *Bittern* on a lee shore breeze. The cutter immediately attempted to raise anchor and sail further out to sea, but the increased swell caused the anchor to break off "short of the crown". The vessel attempted to sail into the wind, but was unsuccessful in tacking, possibly due to a length of anchor chain hanging from the hawsepipe.

As the wind continued to increase, *Bittern* was blown onto the reef a short distance to the left of the channel entering the boat harbour. After striking the reef several times, the crew abandoned the vessel, rescued by islanders in whale boats and *Bittern* was smashed. Almost nothing was saved from the wreck except a chronometer and the vessel's papers.

The reported wrecking location indicates that the wreck may have occurred near an area known as the "blow hole", immediately to the west of the Kingston Pier and Landing Place.

3.3.2.4 Other smaller vessels

Two small boats were also recorded as having wrecked near the Landing Place:

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[25] **1873** 'Shipping Intelligence. Port of Auckland', *Daily Southern Cross (Auckland, NZ)*, 31 May 1873, p.1. viewed 15 Apr 2020, https://paperspast.natlib.govt.nz/newspapers/DSC18730531.2.4
1873 'WRECK OF THE MARY HAMILTON.', *The Hay Standard and Advertiser for Balranald, Wentworth, Maude...(Hay, NSW : 1871 - 1873; 1880 - 1881; 1890 - 1900)*, 18 June, p. 4. , viewed 15 Apr 2020, http://nla.gov.au/nla.news-article145704895
[26] **1868** 'TOTAL LOSS OF THE CUTTER BITTERN AT NORFOLK ISLAND.', *The Cornwall Chronicle (Launceston, Tas. : 1835 - 1880)*, 31 October, p. 4. Available at http://nla.gov.au/nla.news-article66463295, accessed 15 April 2020 and
1868 'NOFOLK ISLAND. – THE WRECK OF THE 'BITTERN.' (FROM A CORRESPONDENT.)', *Daily Southern Cross (Auckland, NZ),* 22 September, p.3. Available at https://paperspast.natlib.govt.nz/newspapers/DSC18680922.2.18, accessed 15 April 2020.

- **1826** – a whale boat returning to the landing place from a brig, possibly the *Amity,* was upset on the reef. 7 persons on board were able to swim to shore, but the boat was a total loss.[27]
- **1840** – an anonymous boat, returning from Philip Island, was upset by "tremendous rollers" upon its return to Kingston. All three on board were drowned.[28]

3.4 3rd (Pitcairn) settlement 1856 - present

In 1852, following several years of negotiation, the British Home Office decided to relocate the people of Pitcairn Island to Norfolk Island. The people of Pitcairn Island, a community of descendants of mutineers from the HMS *Bounty* and Tahitians, had outgrown Pitcairn Island. With Norfolk Island's penal settlement closure imminent, it was deemed to be a suitable place for resettlement.[29]

The people of Pitcairn Island voted to make the transfer. They sailed on the *Morayshire* and landed at Kingston on 8 June 1856. The Pitcairn Islanders first stayed in 'barracks', and by 1857 they were in possession of the Kingston buildings that were left vacant when the penal settlement ended. Around 1858, each household head was allocated a fifty-acre lot, away from Kingston.

As the Pitcairners settled into their new surroundings, they began to look for ways to earn money through trade. Early industries included whaling, which would become a mainstay of the Islanders. By 1859, 33 Islanders had formed a whaling company and bought boats and whaling gear from an American whaler.[30]

Whaling continued on and off through the 19th and 20th centuries. A 1959 report on the situation of the Norfolk Island fishing and whaling industries indicated that nine commercial fishing boats were operational, employing several dozen Islanders.[31] By this point, the fishing industry was already in decline, with both the processing company and the fishermen failing to make significant profit. Boats continued to be launched via crane at both Cascade and Kingston Piers, while whales were either processed at sea, or drawn onto the beach for processing at Cascade and Ball Bay.[32] Whale oil processed by the Islanders was pumped onto tankers that brought petrol from Australia.[33]

Throughout this period Norfolk Island, and Kingston specifically, remained an important strategic point for South Pacific trade. Cargoes transported between Norfolk, Australia, New Zealand, New Caledonia and other south seas islands was extremely varied, but chief among imports to Norfolk were manufactured goods that could not be produced on the island. *Oscar Robinson* was travelling from Auckland to Noumea via Norfolk and carried as cargo[34]:

- For Noumea: blasting powder, sporting powder, candles and jams
- For Norfolk Island: drapery, tea, sugar, candles, dates, kerosene, starch, flour, groceries, mattresses, bags, photo goods, stationery, earthenware, soda, paper, and saddlery

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27 **Anon, 1826** 'Norfolk Island.', *Colonial Times and Tasmanian Advertiser (Hobart, Tas. : 1825 - 1827)*, 3 February, p. 2. Available at http://nla.gov.au/nla.news-article2447070, accessed 12 April 2020.
28 **Anon, 1840** 'Original Correspondence.', *Australasian Chronicle (Sydney, NSW : 1839 - 1843)*, 17 March, p. 2. Available at http://nla.gov.au/nla.news-article31727834, accessed 15 April 2020.
29 Op. Cit., **Jean Rice Architect, Context Pty Ltd, and GML Heritage Pty Ltd. 2016**, p.29.
30 Op. Cit., **Hoare,** p.85.
31 Op. Cit., **Van Pel**, p.8.
32 Op. Cit., **Hoare, 1999**, p. 85.
33 Op. Cit., **Van Pel, 1959**, pp. 5-7.
34 **Sydney Morning Herald** (NSW : 1842 - 1954), Saturday 12 February 1898, p. 9.

- For Lord Howe Island: furniture, groceries, drapery, sheet iron, bags, hardware, books, rattans.

During WWII, Norfolk Island became militarised as a location for Australian, New Zealand, and American armed forces to monitor South Pacific waters. The chief development of this period was the aerodrome, later to become the Norfolk Island airport. The aerodrome was constructed between 1942 and 1943 under the supervision of American and Australian military engineers.[35] Military garrisons were regularly supplied by American, Australian and New Zealand ships, including sailing schooners drafted into armed service. One of these vessels, *Ronaki* IX-94, wrecked near Kingston Pier in 1943. *Ronaki* was carrying war supplies to Norfolk Island, including a large quantity of electrical equipment, possibly for use in construction of the aerodrome, when it ran aground on the reef.

Kingston Pier was significantly damaged during the war as a result of landing supplies and operating heavy machinery in the construction of the aerodrome. Further damage was caused to the seawalls, which were breached in order to undertake salvage operations on *Ronaki.*[36]

3.4.1 Third settlement shipwrecks

3.4.1.1 Ronaki IX-94 (1943)

Ronaki was a 255 ton, timber hulled, twin diesel engine, three-masted auxiliary schooner built in Auckland in 1922. The vessel was owned by the Northern Steam Ship Company prior to WWII and was intended to operate in the coastal cement trade in New Zealand. On 21st October 1942, *Ronaki* was transferred to the US government as a store ship for US troops in the Pacific War Zone and redesignated IX-94.[37] *Ronaki* was involved in the supply of Allied forces stationed on Norfolk Island during the war years, indicated by its cargo which included war supplies, including munitions and a large quantity of electrical goods.[38]

On 18 June 1943, *Ronaki* foundered in a violent storm and washed onto the reef south east of Kingston Pier. A line was extended from the vessel to shore and the vessel was pulled up high onto the reef only 50 m east of Kingston Pier. An access was cut through the sea wall nearest to the vessel, and over several days the vessel was successfully salvaged (Figure 13). According to local informants consulted during the 1985 HMS *Sirius* Expedition, the wooden hull of *Ronaki* was burned and most of the structural iron was removed to the base of a cliff near Bloody Bridge.[39] Several artefacts from *Ronaki* were examined by researchers in 1985, along with several items in the Norfolk Island museum.

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[35] Op. Cit. **Hoare 1999 :** 130.
[36] Op. Cit. **KAVHA Heritage Management Plan, April 2016**, p.38.
[37] **Mooney, J. ed., 1976**, *Dictionary of American Naval Fighting Ships, Vol.VI,* p.154. Naval History Division, Dept. of the Navy. Washington, DC.
[38] "WWII Merchant Ship Movement Records, *Ronaki* to *Samuel Heintzelman",* Royal Australian Navy Naval History Section, available at https://www.navy.gov.au/sites/default/files/documents/RONAKI_TO_SAMUEL_HEINTZELMAN.pdf accessed 15 April 2020.
[39] **Henderson, G., M. Stanbury, 1985**, Report to the Australian Bicentennial Authority on the February – March 1985 Bicentennial Project Expedition to the Wreck of HMS Sirius (1790) at Norfolk at Norfolk Island, Report prepared for Department of Maritime Archaeology, Western Australian Maritime Museum No.24: p.21.

Figure 13: Ronaki IX-94 run aground on reef immediately east of Kingston Pier. Salvage efforts underway. Note the Pier is visible in the right of image.[40]

3.4.1.2 Other smaller vessels

Two small boats were also recorded as having wrecked near Kingston Pier:

- **1907** – a whaleboat belonging to the No.3 Whaling Company was wrecked on the reef sticking out from the end of Kingston Pier. The crew were rescued, but the boat was destroyed on the rocks opposite the Pier.[41]
- **1922** – a whaleboat was destroyed on the rocks while loading timber. [42]

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[40] **AUCHD** wreck ID 7955 https://dmzapp17p.ris.environment.gov.au/shipwreck/public/wreck/wreck.do?key=7955, accessed 18 December 2020.

[41] **Anon, 1907,** 'WHALE-BOAT CAPSIZES.', *The Argus (Melbourne, Vic. : 1848 - 1957)*, 24 July, p. 6. Available at http://nla.gov.au/nla.news-article10136833, viewed 15 April 2020.

[42] **Anon, 1922** 'Whaleboat Smashed to Pieces.', *The Age (Melbourne, Vic. : 1854 - 1954)*, 6 February, p. 6. , viewed 15 Apr 2020, http://nla.gov.au/nla.news-article205750810

5 ARCHAEOLOGICAL POTENTIAL

Based on an understanding of the historical development of Norfolk Island, KAVHA and Kingston Pier and the non-disturbance dive survey undertaken in February 2020, an assessment on the archaeological potential was prepared. The following section presents a revised assessment of archaeological potential based on the results from the test excavation undertaken in November 2020.[43]

Four test trenches were excavated over seven days recovering 1,442 artefacts, the overwhelming majority being from the 20th and 21st century. Twenty-three artefacts were assessed as being potentially 19th century or earlier. These artefacts are in the possession of KAVHA, the remainder (1,399 artefacts) were discarded after cataloguing. The test trenches were positioned with the intention of sampling different seabed contexts across the study area and to excavate in areas where it was thought artefacts were more likely to be concentrated (Figure 14).

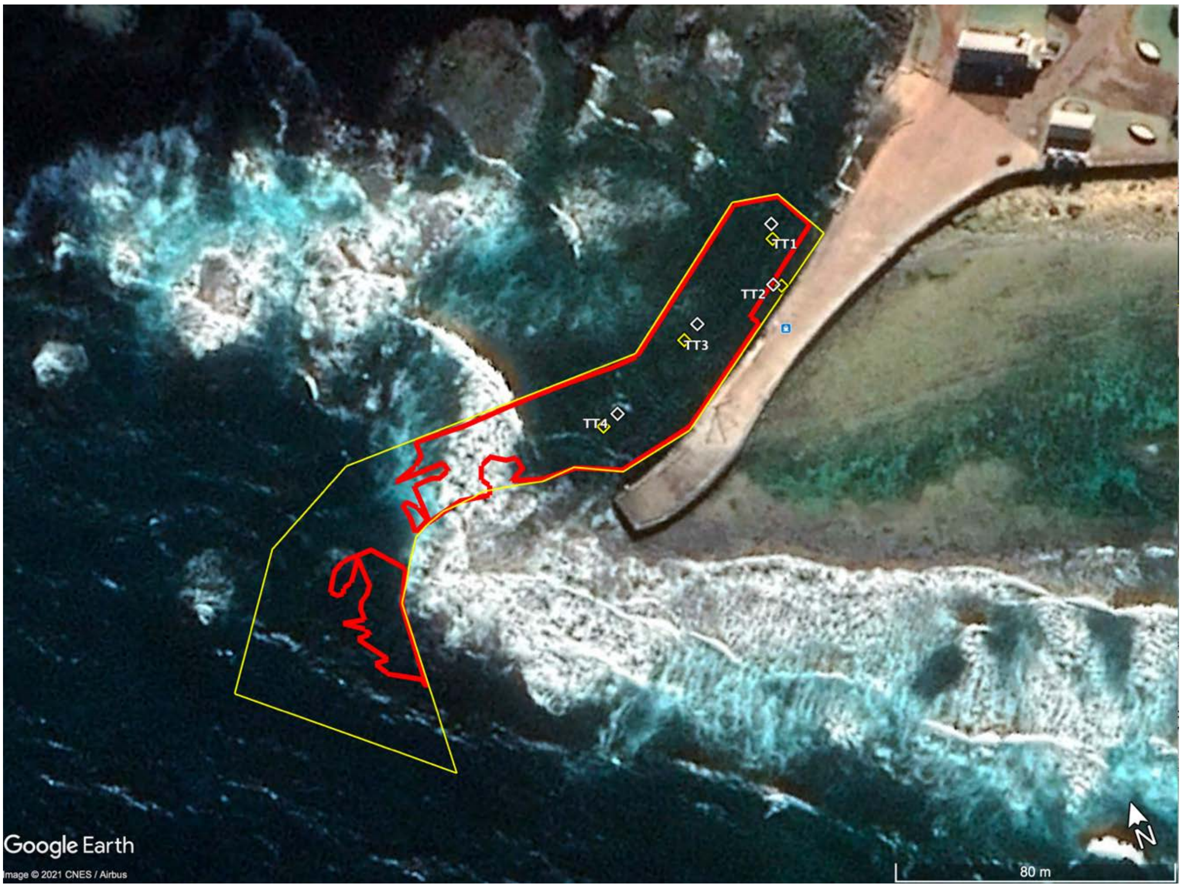

Figure 14: Final positions of test trenches (in yellow). Red outline is dredge footprint; yellow outline is navigation channel. Base image on Google Earth.

The majority of artefacts located during the test excavation were identified as post-dating 1898. Twenty-five objects were assessed as either likely or possibly pre-dating 1898 and were retained. These objects included 'black' bottle glass, slate pencils, a snaffle bridle bit, a copper token or penny and a copper alloy nail very similar to those found on the wreck site of HMS *Sirius*.

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[43] **Cosmos Archaeology Pty Ltd, April 2021**, *Norfolk Island, Kingston Pier Underwater Archaeological Test Excavation.*

Test Trench 1 (TT1) contained the second highest number of artefacts. Located close to the eastern boundary of the proposed dredge footprint, this trench was closest to the original shore landing from 1788 to 1856. The majority of the artefacts found in this trench were also modern with some very few dating to the 19th century. There was one example of black bottle glass (<1898) found in this trench.

The majority of the artefacts recovered were from Test Trench 2 (TT2) and were all modern materials. This was expected as this trench was sited adjacent to the Pier and had been dredged in the 1980s and excavated again in 2005.[44] The findings from this trench suggest that there is little likelihood of earlier artefacts having migrated into this dredged zone in heavy seas.

Test Trench 3 (TT3) was similar to TT1, in that it was located within a sandy depression within the hardened grey tuff 'reef' surroundings. However, this trench had the least number of artefacts (47) which were predominantly modern (> 1898). None of the artefacts from TT3 were retained.

Test Trench 4 (TT4) was located at the bottom of a wide sandy gully at the channel entrance and the inshore side of the reef. At this location the seabed is dominated by broken up calcarenite boulders of various sizes. As with the other trenches, TT4 also bottomed out onto grey tuff after 100 to 300 mm. This trench had a moderate number of artefacts, a higher proportion of which are 19th century manufacture or earlier. A copper alloy nail of similar form to those found on the wreck site of HMS *Sirius* was also recovered.

Further artefacts were found around TT4 by hand excavation, including three pieces of 'black' bottle glass, all relatively thick and dense, measuring from 4 to 9 mm in thickness. These pieces are from one or more bottles, and include a portion of bottle base, portion of bottle neck and a portion of bottle body. These artefacts were dated between 1700 and 1850, indicating that they most likely date from the penal settlement eras of Norfolk Island history.

It is interesting to note that there was a larger concentration of light material such as bones, aluminium scraps and synthetic material across Test Trenches 2 and 3 indicating that small, lightweight artefacts are concentrated in near shore areas. Of the heavier artefacts, such as lead, copper alloy and heavy black glass the more significant of these came from Test Trench 4 indicating that heavier items appear to drop into the gullies and fissures and stay there.

Timber wreckage was not found during the text excavation; however, it may exist if it was rapidly buried in the apparent deeper sediments in the entrance to the channel. There was no evidence of the timber remains of the slipway, however what appeared to be a slip rail was located on the seafloor in TT1.

There was no cultural material located in the area towards the entrance to the channel and to the south and southwest of Kingston Pier where a video survey was undertaken. However deep fissures and gullies were noted in the rock platform and rocky reef to the south that may contain artefacts from shipwrecks that have wrecked at the southern edge of the reef.

The footings of the beacon are likely to be present but were not identified as part of the test excavation or video survey and may be difficult to identify.

The results of the test excavation indicate the majority of culturally significant artefacts appear to be concentrated in gutters, gullies, crevasses and cracks in the seafloor and under and around hard calcarenite overhangs and boulders on either side of the existing channel. The area around TT1 and TT3 is a soft reef-like tuff which does not appear to harbour culturally significant artefacts in appreciable quantities. It is thought that the wave activity and morphology of the immediate area sees artefacts eventually migrate towards shore and even

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[44] **Parsons, George, 2020** *pers. comms*. 8th November

dragged back out into the reef. This would explain the dominance of recent artefacts in this area.

The cultural heritage sensitivity of the archaeological resource – a combination of the extent, variety, frequency, condition and significance – has been assessed per trench as outlined in Table 1.

Table 1: Cultural heritage sensitivity as determined by the test excavation.

Area	Description	Total artefacts	Retained	Cultural heritage sensitivity
TT1	Sandy depression surrounded by hardened grey 'tuff' reef	129	3	Low
TT1 ext.	Sandy depression surrounded by hardened grey 'tuff' reef	41	2*	Low
TT2	Sandy depression within the footprint of the 1980s and 2005 dredging footprint	959	1	Low
TT3	Sandy depression surrounded by hardened grey 'tuff' reef	47	0	Low
TT4	Area characterised by broken up calcarenite boulders with fissures and gullies	171	10	High
TT4 ext.	Area characterised by broken up calcarenite boulders with fissures and gullies	46	9	High
SW end Pier	Rocky platform leading to rocky reef with deep gullies and fissures	N/A	N/A	Medium

* One artefact was later diagnosed as an engine shim and would have been discarded as per the artefact retention policy.

Based on the above assessment the areas or sectors of cultural heritage sensitivity can be extrapolated across the study area. These sectors are defined as follows and are depicted in Figure 15.

Sector	**Location**	**Seabed characteristics**	**Cultural heritage sensitivity**
A	Within current berth area	Includes previously dredged area adjacent to the Pier and grey tuff seabed with shallow sandy patches	Low
B	Existing channel through reef at western end of Pier.	Broken up calcarenite reef atop of grey tuff.	High
C	Approaches to channel outside of reef.	Rock rubble on reef platform with deep fissures and gullies.	Medium

Though no test excavation took place within the Sector C it has been conservatively assessed to be of medium cultural heritage sensitivity because of the known wreck events that have taken place in the area.

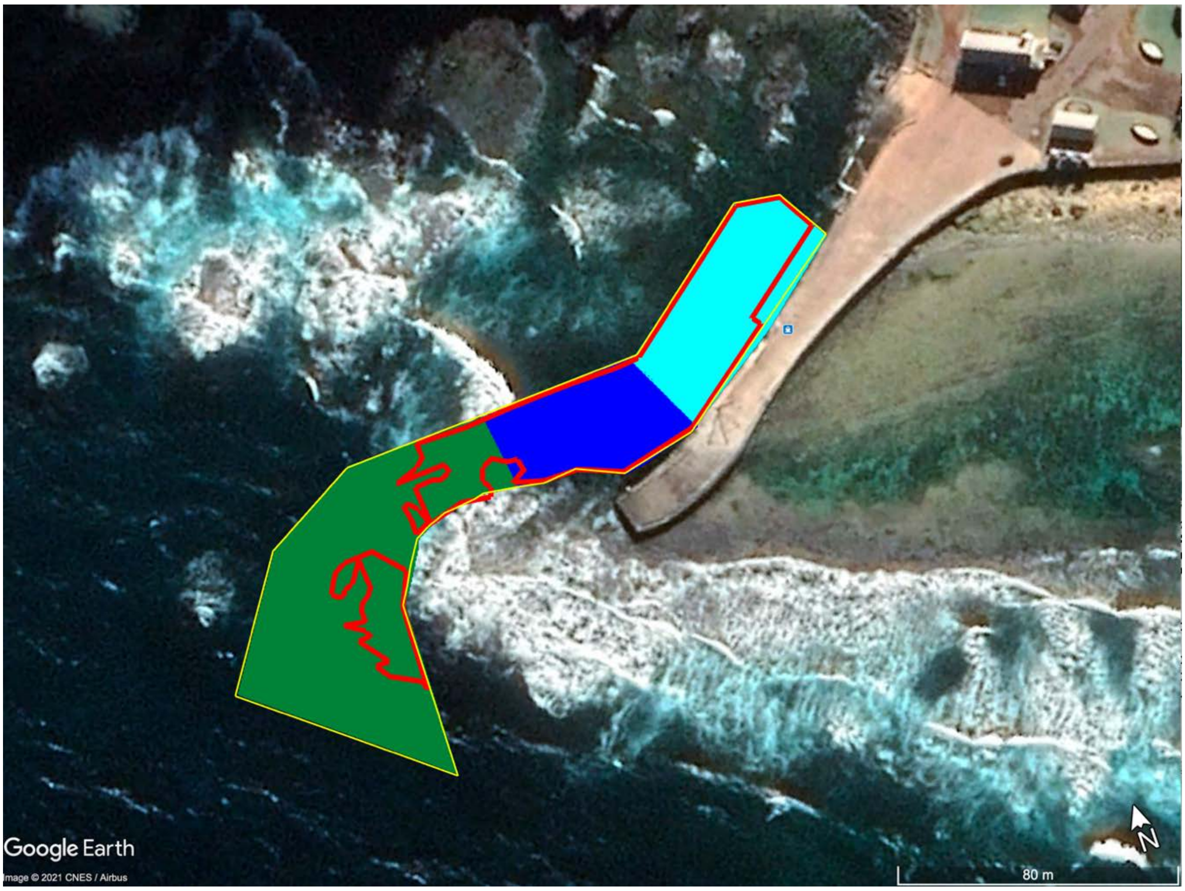

Figure 15: Areas of cultural heritage sensitivity as determined by the test excavation. Light blue is low cultural heritage sensitivity (Sector A), dark blue is high cultural heritage sensitivity (Sector B), and green is tested only through video survey and therefore considered to have medium cultural heritage sensitivity (Sector C). Yellow outline is navigation channel and red outline is Option 3a dredging footprint.

The findings of the test excavation can provide some indication as to the quantity of artefacts that may be present within the study area. The following estimates are for Sectors A and B only as no excavation took place in Sector C (Table 2). The calculations are based only on the finds within the test trenches not the extensions. This is because the extent of the seabed examined for artefact recovery that took place outside the trenches was not measured and therefore not readily quantifiable.

Table 2: Estimated potential quantity of artefacts within sectors A and B.

Sector	Approx. size in m^2	Area excavated in m^2	Artefacts recovered / artefacts per m^2	Potential quantity of artefacts
A	1,200	12	1,135 / 95	114,000
B	720	4	171 / 43	31,000

The figures in Table 2 for both Sectors are large and subject to a large margin of error. With regards to Sector A, the overwhelming majority of the artefacts will have low cultural heritage values as they will post date 1897. It should be noted that excavations within Sector A took place in sand patches which did not cover the whole sector and so perhaps the frequency of artefacts present may be around 25% less than what Table 2 shows for Sector A. Furthermore around 84% of the artefacts recovered from this sector was from within the previously dredged area which has been demonstrated to have very low cultural heritage significance.

The artefact distribution across Sector B will vary greatly. There will be areas where there will be no artefacts, such as where there is calcarenite rock but then it is expected that there will be concentrations of artefacts in cracks and crevices. Of the 171 artefacts recovered from TT4 within Sector B, 10 were considered sufficiently significant for retention. Extrapolating this from the estimated figure of 31,000 artefacts within Sector B, there may be potentially around 3,000 artefacts present that may have merit for retention and even conservation treatment.

5.1 Statement of Cultural Significance

The KAVHA Archaeological Zoning and Management Plan (AZMP) states that with respect to archaeological significance:

> *KAVHA is a rare surviving settlement that provides tangible evidence of a range of different forms of human occupation extending over a period of almost one thousand years. The archaeological remains have significant potential to contribute to understanding of the site's continuous development during each period of occupation.*
>
> *The values detailed in the statement of significance cover a wide range of existing and potential resources. These may vary in their ability to contribute to the core reasons for conserving and interpreting the site.*[45]

The archaeological resource within KAVHA has been assessed in the AZMP as follows in Table 3 (text not in italics has been added by the authors). This assessment also applies to the underwater archaeological resources within the study area, including shipwreck remains other than HMS *Sirius.* This assessment did not change as a result of the test excavation but rather the extent of the potential significant (critical) archaeological resource within the study area was more clearly defined.

Table 3: Cultural heritage significance and sensitivity of underwater archaeological resource by Sector within study area.

Occupation Phase	Occurrence	Condition	Historical relevance	Research value	Resource	Key value	Sensitivity by Sector
Polynesian settlement c.1150 - c. 1450	*Rare*	*Potentially a high degree of integrity*	Tracing Polynesian settlement across the Pacific	*High*	*All physical evidence*	*Critical*	*A - Low* *B - Low* *C - Low*

[45] **Extent, June 2020** *Kingston and Arthur's Vale Historic Area (KAVHA) : Archaeological Zoning and Management Plan*, pg. 65.

Occupation Phase	Occurrence	Condition	Historical relevance	Research value	Resource	Key value	Sensitivity by Sector
The First (Colonial) Settlement 1788 - 1814	Rare	Relatively undisturbed	Key part of the broader operation of the British penal system	High	All physical evidence	Critical	A - Low B – High C - Medium
The Second (Penal) Settlement 1825 - 1855	Rare	Relatively undisturbed	The ultimate expression of Britain's global system of penal discipline	High	All physical evidence	Critical	A - Low B – High C - Medium
The Third (Pitcairn) Settlement 1856 - 1897	Rare	Not assessed	The operation of a culturally distinct Polynesia/European community living within a broader European context	High	All physical evidence	Critical	A - Low B – High C - Medium
The Third (Pitcairn) Settlement 1898 to present	Common	Not assessed		Limited	Evidence relating to WWII defence works, tourism, use of earlier structures and modifications	Secondary	A - Low B – Low C - Low

The majority of artefacts located during the test excavation were from the Third (Pitcairn) Settlement. No artefacts were identified from the Polynesian settlement. However, those artefacts retained from TT4 appear to be from the first and / or second penal settlement as well as the early phase of The Third (Pitcairn) Settlement, which includes black bottle glass and copper alloy tacks.

6 FOCUS

6.1 Maritime Archaeological Research Questions

Bearing in mind the potential significance of the underwater archaeological deposit, the test excavation aims to answer the following questions:

1) *Are artefacts from the wreck of the HMS* Sirius *present?*

HMS *Sirius* was wrecked on the outer reef 200 m to 250 m to the south east of the proposed dredge envelope.[46] The strong currents flowing along the edge of the reef fringing Slaughter Bay may have brought floating wreckage into the vicinity of the study area before sinking or being pushed towards shore by wind and wave. This occurrence was described by Seaman Nagle who saw wreckage from the HMS *Sirius* floating westwards and disappearing into a whirlpool apparently located close to the study area. The finding of the spectacle plate from HMS *Sirius* west of the study area shows how far floating wreckage, in this instance the top part of the vessel's rudder, could be found away from the main wreck site. Furthermore during the November 2020 test excavation, a copper alloy nail of similar form to those found on the wreck site of HMS *Sirius* was also recovered

The remains of wreckage that can be expected in the study area would be the rigging, decking and upper hull of a timber-built vessel as well as cargo – any components that could float. Metal components from such vessels would have been associated with floating timbers which had eventually broken down. It should also be noted that even though the winds, wave and tide for some wreck events may not have been conducive for wreckage to float into the study area, wreckage can float at sea for some time and larger wrecks can break up over a number of years.

The identification of artefacts from the wreck of the HMS *Sirius* will provide valuable insights into how the vessel broke up and where the wreckage spread. This would allow for an informed prediction as to where cultural material associated with the wreck may be found across a wider area beyond the main wreck site as well as to the type of remains.

2) *Are artefacts associated with other shipwrecks present?*

There are at least 14 shipwrecks, other than the HMS *Sirius*, near Kingston and Slaughter Bay, ranging in date from 1788 to 1962, and ranging in size from small wooden lighters and whaleboats to the 312-ton *Mary Hamilton*. Some of these vessels, such as the *Friendship* (1835) and an unnamed whaleboat (1907) were wrecked within the study area while it is possible that wreckage from one or more of the remaining wrecks could also have washed into the study area.

Norfolk Island by its location creates a dependency on the sea and therefore creates in turn a maritime culture. Vessels, whether it be a sea going barque or a locally built whale boat were an integral part of Norfolk Island life from 1788. The cargo from these vessels would help build a better picture of life on the Island while the remains of locally built craft can say something about the craftsmanship of those who built them and availability of materials for the task.

[46] Op. Cit., **Cosmos Archaeology Pty Ltd, 2020**

3) *What can the material culture recovered say about the international connections and relative affluence of the Island over time?*

From 1788 until WWII, the Landing Place followed by the construction of the Pier in 1839 was the portal through which Norfolk Island interacted with the rest of the world. Lost cargoes as well as material discarded deliberately within the study area can be an objective source of information about Norfolk Island's international connections prior to the mid-20th century. These artefacts can also possibly say something about the fluctuating and relative affluence of the Islanders over time.

7 RECOVERY

7.1 Considerations

The excavation approach for this investigation has been shaped by taking the following critical factors into account:

1) The waters around the southern end of Norfolk Island can be rough, creating turbulence and severe surge. This of course limits what can be achieved when compared to a terrestrial excavation. Crucial to the success of the excavation programme is the use of trained, experienced and well-briefed divers.

2) The water depth, of less than 6 m, is shallow enough to avoid concerns of nitrogen build-up and the need for excessive decompression stops, meaning that a diver can stay underwater for most of the day with only short breaks. Such a regimen over a period of days would be fatiguing and, in any case, the threat of hyperthermia would limit a diver to working underwater for between 2 to 4 hours a day. Further to what was stated above, having divers well briefed as to the objectives and methods of the excavation will be crucial.

3) Weather conditions over the site can fluctuate hourly. This may limit the length of diving on any given day. It was found during the February 2020 inspection that the reefs dampened the swells entering the berth area, while in November later that year a very short period of calm weather allowed for more efficient and controlled excavation than what was planned for.

7.2 Recovery Approach

The objective of the recovery phase is to remove artefacts from within the proposed project envelope in a manner that minimises any loss of contextual (and therefore significant) information. Artefact recovery will take the form of a combination of diver-based activities as well as monitoring and sampling of removed seabed. The result of the test excavation determined three sectors of heritage sensitivity (Figure 16).

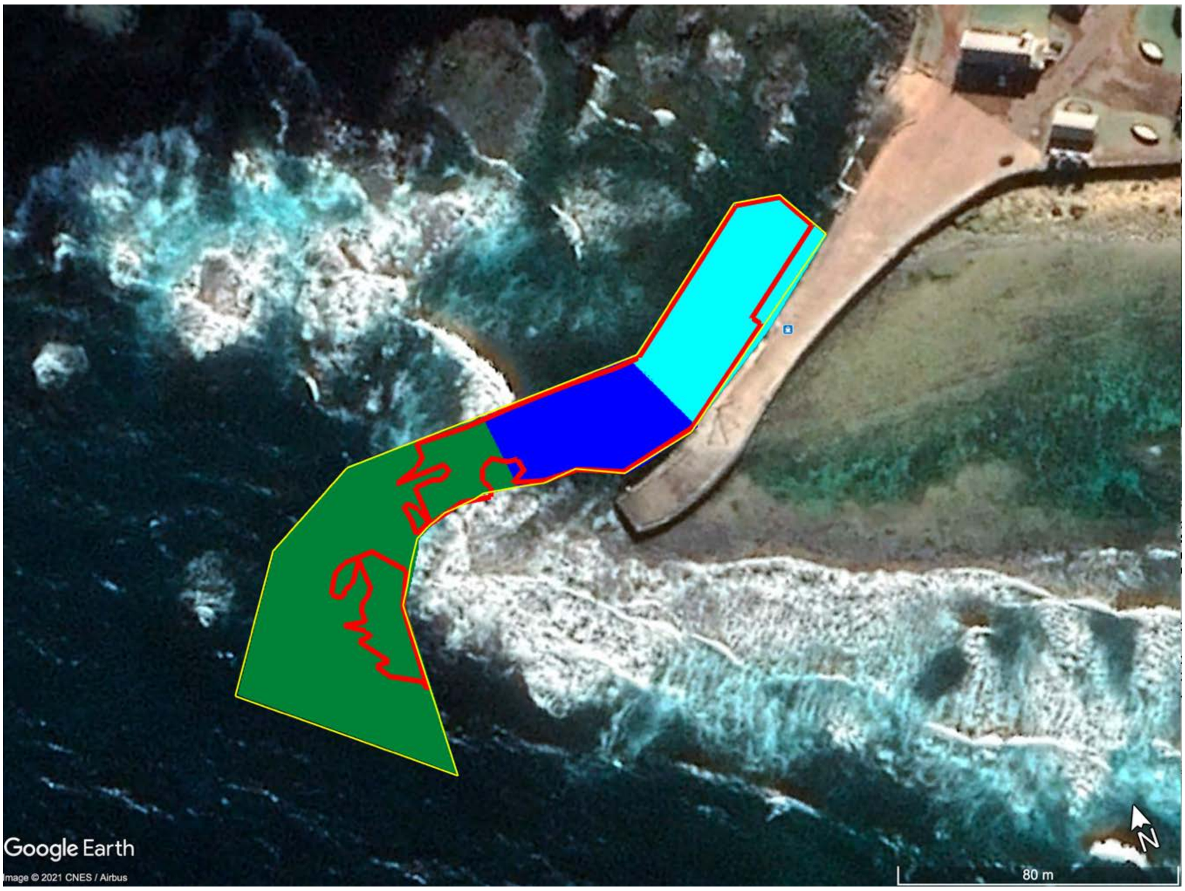

Figure 16: Areas of cultural heritage sensitivity as determined by the test excavation. Light blue is low cultural heritage sensitivity (Sector A), dark blue is high cultural heritage sensitivity (Sector B), and green is tested only through video survey and therefore considered to have medium cultural heritage sensitivity (Sector C). Yellow outline is navigation channel and red outline is Option 3a dredging footprint.

There is no diver-based excavation required within Sector A as it has been assessed as low cultural sensitivity (Figure 16). However, significant artefacts may still be located within this area and as such monitoring of the works will be required. This monitoring should take the form of sample sieving the material excavated by machine to check for artefacts. The amount of sampling is currently proposed to be 1 in 10 buckets or 10% of the loose rubble and calcarenite. Once the fresh tuff is reached, sample sieving can cease. If more artefacts are being found than expected further sieving may be required and vice versa if less artefacts are located.

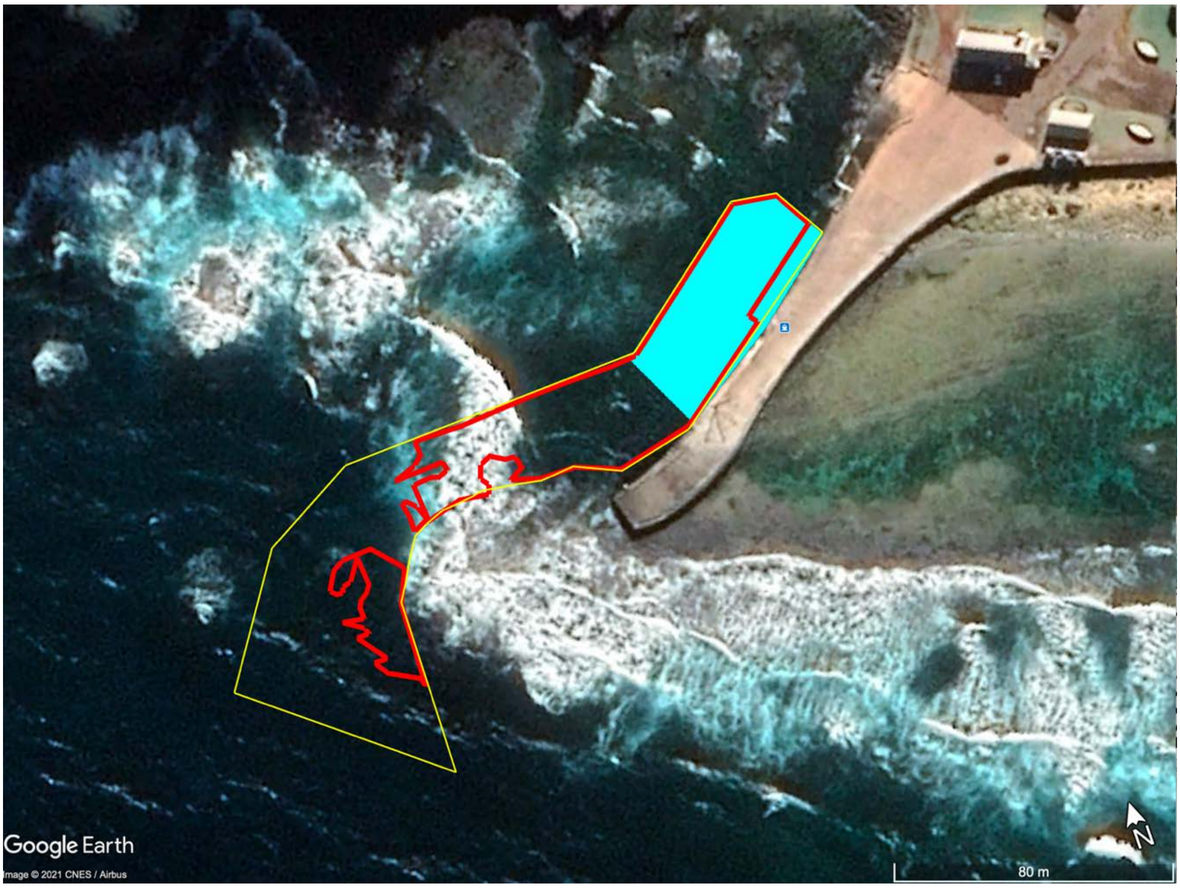

Figure 17: Sector A considered low sensitivity.

There is a requirement for diver-based excavation in Sector B, considered of high cultural sensitivity (Figure 18). It is proposed that this excavation be conducted using a mixture of SSBA/water dredge and SCUBA/manual excavation/metal detector, which will allow for flexibility on locations and conditions on the day. This excavation may take up to two weeks. Diver based excavation is required to remove the risk of damaging significant artefacts through the use of a bucket dredge.

Once the divers have finished excavations in and around the area, 100% of material raised during the main part of the works is to be sieved and checked for artefacts. Once the fresh tuff is reached, sieving can cease.

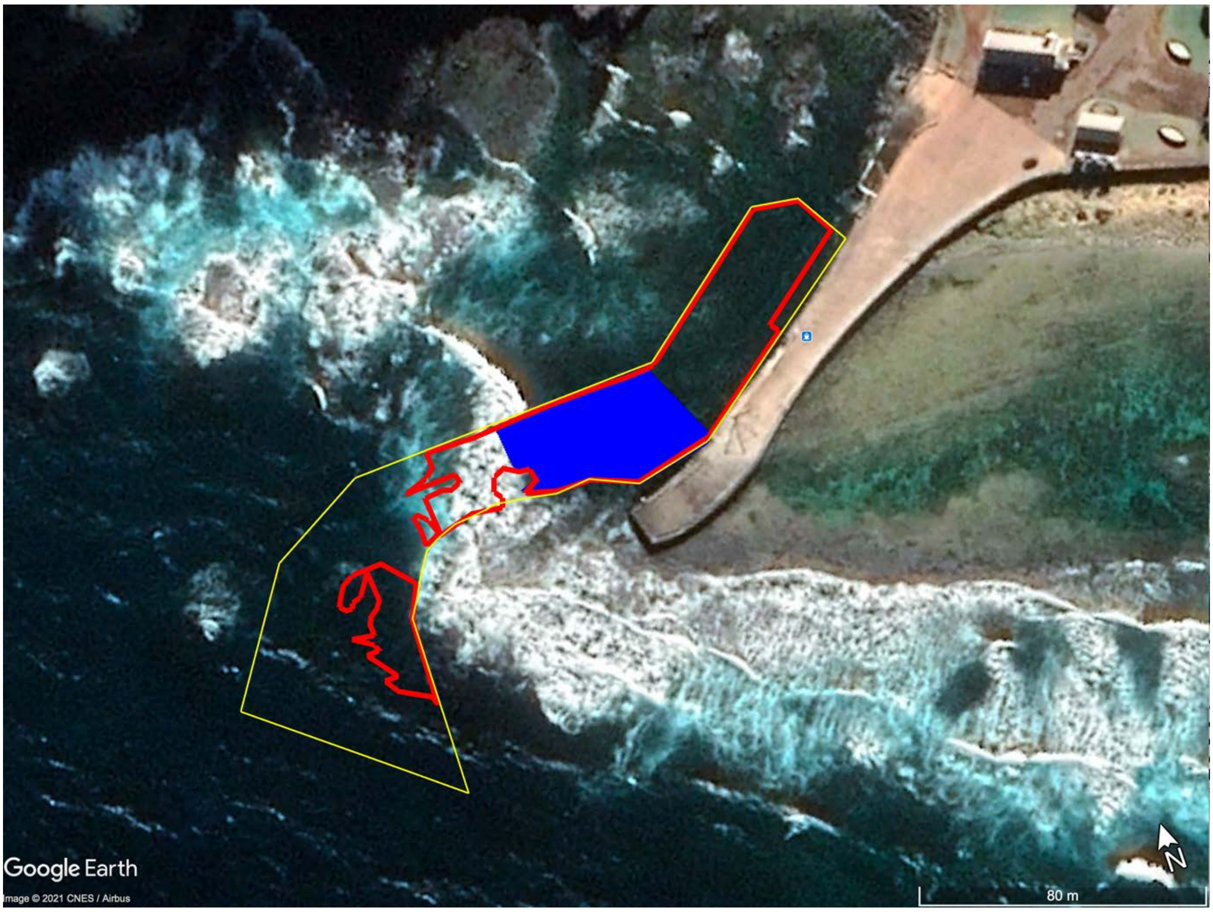

Figure 18: Extent of Sector B within proposed dredging outline, stretching from the shoreward end of the second set of stairs to the reef at the channel entrance.

Diver based excavation in Sector C would be difficult to manage unless diving conditions were considered perfect (Figure 19). Therefore, mitigation for these areas is to be sample sieving of 50% of loose rubble and calcarenite raised during the main works. Once the tuff is reached, sample sieving can cease. If more artefacts are being found than expected further sieving may be required and vice versa if less artefacts are located.

At all times the location and contexts from where artefacts were recovered will be tracked, whether it be from within excavation areas or from the area where the excavator bucket will be operating.

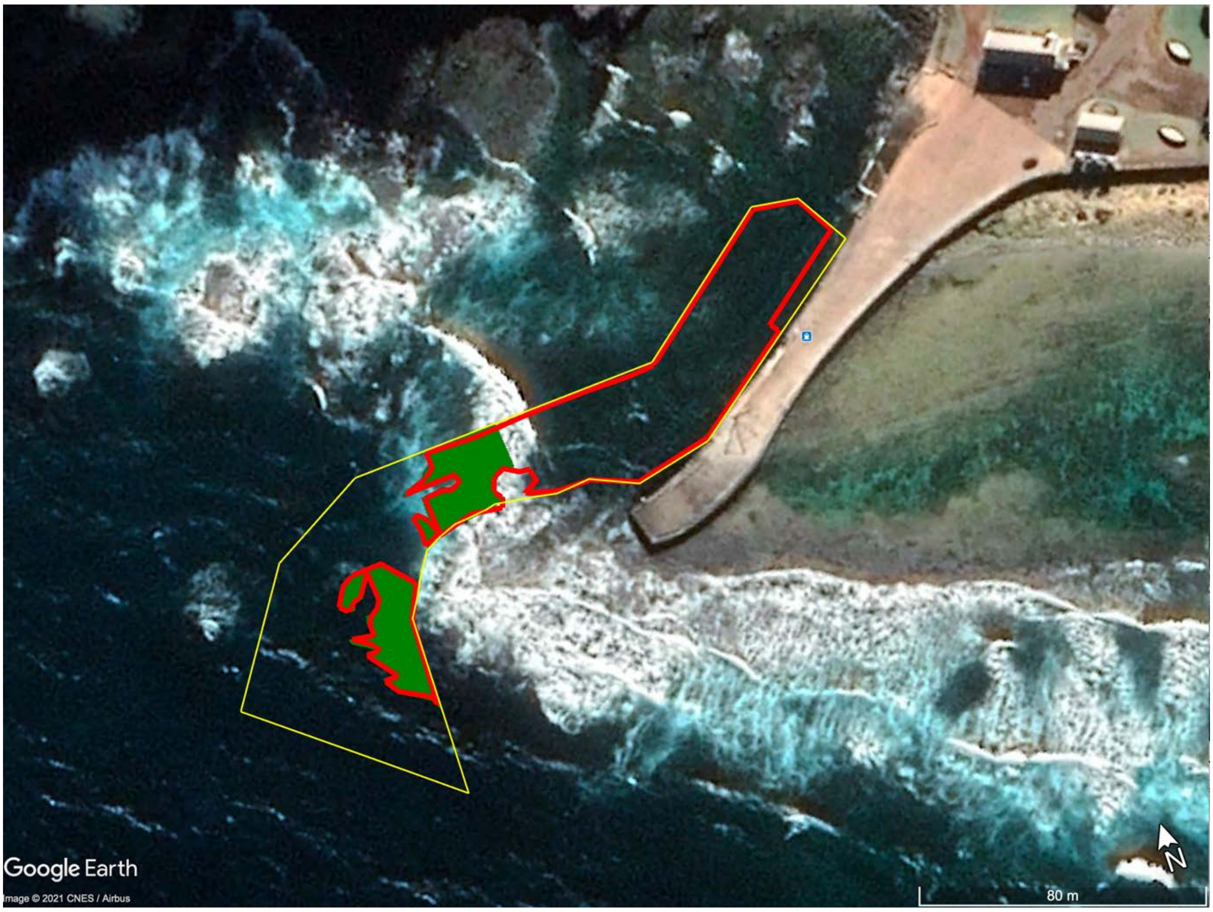

Figure 19: Extent of Sector C within proposed dredging areas in the channel and outside the rock platform to the south west of Kingston Pier.

The proposed archaeological recovery described above is summarised as follows:

Sector	Archaeological Excavation	Monitoring
A	None	10% sample down to fresh tuff
B	SSBA/water dredge, SCUBA manual excavation/metal detector	100% recovery down to fresh tuff
C	None	50% sample down to fresh tuff

7.3 Archaeological excavation approach

An overview of the excavation techniques to be implemented for the excavation are presented below.

Sector B	Description	Reason	Possible Problems	Possible Solutions
Mark out extremities of Sector B on the Pier	Flagging tape or other to be placed on the Pier to mark the southern and northern boundaries of Sector B	For surface staff to monitor diver placement and to ensure coverage of Sector B		
Mark out area to be searched before excavation commences	10 x 10 m grid to be laid out to indicate extent of dive excavation.	To ensure full coverage of sector B.	Conditions will not allow laying of lines or driving in of star pickets.	Mark out corners with lead dive weights with tags.
Video record Sector B before excavation	Diver to use handheld video record the seabed within the Sector.	To understand what seabed characteristics may yield, or not yield artefacts.	Orientation of video for viewing after excavation may be difficult to follow	Pre-planned video route to be worked out and mapped.
Map Sector B	Using video record, aerial imagery and bathymetric data.	Identify areas within each grid for excavation	Reefy seabed too complex to map accurately	Identify broad areas, not important to map accurately
Excavate each grid with water dredge	Excavate pockets of sediment with water dredge on SSBA	This allows for the most areas were sediments, including those in crevasses to be efficiently excavated	Conditions will not allow effective use of water dredge.	1/ Deploy silt boxes 2/ Excavate on SCUBA manually and with metal detector.
Excavate each grid manually and with metal detector	Examine areas not excavated by water dredge.	Expectation that small artefacts fallen within crevices and cracks and water dredge to unwieldy to use.	Conditions too rough for divers to operate	After waiting agreed period of time abandon archaeological investigation and monitor bucket dredging.

All artefacts recovered during the archaeological excavation will be sieved, sorted and labelled at the sieving station established at the northern end of Kingston Pier.

7.4 Archaeological monitoring approach

The monitoring approach will involve the retention material above the tuff recovered by the bucket dredging. The material will then be sieved, and artefacts collected.

Due to the expected volume of material that will be retained during this phase of the project it would not be feasible to store and sieve in the vicinity of the Pier. The material should be placed directly from the bucket into bulka bags which would then be transported by vehicle to where the sieving station will be established. It is understood that this is likely to be at Cascade Quarry.

The sieve station should be composed of at least three 2 m x 1 m across sieves mounted on a stand. The mesh grade should be between 2 mm and 3 mm.

It is proposed for a team of Norfolk Islanders under the supervision of an archaeologist (the Artefact Registrar) will sieve through the material that is brought up in the dredge. Select recovered calcarenite will be broken apart by the sieve team to see if there are any encased artefacts.

7.5 Artefact field recording

Artefacts that are collected manually by divers will be bagged and labelled in the same grid within Sector B from which they are excavated. The date of recovery will also be written on the label.

Artefacts recovered from the sieve and/or freed from calcarenite will be bagged and labelled in the Sector from which they are excavated. The date of recovery will also be written on the label. The labelling on the tags would note if the artefacts originated within calcarenite.

Artefacts of differing composition will be bagged separately so as to avoid staining or galvanic corrosion.

All artefacts will be photographed with a photo scale in each image with an introductory shot that includes the label. Ideally by the end of the day all artefacts recovered for that day will have been photographed. The artefact images will be downloaded onto a laptop and sorted into separate folders according to trench, context and date of recovery. These folders will be backed up daily.

At the end of the excavation the recovered artefacts will be catalogued onto an excel database done by an artefact cataloguer whilst on Norfolk Island. This spreadsheet is based on databases used for other major maritime archaeology excavations such as the Windsor Bridge Project. The database can be amended as required when the artefact retention, conservation and curation element of this project has been determined.

7.6 Site Set-up

The proposed work site configuration for the archaeological excavation takes into consideration the following:

- Cultural heritage sensitivity of the World Heritage KAVHA site
- Daily movements on the Kingston Pier and the use of the derrick.

The proposed work site will be arranged so as to not impede movement along the Pier.

The work site will be set up with cylinders and dive panel set up on a trailer which can be ported manually along the pier to either clear space around the derrick and/or be close to the divers' workspace. The ability to be able to port the cylinders and dive panel close to each of the trenches could reduce the amount of umbilical to be brought in.

As with the test excavation in 2020 the use of the boat shed would be useful to house the cylinders, general excavation equipment, wet suits, etc.. while the dive supervisor and panel will be locked overnight in a secure facility.

7.7 Artefact curation

Artefacts recovered from an underwater environment deteriorate relatively rapidly, particularly organics and some metals, if left untreated. Generally, the artefacts will be stored in saltwater in a storage facility on the KAHVA site as a temporary form of conservation. Consultation will need to be undertaken to determine the best course of conservation and the final location of all recovered artefacts.

7.8 Artefact retention and discard policy

As with terrestrial excavations, not all artefacts recovered are of high archaeological research or interpretative value. Modern materials such as plastics make a contribution to the understanding of site formation processes but apart from that have little research value to merit their retention. Fragmentary or undiagnostic artefacts also have limited further research value that would warrant their retention after they have been recorded.

It is therefore proposed that the artefacts recovered during the excavation are, after recording, subjected to an assessment as to whether they are to be retained or discarded. Retention could result in eventual conservation or reburial however these decisions should be made in conjunction with finds made during the main excavation. The basic principles to guide what is to be done with a recovered artefact once it has been recorded are:

- Cultural heritage significance
- Rarity
- Representativeness
- Condition.

The above principles are applied in the following table which will serve as a guide for the retention or discard of objects recovered during the excavation:

Action	Criteria	Example
Retain	Artefacts associated with the early Polynesian settlement through to the second Penal settlement – 1825 to 1855	Material associated with HMS *Sirius* or the Landing Place.
	Uncommon objects in good condition associated with The Third (Pitcairn) Settlement from 1898 to present.	For example, personal items such as pre-decimal coins, combs, jewellery. Also, unusual examples of glass or ceramic patterns, makers marks or styles.
Discard	Undiagnostic artefacts	Unidentified artefacts, small broken and undiagnostic
	Common objects associated with The Third (Pitcairn) Settlement from 1898 to present.	Beer cans, plastic shoes, concrete, fish bones, stainless steel

It is proposed that the team archaeologists recommend which artefacts are to be discarded/retained according to the table above. This decision-making process will also include the nominated parties for retention, conservation and curating of the artefacts. These parties are to be determined during the consultation phase of the management plan.

7.9 Personnel

The maritime archaeology excavation will be carried out by Cosmos Archaeology with Cosmos Coroneos as the Excavation Director. The Excavation Director (ED) will be responsible for organising the maritime archaeological divers, coordinating the work and liaising with Advisian, KAVHA, the Commonwealth and the NI Regional Council. The ED will also be responsible for ensuring the excavation methodology is being maintained and data is collected at the highest possible standard. The ED will be responsible for the maintaining of the day log of the archaeological activities and decisions taken on site.

A second maritime archaeologist will take on the role of underwater archaeology supervisor (UAS) and will be responsible for implementing the excavation methodology from the seabed to the sieve station either at the top of the ramp at the Kingston Pier or over at Cascade Quarry. The UAS will be responsible for managing, copying and backing up the video files and dive sheets and plans on a daily basis.

The ED and UAS will have a minimum certification of ADAS Part II and will form part of the dive team.

The third archaeologist will have the role of Artefact Registrar (AR). It will be the AR's responsibility to coordinate the sieving of the dredge spoil that is brought up onto the working platform. The AR will be responsible for ensuring the artefacts are bagged, labelled, photographed and catalogued. The AR will manage a team of Norfolk Islanders who will assist with the sieving operations. The AR will also be responsible for downloading the artefact camera, arranging the images into the appropriate folders and back up the files daily.

A commercial dive team, Professional Diving Services (PDS), will be engaged to provide all the equipment required for the test excavation. This includes the excavation equipment such as venturi suction pipe, SSBA/SCUBA equipment and a three-member dive team including dive supervisor. They will also maintain the equipment over the course of the excavation. One or more of the commercial divers will have tertiary archaeological qualifications and all the divers will have experience in archaeological excavation.

In addition to the three archaeologists and three commercial divers all of whom will come from Australia, the test excavation will require the participation of a number of individuals from Norfolk Island to assist recovering artefacts from the sieve and calcarenite. They would work under the direct supervision of the AR. Between two to four people assisting the AR on a daily basis when monitoring is occurring would be a suitable level of assistance.

7.10 Equipment

The following table outlines the required equipment and the organisation responsible for coordinating the arrangements:

Specific Requirements	Indicative Source
Dredge Equipment	Professional Diving Services

Specific Requirements	Indicative Source
3" water pump and hoses	On island from test excavation
Smaller water pump for sieve	Locally sourced preferably
Underwater Metal Detector/s	Professional Diving Services
Milk crate and rope	Cosmos Arch / Locally sourced
Video/camera equipment	PDS/Cosmos Arch
Sieve for bucket dredge sediment	PDS / Construction company
Recording sheets: excavation and artefact	Cosmos Arch
SSBA equipment	PDS
Scale rods/ cards	Cosmos Arch/PDS
SCUBA cylinders x 8	Bounty Dive NI
Lift bags	PDS
Trench boundaries: bolts/PVC pipes/Electrical tape	PDS/Cosmos Arch/
Bulka bags	Construction Company
Transport of Bulka bags to sieve station	Construction Company

7.11 Timings

It is understood the excavation of Sector B will take two weeks and should be conducted prior to the main dredging works starting.

The monitoring of the sediment from the main dredging works will depend on the timeframe for these works.

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