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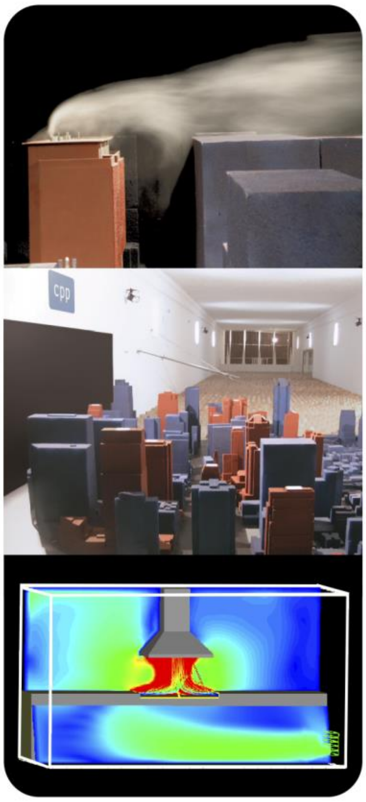
Final Report



Technical Review of:

NASF Guideline B

CPP Project 9315

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EXECUTIVE SUMMARY

It is recommended that NASF Guideline B is updated to include all the wind shear and turbulence criteria developed by the NLR. The assessment process should be similar to that adopted by the NLR, where any proposed development exceeding a 1:35 plane extending perpendicular to the centreline of the runway should be further assessed through discussion with the relevant stakeholders to assess the operational risks.

DOCUMENT VERIFICATION

Date	Revision	Prepared by	Checked by	Approved by
16/05/2016	Initial Draft	CJR/GSW	PAB	GSW
06/06/16	Updated draft	CJR/PAB/GSW	GSW/PAB	GSW
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04/07/16	Minor changes	GSW	GSW	GSW
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

CPP has been engaged by the Department of Infrastructure and Regional Development (DIRD) to review the contents of Guideline B of the National Airports Safeguarding Framework (NASF) and offer recommendations for any changes to the document.

Guideline B is a document to assist in managing the risk of structure generated wind shear and mechanical turbulence at airports. A generic description of the difference between wind shear and turbulence is provided in Appendix 2. Guideline B is primarily used by airports and developers to estimate the potential impact of proposed developments close to runways on aircraft operations. It is understood that the Civil Aviation Safety Authority (CASA) uses, in part, the outcomes of Guideline B to provide recommendations to DIRD for development approvals at Leased Federal Airports.

2. BACKGROUND AND PREVIOUS WORK

The need for an assessment criterion on the impact of structures on the wind conditions affecting landing aircraft was triggered by a series of incidents at Amsterdam Schiphol Airport. This disturbance was caused by wind flow over an engine test facility producing a steady horizontal vortex that impacted aircraft about 700 m downstream of the facility. Based on a limited number of pilot reports, wind-tunnel testing, and simulator tests, the criterion developed in the late 1990s was:

"*The difference in wind velocity perpendicular to the aircraft over a short interval may not exceed 7 kts*"

It was found that the criterion was not well-defined and additional research was conducted by the Dutch National Aerospace Laboratory (Nationaal Lucht-en Rulmtevaartiaboratorium NLR).

2.1 NLR

NLR is the Netherlands Aerospace Centre for identifying, developing, and applying advanced technological knowledge in the area of civil, military, and space flight.

The outcomes of the NLR study (Nieuwpoort, 2010) concluded that the impact of wind shear and turbulence was the most critical for landing aircraft within the lower 60 m above ground level. The study was conducted using wind-tunnel testing, unmanned flight simulators, and piloted simulators of small and large jet aircraft. The output of the study was the development of 3 criteria, the first two addressing wind shear, and the final for turbulence:

1. "The variation in mean wind speed due to wind disturbing structures must remain below 7 kts along the aircraft trajectory at heights below 200 ft. The speed deficit change of 7 kts must take place over a distance of at least 100 m.

2. The variation in mean wind speed due to wind disturbing structures must remain below 6 kts across the aircraft trajectory at heights below 200 ft. The speed deficit change of 6 kts must take place over a distance of at least 100 m.

3. In this altitude range the wind disturbance effect on the aircraft is defined by the turbulence intensity applicable for build-up area affecting the runway and the additional turbulence intensity created by the stand alone structure. It was found that the gust/turbulence components in horizontal direction caused by a wind disturbing structure in combination with the meso-scale surface roughness must remain below RMS values of 4 kts. In this height range the horizontal scale lengths used in the gust/turbulence simulation varied from 50 m to 200 m."

The RMS value is the root mean square value of the fluctuating part of the wind speed. This is the same as the standard deviation of wind speed, and is a measure of the amount of fluctuation in the wind speed with time, essentially turbulence. The reason for a wind speed deficit over a distance of 100 m is to account for the response time of a landing aircraft to changing wind conditions.

A schematic of the first two criteria from the NLR research is presented in Figure 1. From a wind engineering perspective, Figure 1 and the criteria description are unclear and open to interpretation as to their intent particularly as the wind speed deficit is not well defined in terms of an along-wind or cross-wind component, or the duration of the mean wind speed.

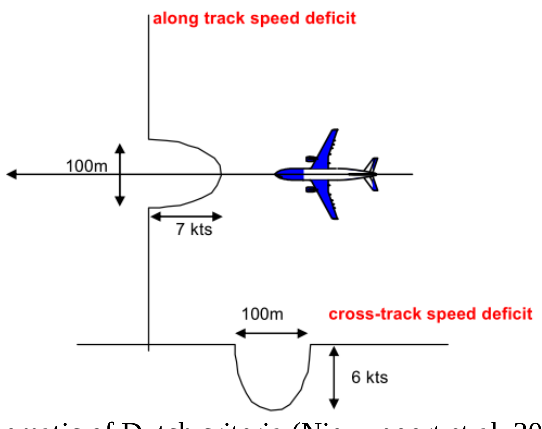


Figure 1: Schematic of Dutch criteria (Nieuwpoort et al. 2010)

From reading the details of the NLR document, our interpretation of the wind shear criteria is that the wind speed deficit relates to a 100 m distance along the flight path. The 6 and 7 kt criteria are associated with the maximum change in mean wind speed in the cross-flight and along-flight directions respectively as illustrated in Figure 2.

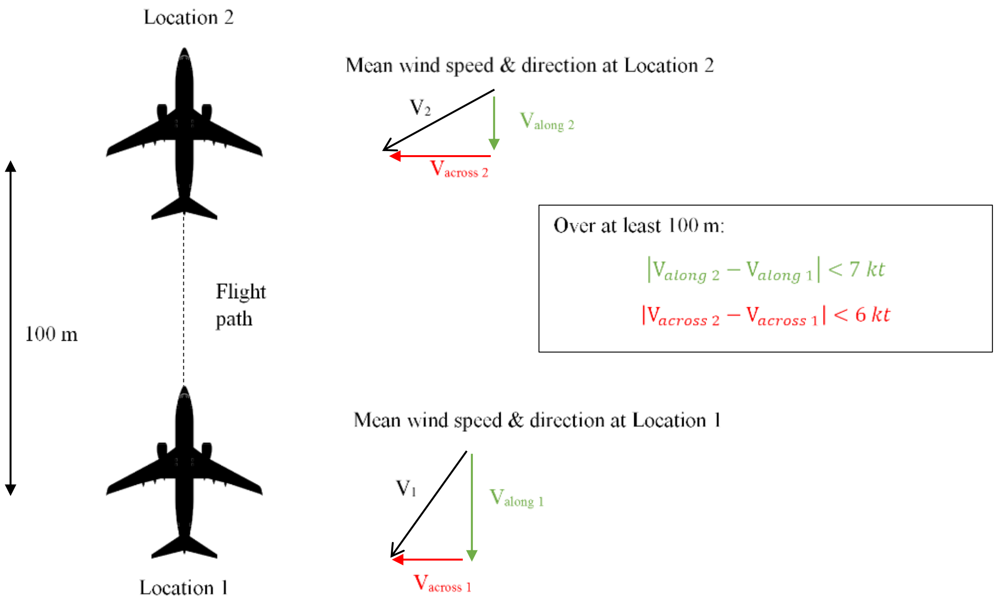


Figure 2: Interpretative sketch of Dutch criteria

The assessment criteria developed for structures, concluded that buildings lower than an inclined surface extending perpendicular to the centreline (or extended centreline) of the runway at a slope of 1:35 would not cause issues for aircraft operations.

The wind shear and standard deviation (turbulence) criteria are based on quality in depth research for a wide range of aircraft types bounded by the Boeing 747 and Fokker 100, and creates a sound starting point for specific site analysis where operating conditions may limit their importance. The consolidated Dutch study is considered the current best in the world.

2.2 SLR's work

Guideline B was developed by consulting engineering firm SLR in 2012. The Guideline B and associated guidance material are a significant body of work distilling a significant amount of information. The only criterion adopted for inclusion in Guideline B was:

"The variation in mean wind speed due to the wind disturbing structures must remain below 7 kts along the aircraft trajectory at heights below 200 ft. The speed deficit change of 7 kts, must take place over a distance of at least 100 m."

2.3 Incorporation into NASF

The primary difference between NASF Guideline B and the NLR criteria are:

1. Only one of the 3 criteria have been adopted,
2. The size of the zone of influence has changed size and shape, as noted in Figure 3 for one runway threshold, particularly the NASF zone being shorter along the length of the runway.

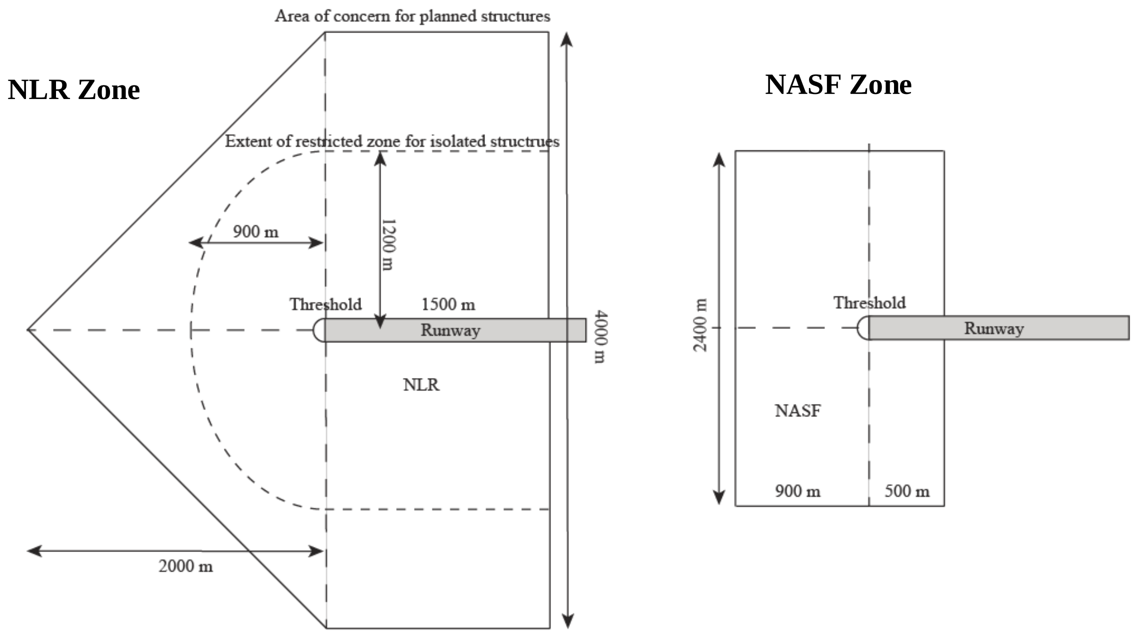


Figure 3: Zone of influence between NLR (L) and NASF (R) for one runway threshold

As stated in clause 73 of Guideline B:

"It is currently not practical for the wind criterion to take into account the inherent levels of turbulence likely to be present. Turbulence levels will vary significantly depending upon building shape details, angle of attack of the approaching wind, upstream terrain, nearby obstacles, etc."

2.4 Reviews Since

Hong Kong Airport has adopted similar advice to the NLR as per Hong Kong Observatory (2012):

"it was established that cross-wind changes of 7 kt or more in short intervals in a background cross-wind of 25 kt could cause difficulties in landing."

The definition is open to interpretation, as a cross-wind mean speed of 25 kt could be considered excessive. This is only a wind shear criterion and does not consider building turbulence.

2.5 Current operational controls

Airservices Australia Aeronautical Information Publication (AIP) provides guidance to pilots and air traffic controllers. With regard to the nomination of runways, the publications states:

"ATC *(Air Traffic Control)* will nominate the runway, preferred runway or take-off direction. Where noise abatement procedures are prescribed, and ATC traffic management permits, the provisions of DAP *(Departure and Approach Procedures)* NAP *(Noise Abatement Procedures)* will be applied, except that ATC will not nominate a particular runway for use if an alternative runway is available (unless required by Noise Abatement legislation), when:

a. the alternative runway would be preferred due to low cloud, thunderstorms and/or poor visibility;

b. for runways that are completely dry:

(1) the crosswind component, including gusts, exceeds 20 kt;

(2) the downwind component, including gusts, exceeds 5 kt.

c. for runways that are not completely dry:

(1) the crosswind component, including gusts, exceeds 20 kt;

(2) there is a downwind component.

d. wind shear has been reported.

Note: Notwithstanding the limitations detailed above, location specific crosswind/downwind limitations may be detailed in AIP DAP East/West NAP"

It is known that certain airports have allowance for an additional 5 kt buffer, to increase the allowable cross-wind gust speed to 25 kt.

It is considered practical to relate any output from analysis to the appropriate operating conditions for the airport under consideration. Air traffic controllers will specify the operational runway, in part, with regard to the wind speed measurements around the airport. As this is the only input into the operational decision making, it is important that the output of any study can be directly related to this control.

3. CURRENT NASF GUIDELINE B

The current wind shear criterion is described in Section 2.2.

3.1 Current Guideline Application

Guideline B assesses the impact of a proposed isolated building on aircraft operations using a staged approach as outlined in Table 1. The four stages relate to different building shapes.

Table 1: Clause 62 of Guideline B: Assessment Methodology Hierarchy

Category	Building Description	Assessment Methodology
Case A	**Building Shape:** Any Shape The building height satisfies the 1:35 rule, i.e. the horizontal distance of the building's closest	In this instance, the building is deemed acceptable and no further assessment is required.

	point from the edge of the runway is more than 35 times the height of the building	
Case B1	**Building Shape:** Single, Regular Shape, e.g. Rectangular Buildings **Prevailing Wind-Building Angle:** Perpendicular to Building Facades	In this instance, all available techniques, including a Qualitative (Desktop) Study, could be used to address the acceptability of the proposal. The mean velocity deficit data provided in **Table 1** could be used in conjunction with the building height and local wind rose information to identify the potential (if any) for adverse cross wind conditions.
Case B2	**Building Shape:** Single, Regular Shape, e.g. Rectangular Buildings **Prevailing Wind-Building Angle:** Oblique to Building Facades	In this instance, a safety margin would need to be added to the mean velocity deficit data provided in **Table 1** in conjunction with the building height and local wind rose* information to identify the potential (if any) for adverse cross wind conditions. The safety margin might be in the form of an increase in perceived distance downstream of the order of at least 25%.
Case C	**Building Shape:** Complex Building Shape AND/ OR Multiple Buildings	In this instance, unless a very conservative safety margin is added to the mean velocity deficit data provided in **Table 1**, one of the following quantitative modelling techniques should be used: 1. Wind Tunnel using Hot-Wire Sensors, 2. Wind Tunnel using Particle Image Velocimetry (PIV), or 3. Computational Fluid Dynamics (CFD).
* wind rose is a plot showing the probability of wind speed and direction.		

It is evident from Table 1, that the assessment of any proposed building could be undertaken by assuming a 'very conservative safety margin', although no guidance is offered as to an appropriate value. As mentioned in Guideline B, the flow behind even regular buildings is complex and it is difficult to accurately predict the wind shear and turbulence characteristic in the wake region.

The assessment procedure to define the Building Wake Deficit is based on research looking at the wind speed measured at building height behind the building and is defined in Clauses 47 to 58. Although considered suitable for isolated buildings, the definition of such an isolated building is not included in Guideline B. The development of a procedure to assess compound building shapes for Building Wake Deficit was proposed for Sydney Airport and surrounding Councils. This document proposed that a building would be classified as isolated, if the distance between the proposed and the adjacent existing buildings of height greater than 70% of the proposed building, is less than the maximum dimension of the two enveloping rectangles drawn around the developments in runway axes.

The output from the assessment combining the data with the wind climate is illustrated in Clause 66 of Guideline B and reproduced in Figure 4. From numerous studies with various airports, the information provided in Figure 4 has not been of assistance to the end user as to whether the building would cause operational issues. Working with the airports, we have found it better to define the gust wind speed that would be required at the airport anemometer to cause an exceedance of the various criteria. The airport can then easily compare this with their operational controls to assess whether the building would influence operations.

Typical output from wind-tunnel measurements and from Computational Fluid Dynamics (CFD) are shown in Figure 5 and Figure 6 respectively. Figure 5 shows results taken at relevant locations along the glideslope behind a proposed development. The testing was conducted in the existing and proposed configurations. A typical wind tunnel model is presented in Figure 7. The effect of surrounding buildings on the wind field pattern is illustrated in the CFD output presented in Figure 6. It is evident from Figure 6 that it is difficult to consider a building in isolation without interference from the neighbouring buildings. This illustrates the difficulty in developing a general procedure for complex and multiple buildings.

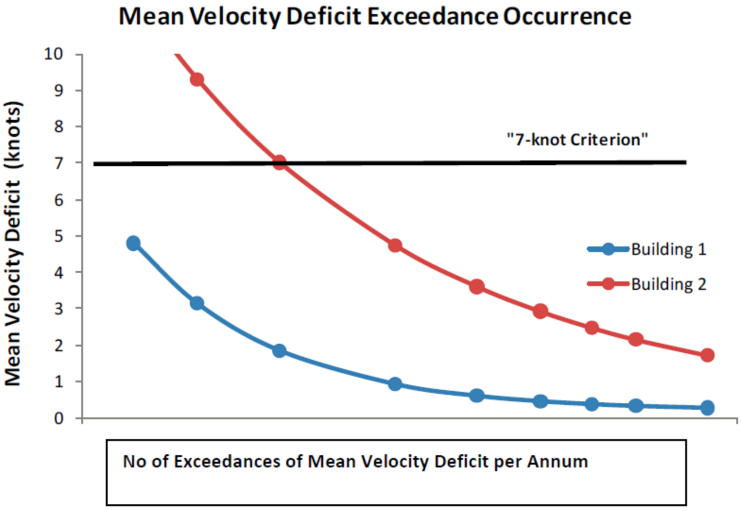


Figure 4: Recommended typical output from assessment, Guideline B Clause 66

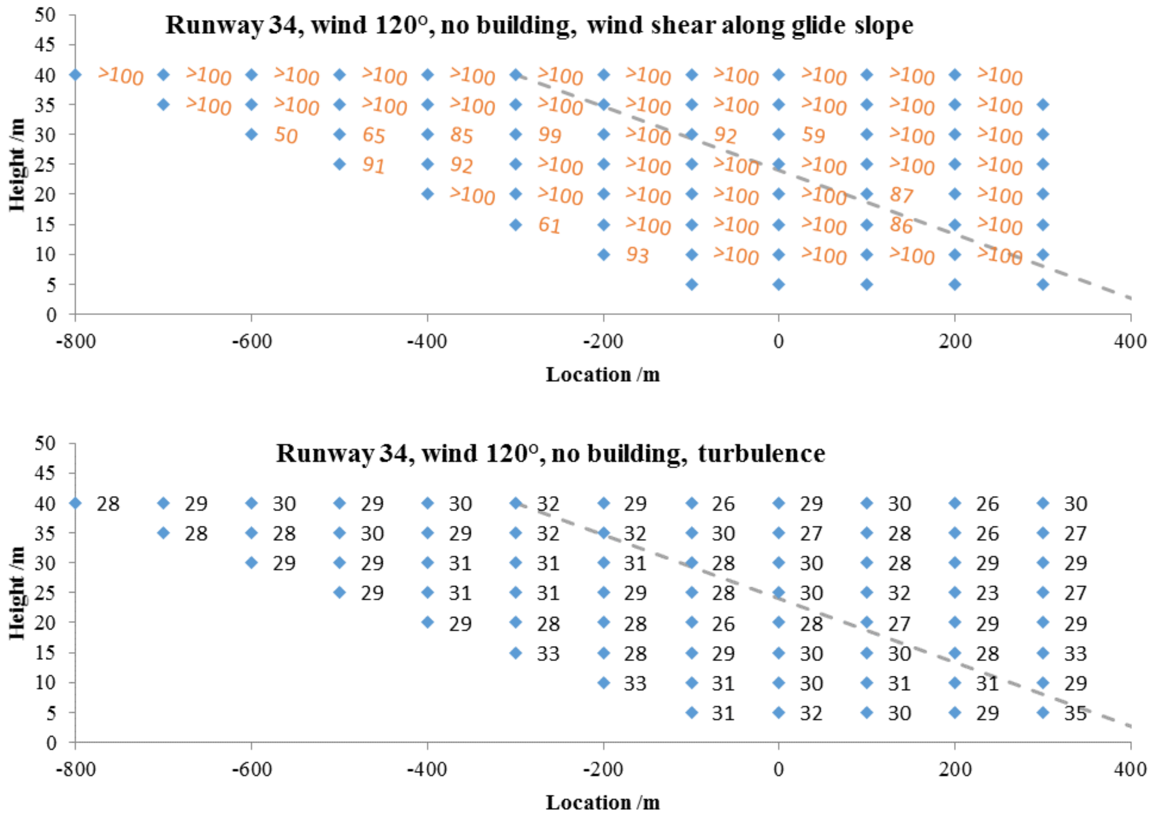


Figure 5: Example of wind-tunnel output showing gust wind speed at airport anemometer location required to exceed the NLR criteria

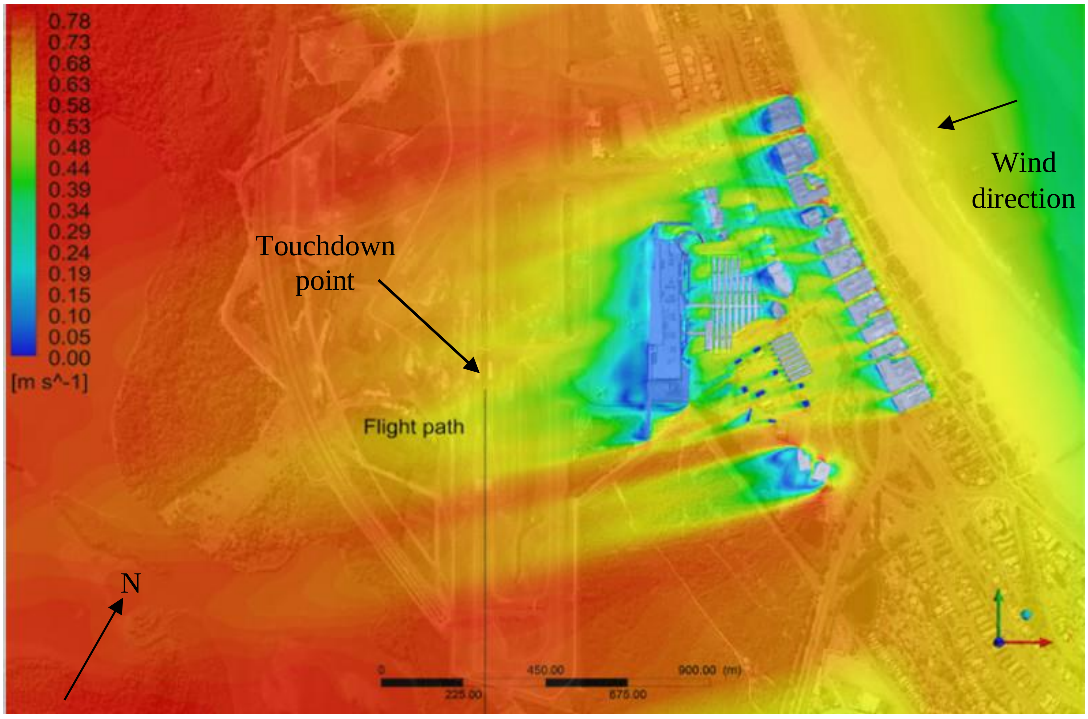


Figure 6: Example of CFD output showing mean wind speed ratio on a plane 4.5 m above ground

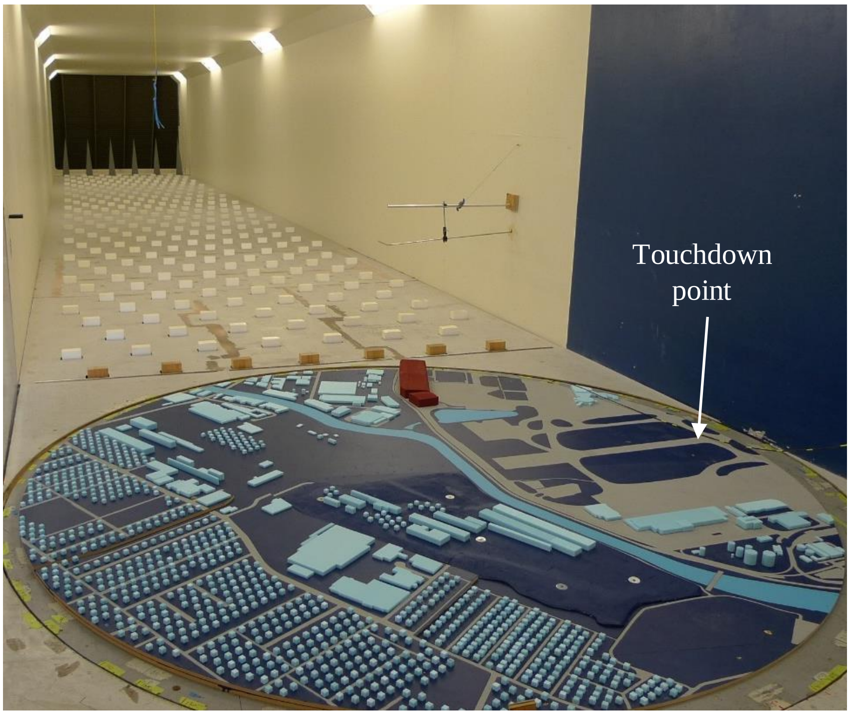


Figure 7: Typical photo of CPP wind tunnel model

3.2 Current Issues and challenges

It is evident that since the release of Guideline B there has been some confusion in the industry. There is no guidance on how the subsequent detailed assessment should be conducted for Case C in Table 1. Some developments have caused issues where they have passed the wind shear criterion in Guideline B, but subsequently failed the turbulence criterion. This uncertainty is not good from an assessment or industry perspective. Guideline B should also define the responsibility of each of the stakeholders in the process: DIRD, CASA, Airservices Australia, pilots, airport management, developers, and local Councils.

3.2.1 Issue from a regulatory body perspective (CASA)

It is understood that the lack of clarity has created operational issues for CASA, with experts using the additional NLR criteria outside of Guideline B as best practice. The lack of agreement amongst experts has added further confusion to the situation. It is understood that in some cases, CASA has asked for the additional turbulence criterion to be assessed, but does not have sufficient guidance on how the assessment should be undertaken, nor what to check for when the assessment is submitted. This uncertainty will continue until Guideline B is amended.

3.2.2 Issues from an airport management perspective/developers

The lack of clarity has caused issues for airports with additional criteria outside of Guideline B being requested from CASA with no accompanying details.

3.2.3 Issues from a local council/developer perspective

For the approving bodies for developments outside of airports, the operational difficulty is compounded by the fact that developments cannot be treated in isolation as the local wind field is influenced by the interaction of flow over all buildings. A new building may make the wind conditions unacceptable, despite being of exactly the same size as the neighbouring building. It is also possible that the removal of a large building could create a wind shear problem by opening a flow corridor.

4. REVIEW METHODOLOGY

Our review methodology is based on the use of the NLR and Guideline B for a number of years, prior to which we developed assessments based on publications on turbulence affecting aircraft. In all assessments we have tried to work closely with the various stakeholders, CASA, Airports, Councils, and developers to develop practical outputs. The industry knew there was a need for assessment criteria, which is when Guideline B was developed and adopted. From numerous consulting projects, we, and other consultants, have recognised the greater importance of turbulence over wind-shear, which tends to govern the suitability of developments around already developed sites. The limitations of Guideline B were highlighted during the review process in 2012.

The review will discuss the various aspects of wind shear and turbulence on aircraft operations with reference to Guideline B. We will discuss the various issues raised by other stakeholders that were provided by the Department, and finally offer recommendations for changes to Guideline B.

5. REVIEW

5.1 Broad themes

5.1.1 Only Partial uptake of NLR criteria

The noted shortcoming with Guideline B is the lack of adoption of the turbulence criterion, and to a lesser extent the cross-track wind shear criterion.

Assuming that the wind speed deficit and standard deviation wind speed associated with the criteria are correct, the gust wind speed required to meet the criteria can be estimated using the standard wind profiles defined in Standards Australia (2011). The results of the wind shear deficit criterion of 6 kt, and the standard deviation criterion of 4 kt are presented in Table 2 and Table 3 respectively. On a 3° glide slope, an aircraft descends about 5 m in 100 m of travel. The results are presented for the various terrain categories from 1 (smooth terrain) to 4 (heavily urbanised terrain). The results for an anemometer located in open country terrain, or in the same terrain as the surrounds are presented. It is evident that the required wind speed in the natural wind to exceed the turbulence criterion is significantly lower than that required to exceed the wind shear criterion. The results for the wind shear criteria are non-physical for a number of cases.

Table 2: Gust wind speed at anemometer height required to exceed the 6 kt wind shear criterion for anemometer in open country terrain (L), same terrain as surrounds (R)

	Gust wind speed at 10 m anemometer height in open country terrain /kt			
Height /m	TC1	TC2	TC3	TC4
5 m to 10 m	100	86	100	-
10 m to 15 m	200	150	120	-
15 m to 20 m	200	300	200	-
20 m to 25 m	400	300	240	400
25 m to 30 m	400	300	240	400
30 m to 35 m	400	300	400	600
35 m to 40 m	400	300	400	600
40 m to 45 m	600	600	400	600
45 m to 50 m	600	600	400	600
50 m to 55 m	750	600	600	333
55 m to 60 m	750	600	600	333

	Gust wind speed at 10 m anemometer height in same terrain /kt			
Height /m	TC1	TC2	TC3	TC4
5 m to 10 m	112	86	83	-
10 m to 15 m	224	150	100	-
15 m to 20 m	224	300	166	-
20 m to 25 m	448	300	199	300
25 m to 30 m	448	300	199	300
30 m to 35 m	448	300	332	450
35 m to 40 m	448	300	332	450
40 m to 45 m	672	600	332	450
45 m to 50 m	672	600	332	450
50 m to 55 m	840	600	498	250
55 m to 60 m	840	600	498	250

Table 3: Gust wind speed at 10 m anemometer height required to exceed the 4 kt standard deviation criterion for anemometer in open country terrain (L), same terrain as surrounds (R)

	Gust wind speed at 10 m anemometer height in open country terrain /kt			
Height /m	TC1	TC2	TC3	TC4
3	38.3	40.3	38.8	33.4
5	37.3	38.5	38.8	33.4
10	35.9	36.4	38.0	33.4
15	35.6	35.5	36.3	33.4
20	35.3	35.4	35.8	33.4
30	35.7	35.3	34.6	34.5
40	36.2	34.7	34.2	35.1
50	36.8	34.9	33.8	35.3
60	37.2	35.0	33.6	33.6

	Gust wind speed at 10 m anemometer height in same terrain /kt			
Height /m	TC1	TC2	TC3	TC4
3	42.9	40.3	32.2	25.1
5	41.8	38.5	32.2	25.1
10	40.2	36.4	31.6	25.1
15	39.8	35.5	30.1	25.1
20	39.6	35.4	29.7	25.1
30	40.0	35.3	28.7	25.9
40	40.6	34.7	28.4	26.3
50	41.2	34.9	28.0	26.5
60	41.7	35.0	27.9	25.2

The assessment distance included in Guideline B is significantly shorter than that proposed by NLR, Figure 3. As a large number of runways at airports in Australia are typically less than 3 km long, the NLR assessment distance is essentially the entire length of the runway. For longer runways, smaller aircraft are more likely to touchdown further along the runway than at the touch-down point and therefore may pass through this centre zone. The centre section of long runways may also be flown through on take-offs and go-arounds operations, and although there are no criteria for these flight operations, it is considered appropriate to assess proposed developments along the entire length of the runway in accordance with the NLR criteria. From previous discussions with NLR staff, it has been established that landings are more critical than take-offs, and that aircraft may be able to withstand about 30% more turbulence on take-offs than landings. These discussions did not include go-arounds.

It should be noted from Table 3 that the wind speed required to exceed the turbulence criterion is relatively constant with height for specific terrain categories. The NLR 4 kt standard deviation criterion, described in section 2.1, is for horizontal turbulence and therefore independent of incident wind direction. However, the operational limits described in section 2.5, relate to a cross-wind component of flow. This indicates that there is an inconsistency between the NLR turbulence criterion and operational procedures. For example, if an aircraft was landing into a direct headwind, the turbulence criterion would be exceeded with no cross-wind.

The unstable nature of the approach wind conditions is important for pilots. As stated in the NLR:

"The alertness of the pilot to possible wind effects, due to stand alone obstacles plays an important role. This was observed during the piloted simulations. During highly turbulent and gusting approaches requiring much effort of the pilot, the effect of the stand alone structure was considered less critical than during smooth weather approaches, where the upset of the stand alone structure was not expected."

The piloted simulations in the NLR study were conducted with a **mean** cross-wind speed component of 20 kt, which is greater than the AIP nominated runway guidelines of a **gust** cross-wind component of 20 kt, hence the wind conditions experienced during the simulations would have been expected to be more severe than normal operational procedures. The observation that constant higher turbulence is more manageable for pilots than variable wind conditions along the final approach for landing, would agree with the findings in Table 3. If the NLR turbulence criterion was considered in combination with the wind shear criterion, or the rate of change of turbulence with distance, then this would somewhat address the inconsistency between the criterion and operational procedures noted above. Pilot discretion is highly important for landing in inclement weather, but information from the air traffic controller of potential variable wind conditions would be necessary to ensure safety.

5.1.2 Only applicable at low altitude if using standard deviation based criteria

The NLR criteria are based on landing aircraft. As discussed above, the natural turbulence in the approach wind flow would exceed the standard deviation criterion at higher altitudes irrespective of the position and/or design of structures nearby the runway. At greater heights, aircraft are moving faster and are less susceptible to fluctuations in the wind speed, hence the reason for the 60 m height restriction on the NLR criteria. Considering the size of the wake generated from a building, the 60 m limit is considered appropriate for inclusion in Guideline B.

5.1.3 Lack of clarity for complex or multiple buildings

As discussed in Section 3.1, there is little guidance on the 'very conservative margin' for assessing complex or multiple buildings. A procedure was developed based on the information in Guideline B to assist with the assessment of proposed developments higher than the 1:35 height plane perpendicular to the runway centreline (or extended runway centreline) around Sydney Airport as defined in Appendix 1.

The discussion in section 5.1.1 regarding constant turbulence is of equal relevance for compound/complex structures. The more similar the developments, the more uniform the turbulence and therefore less severe for pilots.

5.1.4 Small and temporary structures

There are a number of small structures such as chimney stacks, or lattice structures, which would have a minimal impact on wind shear and turbulence. There are also issues with temporary structures, such as large ships berthed next to runways, or stacked shipping containers where the geometry keeps changing. Specific measures would be necessary to deal with such situations.

From the body of the NLR document relating to the impact of stand-alone obstacles on the response of a Fokker 100 aircraft, "…obstacles with a width less than 30 m and producing a maximum speed deficit less than 8 kt are allowed to protrude the 1:35 wind disturbance plane." This follows on from the response of the aircraft to different duration wind speed deficit resulting in a bank angle of 6°.

Notwithstanding the above, all isolated long slender structures in excess of 30 m (such as walls, jet-blast enclosures etc.) should always be considered as having the potential to develop strong wind shear or turbulence on aircraft operations.

This general guidance should be included in Guideline B.

5.1.5 Difficulty in applying basic geometry rules of thumb currently used for shear criteria to turbulence

It is considered that both wind shear and turbulence criteria are required for the assessment of proposed structures. However, as discussed in Guideline B and the supporting documentation, predicting the wind conditions around even standard isolated structures is exceptionally complicated. There are certain configurations where isolated structures can disturb the wind flow pattern for a considerable distance downstream, particularly if the building is rectangular and at an angle to the incident wind direction. It is considered that the 1:35 rule for the height of buildings is considered the most appropriate for an initial assessment. For buildings exceeding this height limit, the proposed structure should be quantitatively assessed using physical or numerical modelling. For structures failing the NLR criteria during the quantitative assessment, subsequent discussion with the airport to discuss the operational implications should be undertaken.

5.1.6 Approaches of experts

Even in implementing the existing criteria, the various experts are not in agreement on how to best assess the impact of the structures. At least one expert has the opinion that the NLR criteria are insufficient to describe the response of aircraft to fluctuating wind loading. To verify/update the criteria would result in a significant research study using wind-tunnel test results and flight simulators. With the current acknowledged shortcomings of Guideline B, at this point in time, it would be considered appropriate to adopt all three of the NLR criteria and develop guidance material for experts and approval bodies on the minimum requirements for assessing structures. This information could then be presented to the Australasian Wind Engineering Society for inclusion in their Quality Assurance Manual, which is currently being reviewed with input from ourselves.

5.1.7 Airport anemometer locations

It is assumed that the control anemometer at the airport would be located in a similar turbulence regime as the approaching aircraft. It is considered that the Airport should ensure that the anemometer is located in a similar terrain and remote from any buildings or structures that could influence the measured wind speed or direction. For airports with multiple levels of surrounding terrain roughness, it would be expected that multiple anemometers would be installed and the relevant anemometer for the conditions would be used to direct operations.

5.1.8 Impractical geometric recommendations

The information in Guideline B to improve the aerodynamics of buildings is correct for wind shear, but would have little impact on building induced turbulence and is not relevant for all incident wind directions. It is recommended to move all such information from Guideline B to the guidance material as it still has important relevance to the topic.

5.1.9 Assessment area

As discussed in section 5.1.1, the assessment plan area for consideration of a development should be increased to the full length of the runway, Figure 8. The NLR assessment is specifically for landing aircraft as these are most susceptible to wind shear and turbulence, and the extension of the assessment area would account for small aircraft landings. The corresponding measurement zone for assessment of the impact of the building on aircraft should be along the runway centreline. It is recommended that the maximum area of assessment should be above the 3° glideslope to the runway threshold to a height of 60 m, Figure 8.

It is appreciated that aircraft could fly elsewhere in the assessable volume, particularly during take-off and go-arounds, however, during these events the aircraft would be under different power levels and may be more able to cope with wind shear and turbulence. Previous private discussions with NLR indicated that aircraft taking-off could experience a 30% increase in turbulence. It is considered that more detailed research would be required before extrapolation to other aircraft manoeuvres. It is considered that applying the landing criterion to other parts of the assessment volume would be conservative.

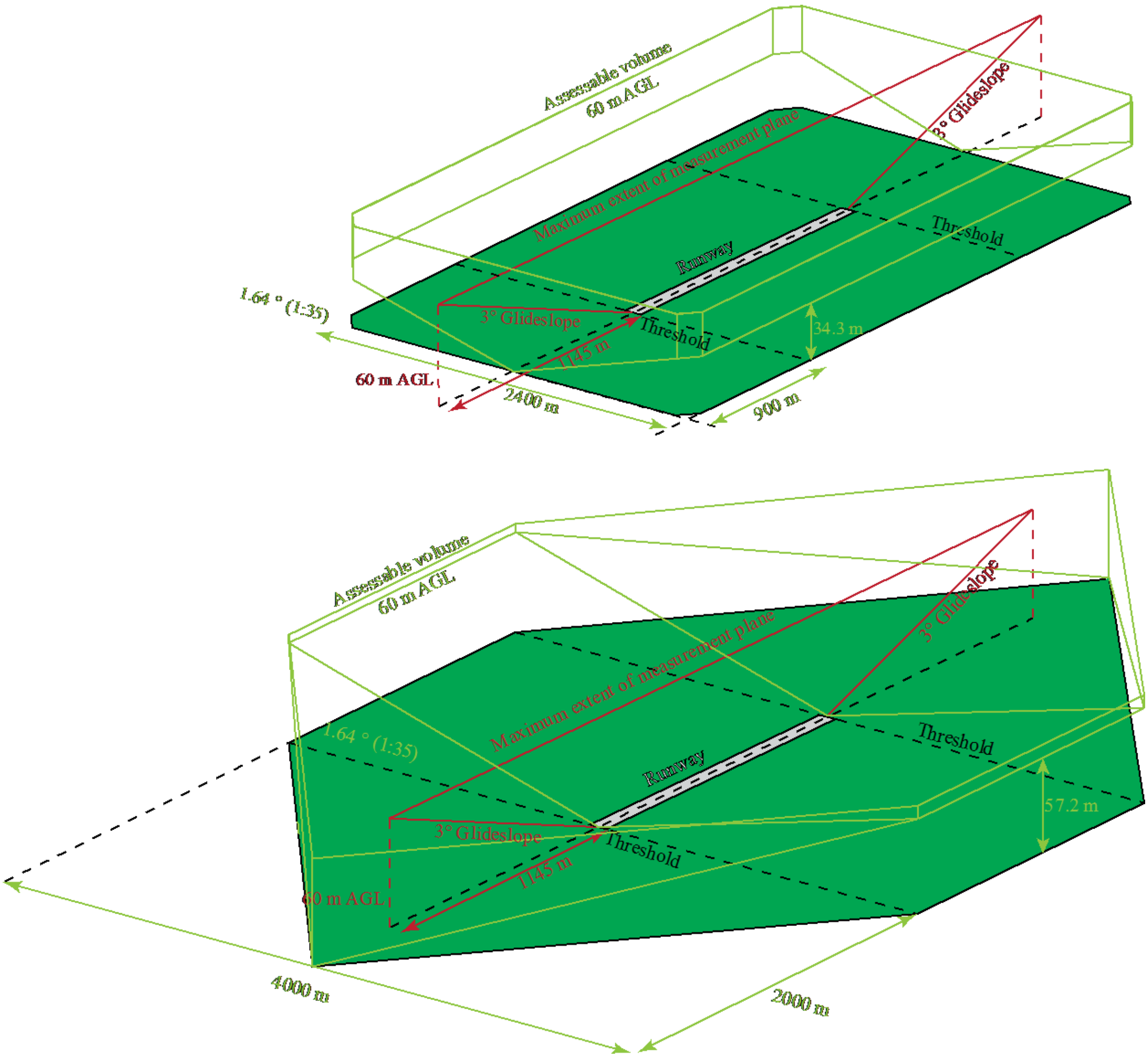


Figure 8: Assessable volume definition for isolated structures (T) and multiple buildings (L)

5.1.10 Lack of clarity regarding additional expert assessments

Guideline B offers little guidance to experts on how to assess for the wind shear criterion. Including a turbulence criterion could further confuse the assessment process without clear guidance material. Preliminary guidance material has been developed in section 5.1.11 to assist experts to conduct such a study using either wind-tunnel testing or numerical modelling.

5.1.11 Expert assessment requirements

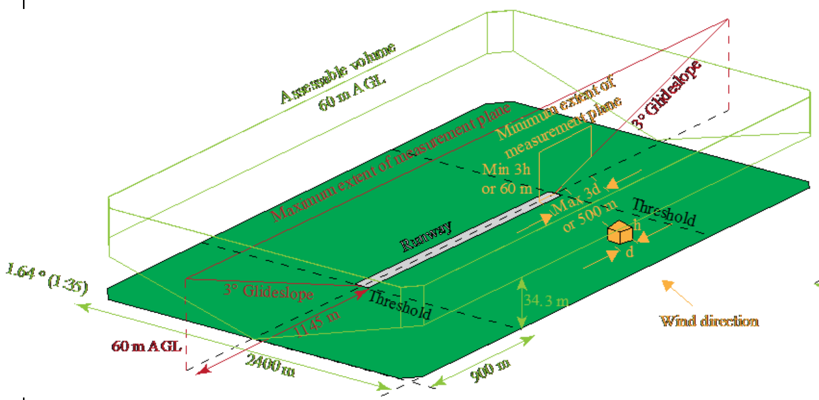
From the review, it is evident that the scope of any additional detailed analysis is not clearly defined for either the expert conducting the work, or the approval body. The difficulties and challenges this causes for non-experts reviewing reports from these studies has been discussed previously in this report. CPP understands that it would be beneficial to better outline the basic requirements of the additional studies, both in terms of technical process, as well as reporting for performance based assessments within the NASF guideline. Currently there are two main categories of performance-based study referenced in the Guideline B: physical scale model wind-tunnel testing, and numerical CFD. Some general requirements for these analysis techniques are outlined in Table 4 for wind-tunnel testing, and Table 5 for CFD, based on the assumption that the target criteria are based on the NLR framework for both wind shear and turbulence. Similar testing and reporting requirements could be included in Guideline B guidance material.

It is important to note that as the current Guideline B does not include a turbulence criterion, it is more suited to simpler forms of CFD simulation. If a turbulence criterion is adopted, some forms of CFD currently used will no longer be adequate, and more advanced forms would be required such as transient turbulence scale resolving approaches. More details on such requirements is provided in Table 5.

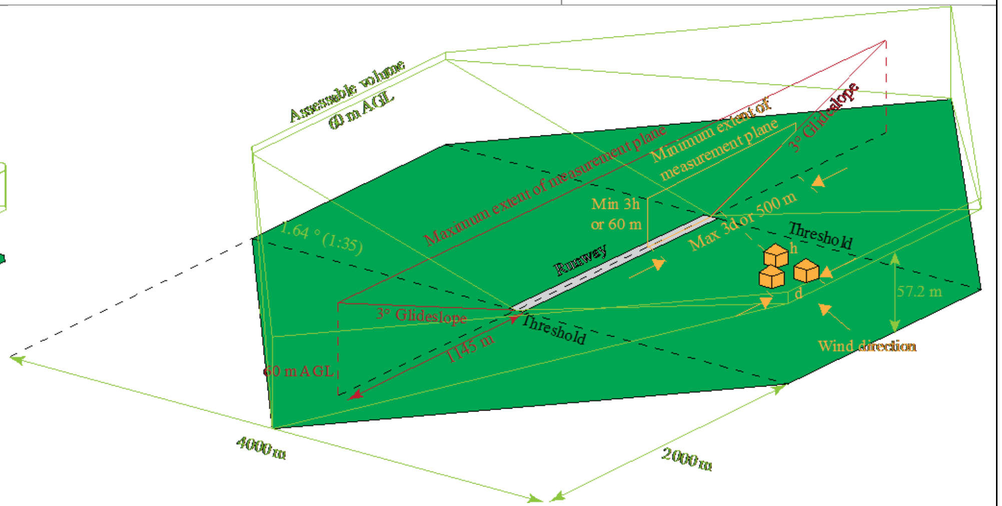
Table 4: Requirements for Wind Tunnel based modelling studies

Requirement.	Discussion	Test Requirements	Reporting Requirements
Model Geometry		A model scale should be chosen in order to represent all nearby influential building structures as well as incorporate the subject structure and the appropriate portion of the runway glideslope. Typically, this scale is in order of 1:500 to 1:1000. The model should generally be designed and constructed in accordance with Part A of the Australasian Wind Engineering Society (2001).	The consultant's report should include a description of the subject building or structure, photographs of the wind tunnel model and a plan view drawing of the wind tunnel model including surrounds.
Atmospheric Boundary Layer Classification	One the key characteristics of these studies is the modelled atmospheric boundary layer (ABL), which is the governing input into the model as well as a reference of existing conditions at the edge of the modelled area. It is particularly important in many airport studies due to absence of large or closely spaced buildings within the modelled area which would otherwise perturb the input condition.	A suitable ABL classification should be selected from an appropriate engineering standard, for Australian airports this would typically be Standard Australia (2011) and be calibrated in accordance with the Australasian Wind Engineering Society (2001). During calibration the ABL should be characterised in terms of vertical velocity profile, vertical turbulence intensity profile and spectral distribution of turbulence. The calibration should also ensure appropriate propagation of the modelled ABL from the edge of the test area to the location of measurement.	The consultant's report should include a brief description of the chosen ABL classification/s and calibration procedure. Graphical, illustration must be provided showing the measurement profiles relative to the target profiles for vertical velocity, turbulence intensity and spectral distribution of turbulence at, or near, building/structure height as well as demonstrate suitable ABL propagation across open airport space if relevant.
Instrumentation	Most model scale wind engineering studies are unique in comparison to full scale studies and specialised instrumentation must be used. Anemometry instrumentation with high frequency response, high sampling rate and high sensitivity must be used. Inappropriate equipment would typically lead to non-conservative turbulence values. CPP has found both single and multi-component anemometry instrumentation can be effective at drawing conclusions in the context of NLR style criteria.	Measurements should be made within a specialised atmospheric boundary layer simulation wind tunnel using suitable anemometers with high sensitivity and frequency response. The apparatus should be capable of measuring turbulent length scales equivalent to 1-2 s full scale. Typical instrumentation would be single or multi component hot-wire or hot-film anemometers, high frequency pressure based sensors such as a Cobra Probe, or Particle Image Velocimetry (PIV). A calibration procedure appropriate for the chosen instrument must be untaken prior to testing.	The consultant's report should include a brief discussion of the wind tunnel apparatus and measurement instrumentation used and any necessary calibration process undertaken to ensure accuracy.
Data Acquisition Settings	The specific configuration and settings used to acquire sampled anemometer data are of critical importance to ensure appropriate levels of turbulence are captured.	Data should be acquired using suitable sample rates to obtain a measured frequency response of 1-2 s full scale equivalent. A sample time shall be used to ensure stable statically averaging of quantities such as the standard deviation of velocity.	The consultant's report should include a description of the data acquisition parameters used including sample frequency, sample length (per measurement) and details of any filtering, or signal conditioning if relevant.
Wind Directions	For any given structure-runway combination only a small range of wind directions will	Test wind directions should be chosen through collective discussion between the consultant and the airport based on	The consultant's report should clearly define all directions tested.

	typically be of interest. These are driven by the building position relative to the runway centreline and threshold, and the operational procedures and limitations at the given airport.	building location and airport operational procedures. Direction should be chosen to represent worst case conditions. A minimum of two wind directions per structure is recommended.	
Measurement locations	The potential measurement locations are extensive and need to be rationalised to areas of critical interest. These are the areas within the wake zone of the subject structure for a particular direction where there is the greatest potential for adverse conditions. The proposed NLR turbulence criteria are only valid up to a maximum height of 60 m above ground level, beyond which they may be exceeded in typical suburban conditions (the potential input profile).	Measurements should be made within an area directly downstream of the subject structure (project along the wind direction axis) on the vertical plane defined by the runway centreline. Measurement should cover a minimum area of the maximum of 3 times the building width along the runway centreline (centred on the project building centreline), or a width of 500 m, and a vertical extent starting from the glideslope line projected from the runway threshold and extending up to a minimum of 3 times the building height and a maximum height of 60 m. This should be done for each tested direction with a suitable measurement area for each wind direction.	The consultant's report should include a tabular or graphical illustration of all test point locations, labelled for identification, for each wind direction tested.

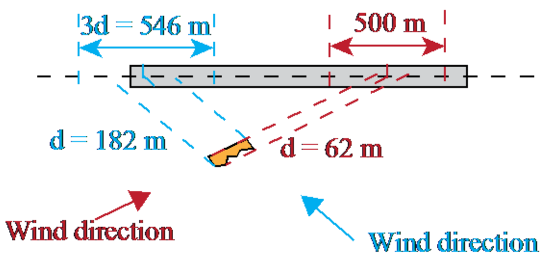


Isolated structure



Multiple buildings

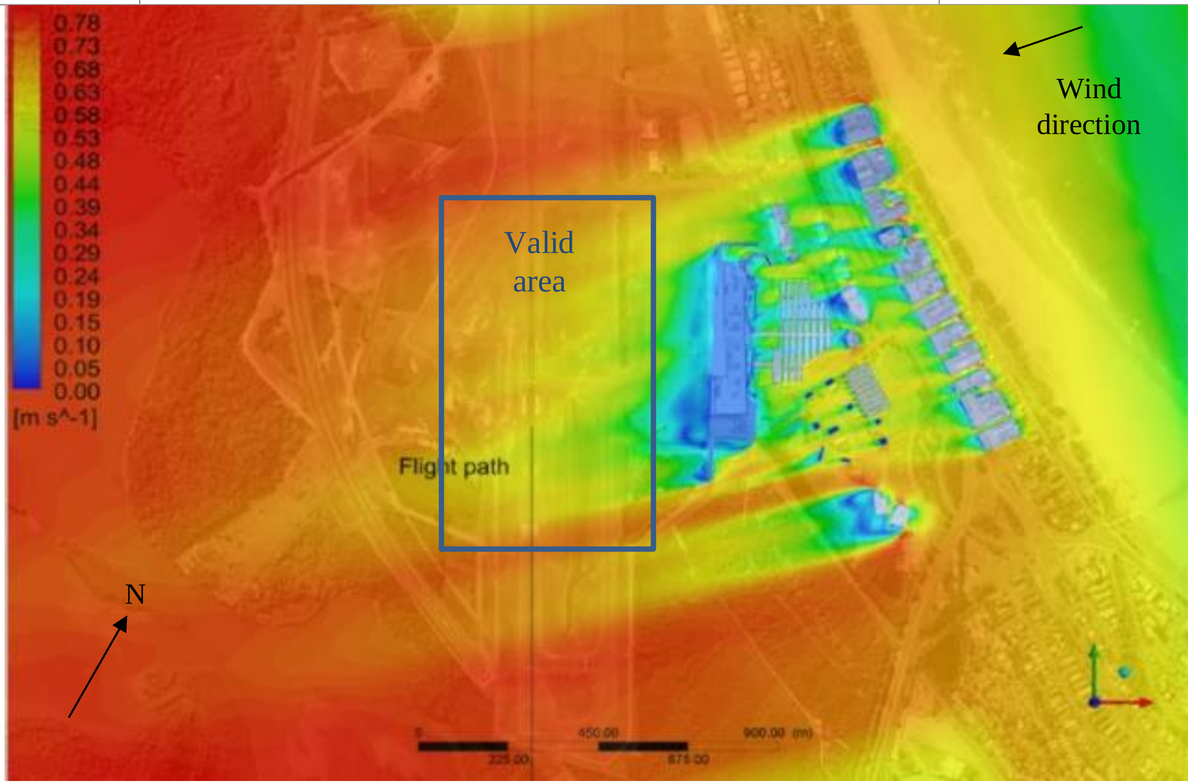
Minimum lengths of measurement planes



Results	Detailed final results should be provided with respect to the selected criteria. Result should be presented in such a way to be easily interpreted for the intended purpose which is generally direct comparison with airport operation wind speed limits. CPP has found this is most effectively achieved by analysing the results to determine the runway anemometer wind speed required to reach the criterion threshold. This result can be compared directly with operational wind speed limits. If any reported values reach the criterion level for a wind speed were the airport intend to have the runway operating, then the subject structure may impact operations.	N/A	The consultant's report should include test results for all test locations and a discussion of the results. It is recommended results are presented as the wind speed at the airport anemometer required to reach the criteria threshold for both wind shear and turbulence. An example illustration of results is given in Figure 5.

Table 5: Requirements for CFD based modelling studies

Requirement.	Discussion	Analysis Requirements	Reporting Requirements
Model Geometry	The starting point for the computation model design is the input geometry.	As per wind tunnel test requirements with the exception that there is no requirement to scale the geometry.	The Consultant's report should include, A plan view drawing and 3d views of the CFD geometry including modelled surrounding area.
CFD Solver		The CFD simulations should be performed on high end validated commercial CFD solver. Typical examples include various solvers provided by Ansys and CD-Adapco. Non-commercial or custom solver software can be used if accompanied by relevant validation material and/or references to peer reviewed validation material.	The Consultant's report should specify the solver software used.
Atmospheric Boundary Layer Simulation	The required characteristics for the simulated atmospheric boundary layer are the same as listed for the equivalent wind tunnel test. The challenges in achieving a suitable setup however are quite different and this is one the more common sources of error or incorrect modelling assumptions in computational wind engineering type studies, especially in regard to correct prorogation of the input boundary layer through the computation domain. It is therefore crucial that any airport turbulence study performed using CFD clearly demonstrates that a suitable simulation environment was achieved.	As per wind tunnel test. Special attention should be given to ensuring as suitable and stable boundary Layer in terms of velocity distribution, turbulence intensity distribution and distribution of turbulence scales is provided at the start of the modelled area (where building and structures are represented geometrically).	The consultant's report should include a brief description of the chosen ABL classification/s and calibration procedure. Graphical illustration must be provided showing the measured profiles relative to the target profiles for vertical velocity and turbulence intensity at the start of the modelled area, and spectral distribution of turbulence at or near building/structure height. Data should be provided demonstrating suitable ABL propagation through the domain and across open airport space where relevant.
Turbulence Modelling		In order to capture the time varying effect of turbulence a transient form of CFD simulation must be used. The simulations should be run using settings suitable to sufficiently resolve and measure velocity fluctuations of 1-2s duration. A turbulence model shall be used in the simulation that is of the scale resolving type (e.g LES, SAS). If zonal methods are used (e.g. zonal LES), then they must be scale resolving in a minimum volume that surrounds the subject building and downstream in the building wake extending to, and surrounding, the runway measurement area.	The consultant's report should include a description of the numerical setup used including the chosen turbulence model and temporal settings. Wherever the simulation has been designed to model or capture turbulence differently in different areas of the modelled area e.g. less advance techniques or resolution in non-critical areas of domain, then the areas were valid results can be measured must be clearly marked.
Computation	The type, quality and size of the	A computational mesh should be designed that is of high quality and suitable to	The consultant's report should include a

grid	computation mesh used to discretize the fluid volume is critical to any CFD model and particularly when turbulence scales are being simulated and measured.	be used in combination with the chosen CFD solver and turbulence modelling approach. The mesh density shall be sufficient to model turbulence scales equivalent to 1-2 seconds gusts in a minimum volume which surrounds the subject building and extends downstream to encompass the full measurement area of the runway.	description of the meshing approach used. Images of the mesh should be included that illustrate the quality and resolution in the significant areas of the domain.
Statistical settings	The transient simulation will be sampled in order to calculate statistical quantities such as mean velocity and standard deviation values. It is important that the solution sufficient length of time to obtain converged and stable statistical quantities.	A total sample length should be used of sufficient length to achieve stable statistical averaging when considering the largest turbulent length scales simulated in the domain.	The consultant's report should specify the sample time used for statistical values and comment or demonstrate how this was determined to be sufficient.
Valid results areas	The majority of wind engineering type CFD simulations are designed to most accurately model the flow field in important areas, away from which simplifications, assumption and sometimes less sophisticated modelling techniques are employed for computational efficiency. These non-critical areas are still often shown in the final result output due to the graphical nature of typical CFD result presentation methods and can be misleading if not well defined.		The consultant's report should clearly illustrate the area intended by the analyst to be accurately modelled and suitable for obtaining measured values and drawing conclusions. Example output with illustration of analysis area, where simulation is correct. Other locations are simulated with the intent of providing a correct solution inside this area.

Results	Generally as per Wind Tunnel test		The consultant's report should include results as either numerical values as per a wind tunnel test or present the equivalent variable in the form of coloured contours, isolines and/or vector plots. Area of criteria exceedance should be clearly defined and a discussion of the results should be included.
Benchmarking and validation	There is a large number of variables describing the numerical setup of CFD models, many of which can heavily affect the final output. Unlike physical simulations, computation fluid simulation can easily produce results that are not physically possible if an incorrect approach is used. Use of CFD for detailed modelling of turbulence in the natural wind environment is complex and not yet considered an established commercial practise for many types of quantitative studies. Given the nature of wind turbulence studies at airports is critical that any approach adopted by an organisation for this form of modelling be validated through benchmarking studies, unless it is intended to also undertake physical experiment for the site e.g. the CFD is being used as a screening study and wind tunnel studies will be used later to quantity the final design.	A comparison study should be undertaken to develop and validate the specific CFD approach used within an organisation for airport wind shear and turbulence assessments. This study should benchmark the CFD output against some form of equivalent physical measurement at model scale in a wind tunnel, or full scale in the field. The CFD validation model should have similarity with the subject CFD simulation in terms of computation domain size, boundary condition types, boundary input profile and propagation strategy, mesh density and type, meshing strategy, time step resolution, turbulence models, numerical discretion schemes and contain geometry that is relevant to an airport wind shear type study.	The consultant's report should include an appendix containing a brief summary of relevant validation studies and present relevant comparative benchmarking data. between simulation and experiment.

5.1 Proposed modifications to guideline clauses

Recommended changes to Guideline B for consideration by NASAG are summarised in Table 6. The development of the exact wording of the revised clauses would occur following approval of the approach taken. In addition, to any updates Guideline B should define the responsibility of each of the stakeholders in the process: DIRD, CASA, Airservices Australia, pilots, airport management, developers, and local Councils. The review process has illustrated some communication issues exist between the relevant parties involved in the conflicting requirements for developments in and around airports. Communication procedures would have to be developed for managing the transfer of information; for example, a proposed development may be acceptable from a wind perspective based on current operating procedures at the airport, however, how would the wind conditions be considered in redefining the operational procedures, and thereafter controlling aircraft operations.

Table 6: Proposed modification to Guideline B

Clause No.	Current Wording	Proposed Wording	Comments/References
10	Buildings that could pose a safety risk are those located: a. 1200 m or closer perpendicular to the runway centreline; or b. 900 m or closer in front of runway threshold (i.e. towards the landside of the airport); or c. 500 m or closer from the runway threshold along the runway.	Buildings that could pose a safety risk are those located: a. 1200 m or closer perpendicular to the extended runway centreline; and b. 900 m or closer in front of runway threshold (i.e. towards the landside of the airport); or c. anywhere along the length of the runway.	
12	The guidelines set out: • empirically determined criteria for windshear and turbulence respectively; • generic guidance on mitigating risks from proposed buildings; • a methodology for assessment of proposed buildings; and • options, where required, for subsequent detailed modelling of wind effects. • options to mitigate wind effects of existing buildings where required	The guidelines set out: • empirically determined criteria for windshear and turbulence respectively; • generic guidance on mitigating risks from proposed buildings; • a methodology for assessment of proposed buildings; and • options, where required, for subsequent detailed modelling of wind effects.	
22	The Australian Government committed in the Aviation White Paper to develop guidance on the impact of turbulence and wind shear generated by buildings in the vicinity of runways. To date, no formal regulation exists in Australia or indeed anywhere in the world on the assessment and mitigation of turbulence and wind shear generated by buildings.	Modify as per latest update to NASF Guideline B. Remove reference to White Paper.	

24	Leased federal airports are protected from tall buildings in the vicinity of airports based on standards established by the International Civil Aviation Organisation (ICAO). These standards form the basis of 'prescribed airspace' legislation under the Airports Act 1996 which is administered by the Department of Infrastructure and Transport (DoIT). Under this legislation, airspace surrounding leased federal airports is regulated to ensure that obstacles to safe air transport are not built.	Leave unchanged	
26	Australia has international obligations as a contracting state to the Convention on Civil Aviation to regulate aviation safety. As discussed previously, neither ICAO nor any other major aviation safety regulator has so far established wind impact assessment criteria.	Leave unchanged	
27	Current practice is generally to rely on standing warnings to pilots about the potential to encounter adverse wind effects. This is the approach in the UK as well as currently in Australia. For example, at Canberra Airport, there is a permanent notice in aviation publications advising pilots about the potential adverse wind effects that can be encountered because of a hangar. After extensive consultation and research, Australian governments have decided to take a pro-active approach on this issue and this option has been discarded.	Modify as per discussions	
30	For buildings that do not meet the 1:35 rule, an alternative approach is required. This approach is: • the adoption of a windshear criterion to be applied as the basis of regulatory controls.	For buildings that do not meet the 1:35 rule, an alternative approach is required as the basis of regulatory controls: • the adoption of along-wind and cross-wind windshear criteria • the adoption of turbulence criteria	
32	Based on this research, NLR developed the following criterion:	Based on this research, NLR developed the following criteria:	
33	The variation in mean wind **speed due to wind disturbing structures must remain below 7 knots** along **the aircraft trajectory at heights below 200ft. The speed deficit change of 7 knots must take place over a distance of at least 100m.**	The variation in mean wind speed due to wind disturbing structures must remain below: • 7 knots along the aircraft trajectory at heights below 200 ft. The speed deficit change of 7 knots must take place over a distance of at least 100 m. • 6 knots across the aircraft trajectory at heights below 200 ft. The speed deficit change of 6 knots must take place over a distance of at least 100 m. The standard deviation of wind speed must remain below 4 knots below 200 ft.	
36	The most critical zone (in plan view) for building positioning, with respect to potential (building-related) windshear problems, is close to the touch-down zones of runways.	The most critical zone (in plan view) for building positioning, with respect to potential (building-related) wind shear problems, is close to the touch-down zones of runways. Critical zones with respect to potential turbulence	

		problems are more difficult to predict as they depend more heavily on building shape and local surrounds	
38-41	Statements about building orientation and width/depth ratio	Move to and amend in guidance material	Does not consider multiple wind directions, and provides recommendations that would not necessarily result in compliance with turbulence criteria
45	Like all aviation safety incidents, building-induced windshear events involve a coincidence of factors including the following: • There would need to be a building of shape and size able to generate wake disturbances large enough to exceed accepted windshear criteria, e.g. the NLR "7-knot criterion". • The wind would need to be blowing in a more or less cross-wind orientation to the runway being used and of a magnitude able to generate conditions where the "7-knot criterion" could be exceeded.	Like all aviation safety incidents, building-induced windshear and turbulence events involve a coincidence of factors including the following: • There would need to be a building of shape and size able to generate wake disturbances large enough to exceed accepted windshear and turbulence criteria • The wind would need to be of a magnitude sufficient to create an exceedance of one of the three criteria • The wind direction would need to create exceedances that intersect the measurement plane. • Aircraft would have to be operating in the measurement plane	
47-58	Details on calculating building wake deficit for wind shear criteria desktop assessment	Delete	Becomes redundant with the addition of the turbulence criteria, since no simple procedure is available for that assessment.
59	A wind consultant or other suitably qualified professional should be asked to provide guidance on the acceptability or otherwise of a proposed building development in relation to the potential wake disturbance caused by the building on nearby runway operations.	Add: The wind consultant or other suitably qualified professional shall comply with the Quality Assurance Manual (QAM) provided in the guidance material	
60	This assessment will be premised on the acceptance criterion, viz. whether the "7-knot criterion", will be exceeded or not, and, if it is predicted to be exceeded, how often.	This assessment will be premised on the acceptance criteria, viz. whether the wind-shear and turbulence criteria will be exceeded or not. If exceeded, an assessment of the expected impact on aircraft operations is required and discussions with the airport are triggered unless the structure is modified to pass the criteria with additional testing	
65	For buildings that do not meet the 1: 35 rule, the assessment hierarchy methodology is described in **Table 2- Cases B1, B2 and C**.	For buildings that do not meet the 1: 35 rule, the assessment hierarchy methodology is described in **Table 2- Cases B1, B2 and C**. Table simplified to include 4 items: • A: Meet the 1:35 rule	Case B1 designed to exempt structures such as cranes and chimneys which do not pose a risk to aircraft in terms of wind shear and turbulence generation.

		• B1: Fail the 1:35 rule but structure deemed to have no impact based on simple assessment • B2: Fail the 1:35 rule but deemed to have no impact after detailed wind tunnel or CFD analysis • C: Fail the 1:35 rule, testing and discussions with airport required	These criteria are currently under development.
66	The output of the consultant's wind assessment for cases B1, B2 and C will typically be of the form displayed in Figure 4.	Delete. This plot is of little use to stakeholders. Replace with: The output of the consultant's wind assessment will provide information relating to the expected impact on standard operating procedures at the airport in question for further discussions with stakeholders.	
67-73	Example analysis and exemption of turbulence	Delete	
74-94	Mitigation options	Move to and amend in guidance material	Many of these recommendations are of little use in reality as they rely on a single wind direction, and would not necessarily result in a reduction of building-induced turbulence

5.2 REVIEW OF EXTERNAL QUERIES

A number of documents and communications regarding reviews and concerns of the NASF Guideline from external stakeholders were provided to CPP as part of this review exercise. This section attempts to address many of the key points that have not already been addressed in prior sections of this report.

General Query or Concern	Response
Suitability of wind tunnels for airport turbulence studies. Measuring turbulence behind structures only 2 cm high at scale is not practical (referring to 1:1000 scale terminal buildings)	The measurement of wind speed and turbulence levels in wind tunnels is an established science. Typically wind speeds are measured with a probe about 2-3 mm long, which is appropriate for measuring the scales of turbulence affecting aircraft. Table 4
Take-off in crosswinds can be more restrictive than landing	Would require a study on the scale of the original NLR document to resolve and is beyond the scope of this update. The NLR study focussed on landing aircraft as these were more problematic. Section 2.1 and Section 5.1.6
Influence of structures on anemometer readings is also of importance	Agreed, as is the upstream surface roughness relative to the anemometer. Implies requirement for testing at anemometer locations in addition to flight paths. Our position is that it would be the airport's responsibility to ensure the accuracy and validity of its own measurement tools, accounting for any changes to the upstream fetch from the anemometer. Section 5.1.7
Using probability and statistics should only be allowable given some (rare) operations; that said ALL the incidents at Hong Kong occurred in very, very rare wind directions.	The use of probability and statistics is required to provide information as to the number of hours the operation of aircraft would be negatively affected in the year for information and assessment by operators. A pass/fail only does not provide a useful indicator of the impact of the development.
Lack of oversight into the quality of work undertaken by specialists.	Verifying the work of specialists is always difficult to police. Peer reviewing is not necessarily beneficial as any technical dispute would require a third party to decide. A quality assurance manual has been developed as part of the current study, Section 5.1.11.
NASF Guideline B fails to address the key flow physics that affect aircraft operation. In particular, the turbulence scale. Scales of importance are on order of 1-5 times the size of aircraft	Turbulence length scale is indirectly addressed through the use of the wind shear and turbulence intensity criteria that is limited in spatial extent (100 m). This was a key conclusion from NLR after extensive simulator studies, and the physics behind the criteria is masked, but addressed. Section 2.1.
All three components of velocity should be measured, and throughout a volume enclosing all possible aircraft approaches and roll-outs	Not financially viable to take measurements in the whole assessment volume unless undertaking a CFD study, or PIV. It is significantly more difficult to ensure quality in CFD studies compared with wind tunnel tests from the perspective of oversight. In addition, the computational cost for such a study is likely to be very high.
Generally, approach is more susceptible to wind-shear and turbulence, but go-arounds involve a transition between configurations and handling errors can significantly exacerbate vulnerability. In addition, go-arounds do not necessarily track the runway centreline and can occur at any part of the approach, including the runway	As above, a CFD study would be required to map the entire volume.
There should be no presumption that flight path management is highly accurate, human and aircraft capabilities should be accounted for in manual flight in difficult conditions when assessing	As above, a CFD study would be required to map the entire volume.

Influence of terrain further afield should also be assessed to determine the significance of any turbulence contribution of a proposed development	This would be accounted for in the development of a site-specific wind climate, and comments could be included in the report relating to any obvious contributors. Section 5.1.11
Use of single-component hot-wires/Irwin probes does not reflect best science	The test technique should be developed to a level appropriate for routine studies rather than a research topic. Section 5.1.11
No guidance in AWES QAM for the selection of model scales for this purpose. Currently, NASF Guideline B relies on best-practice which is undefined. Assessments should include comments about the impact of the chosen model scale on limitations of results as they apply to possible/existing developments further afield	Agreed. Section 5.1.11
Wind data used in wind engineering is mined for a different outcome than that suitable for aerodynamically responsive bodies such as aircraft. Interested in 2-10 second phenomena that may be lost among data averaged on a monthly or annual basis or may not be adequately replicated by standard climate models	This relies on an incorrect assumption. Design loads are derived from wind gust time scales typically significantly shorter than 1 second in duration. Data are seldom averaged on a monthly or annual basis. Indeed, wind engineering analyses the available wind data for a wide range of applications from sub second to long-term averages depending on the application.
A range of wind speeds should be investigated	This is considered to be incorrect, unless the implication is that the fundamental characteristics of the wind changes with wind speed. For this kind of study around bluff bodies, the flow is independent of Reynold number (wind speed) and only requires testing at one wind speed. Standard engineering techniques are used to scale the data to other wind speeds. Other wind speeds are investigated by combining the tunnel/CFD data with a site-specific wind climate to determine the wind speed to exceed the criteria.
Should not use existing data products generated for un-related purposes, and may require a specific statistical analysis of raw BoM data.	Agree, this is the approach that should be taken, with caution about using raw BoM data which almost always requires significant quality control and adjustment to account for erroneous data, anemometer siting, and anemometer relocation/degradation. Data are only measured at a single point.
An independent peer review process should be established to ensure that the quality of the technical advice in wind assessments is best practice	Agreed, although as noted above, the peer review process breaks down if the experts disagree. Quality assurance manual provided in Section 5.1.11.

6. NEXT STEPS

6.1 Further Research

This review has determined that the current NASF Guideline B can be relatively easily improved based on the current available research, particularly with respect to the concerns and challenges which triggered this review process regarding mechanical turbulence. While CPP recommends immediate changes to the guideline be considered based on published research, it also acknowledges that there is a clear need for further research and development in order to address weaknesses in the current guideline's philosophy, its implementation, and surrounding framework. A longer term view should be taken with a framework for ongoing improvement established. Some examples of topics or focus areas are discussed below.

6.1.1 Clarifying NLR definitions, interpretations, and intent

Through this review, many issues have been highlighted whereby the aspects of the original NLR documentation are unclear, confusing, or inconsistent. As a first step to further development, and ideally before any amendment to the current guideline are finalised, attempts should be made to clarify some of these uncertainties, in particular those relating to the interpretation of the various criteria and their application. This would require some level of engagement with the NLR body and its personnel familiar with the research.

6.1.2 Detailed review of NLR research and criteria as it relates to airport operations management.

NLR has published a significant body of research, distilling their conclusions down to simple threshold based criteria. The current form of the criteria may not be ideal with respect to its compatibility with Australia airport operational management practices. It is also somewhat unclear in its definition, due to inconsistences in its documentation in such a large body of work, and has been criticised by some consultants as being overly simplistic. Establishing a new set of criteria from scratch would be considered an ineffective cumbersome and costly exercise, however potential exists to modify, improve, or redefine the criteria based on the original research data to be better suited for the intended NASF application at Australian airports. Such work is beyond the scope of the current review, but could be directed with information gathered from discussions with NLR.

6.1.3 Link between NASF and current operational procedures

There is a clear link between the interpretation of results from NASF wind shear type studies and the operational procedures at a given airport. They both aim to establish whether the wind environment at an allocated runway is suitable for safe landing operations, and therefore the basis for what is deemed acceptable should be reasonably well aligned. It has also become evident that pilots have a significant input as to when and which runway can be used to land their aircraft, which is considered appropriate as they know the capability of the aircraft. Working with the Air Traffic Controllers a suitable wind environment could be described and the pilot can then consider the wind conditions for a landing in non-ideal wind conditions. From the review, it appears that there is often little integration of the two functions and further work is needed to better integrate or align the implementation of the NASF guideline B, and the research it is based on, with operational procedures and decision making at airports.

6.1.4 Criteria for smaller aircraft

As the smallest aircraft considered in the NLR study was a Fokker 100, the impact of wind shear and turbulence on general aircraft are less well understood. The instability criterion developed for jet aircraft may not be directly transferable to general propeller aircraft. Notwithstanding the above, the wing loading of typical smaller general aviation aircraft is about 10% of a Fokker 100, hence, these lighter aircraft would be significantly more susceptible to the effects of incident wind shear and turbulence. If the acceleration response is the important driver for the instability of the aircraft, then the turbulence criterion could be reduced by a factor of 2 to a standard deviation of horizontal wind speed of 2 kts. This aligns with the cross-wind operational restrictions on landing aircraft from 20 kt for larger planes, to 15 kt for general aircraft with the lift force being proportional to the wind speed squared.

6.1.5 Benchmarking criteria against full scale data and operational events

The NLR research was primarily based on wind tunnel testing, and piloted and non-piloted simulator based experiments. In order to close the research loop, further work is needed to assess the effectiveness of any criteria against real life data and events, particularly on known problematic approaches and during severe weather events. This has been investigated slightly at Sydney Airport.

6.1.6 Criteria for Helicopters

The current NASF guideline does not consider helicopter operations and further research would be required in order to incorporate this aspect.

6.1.7 Continuing general research.

While the NLR research is considered by most experts to be the most extensive work to date on this topic, this area is still relatively immature and ongoing research is still required particularly to gain further understanding of how various wind flow mechanisms and their size, duration, and intensity can affect the safe operation of various types of aircraft.

6.2 Recommendations for how this could be carried out

Some of the above potential research areas would be significant bodies of work, or would take significant periods of time to finalise. It is recommended that the role universities can play in providing supplementary research for further development of the guideline be considered, especially where significant quantities of wind tunnel testing or data gathering is expected. Should appropriate university research groups show interest, research funding may be obtained through grant schemes such as ARC Discovery. ARC Linkage grants could also enable specialist consultancies, such as CPP, to work together with universities to achieve mutual outcomes. Evidently this funding would be based on the success of the grant application. Other stakeholders such as the federal government and CASA would need to assist in promoting the need for such studies to ensure the value in any proposed research is recognised and grant applications are successful. Other government grants may be more appropriate for this level of research in the required timeframe. CPP currently work alongside various University departments, and would welcome the opportunity to assist or oversee universities completing research studies in appropriate areas of interest to further the field.

7. REFERENCES

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Appendix 1: ASSESSMENT PROCEDURE FOR COMPOUND BUILDING FORMS

23 April 2014 CPP Project 7725

Sydney Airport Corporation Limited

Central Terrace Building
10 Arrivals Court
Sydney Airport
NSW 2020

Attn: Mr. Ken Allcott

Subject: NASAG guidelines for Council assessment

Dear Mr. Allcott,

Further to recent discussions, please find enclosed some comments for the use of the NASAG (2012) guidelines for Sydney Airport. The primary aim of this assessment was to develop a procedure for Council to apply to development applications in their catchment area to assess whether an assessment for mechanical wind shear would be required and whether it needs to be forwarded to SACL for their assessment.

It should be noted that the NASAG guidelines specify a 7 kt wind deficit in the cross-wind direction over an in-flight distance of 100 m for the wind shear assessment. This is less stringent than the 6 kt wind shear criterion in the cross-wind direction specified in the Dutch criterion (Nieuwpoort, 2010) upon which the NASAG criterion was based. NASAG (2012) nor does include any provisions to assessing building generated mechanical turbulence.

An important factor for wind shear assessment is that the proposed buildings cannot be taken in isolation and the compound shape of adjacent buildings needs to be considered. For example, a large building in isolation may not constitute an operational issue for wind shear, however if an identical building were located on an adjacent site the compound effect of the two buildings could cause issues. Developers claiming precedence over building size is therefore not a valid argument when it comes to wind effects on aircraft safety.

Assessment Procedure

In terms of a procedure a series of steps have been defined for the wind shear assessment of development applications. It has been assumed through the development of this assessment process that the building height would not penetrate the obstacle limitation surface (OLS) for the airport, and that the operating wind criterion for using a Runway is limited by a 3 s gust wind speed measured at the control anemometer location of 30 kt in the cross-wind direction.

Step 1: Location of the development

If the proposed development is wholly outside the zoned plan area presented in Figure 9 then the development does not require any additional assessment.

Step 2: Height of the development

If the development is below the height surface presented in Figure 9 then the development does not require any additional assessment. The height limit surface varies linearly with distance perpendicular to the centreline of the runway.

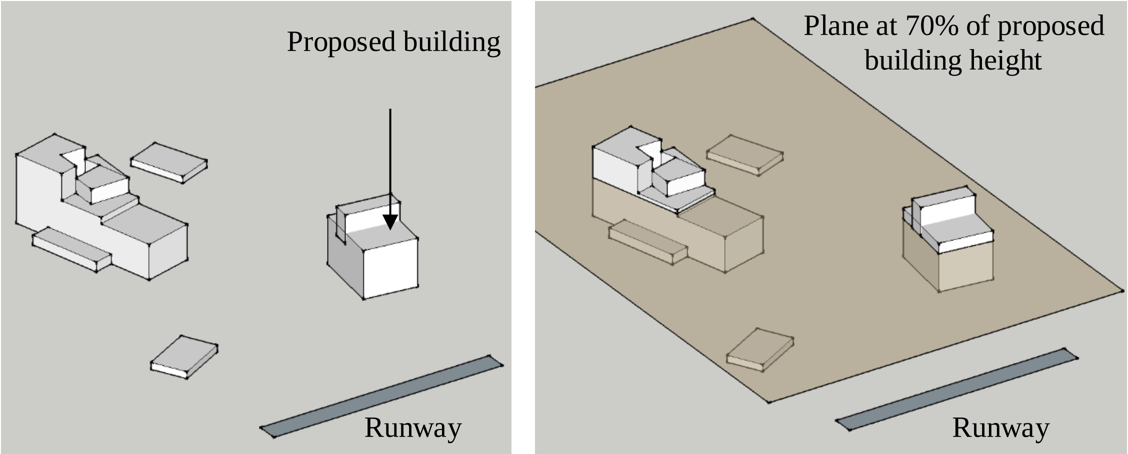
It is assumed that the height of the building is less than the OLS, which is a maximum of 51 m AHD for the assessment areas.

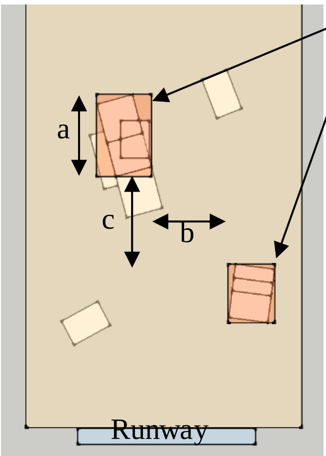
Figure 9: NASAG zones showing minimum height limits requiring assessment and OLS relative to AHD

Step 3: Type of development: isolated or compound

To determine whether a building is isolated, all existing (or Council approved) buildings with a height greater than 70% of the proposed building should be considered. The plan-form shape for each building should be taken as the enveloping rectangle parallel to the runway for all building elements above the plane through the 70% height of the proposed building. This is illustrated in Figure 10.

The proposed building is classified as isolated, if the distance between the proposed and the adjacent existing (or Council approved) buildings of height greater than 70% of the proposed building, is less than the maximum dimension of the two enveloping rectangles.





Enveloping plan-form rectangles in runway axis for all buildings above 70% of proposed building height.

Where a is the largest dimension of both enveloping rectangles, b and c are the distances parallel and perpendicular to the runway respectively between the portion of the buildings exceeding the 70% of proposed building height limit.
If b>a or c>a, then the proposed building is classified as isolated for that combination of buildings,
If b≤a and c≤a then the proposed building is classified as multiple for that combination of buildings, with the total width defined in Figure 11.

Figure 10: Schematic for determining isolated building

For determining the compound size of multiple buildings, the proposed building should be assessed in the first instance individually with all neighbouring existing and Council approved buildings. If a compound building is determined the assessment should progressively expand from the perimeter building, using the dimensions of the individual buildings, not the compound shape.

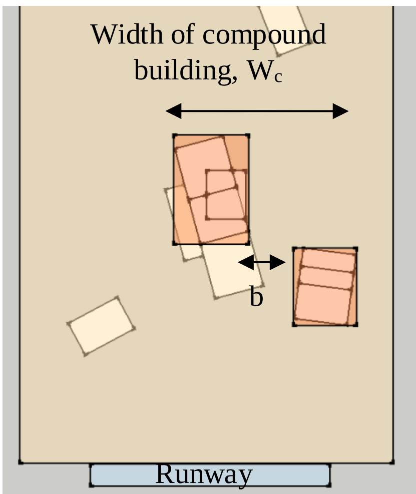


Figure 11: Width of compound building for adjacent buildings

In the example sketched in Figure 12, the proposed building was assessed independently with all buildings and only buildings B and E were classified as compound. Building E is on the edge of the compound shape and should be assessed with neighbouring Building F using their respective building envelopes, not the building envelope of the compound shape, W_c. As Building E and F are considered compound, Building F is on the edge of the compound shape and should be similarly assessed with neighbouring Building G. The width of the compound building is the overall width parallel to the runway as noted in Figure 12.

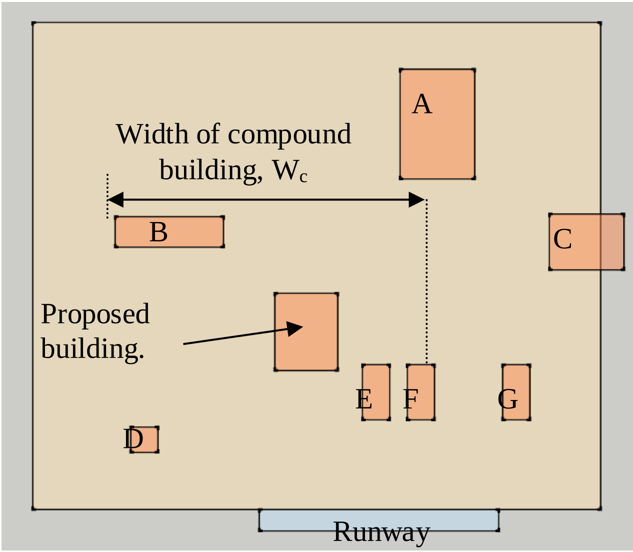


Figure 12: Example for assessing compound size of multiple buildings

Step 4: Isolated building assessment

If the enveloping rectangle dimension parallel to the Runway, W, is less than one third of the distance from the rear face of the building to the Runway Centreline, D, then the building does not require any further wind shear assessment. If W>D/3, then the building requires a qualitative assessment in accordance with NASAG (2012).

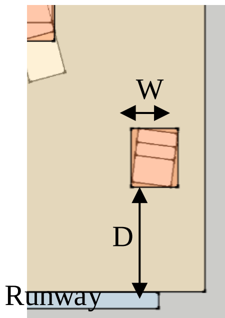


Figure 13: Definition for assessing an isolated building

Step 4: Compound building assessment

If the width of a compound building parallel to the Runway, W_c, is less than one third of the distance from the rear face of the compound building to the edge of the Runway, D, Figure 14, then the building does not require any further wind shear assessment. If W>D/3, then the building requires a qualitative or quantitative assessment in accordance with NASAG (2012).

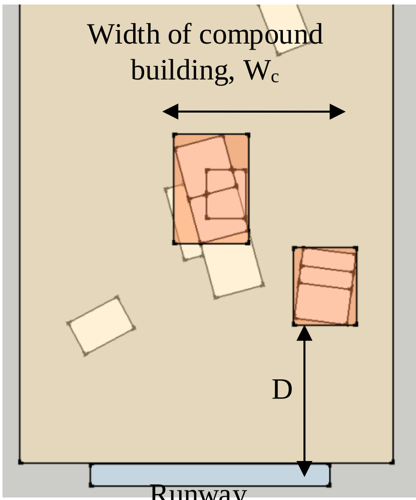


Figure 14 Definition for assessing a compound building

Conclusions

A procedure has been developed to assist with the wind shear assessment of proposed development applications for Council. The assessment is based on the procedures outlined in NASAG (2012) in combination with the upper height restrictions defined in the Sydney Airport OLS (51 m AHD), and an operational 3 s gust wind speed of 30 kt in the cross-wind direction.

I hope this is of assistance, please do not hesitate to contact me if you have any questions regarding any aspect of this report.

Yours sincerely,

Graeme Wood
Director

REFERENCES

NASAG (National Airports Safeguarding Advisory Group), 2012, Managing the risk of building generated windshear and turbulence at airports, Guideline B.

Nieuwpoort, A.M.H., J.H.M. Gooden, & J.L. de Prins, 2010, Wind criteria due to obstacles at and around airports, National Aerospace Laboratory, NLR-TP-2010-312.

Appendix 2: Discussion on Wind Shear and Turbulence

Paragraph 2.2.1 from ICAO (2005) states:

'In the explanation of wind shear given in Chapter 1, the changes in wind speed and/or direction concern changes in the mean (or prevailing) wind from one reference point in space to another. Short-term fluctuations of the wind about a mean direction and/or speed are normally referred to as "variations" from the prevailing wind. Such variations of the wind, individually at least, are temporary, like eddies; while eddies clearly involve wind shear; because they are on a much smaller scale than an aircraft, they tend to affect the aircraft as bumpiness or turbulence. The scale on which the wind shear operates, in relation to the overall size of the aircraft concerned, is therefore of fundamental importance.'

From the above, it can be appreciated that wind shear is based on a difference in mean wind speed between two locations, whereas turbulence is the natural variation in the wind speed and direction due to the flow over the ground.

The "variations" mentioned above are generally called turbulence in the wind engineering community and will be used in this document. Turbulence intensity is a term used to quantify turbulence and is calculated as the standard deviation of wind speed divided by the mean wind speed. This does not give an indication of the size of, or energy level associated with the gusts. A spectral analysis would be required to extract the frequency structure of the gusts from which a measure of the size could be inferred. This is beyond the scope of the current discussion, and would be impractical to monitor full-scale.

To emphasise the difference between wind shear and turbulence, a brief discussion on the driving mechanisms involved in generating turbulence and low level wind shear in the form of a thunderstorm downburst is included. Low level in wind engineering terms is defined as below about 500 m.

The typical atmospheric boundary layer created by synoptic wind events is created by friction at the ground surface, and therefore changes from the ground up. The boundary layer typically extends about 500 to 1000 m above ground level. Increasing friction caused by ground objects causes a decrease in the near ground mean wind speed and an increase in turbulence intensity. The ratio of mean wind speed at 500 m to that at 10 m is typically about 1.6 for winds over open terrain (scattered trees and uncut grass), and 2.1 times for winds over suburbia. The mean wind speed at 500 m over open terrain is about 10% higher than that over suburbia. Turbulence intensity ratios between 500 m and 10 m are typically about 0.4, with winds over suburbia having about 1.3 times the turbulence intensity of those created over open country terrain. It should be noted that at lower wind speeds, less than 10 m/s, the standard deviation and hence turbulence intensity values can increase.

To develop ICAO (2005) defined moderate and strong wind shear in open country terrain from 40 m to 10 m above ground level, the mean wind speed at 10 m would have to be in excess of 18 m/s (36 kt), and 33 m/s (66 kt) respectively. However, paragraph 5.2.8 of ICAO (2005) indicates that an aircraft could withstand a wind shear of 1.67 m/s per s (3 kt/s); for an aircraft landing in open country terrain with a ground speed of 55 m/s on a 3° glide slope, this would relate to a mean wind speed at a height of 10 m of approximately 75 m/s (150 kt), which would evidently never occur.

Turbulence intensity is wind speed dependent and the lower the mean wind speed the higher the turbulence intensity. However, once the mean wind speed exceeds about 10 m/s, (20 kt) the turbulence statistics become relatively less sensitive to wind speed. At the lower wind speeds turbulence intensity is not considered a significant issue to aircraft safety, as the change in relative air speed between the aircraft and the wind is negligible. Turbulence is also a function of the meteorological event; local pressure driven winds such as a summer onshore wind will contain much smoother flow than winds associated with a large frontal system, even if they come from the same direction. This report only deals with developed atmospheric boundary layer flows and does not deal with meteorological events such as frontal systems and thunderstorm events, which cannot be practically modelled.

It is evident from the above, and an appreciation of the different surrounding terrain roughness that the existing wind conditions at an Airport are diverse depending on wind speed and direction. Determining the cause of any turbulence related pilot complaints based on isolated Bureau of Meteorology data would be exceptionally difficult; especially if it could be proven there were a lack of complaints during similar wind event days. It would be considered necessary to investigate the number of similar meteorological events and determine whether similar complaints were received on those days. Discussions with pilots would also be considered important to determine the frequency and severity of turbulent events.

The most likely cause of low level wind shear at the Airport is caused by a frontal system, thunderstorm downdraft, or some form of temperature inversion. One mechanism for generating low level wind shear in thunderstorms is created by a descending column of generally cold air reaching the ground, then being turned by the ground plane, Figure 15. These events are called thunderstorm downbursts. Thunderstorm microbursts have a central diameter of between 400 m and 4 km. The dashed white line starting on the left of Figure 15 at an elevation 1 k ft (300 m) is a typical glide slope for a landing aircraft. The concern for aviation is that a landing aircraft initially experiences a significant headwind in excess of 20 m/s (40 kt), which changes into a tailwind after passing through the impingement point, at the centre of the descending column of air where the wind is coming vertically downward. The headwind causes the aircraft to rise, whereby the pilot will lower the throttle causing the aircraft to descend back to the glide slope, but then tailwind causes a reduction in lift causing the aircraft to land short of the runway. Thunderstorm downburst events typically last for only a few minutes and therefore have the spatial and temporal size to create localised wind shear.

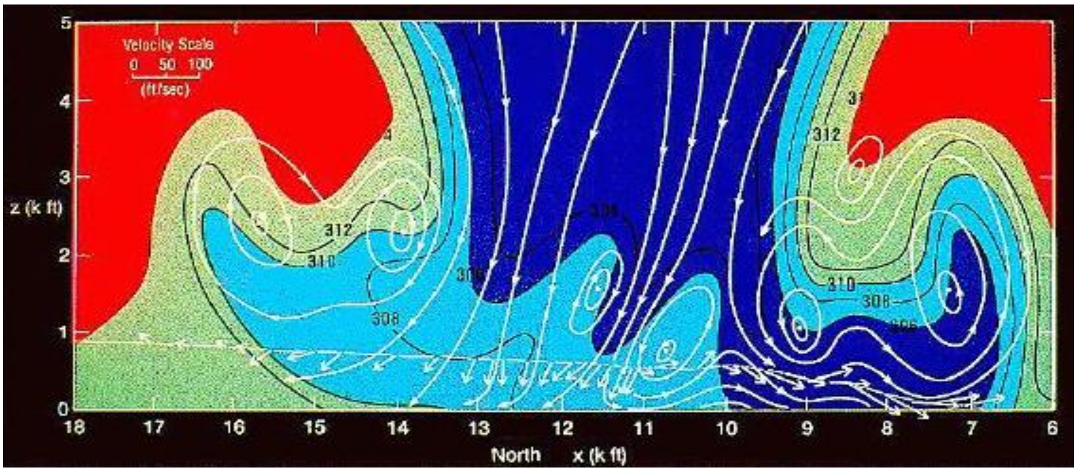


Figure 15: Radar image of a thunderstorm downburst

The wind flow patterns over a building Figure 16, are completely different in that there will be recirculation zones near the windward wall and roof edge, and in the immediate lee of the building. The typical extent of these recirculation zones relative to the height of the structure, h, is illustrated conservatively in Figure 16; for instance Peterka et al. (1985) describe the downstream recirculation zone extending 2 to 6 times the height of the structure. These regions are not fixed but fluctuate in time thereby increasing downstream turbulence, but wind shear would only be experienced in the recirculation zones. As the distance increases from the structure the flow pattern will resort to the undisturbed state. This distance is a function of the geometry of the building, and the roughness of the surrounding terrain, but the mean velocity and turbulence intensity at roof height would be expected to be within 10% of the free stream conditions at 10 times the height of the structure downwind from the building. The building will influence the wind pattern to a distance larger than this, but the magnitude of any change is expected to be slight. The frequency of turbulence shed from the building would be expected to be fairly high and the spatial extend of a similar size to a large aircraft, therefore any effect would be expected to be of short duration.

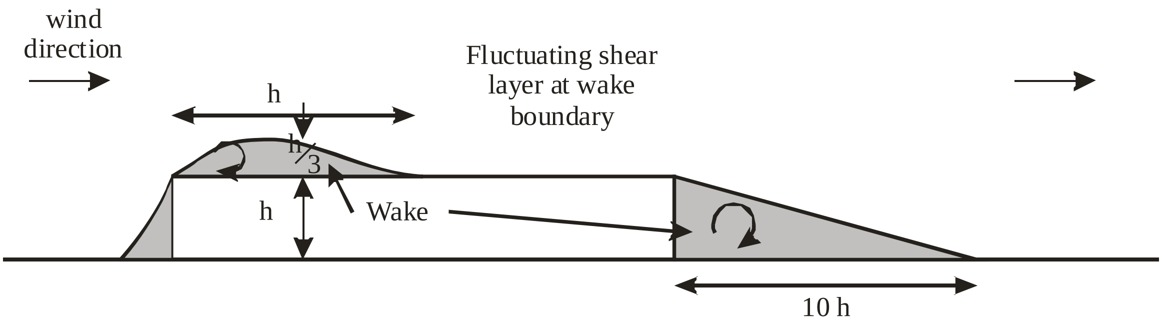


Figure 16: Sketch of the flow pattern over a structure

It is evident from the above that the wind shear situation for flow over a structure is completely different to that for a thunderstorm. Unless the aircraft were to fly directly through one of the small wake regions, which are probably smaller in spatial extent than the aircraft itself, it would not experience any wind shear. The only concern would be if a large building were constructed right next to the runway and there were no provisions for using another runway during strong cross-wind events.

This discussion is in agreement with the ICAO Manual which in section 3.2.2 states:

'…This means that while the buildings are comparatively low, they present a wide and solid barrier to the prevailing surface wind flow. The wind flow is diverted around and over the buildings causing the surface wind to vary along the runway. Such horizontal wind shear, which is normally very localised, shallow and turbulent, is of particular concern to light aircraft operating into smaller aerodromes, but has also been known to affect larger aircraft.'