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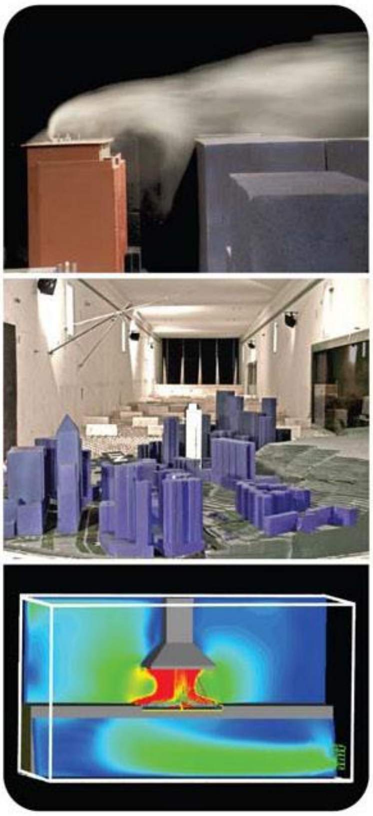
WIND ENGINEERING AND AIR QUALITY CONSULTANTS

Final Report Rev.2

Environmental Wind Tunnel Test Report for SSDA 6:



SYDNEY INTERNATIONAL CONVENTION, EXHIBITION AND ENTERTAINMENT PRECINCT (SICEEP): ICC HOTEL

Sydney, Australia

CPP Project 7006

28 August 2013

Prepared for:
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EXECUTIVE SUMMARY

Cermak Peterka Petersen Pty. Ltd. has been engaged by Lend Lease Project Management & Construction (Australia) Pty to assess the proposed International Convention Centre (ICC) Hotel component of the Sydney International Convention Centre, Exhibition and Entertainment Precinct (SICEEP) in terms of Wind Impact. This report supports a State Significant Development Application (SSDA) submitted to the Minister for Planning and Infrastructure pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act).

The SICEEP Project will result in the lodgement of numerous SSD DAs for the various components of the redevelopment project. SSD DA wind report have already been lodged for the PPP component of the SICEEP Project (comprising the convention centre, exhibition centre, entertainment facility and ancillary premises and associated public domain upgrades), and the Concept Proposal for The Haymarket precinct.

This report provides an assessment of the impact of the ICC Hotel on the amenity of the wind environment of the site by providing a Development Specific Wind Report SSDA6 to meet DGR requirements. To achieve this, a model of the ICC Hotel, with replicas of surrounding buildings within a 570 m radius, was constructed to a 1:400 scale on a turntable in the wind tunnel. A wind tunnel study was conducted as part of the Development Specific assessment, and one configuration was tested: Configuration A comprising the proposed ICC Hotel with the International Convention Centre (ICC), the ICC Exhibition Centre, and The Theatre with otherwise existing surrounds.

The report also makes reference to City of Sydney, (2004), “Central Sydney Development Control Plan 1996” and City of Sydney (2012), “Sydney Development Control Plan 2012, Section 3 General Provisions” as best practice guideline.

The wind tunnel testing was performed in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd., St. Peters. Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 9 locations for 16 wind directions each. These points were tested in the proposed configuration. The measurements were combined with wind statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location.

The street level wind environment is approaching or exceeding the pedestrian walking criterion at several locations. All locations passed the general distress criterion, with the exception of one location, which rated as acceptable for able bodied patrons only.

It should be noted that the model for the ICC Hotel building is a massing model only and further improvement in the conditions at this locations are possible through the development of the design.

The degree of wind mitigation required will depend on the intended use of the space, the final form of the Hotel, and the directional wind climate. A mitigation strategy will be developed with the design team during development of the Hotel building form where required to deal with potential issues.

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D	Characteristic dimension (building height, width, etc.)
n	Mean velocity profile power law exponent
T_u	Turbulence intensity, U_{rms}/U
U	Local mean velocity
U_{ref}	Reference velocity at reference height z_{ref}
U_{pk}	Peak wind speed in pedestrian studies
U_{rms}	Root-mean-square of fluctuating velocity
z	Height above surface
ν	Kinematic viscosity of approach flow
$\sigma(\ )$	Standard deviation of $(\ ), = (\ )'_{\mathrm{rms}}$
ρ	Density of approach flow
$(\ )_{\mathrm{max}}$	Maximum value during data record
$(\ )_{\mathrm{min}}$	Minimum value during data record
$(\ )_{\mathrm{mean}}$	Mean value during data record
$(\ )_{\mathrm{rms}}$	Root mean square about the mean

1. INTRODUCTION

Pedestrian acceptability of footpaths, entrances, plazas, and terraces in terms of wind impact is an important design parameter. Assessment of the acceptability of the pedestrian level wind environment is desirable during the project design phase so that modifications can be made and mitigation measures put in place if necessary, to create wind conditions suitable for the intended use of the space.

Analytical methods such as computational fluid dynamics (CFD) are not capable, except in very simple geometries, of estimating wind pressures, frame loads, or windiness in pedestrian areas.

Techniques have been developed which permit boundary layer wind tunnel modelling of buildings to determine wind velocities in pedestrian areas. This report includes wind tunnel test procedures, test results, and a discussion of test results obtained. Table 1 summarizes the model configurations, test methods, and data acquisition parameters. All data collection was performed in accordance with Australasian Wind Engineering Society (2001), and American Society of Civil Engineers (1999, 2010).

Table 1: Configurations for data acquisition

General Information	
Model scale	1:400
Surrounding model radius (full-scale)	570 m
Reference height (full-scale)	200 m
Approach Terrain Category	Terrain Category 3
Testing Configuration(s)	
Configuration A	Proposed ICC Hotel development with existing surrounding buildings and landscape and the proposed PPP developments, as shown in Figure 5. Pedestrian winds measured at 9 locations for 16 wind directions in 22.5° increments from 0° (north).

2. CLIENT PROVIDED PROJECT INFORMATION

2.1. Introduction

This report supports a State Significant Development Application (SSDA) submitted to the Minister for Planning and Infrastructure pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act).

The Application (referred to as SSDA6) seeks approval for construction of the International Convention Centre (ICC) Hotel component of the Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) at Darling Harbour.

This SSDA follows SSDA1, which seeks approval for the core convention, exhibition and entertainment facilities of the SICEEP Project; SSDA2, a staged application that sets out a Concept Proposal for a new mixed use neighbourhood at Darling Harbour known as ‘The Haymarket’; and a number of detailed proposals (SSDA3, SSDA4, and SSDA5) for use of development plots within The Haymarket. SSDAs 1 and 2 were submitted to the Department of Planning and Infrastructure (DoPI) in March 2013, and the SSDAs 3-5 were submitted in May 2013.

The ICC Hotel forms part of the SICEEP Project, which will deliver Australia’s global city with new world class convention, exhibition and entertainment facilities and support the NSW Government’s goal to “make NSW number one again”.

2.2. Overview of Proposed Development

The proposal relates to a SSDA for the ICC Hotel component of the SICEEP Project. The hotel is located at the northern end of the precinct and comprises a single building with up to 656 keys. The hotel is being developed by Lend Lease and is consistent with Darling Harbour Live’s Preferred Precinct Plan.

More specifically, this SSDA seeks approval for the following components of the development:

- Demolition of existing site improvements;
- Associated tree removal and replanting;
- Construction and use of a single hotel tower providing for up to 656 keys and including guest facilities, restaurant and ballroom;
- Public domain improvements including integration with existing / proposed works; and
- Extension, realignment and augmentation of physical infrastructure / utilities as required.

2.3. Background

The NSW Government considers that a precinct-wide renewal and expansion of the existing convention, exhibition and entertainment centre facilities at Darling Harbour is required, and is committed to Sydney reclaiming its position on centre stage for hosting world-class events with the creation of the Sydney International Convention, Exhibition and Entertainment Precinct.

Following an extensive and rigorous Expressions of Interest and Request for Proposals process, a consortium comprising AEG Ogden, Lend Lease, Capella Capital and Spotless was announced by the NSW Government in December 2012 as the preferred proponent to transform Darling Harbour and create SICEEP.

Key features of the Preferred Precinct Plan include:

- Delivering world-class convention, exhibition and entertainment facilities, including:
    - Up to 40,000m^2 exhibition space;
    - Over 8,000m^2 of meeting rooms space, across 40 rooms;
    - Overall convention space capacity for more than 12,000 people;
    - A ballroom capable of accommodating 2,000 people; and
    - A premium, red-carpet entertainment facility with a capacity of 8,000 persons.
- Providing a hotel complex at the northern end of the precinct, immediately adjacent to the new International Convention Centre.
- A vibrant and authentic new neighbourhood at the southern end of the precinct, called 'The Haymarket', including apartments, student accommodation, community facilities, shops, cafes and restaurants.
- Renewed and upgraded public domain that has been increased by a hectare, including an outdoor event space for up to 27,000 people at an expanded Tumbalong Park.
- Improved pedestrian connections linking to the proposed Goods Line (formerly Ultimo Pedestrian Network) drawing people between Central, Chinatown and Cockle Bay Wharf as well as east-west between Ultimo/Pyrmont and the City.

2.4. Site Description

The SICEEP Site is located within Darling Harbour. Darling Harbour is a 60 hectare waterfront precinct on the south-western edge of the Sydney Central Business District that provides a mix of functions including recreational, tourist, entertainment and business.

With an area of approximately 20 hectares, the SICEEP Site is generally bound by the Light Rail Line to the west, Harbourside shopping centre and Cockle Bay to the north, Darling Quarter, the Chinese Garden and Harbour Street to the east, and Hay Street to the south. The SICEEP Site has been divided into three redevelopment areas – Bayside, Darling Central and The Haymarket.

The ICC Hotel Site (refer to Figure 1):

- Is located within the northern end of the Bayside precinct;
- Is bound by Harbourside Shopping Centre to the north and east, the International Convention Centre to the south and Darling Drive to the west; and
- Occupies an area of approximately 3,730m2.

Figure 1: The SICEEP development site

2.5. Planning Approvals Strategy

The SICEEP Project will result in the lodgement of numerous SSDAs for the various components of the redevelopment project. SSDAs have already been lodged for the PPP component of the SICEEP Project (comprising the convention centre, exhibition centre, entertainment facility and ancillary commercial premises and associated public domain upgrades), the Stage 1 Concept Proposal for The Haymarket, and the Stage 2 detailed proposals for three of the development plots within The Haymarket. Future applications will be lodged for the remaining development plots within The Haymarket Site.

This Application relates to a SSDA6 for the ICC Hotel component of the SICEEP Project and is consistent with Darling Harbour Live’s Preferred Precinct Plan.

3. THE WIND TUNNEL TEST

Modelling of the aerodynamic flow around a structure requires special consideration of flow conditions to obtain similitude between the model and the prototype. A detailed discussion of the similarity requirements and their wind tunnel implementation can be found in Cermak (1971, 1975, 1976). In general, the requirements are that the model and prototype be geometrically similar, that the approach mean velocity and turbulence characteristics at the model building site have a vertical profile shape similar to the full-scale flow, and that the Reynolds number for the model and prototype be equal. Due to modelling constraints, the Reynolds number cannot be made equal and Australasian Wind Engineering Society Quality Assurance Manual (2001) suggests a minimum Reynolds number of 50,000, based on minimum model width and wind velocity at the top of the model; in this study the modelled Reynolds number was over 50,000.

The wind tunnel test was performed in the boundary layer wind tunnel shown in Figure 2. The wind tunnel test section is 3.0 m wide, by 2.4 m high with a porous slatted roof for passive blockage correction. This wind tunnel has a 21 m long test section, the floor of which is covered with roughness elements, preceded by a vorticity generating fence and spires The spires, fence, and roughness elements were designed to provide a modelled atmospheric boundary layer approximately 1.2 m thick with a mean velocity and turbulence intensity profile similar to that expected to occur in the region approaching the modelled area. The approach wind characteristics used for the model test are shown in Figure 3 and are explained more fully in Section 5.1.1.

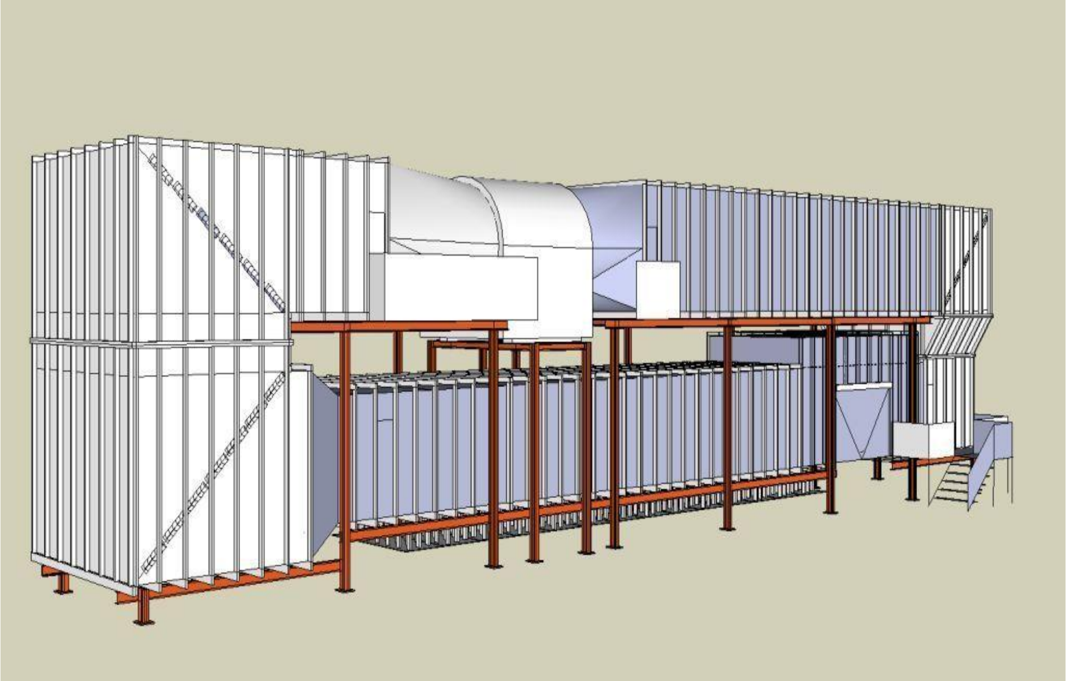


Figure 2: Schematic of the closed circuit wind tunnel

A model of the proposed development and surrounds to a radius of 570 m was constructed at a scale of 1:400, which was consistent with the modelled atmospheric flow, permitted a reasonable test model size with an adequate portion of the adjoining environment to be included in a proximity model, and was within wind tunnel blockage limitations. Significant variations in the building surface were formed into the model. A model of the ICC Hotel building was fabricated based on the design drawings. The models were mounted on the turntable located near the upstream end of the wind tunnel test section, Figure 4. The turntable permitted rotation of the modelled are for examination of velocities from any approach wind direction. Additional photographs of the testing are in Appendix 1.

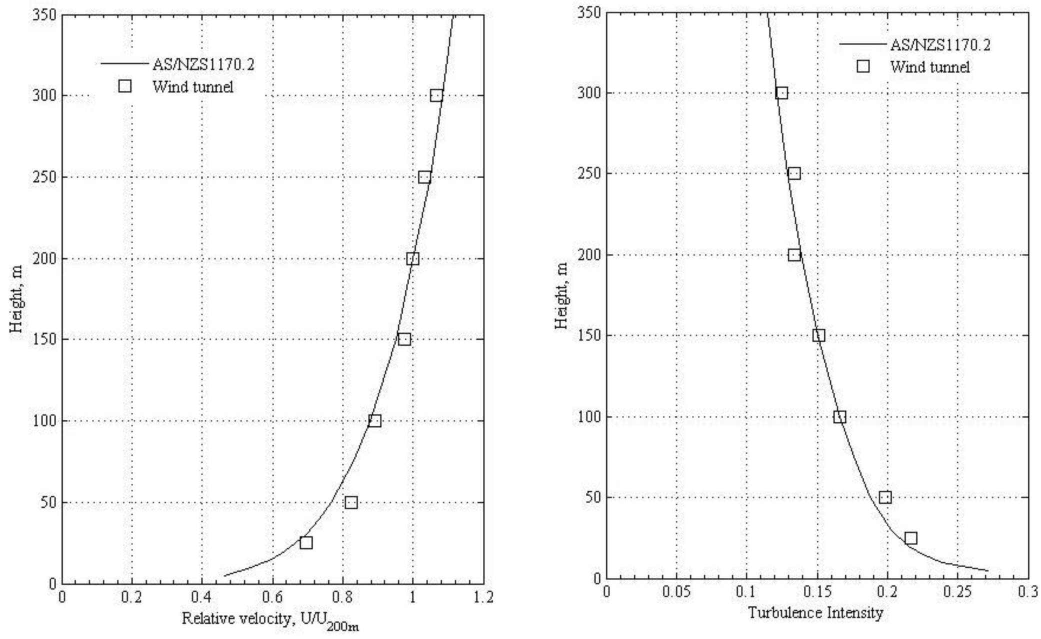


Figure 3: Mean velocity and turbulence profiles approaching the model

Figure 4: Configuration A in the CPP wind tunnel – View from the North

4. ENVIRONMENTAL WIND CRITERIA

Over the years, a number of researchers have added to the knowledge of wind effects on pedestrians by suggesting criteria for comfort and safety. Because pedestrians will tolerate higher wind speeds for a smaller period of time than for lower wind speeds, these criteria provide a means of evaluating the overall acceptability of a pedestrian location. Also, a location can be evaluated for its intended use, such as for an outdoor café or a footpath. One of the most widely accepted set of criteria was developed by Lawson (1990), which is described in Table 2.

Lawson's criteria have categories for comfort, based on wind speeds exceeded five percent of the time, allowing planners to judge the usability of locations for various intended purposes ranging from "Business Walking" to "Pedestrian Sitting". The level and severity of these comfort categories can vary based on individual preference, so calibration to the local wind environment is recommended when evaluating the Lawson ratings. The criteria also include a distress rating, for safety assessment, which is based on occasional (once or twice per year) wind speeds[1]. In both cases, the wind speed used is the larger of a mean or gust equivalent-mean (GEM) wind speed. The GEM is defined as the peak gust wind speed divided by 1.85 for a typical turbulent environment; this is intended to account for locations where the gustiness is the dominant characteristic of the wind. Assessment using the Lawson criteria provides a similar classification as using the once per annum gust, which is the basis of the City of Sydney (2004) DCP, however provides information regarding the serviceability wind climate. The current City of Sydney (2012) DCP specifies wind effects not to exceed 16 m/s as the area is not classified as an 'active frontage'. From discussions with Council this is a once per annum gust wind speed similar to the 2004 DCP, but is meant to be interpreted as a comfort level criterion similar to the lower limit of the Lawson "Business Walking" rating, and is not a distress requirement.

Table 2: Summary of Lawson criteria

Comfort (maximum of mean or gust equivalent mean (GEM^{+}) wind speed exceeded 5% of the time)	
< 4 m/s	Pedestrian Sitting (considered to be of long duration)
4 - 6 m/s	Pedestrian Standing (or sitting for a short time or exposure)
6 - 8 m/s	Pedestrian Walking
8 - 10 m/s	Business Walking (objective walking from A to B or for cycling)
> 10 m/s	Uncomfortable
Distress (maximum of mean or GEM wind speed exceeded 0.022% of the time)	
<15 m/s	not to be exceeded more than two times per year (or one time per season) for general access area
<20 m/s	not to be exceeded more than two times per year (or one time per season) where only able bodied people would be expected; frail or cyclists would not be expected

[1] The rating of "uncomfortable" in Table 2 is the word of the acceptance criteria author and may not apply directly to any particular project. High wind areas are certainly not uncomfortable all the time, just on windier days. The word uncomfortable, in our understanding, refers to acceptability of the site by pedestrians for typical pedestrian use; i.e., on the windiest days, pedestrians will not find the areas "acceptable" for walking and will tend to avoid such areas if possible. The distress rating fail indicates some unspecified potential for causing injury to a less stable individual who might be blown over. The likelihood of such events is not well described in the literature and is likely to be strongly affected by individual differences, presence of water, blowing dust or particulates, and other variables in addition to the wind speed.

5. DATA ACQUISITION AND RESULTS

5.1. Velocities

Velocity profile measurements were taken to verify that appropriate boundary layer flow approaching the site was established and to determine the likely pedestrian level wind climate around the test site. Pedestrian wind measurements and analysis are described in Section 5.1.2. All velocity measurements were made with hot-film anemometers, which were calibrated against a Pitot-static tube in the wind tunnel. The calibration data were described by a King's Law relationship (King, 1914)

5.1.1. Velocity Profiles

Mean velocity and turbulence intensity profiles for the boundary layer flow approaching the model are shown in Figure 3. Turbulence intensities are related to the local mean wind speed. These profiles have the form of Category 3 winds as defined in Standards Australia (2011) and are appropriate for the approach conditions.

5.1.2. Pedestrian Winds

The proposed development is located to the west of Sydney CBD and to the west-northwest of Darling Harbour. The ICC Hotel development is surrounded by the Harbourside Shopping Centre to the East, the proposed International Convention Centre to the south-southeast and the Novotel Sydney hotel to the west, refer to Figure 5. For this report, wind speed measurements were recorded at 9 locations to evaluate pedestrian comfort around the project site, as shown in Figure 7 and Figure 8. Velocity measurements were made at the model scale equivalent of 1.5 to 2.1 m above the ground surface for 16 wind directions at 22.5° intervals. Locations were chosen to determine the degree of pedestrian comfort at the building corners where relatively severe conditions are frequently found, near building entrances, on adjacent pavements with heavy pedestrian traffic, in open plaza areas, and on proposed terraces.

The hot-film signal was sampled for a period corresponding to one hour in prototype. All velocity data were digitally filtered to obtain the two to three second running mean wind speed at each point; this is the minimum size of a gust affecting a pedestrian. These local wind speeds, U, were normalised by the tunnel reference velocity U_{ref}. Mean and turbulence statistics were calculated and used to calculate the normalised effective peak gust using $\frac{U_{pk}}{U_{ref}} = \frac{U + 3 \cdot U_{rms}}{U_{ref}}$.

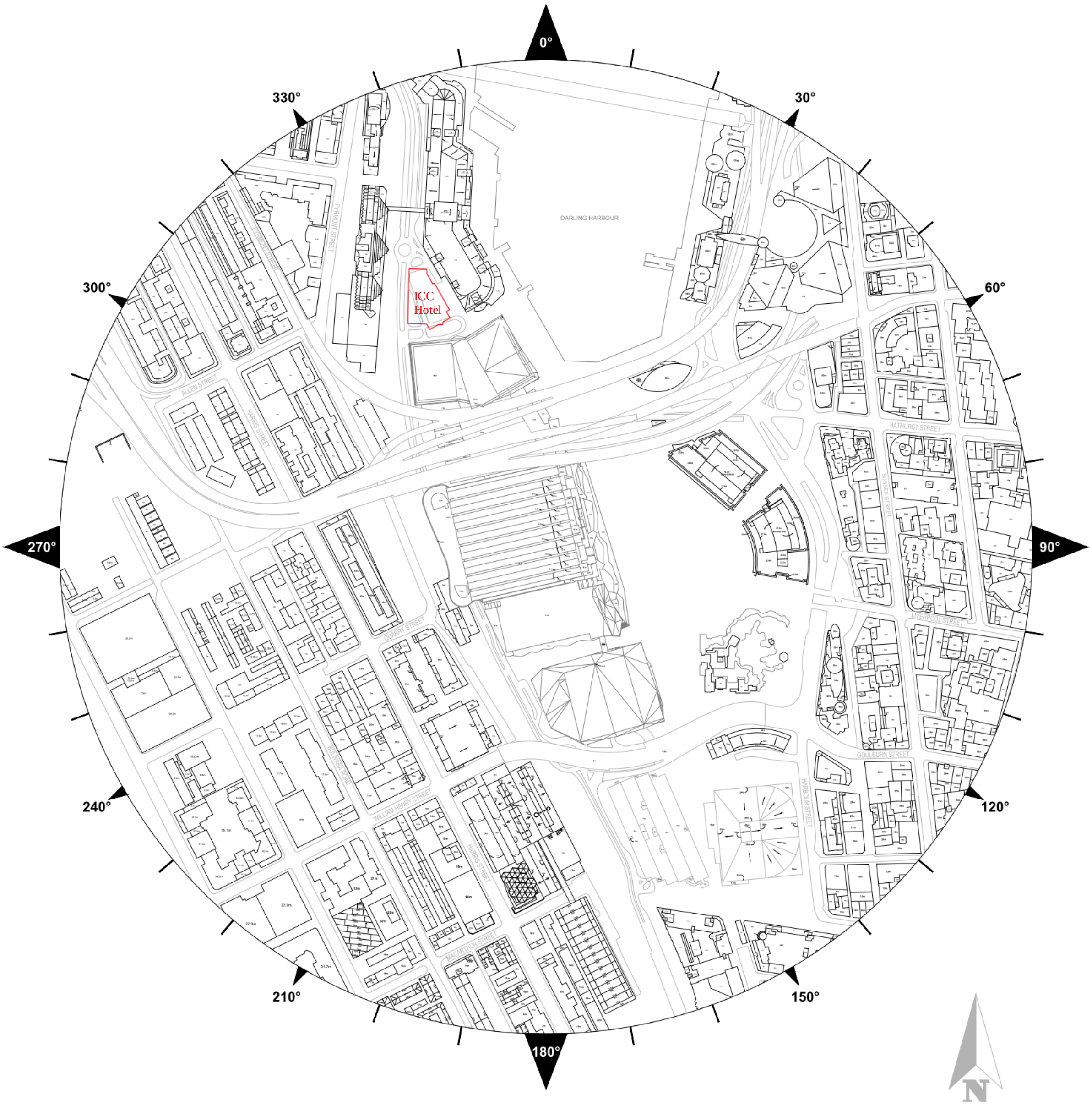


Figure 5: Extent of model for Configuration A

The mean and gust equivalent mean velocities relative to the free stream wind tunnel reference velocity at a full-scale elevation of 200 m are plotted in polar form in Appendix 2. The graphs show velocity magnitude and the approach wind direction for which that velocity was measured. The polar plots aid in visualisation of the effects of the nearby structures or topography, the relative significance of various wind azimuths, and whether the mean or gust is of greater importance.

To enable a quantitative assessment of the wind environment, the wind tunnel data were combined with wind frequency and direction information measured by the Bureau of Meteorology at a standard height of 10 m at Sydney Airport from 1974 to 2008, Figure 6. This anemometer location is considered the most appropriate for analysis of the historic wind climate as the approach flow is flat and relatively consistent from all directions, and the immediate surrounds has not changed significantly through development over time compared with other anemometer locations in Sydney CBD. From these data, directional criterion lines for the Lawson rating wind speeds have been calculated and included on the polar plots in Appendix 2; this gives additional information regarding directional sensitivity at each location.

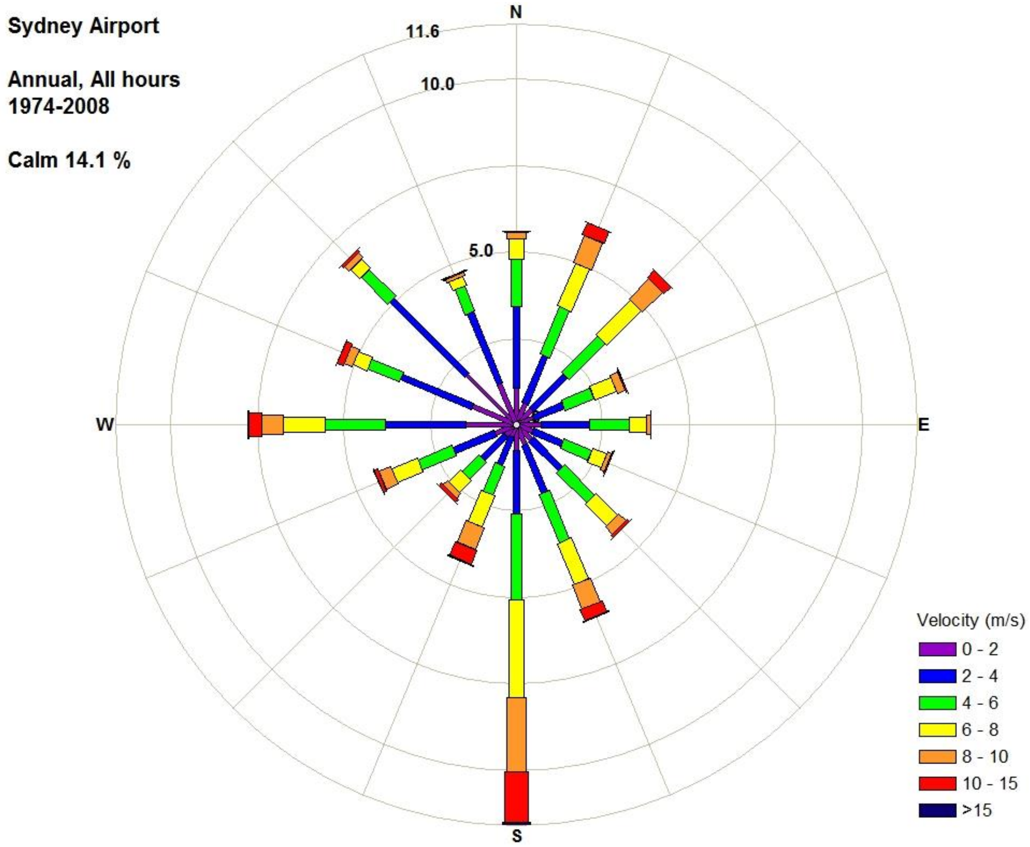


Figure 6: Wind rose of direction and speed for Sydney Airport

The criteria of Lawson consider the integration of the velocity measurements with local wind climate statistical data summarized in Figure 6 to rate each location. From the cumulative wind speed distributions for each location, the percentage of time each of the Lawson comfort rating wind speeds are exceeded are presented in tabular form under the polar plots in Appendix 2.

In addition to the rating wind speeds, the percentage of time that 2 m/s is exceeded is also reported. This has been provided as it has been found that the limiting wind speed for long-term stationary activities such as fine outdoor dining should be about 2 to 2.5 m/s rather than 4 m/s. Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people. The earliest quantitative description of wind effects was established by Sir Francis Beaufort in 1806, for use at sea; the Beaufort scale is reproduced in Table 3 including qualitative descriptions of wind effects.

Table 3: Summary of wind effects on people, Penwarden (1973)

Description	Beaufort Number	Speed (m/s)	Effects
Calm, light air	0, 1	0–2	Calm, no noticeable wind.
Light breeze	2	2–3	Wind felt on face.
Gentle breeze	3	3–5	Wind extends light flag. Hair is disturbed. Clothing flaps
Moderate breeze	4	5–8	Raises dust, dry soil, and loose paper. Hair disarranged.
Fresh breeze	5	8–11	Force of wind felt on body. Drifting snow becomes airborne. Limit of agreeable wind on land.
Strong breeze	6	11–14	Umbrellas used with difficulty. Hair blown straight. Difficult to walk steadily. Wind noise on ears unpleasant. Windborne snow above head height (blizzard).
Near gale	7	14–17	Inconvenience felt when walking.
Gale	8	17–21	Generally impedes progress. Great difficulty with balance in gusts.
Strong gale	9	21–24	People blown over by gusts.

The tables in Appendix 2 additionally provide the wind speed exceeded 5% and 0.022% of the time for direct comparison with the Lawson criteria and the associated Lawson ratings for both mean and GEM wind speeds. The wind speeds for the 0.022% case can be multiplied by 1.4 for general comparison with the City of Sydney Council (2012) requirements.

A colour coded summary assessment of pedestrian comfort and safety with respect to the Lawson criteria is presented in Figure 7 and Figure 8, for each test location in Configuration A. Because some pedestrian wind measurement positions are purposely chosen at sites where large velocities of small spatial extent may exist, the general wind environment about the structure may be less severe than one might infer from an analysis only of the plots. The implications of the results are discussed in Section 6.

It should be noted that Sydney is relatively windy, with an average wind speed at 10 m reference height of approximately 4 m/s (8 kt, 14 kph) at Sydney Airport, and five percent of the time the mean wind speed is in excess of 9.5 m/s (18 kt, 34 kph). Converting the five percent of the time wind speed at Sydney Airport to a typical pedestrian level in a generic urban environment of similar building massing to the SICEEP development would result in about 6.0 m/s (12 kt, 22 kph). Comparing this with the comfort criteria of Table 2 suggests that the pre-existing locale would only just be acceptable for pedestrian walking prior to development; hence any recreational outdoor activity for any significant development of this site will likely require significant amelioration from prevailing Sydney wind directions.

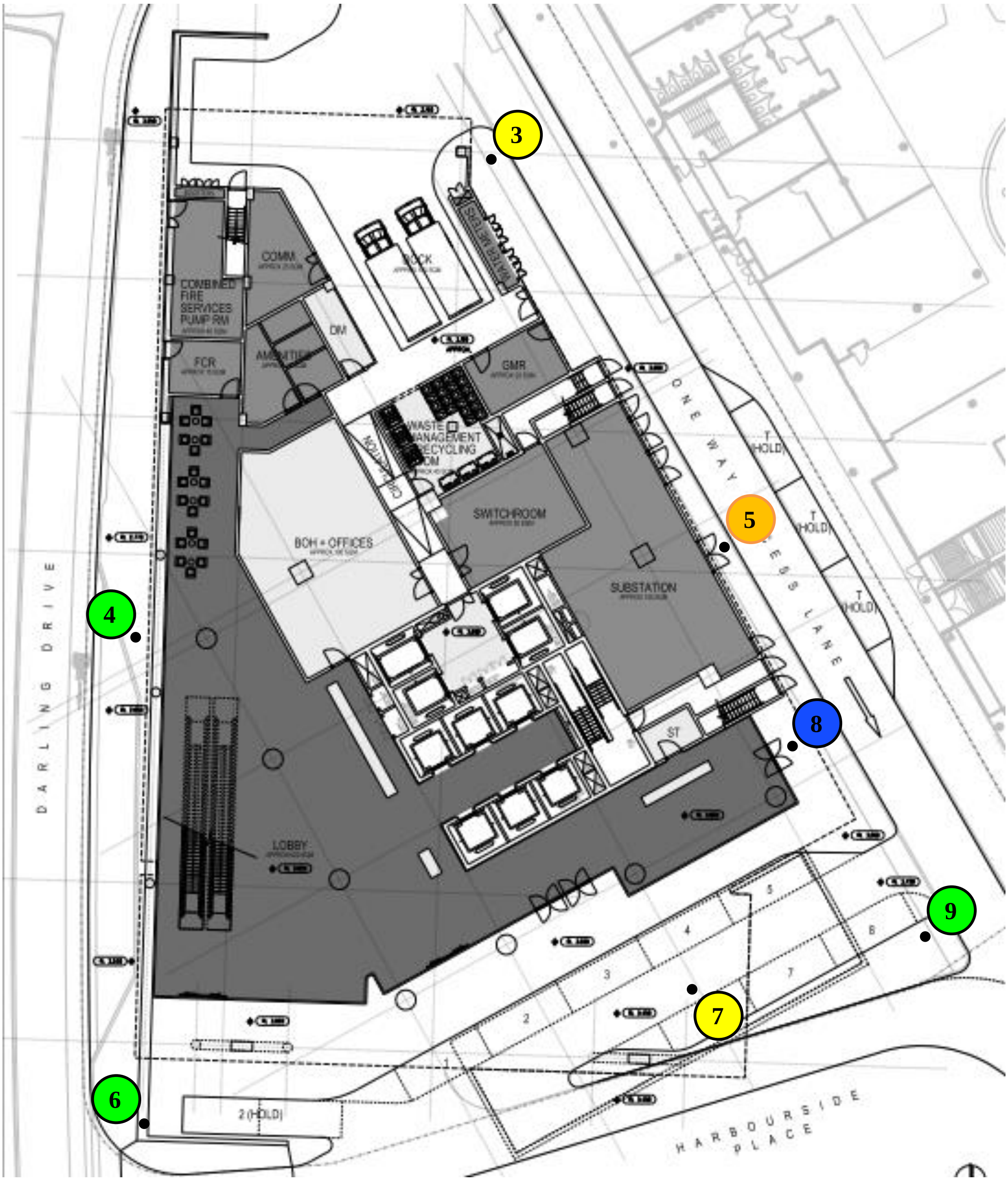


Figure 7: Pedestrian wind speed measurement locations with ratings – Ground Level

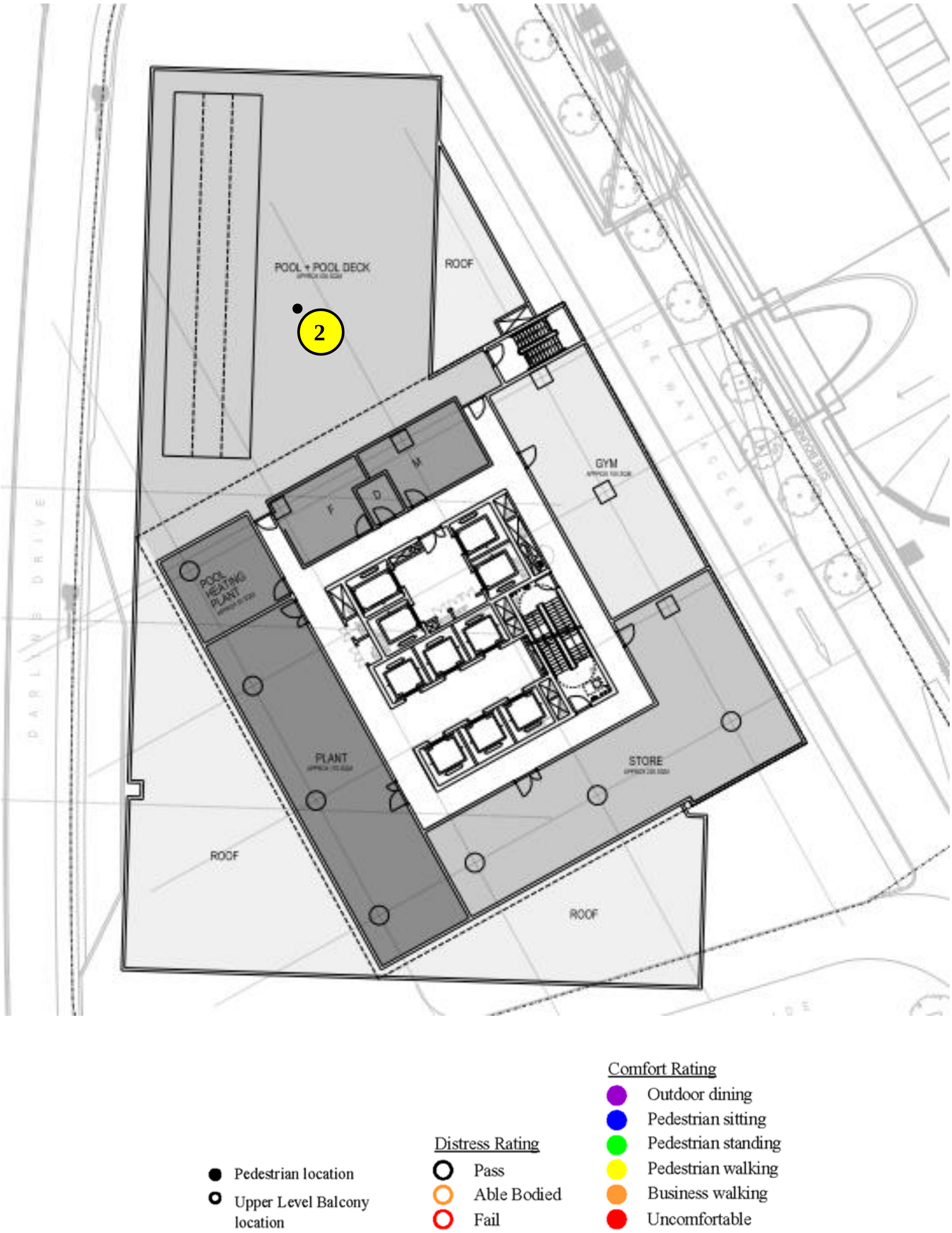


Figure 8: Pedestrian wind speed measurement locations with ratings – Level 4

6. DISCUSSION

The wind climatology chart of Figure 6 indicates that the most frequent strong winds are from the south, and to a lesser extent, the west and north-east. The locations tested around the development site are susceptible to winds from different directions, depending on the relative location of the point tested to the tower geometry and surrounds. The influence of wind direction on the suitability of a location for an intended purpose can also be ascertained from the graphs in Appendix 2.

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded images of Figure 7 and Figure 8, which depict the locations selected for investigation of pedestrian wind comfort around the site along with the Lawson criteria rating for both comfort and distress. The central colour indicates the comfort rating for the location, and the colour of the outer ring indicates whether the location passes the distress criterion.

Mitigation measures are likely to be required for red locations, as well as orange locations on main pedestrian thoroughfares, and may be necessary for other locations depending on the intended use of the space and to meet the City of Sydney ‘active frontage’ requirement.

Although wind conditions may be classified acceptable there may be certain wind directions that cause regular strong events, these can be determined by an inspection of the plots in Appendix 2. Note that testing was performed without planned trees, or other plantings to provide a worst case assessment; heavy streetscape planting typically reduces the wind speeds by less than 10%.

6.1. Configuration A Results

Tests for Configuration A were conducted with the proposed International Convention Centre (ICC), ICC Exhibition Centre and The Theatre in place, and with the Haymarket precinct as it exist today. The proposed ICC Hotel building is taller than the immediately surrounding developments, and will have some exposure to the prevailing wind directions.

It is evident from Figure 7 that the wind environment around the proposed development in Configuration A is approaching or exceeding the pedestrian walking criterion at several locations. All locations passed the general distress criterion, with the exception of Location 5, which rated as acceptable for able bodied patrons only.

The windier conditions at Location 5 can be attributed to southerly winds downwashing against the southern tower façade toward ground level then channelling along the one way access lane between the east tower façade and Harbourside Shopping Centre. Winds at this location may require further treatment if this area is to be designated for continuous pedestrian access. A similar wind flow mechanism is producing strong winds at Location 3 but of lower velocity. Location 9, on the corner of Harbourside Place and one way access lane, rated as suitable for pedestrian standing being less susceptible to downwash flows under prevailing winds. It is noted wind conditions at entrance Location 8 receive wind shelter from the local building recess and are calm meeting the Lawson pedestrian sitting criterion.

Locations 4 and 6 are rated as acceptable for pedestrian standing. The strongest winds at these locations appear to be due to winds channelling along Darling Drive.

Location 7, under the canopy at the south entrance of the building, was rated at pedestrian walking levels. This entry area will be windiest for approaching south-west or north-east wind directions. North-east winds downwash from the east façade then continue to channel beneath the canopy area between the Hotel and the Convention Centre building. Windbreak treatment to the east of the southern lobby entry will be investigated during design development.

Location 2, shown in Figure 8, rated as acceptable for pedestrian walking. Higher winds are encountered at this location given the elevation and wind exposure of podium level 4.

A Location 1 was tested at level 37 adjacent the east façade to assist with façade design during the detail design phase.

7. CONCLUSIONS

A wind tunnel investigation of the pedestrian level wind environment around the proposed ICC Hotel development has been conducted. The street level wind environment is approaching or exceeding the pedestrian walking criterion at several locations. All locations passed the general distress criterion, with the exception of one location, which rated as acceptable for able bodied patrons only.

It should be noted that the model for the ICC Hotel building is a massing model only and further improvement in the conditions at this locations are possible through the development of the design.

The degree of wind mitigation required will depend on the intended use of the space, the final form of the Hotel, and the directional wind climate. A mitigation strategy will be developed with the design team during development of the Hotel building form where required to deal with potential issues.

8. REFERENCES

American Society of Civil Engineers (1999), *Wind Tunnel Model Studies of Buildings and Structures* (ASCE Manual of Practice Number 67).

American Society of Civil Engineers (2010), *Minimum Design Loads for Buildings and Other Structures* (ASCE 7–10).

Australasian Wind Engineering Society (2001), *Wind Engineering Studies of Buildings* (AWES-QAM-1-2001).

Cermak, J.E. (1971), "Laboratory Simulation of the Atmospheric Boundary Layer," *AIAA Jl.*, Vol. 9, September.

Cermak, J.E. (1975), "Applications of Fluid Mechanics to Wind Engineering," A Freeman Scholar Lecture, *ASME Journal of Fluids Engineering*, Vol. 97, No. 1, March.

Cermak, J.E. (1976), "Aerodynamics of Buildings," *Annual Review of Fluid Mechanics*, Vol. 8, pp. 75 – 106.

City of Sydney, (2004), "Central Sydney Development Control Plan 1996".

City of Sydney (2012), "Sydney Development Control Plan 2012, Section 3 General Provisions".

King, C.V. (1914), "On the Convection of Heat From Small Cylinders in a Stream of Fluid," *Philosophical Transactions of the Royal Society*, London, Vol. A214, p. 373.

Lawson, T.V. (1990), "The Determination of the Wind Environment of a Building Complex before Construction" Department of Aerospace Engineering, University of Bristol, *Report Number TVL 9025*.

Penwarden, A.D. (1973), "Acceptable wind speeds in towns", Building Science, Vol.8, pp. 259-267.

Standards Australia (2011), *Australian/New Zealand Standard, Structural Design Actions, Part 2: Wind Actions* (AS/NZS1170 Pt.2).

Architectural Drawings

Assessment of wind effects in this report has been based upon drawings provided by Lend Lease Design.

Appendix 1: Additional Photographs of the CPP Wind Tunnel Model

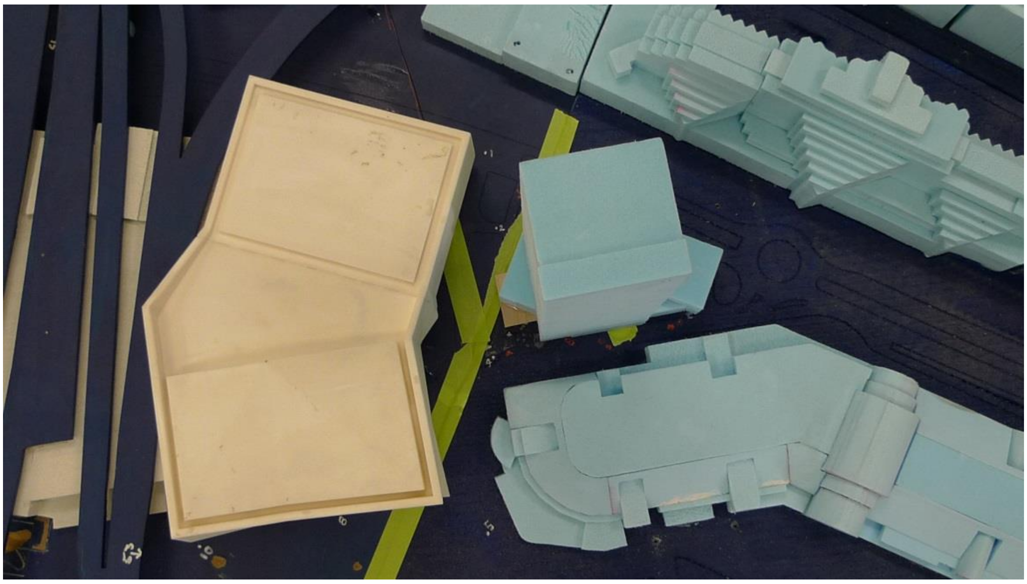


Figure 9: ICC Hotel – Top View

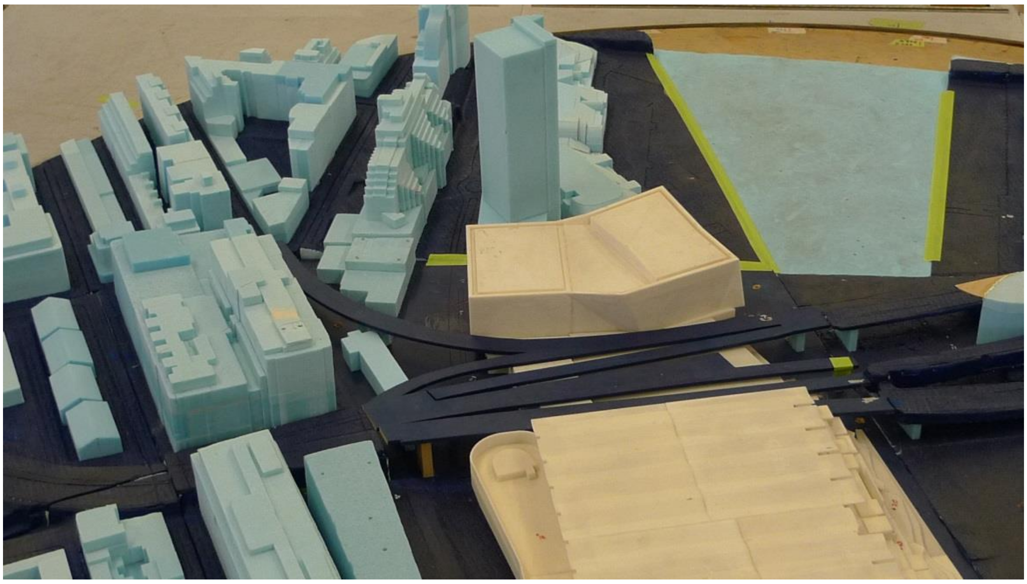


Figure 10: ICC Hotel – South View

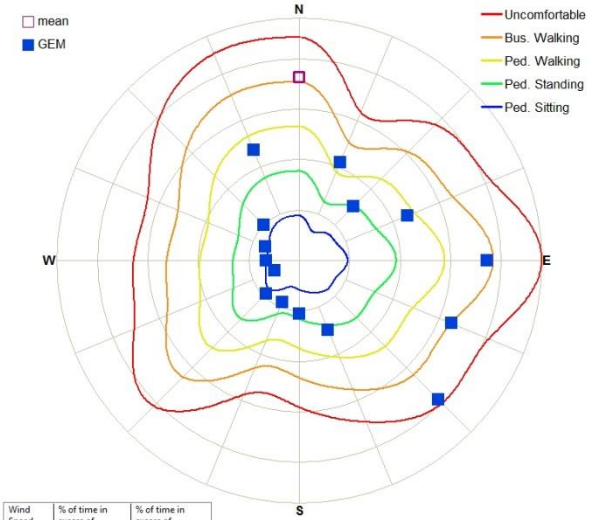
Figure 11: ICC Hotel – West View

Figure 12: ICC Hotel – North View

Figure 13: ICC Hotel – East View

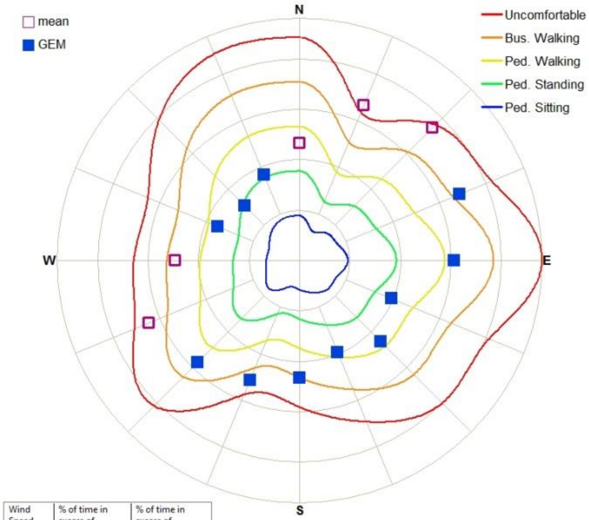
Appendix 2: Directional Wind Results for Configuration A

LOCATION 1



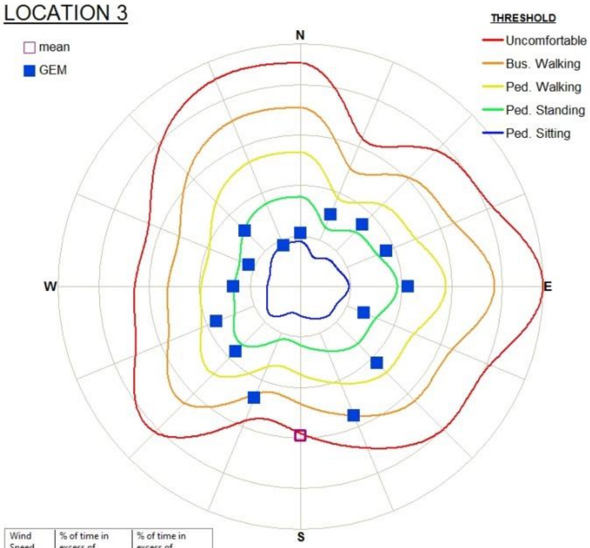
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	39.4	51.6
4.0	14.0	18.3
6.0	4.4	6.6
8.0	0.9	1.7
10.0	0.2	0.4
5.7	**5.0**	Ped Standing
12.6	**0.022**	Pass
6.4	Ped Walking	**5.0**
12.9	Pass	**0.022**

LOCATION 2



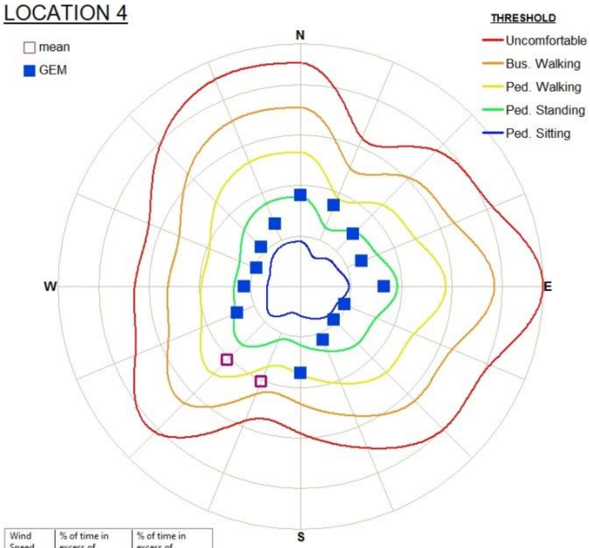
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	71.1	75.3
4.0	32.9	38.5
6.0	12.5	14.5
8.0	4.0	3.8
10.0	1.0	0.6
7.5	**5.0**	Ped Walking
13.5	**0.022**	Pass
7.6	Ped Walking	**5.0**
12.9	Pass	**0.022**

LOCATION 3



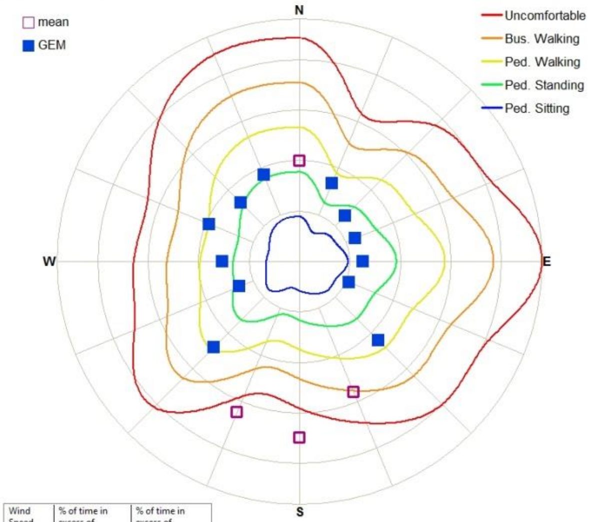
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	47.4	55.8
4.0	18.8	22.9
6.0	9.2	8.7
8.0	3.0	2.4
10.0	0.8	0.5
7.1	**5.0**	Ped Walking
14.2	**0.022**	Pass
6.9	Ped Walking	**5.0**
13.4	Pass	**0.022**

LOCATION 4



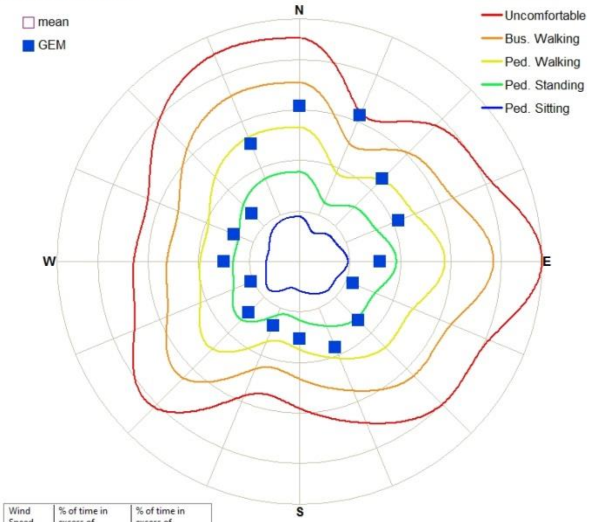
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	34.7	45.7
4.0	9.3	10.3
6.0	1.3	1.1
8.0	0.1	0.1
10.0	0.0	0.0
4.6	**5.0**	Ped Standing
9.7	**0.022**	Pass
4.7	Ped Standing	**5.0**
9.0	Pass	**0.022**

LOCATION 5



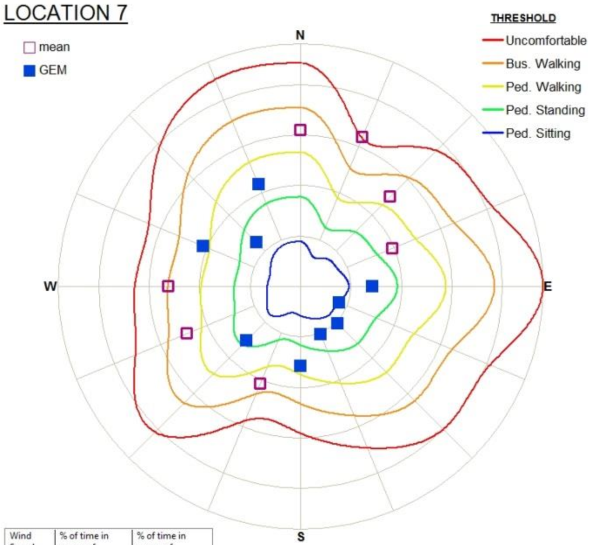
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	51.5	61.0
4.0	23.7	24.6
6.0	13.1	11.2
8.0	6.5	3.9
10.0	2.5	1.1
8.5	**5.0**	Bus Walking
17.1	**0.022**	Able Body
7.5	Ped Walking	**5.0**
14.9	Pass	**0.022**

LOCATION 6



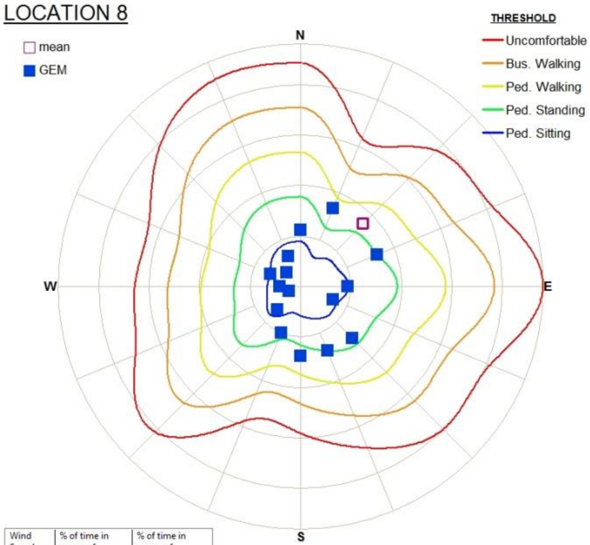
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	50.6	61.6
4.0	10.7	18.7
6.0	2.2	4.9
8.0	0.3	1.7
10.0	0.0	0.4
4.8	**5.0**	Ped Standing
9.6	**0.022**	Pass
5.9	Ped Standing	**5.0**
12.3	Pass	**0.022**

LOCATION 7



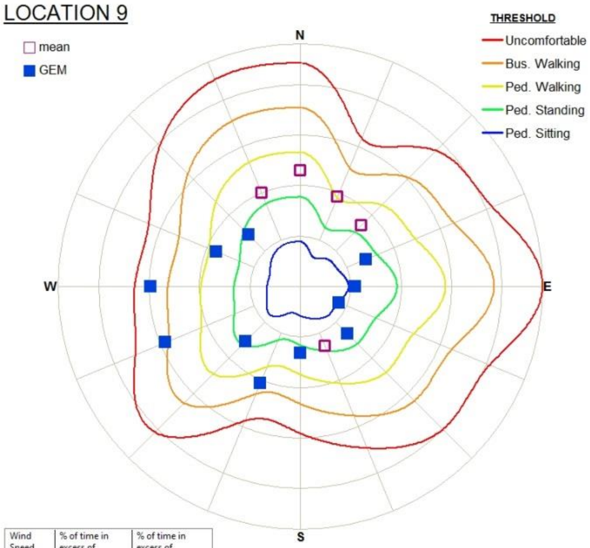
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	55.3	61.8
4.0	21.6	22.0
6.0	7.7	5.5
8.0	2.5	1.2
10.0	0.6	0.1
6.6	**5.0**	Ped Walking
12.7	**0.022**	Pass
6.1	Ped Walking	**5.0**
11.1	Pass	**0.022**

LOCATION 8



Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	22.6	31.7
4.0	2.0	5.0
6.0	0.0	0.2
8.0	0.0	0.0
10.0	0.0	0.0
3.3	**5.0**	Ped Sitting
6.0	**0.022**	Pass
4.0	Ped Sitting	**5.0**
6.9	Pass	**0.022**

LOCATION 9



Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	54.4	58.4
4.0	15.3	16.9
6.0	4.1	5.1
8.0	1.0	1.2
10.0	0.2	0.3
5.7	**5.0**	Ped Standing
12.3	**0.022**	Pass
6.0	Ped Standing	**5.0**
12.9	Pass	**0.022**