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Final Report

Issue for SSD DA

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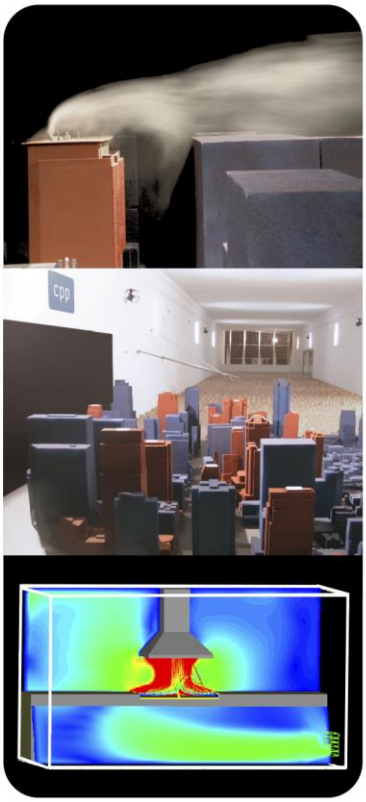

Pedestrian Wind Tunnel Tests for:

Sydney Metro

Pitt Street South Over Station

Development

Prepared for:

Pitt Street Developer South Pty Ltd

18 May 2020

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Revision C

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EXECUTIVE SUMMARY

A wind tunnel study of the proposed Pitt Street South Over Station Development (PSS OSD) development to be located in Sydney, Australia was conducted to assess the pedestrian wind environment in and around the development site. A model of the project was fabricated to a 1:400 scale and centred on a turntable in the wind tunnel. Replicas of surrounding buildings within a 570 m radius were constructed and placed on the turntable.

The wind tunnel testing was performed in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd., St. Peters. Approach boundary layers, representative of the environment surrounding the proposed development, were established in the test section of the wind tunnel. The approach wind flow had appropriate turbulence characteristics corresponding to an Suburban Approach as defined in Standards Australia (2011).

Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 20 locations for 16 wind directions each. These points were tested around the development in the proposed configuration, focusing on access routes, doorways, balconies, and outdoor seating areas. The measurements were combined with site specific wind statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location.

The wind environment around the proposed development site at ground level were found to be generally suitable for pedestrian sitting and standing type activities from a comfort perspective with only two locations, affected by strong channelling flow along Bathurst Street, classified as suitable for business walking from a Lawson comfort perspective.

Locations on the podium rooftop terraces were classified as suitable for pedestrian standing and walking type activities, while conditions on the rooftop were considerably windier, being rated as business walking from a Lawson comfort perspective. It would be recommended to incorporate tall balustrades and potentially canopy structures, porous or solid, to assist in improving wind conditions in these spaces.

PURPOSE OF THIS REPORT

Introduction

This report has been prepared to accompany a detailed State Significant Development (SSD) development application (DA) for a residential Over Station Development (OSD) above the new Sydney Metro Pitt Street South Station. The detailed SSD DA is consistent with the Concept Approval (SSD 17_8876) granted for the maximum building envelope on the site, as proposed to be modified.

The Minister for Planning, or their delegate, is the consent authority for the SSD DA and this application is lodged with the NSW Department of Planning, Industry and Environment (NSW DPIE) for assessment.

This report has been prepared in response to the requirements contained within the Secretary's Environmental Assessment Requirements (SEARs) dated 28 October 2019.

The detailed SSD DA seeks development consent for:

- Construction of a new residential tower with a maximum building height of RL 171.6 m.
- Integration with the approved CSSI proposal including though not limited to:
    - Structures, mechanical and electronic systems, and services; and
    - Vertical transfers;
- Use of spaces within the CSSI 'metro box' building envelope for the purposes of:
    - Retail tenancies;
    - Residential lobby and residential amenities;
    - Loading and services access.
- Utilities and services provision.
- Stratum subdivision (Station/ OSD).

The Site

The site is located within the Sydney CBD, on the corner of Bathurst Street and Pitt Street. It has two separate street frontages, Pitt Street to the west and Bathurst Street to the north. The area surrounding the site consists of predominantly residential high-density buildings and some commercial buildings, with finer grain and heritage buildings dispersed throughout.

The site has an approximate area of 1,710 sqm and is legally described as follows:

- 125 Bathurst Street (Lot 10 in DP 1255507)

Figure 1: Location plan

Sydney Metro Description

Sydney Metro is Australia's biggest public transport program. A new standalone railway, this 21st century network will revolutionise the way Sydney travels.

There are four core components:

Sydney Metro Northwest (formerly the 36km North West Rail Link)

This project is now complete and passenger services commenced in May 2019 between Rouse Hill and Chatswood, with a metro train every four minutes in the peak. The project was delivered on time and $1 billion under budget.

Sydney Metro City & Southwest

Sydney Metro City & Southwest project includes a new 30km metro line extending metro rail from the end of Metro Northwest at Chatswood, under Sydney Harbour, through new CBD stations and southwest to Bankstown. It is due to open in 2024 with the ultimate capacity to run a metro train every two minutes each way through the centre of Sydney.

Sydney Metro City & Southwest will deliver new metro stations at Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street, Waterloo and new underground metro platforms at Central Station. In addition it will upgrade and convert all 11 stations between Sydenham and Bankstown to metro standards.

In 2024, customers will benefit from a new fully-air conditioned Sydney Metro train every four minutes in the peak in each direction with lifts, level platforms and platform screen doors for safety, accessibility and increased security.

Sydney Metro West

Sydney Metro West is a new underground railway connecting Greater Parramatta and the Sydney CBD. This once-in-a-century infrastructure investment will transform Sydney for generations to come, doubling rail capacity between these two areas, linking new communities to rail services and supporting employment growth and housing supply between the two CBDs.

The locations of seven proposed metro stations have been confirmed at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock and The Bays.

The NSW Government is assessing an optional station at Pyrmont and further planning is underway to determine the location of a new metro station in the Sydney CBD.

Sydney Metro Greater West

Metro rail will also service Greater Western Sydney and the new Western Sydney International (Nancy Bird Walton) Airport. The new railway line will become the transport spine for the Western Parkland City's growth for generations to come, connecting communities and travellers with the rest of Sydney's public transport system with a fast, safe and easy metro service. The Australian and NSW governments are equal partners in the delivery of this new railway.

The Sydney Metro Project is illustrated in the figure below.

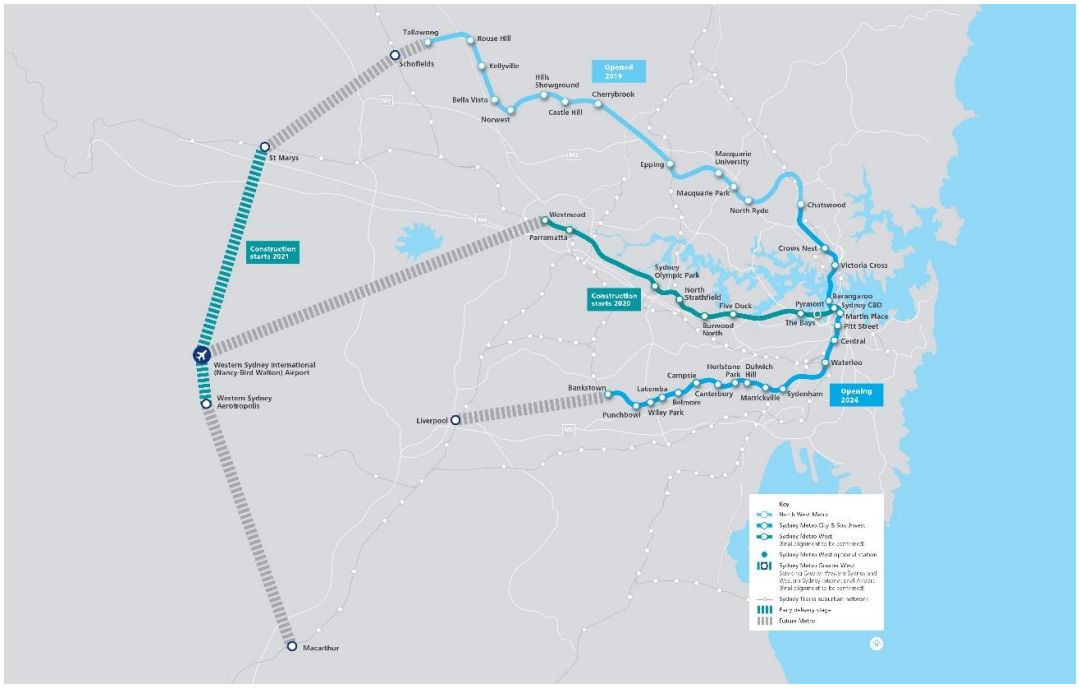

Figure 2: Sydney Metro alignment map [Source: Sydney Metro]

On 9 January 2017, the Minister for Planning approved the Sydney Metro City & Southwest - Chatswood to Sydenham project as a Critical State Significant Infrastructure project (reference SSI 15_7400) (CSSI Approval). The terms of the CSSI Approval includes all works required to construct the Sydney Metro Pitt Street Station, including the demolition of existing buildings and structures on both sites (North and South). The CSSI Approval also includes construction of below and above ground works within the metro station structure for appropriate integration with Over Station Developments.

The CSSI Approval included Indicative Interface Drawings for the below and above ground works at Pitt Street South Metro Station site. The delineation between the approved Sydney Metro works, generally described as within the “metro box”, and the Over Station Development (OSD) elements are illustrated below. The delineation line between the CSSI Approved works and the OSD envelope is generally described below or above the transfer slab level respectively.

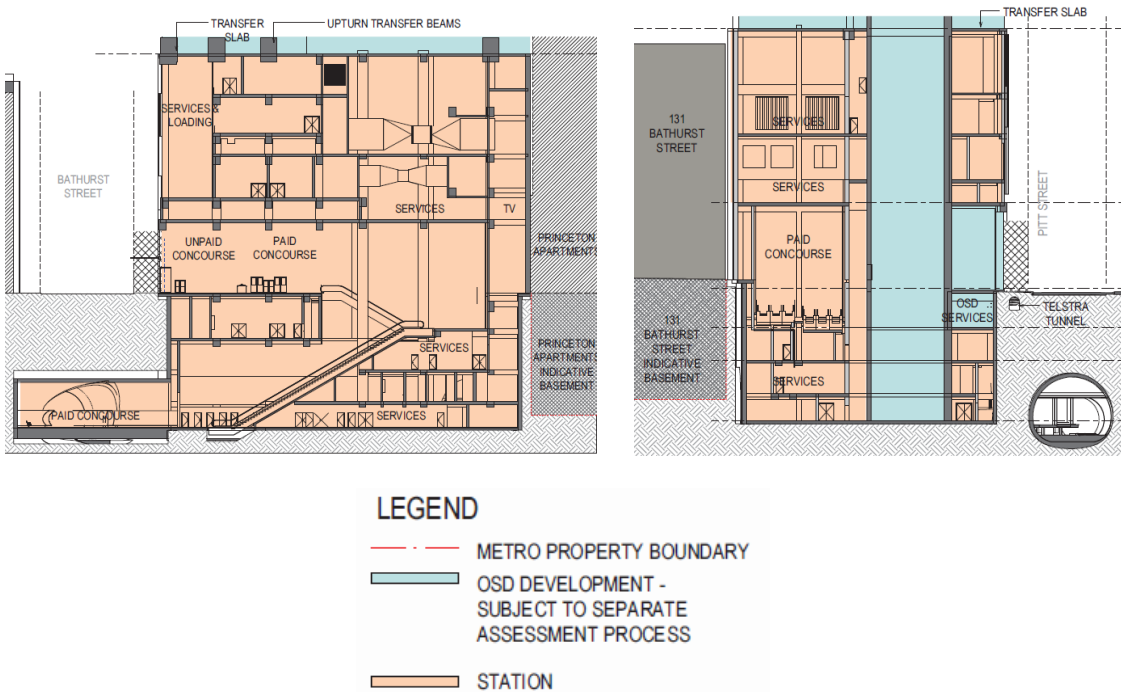

Figure 3: Pitt Street station North-South section (L) and East-West section (R) [Source: CSSI Preferred Infrastructure Report (TfNSW)]

The Preferred Infrastructure Report (PIR) noted that the integration of the OSD elements and the metro station elements would be subject to the design resolution process, noting that the detailed design of the "metro box" may vary from the concept design assessed within the planning approval.

As such in summary:

- The CSSI Approval provides consent for the construction of all structures within the approved "metro box" envelope for Pitt Street South.
- The CSSI Approval provides consent for the fit out and use of all areas within the approved "metro box" envelope that relate to the ongoing use and operation of the Sydney Metro.
- The CSSI Approval provides consent for the embellishment of the public domain, and the architectural design of the "metro box" envelope as it relates to the approved Sydney Metro and the approved Pitt Street South Station Design & Precinct Plan.
- Separate development consent however is required to be issued by the NSW DPIE for the use and fit-out of space within the "metro box" envelope for areas related to the OSD, and notably the construction and use of the OSD itself.

As per the requirements of clause 7.20 of the *Sydney Local Environmental Plan 2012*, as the OSD exceeds a height of 55 metres above ground level (among other triggers), development consent is first required to be issued in a Concept (formerly known as Stage 1) DA. This is described below.

Pitt Street South Over Station Development (OSD)

Development consent was granted on 25 June 2019 for the Concept Development Application (SSD 8876) for Pitt Street South OSD including:

- A maximum building envelope, including street wall and setbacks for the over station development.
- A maximum building height of RL171.6.
- Podium level car parking for a maximum of 34 parking spaces.
- Conceptual land use for either one of a residential or commercial scheme (not both).

NO maximum Gross Floor Area was approved as part of SSD 8876.

The building envelope approved within the Concept SSD DA provides a numeric delineation between the CSSI Approval "metro box" envelope and the OSD building envelope. As illustrated in the figures below, the delineation line between the two projects is defined at RL 58.25 m (Level 7).

For the purposes of the Detailed (Stage 2) SSD DA, it is noted that while there are two separate planning applications that apply to the site (CCSI and SSD DA), this report addresses the full development across the site to provide contextual assessment.

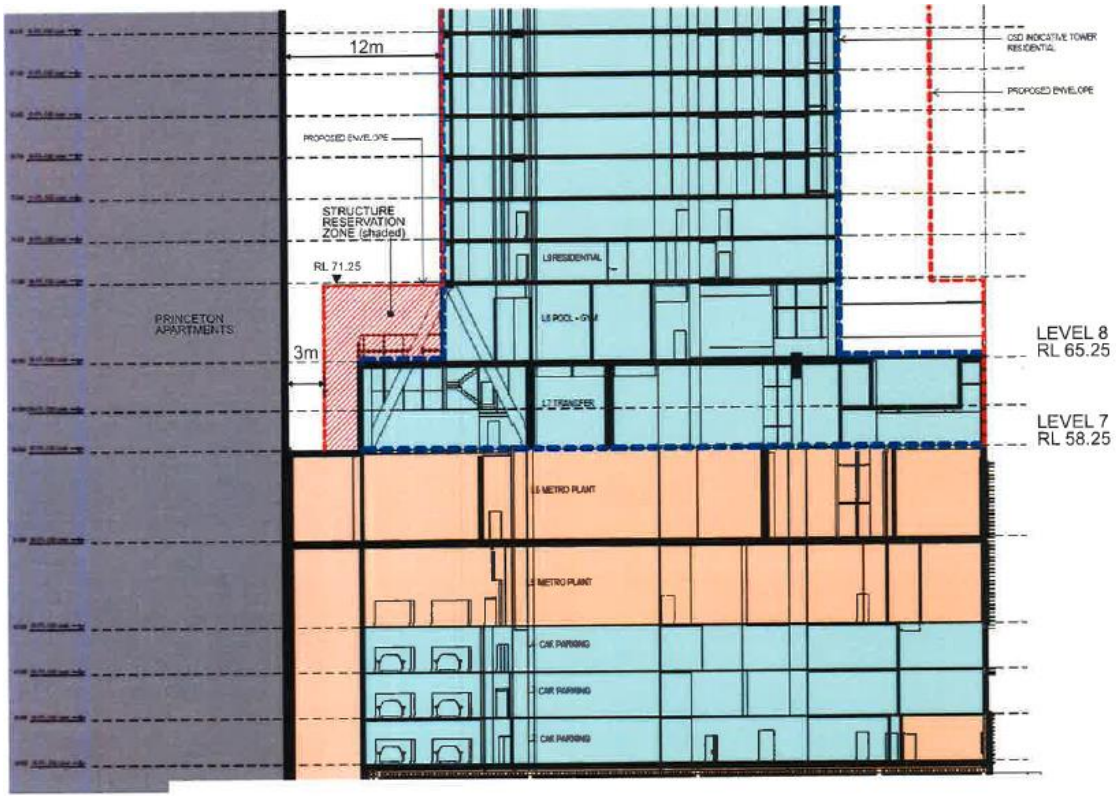

Figure 4: Pitt Street South concept SSD DA – Building section [Source: SSD 8876 Concept Stamped Plans]

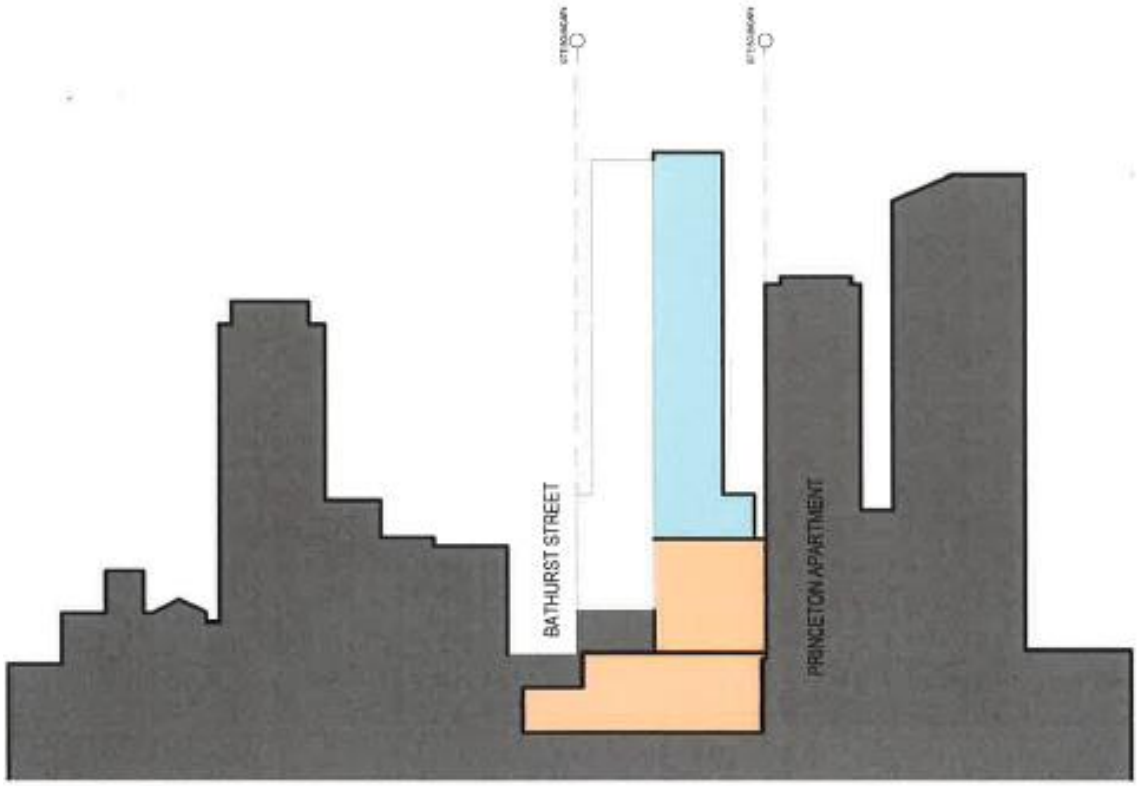

Figure 5: Pitt Street South concept SSD DA – North-South section [Source: SSD 8876 Concept Stamped Plans]

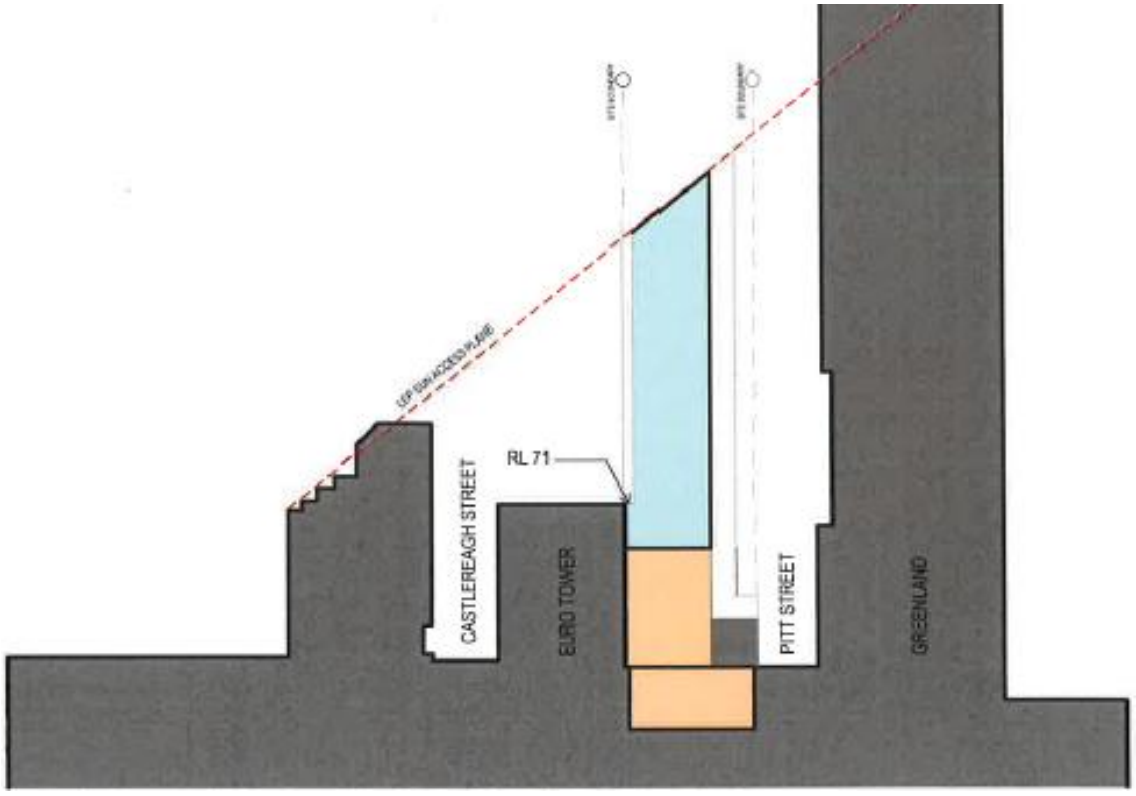

Figure 6: Pitt Street South concept SSD DA – East-West section [Source: SSD 8876 Concept Stamped Plans]

SEARs Requirements

This report has been prepared in response to the requirements contained within the Secretary's Environmental Assessment Requirements (SEARS) Dated 28 October 2019. Specifically, this report has been prepared to respond to the SEARS requirements summarised in Table 1.

Table 1: SEARs requirements pertaining to wind impacts

Item	**Description of Requirement**	**Section Reference (this report)**
SEARS 5 - Visual and amenity impacts (Wind)	Include a wind assessment (based on wind tunnel testing), identifying the impact of the proposal on surrounding wind conditions and any required measures to ameliorate wind impacts at podium level and street level. Communal open spaces must remain fit for purpose with any adverse wind impacts ameliorated.	Details of the wind tunnel testing are included in Sections 2 and 4, with a discussion of the measured wind conditions around the project site in Section 5.

This report has also been prepared in response to the following Condition of Consent for the State Significant Development Concept (SSD 8876) for the OSD summarised in Table 2.

Table 2: Concept approval of Conditions of Consent – Wind impacts

Item	**Description of Requirement**	**Section Reference (this report)**
B3 - Built Form and Urban design	The detailed development application shall address the following built form considerations: i) wind mitigation arising from compliance with Condition B11 below.	Discussion of the measured wind conditions and any recommended mitigation options are included in Section 5.
B11 Wind Impacts	Wind Impact Assessment including computer modelling of the detailed building form. Compliance shall be demonstrated with the Lawson wind comfort criteria through the incorporation of mitigation measures within the detailed design.	A description of the Lawson criteria is included in Section 3, with the results of the wind tunnel testing provided in Section 5.

DOCUMENT VERIFICATION

Date	Revision	Prepared by	Checked by	Approved by
12/12/19	Draft report	JS	AVD	AVD
03/02/20	Minor revision	AVD	AVD	AVD
14/02/20	Minor revision	JS	AVD	AVD
30/03/20	Minor revision	AVD	AVD	AVD
18/05/20	Minor revision	AVD	AVD	AVD

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LIST OF SYMBOLS

D	Characteristic dimension (building height, width, etc.), m
n	Mean velocity profile power law exponent
T_u	Turbulence intensity, U_{rms}/U
U	Local mean velocity, m/s
U_{ref}	Reference mean velocity at reference height z_{ref}, m/s
U_{pk}	Peak wind speed in pedestrian studies, m/s
U_{rms}	Root-mean-square of fluctuating velocity, m/s
z	Height above surface, m
ν	Kinematic viscosity of approach flow, m²/s
$\sigma(\ )$	Standard deviation of $(\ ), = (\ )'_{\mathrm{rms}}$
ρ	Density of approach flow, kg/m³
$(\ )_{\mathrm{max}}$	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 is an important design parameter of interest to the building owner and architect. Assessment of the acceptability of the pedestrian level wind environment is desirable during the project design phase so that modifications can be made, if necessary, to create wind conditions suitable for the intended use of the space.

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 discussion of acquired test results. Table 3 summarises the model configurations, test methods, and data acquisition parameters used. All the data collection was performed in accordance with Australasian Wind Engineering Society (2001), and American Society of Civil Engineers (1999, 2010). While analytical methods such as computational fluid dynamics (CFD) have some utility in the field of pedestrian wind comfort, they are not yet capable of reliably and accurately predicting gust wind speeds for assessment of wind conditions from a safety perspective.

Table 3: Parameters and configurations for data acquisition.

General Information	
Model scale	1:400
Surrounding model radius (full-scale)	570 m
Reference height (full-scale)	200 m AGL
Approach Terrain Category	Suburban Approach (Terrain Category 3)
Testing Configurations	
Configuration	Proposed Pitt Street South Over Station Development with existing and approved surrounding buildings, as shown in Figure 9. Pedestrian winds measured at 20 locations for 16 wind directions at 22.5° increments from 0° (north).

2 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 the 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 7. 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 vorticity generating fence and spires. The spires, barrier, 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 8 and are explained more fully in Section 4.1.1.

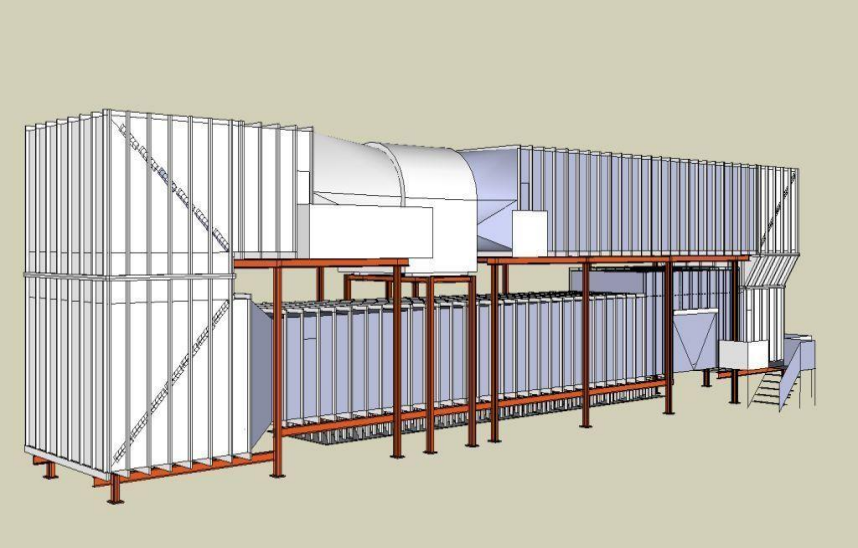

Figure 7: Schematic of the closed-circuit wind tunnel.

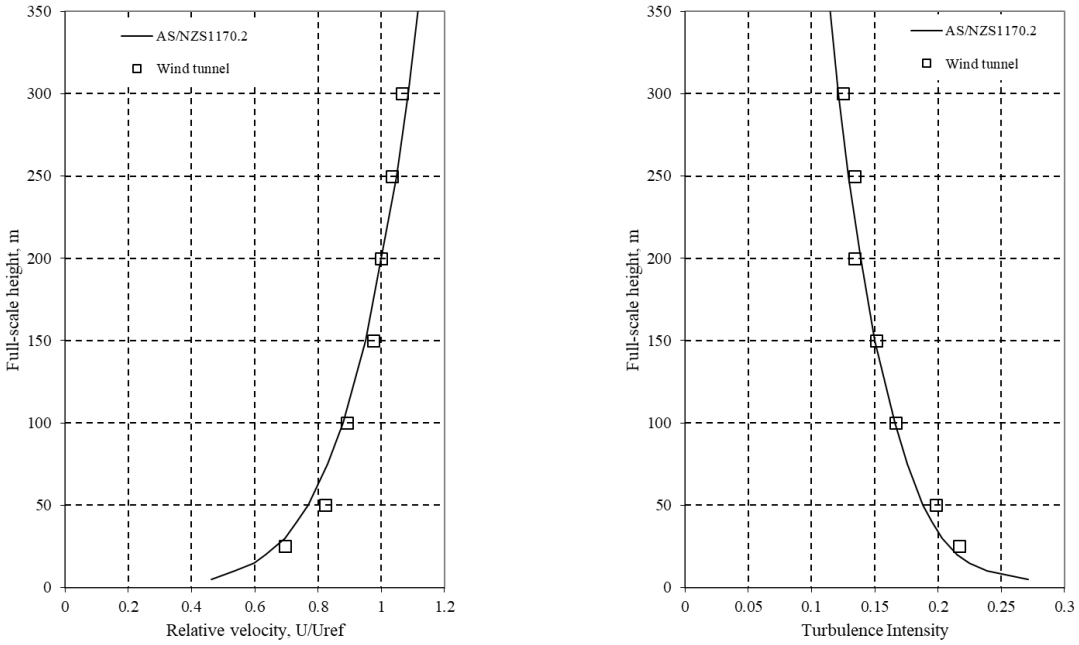

Figure 8: Mean velocity and turbulence profiles (Terrain Category 3) approaching the model.

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, Figure 9, and was within wind tunnel blockage limitations. Significant variations in the building surface were formed into the model. The models were mounted on the turntable located near the downstream end of the wind tunnel test section, Figure 10. The turntable permitted rotation of the modelled area for examination of velocities from any approach wind direction. Additional photos of the test models are included in Appendix 1.

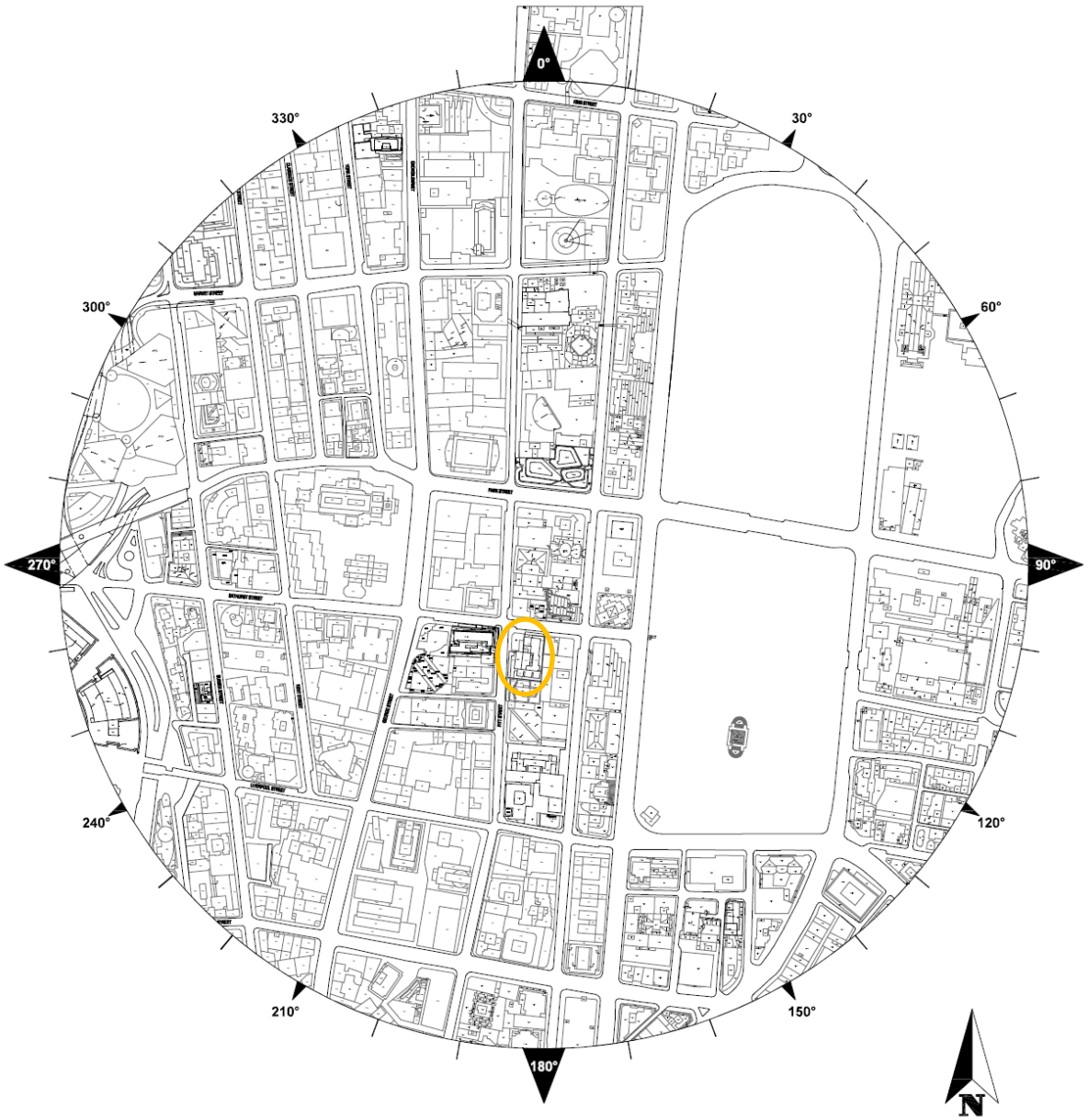

Figure 9: Project location and turntable layout.

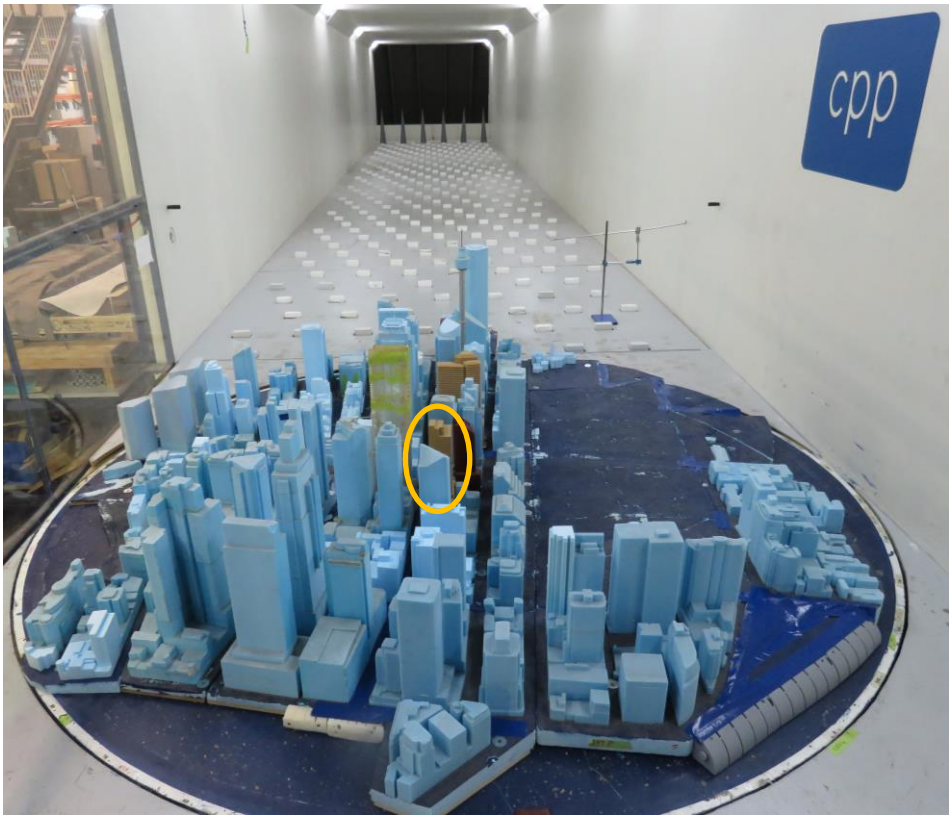

Figure 10: PSS OSD model in the CPP wind tunnel viewed from the south.

3 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 4.

Lawson's criteria have categories for comfort, based on wind speeds exceeded 5% 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; 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 once per annum gust criteria, but also provides significantly more information regarding the serviceability wind climate.

Table 4: 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[1]
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

Note: †, The gust equivalent mean (GEM) is the peak 3 s gust wind speed divided by 1.85.

[1] The rating of "uncomfortable" in Table 4 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.

4 DATA ACQUISITION AND RESULTS

4.1 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 4.1.2. 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).

4.1.1 Velocity Profiles

Mean velocity and turbulence intensity profiles for the boundary layer flow approaching the model are shown in Figure 8. Turbulence intensities are related to the local mean wind speed. These profiles have the form as defined in Standards Australia (2011) and are appropriate for the approach conditions.

4.1.2 Pedestrian Winds

The proposed development is located in the heart of the Sydney CBD. The site is located on the south-east corner of Bathurst and Pitt Street, Figure 9. The development is surrounded by medium to high-rise buildings. Topography surrounding the site is essentially flat from a wind perspective.

For this report, wind speed measurements were recorded at 20 locations, as described in Table 3, to evaluate pedestrian wind comfort and safety in and around the project site shown in Figure 12 to Figure 14. Velocity measurements were made at the model scale equivalent of 1.5 to 2.1 m above the surface for 16 wind directions at 22.5° intervals. Locations were chosen to determine the degree of pedestrian wind comfort and safety at building corners where relatively severe conditions are frequently found, near building entrances and passageways, and at upper level outdoor locations.

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 and is the basis for the various acceptability criteria. 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:

$$\frac{U_{pk}}{U_{ref}} = \frac{U + 3U_{rms}}{U_{ref}}$$

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 wind speed is of greater importance.

To enable a quantitative assessment of the wind environment in the region, 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 1995 to 2017, Figure 11.

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.

The criteria of Lawson consider the integration of the velocity measurements with local wind climate statistical data summarised in Figure 11 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 5 including qualitative descriptions of wind effects.

The tables in Appendix 2 additionally provide the wind speed exceeded 5% and 0.022% of the time for direct comparison with the Lawson comfort and distress criteria, and the associated Lawson ratings for both mean and GEM wind speeds. A colour coded summary assessment of pedestrian wind comfort and safety with respect to the Lawson criteria is presented in Figure 12 to Figure 14 for each test location. The implications of the results are discussed in Section 5.

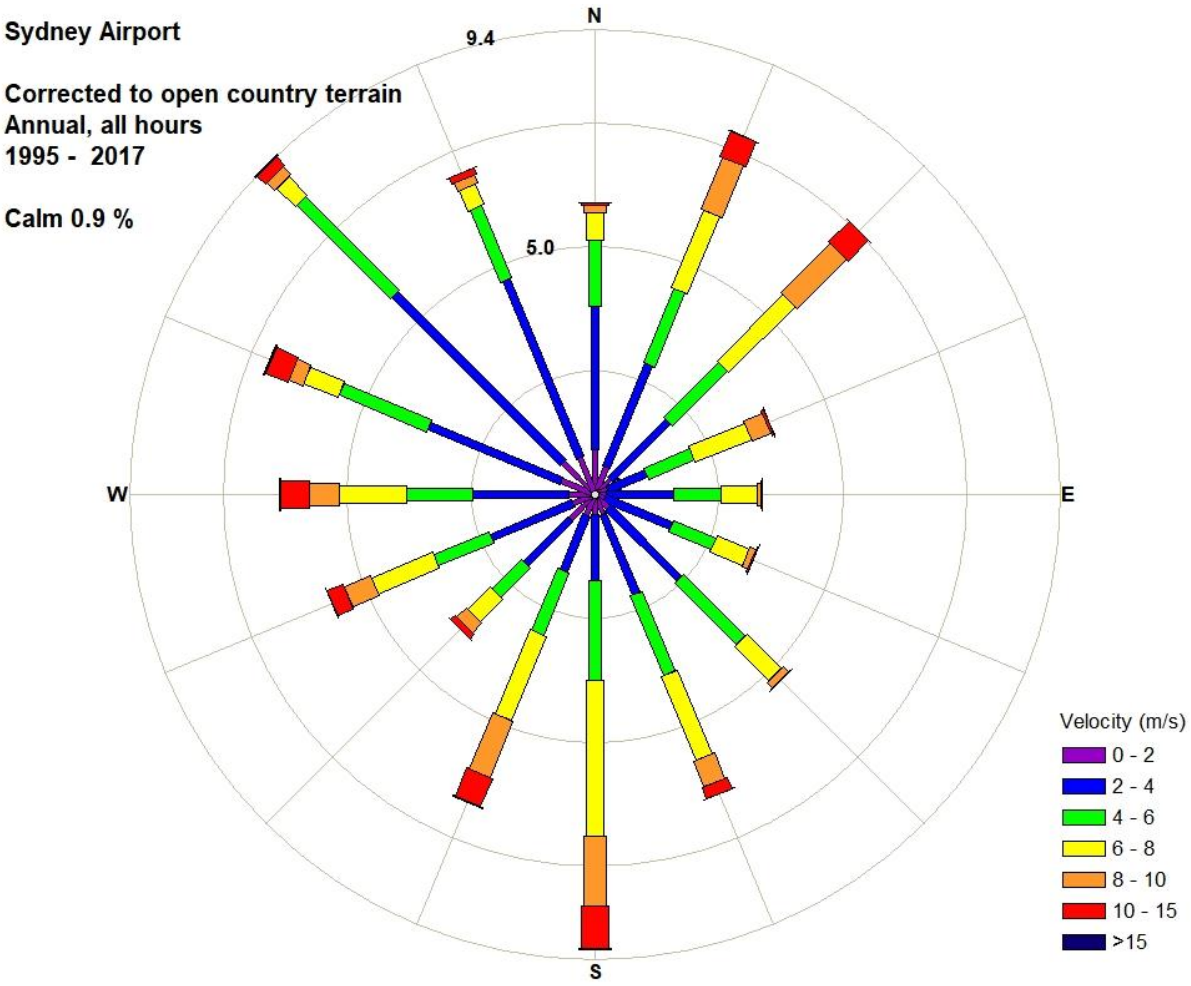

Figure 11: Wind rose for Sydney Airport.

Table 5: 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.

5 DISCUSSION

The wind climatology chart of Figure 11 indicates that the most frequent strong winds are from the south, north-east and west quadrants. The locations tested around the development site are susceptible to winds from these directions, depending on the relative position of the location tested to the geometry of the proposed development and surrounds. The influence of wind direction on the suitability of a location for an intended purpose can be ascertained from the polar plots in Appendix 2. The polar plots show the severity, distribution, and frequency of steady winds and gusts from 16 directions at 22.5° intervals.

A summary of the expected wind rating targets based on the intended use of the space at the investigated locations and the wind tunnel results, including the Lawson comfort and safety ratings, is provided in Table 6.

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded images of Figure 12 to Figure 14, which depict the locations selected for investigation along with the Lawson comfort and distress criteria ratings. The central colour indicates the comfort rating for the location, and the colour of the outer ring indicates whether the location passes or exceeds the distress criterion, Table 4. Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people found in Table 5.

Note that testing was performed without existing and proposed trees, and other plantings to provide a worst-case assessment; heavy landscape planting typically reduces the wind speeds by less than 10%. However, landscaping cannot be relied on to provide sufficient shielding from winds that potentially pose a safety risk due to their vulnerabilities. Mitigation measures are likely to be required for orange and red locations and may be necessary for other locations depending on the intended use of the space. Although conditions may be classified as acceptable, there may be certain wind directions that cause regular strong events, and these can be determined by an inspection of the polar plots in Appendix 2.

Table 6: Summary of expected wind rating targets versus wind tunnel results.

Description / Location		Target	Wind Tunnel Results – Base case Configuration			Notes
		Comfort rating, 5% exceedance wind speed (m/s)	Comfort rating, 5% exceedance wind speed (m/s)	Meets target Y(es)/N(o)	Safety rating, 0.022% exceedance wind speed (m/s)	
Remote Locations	1	>6 to 8	3.8	Y	7.5	
	2	>6 to 8	4.0	Y	7.5	
Ground Floor	3	>6 to 8	3.8	Y	7.1	
	4	>6 to 8	4.7	Y	9.2	
	5	>6 to 8	8.2	N	15.2	Exisitng condition.
	6	>6 to 8	3.6	Y	7.4	
	7	>6 to 8	1.4	Y	2.9	
	8	>6 to 8	2.3	Y	4.7	
	9	>6 to 8	2.9	Y	6.7	
	10	>6 to 8	4.6	Y	11.8	
	11	>6 to 8	4.4	Y	11.1	
	12	>6 to 8	3.5	Y	7.8	
	13	>6 to 8	8.3	N	16.4	Exisitng condition.
Podium	14	>4 to 6	5.0	Y	9.5	
	15	>4 to 6	4.4	Y	10.6	
	16	>4 to 6	6.5	N	12.3	The proposed awning, implemented based on the results presented herein, would be expected to assist in improving wind conditions at this location.
Rooftop	17	>4 to 6	3.2	Y	6.5	
	18	>4 to 6	8.1	N	18.0	The inclusion of tall balustrades along with a canopy structure in the design, as a result of the recommendations of this report, would be expected to assist in improving wind amenity for these locations.
	19	>4 to 6	8.2	N	18.1	
	20	>4 to 6	8.8	N	19.8	

LEGEND

Comfort Criteria

- Outdoor Dining
- Pedestrian Sitting
- Pedestrian Standing
- Pedestrian Walking
- Business Walking
- Uncomfortable

Safety Criteria

- Passes safety criteria
- Able bodied
- Fails safety criteria

The wind conditions at locations remote to the site are presented in Figure 12. Wind conditions at Locations 1 and 2 are representative of general wind conditions in the Sydney CBD for locations nested within the CBD, and in the absence of shielding respectively. These locations are classified as suitable for pedestrian sitting and standing respectively and give a general indication of the surrounding wind environment and can be used for comparison to the wind conditions in and around the proposed development site.

Figure 12: Pedestrian wind speed measurement locations with comfort/distress ratings – Remote locations.

The wind conditions at ground level are presented in Figure 13, locations marked by an open circle indicate a measurement taken beneath an overhang, for example an awning. Wind conditions in the vicinity of the site along Pitt and Bathurst Streets are typically classified as suitable for pedestrian standing and sitting type activities from a Lawson comfort perspective. Location 5 and 13 experience windier conditions than other locations along Bathurst Street, with both locations rated as suitable for business walking, and exceeding the Lawson distress criterion. Reference to the polar plots in Appendix 2 indicate Location 5 and 13 are susceptible to strong steady winds from the north-east and west quadrants. As prevailing winds from these quadrants reach the east and west fringes of the Sydney CBD, respectively, they are brought to ground level in the form of downwash by large exposed towers upstream of the project site, with the resulting flow being channelled along Bathurst Street. Locations along Bathurst Street at the east and west extremeties of the Sydney CBD are most prone to this effect, as indicated by the windy conditions at Locations 5 and 13. From CPP's previous experience with wind conditions along this region of Bathurst Street it is noted that wind conditions at Locations 5 and 13 are consistent with wind conditions with the proposed tower absent, indicating little contribution to these adverse wind conditions from the proposed tower. The calmest wind conditions on the ground plane in the vicinity of the proposed development were measured at Location 7. Situated beneath the proposed awning on the Pitt Street frontage and setback from the street, Location 7 is well-shielded from downwash and channelling flow along Pitt Street and was classified as suitable for outdoor dining type activities from a comfort perspective. With the exception of Locations 5 and 13, all other locations on the ground plane passed the Lawson distress criterion.

Figure 13: Pedestrian wind speed measurement locations with comfort/distress ratings – Ground Floor.

Wind conditions on the podium areas of the proposed development are presented in Figure 13. Locations 14 and 15 on the lower podium terrace were found to be classified as suitable for pedestrian standing type activities from a Lawson comfort perspective. Situated on the raised podium terrace, Location 16 experiences stronger wind conditions, and is classified as suitable for pedestrian walking type activities. Reference to the polar plots in Appendix 2 suggest that Location 14, 15 and 16 are subject to downwash from the west and east facades accelerating around south-west and south-east corners of the tower respectively. It is noted that testing was conducted without balustrades and landscaping, which would be expected to improve wind conditions at these locations. Provision of awnings on the raised podium near the south-west and south-east corners of the tower would assist in deflecting downwash away from the terraces, thereby improving wind comfort.

Due to exposed nature of the rooftop, most measurement locations were found to be windy, Figure 13, with the exception of Location 17 which was classified as pedestrian sitting from a comfort

perspective. The recessed nature of Location 17 ensured protection from the strong prevailing winds from the north-east and south, resulting in the amiable conditions experienced at this location. Conversely, Locations 18 to 20 are exposed to prevailing winds from the north-east and south accelerating over the roof edge, generating stronger wind conditions with these locations being classified as suitable for business walking type activities, and exceeding the Lawson distress criterion. As testing was conducted without balustrades, wind conditions would be expected to improve with implementation of tall balustrades. Further enclosing of the rooftop space with canopy structures, porous or solid, would assist in keeping incoming flow elevated above the rooftop terrace, improving wind amenity.

Figure 14: Pedestrian wind speed measurement locations with comfort/distress ratings – Podium and rooftop.

Given the recessed nature of the majority of the balconies for the project tower it is expected that wind conditions on these balconies will be suitable for the intended use of space. Conversely, the exposed balconies on the south-east corner of the tower would be expected to experience windier

conditions as approach flow from the south and north-east quadrants is accelerated around the south-east corner of the tower. As the balcony is open on three sides this accelerated flow will tend to pass straight through the balcony space creating windy conditions. Incorporating a full-height screen on the southern aspect of these balconies would assist in improving wind conditions within the balcony space. If calmer wind conditions are desired these balconies could be converted to wintergardens.

6 CONCLUSION

Cermak Peterka Petersen Pty. Ltd. has conducted a wind tunnel test concerning the impact of the South Tower of the proposed PSISD, Sydney, Australia, on the local wind environment. Our summary assessment of the proposed development is as follows:

The wind environment around the proposed development site on the ground plane were found to be generally suitable for pedestrian sitting and standing type activities from a comfort perspective with reference to the Lawson comfort criteria. Two locations toward the eastern fringe of the city were classified as suitable for business walking and exceeded the distress Lawson criterion. Based on previous experience these conditions are considered typical for such locations and are similar to existing wind conditions in this area.

Generally, elevated locations open to the air that are exposed to prevailing winds experience uncomfortable wind conditions for recreational activities for a large portion of the time. The rooftop area was found to be windy and would benefit from significant enclosing of the space. Implementation of tall balustrades and canopy structures, porous or solid, would be expected to assist in ameliorating wind conditions on the rooftop.

7 REFERENCES

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

Appendix 1: Additional photographs of the CPP wind tunnel model

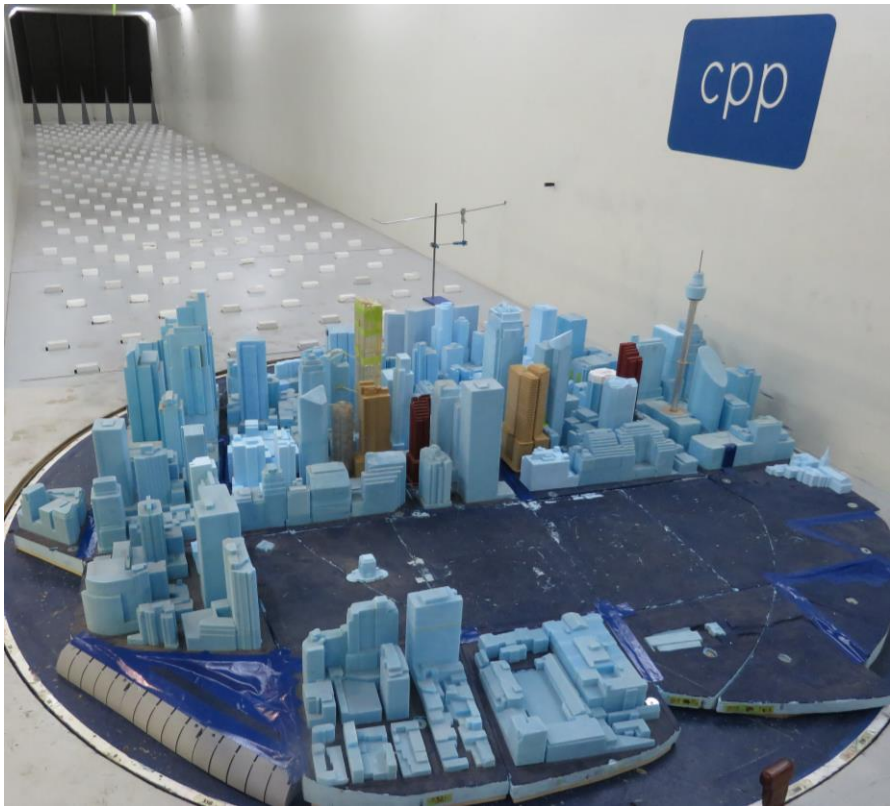


Figure 15: Photograph of PSS OSD model in the wind tunnel viewed from the east.

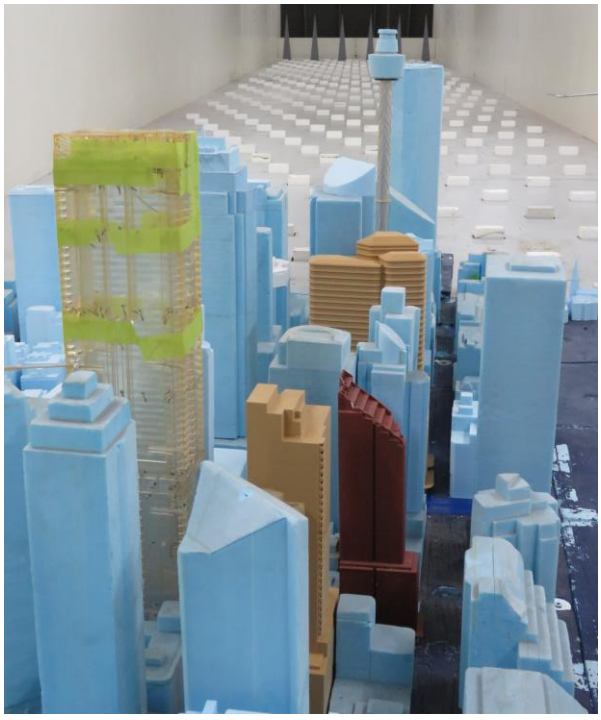
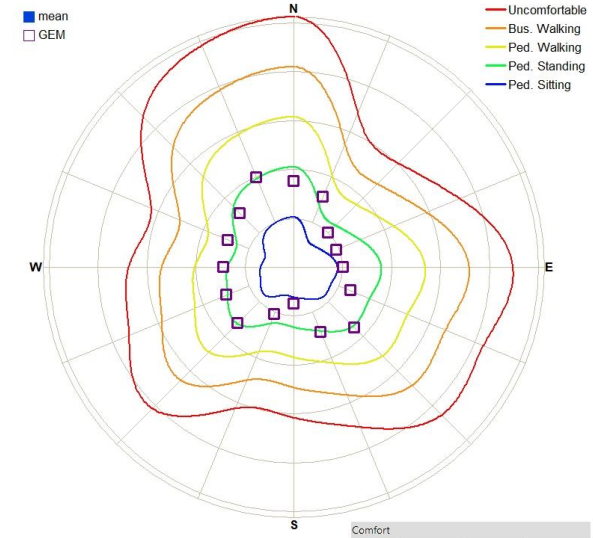


Figure 16: Close-up of the PSS OSD model in the wind tunnel viewed from the south.

Appendix 2: Directional wind results

LOCATION 1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	13.49	39.11	39.11
4	0.44	4.22	4.22
6	0.01	0.27	0.27
8	0.00	0.01	0.01
10	0.00	0.00	0.00

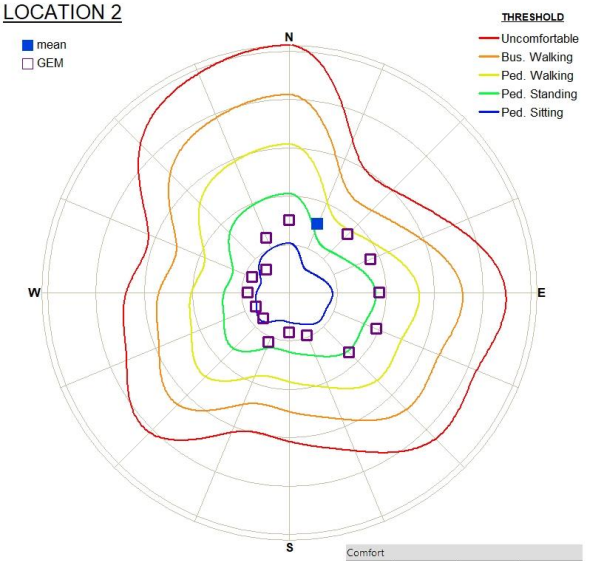
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.6	3.8	3.8
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.7	7.5	7.5
Rating	Pass	Pass	Pass

LOCATION 2



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	17.39	31.54	31.63
4	3.81	5.41	5.49
6	0.22	0.34	0.35
8	0.00	0.01	0.01
10	0.00	0.00	0.00

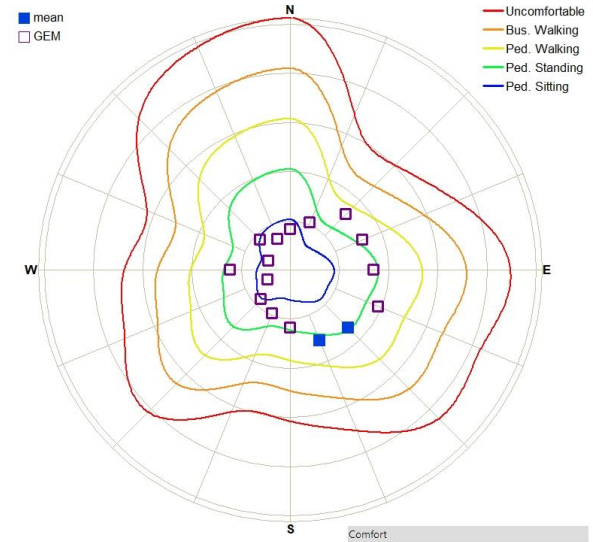
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.7	4.0	4.0
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.1	7.5	7.5
Rating	Pass	Pass	Pass

LOCATION 3



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	20.62	33.19	33.28
4	1.38	4.09	4.14
6	0.06	0.24	0.24
8	0.00	0.00	0.00
10	0.00	0.00	0.00

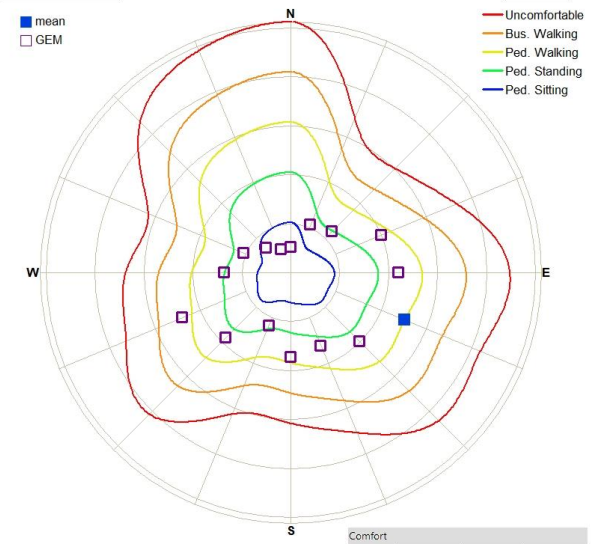
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.3	3.8	3.8
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.6	7.1	7.1
Rating	Pass	Pass	Pass

LOCATION 4



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.32	45.42	45.50
4	6.78	10.35	10.61
6	0.74	1.06	1.12
8	0.06	0.10	0.11
10	0.00	0.01	0.01

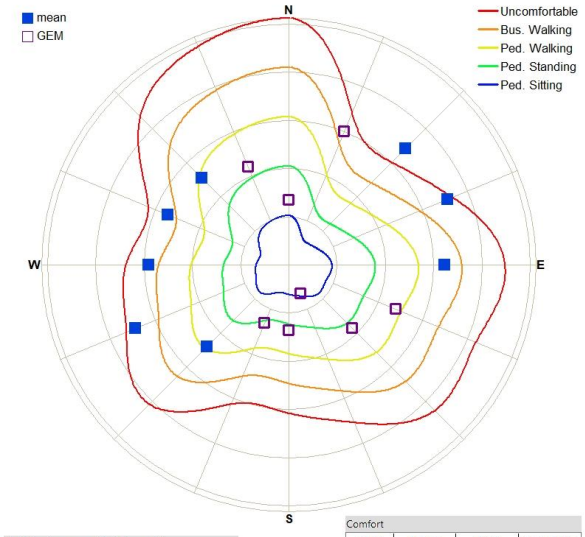
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.2	4.6	4.7
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.6	9.1	9.2
Rating	Pass	Pass	Pass

LOCATION 5



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	58.21	62.34	66.15
4	26.08	24.50	28.80
6	13.39	10.32	14.18
8	5.52	3.29	5.87
10	1.60	0.65	1.68

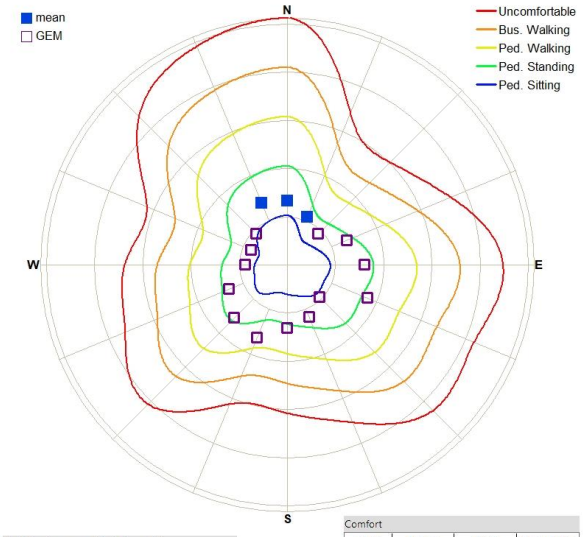
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	8.1	7.3	8.2
Rating	Bus Walking	Ped Walking	Bus Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	15.2	13.4	15.2
Rating	Able Body	Pass	Able Body

LOCATION 6



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	18.86	32.56	34.30
4	1.01	3.07	3.16
6	0.05	0.18	0.18
8	0.00	0.01	0.01
10	0.00	0.00	0.00

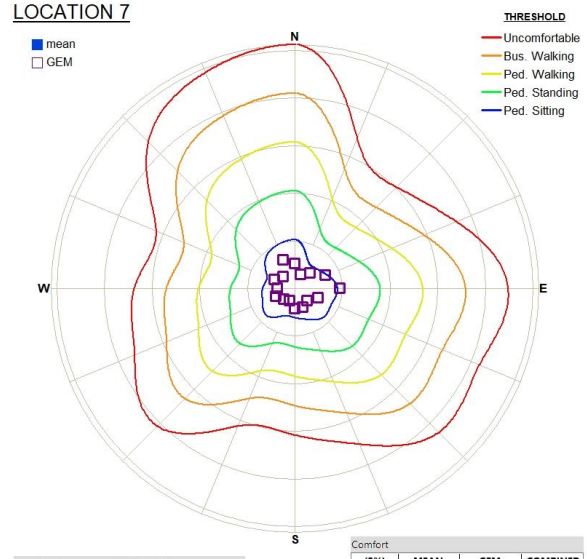
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.9	3.6	3.6
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.5	7.4	7.4
Rating	Pass	Pass	Pass

LOCATION 7



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	0.01	0.52	0.52
4	0.00	0.00	0.00
6	0.00	0.00	0.00
8	0.00	0.00	0.00
10	0.00	0.00	0.00

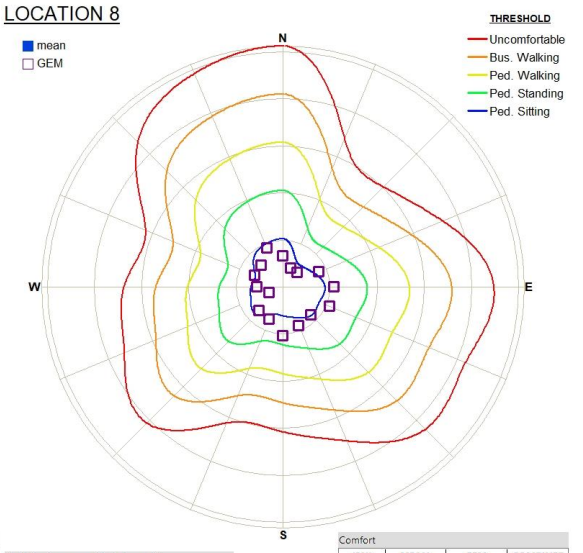
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	1.0	1.4	1.4
Rating	Outdoor Dining	Outdoor Dining	Outdoor Dining

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	1.8	2.9	2.9
Rating	Pass	Pass	Pass

LOCATION 8



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	1.68	9.49	9.49
4	0.00	0.13	0.13
6	0.00	0.00	0.00
8	0.00	0.00	0.00
10	0.00	0.00	0.00

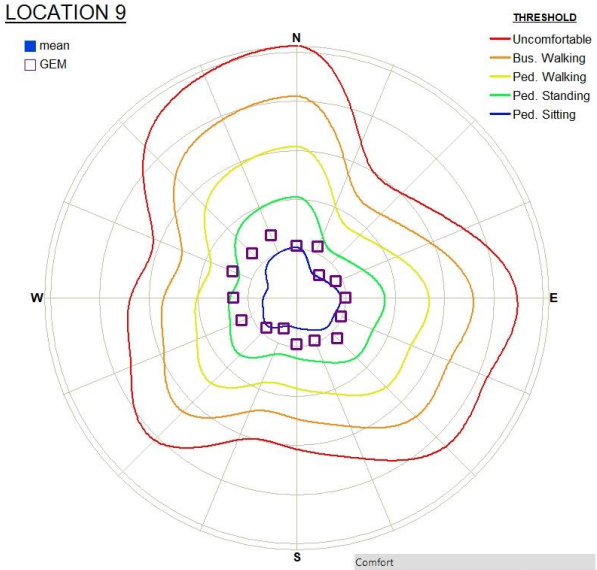
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	1.5	2.3	2.3
Rating	Outdoor Dining	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	3.5	4.7	4.7
Rating	Pass	Pass	Pass

LOCATION 9



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	7.12	21.74	21.74
4	0.55	1.20	1.20
6	0.02	0.08	0.08
8	0.00	0.00	0.00
10	0.00	0.00	0.00

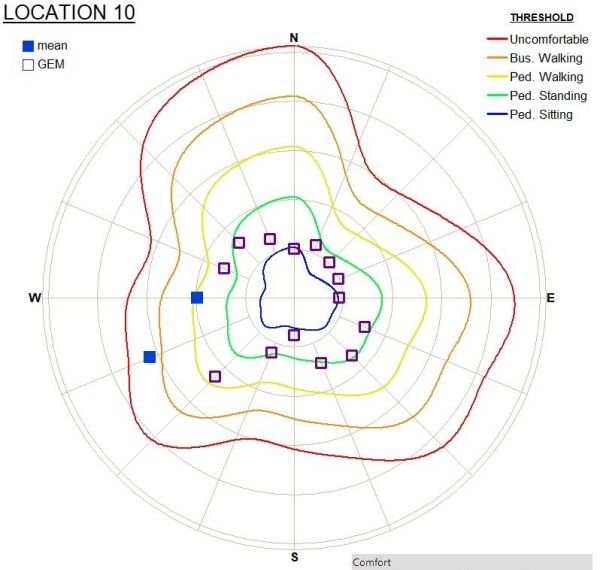
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.2	2.9	2.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.9	6.7	6.7
Rating	Pass	Pass	Pass

LOCATION 10



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	20.72	39.17	39.76
4	5.99	6.60	7.48
6	1.95	1.21	2.07
8	0.47	0.18	0.48
10	0.11	0.02	0.11

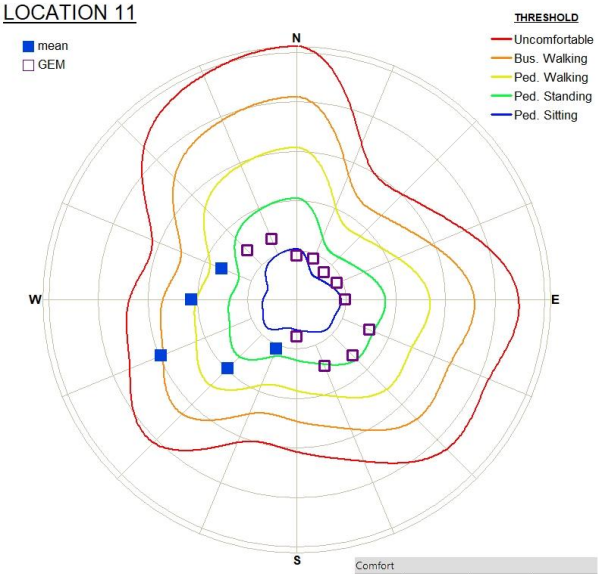
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.3	4.3	4.6
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.8	10.0	11.8
Rating	Pass	Pass	Pass

LOCATION 11



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	24.65	32.23	34.29
4	6.25	5.16	7.02
6	1.80	0.79	1.84
8	0.38	0.07	0.38
10	0.06	0.01	0.06

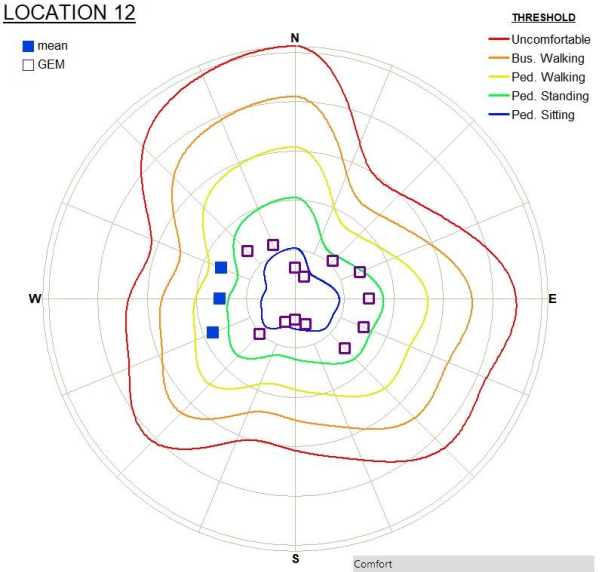
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.3	4.0	4.4
Rating	Ped Standing	Ped Sitting	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.1	8.9	11.1
Rating	Pass	Pass	Pass

LOCATION 12



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	20.97	24.29	24.88
4	2.45	2.39	2.90
6	0.27	0.20	0.29
8	0.01	0.01	0.02
10	0.00	0.00	0.00

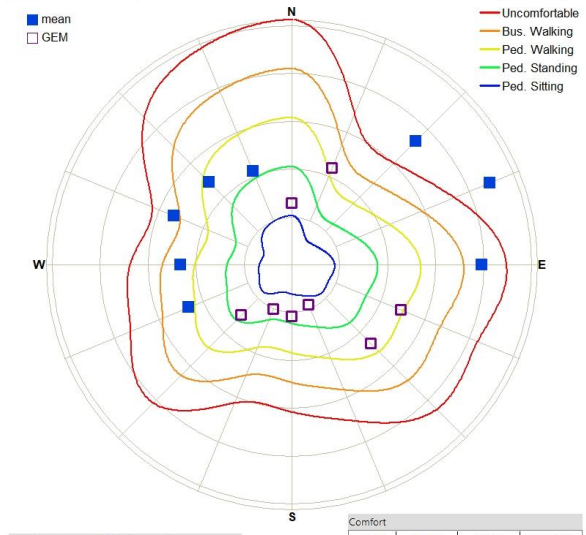
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.3	3.4	3.5
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.8	7.5	7.8
Rating	Pass	Pass	Pass

LOCATION 13

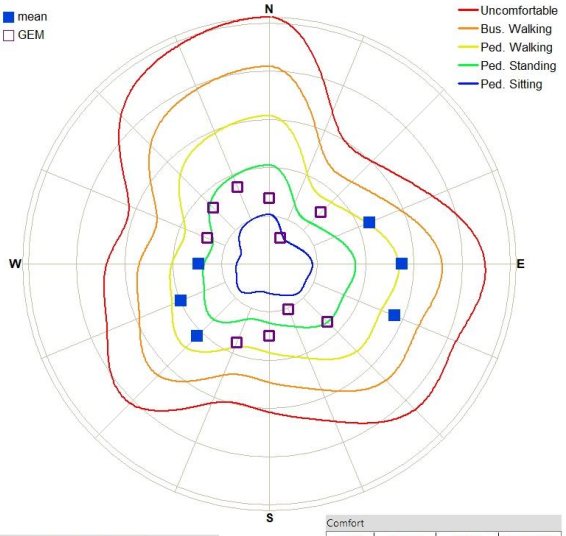


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	50.15	56.01	61.01
4	22.26	20.60	25.19
6	10.99	8.75	11.68
8	5.86	3.38	5.91
10	2.43	0.91	2.43

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	8.3	7.1	8.3
Rating	Bus Walking	Ped Walking	Bus Walking

Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	16.4	14.3	16.4
Rating	Able Body	Pass	Able Body

LOCATION 14

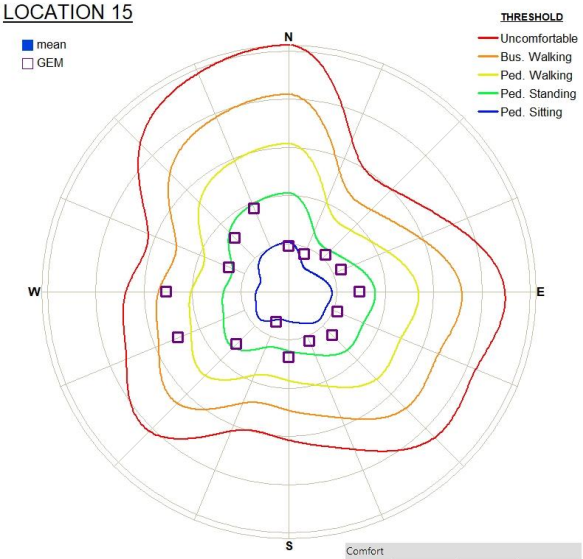


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	39.54	48.18	48.88
4	9.94	12.51	13.49
6	1.17	1.22	1.53
8	0.12	0.11	0.14
10	0.01	0.01	0.01

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	4.9	5.0
Rating	Ped Standing	Ped Standing	Ped Standing

Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.3	9.2	9.5
Rating	Pass	Pass	Pass

LOCATION 15

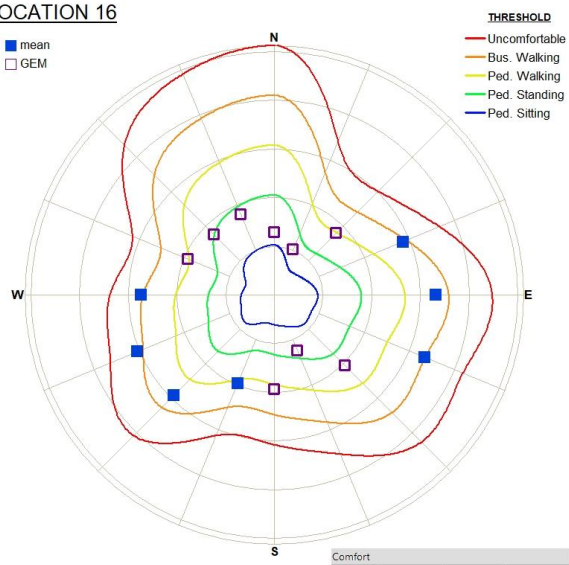


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	14.26	38.78	38.78
4	1.58	7.16	7.16
6	0.12	1.48	1.48
8	0.01	0.31	0.31
10	0.00	0.05	0.05

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.9	4.4	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.1	10.6	10.6
Rating	Pass	Pass	Pass

LOCATION 16

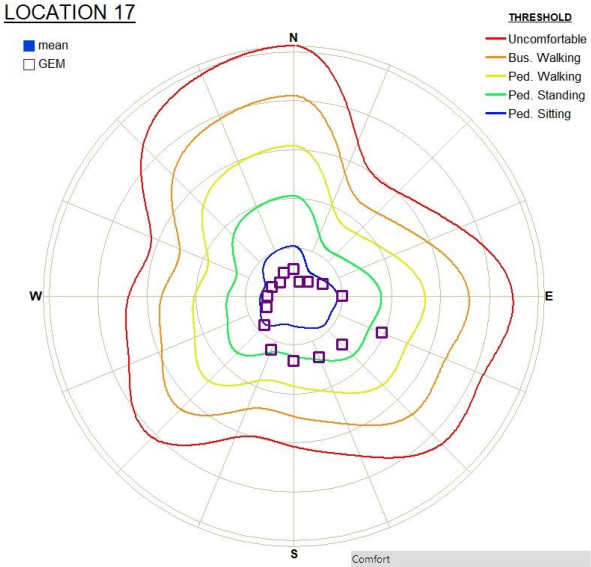


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	48.44	59.59	61.17
4	20.95	22.42	25.03
6	6.55	4.50	7.64
8	1.27	0.66	1.43
10	0.22	0.07	0.23

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.3	5.9	6.5
Rating	Ped Walking	Ped Standing	Ped Walking

Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.3	10.9	12.3
Rating	Pass	Pass	Pass

LOCATION 17



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	6.05	19.14	19.14
4	0.08	1.74	1.74
6	0.00	0.07	0.07
8	0.00	0.00	0.00
10	0.00	0.00	0.00

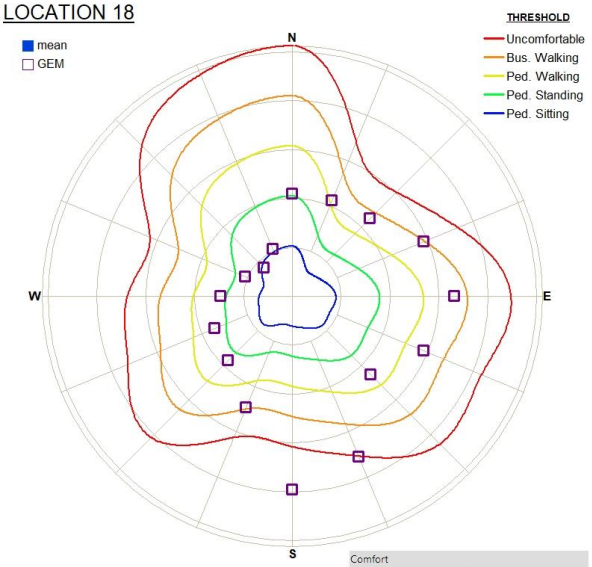
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.1	3.2	3.2
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.4	6.5	6.5
Rating	Pass	Pass	Pass

LOCATION 18



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	44.87	59.99	59.99
4	19.34	32.10	32.10
6	5.47	15.24	15.24
8	1.19	5.43	5.43
10	0.24	2.12	2.12

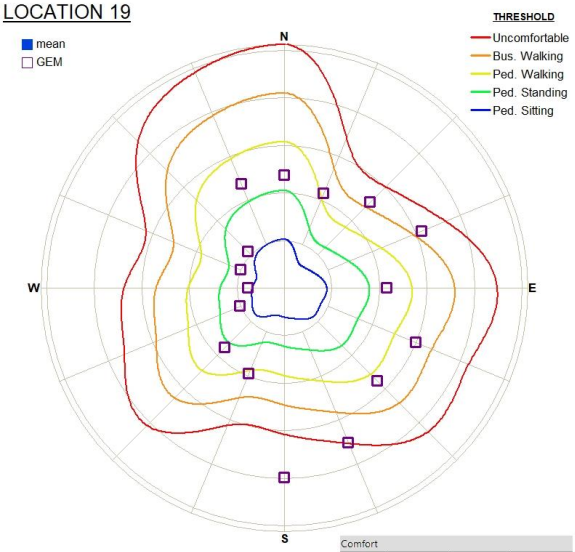
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	6.1	8.1	8.1
Rating	Ped Walking	Bus Walking	Bus Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.7	18.0	18.0
Rating	Pass	Able Body	Able Body

LOCATION 19



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	43.90	59.05	59.05
4	18.53	31.12	31.12
6	6.46	15.30	15.30
8	1.63	5.72	5.72
10	0.39	2.20	2.20

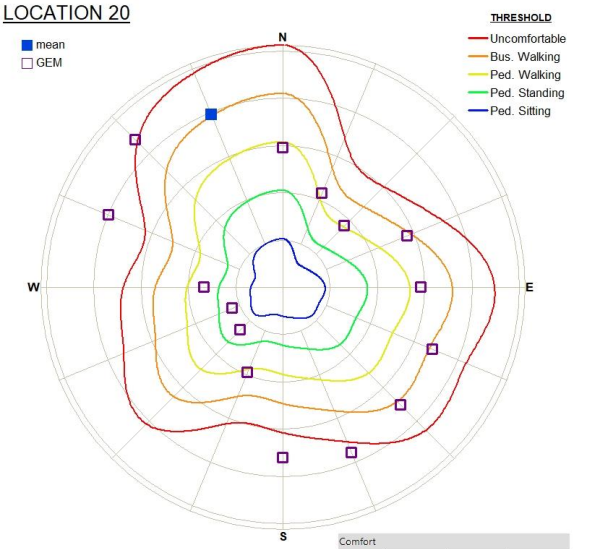
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	6.4	8.2	8.2
Rating	Ped Walking	Bus Walking	Bus Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.9	18.1	18.1
Rating	Pass	Able Body	Able Body

LOCATION 20



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	66.36	78.79	78.85
4	29.12	43.42	43.68
6	9.70	19.36	19.47
8	3.19	7.40	7.47
10	1.11	3.03	3.08

Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	7.1	8.7	8.8
Rating	Ped Walking	Bus Walking	Bus Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	17.2	19.8	19.8
Rating	Able Body	Able Body	Able Body