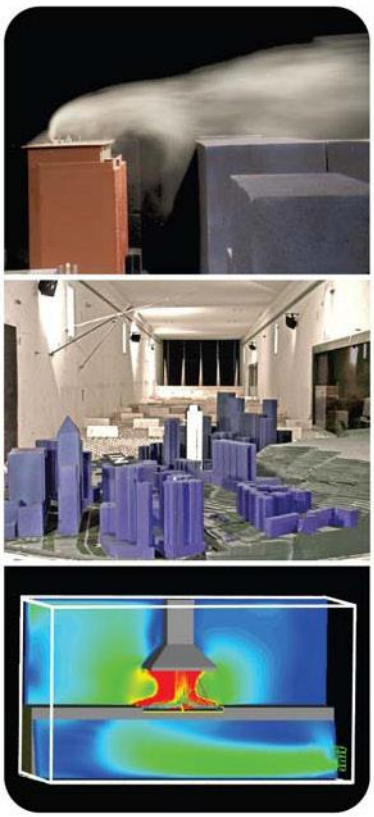
CERMAK
PETERKA
PETERSEN

WIND ENGINEERING AND AIR QUALITY CONSULTANTS

FINAL REPORT



Pedestrian Wind Environment Wind Tunnel Assessment for:

COCKLE BAY PARK DEVELOPMENT

Sydney, Australia

CPP Project 9020

Prepared for:

DPT Operator and DPPT Operator

Prepared by:

Andrew Nguyen, Project Engineer
Joe Paetzold, Engineering Manager
Matt Glanville, Ph. D, Director

September 2017

CPP
Unit 2, 500 Princes Highway
St. Peters, NSW 2044, Australia
info-syd@cppwind.com
www.cppwind.com

EXECUTIVE SUMMARY

A detailed wind tunnel study was conducted to assess the impacts of the proposed Cockle Bay Park development in Sydney, Australia on the pedestrian wind amenity in and around the development site. Measurements were taken at various locations in and around the building site, focusing on ground level near trafficable areas, such as pathways, building entrances and sitting areas, as well as in the northern publicly accessible space and podium outdoor terrace of the proposed building.

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 Terrain Category 3 as defined in Standards Australia (2011) for all wind directions.

Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 34 locations for 16 wind directions each. The measurements were combined with local wind statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location.

The general pedestrian wind conditions surrounding the development site have been assessed under the Lawson comfort and distress/safety criteria. It was found that the impacts of the addition of the proposed development on the pre-existing wind conditions along the boardwalk, in Crescent Garden, and at the corner of Market and Sussex Streets were **insignificant**, and these areas would be expected to remain suitable for continued use as public accessways from a wind perspective. **Wind conditions at all locations measured at ground plane around the proposed development passed the distress/safety criterion.**

The degree of recommended mitigation would depend on the intended use of the space which will be the subject of a Stage 2 SSDA, and further wind assessment upon selection of the detailed design through the design excellence process. Majority of the northern publicly accessible space and level 3 podium rooftop to the south experienced wind conditions at a pedestrian standing comfort level, with the exception of some small windy areas near the tower. Local mitigation such as vertical screening and dense, robust, evergreen landscaping would be recommended to help create calmer areas to achieve suitable wind conditions for stationary activities should these be desired, and can be developed as part of the Stage 2 SSDA process.

Wind conditions exceeding the distress/safety criterion were identified in locations including the level 3 as well as level 5 podium rooftops, which are understood not to be publicly accessible areas.

These would require more elaborate mitigation in the form of semi enclosed booths, cabanas or marquees to shield the area to help reduce conditions to a pass rating. Areas closer to the tower would also benefit from architectural features to help contain and divert a quantity of the downwash from the façades away these areas. The extent, design and necessity of wind mitigation depends on the intended use of these areas, subject to further design for the Stage 2 SSDA, and as such will be refined during the design excellence process.

It is recommended that mitigation measures outlined in this report are to be considered during the design excellence process in order to learn about their impacts and to assist with achieving suitable wind conditions at the measured locations for the intended use of the spaces, which will be defined during the design excellence process as part of the Stage 2 SSDA.

DOCUMENT VERIFICATION

Date	Revision	Prepared by	Checked by	Approved by
07/09/2017	Initial release for review	AN	AN/JP	JP
15/09/2017	Addressed comments	AN	AN/JP	JP
22/09/2017	Minor amendments	AN	AN/JP	JP

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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 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 $(\ )$, $=(\ )'_{rms}$
ρ	Density of approach flow, kg/m³
$(\ )_{max}$	Maximum value during data record
$(\ )_{min}$	Minimum value during data record
$(\ )_{mean}$	Mean value during data record
$(\ )_{rms}$	Root mean square about the mean

1. INTRODUCTION

This report supports the Response to Submissions and amended Concept Proposal associated with a State Significant Development Application (SSDA 7684) submitted to the Minister for Planning and Infrastructure pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act).

DPT Operator Pty Ltd and DPPT Operator Pty Ltd (the Proponent) are seeking approval for a Concept Proposal for the redevelopment of the Cockle Bay Wharf Building and the surrounding area to create new open space and a commercial, retail and tourist precinct in the heart of the CBD (now referred to as Cockle Bay Park). The amended Concept Proposal includes:

- a large area of publicly accessible open space;
- new retail outlets, including new food and beverage destinations;
- new cultural and entertainment destinations; and
- a new commercial office tower.

The project will add new open space to the Sydney CBD and help to reconnect the city to the Darling Harbour waterfront. Cockle Bay Park will take its place in a revitalised Sydney CBD and speaks directly to local government objectives to create a 'Green, Global and Connected City' (City of Sydney) as well as the strategic vision outlined in 'Towards Greater Sydney 2056' to grow the "developing central city". The vision for this project was developed with consideration for the NSW Government objectives to support and "grow the knowledge industry", double tourism expenditure and "strengthen our local environment and communities" as outlined in 'NSW 2021: A Plan to Make NSW Number One'.

Please note that all plans, diagrams, images and graphics within this report and the supporting documentation (excluding the amended Concept Proposal Envelope Plans prepared by Francis-Jones Morehen Thorp Pty Ltd) are indicative only and have been included to communicate the intent of the amended Concept Proposal, including representative building shapes, forms, locations, layouts and relationships. It is proposed that these representations, together with acceptance of the building envelopes and massing, and associated design principles, will then be used to inform the Design Excellence process to follow the Stage 1 SSD Determination. Design Excellence outcomes will form the basis of the Stage 2 SSDA.

1.1 Background

The Proponent controls the lease of the Site, and also of the adjacent Darling Park precinct. The Darling Park site is a successful premium grade office precinct located on the west of the Sydney CBD, the associated Crescent Garden, located to the west of the three existing Darling Park towers, is a key area of open space in this part of the city.

The Proponent has recognised a number key issues with the existing layout of the Darling Park and Cockle Bay precinct, these being:

- The existing Cockle Bay Wharf building is not well integrated with the city, the Western Distributor freeway currently acts as a barrier to separate this area from the CBD;
- Publicly accessible open space is limited to the existing Crescent Garden in Darling Park; and
- The existing Cockle Bay Wharf building is outdated and is not in keeping with the future of Darling Harbour area as a vibrant entertainment and tourist destination.

The Cockle Bay precinct is at risk of being left behind and undermining the significant investment being made in Darling Harbour that will see it return to the world stage as a destination for events and entertainment. Accordingly, the Proponent is taking a carefully considered and staged approach to the complete revitalisation of the site and its surrounds. The envisaged development, which will be facilitated by the proposed building envelopes will:

- reconnect the city with the Darling Harbour waterfront;
- create new publicly accessible open space in the heart of the Sydney CBD;
- create new public land above the Western Distributor;
- provide new access routes between the city and the ICC Sydney / Darling Harbour Live precinct;
- support the Sydney economy by providing a new premium commercial building; and
- refresh and renew an existing entertainment and tourist destination.

1.2 Site Description

The 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.

The Site is located to the immediate south of Pyrmont Bridge, within the Sydney CBD on the eastern side of the Darling Harbour precinct. The Site is also located within the City of Sydney local government area (LGA). A locational context area plan and location plan are provided at Figure 1 below.

The project Site area has been slightly amended by this Response to Submissions, a comparison of the exhibited and now-proposed Site area is provided as Figure 1, and the now proposed Site area is shown below as Figure 2.

The Darling Harbour precinct is undergoing significant redevelopment as part of the SICEEP, Darling Square, and IMAX renewal projects. The urban, built form and public transport / pedestrian context for the proposed Harbourside development will fundamentally change as these developments are progressively completed.

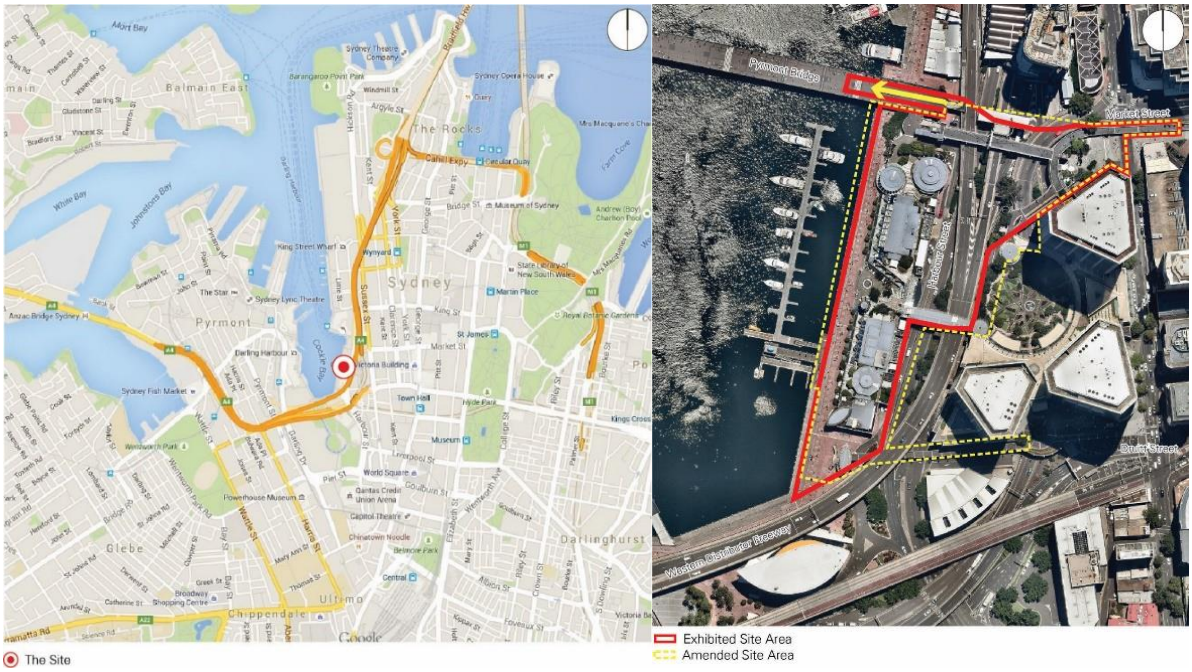


Figure 1: Location Context Area Plan (left) and Location Plan (revised site area in yellow, right)

Figure 2: Amended Location Plan

1.3 Overview of Proposed Development

The proposal relates to a staged SSDA and seeks to establish amended concept proposal details for the renewal and re-imagining of the Cockle Bay precinct. The amended Concept Proposal establishes the vision, planning and development framework which will be the basis for the consent authority to assess future detailed development proposals. The Cockle Bay Park Site is to be developed for a mix of Retail, Cultural and Commercial (Office) uses including retail and restaurants, offices, and publicly accessible open space.

The amended Concept Proposal seeks approval for the following key components and development parameters:

- Demolition of existing site improvements, including the existing Cockle Bay Wharf building complex, pedestrian bridge links across the Western Distributor, and obsolete monorail infrastructure;
- Building envelopes;
- Land uses across the Site;
- A maximum total Gross Floor Area (GFA) across the Cockle Bay Park of 75,000m^2 for commercial development and 14,000m^2 for retail (including food and beverage) development;
- Urban Design and Public Realm design principles to provide a Design Excellence framework; and
- Strategies for utilities and services provision, drainage and flooding, and ecological sustainable development.

1.4 Changes to the Exhibited Concept Proposal

The overall geometry of the building has not significantly changed from a wind perspective, with the exception of the relocation of the tower in the south direction.

1.5 Building Envelope

The revised Concept Proposal establishes a building envelope and maximum areas for specific land uses. The key revisions to the envelope are outlined below.

1.6 Relocation and Refinement of Open Space

The site has a great deal of potential to provide an excellent area of open space, located conveniently between the Sydney CBD and the Darling Harbour waterfront. The exhibited EIS did not provide specific detail about the potential for provision of open space within the site, deferring this to Stage 2 following a competitive design process. Since the exhibition of the EIS, the future open space areas within the site have been re-examined, relocated and refined providing greater detail at Stage 1.

The primary open space provided within the site has been shifted to the north, the principal advantages of this are twofold:

- the relocation of the open space to the north will allow for better solar access throughout the day, leading to a more useable open space that provides a greater level of amenity for the users of the open space;
- the co-location of the open space with the State heritage-listed Pyrmont Bridge allows for an enhanced interface with the heritage asset and allows for improved passive views to, and past, the bridge from new open space.

The refined scheme has been developed with input from Aspect Studios who have provided concept landscape plans.

1.7 Relocation of Tower

The tower element within the Concept Proposal has been relocated further south to allow space for the open space to move to the north. The impact of this relocation is that the overall height of the tower has reduced as the new location is more affected by the solar access plane to Tumbalong Park.

2. THE WIND TUNNEL TEST

Pedestrian acceptability of footpaths, entrances, plazas, and terraces is often an important design parameter of interest to the building owner and architect. Assessment of the acceptability of the pedestrian level wind environment is desirable and more appropriate 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 that 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 summarises the model configurations, test methods, and data acquisition parameters used. All data collection was performed in accordance with Australasian Wind Engineering Society (2001), and American Society of Civil Engineers (1999, 2006). Analytical methods such as computational fluid dynamics (CFD) are not capable, except in very simple geometries, to estimate wind pressures, frame loads, or windiness in pedestrian areas.

Table 1: Configurations for data acquisition

General Information	
Model length scale	1:400
Surrounding model radius (full-scale)	570 m
Reference height (full-scale)	200 m above ground level
Approach Terrain Category	Terrain Category 3
Study Information	
Number of test locations	34
Wind directions	16 wind directions in 22.5° increments from 0° (north)
Testing Configuration(s)	
Configuration A (Existing Site)	Existing Cockle Bay Wharf site with existing surrounding buildings, as shown in Figure 5.
Configuration B (Proposed Site)	Proposed Cockle Bay Park development with surrounding existing and approved buildings, as shown in Figure 6 and Figure 7.

Modelling of the aerodynamic loading on 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 characteristic 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 3. 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, 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 4 and are explained more fully in Section 4.1.1.

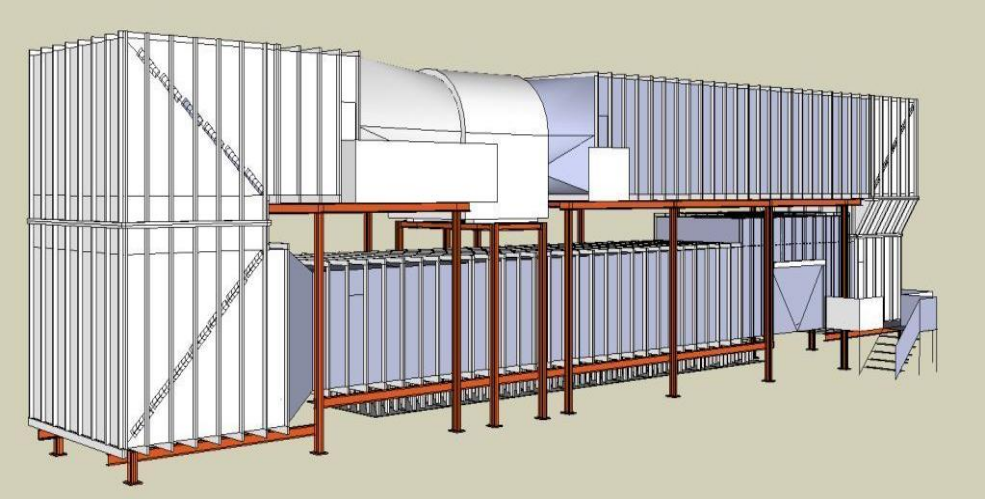


Figure 3: Schematic of the closed-circuit wind tunnel

A model of the proposed development and surrounds to a radius of 570 m was constructed at a length scale of 1:400, Figure 5. The model scale 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. The models were mounted on the turntable located near the downstream end of the wind tunnel test section, Figure 7. The turntable permitted rotation of the

modelled area for examination of wind speeds from any approach wind direction. Additional photos of the testing are presented in Appendix 1.

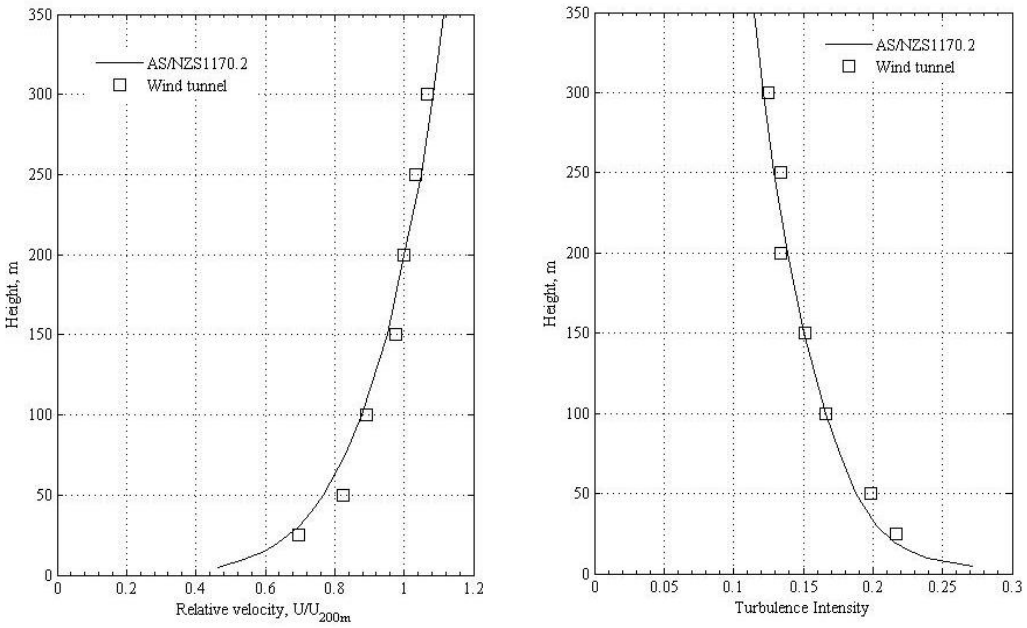


Figure 4: Mean velocity and turbulence profiles approaching the model

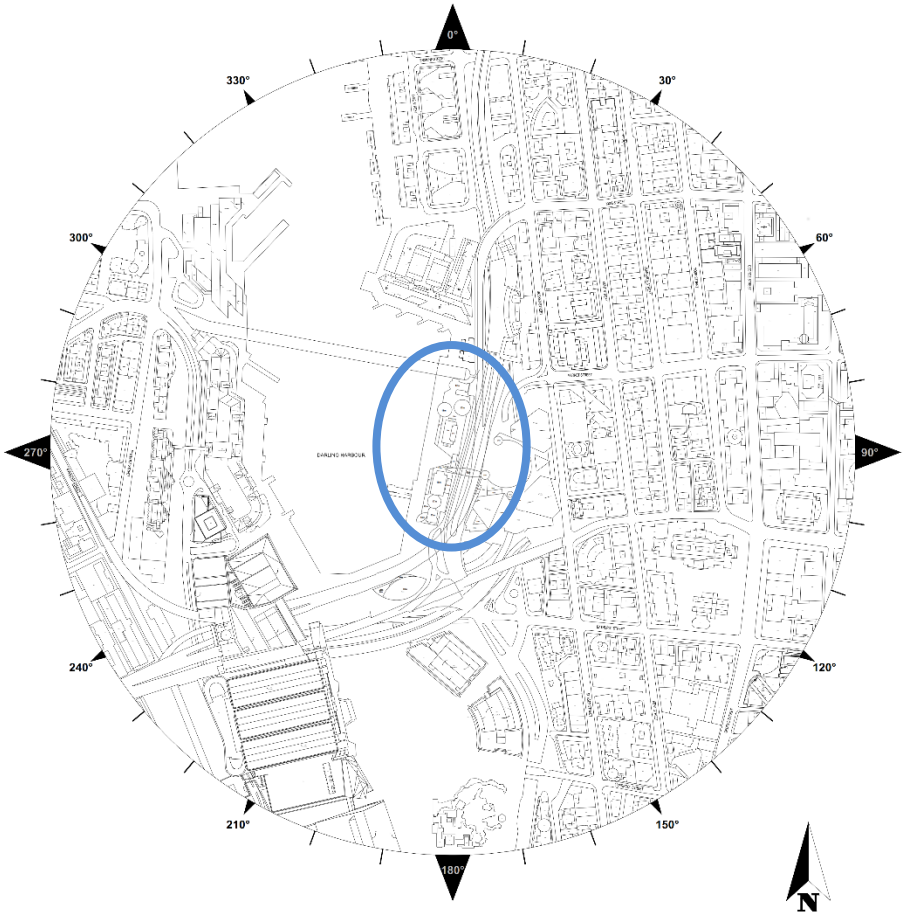


Figure 5: Tunnel model layout of existing site with surroundings – Configuration A

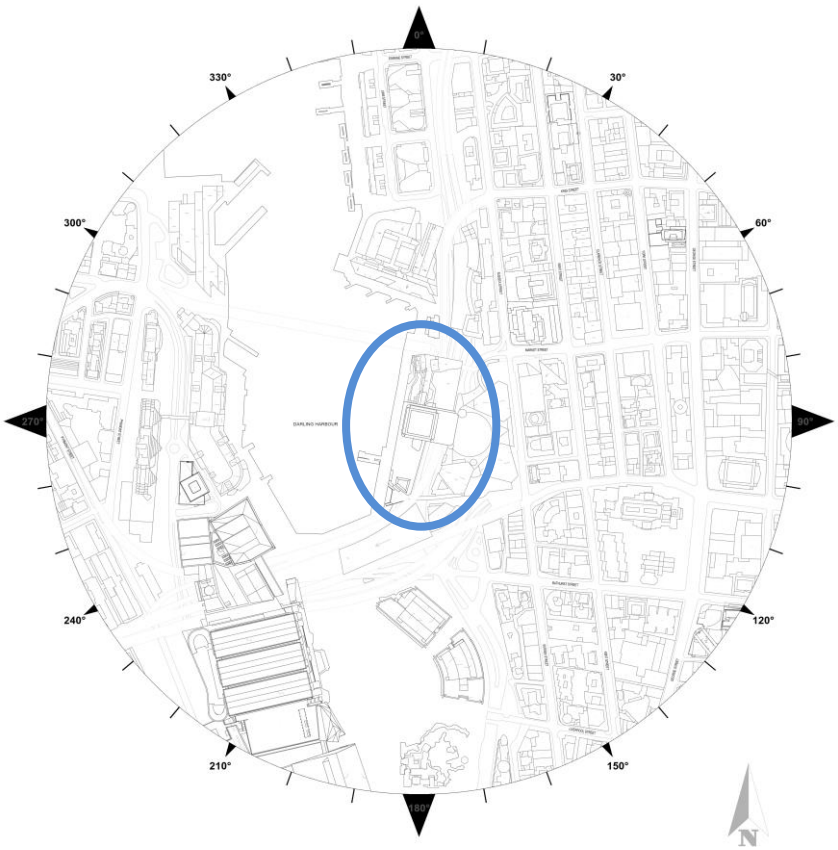


Figure 6: Tunnel model layout of proposed site with surroundings – Configuration B

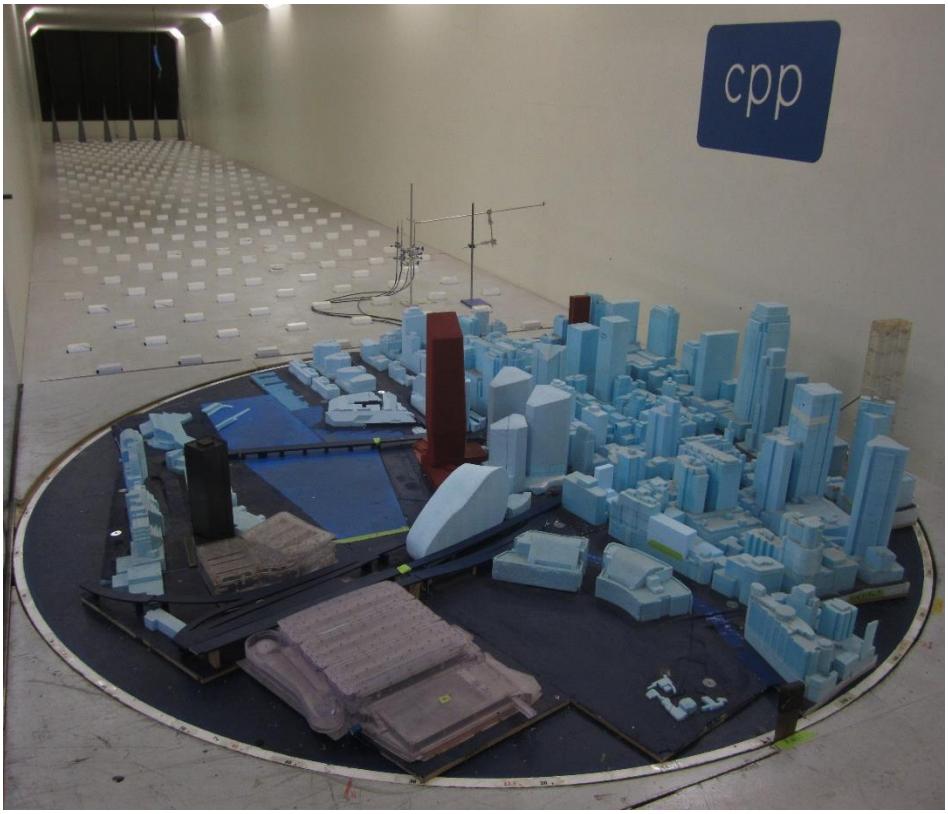


Figure 7: Photograph of the tunnel model in Configuration B viewed from the south-west

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 2.

Lawson's criteria have categories for discomfort, 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 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.

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

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 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.

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 4. Turbulence intensities are related to the local mean wind speed. These profiles have the form as derived from Standards Australia (2011) and are appropriate for the approach conditions.

4.1.2 Pedestrian Winds

Wind speed measurements were recorded at 34 locations to evaluate pedestrian comfort in and around the project site, the results of which are presented in Figure 9 to Figure 14. Wind speed 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 in conjunction with the design team to investigate areas of concern.

The hot-film signal was sampled for a period corresponding to one hour in prototype. All wind speed data were digitally filtered to obtain the two to three second running mean wind speed at each point; this is the size of a gust affecting a pedestrian and used as the basis for the assessment criterion. 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:

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

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 1995 to 2016, Figure 8. 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 Lawson criteria consider the integration of the velocity measurements with local wind climate statistical data summarized in Figure 8 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 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.

The tables in Appendix 2 also give the wind speed exceeded 5% and 0.022% for direct comparison with the Lawson comfort and distress criteria and the associated Lawson ratings for both mean, GEM, and combined wind speeds. Colour coded summary assessments of pedestrian comfort and safety with respect to the Lawson criteria are presented in Figure 9 to Figure 14 for each test location. Because some pedestrian wind measurement positions are 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 of these summary findings. The implications of the results are discussed in Section 5.

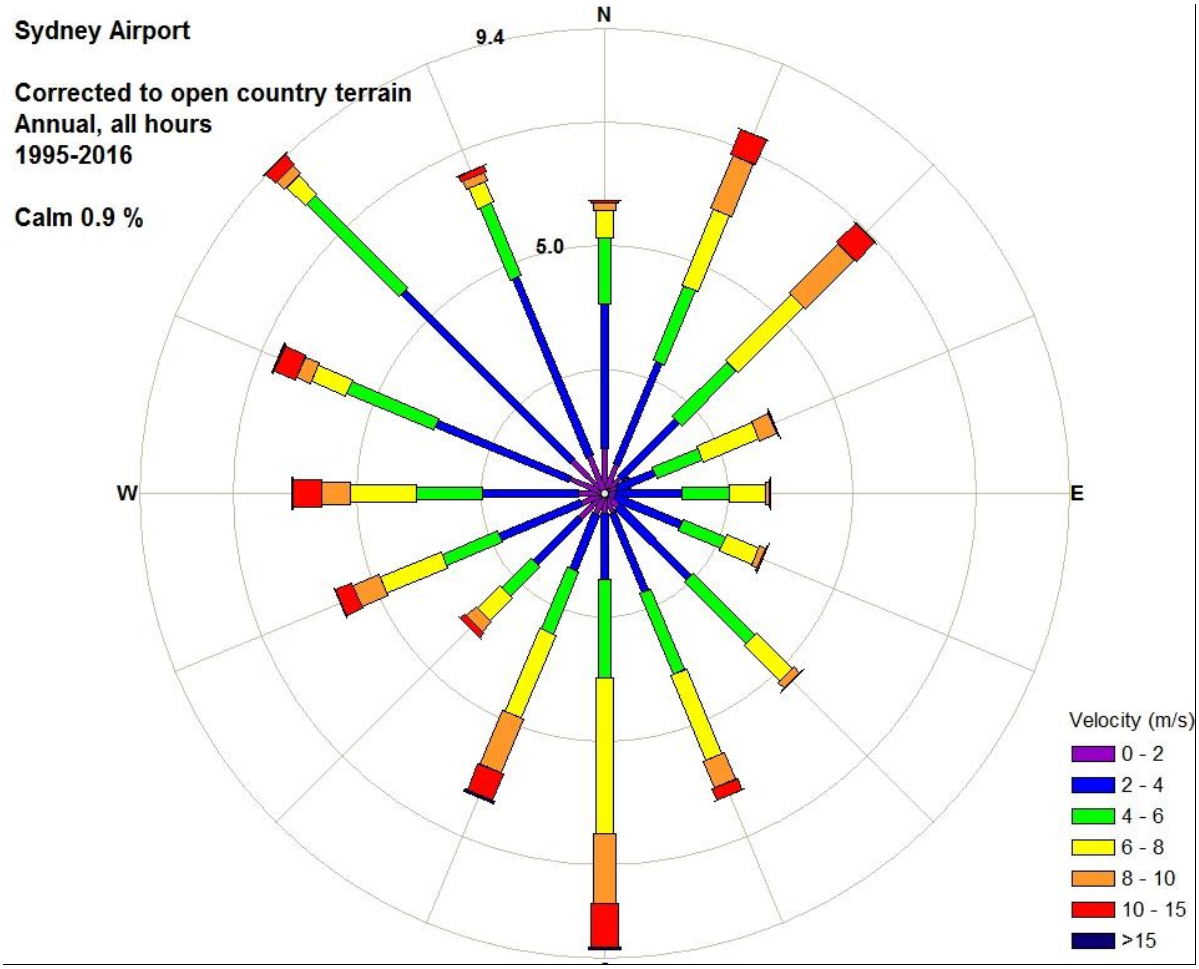


Figure 8: Wind rose of direction and speed for Sydney Airport

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.

5. DISCUSSION

The wind climatology chart of Figure 8 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 geometry of development and surrounding structures. However, in general terms the winds from the north-east, south, and west quadrants had the most pronounced effect on the site as higher-level winds were brought to street level as downwash and/or channelled winds between the surrounding buildings. The influence of wind direction on the suitability of a location for an intended purpose can be ascertained from the graphs in Appendix 2.

A summary of the wind results against the expected wind rating target for each measured location are provided in Table 4. The wind rating targets are based on the intended use of the measured location which will be further developed during the design excellence process for a Stage 2 SSDA It is clear from Table 4 that from a comfort perspective, all the measurement locations on ground plane and Pyrmont Bridge around the development site meet the wind rating targets, and pass the distress criterion. Most measured locations on the podium rooftops and northern publicly accessible space would require the mitigation recommendations outlined in this report to help achieve suitable wind conditions from a comfort and distress/safety perspective.

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded images of Figure 9 to Figure 14, which depict the locations selected for investigation of pedestrian wind comfort in and around the existing and proposed development sites 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. It should be noted that the comfort criteria are based on 95% of the time that the mean wind speed is below specific wind speed levels. Mitigation measures are likely to be required for any orange and red locations, and may be necessary for other locations depending on the intended use of the space. Although 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%, yet can be effective in providing a localised calmer wind environment.

It should also be noted that a model of the northern publicly accessible space was tested in Configuration B as shown in Figure 15 in Appendix 1 despite not being shown in Figure 11, Figure 13 and Figure 14.

Table 4: Summary of wind tunnel results against wind rating targets for each measured location

Description / Location		Expected Wind Rating Target	Wind Tunnel Results			
		Comfort rating, 5% exceedance wind speed (m/s)	Lawson comfort rating	5% exceedance wind speed (m/s)	Lawson distress rating	0.022% exceedance wind speed (m/s)
Remote	1	PW, >6-8	PW	6.0	Pass	11.7
	2	PW, >6-8	PSt	5.2	Pass	11.0
	3	PW, >6-8	PW	6.4	Pass	12.8
Boardwalk, Pyrmont Bridge, and Corner Market and Sussex Street	4.1	PW, >6-8	PSi	3.3	Pass	7.3
	4	PW, >6-8	PSi	3.1	Pass	6.1
	5	PW, >6-8	PSt	4.6	Pass	10.2
	6.1	PW, >6-8	PSt	5.4	Pass	10.8
	6	PW, >6-8	PSt	5.8	Pass	11.9
	7.1	PW, >6-8	PSt	4.4	Pass	9.2
	7	PW, >6-8	PSt	5.0	Pass	10.8
	8.1	PW, >6-8	PSt	5.1	Pass	11.5
	8	PW, >6-8	PSi	3.6	Pass	10.1
	9	PW, >6-8	PSt	5.3	Pass	12.5
	10.1	PW, >6-8	PSt	5.5	Pass	11.4
	10	PW, >6-8	PSt	5.4	Pass	11.8
	11	PW, >6-8	PSt	4.1	Pass	10.1
	12.1	PSt, >4-6	PSi	3.9	Pass	9.1
	12	PSt, >4-6	PSt	4.1	Pass	9.0
	13.1	PW, >6-8	PSt	5.5	Pass	11.4
	13	PW, >6-8	PSi	3.6	Pass	9.0
	14.1	PW, >6-8	PSt	5.3	Pass	12.6
	14	PW, >6-8	PSt	4.5	Pass	11.1
Level 3 Podium Rooftop and Northern Open Spa	15	PSi, >2-4	PSt	4.8	Pass	9.7
	16	PSi, >2-4	PSt	5.5	Pass	11.7
	17	PSi, >2-4	PW	6.7	Pass	13.9
	18	PSi, >2-4	PSt	5.3	Pass	10.2
	19	OD, <2	PW	6.0	Pass	11.8
	20	OD, <2	PSt	5.1	Pass	9.7
	21	PSi, >2-4	PSt	5.2	Pass	10.7
	22	PSi, >2-4	PSt	5.8	AB	15.5
	23	PSi, >2-4	PW	6.0	Pass	11.6
	24	PSi, >2-4	PW	7.3	AB	17.1
	25	PSt, >4-6	PW	6.8	AB	18.9
	26	PSi, >2-4	PSt	5.4	Pass	11.8
	27	OD, <2	PSt	5.0	Pass	13.2
	28	PW, >6-8	PSt	4.7	Pass	10.6
Level 5 Podium Rooftop	29	PSt, >4-6	PSt	5.6	Pass	12.6
	30	PSt, >4-6	PSt	4.7	Pass	12.8
	31	PSt, >4-6	BW	9.9	Fail	21.9
	32	PSt, >4-6	PSt	4.9	Pass	12.9
	33	PSt, >4-6	BW	8.2	AB	17.0
	34	PSt, >4-6	BW	8.9	Fail	21.1

LEGEND

Comfort Criteria

OD Outdoor Dining

PSt Pedestrian Standing

BW Business Walking

PSi Pedestrian Sitting

PW Pedestrian Walking

U Uncomfortable

Distress/Safety Criteria

Pass Passes safety criteria

AB Able bodied

Fail Fails safety criteria

5.1 Remote Locations

An indication of the general wind conditions in Sydney can be obtained from inspection of Figure 9 at Location 1 to 3. These locations are somewhat remote from the site and less influenced by the massing of the development. Wind conditions at Location 2 in Tumbalong Park is classified as pedestrian standing. This location is within relatively open space compared to Locations 1 and 3 which are nested within high-rise buildings, and are susceptible to downwash and/or channeled winds between surrounding high-rise buildings. Wind conditions at these locations were classified as pedestrian walking. Wind conditions at all remote locations in Figure 9 pass the distress criterion.

Figure 9: Pedestrian wind speed measurements with comfort and distress/safety ratings at remote locations

5.2 Configuration A – Existing Site

5.2.1 Boardwalk, Pyrmont Bridge, and Corner of Market and Sussex Streets

Measurements were taken in the vicinity of the current Cockle Bay Wharf precinct, including Crescent Garden of Darling Park and the boardwalk, to ascertain the pre-existing wind conditions in the area, Figure 10.

Location 4.1 and 12.1 near Sydney Aquarium and within Crescent Garden, respectively, received wind comfort ratings of pedestrian sitting. Wind conditions on Pyrmont Bridge and along the boardwalk

at Locations 6.1 to 8.1, and 10.1 were classified at a pedestrian standing comfort level. These locations would experience wind speeds of 4 m/s or less for about 80-90% of the time and are primarily exposed for winds from the south and west quadrants as can be seen in the polar plots in Appendix 2. The effects of these wind conditions can be aided by inspecting the Beaufort Scale in Table 3 of Section 4. Wind conditions at Locations 13.1 and 14.1, on the Western Distributor overpass footbridge and at the corner of Market and Sussex Streets respectively, were classified as pedestrian standing. All measured locations in Configuration A passed the distress/safety criterion.

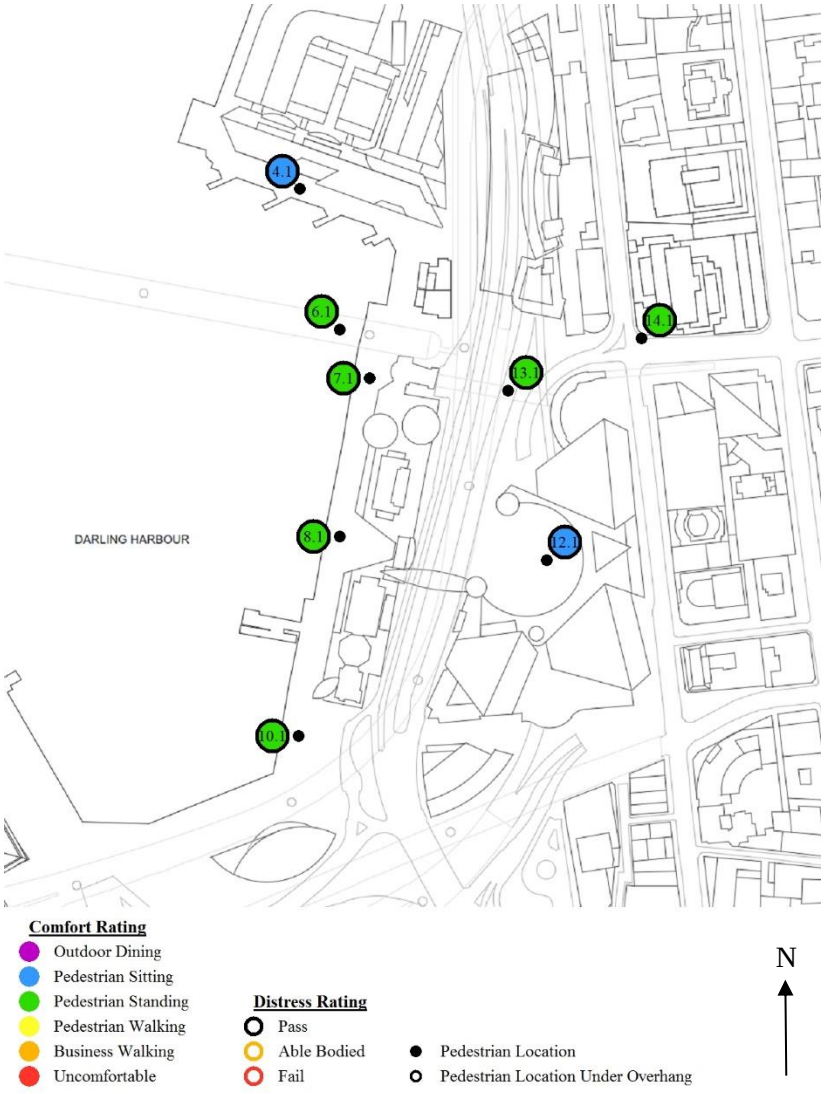


Figure 10: Pedestrian wind speed measurements with comfort and distress/safety ratings around the existing development site – Configuration A

5.3 Configuration B – Proposed Site

5.3.1 Boardwalk, Pyrmont Bridge, and Corner of Market and Sussex Streets

With comparison to existing conditions in Figure 10, wind conditions along the boardwalk, within Crescent Garden and at the corner of Market and Sussex Streets were marginally impacted by the addition of the proposed development, however these areas are expected to remain suitable for

continued use as public accessways with Lawson comfort ratings of pedestrian sitting and standing. All measured locations in Figure 10 passed the distress/safety criterion.

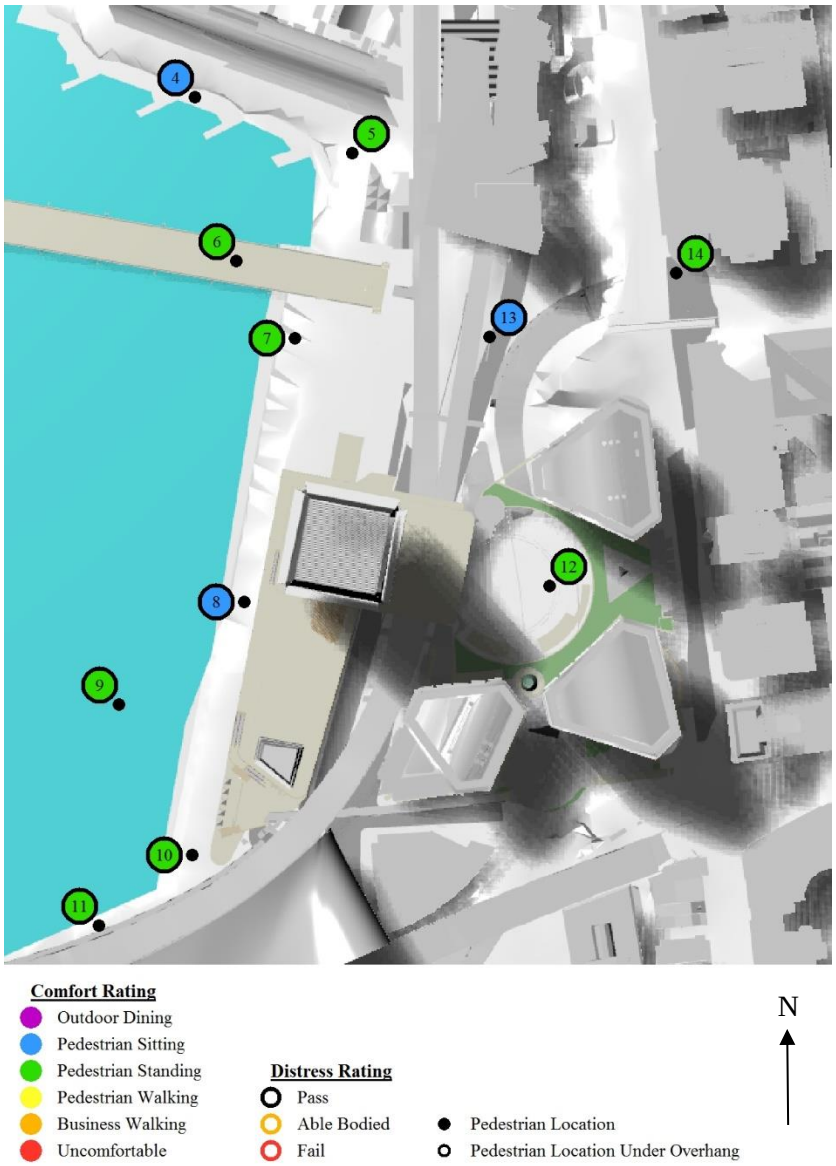


Figure 11: Pedestrian wind speed measurements with comfort and distress/safety ratings around the proposed development site – Configuration B

5.3.2 Level 3 Podium Rooftop and northern publicly accessible space

Figure 12 shows the measured pedestrian level wind conditions on the level 3 podium rooftop and the northern publicly accessible space. From a wind perspective, the primary purpose of a podium is to protect pedestrians at ground level from downwash and therefore the podium rooftop is expected to be windy closer to the tower, specifically locations 17, 22, 24 and 25, which were rated at high pedestrian standing and walking comfort levels, and exceeded the distress/safety criterion to an able-bodied rating (except for Location 17). Should outdoor dining style activities be assigned to these areas as part of the Stage 2 SSDA then more elaborate mitigation measures would be required for Locations 17, 22, 24 and

25 to help achieve suitable conditions. These locations would benefit from more enclosed booths/cabanas, in combination with dense, robust landscaping to help shield these areas from horizontal approach wind flow and tower downwash. Increasing the level 5 podium setback from the west and south sides would help contain a large portion of the downwash from the tower facades and redirect the flow away from the Level 3 rooftop podium. The extent of the setback will be refined during the design-excellence process for the Stage 2 SSDA.

Wind conditions at the remaining measured locations (Locations 15, 16, 18 to 20, 21, 23, and 24 to 26) are mostly exposed to incident winds from the west quadrant, and were rated at a pedestrian standing level. Should outdoor dining style activities be assigned to these areas as part of the Stage 2 SSDA then mitigation measures in the form of vertical screening is recommended to create local 'pockets' of calm space in these areas.

Figure 12: Pedestrian wind speed measurements with comfort and distress/safety ratings on the podium rooftop, northern publicly accessible space and Level 3 Podium Rooftop – Configuration B

5.3.3 Level 5 Podium Rooftop

Figure 13 and Figure 14 show the measured wind conditions on the level 5 podium rooftop. Locations 29, 30 and 32 experienced wind conditions suitable for pedestrians standing style activities, and passed the distress/safety criterion. Note, these locations are situated away from the tower corners.

Location 31 in Figure 14 near the south-west corner of the tower experiences windy conditions rated at a business walking comfort level, and exceeding the distress/safety criterion to a 'fail' rating, due to downwash from the west and south facades during winds from the west and south quadrants. Elaborate mitigation measured would be required if these areas are intended to be generally accessible for pedestrians; extensive awnings in combination with vertical screening, and signage notifying patrons of potential windy conditions in these areas, and other areas near the tower corners would be recommended. Locations 33 and 34 in Figure 14 experienced similar levels of wind due to downwash from the tower's facades during wind events from the south and north-west quadrants, and pressure driven flow between the proposed tower and the Darling Park Towers during winds from the north-east. The mitigation measures abovementioned are recommended to be included as part of the detailed design development of the proposal, as part of the Stage 2 SSDA. With the inclusion of these mitigation measured these areas would be expected to be suitable for pedestrian walking

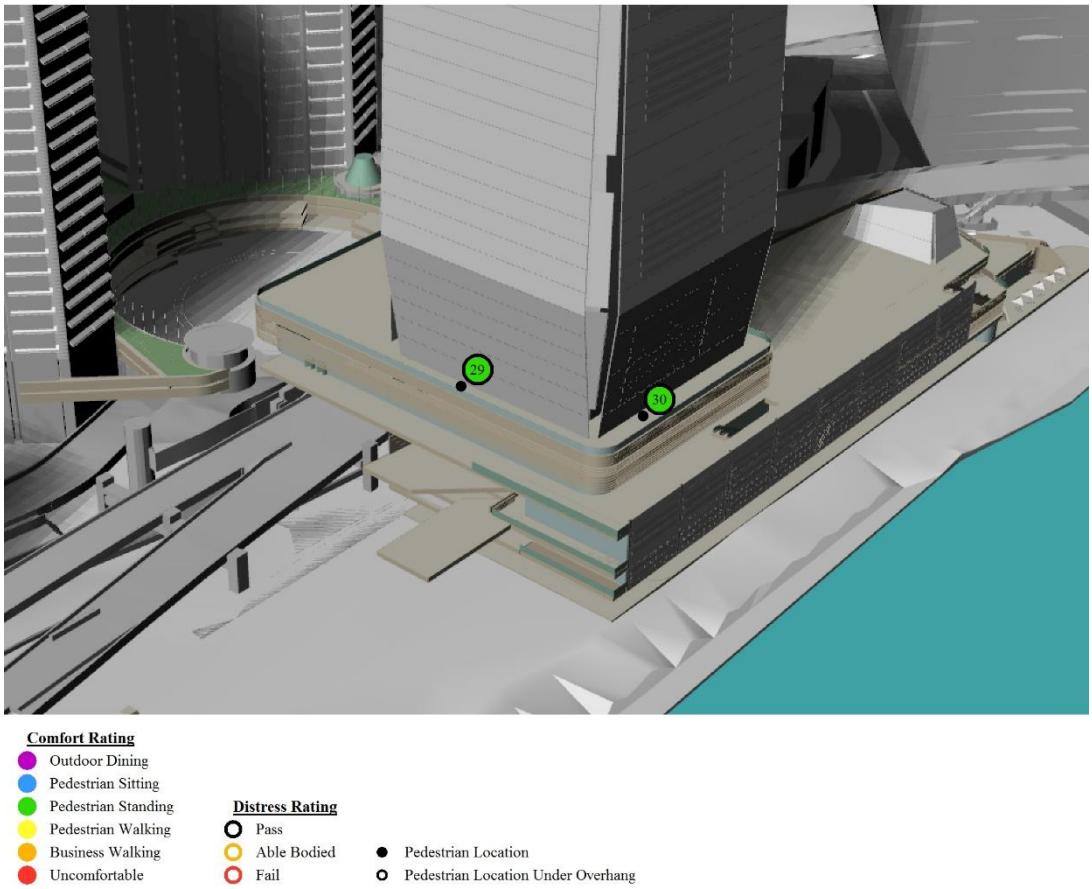


Figure 13: Pedestrian wind speed measurements with comfort and distress/safety ratings on the level 5 podium viewed from the north-west – Configuration B

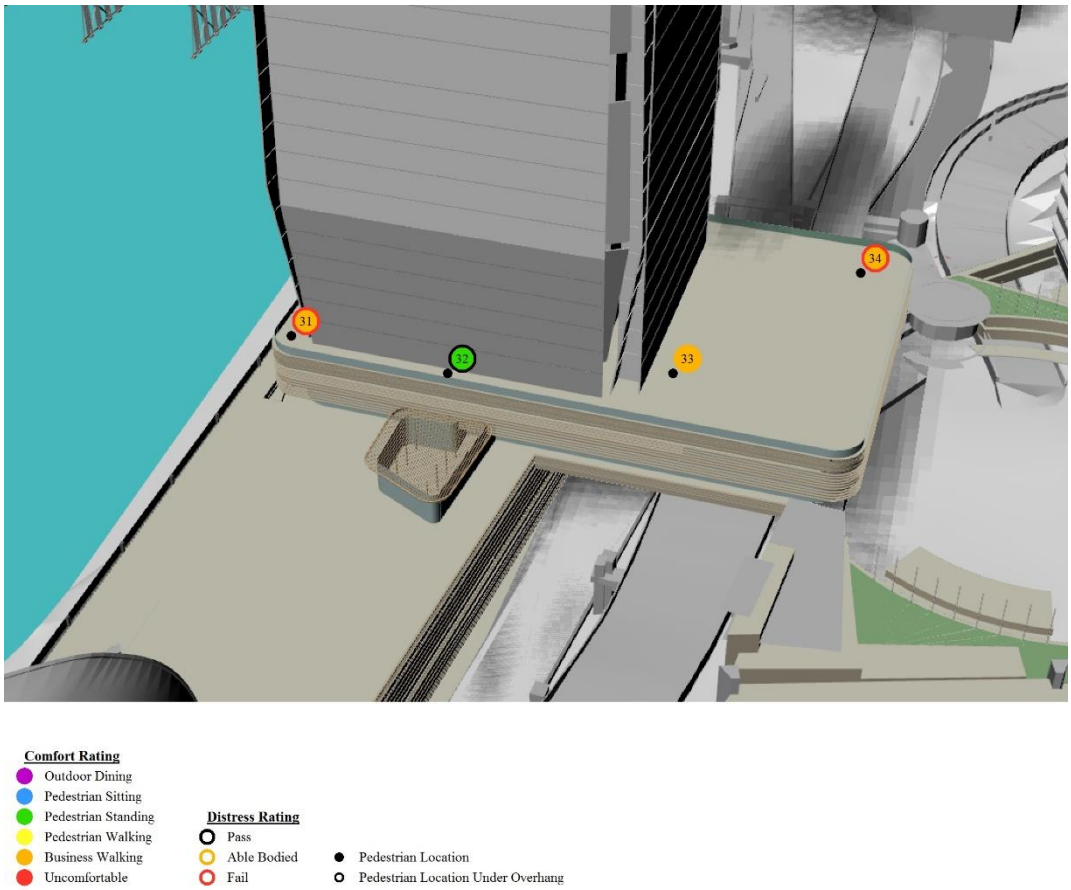


Figure 14: Pedestrian wind speed measurements with comfort and distress/safety ratings on the level 5 podium viewed from the south-east – Configuration B

6. CONCLUSIONS

A wind tunnel study of the proposed Cockle Bay Park development site was conducted to assess pedestrian wind comfort and safety around the site at ground level and on the upper terraces of the podiums and northern publicly accessible space. Measurements of wind speeds likely to be experienced by pedestrians were made with a hot-film anemometer at 34 locations for 16 wind directions each. The measurements were combined with wind climate statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location.

The general pedestrian wind conditions surrounding the development site have been assessed under the Lawson comfort and distress/safety criteria. It was found that the impacts of the addition of the proposed development on the pre-existing wind conditions along the boardwalk, in Crescent Garden, and at the corner of Market and Sussex Streets were **insignificant**, and these areas would be expected to remain suitable for continued use as public accessways from a wind perspective. **Wind conditions at all locations measured at ground plane around the proposed development passed the distress/safety criterion.**

The degree of recommended mitigation would depend on the intended use of the space which will be the subject of a Stage 2 SSDA, and further wind assessment upon selection of the detailed design through the design excellence process. Majority of the northern publicly accessible space and level 3 podium rooftop to the south experienced wind conditions at a pedestrian standing comfort level, with the exception of some small windy areas near the tower. Local mitigation such as vertical screening and dense, robust, evergreen landscaping would be recommended to help create calmer areas to achieve suitable wind conditions for stationary activities should these be desired, and can be developed as part of the Stage 2 SSDA process.

Wind conditions exceeding the distress/safety criterion were identified in individual locations on the level 3 as well as level 5 podium rooftops, which are understood not to be publicly accessible areas. These would require more elaborate mitigation in the form of semi enclosed booths, cabanas or marquees to shield the area to help reduce conditions to a pass rating. Measured locations closer to the tower would also benefit from architectural solutions to help contain and divert a quantity of the downwash from the façades away these areas. The extent, design and necessity of wind mitigation depends on the intended use of these areas, subject to further design for the Stage 2 SSDA, and as such will be refined during the design excellence process.

It is recommended that mitigation measures outlined in this report are to be considered during the design excellence process in order to learn about their impacts and to assist with achieving suitable wind conditions at the measured locations for the intended use of the spaces, which will be defined during the design excellence process as part of the Stage 2 SSDA.

7. REFERENCES

American Society of Civil Engineers (2006), *Minimum Design Loads for Buildings and Other Structures* (ASCE 7–05).

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

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.

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/NZS1170.2:2011).

Appendix 1: Additional Photographs of the CPP Wind Tunnel Model

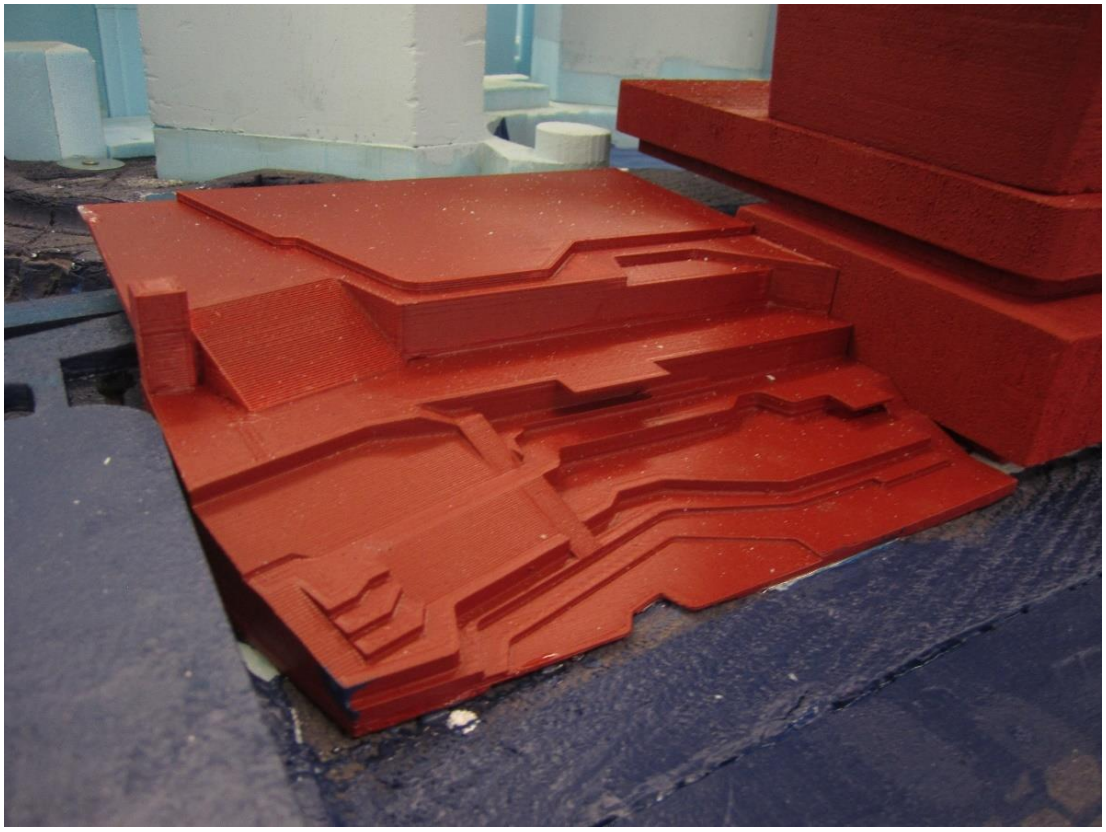


Figure 15: Closeup of the northern publicly accessible space model viewed from the north-west

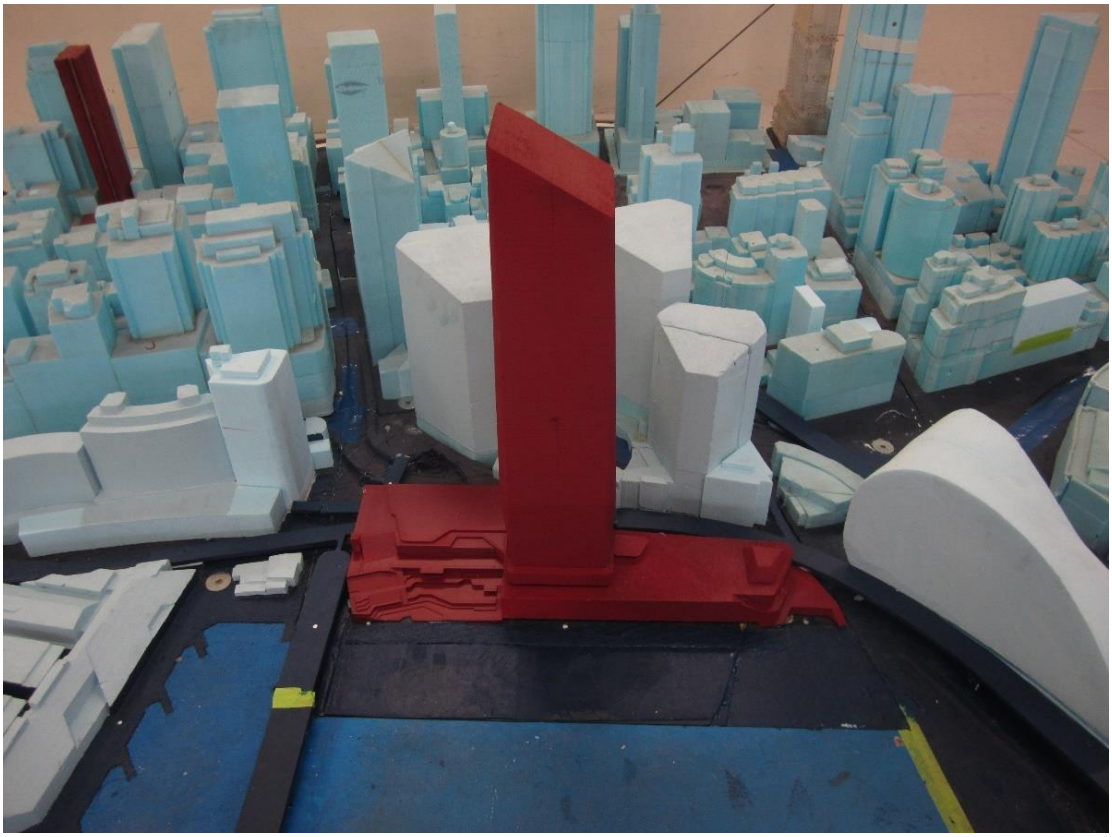
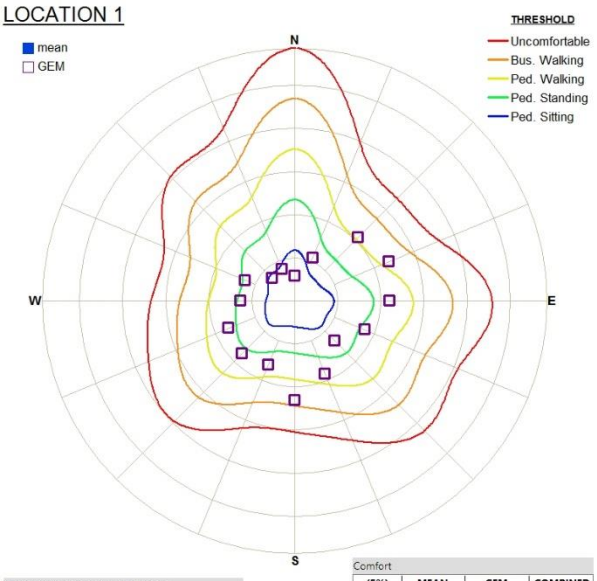


Figure 16: CPP wind tunnel model viewed from the west

Appendix 2: Directional Wind Results

7.1 Remote Locations

LOCATION 1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	41.34	52.10	52.10
4	12.58	19.97	19.97
6	2.38	5.26	5.26
8	0.23	0.97	0.97
10	0.01	0.11	0.11

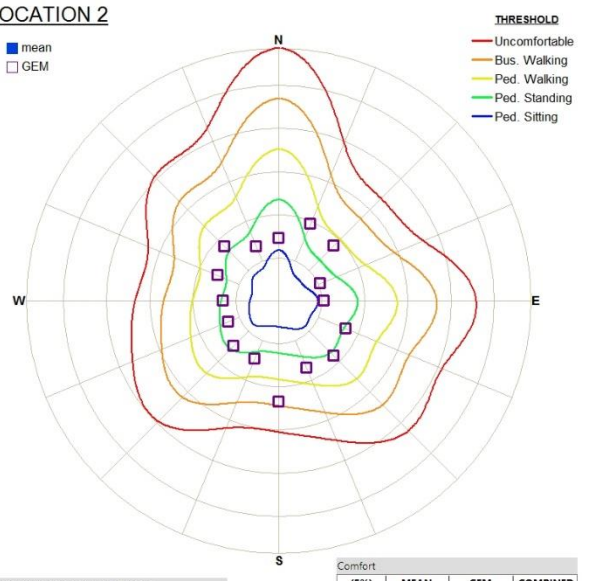
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	6.0	6.0
Rating	Ped Standing	Ped Walking	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.4	11.7	11.7
Rating	Pass	Pass	Pass

LOCATION 2



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.60	51.70	51.70
4	5.92	14.57	14.57
6	0.56	2.75	2.75
8	0.03	0.44	0.44
10	0.00	0.06	0.06

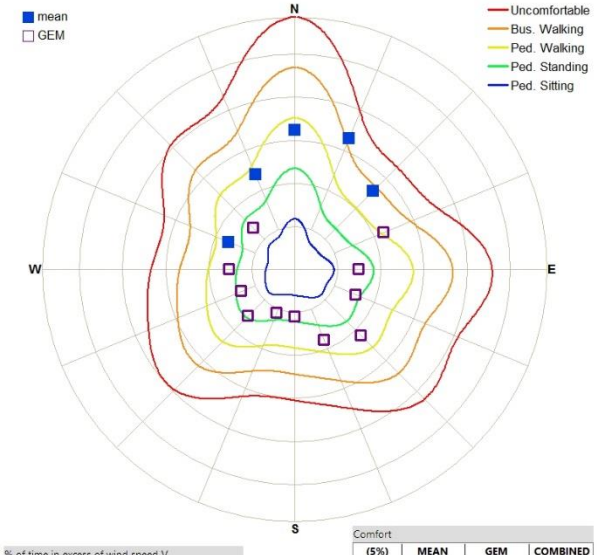
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	5.2	5.2
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.2	11.0	11.0
Rating	Pass	Pass	Pass

LOCATION 3



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	48.56	57.27	58.39
4	15.61	16.82	18.00
6	6.16	5.66	6.60
8	1.95	1.33	1.97
10	0.41	0.18	0.41

Comfort

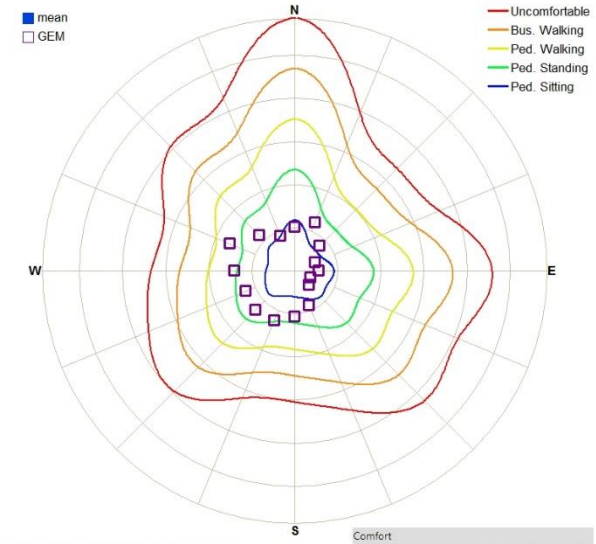
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.3	6.1	6.4
Rating	Ped Walking	Ped Walking	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.8	11.7	12.8
Rating	Pass	Pass	Pass

7.2 Configuration A – Existing Site

LOCATION 4.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	10.19	26.09	26.09
4	0.30	2.07	2.07
6	0.00	0.17	0.17
8	0.00	0.00	0.00
10	0.00	0.00	0.00

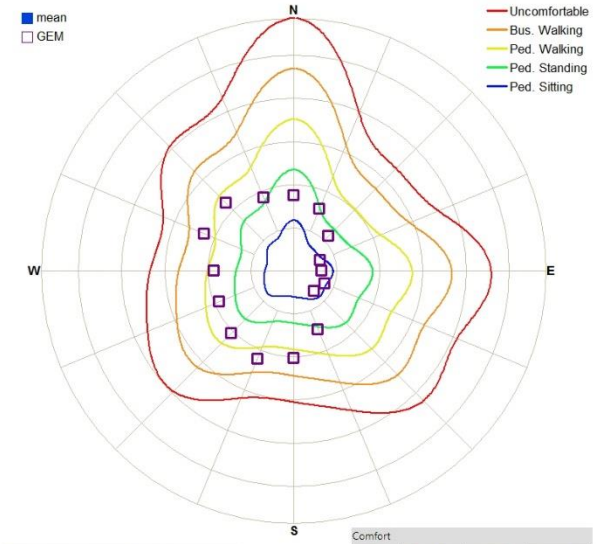
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.4	3.3	3.3
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.5	7.3	7.3
Rating	Pass	Pass	Pass

LOCATION 6.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	33.90	49.84	49.84
4	7.91	14.76	14.76
6	1.48	3.07	3.07
8	0.17	0.51	0.51
10	0.01	0.07	0.07

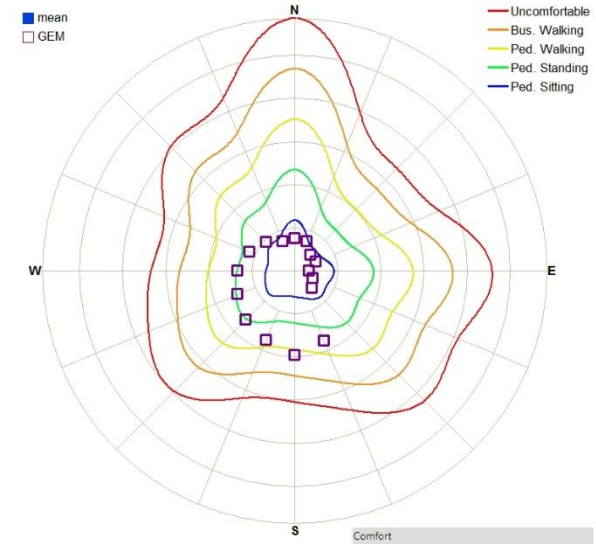
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.4	5.4
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.6	10.8	10.8
Rating	Pass	Pass	Pass

LOCATION 7.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	19.03	28.10	28.10
4	3.98	7.47	7.47
6	0.48	1.09	1.09
8	0.03	0.10	0.10
10	0.00	0.01	0.01

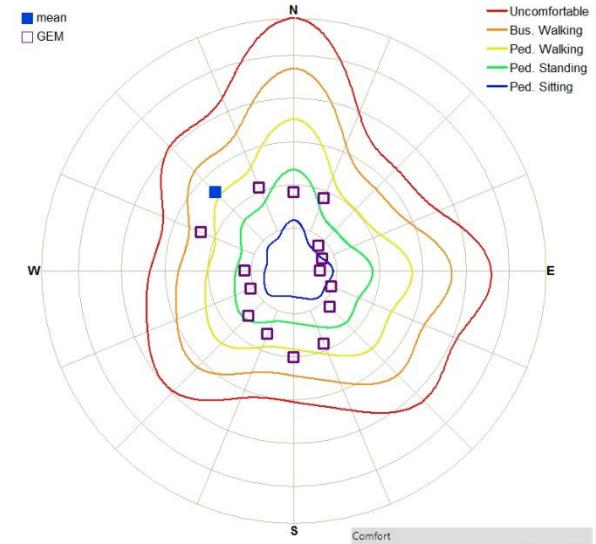
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.7	4.4	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.3	9.2	9.2
Rating	Pass	Pass	Pass

LOCATION 8.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	39.81	46.94	47.75
4	10.66	11.88	12.21
6	2.12	2.26	2.39
8	0.39	0.41	0.49
10	0.07	0.08	0.10

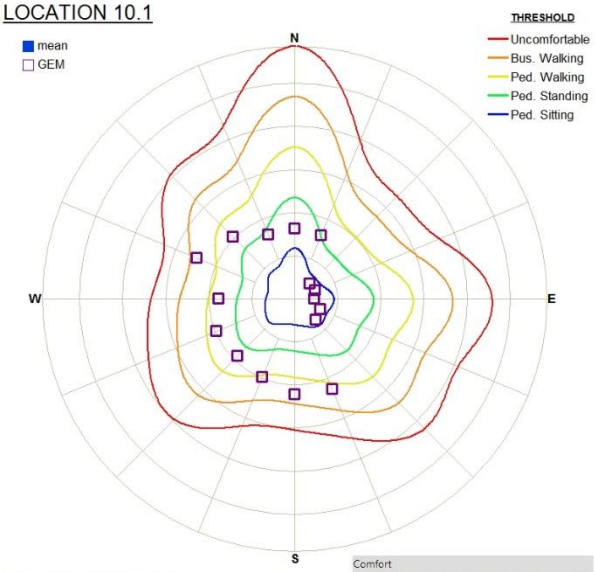
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.9	5.0	5.1
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.3	11.0	11.3
Rating	Pass	Pass	Pass

LOCATION 10.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	35.60	46.09	46.09
4	8.70	16.99	16.99
6	1.32	3.57	3.57
8	0.13	0.70	0.70
10	0.01	0.13	0.13

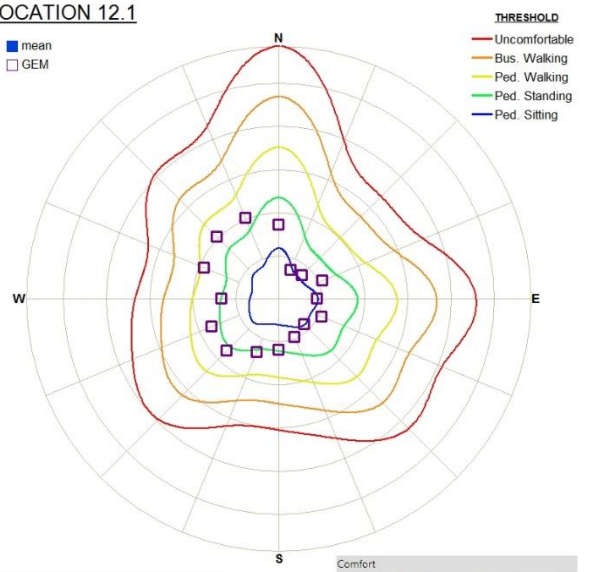
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.5	5.5
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.3	11.4	11.4
Rating	Pass	Pass	Pass

LOCATION 12.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	18.48	37.99	37.99
4	1.46	4.48	4.48
6	0.12	0.68	0.68
8	0.01	0.10	0.10
10	0.00	0.01	0.01

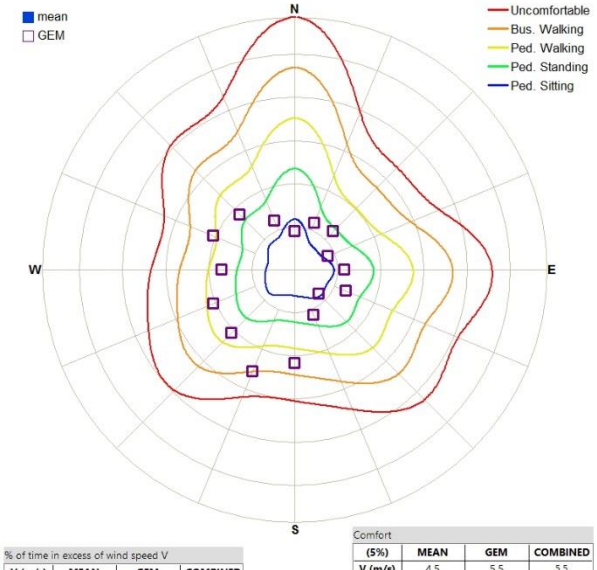
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.9	3.9	3.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.1	9.1	9.1
Rating	Pass	Pass	Pass

LOCATION 13.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	25.94	46.64	46.64
4	7.39	14.34	14.34
6	1.37	3.80	3.80
8	0.15	0.71	0.71
10	0.01	0.10	0.10

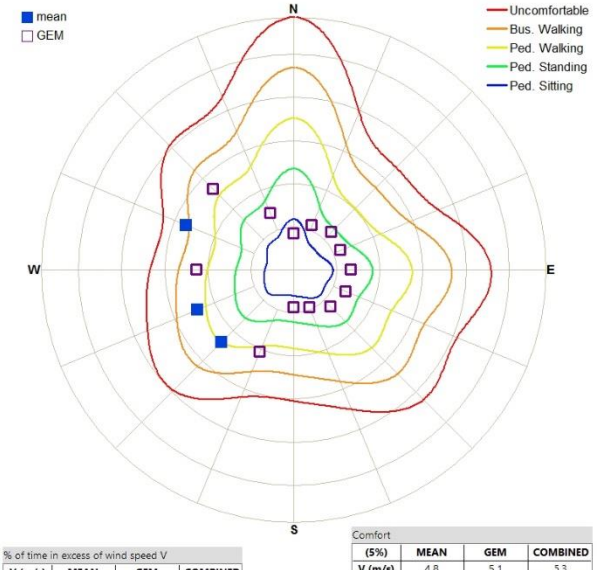
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.5	5.5
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.7	11.4	11.4
Rating	Pass	Pass	Pass

LOCATION 14.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	35.18	46.93	47.57
4	8.85	11.41	12.16
6	2.12	2.88	3.16
8	0.62	0.75	0.90
10	0.16	0.19	0.21

Comfort

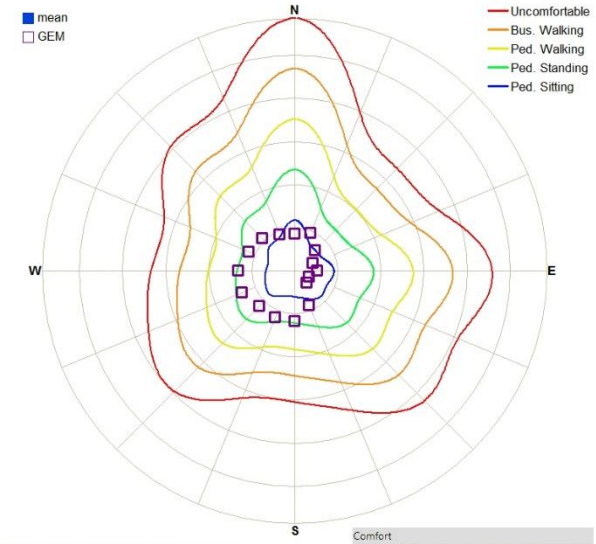
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.8	5.1	5.3
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.3	12.2	12.6
Rating	Pass	Pass	Pass

7.3 Configuration B – Proposed Site

LOCATION 4



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	6.99	22.06	22.06
4	0.04	1.37	1.37
6	0.00	0.03	0.03
8	0.00	0.00	0.00
10	0.00	0.00	0.00

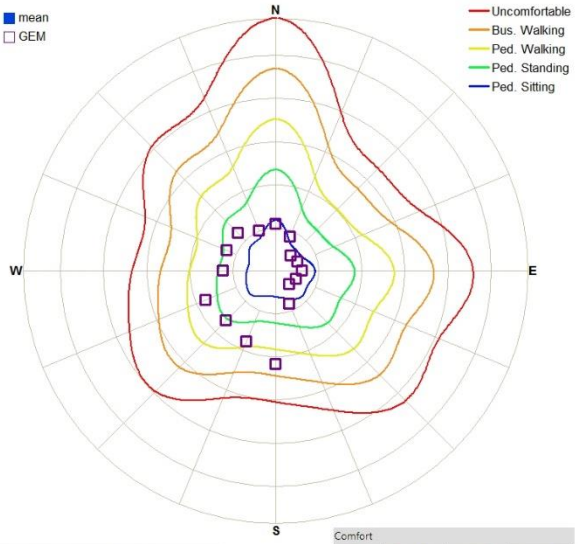
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.1	3.1	3.1
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.1	6.1	6.1
Rating	Pass	Pass	Pass

LOCATION 5



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	16.44	27.04	27.04
4	3.38	8.48	8.48
6	0.51	1.62	1.62
8	0.04	0.25	0.25
10	0.00	0.03	0.03

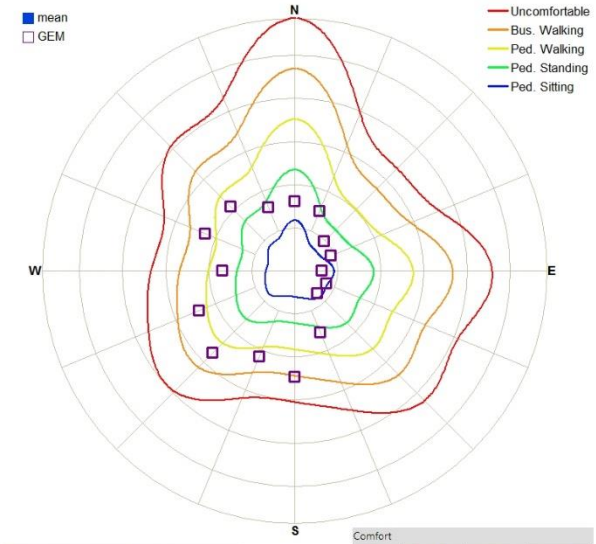
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.5	4.6	4.6
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.5	10.2	10.2
Rating	Pass	Pass	Pass

LOCATION 6



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.34	50.11	50.11
4	7.86	17.33	17.33
6	1.39	4.62	4.62
8	0.14	1.03	1.03
10	0.01	0.16	0.16

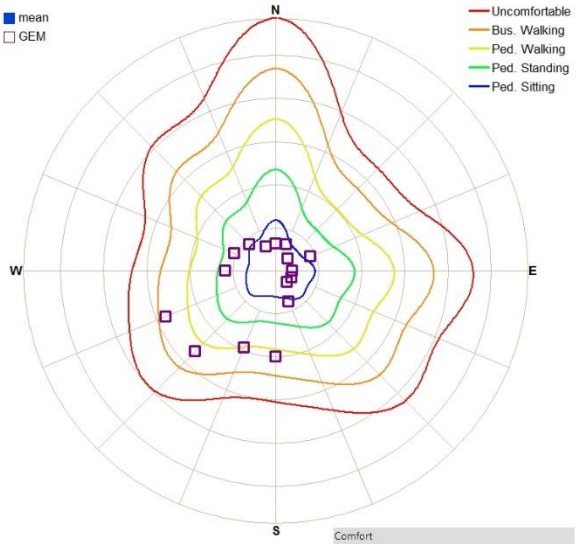
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.8	5.8
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.4	11.9	11.9
Rating	Pass	Pass	Pass

LOCATION 7



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	16.89	26.42	26.42
4	3.19	10.47	10.47
6	0.35	2.47	2.47
8	0.03	0.44	0.44
10	0.00	0.06	0.06

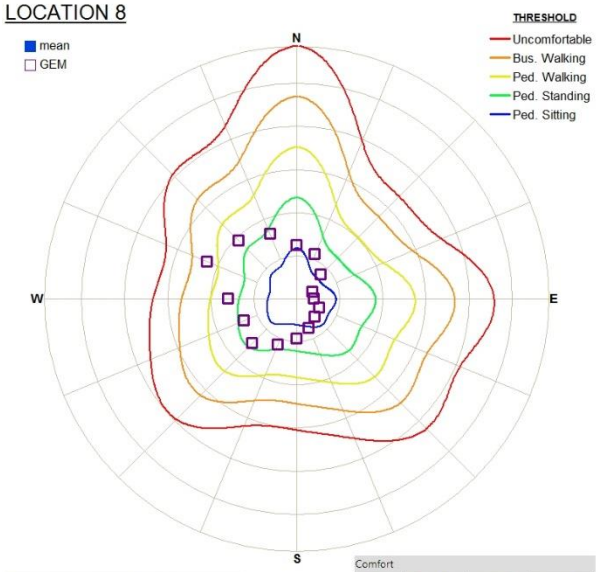
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.5	5.0	5.0
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.2	10.8	10.8
Rating	Pass	Pass	Pass

LOCATION 8



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	15.21	30.27	30.27
4	1.30	3.57	3.57
6	0.23	0.81	0.81
8	0.02	0.19	0.19
10	0.00	0.03	0.03

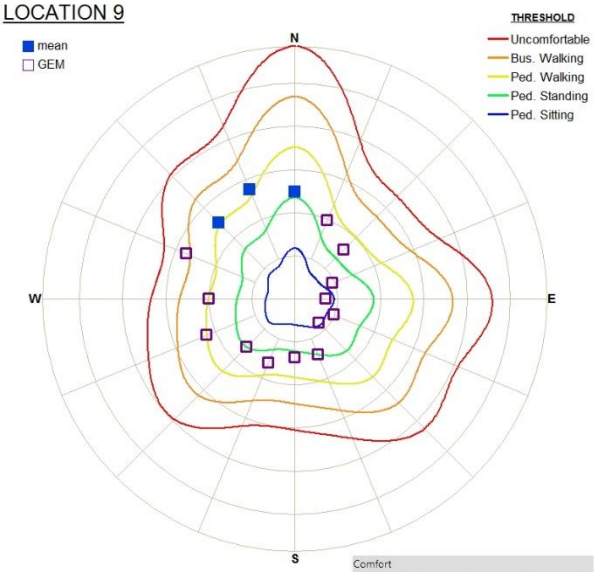
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.7	3.6	3.6
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.9	10.1	10.1
Rating	Pass	Pass	Pass

LOCATION 9



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	46.16	56.49	57.15
4	8.16	14.94	15.20
6	1.80	2.98	3.08
8	0.54	0.72	0.77
10	0.16	0.18	0.20

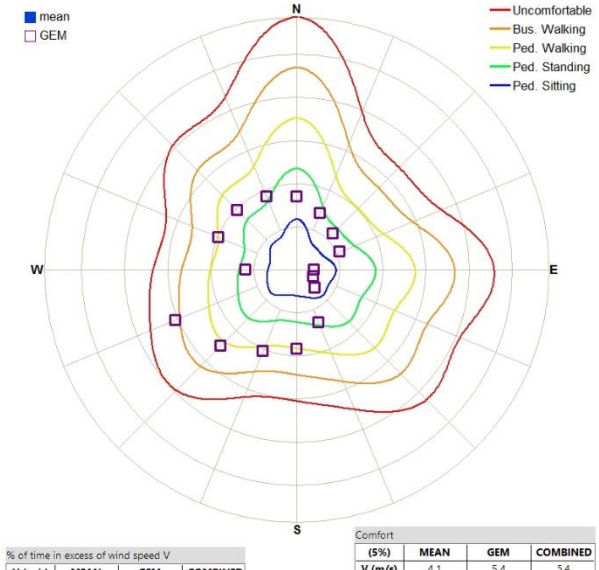
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.3	5.3
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.8	12.4	12.5
Rating	Pass	Pass	Pass

LOCATION 10



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	31.01	48.67	48.67
4	5.81	13.42	13.42
6	0.74	3.25	3.25
8	0.06	0.66	0.66
10	0.01	0.11	0.11

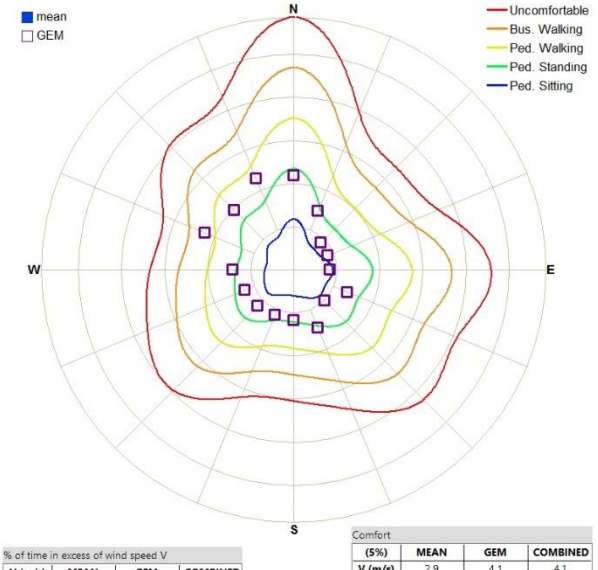
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	5.4	5.4
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.0	11.8	11.8
Rating	Pass	Pass	Pass

LOCATION 11



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	18.17	44.51	44.51
4	1.72	5.63	5.63
6	0.34	1.04	1.04
8	0.05	0.21	0.21
10	0.00	0.03	0.03

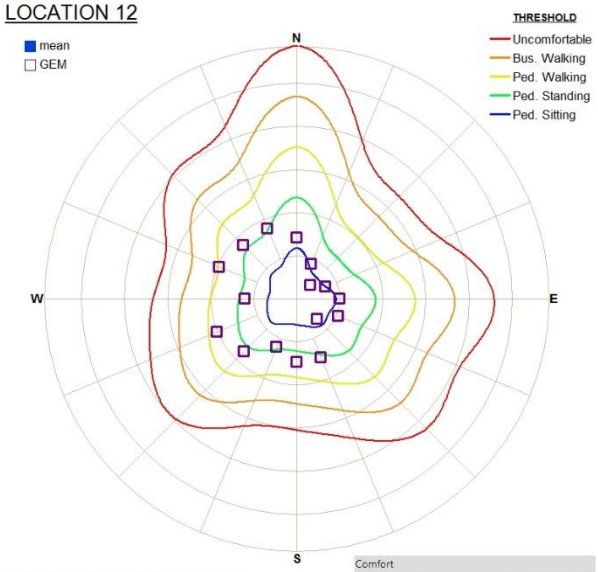
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.9	4.1	4.1
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.5	10.1	10.1
Rating	Pass	Pass	Pass

LOCATION 12



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	15.46	36.62	36.62
4	0.80	5.74	5.74
6	0.03	0.74	0.74
8	0.00	0.09	0.09
10	0.00	0.01	0.01

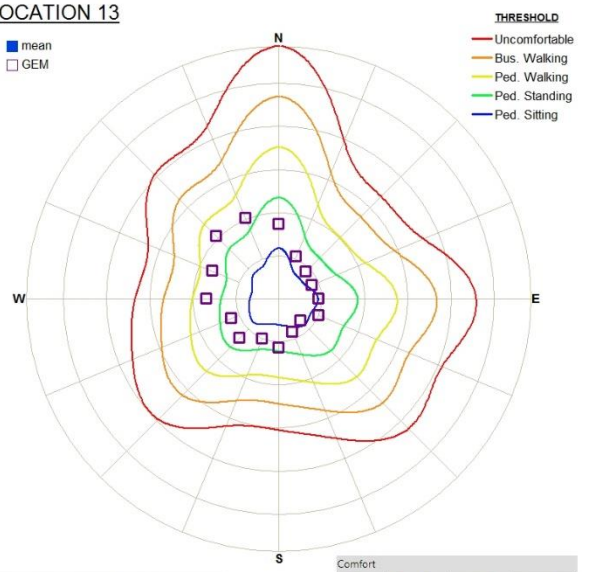
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.7	4.1	4.1
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.1	9.0	9.0
Rating	Pass	Pass	Pass

LOCATION 13



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	12.84	35.57	35.57
4	0.81	3.56	3.56
6	0.05	0.59	0.59
8	0.00	0.07	0.07
10	0.00	0.01	0.01

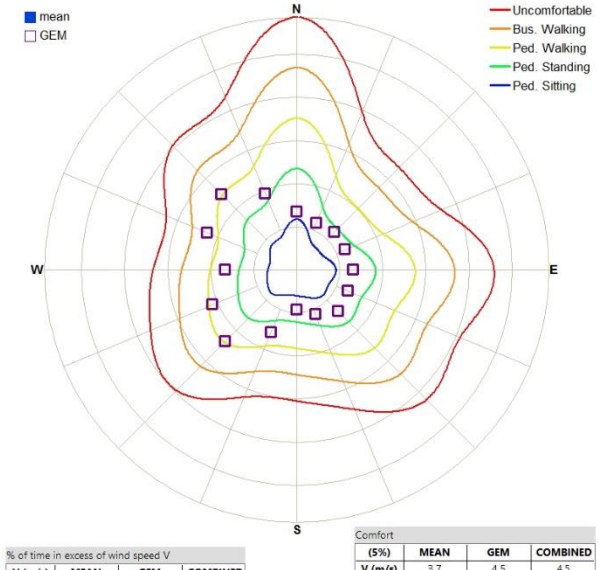
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.6	3.6	3.6
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.5	9.0	9.0
Rating	Pass	Pass	Pass

LOCATION 14



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.40	49.33	49.33
4	3.86	8.27	8.27
6	0.51	1.64	1.64
8	0.04	0.35	0.35
10	0.01	0.07	0.07

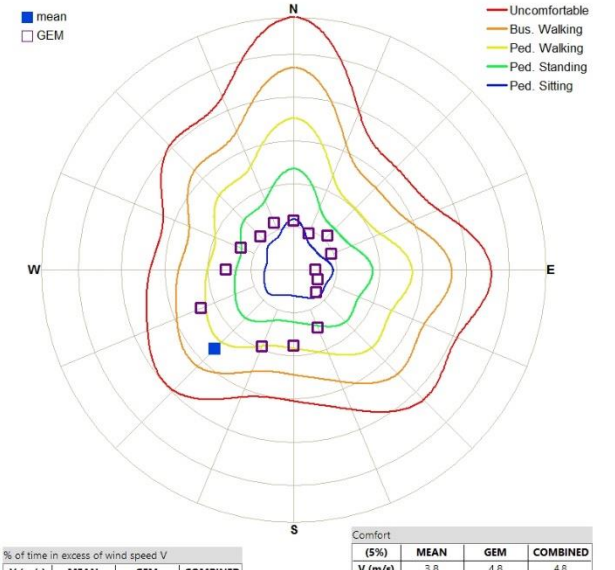
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.7	4.5	4.5
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.6	11.1	11.1
Rating	Pass	Pass	Pass

LOCATION 15



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	23.83	38.37	38.44
4	4.29	9.87	9.92
6	0.57	1.58	1.62
8	0.08	0.19	0.20
10	0.01	0.02	0.02

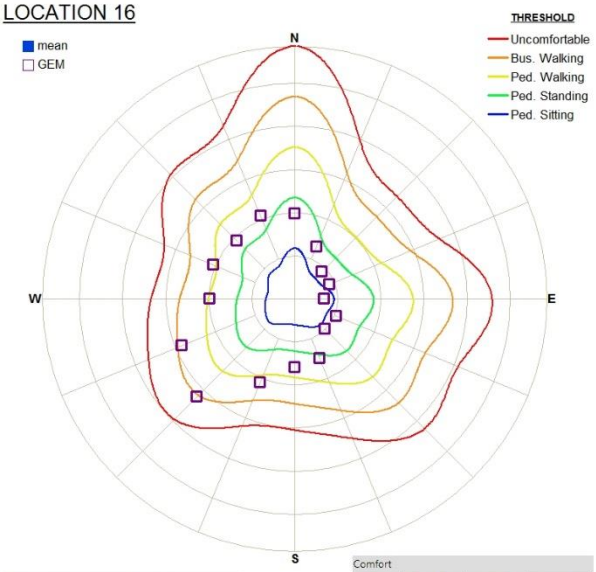
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.8	4.8
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.0	9.6	9.7
Rating	Pass	Pass	Pass

LOCATION 16



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	34.25	51.34	51.34
4	6.71	14.17	14.17
6	1.45	3.60	3.60
8	0.26	0.77	0.77
10	0.03	0.13	0.13

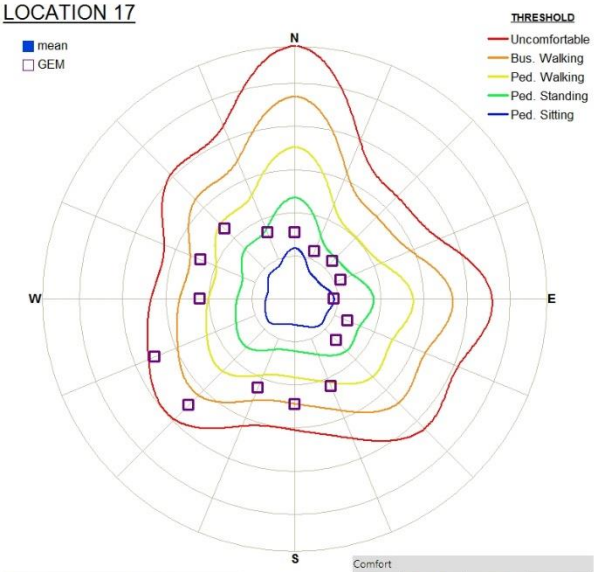
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.3	5.5	5.5
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.2	11.7	11.7
Rating	Pass	Pass	Pass

LOCATION 17



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	46.62	59.20	59.20
4	13.52	22.54	22.54
6	3.76	7.82	7.82
8	0.92	2.18	2.18
10	0.20	0.54	0.54

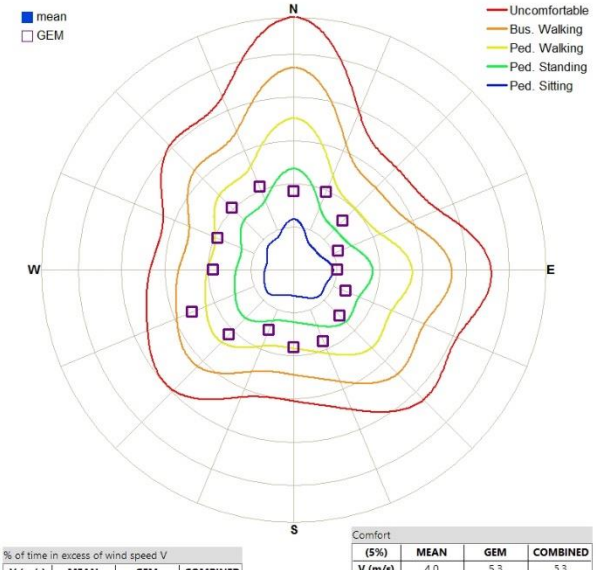
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.5	6.7	6.7
Rating	Ped Standing	Ped Walking	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.3	13.9	13.9
Rating	Pass	Pass	Pass

LOCATION 18



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	40.47	58.60	58.60
4	4.98	15.95	15.95
6	0.57	2.67	2.67
8	0.07	0.33	0.33
10	0.01	0.03	0.03

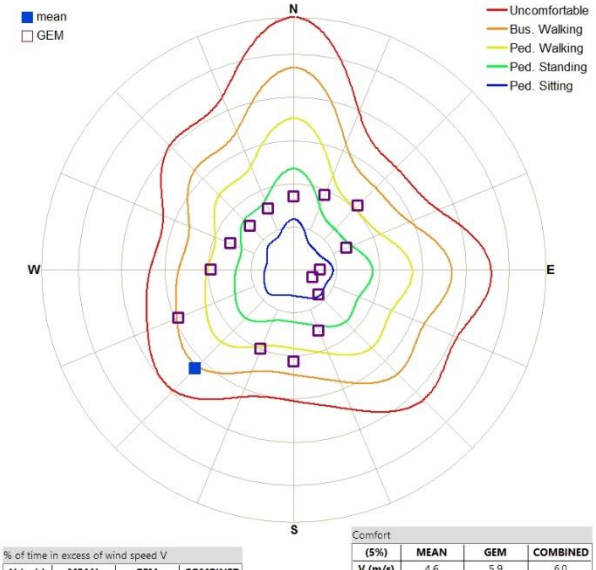
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	5.3	5.3
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.7	10.2	10.2
Rating	Pass	Pass	Pass

LOCATION 19



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	34.25	51.68	51.84
4	7.99	20.64	20.77
6	1.68	4.94	5.07
8	0.34	0.87	0.93
10	0.07	0.13	0.15

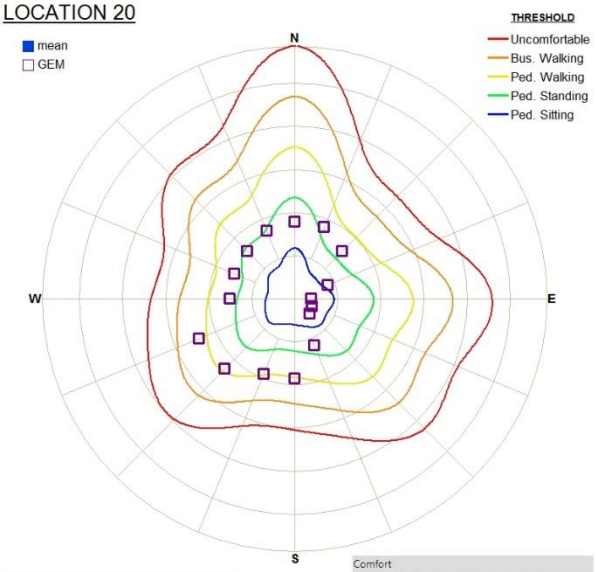
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.6	5.9	6.0
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.3	11.6	11.8
Rating	Pass	Pass	Pass

LOCATION 20



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	34.73	46.15	46.15
4	7.52	13.73	13.73
6	0.75	1.96	1.96
8	0.05	0.20	0.20
10	0.00	0.01	0.01

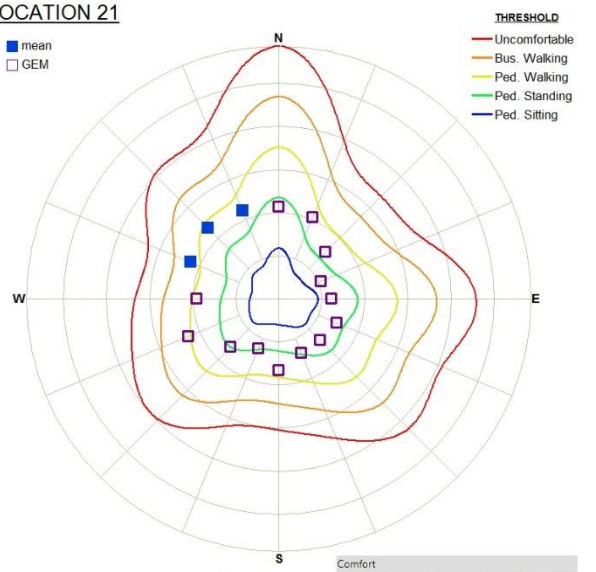
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.3	5.1	5.1
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.5	9.7	9.7
Rating	Pass	Pass	Pass

LOCATION 21



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	41.18	58.05	58.54
4	6.72	13.59	13.78
6	1.21	2.42	2.50
8	0.26	0.32	0.37
10	0.04	0.04	0.05

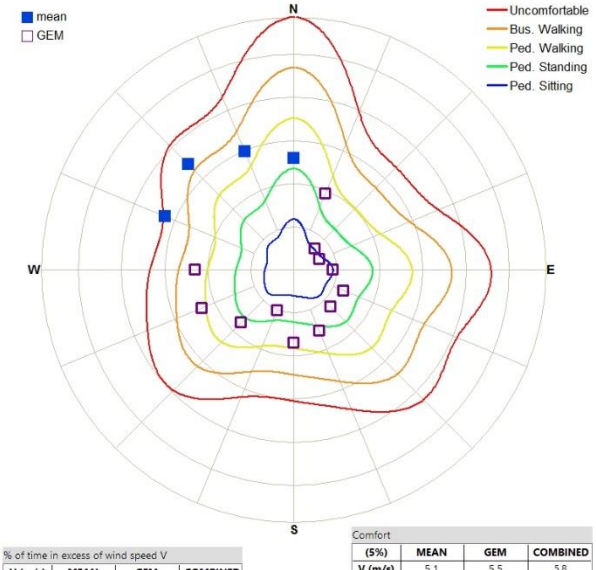
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.3	5.2	5.2
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.5	10.4	10.7
Rating	Pass	Pass	Pass

LOCATION 22



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	45.78	54.17	57.30
4	12.18	15.26	18.50
6	3.06	3.70	4.57
8	1.28	1.05	1.51
10	0.60	0.29	0.62

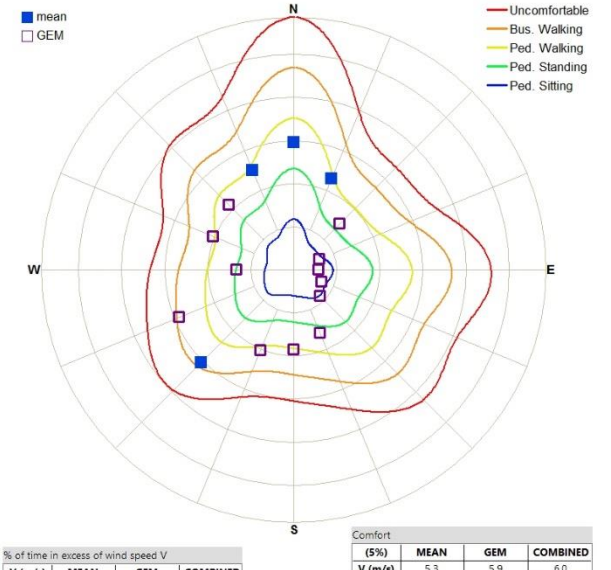
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.5	5.8
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	15.5	13.3	15.5
Rating	Able Body	Pass	Able Body

LOCATION 23



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	46.76	56.34	56.88
4	12.73	19.22	19.67
6	3.12	4.71	5.01
8	0.53	0.84	0.94
10	0.07	0.10	0.13

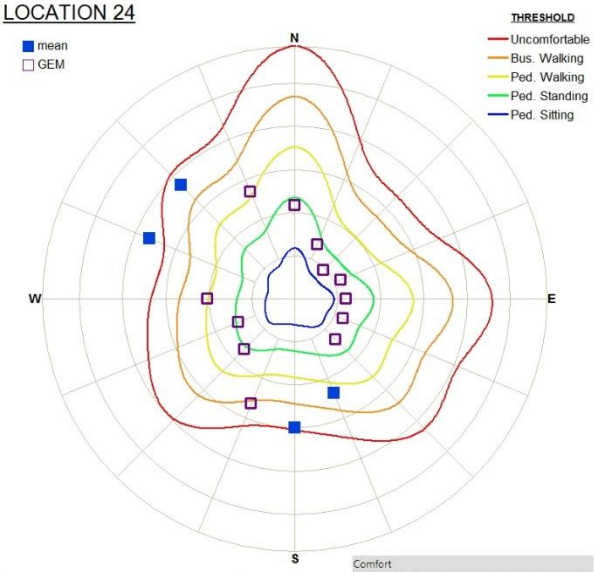
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.3	5.9	6.0
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.1	11.5	11.6
Rating	Pass	Pass	Pass

LOCATION 24



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	43.96	64.13	64.51
4	21.94	24.92	25.89
6	8.88	8.58	9.99
8	3.34	2.82	3.59
10	1.35	1.02	1.40

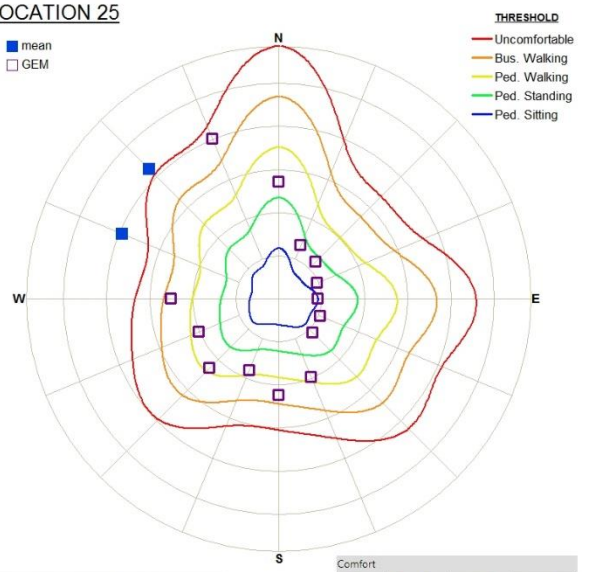
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	7.0	6.9	7.3
Rating	Ped Walking	Ped Walking	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	17.1	16.3	17.1
Rating	Able Body	Able Body	Able Body

LOCATION 25



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	49.56	65.98	66.11
4	16.10	26.78	27.31
6	4.83	7.60	7.94
8	2.23	2.76	2.96
10	1.15	1.23	1.35

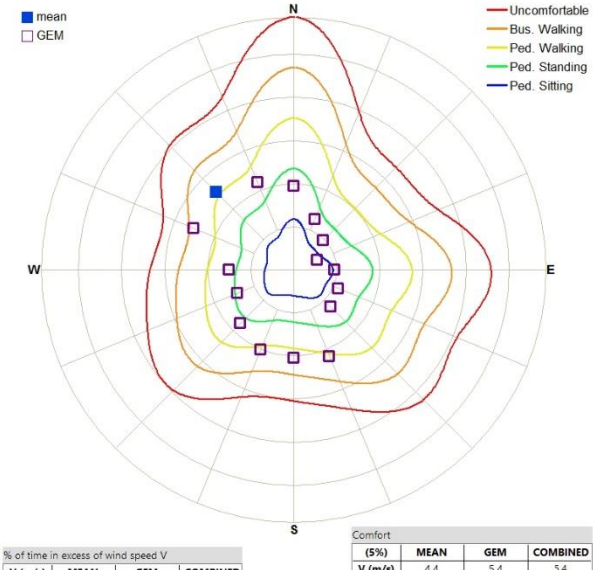
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.9	6.7	6.8
Rating	Ped Standing	Ped Walking	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	18.9	18.1	18.9
Rating	Able Body	Able Body	Able Body

LOCATION 26



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	36.89	53.03	53.08
4	7.67	14.74	14.76
6	1.59	3.17	3.18
8	0.46	0.69	0.69
10	0.13	0.16	0.16

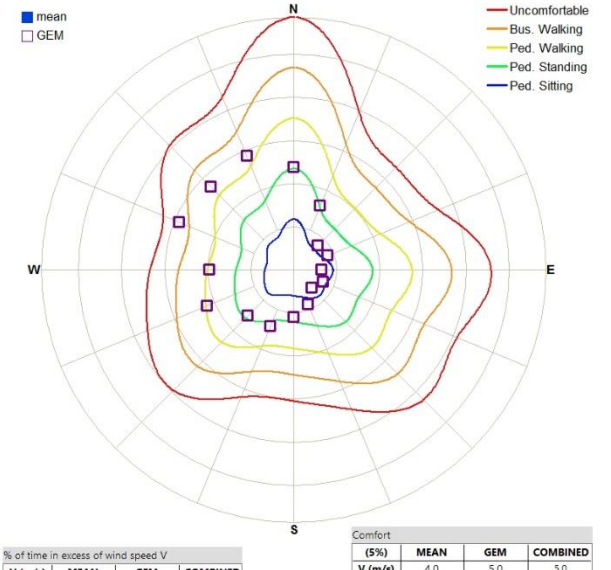
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.4	5.4	5.4
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.7	11.8	11.8
Rating	Pass	Pass	Pass

LOCATION 27



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	33.95	47.77	47.77
4	5.40	11.04	11.04
6	1.46	2.76	2.76
8	0.48	0.92	0.92
10	0.14	0.27	0.27

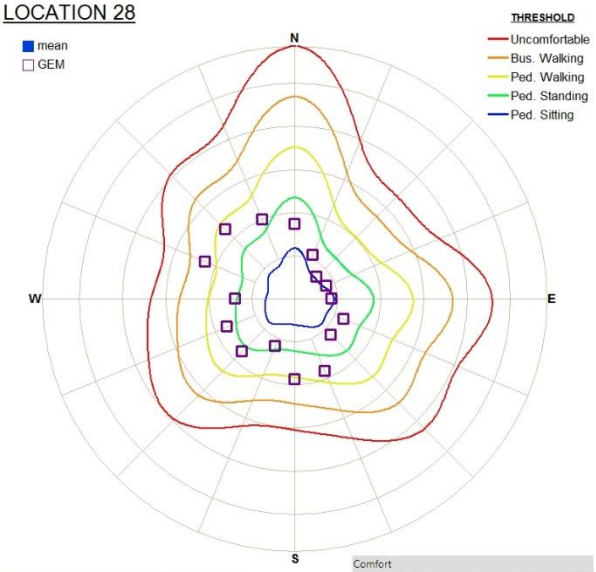
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	5.0	5.0
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.8	13.2	13.2
Rating	Pass	Pass	Pass

LOCATION 28



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	32.07	46.19	46.19
4	4.78	9.17	9.17
6	0.88	1.75	1.75
8	0.17	0.31	0.31
10	0.02	0.05	0.05

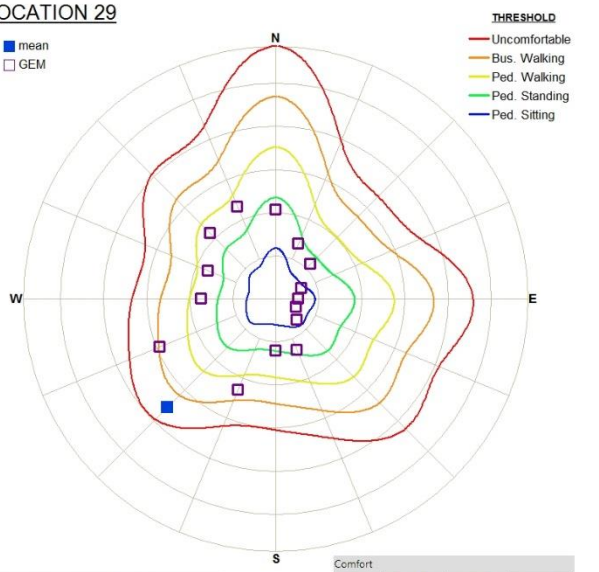
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.7	4.7
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.8	10.6	10.6
Rating	Pass	Pass	Pass

LOCATION 29



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	33.13	49.26	49.62
4	7.35	12.90	13.20
6	2.05	3.56	3.90
8	0.56	0.76	0.95
10	0.14	0.14	0.21

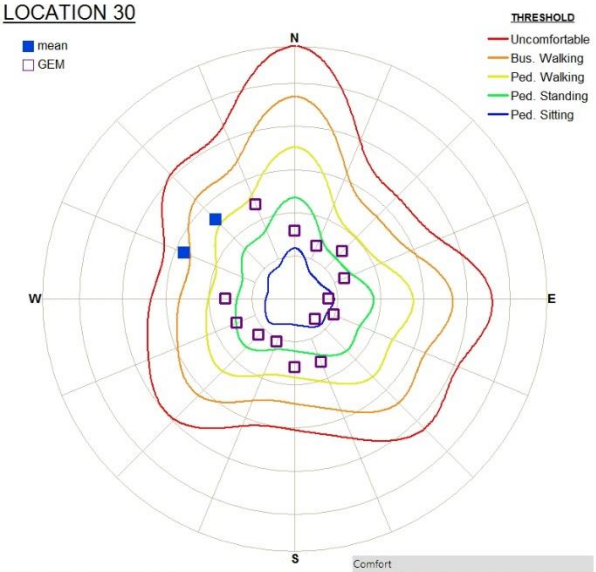
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.5	5.6
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.3	11.8	12.6
Rating	Pass	Pass	Pass

LOCATION 30



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	32.51	50.18	50.72
4	4.33	9.58	9.90
6	1.42	1.77	1.94
8	0.63	0.53	0.67
10	0.20	0.16	0.20

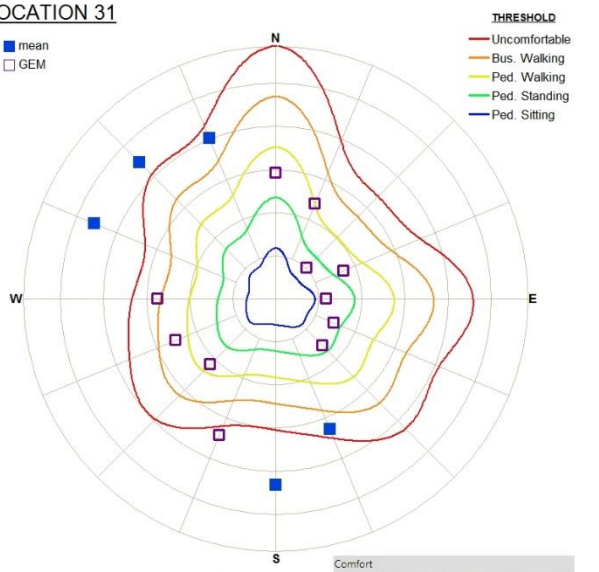
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.7	4.7
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.7	12.1	12.8
Rating	Pass	Pass	Pass

LOCATION 31



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	66.98	75.58	76.93
4	35.99	37.64	41.90
6	19.56	17.26	21.82
8	10.21	7.00	10.87
10	4.86	2.68	5.00

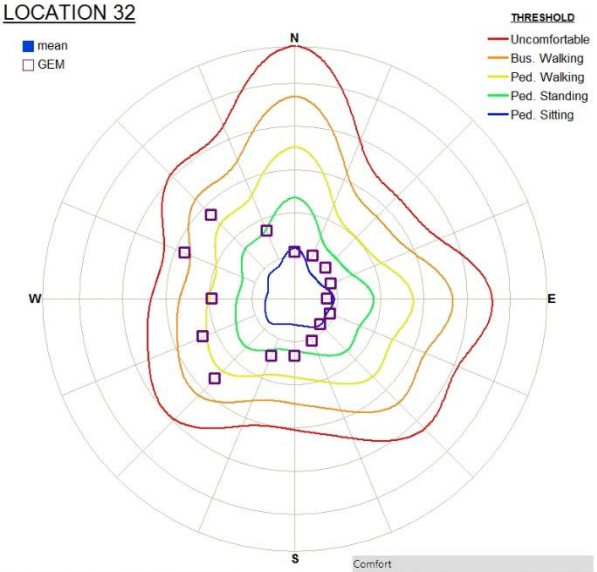
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	9.8	8.6	9.9
Rating	Bus Walking	Bus Walking	Bus Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	21.9	17.8	21.9
Rating	Fail	Able Body	Fail

LOCATION 32



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	24.88	46.74	46.74
4	3.93	10.19	10.19
6	0.72	2.58	2.58
8	0.11	0.82	0.82
10	0.01	0.22	0.22

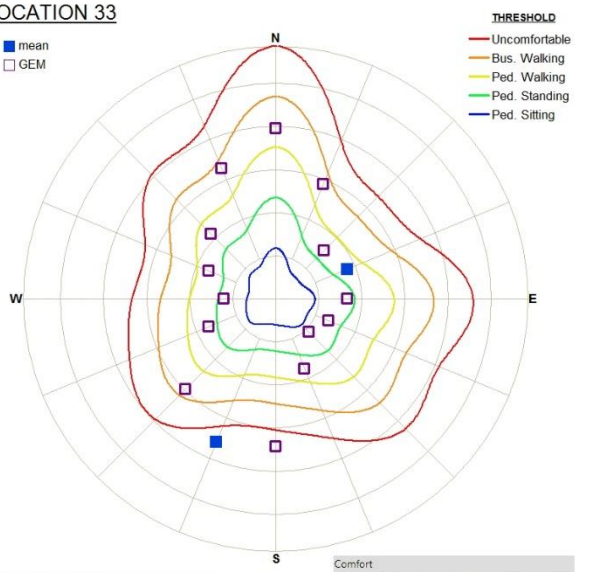
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.7	4.9	4.9
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.1	12.9	12.9
Rating	Pass	Pass	Pass

LOCATION 33



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	49.78	66.46	66.69
4	19.70	28.01	28.59
6	9.58	13.36	14.29
8	3.84	4.97	5.74
10	1.31	1.62	1.97

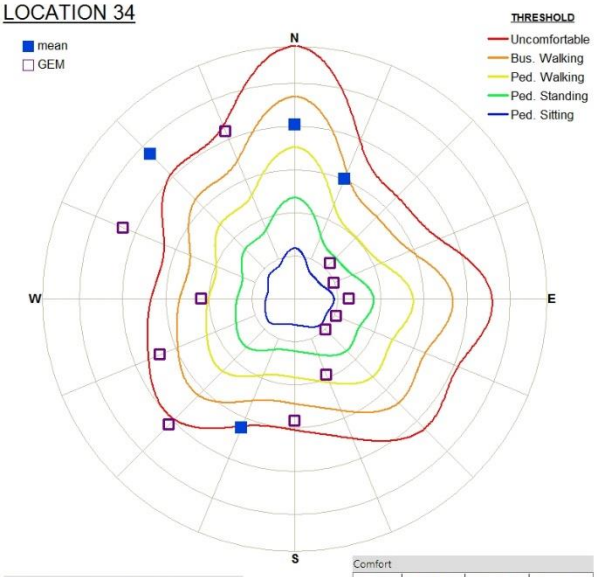
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	7.3	7.9	8.2
Rating	Ped Walking	Ped Walking	Bus Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	16.3	16.2	17.0
Rating	Able Body	Able Body	Able Body

LOCATION 34



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	63.60	74.42	74.94
4	35.48	38.95	40.60
6	16.92	17.64	19.81
8	6.65	6.78	7.83
10	2.52	2.57	3.03

Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	8.5	8.5	8.9
Rating	Bus Walking	Bus Walking	Bus Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	20.8	20.0	21.1
Rating	Fail	Fail	Fail