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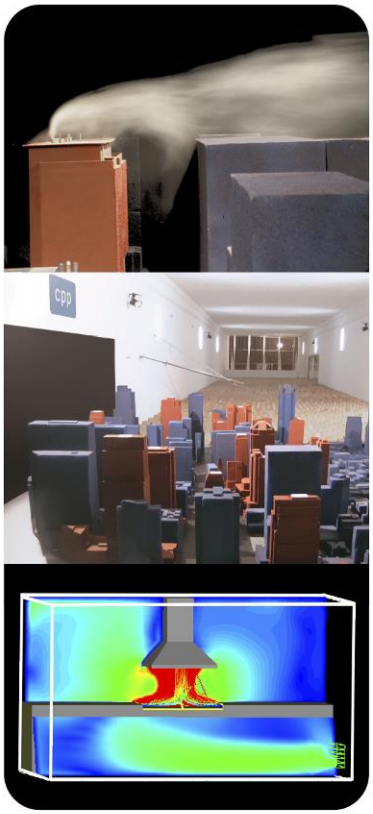
WIND ENGINEERING AND AIR QUALITY CONSULTANTS

Final Report



Wind Tunnel Tests for:

SICEEP PCP
Sydney, Australia

CPP Project 7094
August 2015

Prepared for:
Lend Lease
30 The Bond
30 Hickson Rd
Millers Point
NSW 2000

Prepared by:
Michelle Noguez, Project Engineer
Matt Glanville, Ph.D., Director

EXECUTIVE SUMMARY

A wind tunnel study of the proposed SICEEP PCP development to be located in Sydney, Australia, was conducted to assess pedestrian wind comfort. 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).

Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 23 locations for 16 wind directions each. These points were tested around the development in the proposed configuration, focusing especially on access routes, doorways and 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 development was found to be suitable for pedestrian standing activities at most locations, under the Lawson criteria, with all but one location passing the Lawson distress criterion.

DOCUMENT VERIFICATION

Date	Revision	Prepared by	Checked by	Approved by
12/08/2015	Final Report	MNC	MG	MG
28/09/2015	Final Report	MG	MG	MG
30/09/2015	Final R02	MNC	MG	MG

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D	Characteristic dimension (building height, width, etc.)
n	Mean velocity profile power law exponent
T_u	Turbulence intensity, U_{rms}/U
U	Local mean velocity
U_{ref}	Reference velocity at reference height z_{ref}
U_{pk}	Peak wind speed in pedestrian studies
U_{rms}	Root-mean-square of fluctuating velocity
z	Height above surface
ν	Kinematic viscosity of approach flow
$\sigma(\ )$	Standard deviation of $(\ ),=(\ )'_{rms}$
ρ	Density of approach flow
$(\ )_{max}$	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 an application made under section 96 of the Environmental Planning and Assessment Act 1979 (EP&A Act) to modify Development Consent, SSD-6013 relating to the development of the North West Plot of Darling Square which is part of the Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP).

Development Consent SSD-6013 was granted on 7 May 2014 by the delegate of the Minister for Planning for the following components of development:

- site preparation works including demolition of existing structures, tree removal, minor excavation, and site remediation as required;
- staged construction of a 12 storey building to be used for commercial premises, and above ground car parking;
- various public domain improvements including provision (part) new east-west pedestrian laneway (known as Dickson's Lane) linking Darling Drive to the Boulevard, upgrading of existing footpaths, provision of street trees, and provision of bicycle parking facilities;
- building identification signage and wall advertising sign.

This section 96 application (the Modification Application) constitutes the second modification to the consent. This Modification Application follows the approval and current assessment of a number of SSDAs within the SICEEP site, including:

- SSDA1 which secured approval for the core convention, exhibition and entertainment facilities of the SICEEP Project;
- SSDA2, a staged application that established a Concept Proposal for a new mixed use neighbourhood at Darling Harbour known as Darling Square;
- SSDA3, SSDA4, and SSDA5 which related to three detailed proposals for use of the development plots within Darling Square;
- SSDA 6 which secured approval for the construction of the ICC Hotel; and
- SSDA7 which secured approval for the construction and use of a mixed use development on the North-East Plot of Darling Square.

2. OVERVIEW OF PROPOSED MODIFICATIONS

This Modification Application seeks approval for the following amendments:

- rationalisation of plant requirements resulting in a consequential increase in Gross Floor Area; and
- minor external amendments to the building design including the addition of solar panels on the roof and changes to the façade and signage zones.

A range of other minor amendments resulting from design development (including in response to feedback from a range of potential tenants and commercial property agents) are illustrated on the amended Architectural Drawings. These changes are to be expected in any project, especially given the nature and scale of the approved North West Plot development.

3. SITE DESCRIPTION

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

With an area of approximately 20 hectares, the SICEEP Site is generally bound by the Light Rail Line to the west, Harbourside shopping centre and Cockle Bay to the north, Darling Quarter, the Chinese Garden and Harbour Street to the east, and Hay Street to the south (refer to Figure 1).

The Darling Square Site is:

- located in the south of the SICEEP Site, within the northern portion of the suburb of Haymarket;
- bounded by the Powerhouse Museum to the west, the Pier Street overpass and Little Pier Street to the north, Harbour Street to the east, and Hay Street to the south; and
- irregular in shape and occupies an area of approximately 37,700m2.

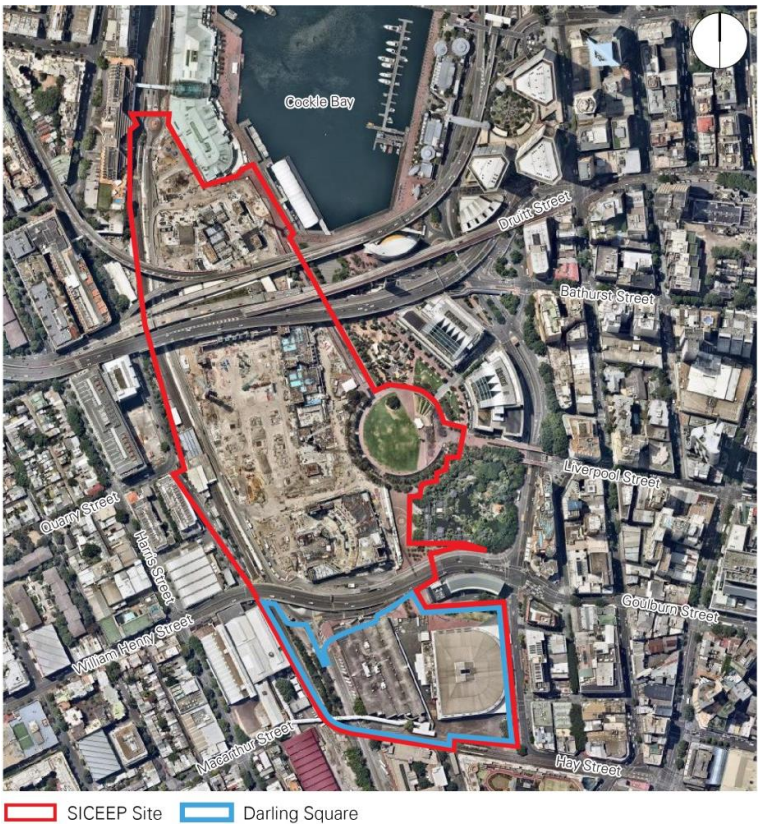

Figure 1 – Aerial Photograph of the SICEEP Site

The Modification Application Site relates to the North West Plot and surrounds as detailed within the drawings submitted in support of Modification Application. Figure 2 illustrates the North West Plot in the approved Concept Proposal.

Figure 2 – Concept Proposal Development Plots

4. BACKGROUND

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.

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.

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. Table 1 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).

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 AGL
Approach Terrain Category	Terrain Category 3

Testing Configuration(s)	
Configuration A	Proposed SICEEP PCP development with surrounding buildings, as shown in Figure 5. Pedestrian winds measured at 23 locations for 16 wind directions at 22.5° increments from 0° (north)

5. THE WIND TUNNEL TEST

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

The wind tunnel test was performed in the boundary layer wind tunnel shown in Figure 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 7.1.1.

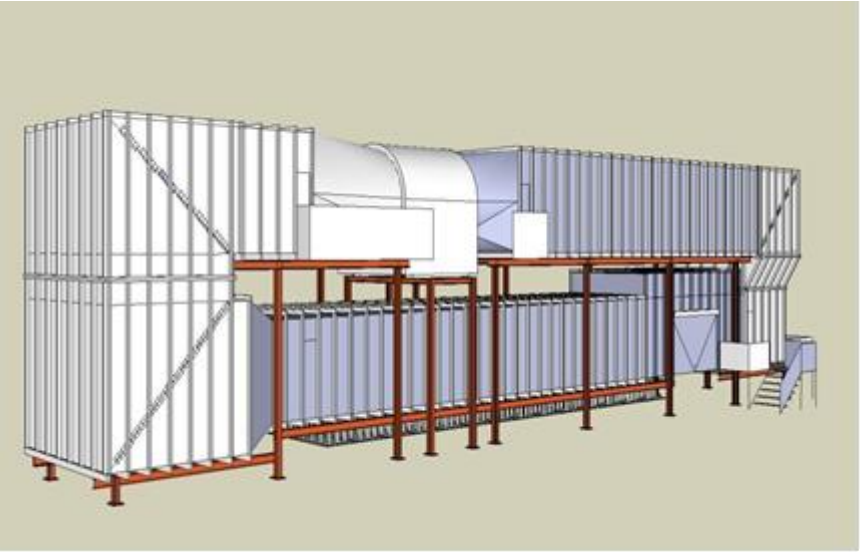

Figure 3: Schematic of the closed circuit wind tunnel

A model of the proposed development and surrounds to a radius of 570 m was constructed at a 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 5, 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 5. The turntable permitted rotation of the modelled area for examination of velocities from any approach wind direction. Additional photos of the testing are included in Appendix 1.

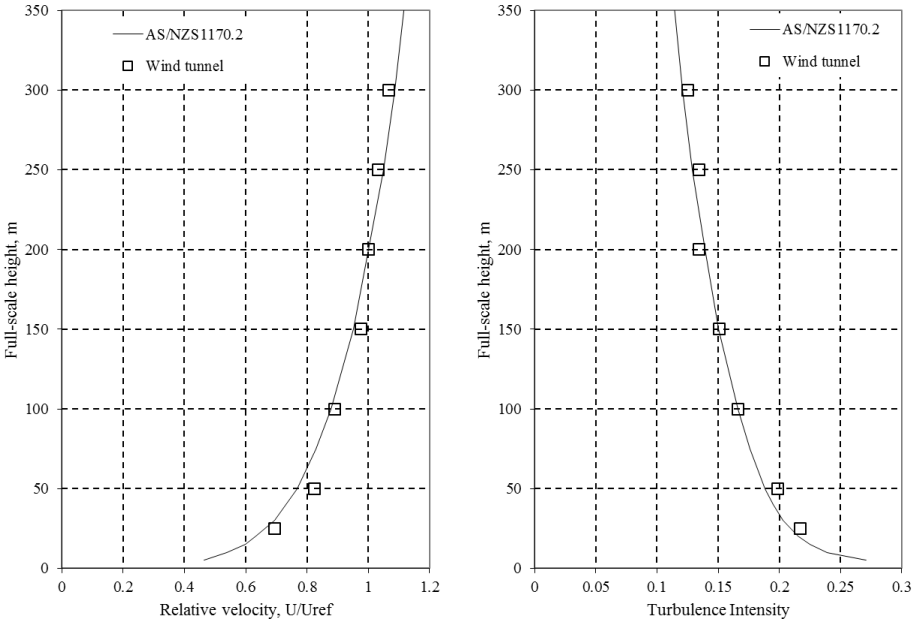

Figure 4: Mean velocity and turbulence profiles

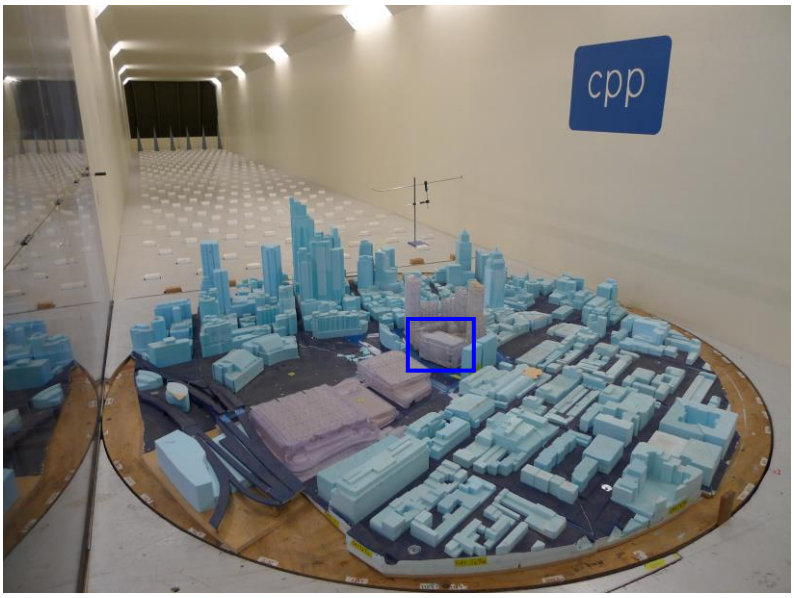

Figure 5: Proposed SICEEP PCP model in the wind tunnel viewed from the northwest

6. ENVIRONMENTAL WIND CRITERIA

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

Lawson's criteria have categories for comfort, based on wind speeds exceeded five percent of the time, allowing planners to judge the usability of locations for various intended purposes ranging from "Business Walking" to "Pedestrian sitting". The level and severity of these comfort categories can vary based on individual preference, so calibration to the local wind environment is recommended when evaluating the Lawson ratings. The criteria also include a distress rating, for safety assessment, which is based on occasional (once or twice per year) wind speeds[1]. In both cases, the wind speed used 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, however provides significantly more information regarding the serviceability wind climate.

Table 2: Summary of Lawson criteria

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

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

7. DATA ACQUISITION AND RESULTS

7.1 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 7.1.2. 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)

7.1.1 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 defined in Standards Australia (2011) and are appropriate for the approach conditions.

7.1.2 Pedestrian Winds

The proposed development is located in Sydney's Darling Harbour. The site is bounded by The Boulevard, Theatre access road, Darling Drive and Dickson's Lane. The development is surrounded by Sydney's CBD high rise buildings to the east quadrant and by medium rise buildings to the west quadrant. The site is more exposed to winds from the north.

For this report wind speed measurements were recorded at 23 locations to evaluate pedestrian comfort in and around the project site, Figure 7 to Figure 9. All points tested were for the configurations described in Table 1. 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 comfort primarily for the outdoor leisure areas, as well as at building corners where relatively severe conditions are frequently found, near building entrances, and on adjacent pavements with pedestrian traffic.

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:

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

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 wind speed 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 2011, Figure 6.

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 summarized in Figure 6 to rate each location. From the cumulative wind speed distributions for each location, the percentage of time each of the Lawson comfort rating wind speeds are exceeded are presented in tabular form under the polar plots in Appendix 2. In addition to the rating wind speeds, the percentage of time that 2 m/s is exceeded is also reported. This has been provided as it has been found that the limiting wind speed for long-term stationary activities such as fine outdoor dining should be about 2 to 2.5 m/s rather than 4 m/s.

Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people. The earliest quantitative description of wind effects was established by Sir Francis Beaufort in 1806, for use at sea; the Beaufort scale is reproduced in Table 3 including qualitative descriptions of wind effects.

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 comfort and safety with respect to the Lawson criteria is presented in, Figure 7 to Figure 9, for each test location. The implications of the results are discussed in Section 8.

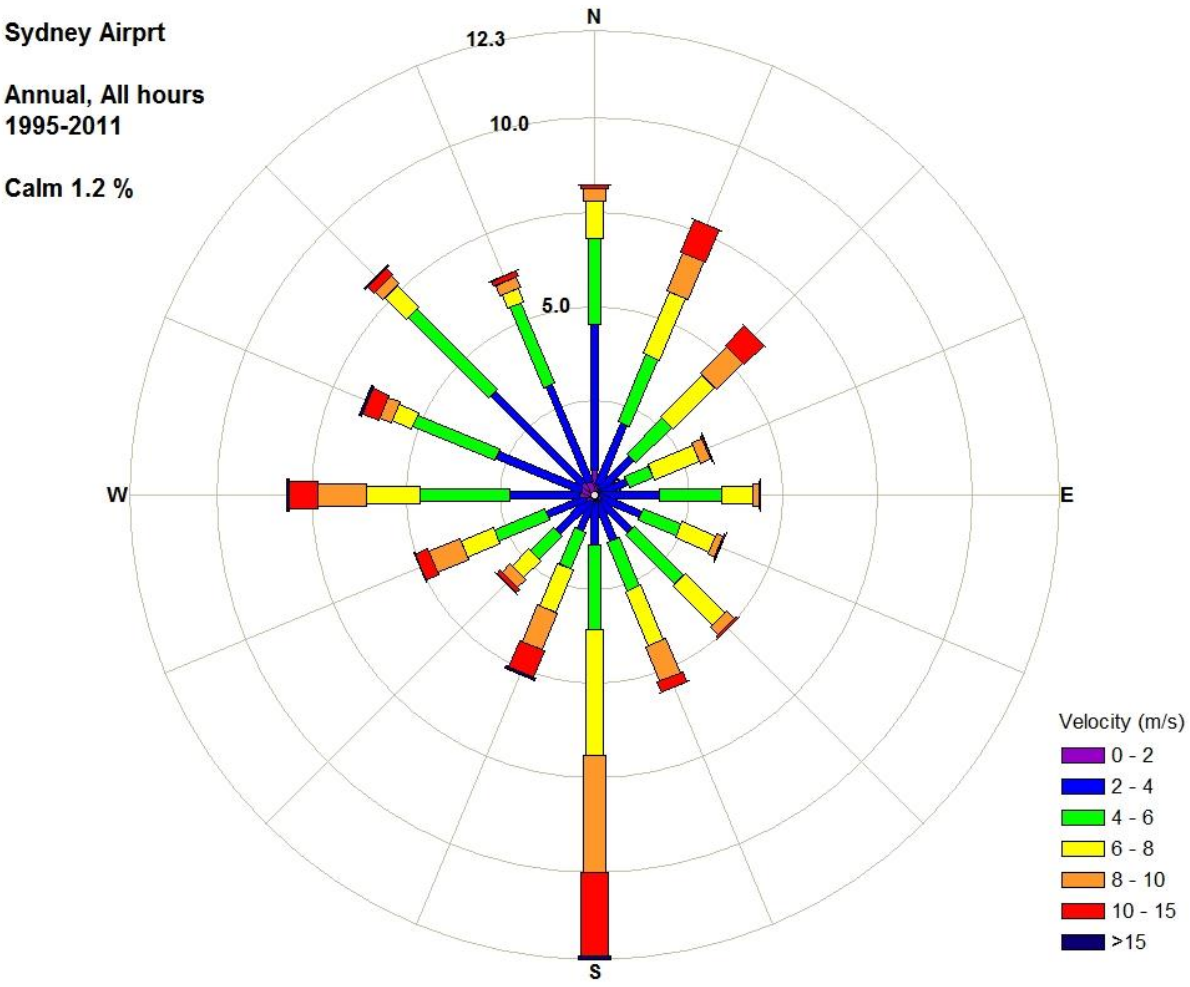

Figure 6: Wind rose of direction and speed for Sydney Airport

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.

8. DISCUSSION

The wind climatology chart of Figure 6 indicates that the most frequent strong winds are from the south quadrant. The locations tested around the development site are susceptible to winds from the different directions, depending on the relative location of the point 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 graphs in Appendix 2.

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded images of Figure 7 to Figure 9, which depict the locations selected for investigation of pedestrian wind comfort along with the Lawson criteria rating for both comfort and distress. Note that testing was performed without planned trees, or other plantings to provide a worst case assessment; heavy landscape planting typically reduces the wind speeds by less than 10%. The central colour indicates the comfort rating for the location, and the colour of the outer ring indicates whether the location passes the distress criterion. Mitigation measures are likely to be required for red locations, 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.

It is evident from Figure 7, that the wind environment around the proposed development, at ground level on The Boulevard, Theatre access road, Darling Drive and Dickson's Lane, is generally satisfactory for pedestrian standing activities under Lawson.

Locations 1 to 3, along the Theatre access road, rated as suitable for pedestrian standing and sitting activities, and passed the distress criterion. Polar plots show these locations are primarily influenced by winds from the north quadrant channelling through Darling Harbour's Tumbalong Park.

Locations 4 and 7 presented the windiest conditions and classified as suitable for pedestrian and business walking, respectively under the Lawson criterion, due to north-easterly and south-westerly winds channelling along Darling Drive. Location 7 rated for able bodied patrons under the Distress criterion. Locations 5 and 6 show relatively calmer wind conditions due to shielding from north-easterly winds by the proposed development. Locations 3 and 17 were tested with and without the Pier Street road deck with negligible difference in the measured results demonstrating the significance of the building form upon surrounding wind conditions.

Wind conditions along Dickson's Lane, Locations 8 to 10, rated as suitable for pedestrian standing activities and passed the distress criterion. Polar plots, in Appendix 2, show south-westerly winds are

channelling through the lane. Winds are marginally above the Lawson pedestrian sitting criteria, which would be best for long term stationary activities such as outdoor dining. This level of wind amenity would be best achieved using vertical screening elements, as the flows contributing to the highest velocities are horizontal in nature. From experience, awnings would provide some benefit in terms of wind amelioration, but vertical screens would provide a greater benefit. The placement and extent of screening will depend on the intended use of the sitting areas and the desired level of pedestrian comfort.

Environmental wind conditions along The Boulevard are generally satisfactory for pedestrian standing activities; with the exception of Locations 12, 14 and 16 which classified as suitable for pedestrian sitting activities, due to shielding provided by the building undercroft. Polar plots show locations at The Boulevard are more exposed to winds from the northeast and southwest quadrants.

Location 14.1, in Figure 9, was tested without the proposed east awning, Figure 11. From comparison with Figure 7, it is evident that the awning does not affect the wind conditions at this location significantly, showing there are negligible downwash winds from the northeast quadrant.

Figure 8, shows environmental wind conditions at roof level, Locations 19 to 23, are generally satisfactory for pedestrian standing and walking activities, under the Lawson criterion. All locations passed the distress criterion.

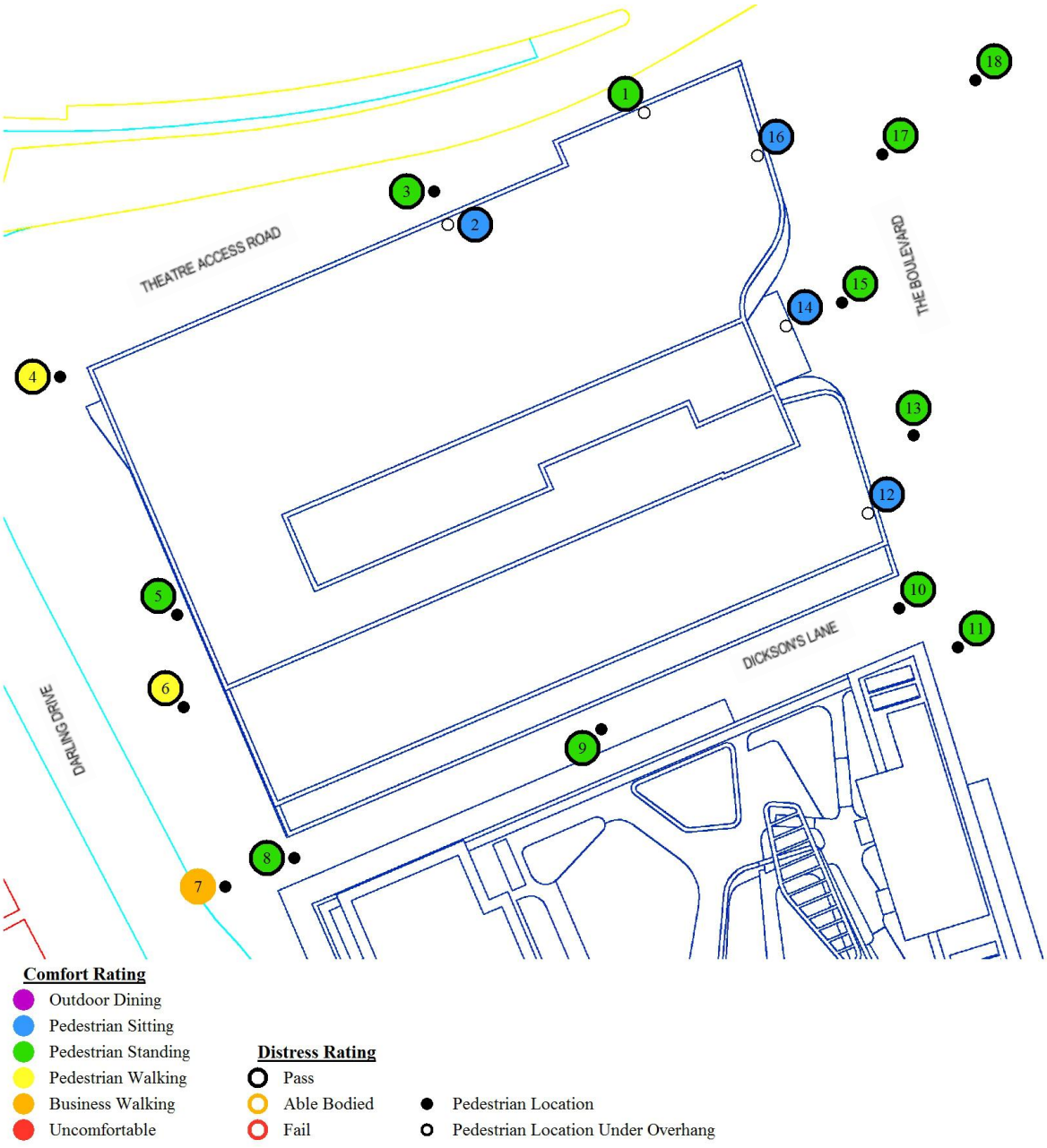

Figure 7: Pedestrian wind speed measurement locations with comfort/distress ratings – Ground Level

Figure 8: Pedestrian wind speed measurement locations with comfort/distress ratings – Roof

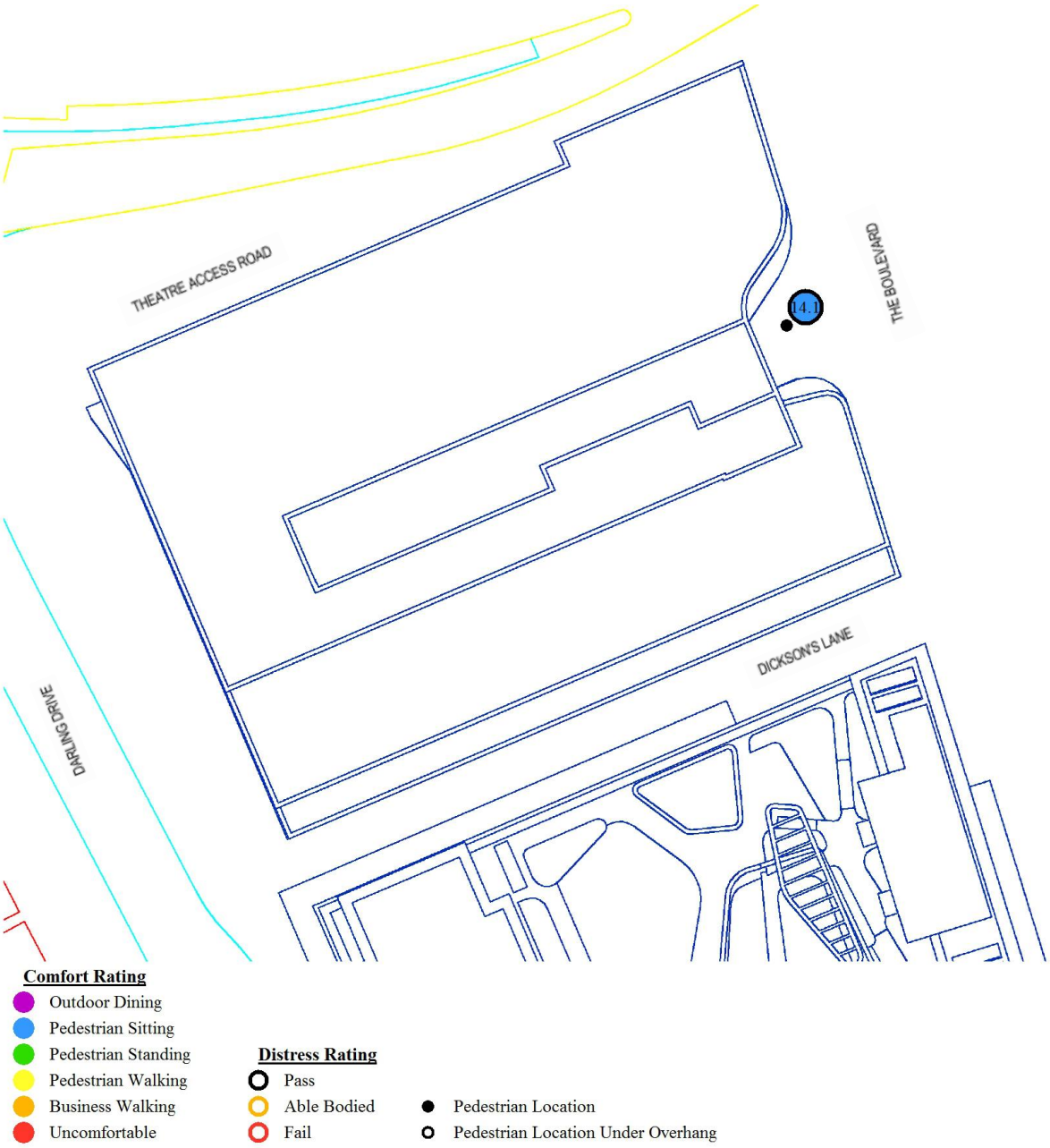

Figure 9: Pedestrian wind speed measurement locations with comfort/distress ratings – East awning removed

9. REFERENCES

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Appendix 1: Additional photographs of the CPP wind tunnel model

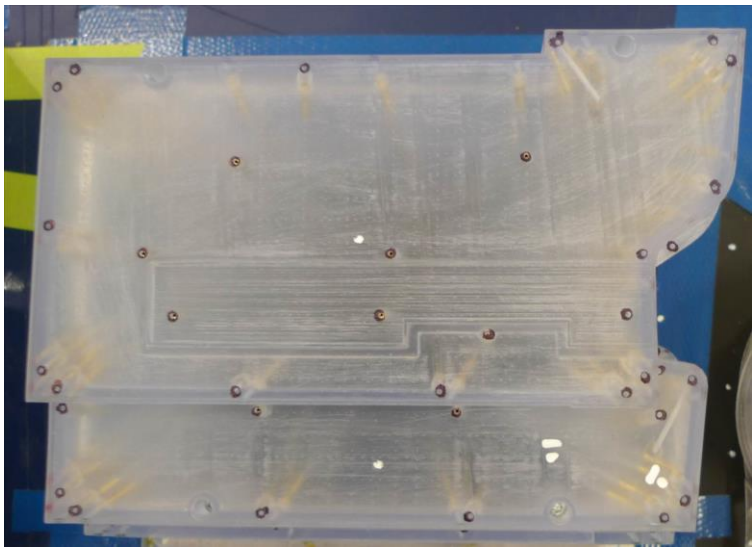


Figure 10: SICEEP PCP development viewed from the top

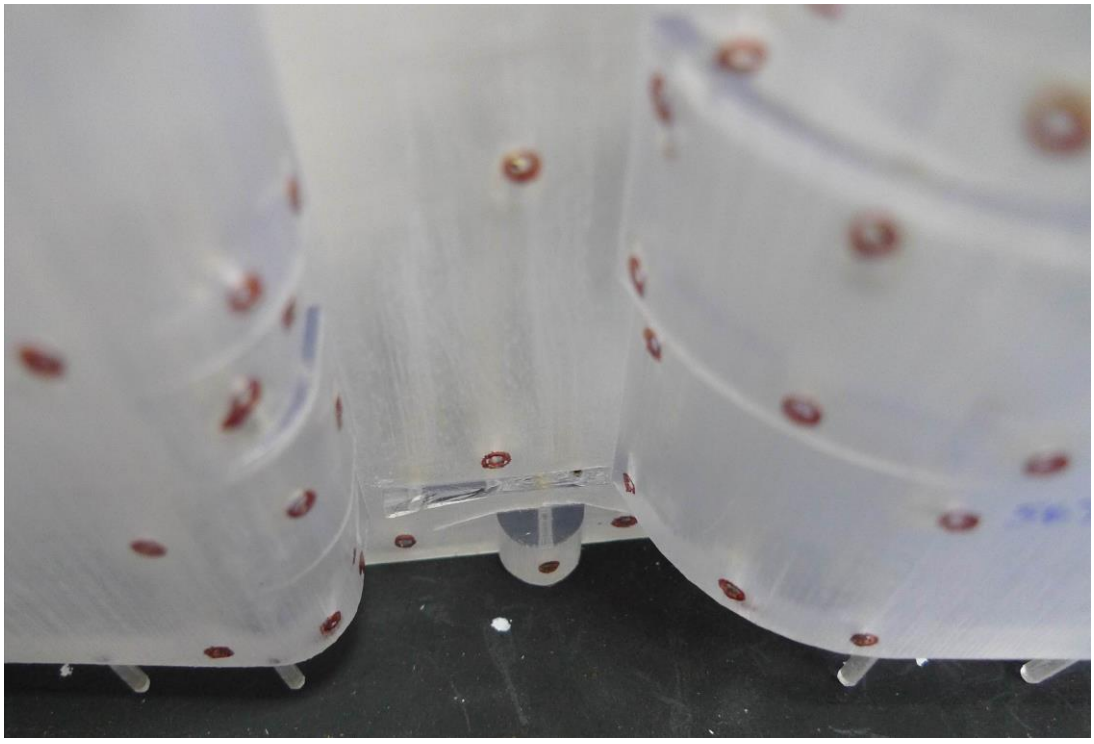
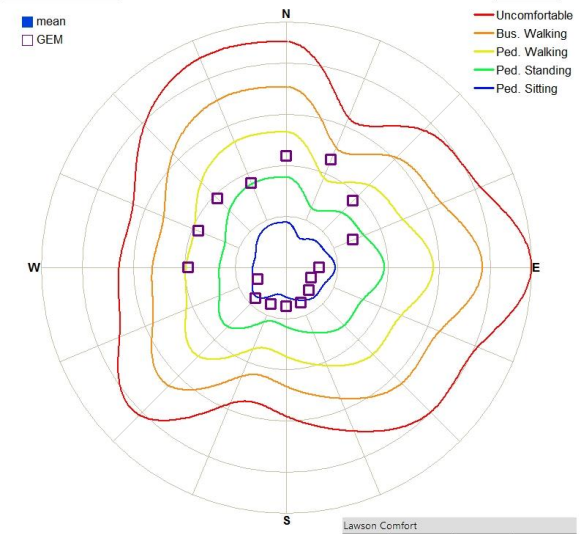


Figure 11: SICEEP PCP development without east awning

Appendix 2: Directional Wind Results

LOCATION 1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	25.06	40.13	40.13
4	5.61	9.52	9.52
6	1.45	2.21	2.21
8	0.13	0.25	0.25
10	0.00	0.01	0.01

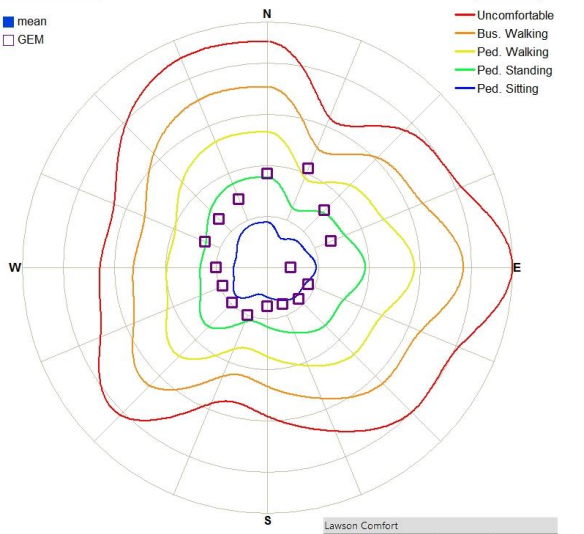
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	4.8	4.8
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.9	9.4	9.4
Rating	Pass	Pass	Pass

LOCATION 2



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	14.40	30.98	30.98
4	2.85	4.76	4.76
6	0.48	0.87	0.87
8	0.01	0.04	0.04
10	0.00	0.00	0.00

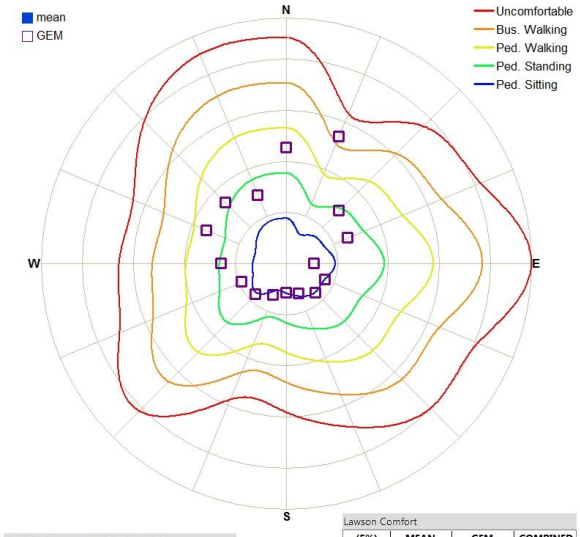
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.1	3.9	3.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.6	8.2	8.2
Rating	Pass	Pass	Pass

LOCATION 3



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	17.30	32.29	32.29
4	4.26	7.49	7.49
6	1.22	2.43	2.43
8	0.11	0.64	0.64
10	0.00	0.06	0.06

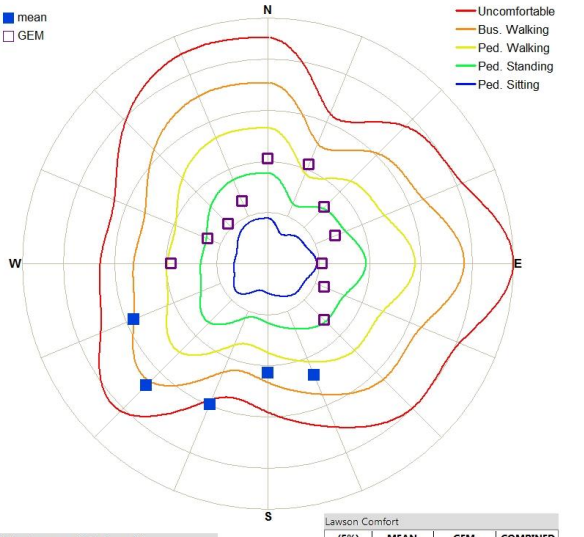
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.7	4.7	4.7
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.8	10.5	10.5
Rating	Pass	Pass	Pass

LOCATION 4



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	50.87	58.69	59.07
4	22.48	24.48	25.24
6	8.04	7.48	8.42
8	1.87	1.41	1.90
10	0.45	0.29	0.45

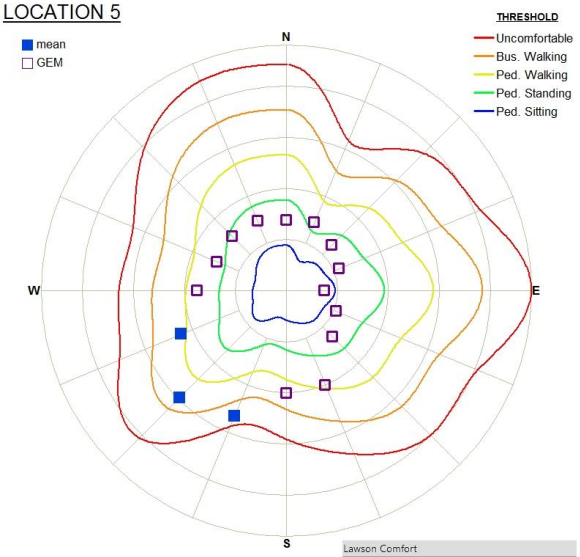
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	6.6	6.5	6.7
Rating	Ped Walking	Ped Walking	Ped Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	14.2	13.2	14.2
Rating	Pass	Pass	Pass

LOCATION 5



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	39.97	51.58	52.01
4	14.42	18.09	18.93
6	3.53	4.08	4.67
8	0.77	0.68	0.90
10	0.17	0.12	0.18

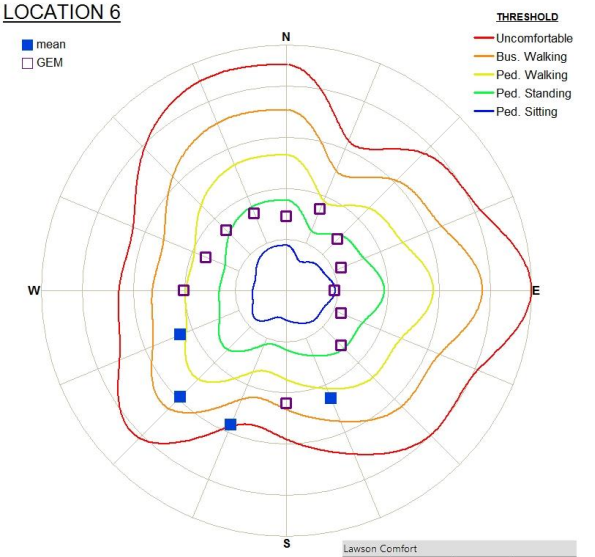
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.5	5.7	5.9
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.5	12.0	12.6
Rating	Pass	Pass	Pass

LOCATION 6



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	45.78	59.26	59.58
4	18.69	22.84	23.48
6	5.64	6.32	6.98
8	1.22	1.12	1.45
10	0.29	0.19	0.31

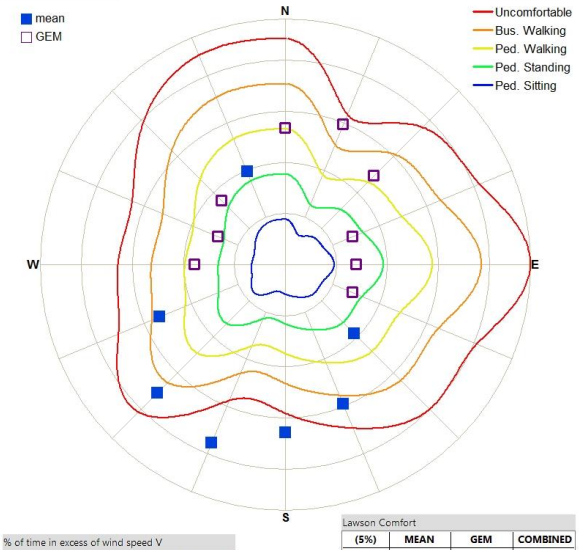
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	6.1	6.2	6.4
Rating	Ped Walking	Ped Walking	Ped Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.4	12.4	13.4
Rating	Pass	Pass	Pass

LOCATION 7



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	66.22	70.31	71.53
4	33.78	32.96	35.92
6	18.08	13.79	18.79
8	8.14	4.10	8.25
10	2.81	0.89	2.83

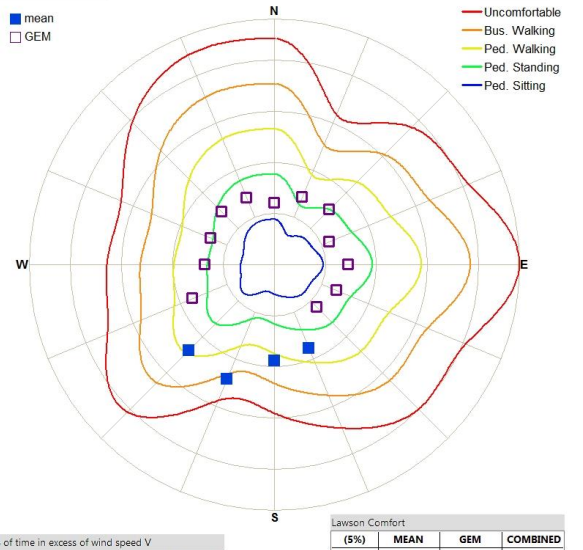
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	8.9	7.7	8.9
Rating	Bus Walking	Ped Walking	Bus Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	18.0	14.6	18.0
Rating	Able Body	Pass	Able Body

LOCATION 8



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	38.77	49.29	50.29
4	11.97	12.11	14.65
6	2.69	1.62	2.82
8	0.45	0.21	0.46
10	0.08	0.03	0.08

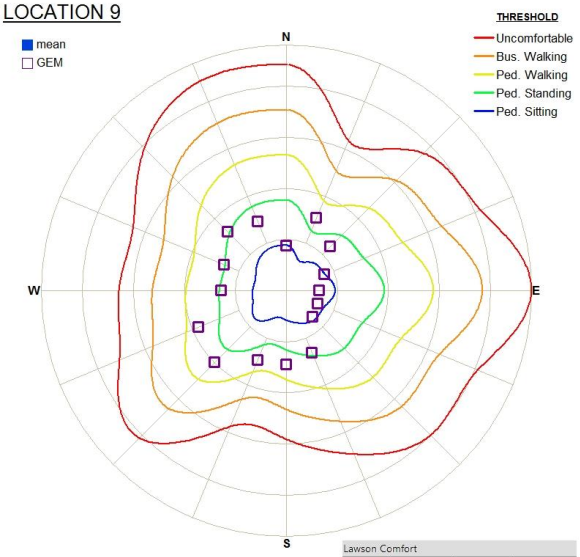
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.2	4.9	5.3
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.4	10.2	11.4
Rating	Pass	Pass	Pass

LOCATION 9



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	26.30	40.49	40.49
4	3.02	7.67	7.67
6	0.10	0.43	0.43
8	0.00	0.03	0.03
10	0.00	0.00	0.00

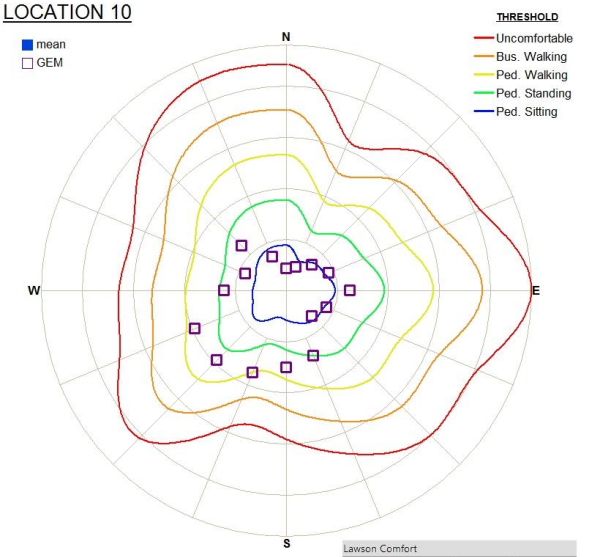
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	4.3	4.3
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.0	8.1	8.1
Rating	Pass	Pass	Pass

LOCATION 10



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	21.87	30.67	30.67
4	3.10	6.99	6.99
6	0.24	0.60	0.60
8	0.02	0.05	0.05
10	0.00	0.00	0.00

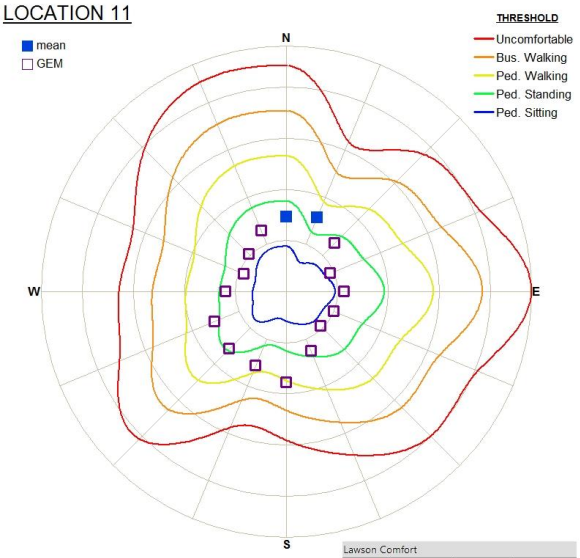
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	4.3	4.3
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.7	8.5	8.5
Rating	Pass	Pass	Pass

LOCATION 11



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.12	40.71	40.85
4	4.31	8.97	9.01
6	0.13	0.89	0.90
8	0.00	0.05	0.05
10	0.00	0.00	0.00

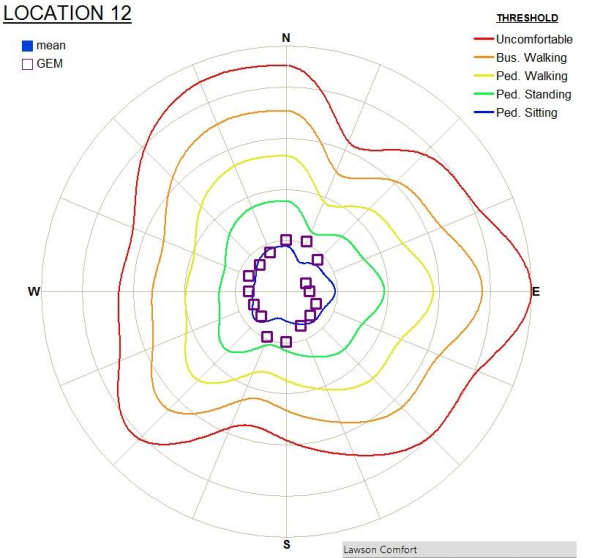
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.5	4.5
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.9	8.6	8.6
Rating	Pass	Pass	Pass

LOCATION 12



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	8.36	16.20	16.20
4	0.04	0.25	0.25
6	0.00	0.00	0.00
8	0.00	0.00	0.00
10	0.00	0.00	0.00

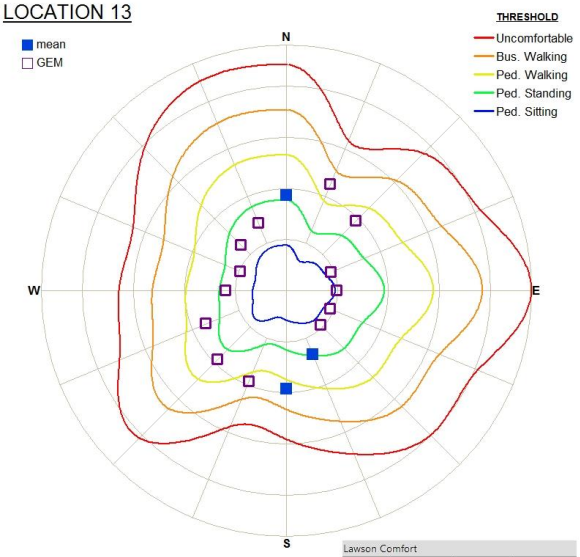
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.2	2.7	2.7
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.1	5.0	5.0
Rating	Pass	Pass	Pass

LOCATION 13



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	39.90	47.34	47.71
4	13.53	14.41	15.43
6	2.57	2.60	3.06
8	0.19	0.22	0.25
10	0.01	0.01	0.02

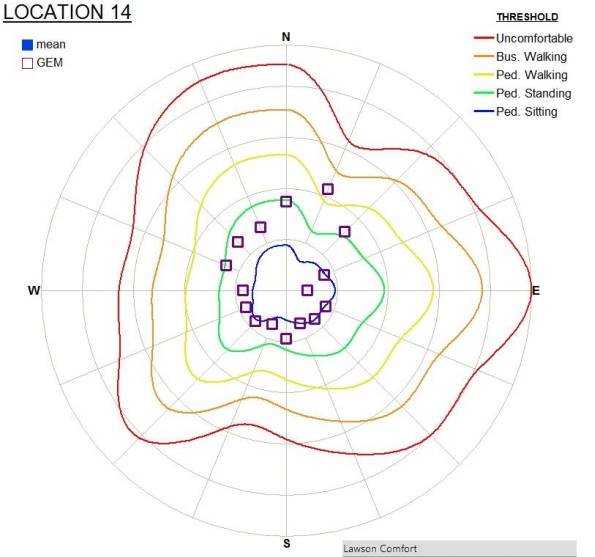
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.2	5.2	5.4
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.5	9.6	9.8
Rating	Pass	Pass	Pass

LOCATION 14



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	15.54	27.85	27.85
4	3.03	4.66	4.66
6	0.57	0.94	0.94
8	0.02	0.06	0.06
10	0.00	0.00	0.00

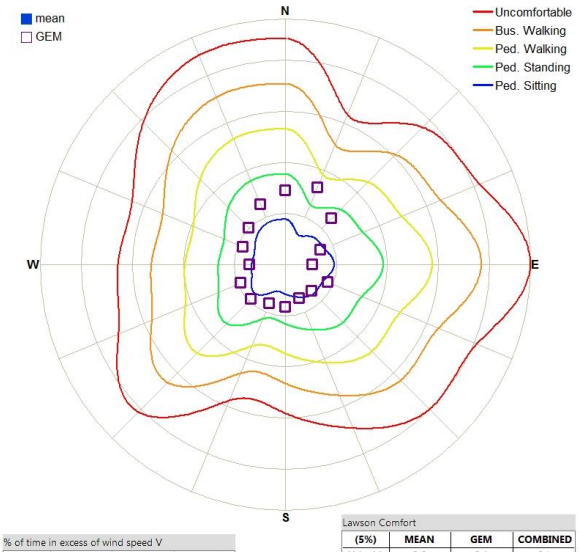
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.2	3.9	3.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.8	8.4	8.4
Rating	Pass	Pass	Pass

LOCATION 14.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	10.72	21.42	21.42
4	0.99	2.04	2.04
6	0.01	0.07	0.07
8	0.00	0.00	0.00
10	0.00	0.00	0.00

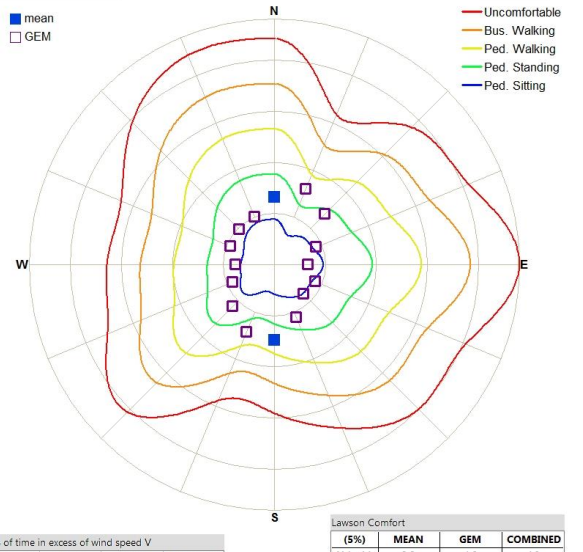
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.6	3.1	3.1
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.6	6.4	6.4
Rating	Pass	Pass	Pass

LOCATION 15



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	27.48	31.69	31.99
4	4.68	5.09	5.34
6	0.17	0.20	0.22
8	0.01	0.01	0.01
10	0.00	0.00	0.00

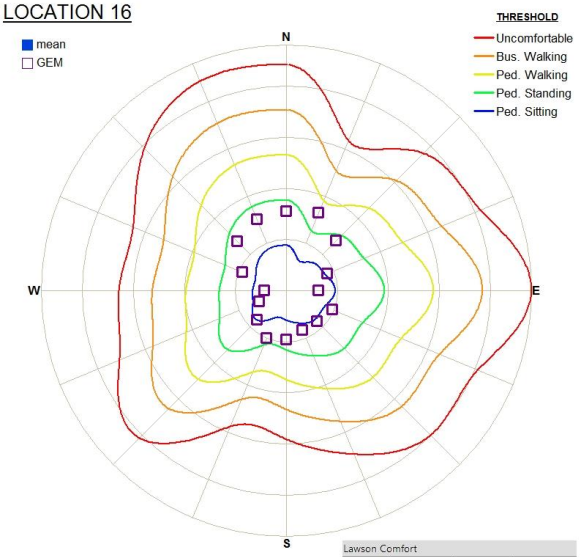
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.0	4.0
Rating	Ped Sitting	Ped Sitting	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.2	7.3	7.3
Rating	Pass	Pass	Pass

LOCATION 16



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	19.36	26.31	26.31
4	1.83	2.56	2.56
6	0.04	0.11	0.11
8	0.00	0.00	0.00
10	0.00	0.00	0.00

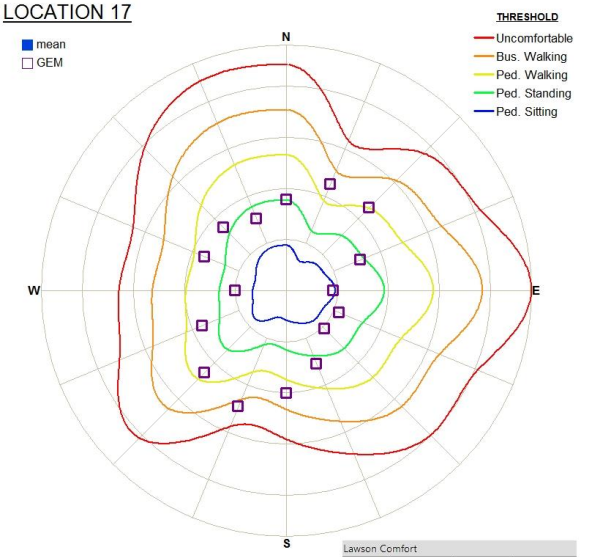
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.1	3.4	3.4
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.2	6.7	6.7
Rating	Pass	Pass	Pass

LOCATION 17



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	41.94	56.17	56.17
4	14.25	20.04	20.04
6	2.61	5.07	5.07
8	0.28	0.70	0.70
10	0.04	0.10	0.10

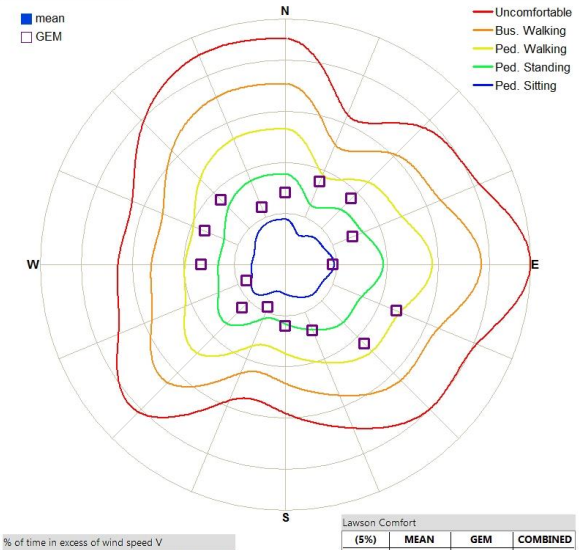
Lawson Comfort

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

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.6	11.6	11.6
Rating	Pass	Pass	Pass

LOCATION 18



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	29.91	50.34	50.34
4	3.23	9.21	9.21
6	0.11	0.97	0.97
8	0.00	0.05	0.05
10	0.00	0.01	0.01

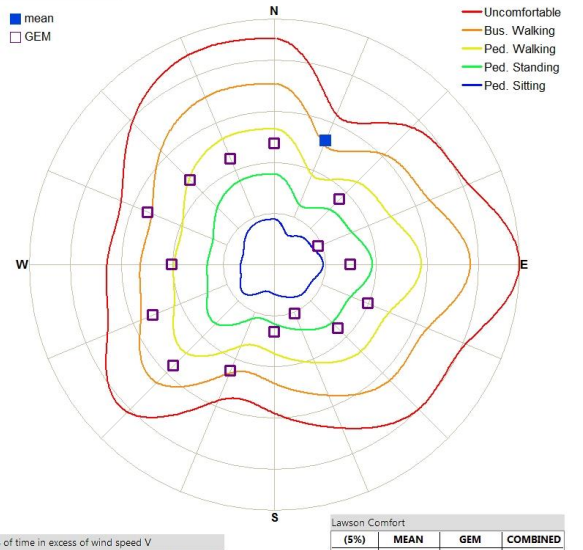
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	4.6	4.6
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.7	8.6	8.6
Rating	Pass	Pass	Pass

LOCATION 19



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	54.13	70.49	70.54
4	13.52	21.17	21.29
6	3.62	6.05	6.13
8	0.75	1.41	1.48
10	0.06	0.26	0.27

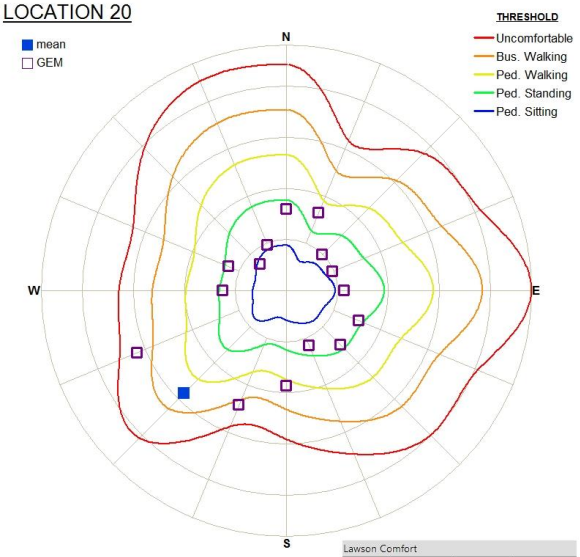
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.4	6.2	6.3
Rating	Ped Standing	Ped Walking	Ped Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.7	12.6	12.6
Rating	Pass	Pass	Pass

LOCATION 20



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	34.43	47.05	47.05
4	11.49	16.10	16.11
6	3.00	4.50	4.50
8	0.65	0.93	0.93
10	0.12	0.19	0.19

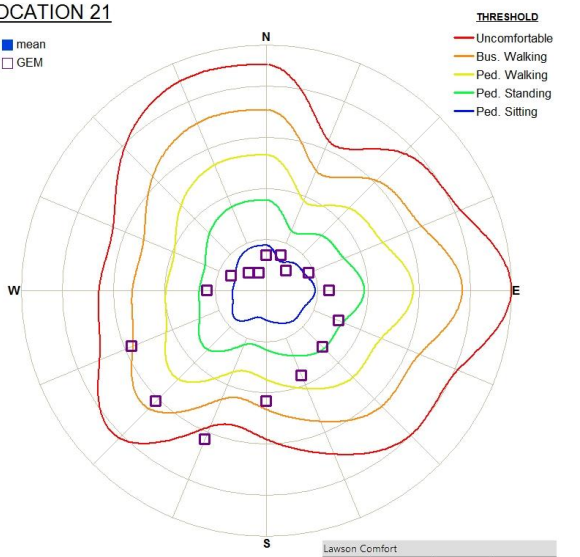
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.2	5.8	5.8
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.7	12.5	12.5
Rating	Pass	Pass	Pass

LOCATION 21



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	27.02	39.03	39.03
4	10.68	17.52	17.52
6	3.23	6.73	6.73
8	0.75	1.95	1.95
10	0.16	0.55	0.55

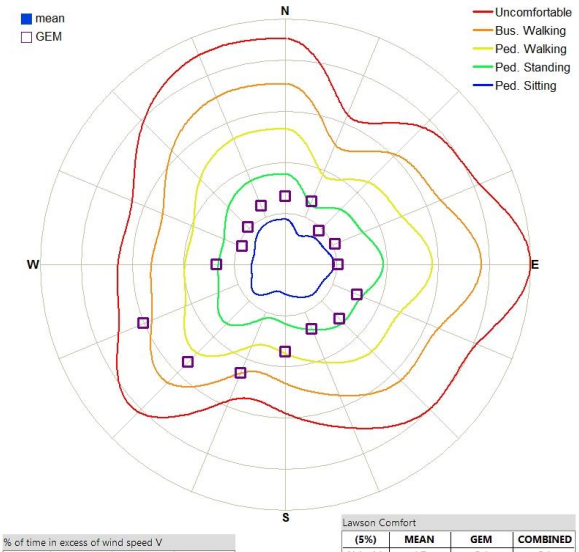
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.3	6.4	6.4
Rating	Ped Standing	Ped Walking	Ped Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.4	14.9	14.9
Rating	Pass	Pass	Pass

LOCATION 22



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	34.07	45.38	45.38
4	8.29	13.26	13.26
6	1.76	3.36	3.36
8	0.29	0.66	0.66
10	0.04	0.12	0.12

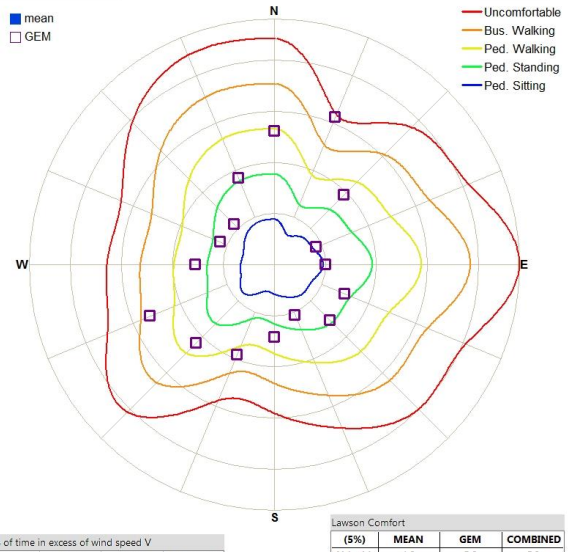
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.4	5.4
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.5	11.8	11.8
Rating	Pass	Pass	Pass

LOCATION 23



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	38.57	56.08	56.08
4	8.96	17.16	17.16
6	2.04	4.99	4.99
8	0.20	1.73	1.73
10	0.01	0.38	0.38

Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.8	5.9	5.9
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.5	12.3	12.3
Rating	Pass	Pass	Pass