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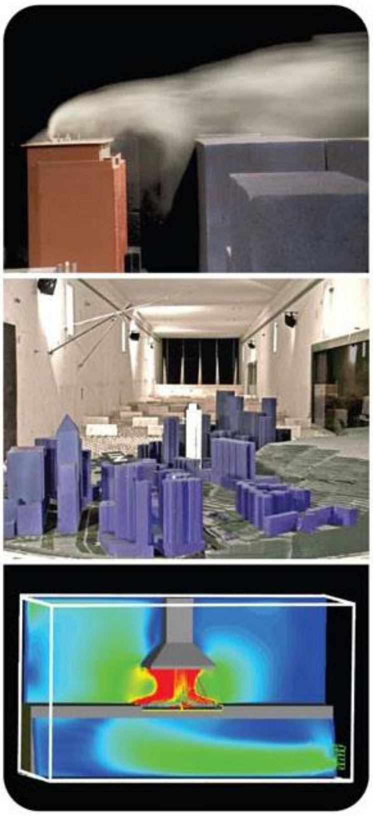
WIND ENGINEERING AND AIR QUALITY CONSULTANTS

Wind Tunnel Test Report for:

SYDNEY INTERNATIONAL CONVENTION, EXHIBITION AND ENTERTAINMENT PRECINCT (SICEEP), DARLING SQUARE NORTH-EAST PLOT



Sydney, Australia

CPP Project 7479

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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
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, m^2/s
$\sigma(\,)$	Standard deviation of $(\,)' = (\,)_{\mathrm{rms}}$
ρ	Density of approach flow, kg/m^3
$(\,)_{\mathrm{max}}$	Maximum value during data record
$(\,)_{\mathrm{min}}$	Minimum value during data record
$(\,)_{\mathrm{mean}}$	Mean value during data record
$(\,)_{\mathrm{rms}}$	Root mean square about the mean

1. CLIENT PROVIDED SUMMARY INFORMATION

1.1. Introduction

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

The Application (referred to as SSDA 7) follows the approval of a staged SSD DA (SSDA 2) in December 2013. SSDA 2 sets out a Concept Proposal for a new mixed use residential neighbourhood at Haymarket referred to as "Darling Square", previously known as "The Haymarket". Darling Square forms part of the Sydney International Convention, Exhibition and Entertainment precinct (SICEEP) Project, which will deliver Australia's global city with new world class convention, exhibition and entertainment facilities and support the NSW Government's goal to "make NSW number one again".

More specifically this subsequent DA seeks approval for mixed use development within the North East development plot of Darling Square and associated public domain works. The DA has been prepared and structured to be consistent with the Concept Proposal DA.

1.2. Overview of Proposed Development

The proposal relates to a detailed ('Stage 2') DA for a mixed use residential development in the North East Plot of Darling Square together with associated public domain works. The Darling Square Site is to be developed for a mix of residential and non-residential uses, including but not limited to residential buildings, commercial, retail, community and open space. The North East Plot is one of six development plots identified within the approved Concept Proposal.

Under the Concept Proposal, the North East Plot is planned to accommodate a mixed use podium and three residential buildings (NE1, NE2, and NE3) above and within the podium structure. More specifically, this SSD DA seeks approval for the following components of the development:

- Demolition of existing site improvements, including the Sydney Entertainment Centre (SEC);
- Associated tree removal and planting;
- Construction and use of a predominantly 6 storey mixed use podium, including:
  - retail floor space and residential lobbies on Ground Level;
  - above ground parking;
  - residential apartments; and
  - communal facilities.
- Construction and use of three residential buildings above podium;
- Public domain improvements surrounding the site, including interim works;
- Provision of vehicle access to the development from Harbour Street;
- Landscaping works to the podium roof level; and
- Extension and augmentation of physical infrastructure / utilities as required.

1.3. Background

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

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

Key features of the Preferred Master Plan include:

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

On 21 March 2013 a critical step in realising the NSW Government’s vision for the SICEEP Project was made, with the lodgement of the first two SSD DAs with the (now) Department of Planning and Environment. The key components of these proposals are outlined below.

Public Private Partnership SSD DA (SSD 12_5752)

The Public-Private Partnership (PPP) SSD DA (SSDA 1) includes the core facilities of the SICEEP Project, comprising the new, integrated and world-class convention, exhibition and entertainment facilities along with ancillary commercial premises and public domain upgrades. SSDA1 was approved on 22 August 2013.

Concept Proposal (SSD 13_5878)

The Concept Proposal SSD DA (SSDA 2) establishes the vision and planning and development framework which will be the basis for the consent authority to assess detailed development proposals within the Darling Square Site. SSDA2 was approved on 5 December 2013. The Stage 1 Concept Proposal approved the following key components and development parameters:

- Indicative staging of demolition and development of future development plots;
- Land uses across the site including residential and non-residential uses;
- Street and laneway layouts and pedestrian routes;
- Open spaces and through-site links;
- Six separate development plots, development plot sizes and separation, building envelopes, building separation, building depths, building alignments, and benchmarks for natural ventilation and solar access provisions;
- A maximum total gross floor area of 197,236m^2 (excluding ancillary above ground parking), comprised of:
  - A maximum of 49,545m^2 non-residential GFA; and
  - A maximum of 147,691m^2 residential GFA
- Above ground car parking including public car parking;
- Residential car parking rates;
- Design Guidelines to guide future development and the public domain; and
- A remediation strategy.

In addition to the approval of SSDA1 and SSDA2, the following approvals have been granted for various stages of Darling Square site:

- Darling Drive (part) development plot (SSDA3) for the construction and use of a residential building (student accommodation) and the provision of associated public domain works approved on 7 May 2014;
- North-West development plot (SSDA4) for the construction and use of a mixed use commercial development and public car park building and associated public domain works approved on 7 May 2014; and
- South-West development plot (SSDA5) – construction and use of a mixed use residential development and associated public domain works approved on 21 May 2014.

Approval was also granted on 15 June 2014 for SSDA6 which includes the construction and use of the International Convention Centre (ICC) Hotel and provision of public domain works.

This report has been prepared to support a detailed Stage 2 SSD DA for mixed use development and associated public domain works within Darling Square (SSDA 7), consistent with the approved Concept Proposal (SSDA 2).

1.4. Site Description

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

With an area of approximately 20 hectares, the SICEEP Site is generally bound by the light rail Line to the west, Harbourside shopping centre and Cockle Bay to the north, Darling Quarter, the Chinese Garden and Harbour Street to the east, and Hay Street to the south (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 43,807m^2.

Figure 1: Aerial photograph of the SICEEP site

The Concept Proposal DA provides for six (6) separate development plots across the Darling Square Site, Figure 2:

1. North Plot;
2. North East Plot;
3. South East Plot;
4. South West Plot;
5. North West Plot; and
6. Western Plot (Darling Drive).

The Application Site area relates to the North East Plot and surrounds as detailed within the architectural and landscape plans submitted in support of the DA.

Figure 2: Concept proposal development plots

1.5. Planning Approvals Strategy

The SICEEP Project has resulted in the lodgement of numerous SSD DAs for the various components of the redevelopment project. Future applications will continue to be lodged in accordance with the Concept Proposal SSD DA for the remaining development plots of Darling Square Site.

2. EXECUTIVE SUMMARY

Cermak Peterka Petersen Pty. Ltd. has been engaged by Lend Lease to assess the proposed Darling Square north-east plot of Sydney International Convention Centre, Exhibition and Entertainment Precinct (SICEEP) in terms of Wind Impact. This report supports a State Significant Development (SSD) Development Application (DA) submitted to the Minister for Planning and Infrastructure pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act).

The report provides an assessment of the impact of the Darling Square north-east plot mixed-use development on the amenity of the wind environment in and around the site. The proposed development was modelled with proposed and existing surrounding developments, including the SICEEP Precinct Plan.

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

A model of the proposed Darling Square north-east plot development, with replicas of surrounding buildings within a 570 m radius, was constructed at 1:400 scale and centred on a turntable in the wind tunnel. A wind tunnel study was conducted as part of the Development Specific assessment. The wind tunnel testing was performed in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd., St. Peters. Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 25 locations for 16 wind directions each. The measurements were combined with wind statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location.

The wind environment for pedestrian comfort at ground level around the site was found to be suitable for at least pedestrian walking at all locations. No locations were classified as uncomfortable. Windy locations were found around the north-east corner along the east side of Harbour Street. The majority of the strong winds are caused by the relatively exposed nature of the large buildings generating downwash and funnelling effects.

The majority of locations passed the distress criterion, with two locations classified as suitable for able-bodied pedestrians caused by downwash from the tall tower at the northern end of the site. No location failed the distress criterion.

3. INTRODUCTION

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 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, of estimating wind pressures, frame loads, or windiness in pedestrian areas.

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

Table 1: Configurations for data acquisition

General Information	
Model scale	1:400
Surrounding model radius (full-scale)	570 m
Reference height (full-scale)	200 m
Approach Terrain Category	Terrain Category 3

Testing Configuration
The proposed Darling Square north-east plot with adjacent PPP surrounding buildings and other plots part of The Darling Square precinct, and existing surrounding buildings, as shown in Figure 6.
Pedestrian winds measured at 25 locations for 16 wind directions at 22.5° increments from 0° (north)

4. THE WIND TUNNEL TEST

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

The wind tunnel test was performed in the boundary layer wind tunnel shown in Figure 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, fence, and roughness elements were designed to provide a modelled atmospheric boundary layer approximately 1.2 m thick with a mean velocity and turbulence intensity profile similar to that expected to occur in the region approaching the modelled area. The approach wind characteristics used for the model test are shown in Figure 4 and are explained more fully in Section 6.1.1.

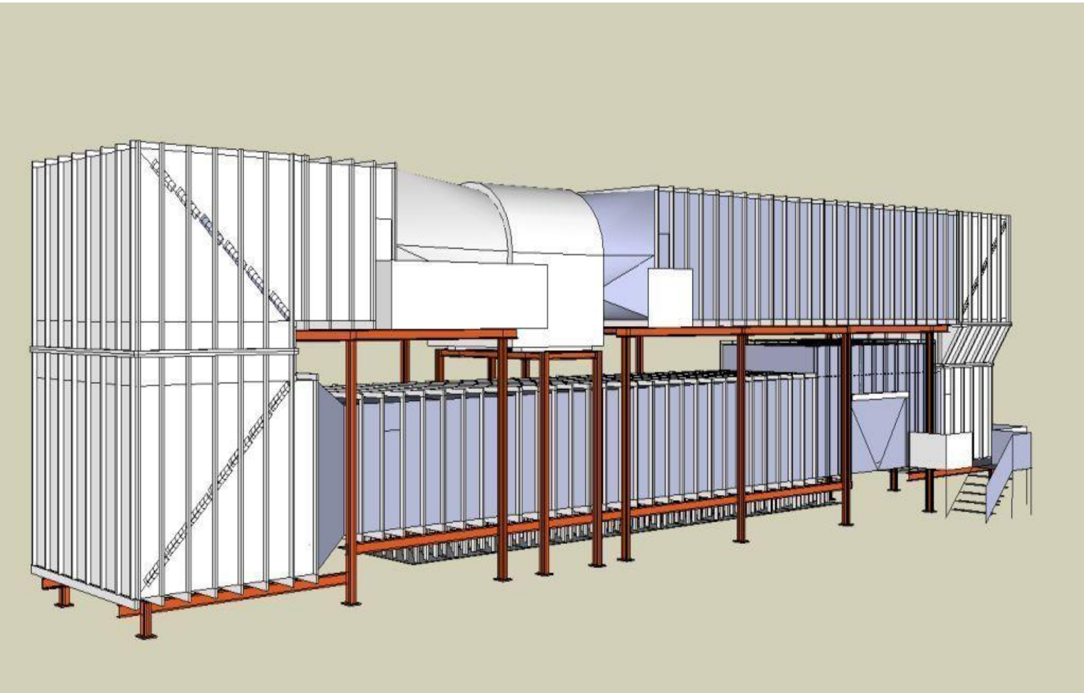

Figure 3: Schematic of the closed circuit wind tunnel

A model of the proposed development and surrounds to a radius of 570 m was constructed at a scale of 1:400. This 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 5. The turntable permitted rotation of the modelled area for examination of velocities from any approach wind direction. Additional photos of the testing are in Appendix 1.

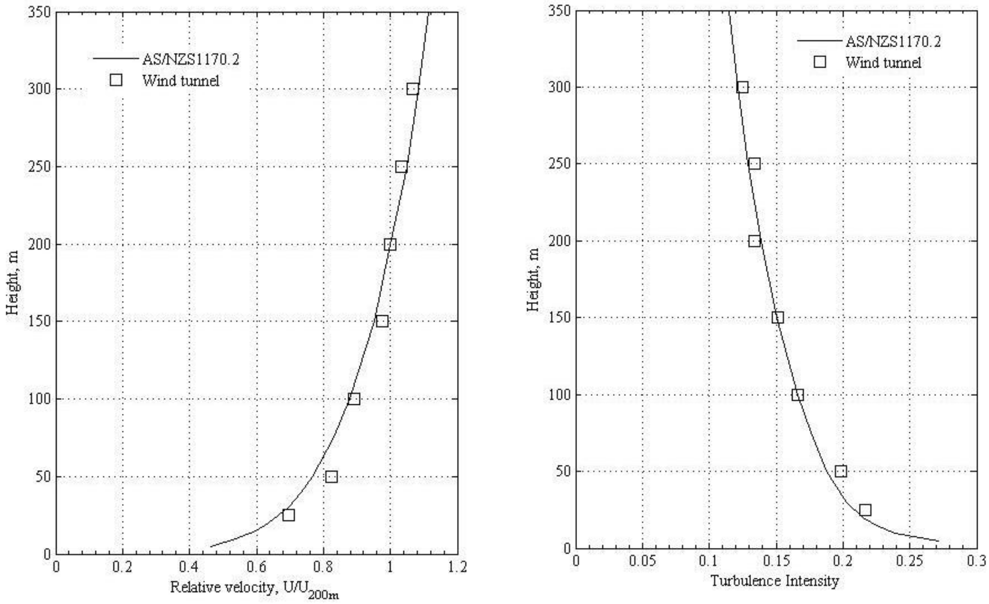

Figure 4: Mean velocity and turbulence profiles approaching the model

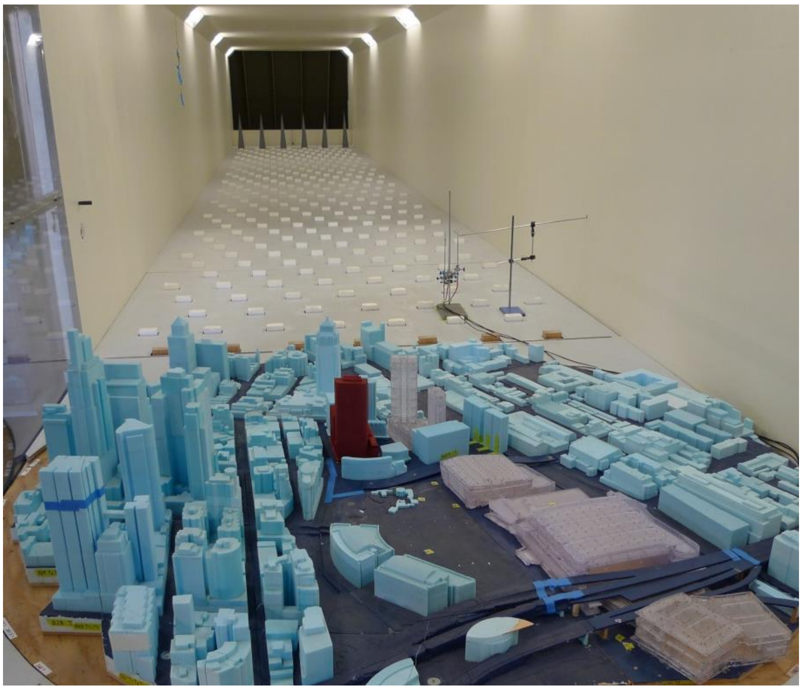

Figure 5: Photograph of the model in the CPP wind tunnel looking south

5. ENVIRONMENTAL WIND CRITERIA

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

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

Table 2: Summary of Lawson criteria

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

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

6. DATA ACQUISITION AND RESULTS

6.1. 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. The pedestrian wind measurements and analysis are described in Section 6.1.2. 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).

6.1.1. 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 of terrain category 3 approach winds as defined in Standards Australia (2011) and are appropriate for the approach conditions.

6.1.2. Pedestrian Winds

The proposed development is located to the west of Sydney CBD to the south of Darling Harbour. The Darling Square north-east plot mixed use development consists of a podium structure with three tower sections of varying height, Figure 5 and Figure 6. For this report, wind speed measurements were recorded at 25 locations to evaluate pedestrian comfort in and around the project site, Figure 7. The locations were tested for the configuration described in Table 1. Velocity measurements were made at the model scale equivalent of 1.5 to 2.1 m above the ground surface for 16 wind directions at 22.5° intervals. Locations were chosen to determine the degree of pedestrian comfort at the building corners where relatively severe conditions can be frequently found; near building entrances, on adjacent pavements with heavy pedestrian traffic, in open plaza areas, and on proposed terraces.

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

Figure 6: Extent of model

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.

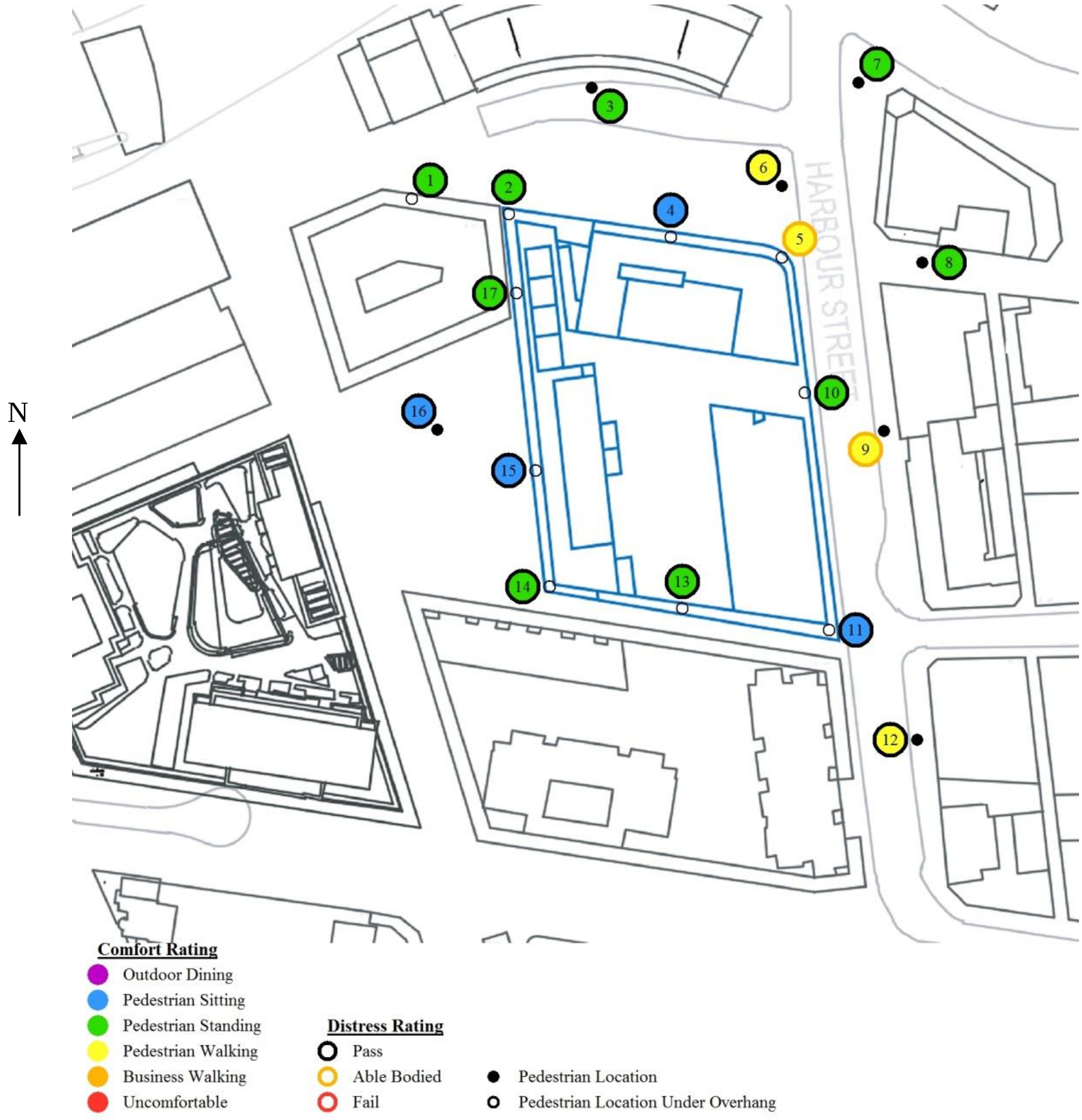

Figure 7: ground plane wind speed measurement locations with comfort/distress ratings

To enable a quantitative assessment of the wind environment, the wind tunnel data were combined with wind frequency and direction information measured by the Bureau of Meteorology at a standard height of 10 m at Sydney Airport from 1974 to 2013, Figure 8. This anemometer location is considered the most appropriate for analysis of the historic wind climate as the approach flow is flat and relatively consistent from all directions, and the immediate surrounds has not changed significantly through development over time compared with other anemometer locations in the city. From these data, directional criterion lines for the Lawson rating wind speeds have been calculated and included on the polar plots in Appendix 2; this gives additional information regarding directional sensitivity at each location.

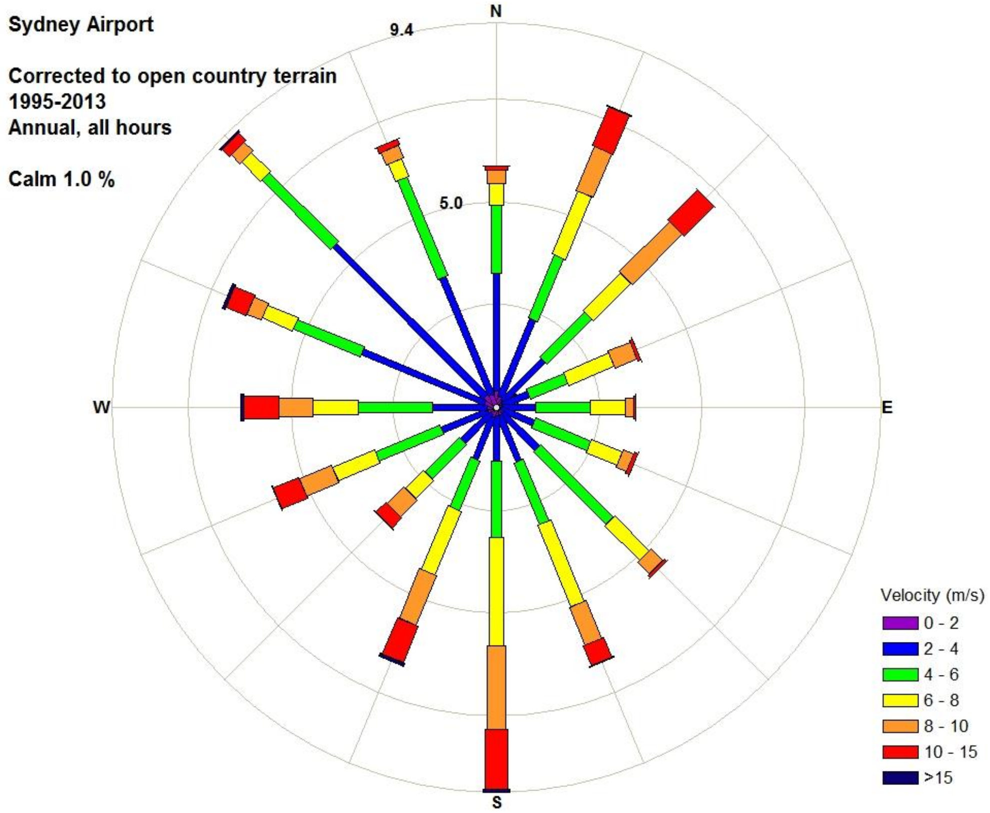

Figure 8: Wind rose of direction and speed for Sydney Airport

The criteria of Lawson consider the integration of the velocity measurements with local wind climate statistical data summarized in Figure 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 is 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, whilst intended for use at sea, the Beaufort scale is reproduced in Table 3 including qualitative descriptions of wind effects.

The tables in Appendix 2 additionally identify when the wind speed exceeded 5% and 0.022% of the time for direct comparison with the Lawson criteria and the associated Lawson ratings for both mean and GEM wind speeds. A colour coded summary assessment of pedestrian comfort and safety with respect to the Lawson criteria is presented in Figure 7 for each test location. Because some pedestrian wind measurement positions are purposely chosen at sites where large velocities of small spatial extent may exist, the general wind environment about the structure may be less severe than one might infer from an analysis only of the plots. The implications of the results are discussed in Section 6.

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.

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

7. CONCLUSIONS

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. However, in general terms the winds from the south-east and north-west quadrants had the most pronounced effect on the site as these directions are relatively exposed causing higher level winds to be brought to street level as downwash wind and channelled between the proposed and existing buildings. This is not unusual for a Sydney CBD location. Options are available to promote an improved environment such as fixed canopies, retail awnings or local vertical screening consistent with typical outdoor dining areas. 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 image of Figure 7 and Figure 9, which depict the locations selected for investigation of pedestrian wind comfort around the site along with the Lawson criteria rating for both comfort and distress. Note that testing was performed without planned trees or other plantings to provide a worst case assessment, and typically heavy streetscape planting 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 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.

Wind conditions at Locations 1 to 4 along Little Pier Street to the north of the side, Figure 7, are classified as suitable for pedestrian standing and sitting. Calmer conditions are experienced close to the north face of the proposed tower, with windier conditions experienced further away from the north tower. All locations pass the distress criterion.

Wind conditions at locations 5 to 12 along Harbour Street to the east of the site, Figure 7, are classified as suitable for standing and walking with the windier locations impacted by the proposed and existing buildings. The strong wind conditions at Location 5 on the corner of Little Pier Street and Harbour Street are caused by downwash from the tall building, combined with channelled flow accelerating along the north face of the building for winds from the south-east and north-west respectively. The fixed canopies and planting along Harbour Street will also help provide mild reduction in wind speeds through this section of Harbour Street. Wind conditions improve with distance from the corner. Moving south along Harbour Street, wind conditions are calmer on the west side of the street. The wind conditions at Location 12 are classified as suitable for pedestrian walking with strong events from the south-west and north-west caused by channelled flow through the existing and proposed medium-rise buildings on the north-east and south-east plots. Locations 5 and 9 marginally exceed the distress criterion (in terms of magnitude a couple of times per year) for pedestrians, and are classified for able-bodied pedestrians. For winds from the north-west, Location 9 has been selected at the position where the downwash from the tall tower would impinge the ground plane.

The wind conditions at Locations 13 to 17 to the south-east of the development, Figure 7, are classified as suitable for pedestrian standing and sitting activities. The Square to the west of the site is well shielded from the prevailing wind conditions and is suitable for the intended use of the space. All locations pass the distress criterion.

The wind conditions at Locations 18 to 25 on the private podium level rooftop, Figure 9, are classified as suitable for pedestrian sitting in areas close to the buildings or protected by vertical open walls such as around the pool area. Further from the building in exposed areas towards the south of the podium are classified as suitable for pedestrian. A wind speed of less than 4 m/s, which is the Lawson comfort criterion threshold for café-style/standing activities, would occur for over 75% of the time, Appendix 2. Additional screening or landscaping could further enhance the local wind conditions.

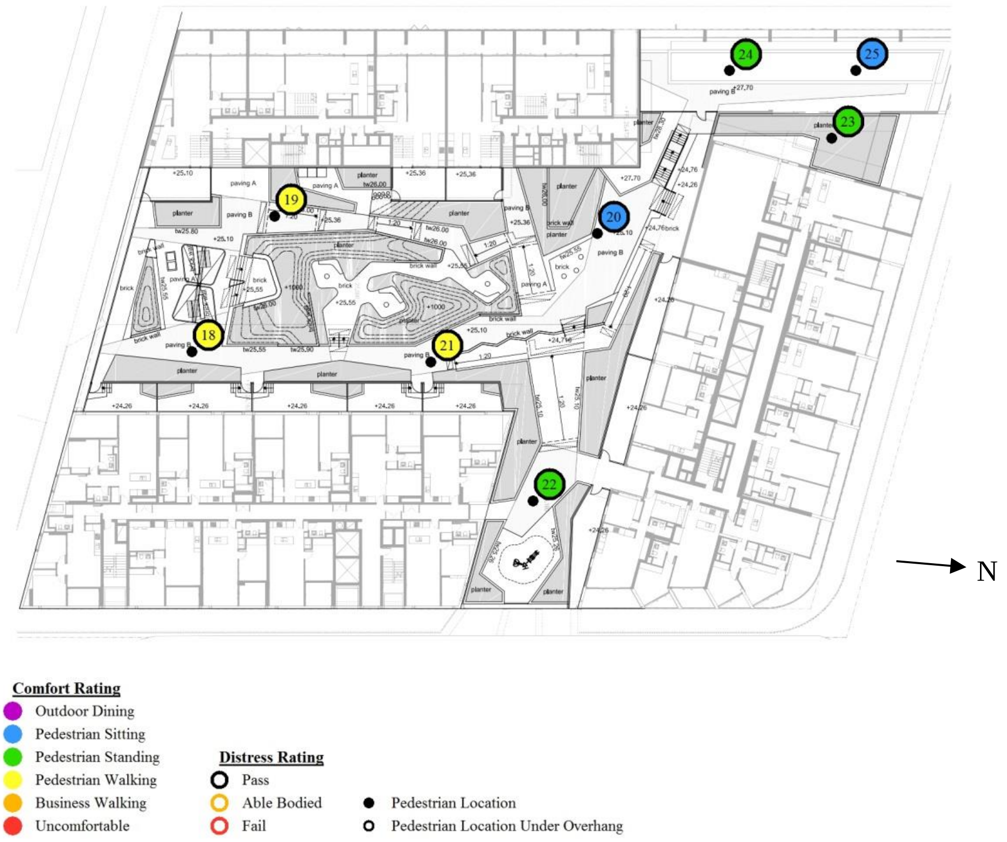

Figure 9: Podium level wind speed measurement locations with comfort/distress ratings

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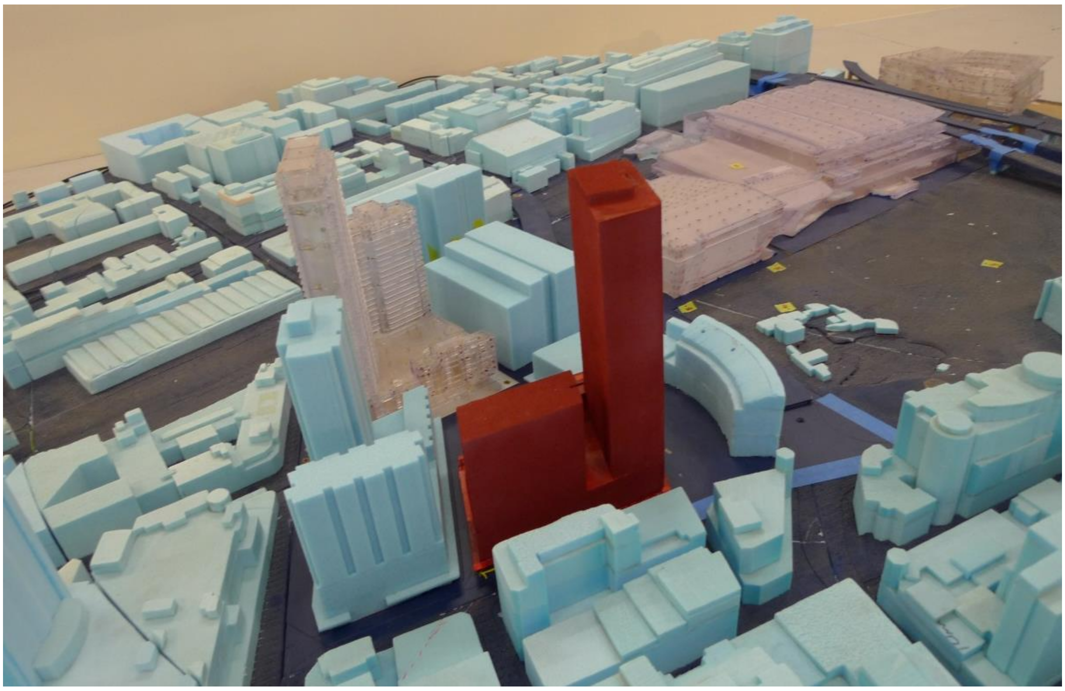
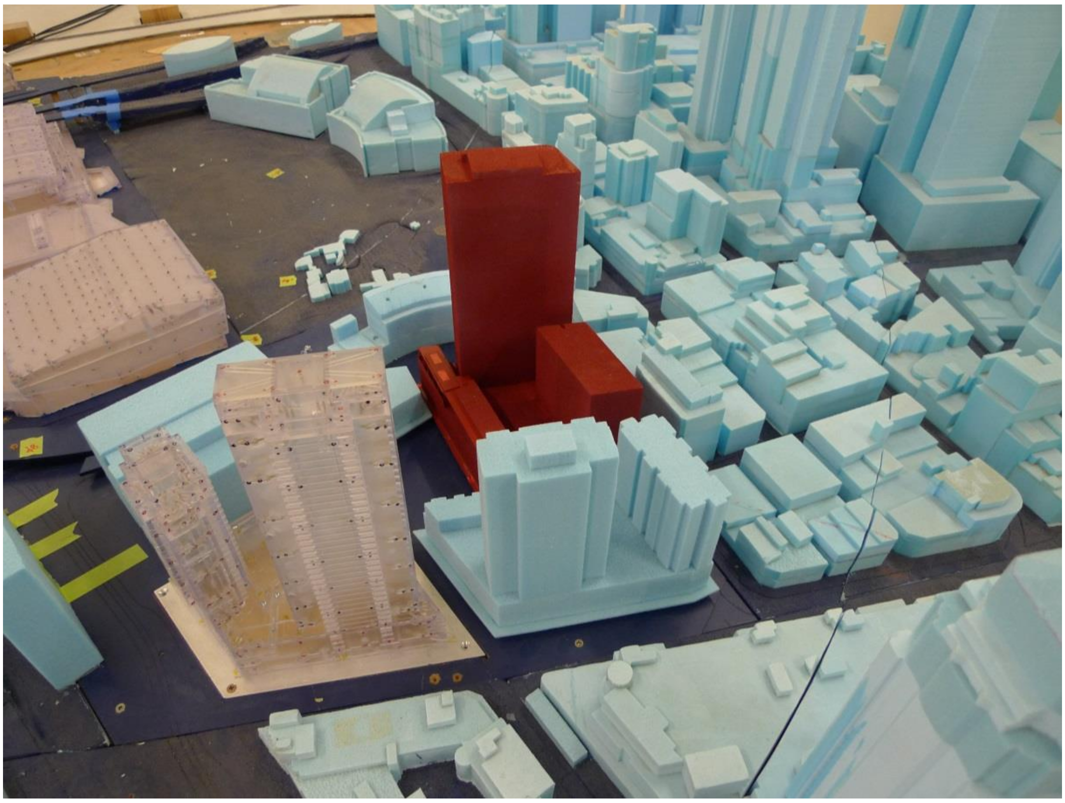
Appendix 1: Additional Photographs of the CPP Wind Tunnel Model



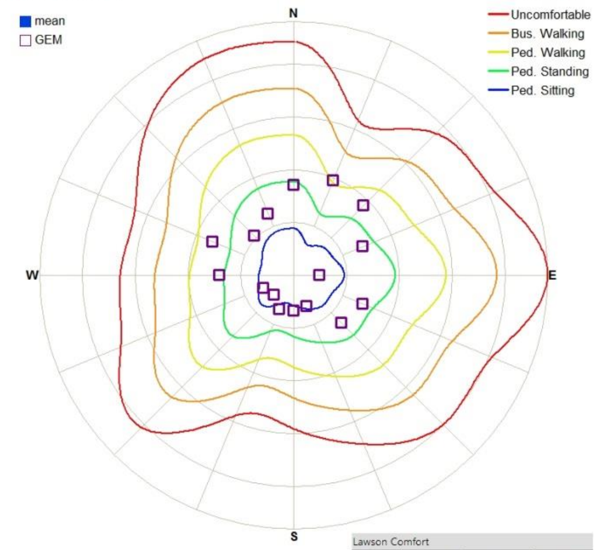
Aerial view from the east



Aerial view from the south

Appendix 2: Directional Wind Results

LOCATION 1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	14.9	30.9	30.9
4.0	1.8	5.3	5.3
6.0	0.0	0.7	0.7
8.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0

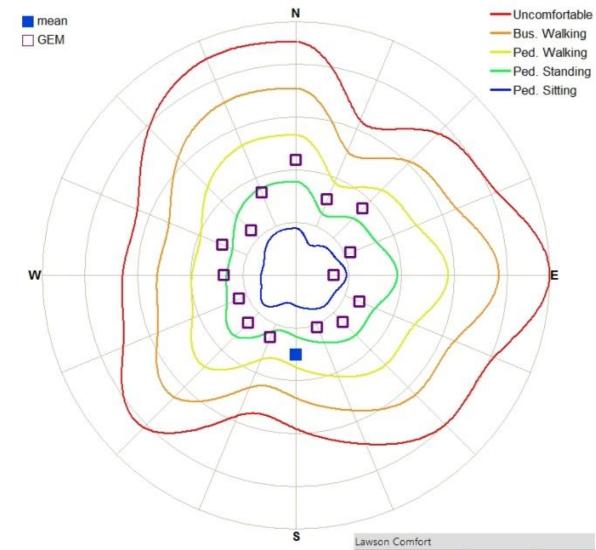
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.1	4.0	4.0
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.0	7.9	7.9
Rating	Pass	Pass	Pass

LOCATION 2



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	34.8	47.4	47.7
4.0	4.5	7.7	8.3
6.0	0.2	0.4	0.5
8.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0

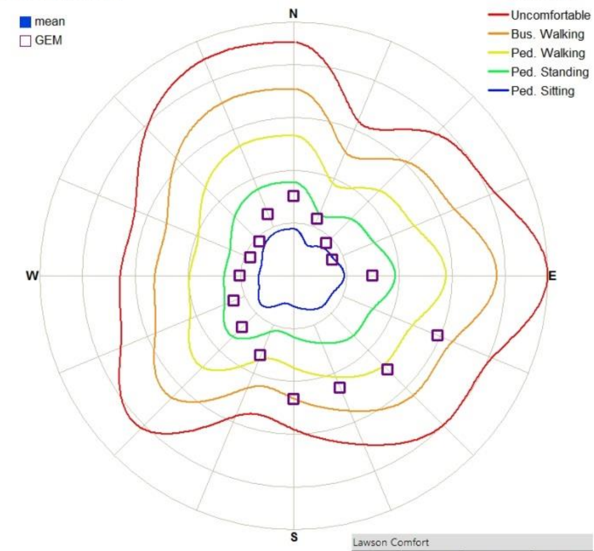
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.3	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.3	7.8	7.9
Rating	Pass	Pass	Pass

LOCATION 3



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	33.8	45.2	45.2
4.0	12.1	17.2	17.2
6.0	2.0	4.8	4.8
8.0	0.2	0.9	0.9
10.0	0.0	0.1	0.1

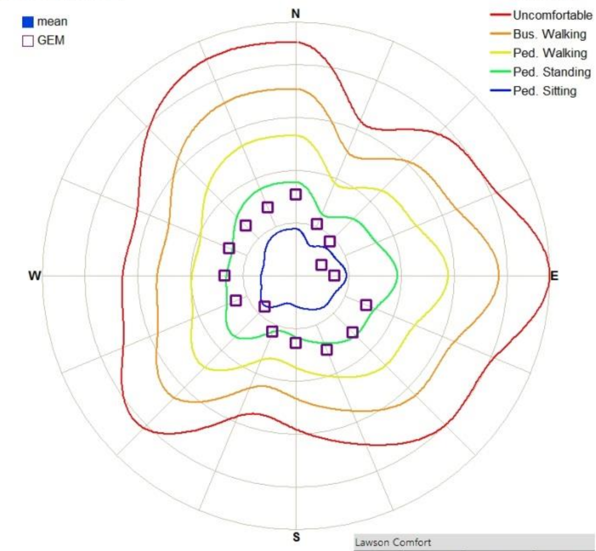
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.9	5.9
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

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

LOCATION 4



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	23.5	38.4	38.4
4.0	0.9	3.9	3.9
6.0	0.0	0.1	0.1
8.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0

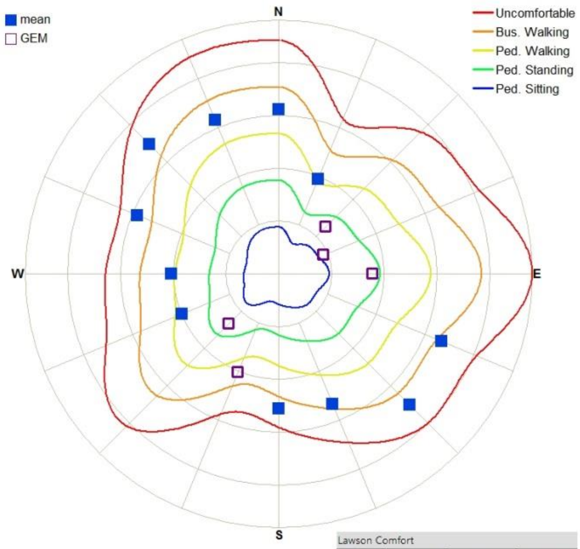
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.0	3.8	3.8
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.9	7.0	7.0
Rating	Pass	Pass	Pass

LOCATION 5



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	74.9	74.5	77.7
4.0	36.8	29.6	38.0
6.0	13.6	7.3	14.1
8.0	3.4	1.4	3.5
10.0	0.8	0.3	0.8

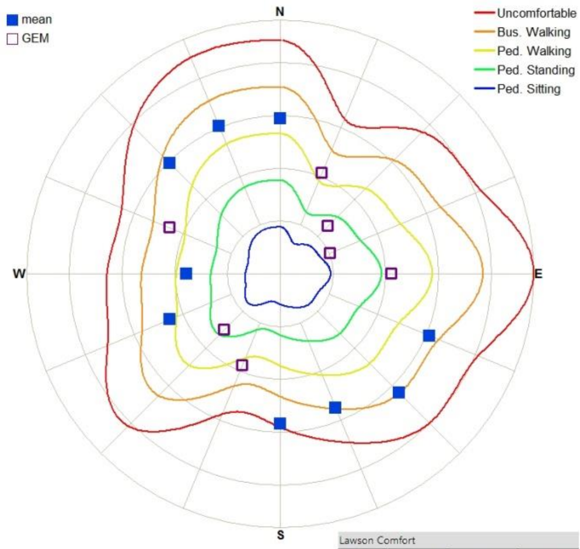
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	7.4	6.4	7.5
Rating	Ped Walking	Ped Walking	Ped Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	15.7	13.3	15.7
Rating	Able Body	Pass	Able Body

LOCATION 6



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	74.3	74.6	77.2
4.0	33.6	29.1	34.8
6.0	13.2	7.6	13.7
8.0	3.5	1.3	3.6
10.0	0.8	0.2	0.8

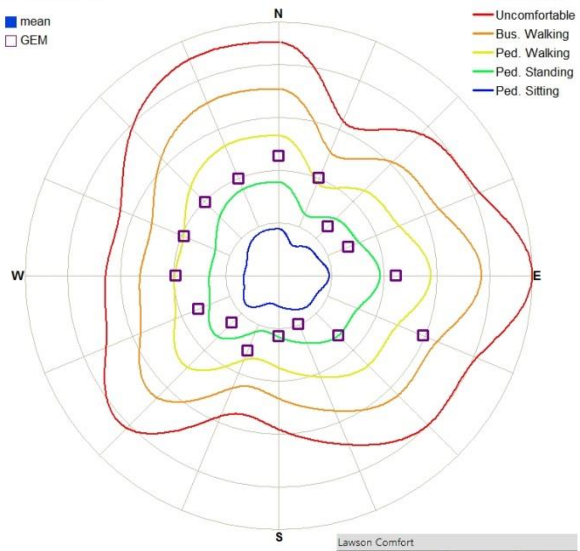
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	7.4	6.5	7.5
Rating	Ped Walking	Ped Walking	Ped Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	14.6	12.1	14.6
Rating	Pass	Pass	Pass

LOCATION 7



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	46.8	62.8	62.8
4.0	8.1	13.2	13.2
6.0	1.1	2.3	2.3
8.0	0.1	0.3	0.3
10.0	0.0	0.0	0.0

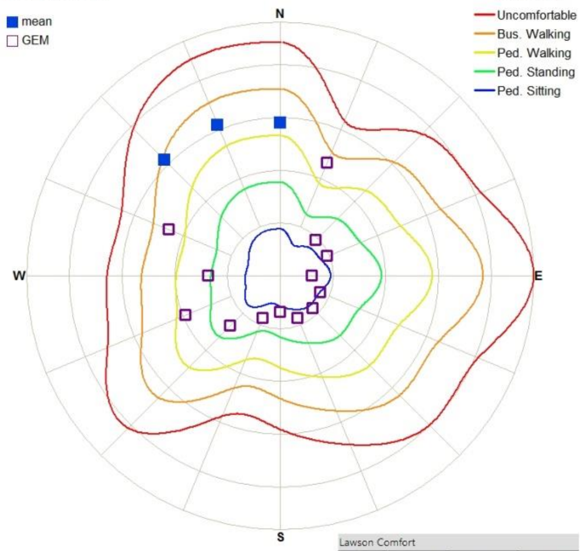
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.2	5.2
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.5	9.9	9.9
Rating	Pass	Pass	Pass

LOCATION 8



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	35.3	45.7	46.7
4.0	10.5	11.7	13.4
6.0	2.9	3.5	4.1
8.0	0.7	0.7	1.0
10.0	0.2	0.1	0.3

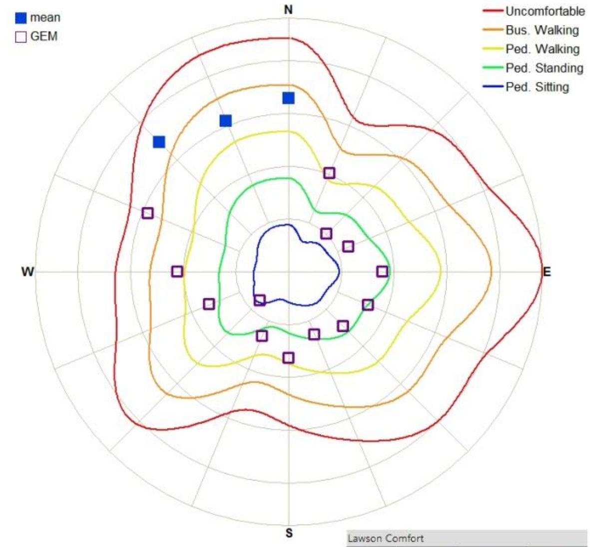
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.3	5.6
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.9	12.2	13.9
Rating	Pass	Pass	Pass

LOCATION 9



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	60.7	68.2	69.1
4.0	18.1	19.8	21.9
6.0	4.4	4.6	5.5
8.0	1.4	1.3	1.6
10.0	0.5	0.4	0.6

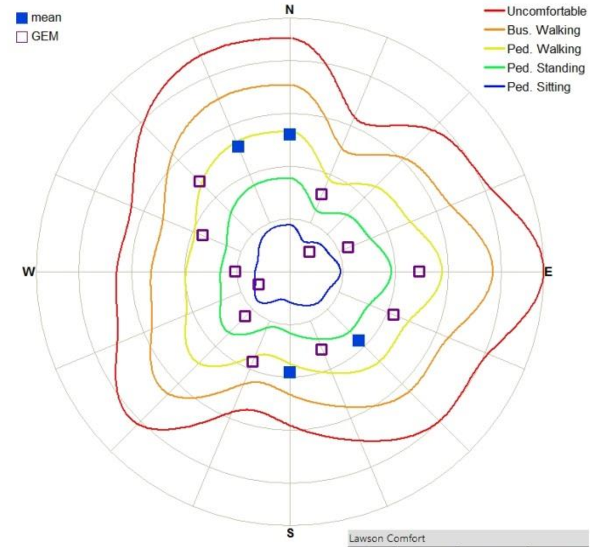
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.7	5.8	6.1
Rating	Ped Standing	Ped Standing	Ped Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	15.6	14.3	15.6
Rating	Able Body	Pass	Able Body

LOCATION 10



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	53.3	59.6	60.7
4.0	14.3	17.0	17.9
6.0	2.5	2.7	3.1
8.0	0.3	0.3	0.4
10.0	0.1	0.1	0.1

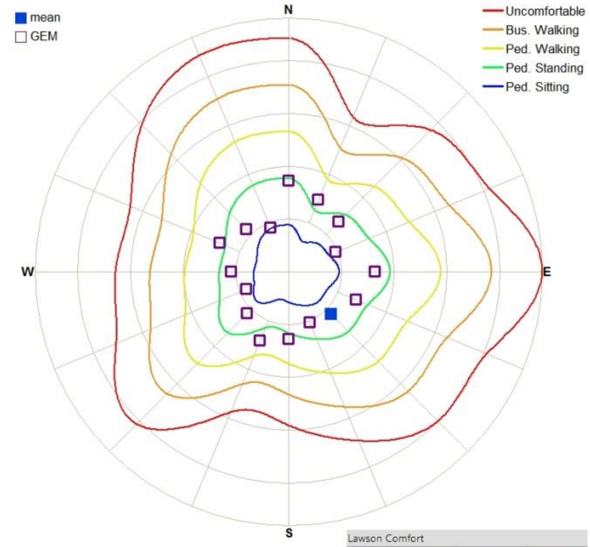
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.2	5.3	5.5
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.9	10.9	11.0
Rating	Pass	Pass	Pass

LOCATION 11



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	30.0	39.9	40.0
4.0	1.7	4.4	4.4
6.0	0.1	0.2	0.2
8.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0

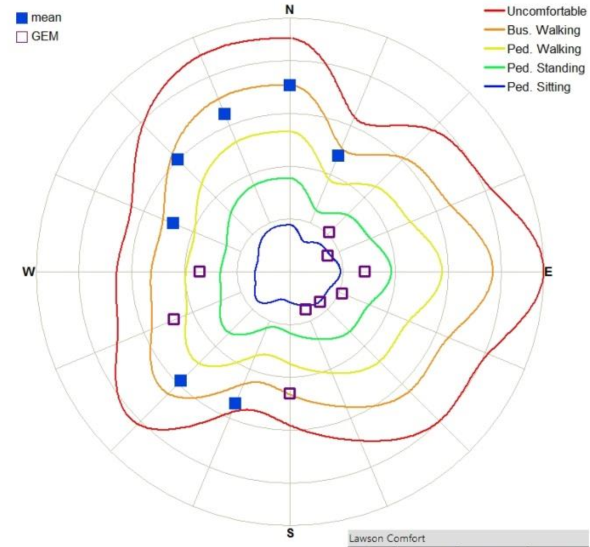
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.3	3.9	3.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.5	7.0	7.0
Rating	Pass	Pass	Pass

LOCATION 12



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	59.5	62.7	65.9
4.0	25.0	25.4	29.4
6.0	8.4	8.7	10.9
8.0	2.2	1.8	2.7
10.0	0.5	0.3	0.6

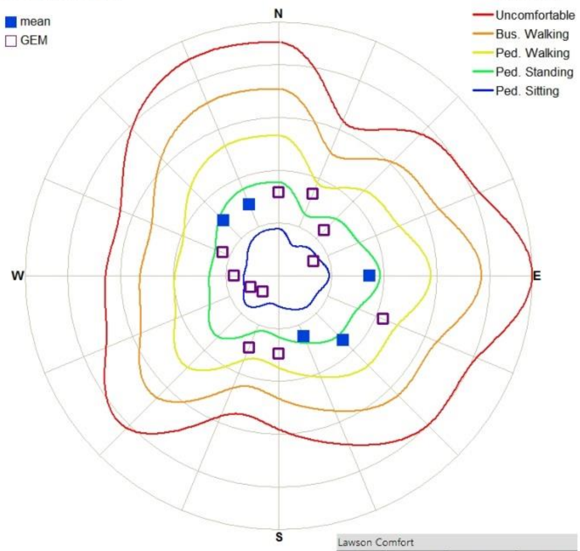
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	6.7	6.7	7.2
Rating	Ped Walking	Ped Walking	Ped Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	14.2	13.1	14.2
Rating	Pass	Pass	Pass

LOCATION 13



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	39.2	41.8	42.7
4.0	6.3	7.3	7.5
6.0	0.3	0.4	0.4
8.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0

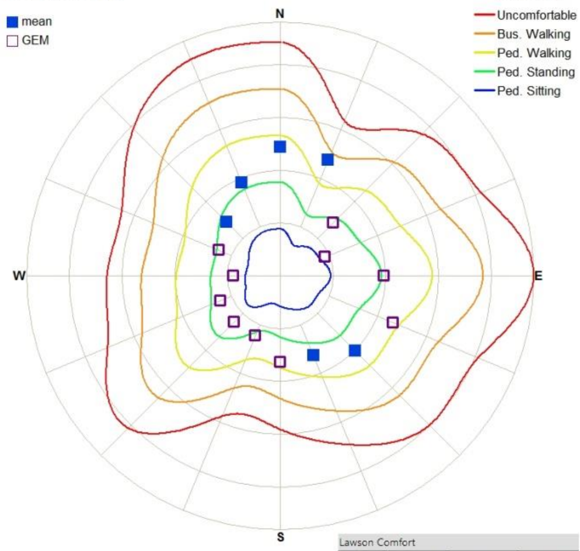
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.2	4.3	4.3
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.6	7.8	7.9
Rating	Pass	Pass	Pass

LOCATION 14



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	49.8	52.8	55.1
4.0	12.6	11.7	14.2
6.0	2.3	1.5	2.5
8.0	0.3	0.1	0.3
10.0	0.0	0.0	0.0

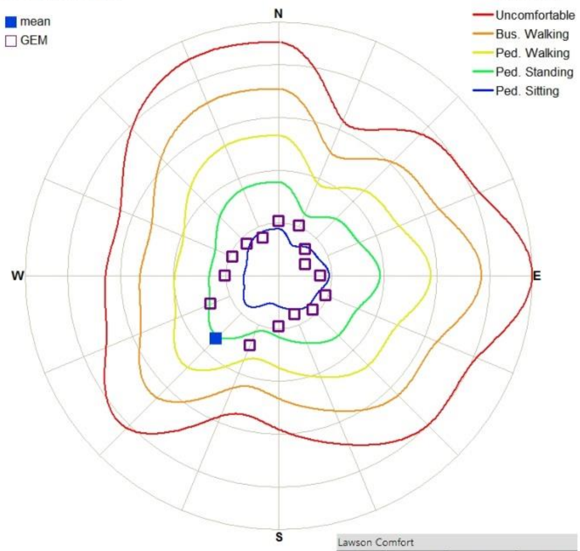
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.0	4.8	5.1
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.5	8.7	9.5
Rating	Pass	Pass	Pass

LOCATION 15



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	13.1	23.5	23.7
4.0	0.6	1.4	1.5
6.0	0.0	0.1	0.1
8.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0

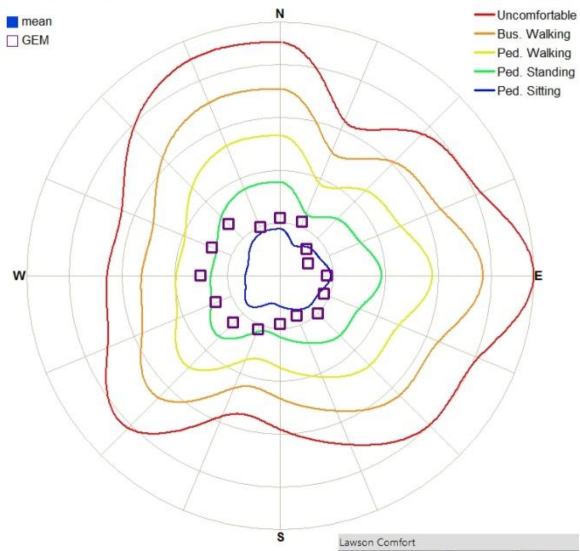
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.6	3.2	3.2
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.0	6.8	6.8
Rating	Pass	Pass	Pass

LOCATION 16



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	8.4	27.5	27.5
4.0	0.1	2.0	2.0
6.0	0.0	0.1	0.1
8.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0

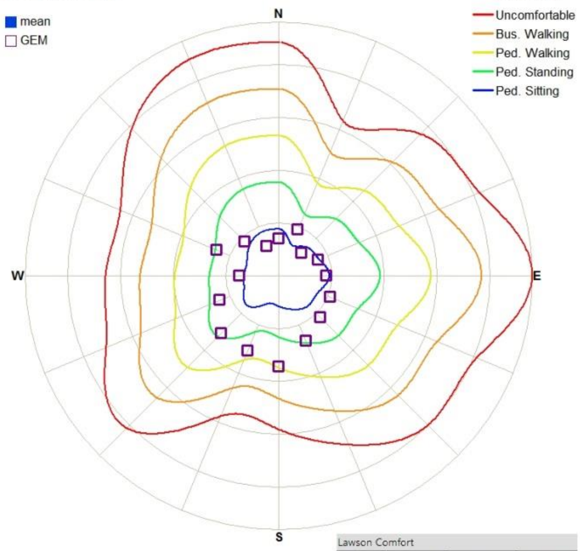
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.2	3.3	3.3
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.6	6.9	6.9
Rating	Pass	Pass	Pass

LOCATION 17



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	20.0	29.6	29.6
4.0	4.7	6.5	6.5
6.0	0.4	0.7	0.7
8.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0

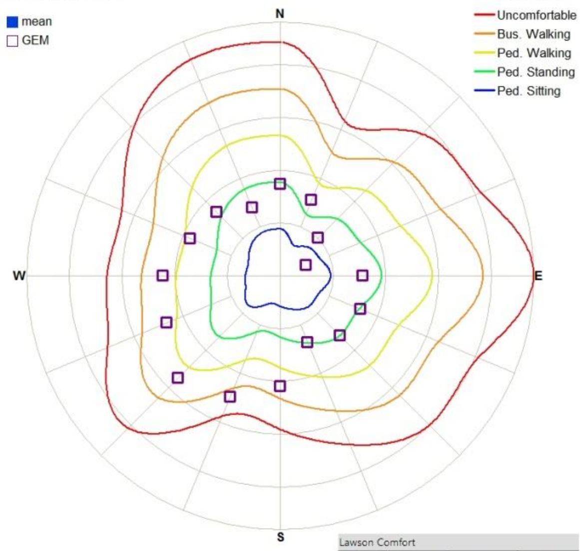
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.2	4.2
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.9	8.4	8.4
Rating	Pass	Pass	Pass

LOCATION 18



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	42.7	58.4	58.4
4.0	9.5	20.7	20.7
6.0	0.9	5.3	5.3
8.0	0.1	1.0	1.0
10.0	0.0	0.1	0.1

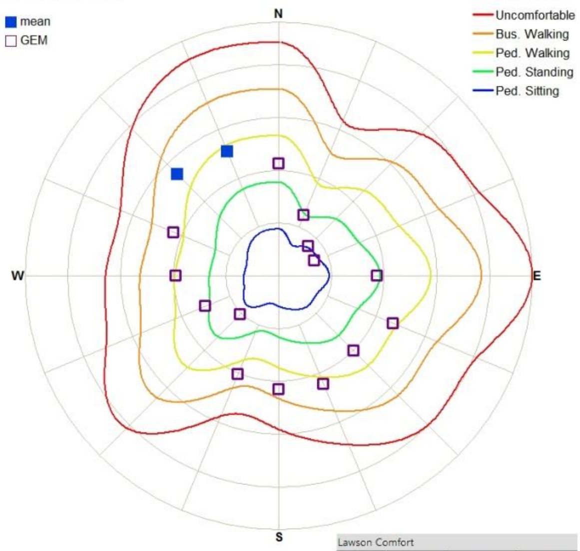
Lawson Comfort

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

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.8	11.9	11.9
Rating	Pass	Pass	Pass

LOCATION 19



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	51.9	65.5	65.7
4.0	9.8	22.4	22.7
6.0	1.4	5.3	5.3
8.0	0.3	0.8	0.9
10.0	0.1	0.1	0.1

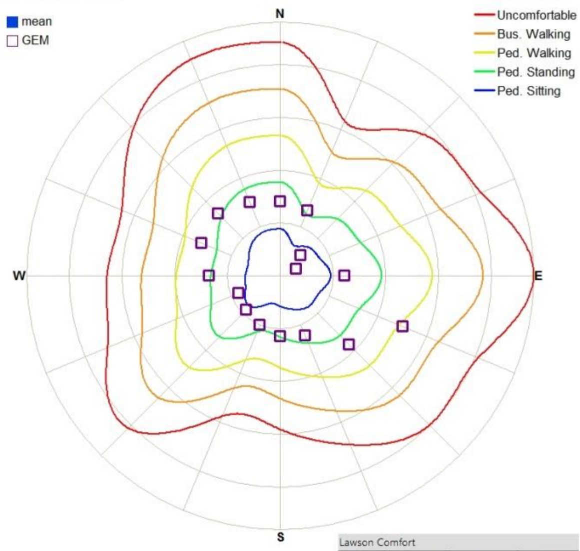
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	6.0	6.0
Rating	Ped Standing	Ped Walking	Ped Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.2	11.7	12.3
Rating	Pass	Pass	Pass

LOCATION 20



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	24.2	41.0	41.0
4.0	1.5	5.1	5.1
6.0	0.1	0.5	0.5
8.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0

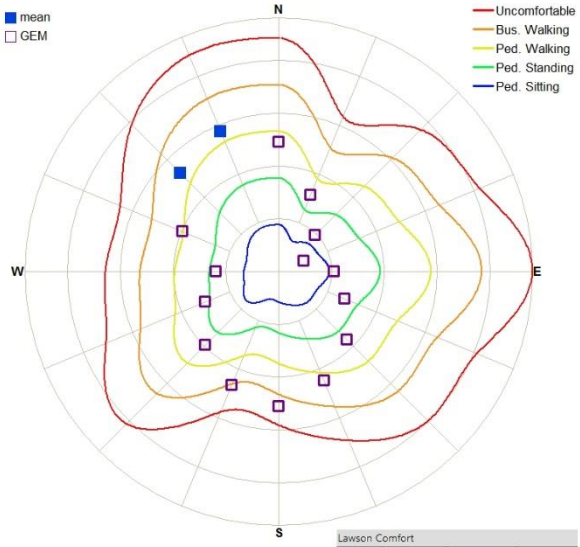
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.1	4.0	4.0
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.9	8.3	8.3
Rating	Pass	Pass	Pass

LOCATION 21



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	51.3	62.4	63.4
4.0	13.9	22.5	23.3
6.0	2.9	7.6	7.9
8.0	0.5	1.8	1.9
10.0	0.1	0.3	0.3

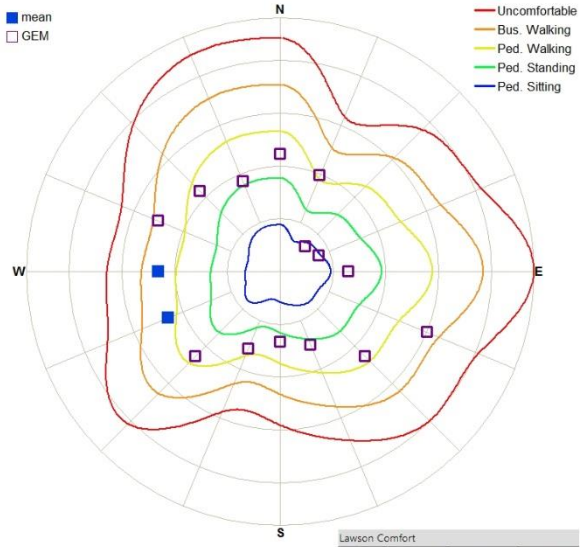
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.3	6.5	6.6
Rating	Ped Standing	Ped Walking	Ped Walking

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.1	12.8	13.2
Rating	Pass	Pass	Pass

LOCATION 22



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	45.5	64.6	64.7
4.0	9.2	19.1	19.4
6.0	1.7	3.6	3.8
8.0	0.3	0.7	0.7
10.0	0.0	0.1	0.1

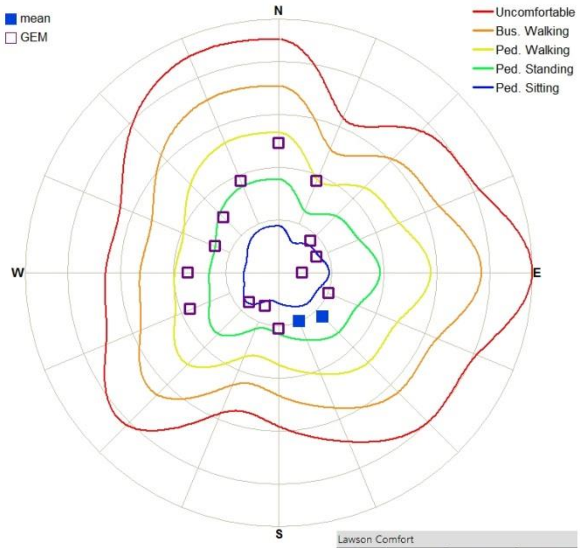
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.6	5.7
Rating	Ped Standing	Ped Standing	Ped Standing

Lawson Safety

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

LOCATION 23



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	34.0	40.7	40.9
4.0	4.3	7.5	7.5
6.0	0.3	1.0	1.0
8.0	0.0	0.1	0.1
10.0	0.0	0.0	0.0

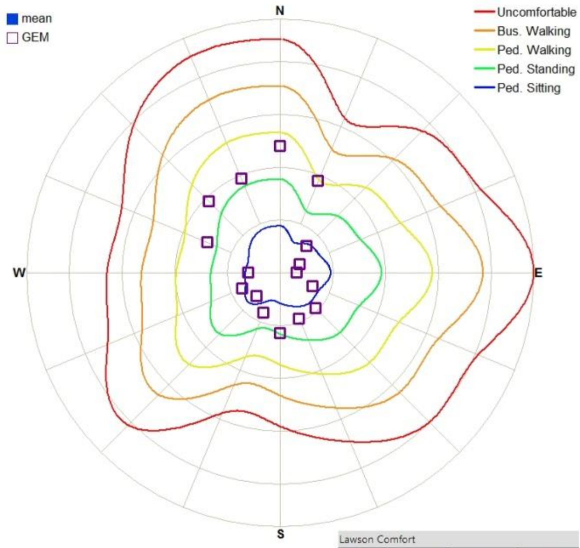
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.4	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.0	8.7	8.7
Rating	Pass	Pass	Pass

LOCATION 24



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	22.7	35.1	35.1
4.0	2.4	6.0	6.0
6.0	0.2	0.9	0.9
8.0	0.0	0.1	0.1
10.0	0.0	0.0	0.0

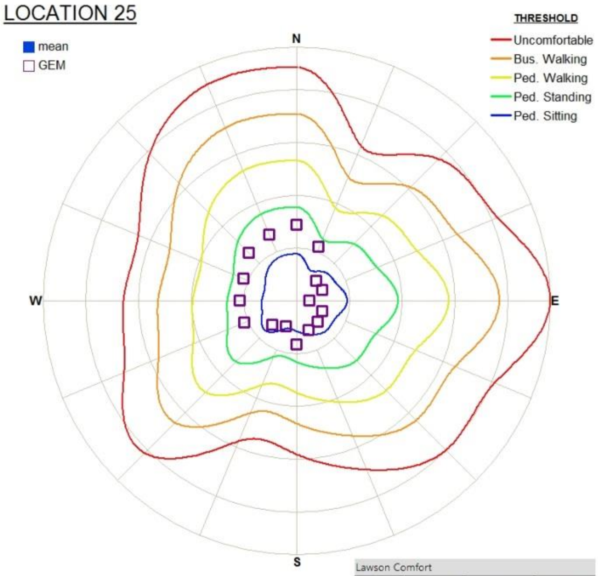
Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.4	4.2	4.2
Rating	Ped Sitting	Ped Standing	Ped Standing

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.6	8.8	8.8
Rating	Pass	Pass	Pass

LOCATION 25



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2.0	9.9	18.4	18.4
4.0	0.1	0.7	0.7
6.0	0.0	0.0	0.0
8.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0

Lawson Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.3	2.9	2.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Lawson Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.9	5.8	5.8
Rating	Pass	Pass	Pass