THE STAR

PEDESTRIAN WIND ENVIRONMENT ASSSESSMENT

PREPARED BY

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Final Report

Wind Tunnel Study of Pedestrian Wind Environment for:

THE STAR

MOD13 DA SCHEME

Sydney, Australia

Prepared for:

The Star Entertainment Group Limited

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NSW 2009

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EXECUTIVE SUMMARY

Wind tunnel studies of the proposed redevelopment of The Star, Sydney, based on the MOD13 DA design scheme, were conducted to assess the impacts of the proposed buildings on the wind environment surrounding the site at ground level and within the upper terrace levels.

Both the existing and proposed development site configurations were assessed. Models of the configurations were fabricated to a length scale of 1:400 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. Measurements of wind speeds likely to be experienced by pedestrians were made with a hot-film anemometer. 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). The pedestrian wind environment was investigated at several locations along the ground plane and within upper level terraces for 16 wind directions each in accordance with Australasian Wind Engineering Society (2001). 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.

Comparison of wind measurements for both development site configurations has shown the proposed buildings will have a limited impact at most investigated locations along the surrounding roadways and parklands on ground plane, as wind conditions were found to be similar in both configurations. Locations closer to the proposed tower experienced slightly windier conditions than existing, however the conditions remained at a level that is suitable for the purpose of these areas as footpaths for moving pedestrian traffic. The wind tunnel study also found suitably calm conditions along Pirrama Road, particularly in the VIP drop off and porte cochere areas, at the outdoor seating area on Jones Bay Road and at 16 Pyrmont Bay Road. Wind conditions at all investigated locations on the ground plane passed the distress/safety criterion.

Most investigated locations on the upper level outdoor terraces experienced wind conditions at a pedestrian standing and walking comfort level while passing the distress/safety criterion, with locations within the semi-enclosed pool terraces on Level 7 experiencing calmer conditions at a pedestrian sitting comfort rating. Locations in the BBQ area of the Level 7 Residential Terrace and Level 59 Club Lounge Terrace experienced winds classified as business walking and pedestrian walking, respectively, and exceeded the distress/safety criteria. Mitigation at locations exceeding the distress/safety criterion is recommended, such as local, porous vertical screening to help reduce strong winds. Dense landscaping surrounding these areas will help improve the measured wind conditions to suitable comfort levels, and can be mobile/portable and deployed during strong wind events.

The remaining balance of the MOD13 developments to the existing site, including proposed elements such as awnings and signages, will have limited environmental impacts to the existing wind amenity along the adjacent footpaths and roadways at ground level. The awnings would be slightly beneficial by providing some shielding from wind-driven rain to the covered areas.

In consideration of all the above mentioned, The Star MOD13 redevelopment as documented in this DA application will have a limited environmental impact on the ground plane from a wind perspective.

DOCUMENT VERIFICATION

Date	Revision	Prepared by	Checked by	Approved by
18/04/2018	Initial release for review	AN	JP	JP
08/11/2018	Additional wind tunnel study	AN	JP	JP
19/11/2018	Minor amendments	AN	JP	JP

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D	Characteristic dimension (building height, width, etc.) (m)
n	Mean velocity profile power law exponent
T_u	Turbulence intensity, U_{stdev}/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_{stdev}	Standard deviation of fluctuating velocity (m/s)
z	Height above surface (m)
ν	Kinematic viscosity of approach flow (m^2/s)
$\sigma(\ )$	Standard deviation of $(\ ),=(\ )'_{rms}$
ρ	Density of approach flow (kg/m^3)
$(\ )_{max}$	Maximum value during data record
$(\ )_{min}$	Minimum value during data record
$(\ )_{mean}$	Mean value during data record
$(\ )_{stdev}$	Standard deviation

1. INTRODUCTION

A wind tunnel study on the proposed redevelopment of The Star, Sydney, based on the MOD13 DA scheme was conducted to assess the impacts of the proposal on the wind environment along the adjacent roadways and footpaths, Figure 1, and on the upper level and rooftop terraces.

Figure 1: Proposed site location for The Star project

1.1 MOD13 Description (Provided by The Star Group)

New Ritz-Carlton Hotel and Residential Tower

- Demolition of part of the existing building in the northern portion of the site, including part of the Pirrama Road façade and part of the Jones Bay Road façade.
- Construction of a new Tower, 237.0 metres AHD (approximate, 234 metres from Pirrama Road);
- Residential uses across 35 levels, comprising:
    - A residential vehicular drop off lobby on Level B2
    - A residential lobby on Level 00 to be accessed from Jones Bay Road;
    - Residential communal space on Level 07 to be accessed via Level 08; and
    - 204 residential apartments located from Levels 05 to 06 and from Levels 08 to 38, featuring one-bedroom, two-bedroom and three-bedroom unit types *(Note – no Level 13)*
- Hotel uses across 31 levels, comprising:
    - A hotel arrival lobby on Level B2 to be accessed from the new Ritz-Carlton porte-cochere along Pirrama Road;
    - A hotel Sky Lobby for guest check-in on Level 39 and 40, featuring a restaurant, bar and lounge;
    - 220 hotel rooms located from Level 42 to 58 and from Level 60 to 61

  - A hotel spa and gym on Level 07
  - A VIP link to the Sovereign Room on Level 04 and 04 Mezzanine
  - A Ritz-Carlton Club lounge and terrace on Level 59
  - Hotel staff end-of-trip facilities on Level B3
  - Hotel staff arrival point on Level 00
  - Hotel back-of-house and plant on Level B2, 02, 03, 05, 41 and 42
- A Neighbourhood Centre consisting of the following proposed uses including street level cafe, library, learning / innovation hub, multipurpose function centre, practice rooms (functional use to be finalised in conjunction with a neighbourhood panel)
- A new car-parking stacker system below the new porte-cochere of the Ritz-Carlton Hotel, with a total capacity of 221 spaces, to serve the new hotel and apartments
- Vertical transport associated with the tower and podium; and
- A new drop-off / pick up area (short-term parking) on Jones Bay Road for the proposed apartments.

Level 07

- A 'Ribbon' at Level 07 connecting the new Hotel and Residential Tower to the existing building along Pirrama Road, comprising:
  - Two pools and associated pool decks (one for the new Hotel, one for The Star); and
  - Two food and beverage premises with associated store rooms and facilities;
- Lift access from the Level 05 Terrace to Level 07;
- Residential communal open space associated with the new residential apartments, comprising pool and landscaped terrace at the base of the Tower adjacent to Jones Bay Road;
- Gym and associated change rooms and facilities for the residents;
- Gym and associated change rooms and facilities for hotel guests; and
- Landscaping treatments.

Level 05 Sky Terrace

- Three food and beverage outlets with external areas;
- Completion of the Vertical Transportation drum to connect with Level 05 Sky Terrace;
- Designated event spaces on the Terrace; and
- Landscaping treatment.

Level 05 Astral Hotel Pool and Spa Recreational Facility Upgrade

- New pool deck, pool, spa, gym and amenities upgrade for Astral Hotel and Residences.

Tower to Sovereign Link by Escalator and Lift

- Link from the Tower (across Level 04 and Level 04 Mezzanine) to the Sovereign Resort and MUEF at Level 03, connected via Lift G4, Lift VIP 1 and escalators.
- Extension of the lift service to stop at Level 00, 01 and 05 in addition to Level 3, 4 and 4M.

Level 03 Sovereign Column Façade Treatment along Pirrama Road

- New glazed detail to enclose exposed Level 03 Sovereign columns along the Pirrama Road façade.

Various reconfiguration works around Vertical drum Level 00 to L5

- Revolving door at L00 main entrance landing Pirrama Road end
- Sliding door at L00 landing at stairs from Light Rail
- Reconfiguring of existing L1 and 2 void edge
- New escalators from L2 to L3 due to revised landing at Level 3
- Infill of L2 atrium void to main entrance at Pirrama Road

Façade Integration Works

- Upgrades to the Pirrama Road and Jones Bay Road façades to integrate the new Ritz Carlton Hotel and Residential Tower with the existing building.

Infrastructure Upgrades

- A new plant room located within the podium over Levels 03, 04, 05 and 06 of the proposed Hotel and Residential Tower;
- Relocation of the current Level 03 cooling towers (adjacent to the MUEF) to the Level 09 plant room above the Level 06 plantroom adjacent to the Astral Hotel;
- New capstone microturbine units and associated flues in the proposed plant room at Level 03 between the Darling Hotel and the Astral Residence Tower;
- New capstone microturbine units and associated flues in the new Level 03 plant room at the base of the Tower;
- Relocation of the existing main switch-room to the new plant room on Level 02, south of the demolition cut line;
- Relocation of the existing data recovery centre to the new plant room on Level B1 of the Darling Hotel;
- Relocation of diesel generator flues to the side of the new Level 09 plantroom, adjacent to Astral Hotel

Level B2 Transport Interchange

- Upgrades to the Event Centre Loading Dock;
- Entry into Basement car stacker for the Tower apartments and Ritz-Carlton Hotel;
- New commuter bike parking and hire bike system;
- Upgrade of finishes to light rail station surrounds (but not within Light Rail corridor) and removal of existing wall barrier to the Pirrama Road frontage;
- Upgraded taxi-rank arrangements;
- Designated Star coach parking along Service Road in front of Light Rail station; and
- Realignment of kerbs and line-marking.
- *Note – no works within the Light Rail corridor*

Transport Improvements – Other Locations

- Reconfiguration of existing median strips on Jones Bay Road and addition of new median strip on Pyrmont Street, with associated line-marking to enable a new right-hand turning lane into the Astral Hotel Porte-Cochere;
- New Pyrmont Street carpark entry and exit, associated line marking, changes to internal circulation, and reconstruction of the pedestrian footpath along Pyrmont Street; and
- Relocation of existing feeder taxi-rank from Jones Bay Road to the Level B2 transport interchange.

Site Wide Landscape and Public Domain Upgrades

- Upgrades to street frontages along Pirrama Road (for the Hotel Porte Cochere) and Jones Bay Road (for the residential entry);
- Upgrades to street frontage to Pyrmont Street, due to new car parking entry; and
- Upgrade to the entry forecourt of SELS building at the corner of Jones Bay Road and Pyrmont Street. (Note: no works within SELS building is proposed)

Level 00 - Restaurant Street

- Creation of a new destination Restaurant Street by:
    - Incorporating existing Balla & Black Food and Beverage premises on Level 00; and
    - Converting existing retail shops into new Food and Beverage tenancies

Pirrama Road and Jones Bay Road - Food and Beverage tenancies

- A revised food and beverage tenancy at the existing Pizzaperta outlet along Pirrama Road;
- A new food & beverage tenancy at the Marquee street entry; and
- A small café outlet adjacent to the residential lift lobby at Jones Bay Road.
- A new food & beverage tenancy accessed off existing walkway from Jones Bay Road

Food and Beverage – Other Locations

- Reconfiguration of Harvest Buffet, including new escalators from Level 00 Food Court to Level 01; and
- Refurbishment of Bistro 80 into the interim Century tenancy. (Note: The Century tenancy post construction is proposed to be at the Jones Bay end of L00 – Restaurant Street

Darling Hotel Corners

- Upgrade of the corner plaza at the Union/Edward Street property entry to accommodate:
    - A new food and Beverage premises on Level 01 and 02;
    - A new entry foyer leading to the Food Court;
    - A relocated awning enclosure at street level;
- Upgrade of the corner plaza at the Union/Pyrmont Street property entry to accommodate:
    - A new awning enclosure for the existing café;
    - New revolving door at entry to Darling Hotel
    - Eight (8) luxury display cases at Darling Hotel car park entry; and
    - Two car display areas at Darling Hotel car park entry.

Site-Wide Acoustic Strategy

- A site-wide acoustic monitoring strategy applied to assess impact of potential noise generating sources in Mod13.

Site-Wide Lighting Strategy

- A site-wide lighting strategy integrating and improving the existing lighting across the precinct, with new lighting the proposed Tower, Podium and Ribbon, including:
    - Internal lighting of Hotel and Residential spaces;
    - Illuminated highlights at the Sky Lobby and Club Lounge levels;
    - Integrated lighting on the eastern and western vertical façade slots and angled roof profile;
    - Podium external illumination from awnings, and under retail and lobby colonnades;
    - Landscape lighting on Level 07 open terraces and pool decks;
    - Feature lighting accentuating the wing-like profile of the Ribbon and vertical element;
    - Internal and external lighting to Food and Beverage outlet at Union/Edward Street corner;
    - Façade LED lighting to the heritage SELS Building

Special Lighting Events

- Approval for fifty three (53) Special Lighting Events per year for the use of permanent installation of moving projector lights on the rooftop of the Astral Hotel.
- Approval for fifty three (53) Special Lighting Event nights per year for the use of permanent installation of moving projector lights on the rooftop of the Astral Hotel.

Signage Upgrades

- Consolidation of existing signage approvals and new signage, including:
    - Approved signs
    - Wayfinding signs;
    - Business identification (including for Food and Beverage outlets); and
    - Signage on the Tower and Podium.

Stormwater upgrades

- Stormwater upgrade works, including increased pit inlets and pipe capacities at the low points along Pyrmont Street and Edward Street.

1.2 MOD14

Modification 14 (MOD14) was determined in October 2017 and included approval for a range of upgrades to the existing site. These upgrades included the enclosure of the level 3 terrace to facilitate an expansion in gaming floor area and a new bar and restaurants, expansion of the level 3 pre-function space, changes to the Astral Hotel lobby and retail space, and alterations to internal vertical transportation, services and infrastructure, including the harbour heat rejection system.

MOD13 is a modification to the development as approved under MP08_0098, up to and including MOD14.

2. THE WIND TUNNEL TEST

Pedestrian acceptability of footpaths, entrances, plazas, and terraces is often an important design parameter of interest to the development approvals body, 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. The wind tunnel testing was performed in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd., St. Peters. This report includes wind tunnel test procedures, test results, and a discussion of results. 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: Parameters and configurations for data acquisition

Test Parameters	
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
Wind directions	16 wind directions in 22.5° increments from 0° (north)
Number of test locations	31
Test Configurations	
Existing Configuration	Existing buildings on development site with existing surrounding buildings and landscape, as shown in Figure 4 and Figure 6.
Proposed Configuration	Proposed MOD13 DA scheme of The Star redevelopment with existing surrounding buildings and landscape, as shown in Figure 5 and Figure 7.

Modelling of the aerodynamic flow around structures requires special consideration of flow conditions to obtain similitude between the model and the prototype. A detailed discussion of the similarity requirements and their wind tunnel implementation can be found in Cermak (1971, 1975, 1976). In general, the requirements are that the model and prototype be geometrically similar, that the approach mean velocity and turbulence characteristics at the model building site have a vertical profile shape similar to the full-scale flow, and that the Reynolds number for the model and prototype be equal.

Due to modelling constraints the Reynolds number cannot be made equal and Australasian Wind Engineering Society Quality Assurance Manual (2001) suggests a minimum Reynolds number of 50,000, based on minimum model width and wind velocity at the top of the model; in this study the modelled Reynolds number was over 50,000.

The wind tunnel test was performed in the boundary layer wind tunnel shown in Figure 2. The wind tunnel test section is 3.0 m wide, by 2.4 m high with a porous slatted roof for passive blockage correction. This wind tunnel has a 21 m long test section, the floor of which is covered with roughness elements, preceded by a vorticity generating fence and spires. The spires, 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 3 and are explained more fully in Section 4.1.1.

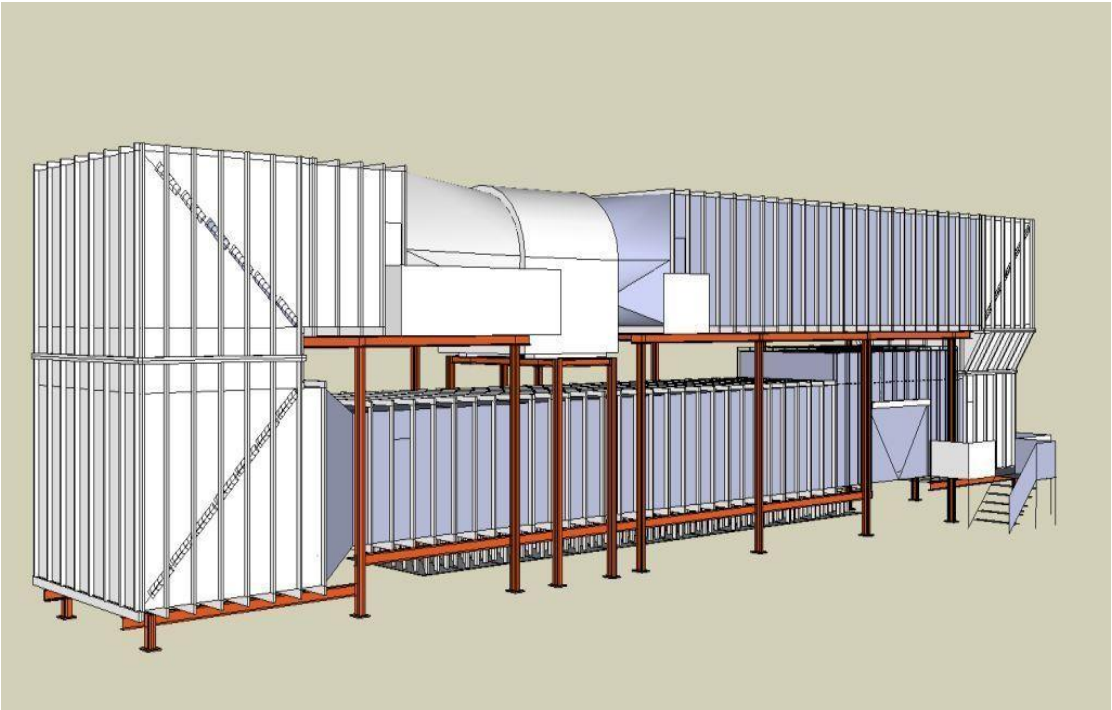


Figure 2: Schematic of the closed-circuit wind tunnel

A model of the proposed development and surrounds to a radius of 570 m was constructed at a scale of 1:400, which was consistent with the modelled atmospheric flow, and permitted a reasonable test model size with an adequate portion of the adjoining environment to be included in a proximity model that was within wind tunnel blockage limitations. The external articulations on the building surface from the provided architectural drawings, dated November 2016, were formed into the model. The models were mounted on the turntable located near the downstream end of the wind tunnel test section, Figure 6 and Figure 7. 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.

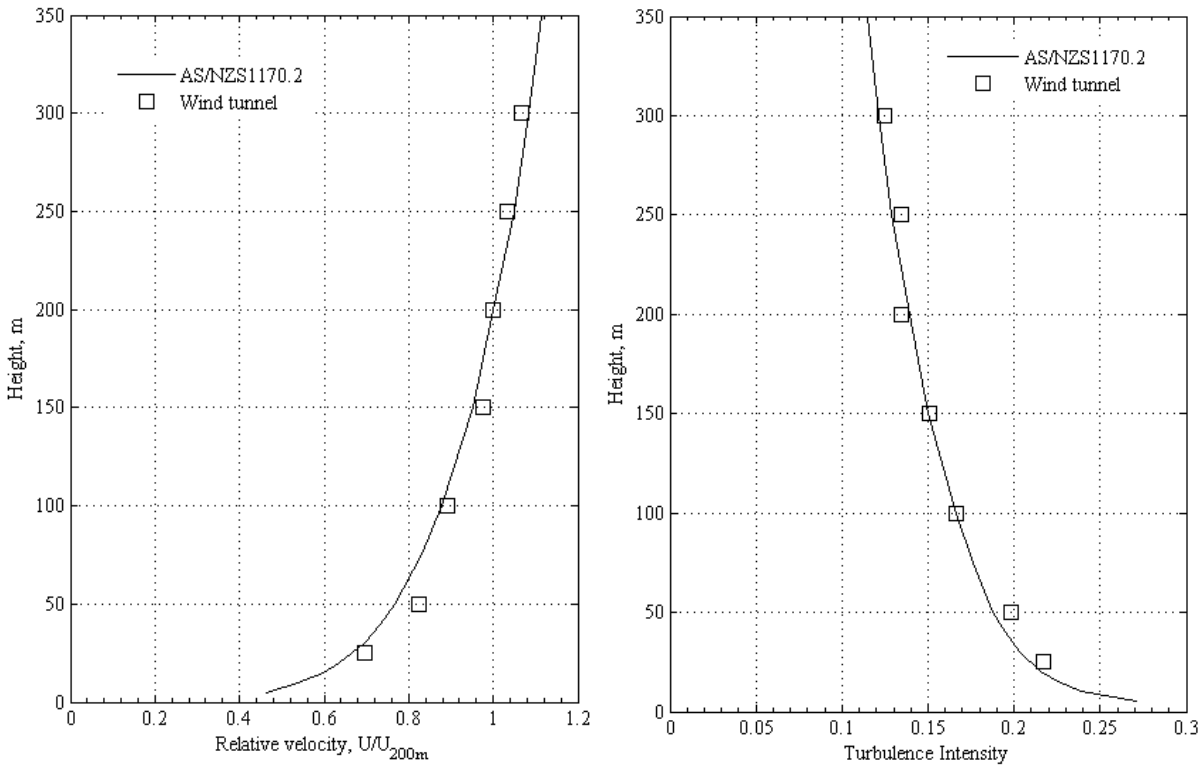


Figure 3: Mean velocity and turbulence profiles approaching the model, Terrain Category 3

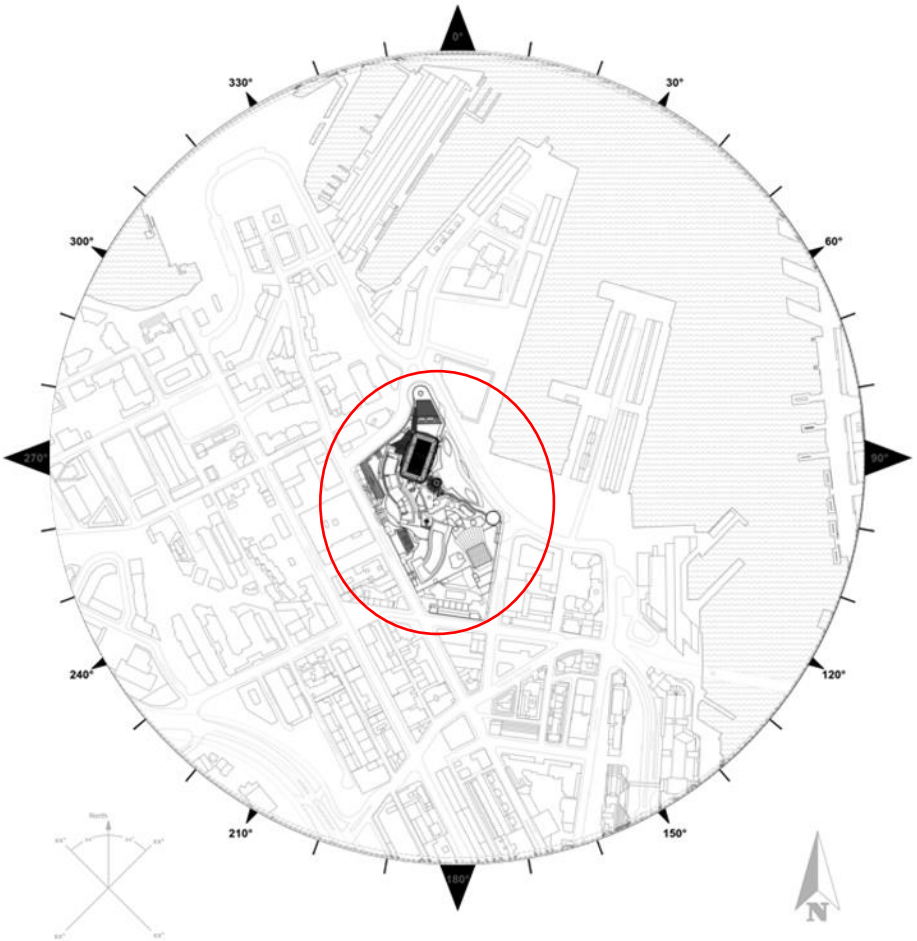


Figure 4: Turntable layout with existing development site circled in red

Figure 5: Turntable layout with proposed development site circled in red

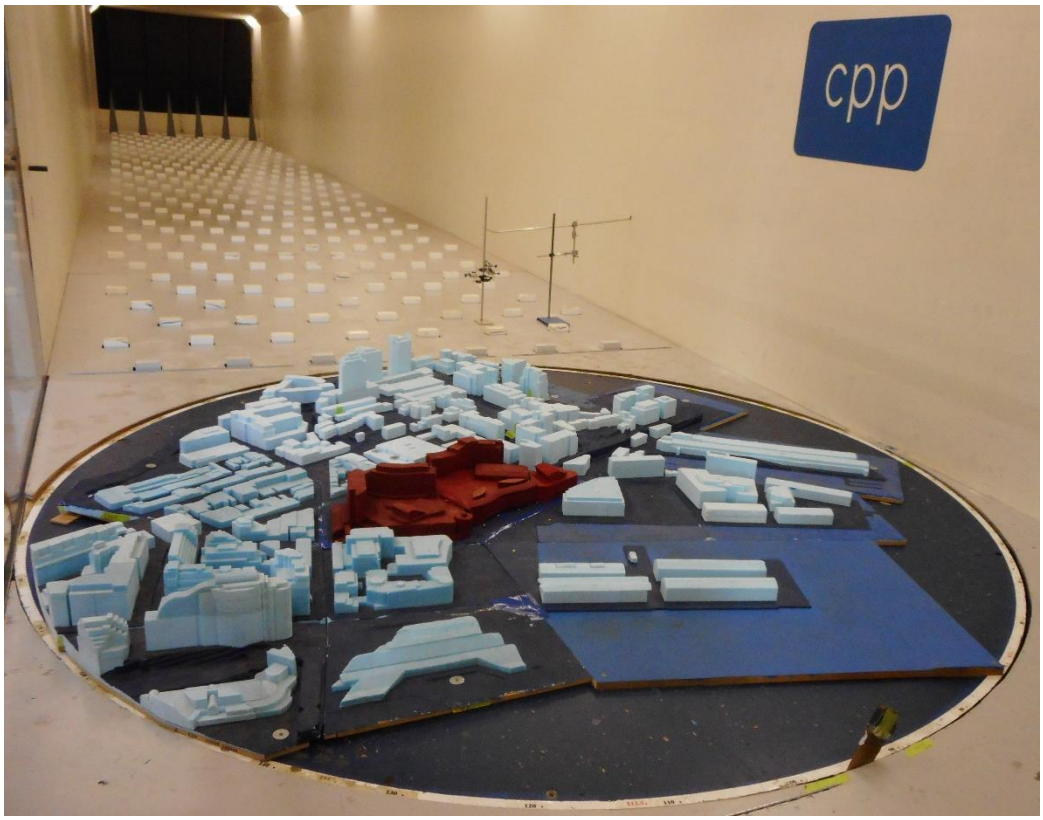


Figure 6: The Star model in the wind tunnel viewed from the south-east, existing configuration

Figure 7: The Star model in the wind tunnel viewed from the south-east, proposed configuration

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. A location can further 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 5% 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. In both cases, the wind speed used is the larger of a mean or gust equivalent-mean (GEM) wind speed. The GEM is defined as the peak gust wind speed divided by 1.85; this is intended to account for locations where the gustiness is the dominant characteristic of the wind. Assessment using the Lawson criteria provides a similar classification as using the once per annum gust, which was the basis of the City of Sydney (2011) DCP, however provides additional 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 classified as not an 'active frontage'. There are few locations in Sydney that would meet this criterion without shielding to improve the wind conditions. 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 to promote outdoor café style activities and is not a distress requirement.

Table 2: The Lawson comfort 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.

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 3. 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 Measured Pedestrian Winds

The proposed development site is situated on the north end of the block bounded by Jones Bay and Pirrama Roads, and Pyrmont, Union, and Edward Streets, Figure 5. The site is mostly surrounded by medium-rise buildings with the exception of relatively open-terrain of Pyrmont Bay to the north-east of the site. The proposed tower will be an articulated tower with curved facades, and the broad sides facing north-east and south-west. The proposed podium and ribbon structure will extend over the existing building, and were modelled and tested to assess pedestrian wind comfort. The wind tunnel model in proposed configuration was based on the MOD13 exhibited scheme.

Wind speed measurements were recorded at 31 locations to evaluate pedestrian comfort and safety in and around the project site, and are presented in Figure 10 to Figure 13 and Figure 15. Wind speed 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 at the building corners where relatively severe conditions frequently are found, near building entrances, on adjacent pavements with heavy pedestrian traffic, in proposed alfresco dining areas and on upper level outdoor 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 and the gust duration on which the wind criteria are based. 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

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

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 2017, 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 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 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 also give the wind speed exceeded 5% and 0.022% for direct comparison with the Lawson criteria and the associated Lawson ratings for both mean and GEM wind speeds. Colour coded summary assessments of pedestrian comfort and safety with respect to the Lawson criteria are presented in Figure 10 to Figure 13 and Figure 15 for each investigated 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 Figure 10 to Figure 13 and Figure 15. The implications of the results are discussed in Section 5.

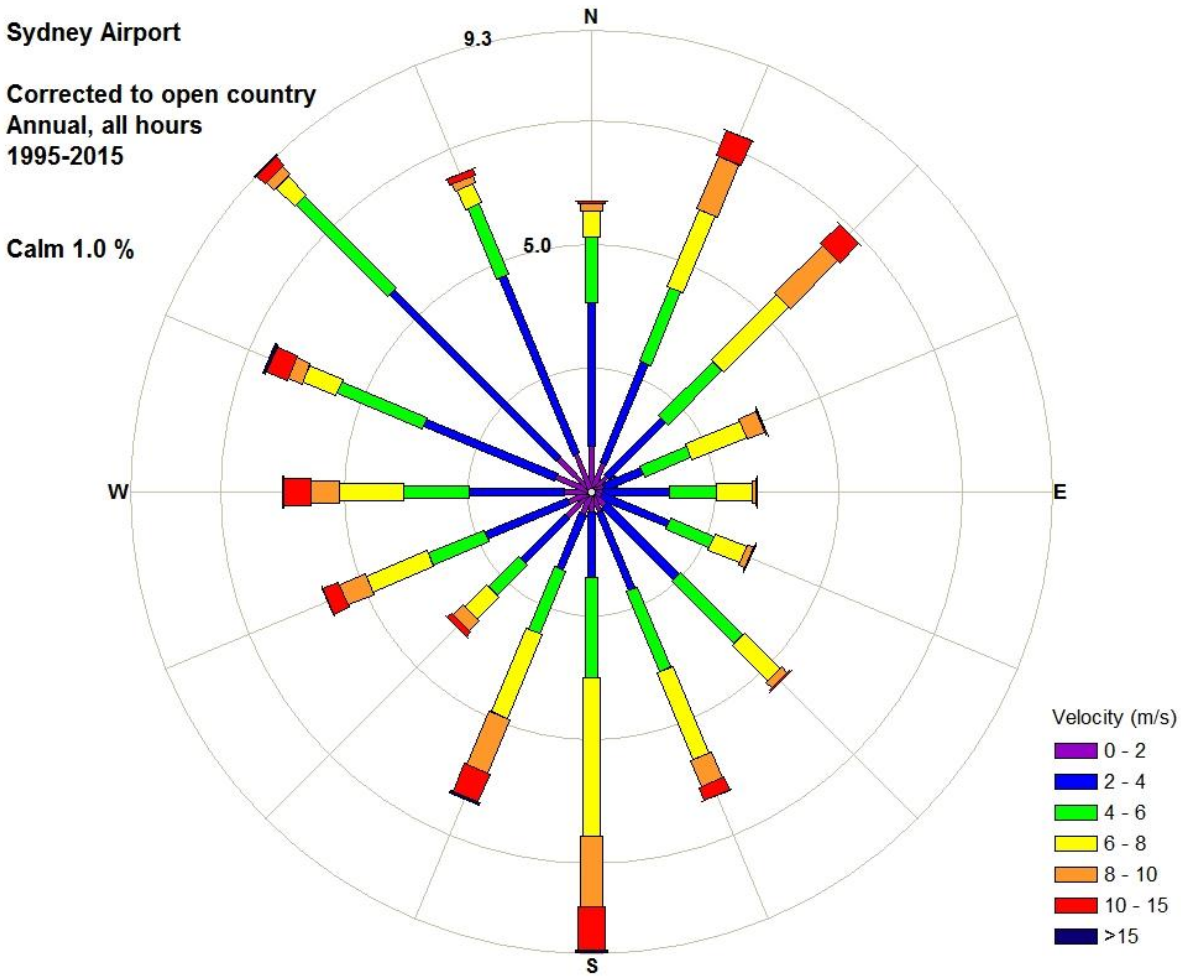


Figure 8: Wind rose of direction and speed for Sydney Airport

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 north-east and west. The development site will be surrounded by mostly medium-rise buildings, exposing the proposed high-rise tower to unimpeded winds from all directions. To the east of the site is Pyrmont Bay, allowing considerably unimpeded wind flow to reach the lower levels. The topography and surrounding building layout relative to the prevailing strong winds will also influence wind flow in and around the development. Individual locations around the development are more susceptible to winds from different directions, depending on the relative location of the point tested to the geometry of development. 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 high-level comparison of the expected wind target ratings at the investigated locations against the wind tunnel results with the Lawson comfort and safety ratings is provided in Table 4 and Table 5 for the existing and proposed site configurations, respectively. It is evident that for both the existing and proposed site configurations most ground plane locations meet the intended use of the space from a comfort perspective. Wind conditions at all investigated ground plane locations around both configurations pass the distress criterion.

More detailed conclusions of the pedestrian study can be understood by reviewing the colour coded images in Figure 10 to Figure 13 and Figure 15 that present the locations selected for investigation of the pedestrian wind conditions in and around the site along with the Lawson comfort and distress criteria ratings. The central colour indicates the comfort rating for the location and the colour of the outer ring indicates whether the location passes the distress/safety criterion. Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people, Table 3.

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%. However, landscaping should not be relied upon to provide sufficient shielding from winds that potentially pose a safety risk due their vulnerabilities. Mitigation measures are likely to be required for red and orange 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.

Table 4: Summary of expected target criteria and wind tunnel results, existing configuration

Description / Location		Expected Wind Rating Target	Wind Tunnel Results				
		Comfort rating, 5% exceeded wind speed (m/s)	Lawson comfort rating	5% exceeded wind speed (m/s)	Meets target Y(es)/N(o)	0.022% exceeded wind speed (m/s)	Lawson distress rating
Ground Plane	1	PSi, >2-4	PSi	3.5	Y	7.8	Pass
	2	PW, >6-8	PSt	5.1	Y	9.2	Pass
	3	PW, >6-8	PSt	4.7	Y	10.1	Pass
	4	PSt, >4-6	PSt	4.1	Y	8.7	Pass
	5	PW, >6-8	PSi	3.0	Y	6.9	Pass
	6	PSt, >4-6	PSt	4.8	Y	8.6	Pass
	7	PW, >6-8	PSt	4.6	Y	9.1	Pass
	8	PSt, >4-6	PSt	4.4	Y	9.6	Pass
	9	PW, >6-8	PSt	4.9	Y	9.6	Pass
	10	PW, >6-8	PSt	5.6	Y	10.2	Pass
	11	PSt, >4-6	PSi	2.7	Y	5.9	Pass
	12	PSi, >2-4	PSi	3.5	Y	7.4	Pass
	13	PSt, >4-6	PSi	3.0	Y	6.1	Pass
	14	PSi, >2-4	PSt	4.6	N	8.9	Pass
	15	PSt, >4-6	PSt	4.8	Y	8.9	Pass
	16	PSt, >4-6	PSt	5.6	Y	10.2	Pass
	17	PW, >6-8	PSt	5	Y	9.0	Pass
	18	PSt, >4-6	PSi	3.8	Y	7.5	Pass

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

Table 5: Summary of expected target criteria and wind tunnel results, proposed configuration

Description / Location		Expected Wind Rating Target	Wind Tunnel Results				
		Comfort rating, 5% exceeded wind speed (m/s)	Lawson comfort rating	5% exceeded wind speed (m/s)	Meets target Y(es)/N(o)	0.022% exceeded wind speed (m/s)	Lawson distress rating
Ground Plane	1.1	PSi, >2-4	PSi	3.7	Y	8.2	Pass
	2.1	PW, >6-8	PSi	3.7	Y	7.3	Pass
	3.1	PW, >6-8	PSt	5.6	Y	10.7	Pass
	4.1	PSt, >4-6	PSi	3.6	Y	8.0	Pass
	5.1	PW, >6-8	PW	7.3	Y	13.7	Pass
	6.1	PSt, >4-6	PW	6.4	N	11.9	Pass
	7.1	PW, >6-8	PW	6.2	Y	11.5	Pass
	8.1	PSt, >4-6	PSt	4.9	Y	11.5	Pass
	9.1	PW, >6-8	PW	6.4	Y	11.4	Pass
	10.1	PW, >6-8	PSt	5.5	Y	10.1	Pass
	11.1	PSt, >4-6	PSi	3.2	Y	6.2	Pass
	12.1	PSi, >2-4	PSi	3.9	Y	9.4	Pass
	13.1	PSt, >4-6	PSi	3.9	Y	7.2	Pass
	14.1	PSi, >2-4	PSt	4.6	N	8.4	Pass
	15.1	PSt, >4-6	PSt	4.6	Y	8.3	Pass
	16.1	PSt, >4-6	PSt	5.1	Y	9.0	Pass
	17.1	PW, >6-8	PSt	5.5	Y	10.2	Pass
	18.1	PSt, >4-6	PSi	2.7	Y	5.2	Pass
L5 Sky Terrace	19.1	PW, >6-8	PW	7.5	Y	15.8	AB
	20.1	PW, >6-8	PW	6.3	Y	11.8	Pass
	21.1	PSi, >2-4	PSi	2.5	Y	4.9	Pass
	22.1	PSi, >2-4	PSt	5.0	N	9.7	Pass
	23.1	PSi, >2-4	PSt	5.6	N	10.1	Pass
	24.1	PW, >6-8	PSt	4.8	Y	8.3	Pass
L7 Pool Terrace	25.1	PSt, >4-6	PW	7.2	N	13.1	Pass
	26.1	PSi, >2-4	PSi	2.7	Y	5.5	Pass
	27.1	PSi, >2-4	PSi	2.9	Y	5.3	Pass
	28.1	PW, >6-8	PSt	5.2	Y	10.9	Pass
	29.1	PSt, >4-6	BW	9.8	N	16.9	AB
	30.1	PSt, >4-6	PSt	5.8	Y	11.1	Pass
L59 Terrace	31.1	PSt, >4-6	PW	6.4	N	15.6	AB

5.1 Ground Plane

Measured wind conditions at ground level around the existing and proposed development sites are shown in Figure 10 and Figure 11, respectively. Majority of the test locations experienced wind conditions at a pedestrian sitting and standing comfort level in both site configurations. These conditions will be suitable for short-term stationary style activities such as bus stops and taxi ranks. In the proposed configuration, conditions at locations around the intersection of Pirrama and Jones Bay Roads were classified as pedestrian walking, suitable for transient spaces such as footpaths and pedestrian crossings.

With inspection of the proposed architectural drawings, seating is evident at measured locations 12.1 and 14.1 where wind speeds below the 2 m/s threshold for outdoor dining activities will occur about 75% of the time. It is evident in the architectural plans that local amelioration in the form of landscaping, Figure 9, are utilised to surround these seating areas in order to improve local comfort conditions. During windy days, temporary vertical screening could be used around seating areas to provide additional protection.

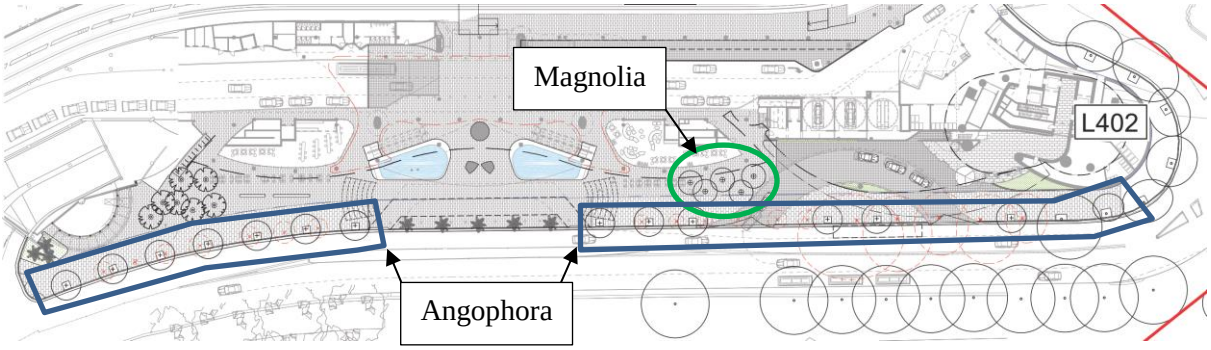
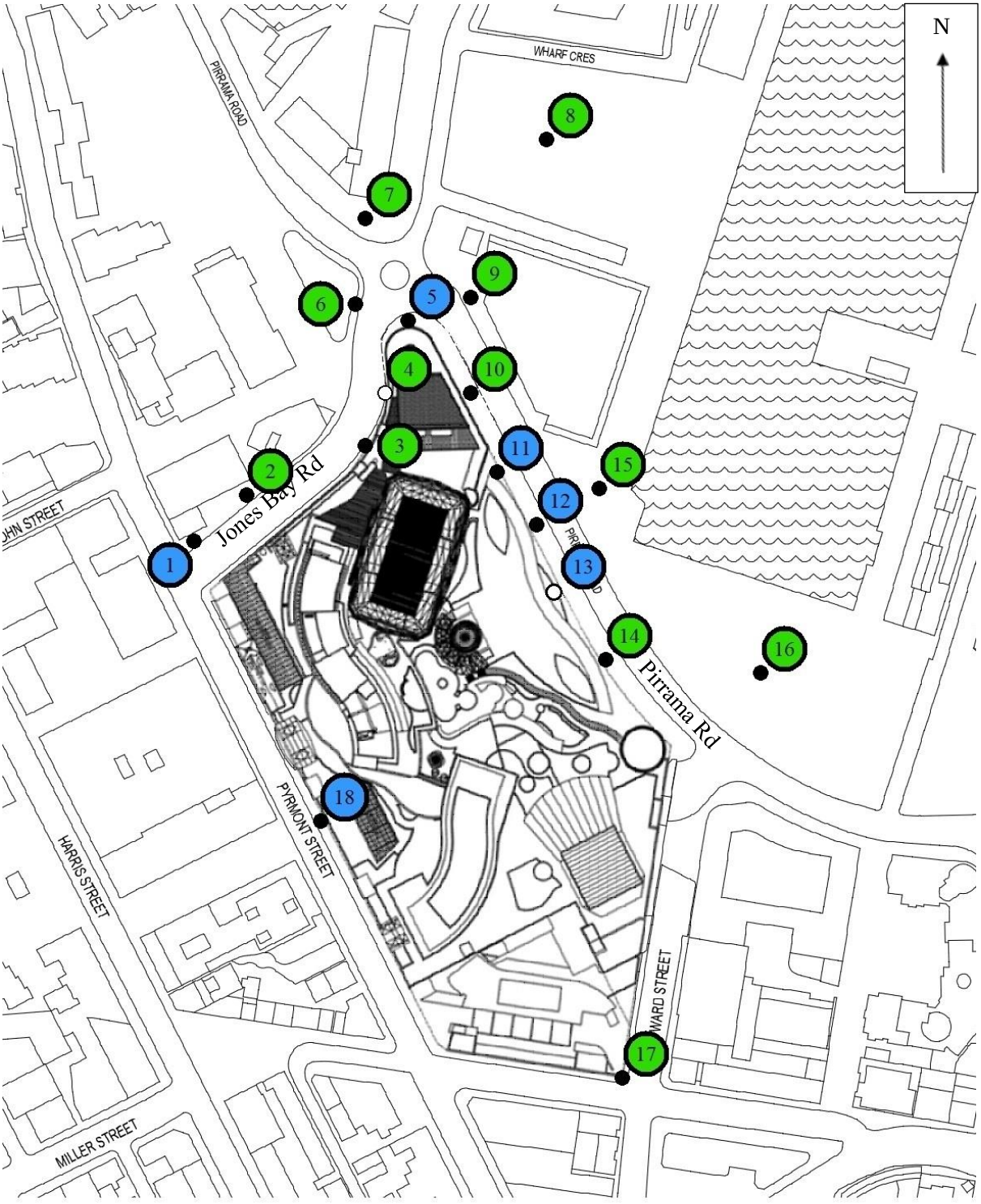


Figure 9: Proposed landscaping along Pirrama Road

Wind conditions on Jones Bay Road (Location 3), Pyrmont Bay foreshore (Location 15), Pyrmont Bay Park (Location 16) and Metcalf Park (Location 8) experienced similar wind conditions in both existing and proposed configurations, and thus the Mod13 exhibited scheme had limited impacts on the wind environment in these areas.

Wind conditions at all investigated locations around the site on the ground plane passed the distress/safety criterion.



Comfort Rating

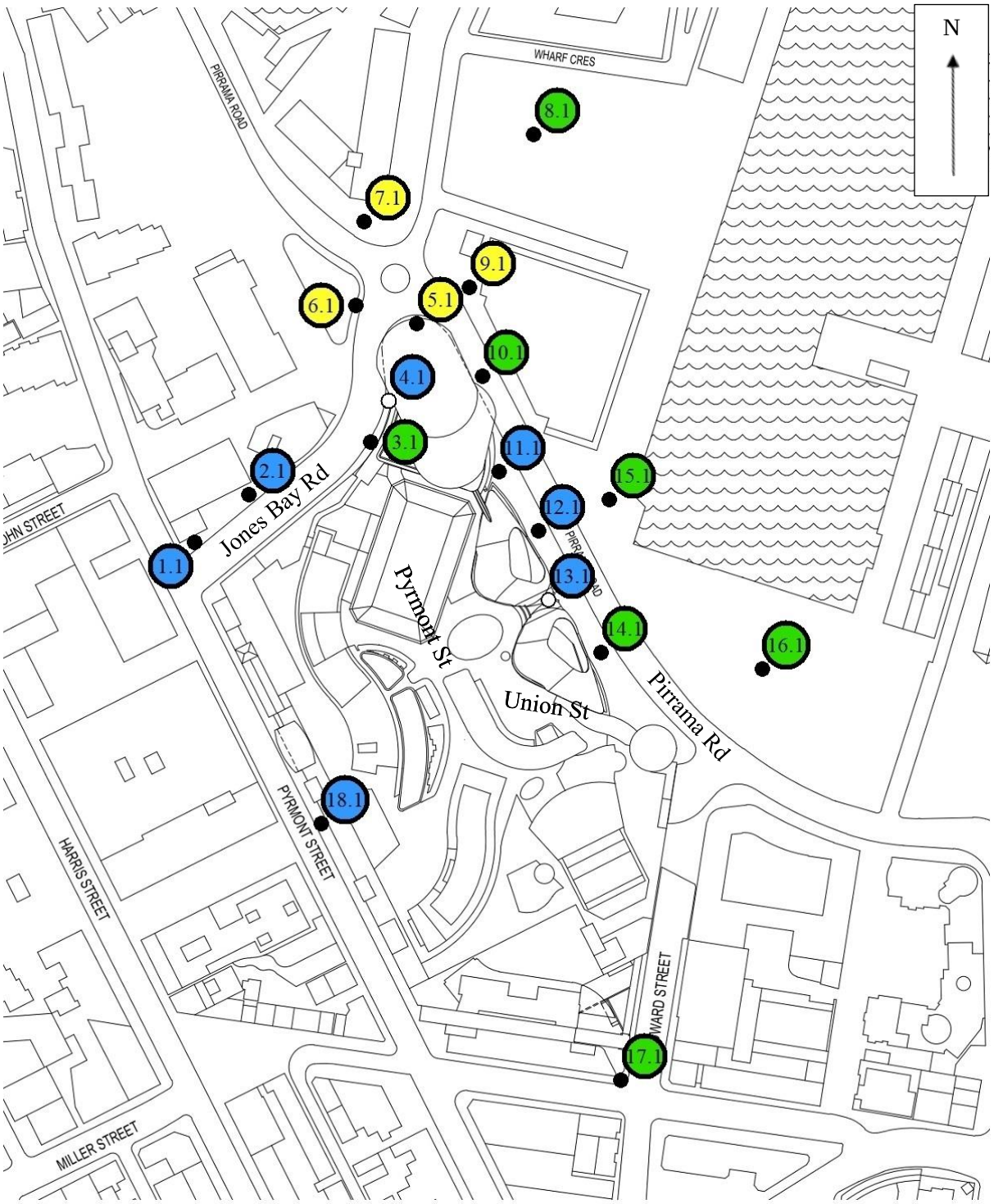
- Outdoor Dining
- Pedestrian Sitting
- Pedestrian Standing
- Pedestrian Walking
- Business Walking
- Uncomfortable

Distress Rating

- Pass
- Able Bodied
- Fail

- Pedestrian Location
- Pedestrian Location Under Overhang

Figure 10: Pedestrian wind speed measurements on ground plane, existing configuration



Comfort Rating

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

Distress Rating

- Pass
- Able Bodied
- Fail

- Pedestrian Location
- Pedestrian Location Under Overhang

Figure 11: Pedestrian wind speed measurements on ground plane, proposed configuration

5.2 Level 5 Sky Terrace

Wind conditions at investigated locations on the Level 5 Sky Terrace are shown in Figure 12. Location 19.1 between the existing Astral Apartments and Hotel buildings experienced wind conditions classified at a pedestrian walking comfort level, while slightly exceeding the distress/safety criterion. Inspection of the corresponding plot in Appendix 2 indicates the location is dominated by channelling downwash between the Astral buildings during winds from the south-west quadrant. It would be recommended vertical screening in combination with landscaping are employed in a way to obstruct the wind flow through the space while allowing pedestrian access.

Wind conditions at Location 20.1 near the Astral Hotel entrance are classified as pedestrian walking, suitable for the pathway to be used by travelling pedestrians.

Locations 21.1 and 22.1 within the Event Terrace experienced wind conditions rated at pedestrian sitting and standing, respectively. Location 22.1 is relatively shielded from most wind directions whereas Location 22.1 faces channelling winds between the southern F&B venue and the Astral Apartments building during winds from the south-east. Architectural drawings show seating proposed at Location 22.1. To help improve wind conditions to more comfortable levels for seated patrons, vertical screening or dense landscaping employed locally is recommended to help shield the seating area.

Locations 23.1 and 24.1 experienced wind conditions classified as pedestrian standing and passed the distress/safety criterion. Location 23.1 is situated within an evidently seating area and will experience wind speeds below the 2 m/s threshold for outdoor dining activities for about 40% of the time. If suitable wind speeds for longer periods of time are desired, it would be recommended local amelioration such as vertical screening and landscaping surrounding the seated areas are utilised to help improve local comfort conditions. Location 24.1 between the F&B venues experienced wind conditions classified as pedestrian standing, suitable for the passageway for moving pedestrian traffic.

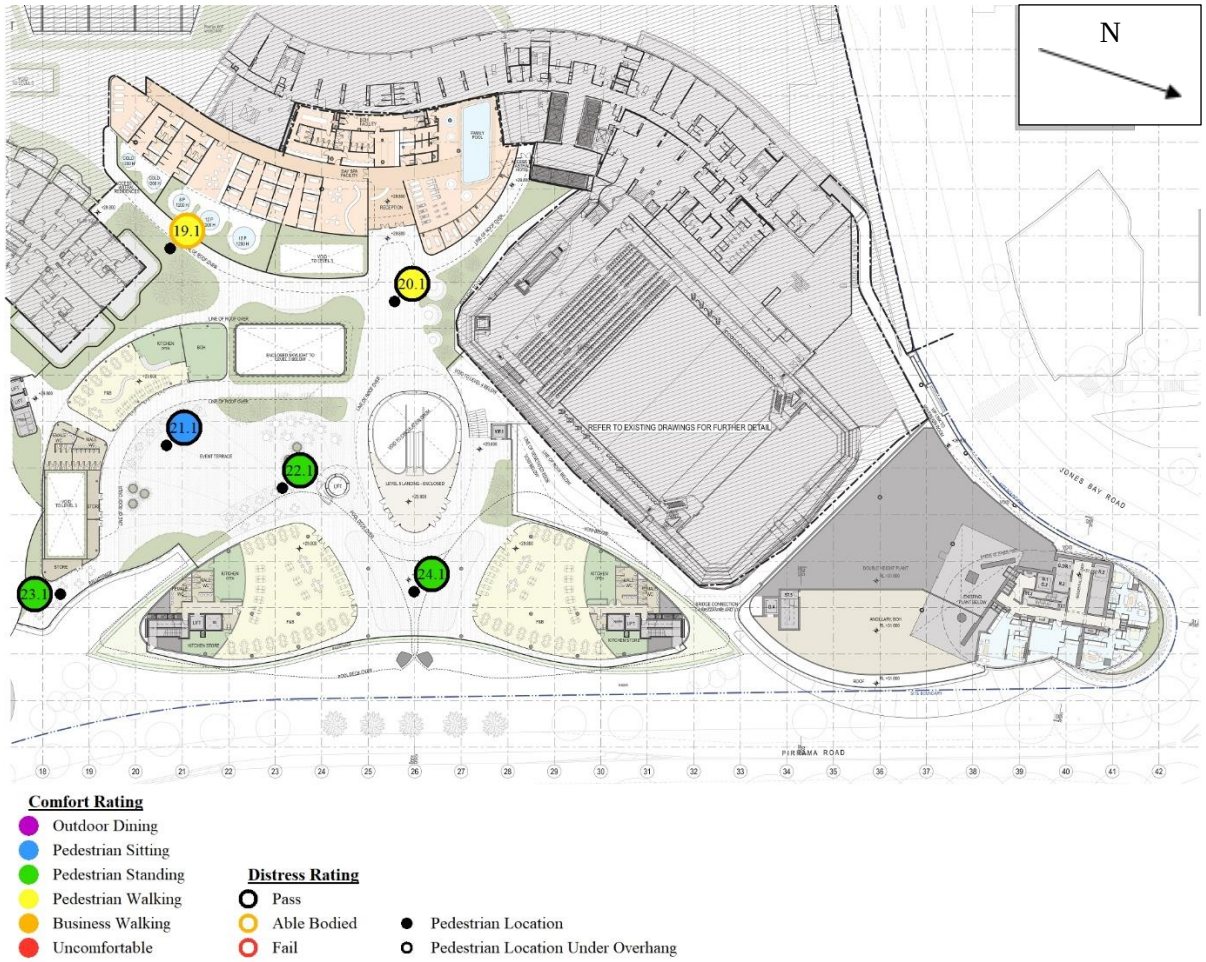


Figure 12: Pedestrian wind speed measurements on the Level 5 Sky Terrace

5.3 Level 7 Pool and Residential Terraces

Wind conditions at investigated locations on the Level 7 Pool Terrace are shown in Figure 13. Location 25.1 situated slightly beyond the southern pool's edge experienced conditions classified as pedestrian walking. Increasing the balustrade height as high as possible will create a larger calm area along the pool's edge during winds from the north-east. Locations 26.1 and 27.1 are situated within the roofed seating areas where measured wind conditions are classified as pedestrian sitting, suitable for seated patrons by the pools. Wind conditions at Location 28.1 are classified as pedestrian standing, suitable for travelling patrons along the connecting walkway between the pool terraces.

Wind conditions at investigated locations on the Level 7 Residential Terrace are also shown in Figure 13. Location 29.1 situated within the BBQ area experienced strong wind conditions classified as business walking while exceeding the distress/safety criterion. The conditions are caused by winds from the north-east and south-west quadrants accelerating between the tower and gym venue. From a wind perspective, the BBQ area would benefit from a porous vertical screen as illustrated Figure 13 to help mitigate the strong wind flow through the space. Dense, tall landscaping could also be used. It is also recommended to extend the solid roof-over in combination with the vertical screening as shown in

Figure 14 to further discourage wind flow through the BBQ area. Implementing these measures is expected to reduce conditions to suitable comfort levels that will pass the distress/safety criterion.

Wind conditions at Location 30.1 are classified as pedestrian standing which is considered suitable for the pool area of the Residential Terrace.

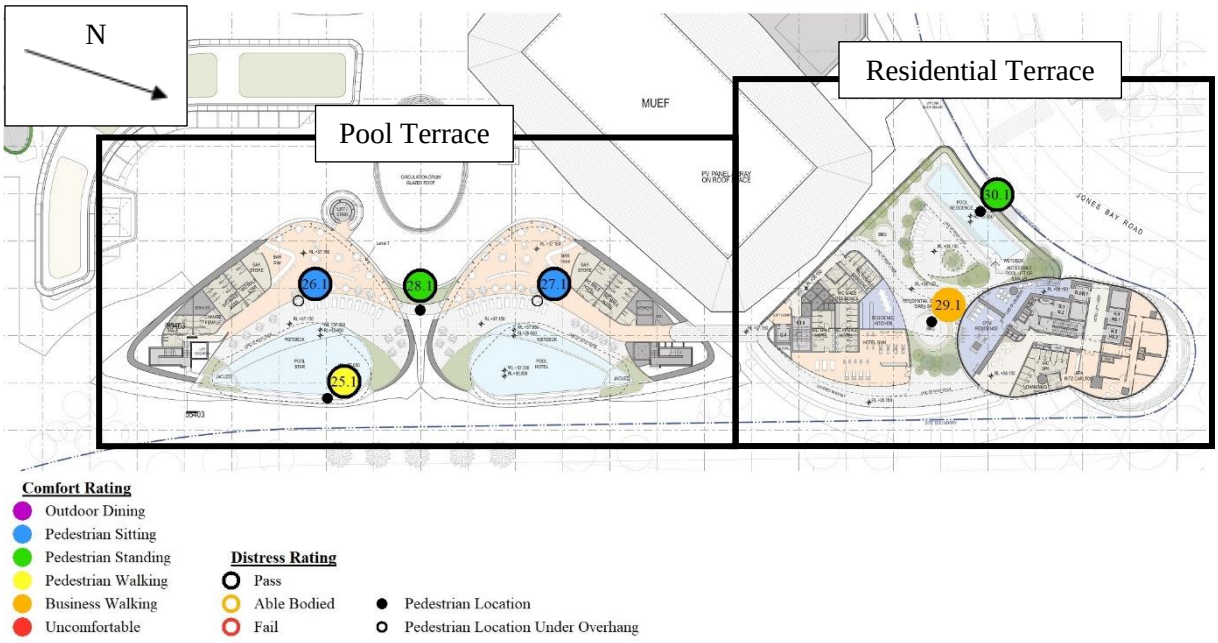


Figure 13: Pedestrian wind speed measurements on the Level 7 Pool and Residential terraces

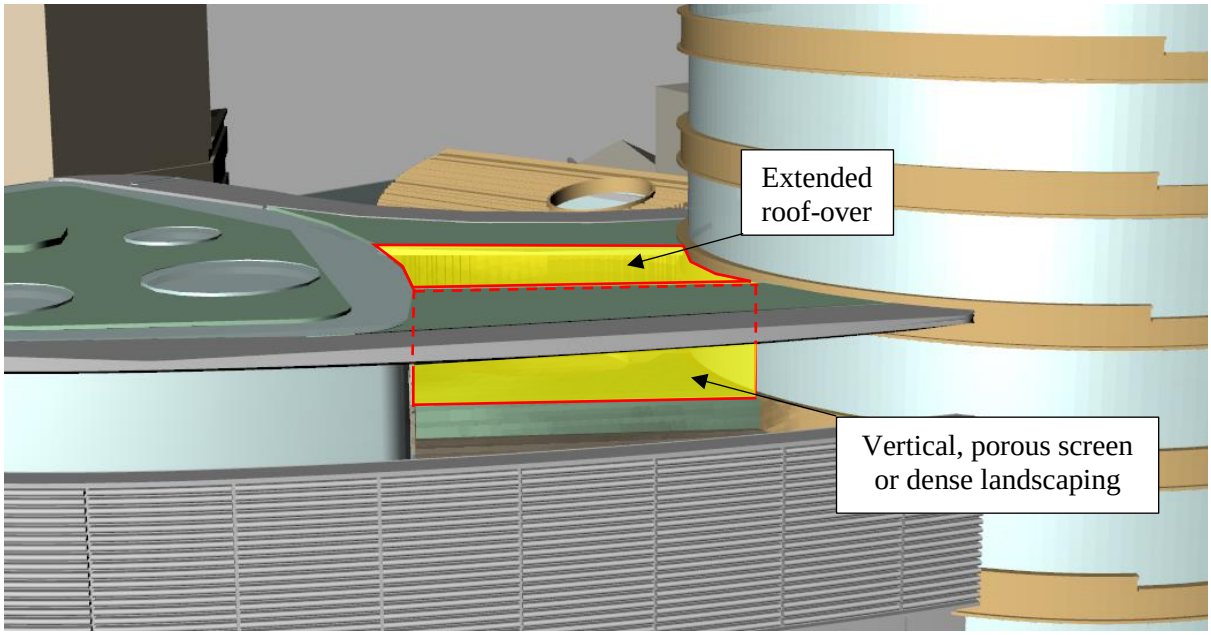


Figure 14: Recommended mitigation for the BBQ area viewed from the north-east

5.4 Level 59 Club Lounge Terrace

Location 31.1 in the Club Lounge Sky Terrace on Level 59, Figure 15, experienced wind conditions at a pedestrian walking comfort level while slightly exceeding the distress/safety criteria to an able-bodied rating. The test model included a balustrade equivalent to 6 m in height at full-scale around the terrace, however was tested without proposed landscaping. Proposed local landscaping and vertical screening surrounding the seating areas, evident in the exhibited scheme landscaping plans, would help improve conditions to levels that will be suitable for its intended purposes and will pass the distress/safety criterion. During winds from the south the terrace will experience downwash from the tower facade, and thus overhead protection (temporary or fixed) such as an awning along the façade is suggested to further protect the area beneath. This element will be incorporated into the scheme during design development.

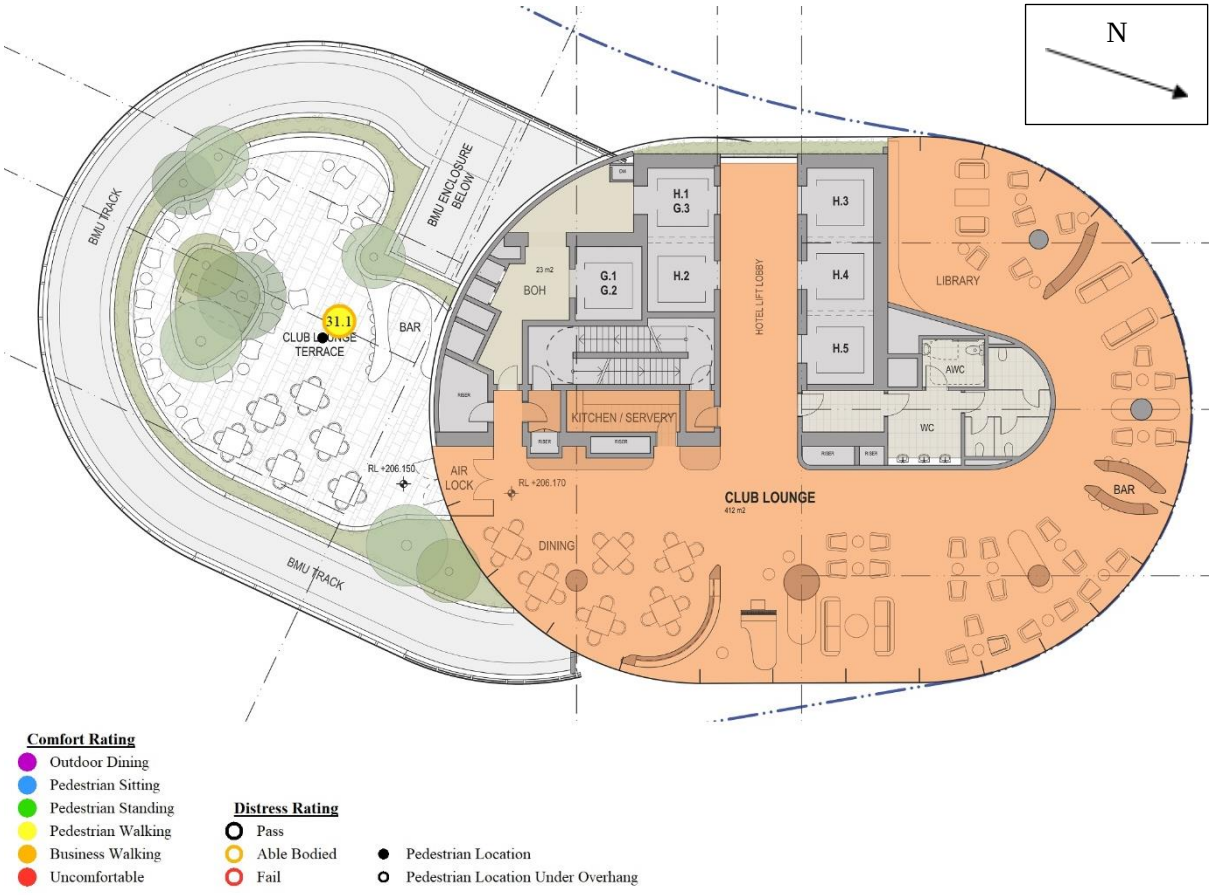


Figure 15: Pedestrian wind speed measurements in the Club Lounge Sky Terrace on Level 59

5.5 MOD13 remaining site balance, August 2017 – DWP

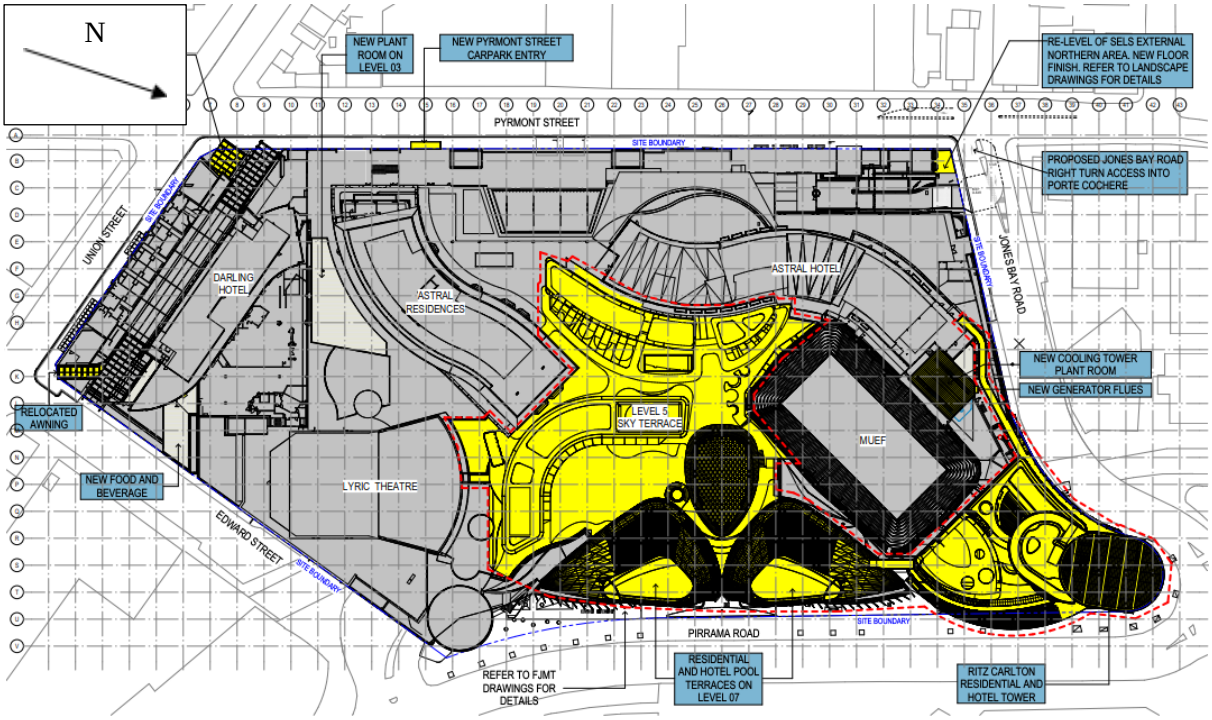


Figure 16: Site plan (DWP, 2017)

The remaining balance of the changes and additions, including the awnings and signages, to the existing development site will have limited environmental impacts to the existing wind amenity along the adjacent public accessways.

The additional awnings at the corners of Edward, Union and Pyrmont Streets would be slightly beneficial for the wind conditions in the area directly underneath awnings as they would provide some shielding from wind and wind-driven rain. The awnings are design features of the MOD13 proposal and are not a result of the wind tunnel studies nor recommendations from CPP. Any comments in this this report relating to these awnings are general observations.

6. CONCLUSIONS

A wind tunnel study of the proposed The Star redevelopment, based on the MOD13 DA scheme, was conducted to assess the impact of the proposal on the pedestrian level wind environment in and around the proposed buildings. Measurements of wind speeds likely to be experienced by pedestrians were made with hot-film anemometers at 31 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 a that a wind speed is exceeded for each investigated location.

The wind tunnel studies showed that with the addition of the proposed MOD13 development, including tower, the general wind environment at ground level at most locations around the development site were found to be similar to existing wind conditions. With the proposed buildings, wind conditions near the intersection of Pirrama and Jones Bay Roads are classified as pedestrian walking, suitable for the surrounding footpaths and crossings. Wind conditions at all investigated locations on the ground plane passed the distress/safety criterion.

Wind conditions at most investigated locations on the upper level terraces are classified as pedestrian standing and walking, while locations within the semi-enclosed areas of the Level 7 Pool Terraces experiences conditions classified as pedestrian sitting, suitable for the poolside seating. Locations in the BBQ area of the Level 7 Residential Terrace and the Level 59 Club Lounge Terrace will experience wind conditions classified as business walking and pedestrian walking, respectively, and exceed the distress criterion. Mitigation at locations exceeding the distress/safety criterion is recommended, such as local, porous vertical screening to help reduce strong winds. Dense landscaping surrounding these areas will help improve the measured wind conditions to suitable comfort levels, and can be mobile/portable and deployed during strong wind events.

The remaining balance of the MOD13 developments to the existing site, including design features such as awnings and signages, will have limited environmental impacts to the existing wind amenity along the adjacent footpaths and roadways at ground level. The awnings would be slightly beneficial by providing some shielding from wind-driven rain to the covered areas.

In consideration of all the above mentioned, The Star MOD13 redevelopment as documented in this DA application will have a limited environmental impact on the ground plane from a wind perspective.

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Appendix 1: Additional Photographs of the Wind Tunnel Models

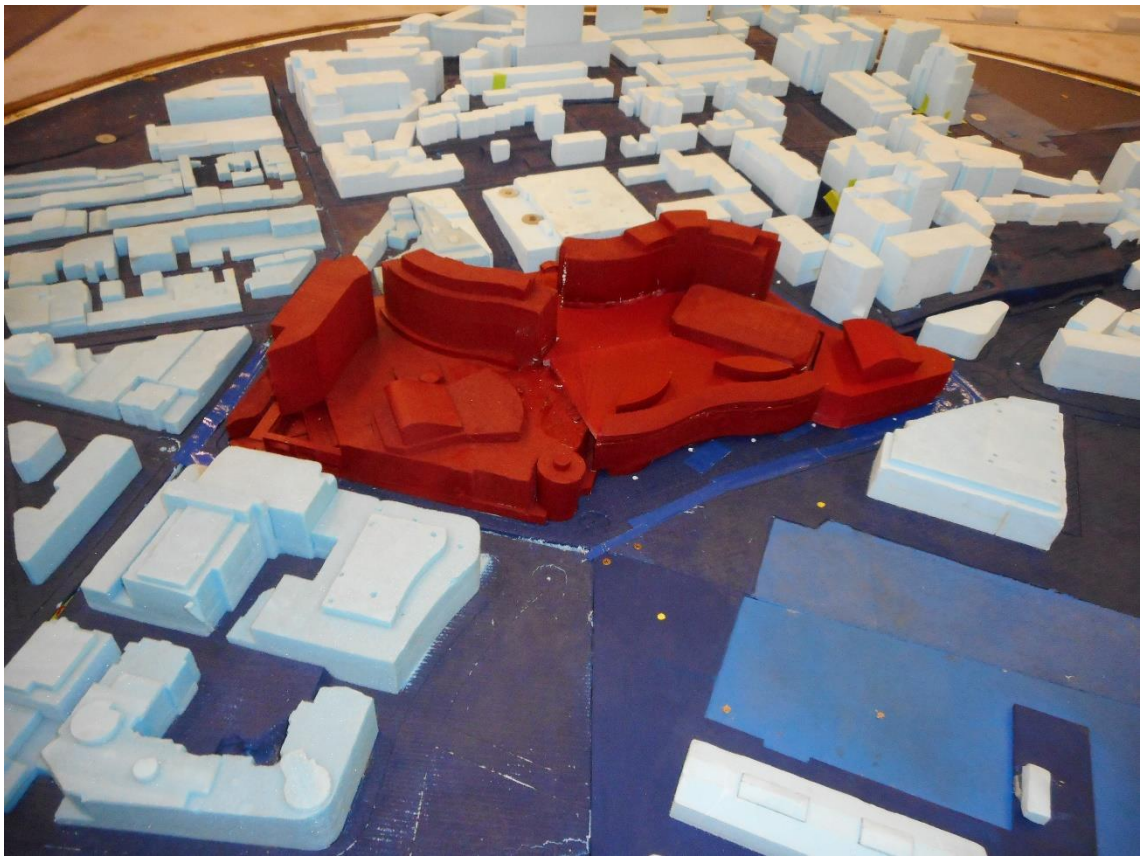


Figure 17: Existing site viewed from the east

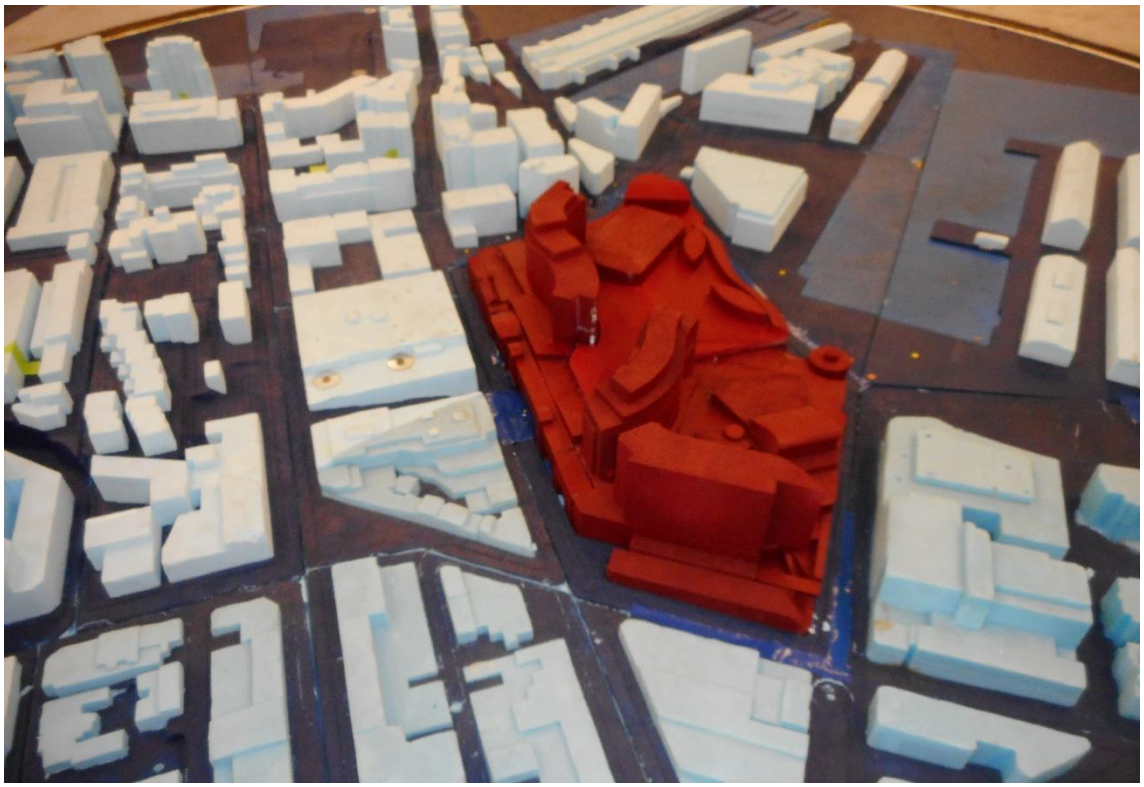


Figure 18: Existing site viewed from the south

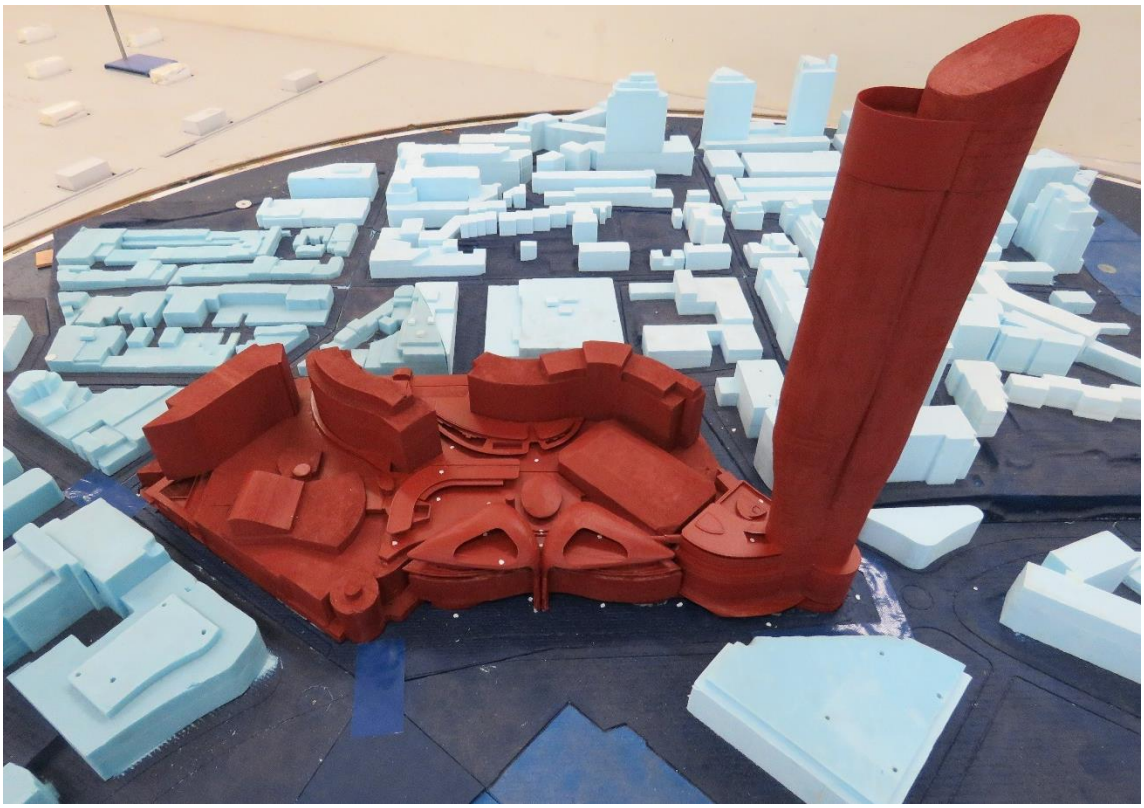


Figure 19: Proposed development viewed from the north-east

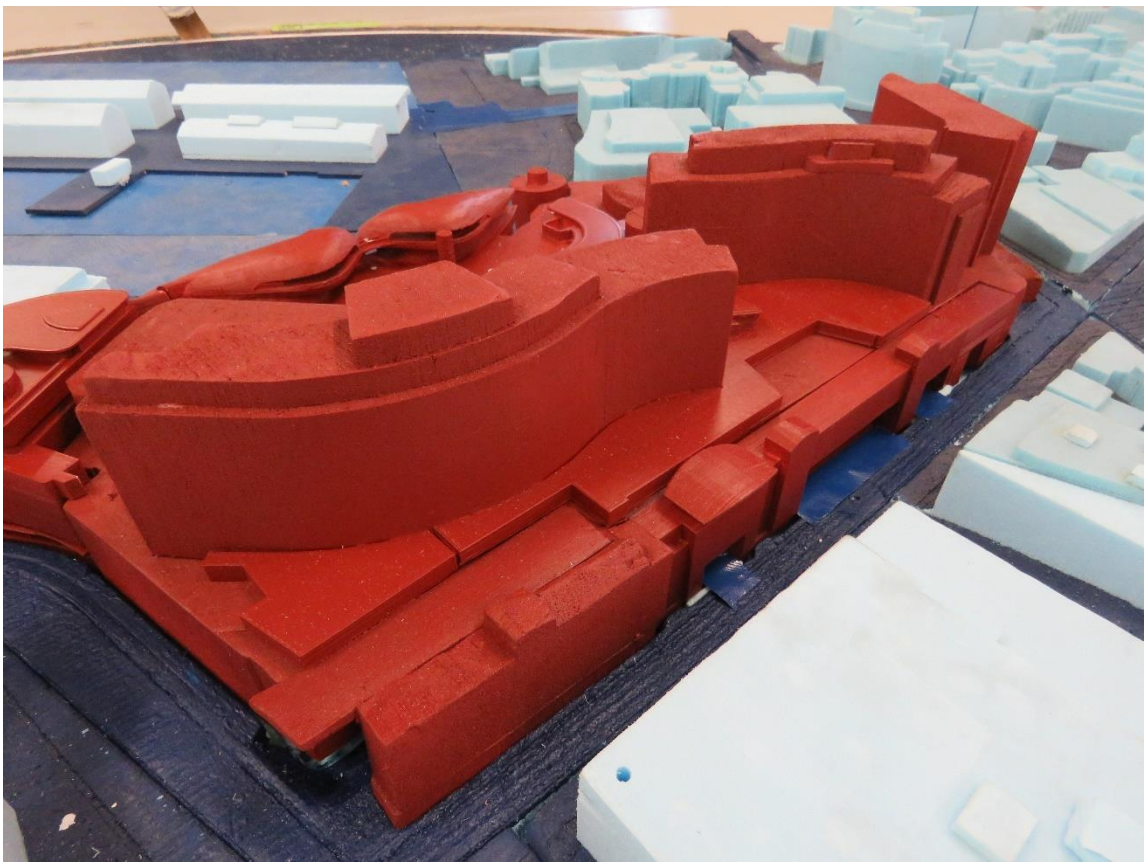
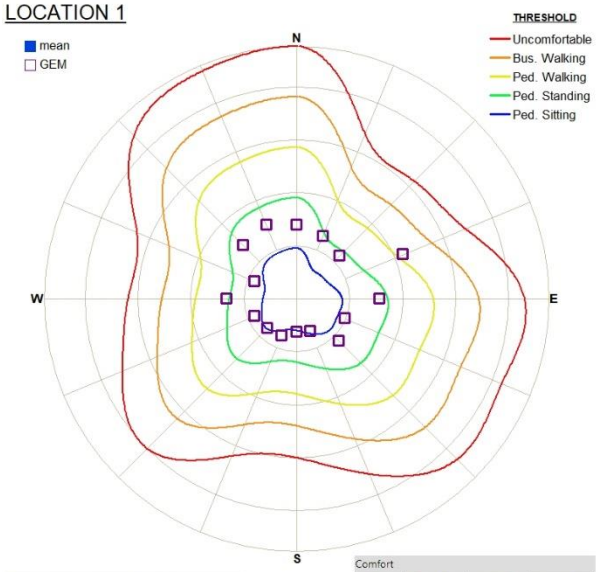


Figure 20: Proposed development viewed from the north-west

Appendix 2: Directional Wind Results

6.1 Existing Development Site

LOCATION 1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	7.09	25.00	25.00
4	0.22	3.35	3.35
6	0.00	0.37	0.37
8	0.00	0.02	0.02
10	0.00	0.00	0.00

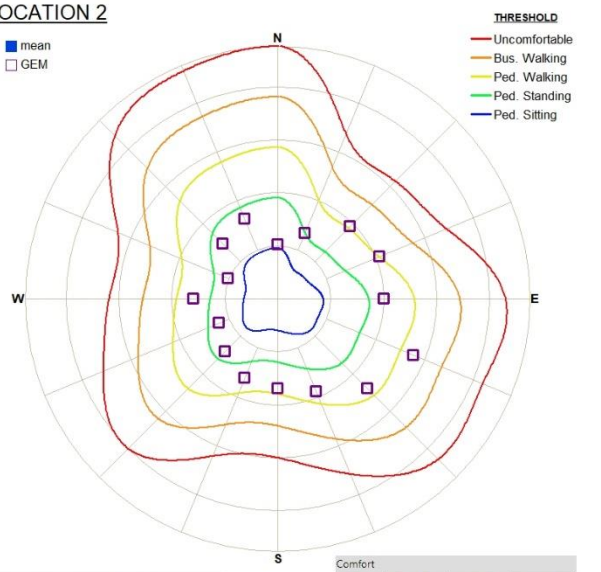
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.2	3.5	3.5
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.0	7.8	7.8
Rating	Pass	Pass	Pass

LOCATION 2



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	37.37	52.49	52.49
4	5.81	15.38	15.38
6	0.31	1.77	1.77
8	0.01	0.14	0.14
10	0.00	0.01	0.01

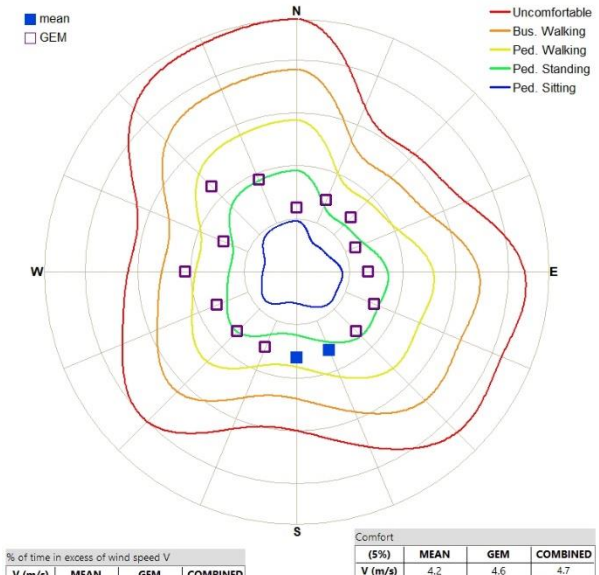
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	5.1	5.1
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.6	9.2	9.2
Rating	Pass	Pass	Pass

LOCATION 3



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	44.31	53.66	53.81
4	6.92	10.04	10.24
6	0.73	1.36	1.40
8	0.07	0.17	0.18
10	0.01	0.03	0.03

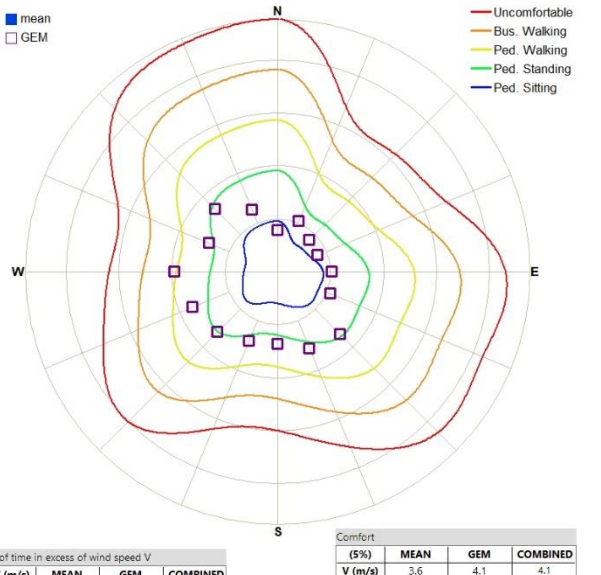
Comfort

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

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.8	10.1	10.1
Rating	Pass	Pass	Pass

LOCATION 4



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	27.19	40.51	40.51
4	3.12	5.78	5.78
6	0.24	0.64	0.64
8	0.01	0.05	0.05
10	0.00	0.00	0.00

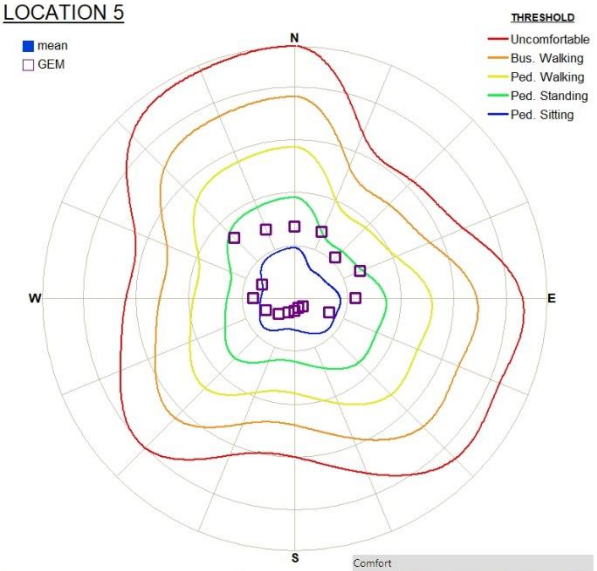
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	4.1	4.1
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.6	8.7	8.7
Rating	Pass	Pass	Pass

LOCATION 5



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	5.04	17.38	17.38
4	0.17	1.21	1.21
6	0.01	0.06	0.06
8	0.00	0.01	0.01
10	0.00	0.00	0.00

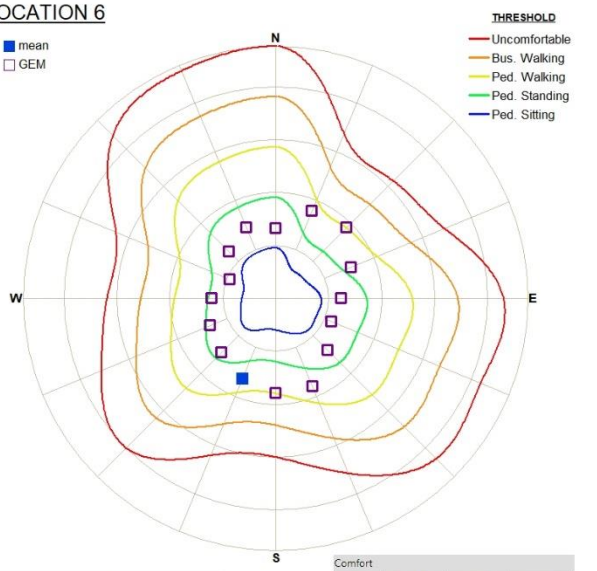
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.0	3.0	3.0
Rating	Outdoor Dining	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.5	6.9	6.9
Rating	Pass	Pass	Pass

LOCATION 6



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	32.06	46.06	46.07
4	6.84	11.31	11.34
6	0.64	1.20	1.21
8	0.04	0.07	0.07
10	0.00	0.00	0.00

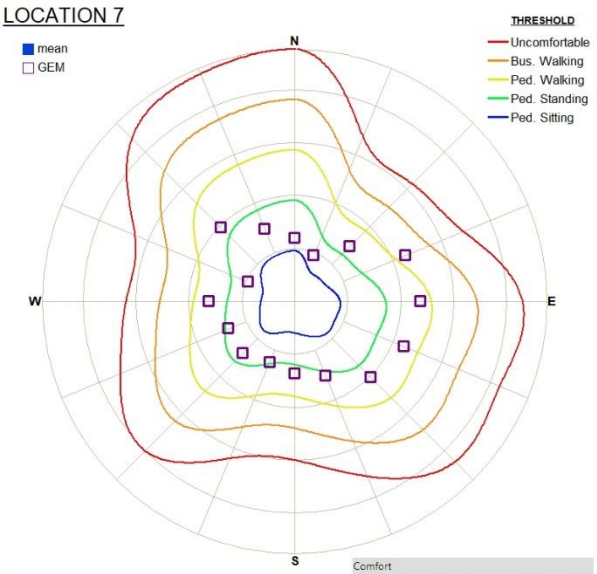
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.2	4.8	4.8
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.3	8.6	8.6
Rating	Pass	Pass	Pass

LOCATION 7



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.33	49.58	49.58
4	2.48	9.79	9.79
6	0.16	1.03	1.03
8	0.01	0.08	0.08
10	0.00	0.01	0.01

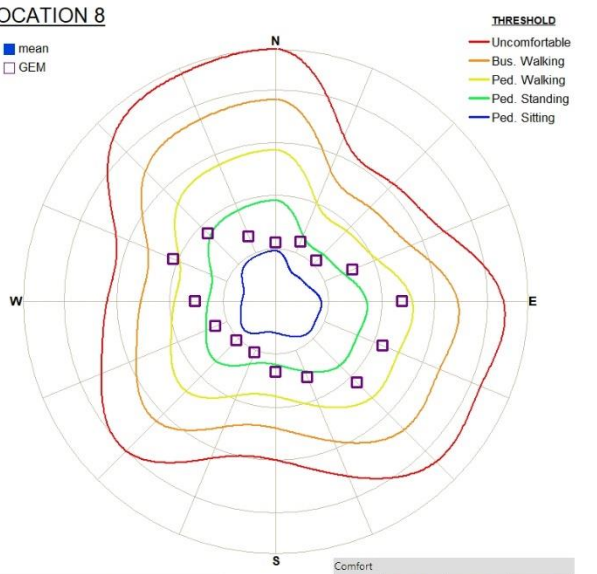
Comfort

(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)	7.5	9.1	9.1
Rating	Pass	Pass	Pass

LOCATION 8



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	18.80	49.26	49.26
4	1.74	8.18	8.18
6	0.17	0.96	0.96
8	0.00	0.15	0.15
10	0.00	0.01	0.01

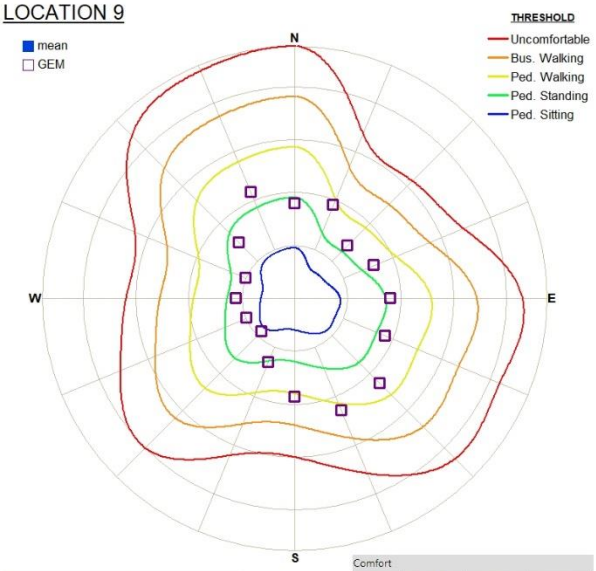
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.1	4.4	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.3	9.6	9.6
Rating	Pass	Pass	Pass

LOCATION 9



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	34.89	51.34	51.34
4	6.35	12.90	12.90
6	0.77	1.59	1.59
8	0.07	0.15	0.15
10	0.01	0.01	0.01

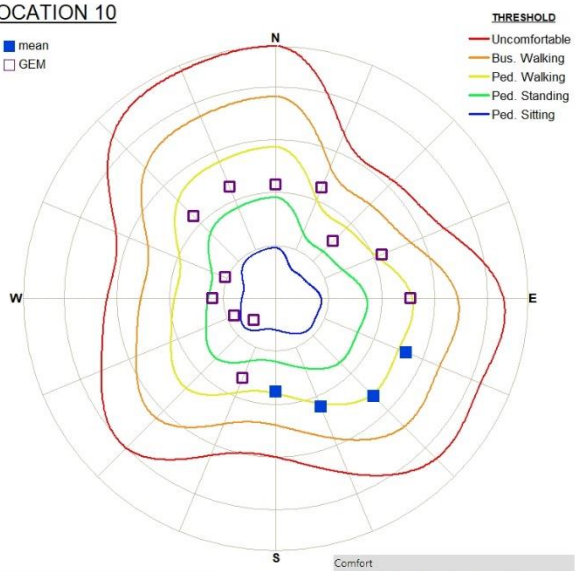
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.2	4.9	4.9
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

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

LOCATION 10



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	48.77	58.09	58.71
4	12.98	18.51	20.02
6	1.81	2.81	3.34
8	0.21	0.26	0.34
10	0.02	0.02	0.03

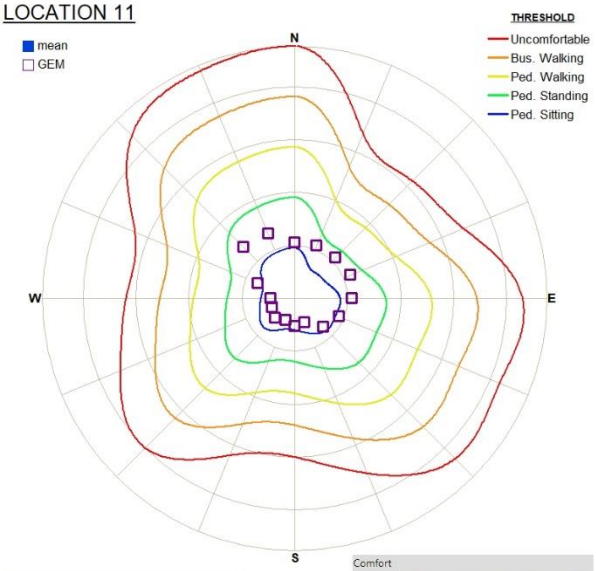
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.0	5.4	5.6
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.8	10.0	10.2
Rating	Pass	Pass	Pass

LOCATION 11



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	5.28	13.68	13.68
4	0.05	0.50	0.50
6	0.00	0.02	0.02
8	0.00	0.00	0.00
10	0.00	0.00	0.00

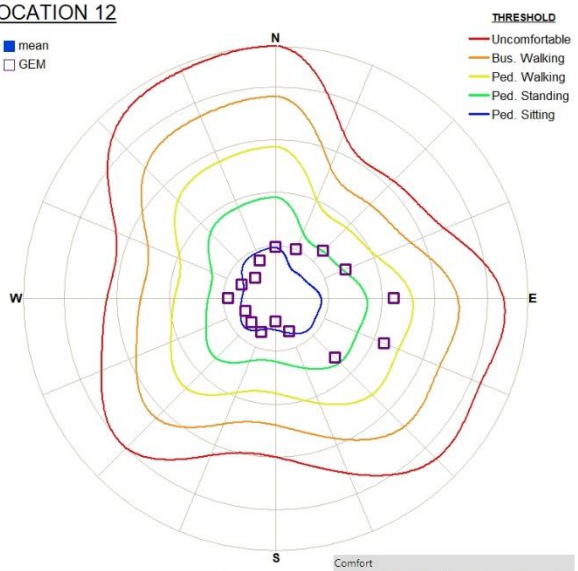
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.0	2.7	2.7
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.3	5.9	5.9
Rating	Pass	Pass	Pass

LOCATION 12



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	5.52	20.89	20.89
4	0.06	2.71	2.71
6	0.00	0.14	0.14
8	0.00	0.01	0.01
10	0.00	0.00	0.00

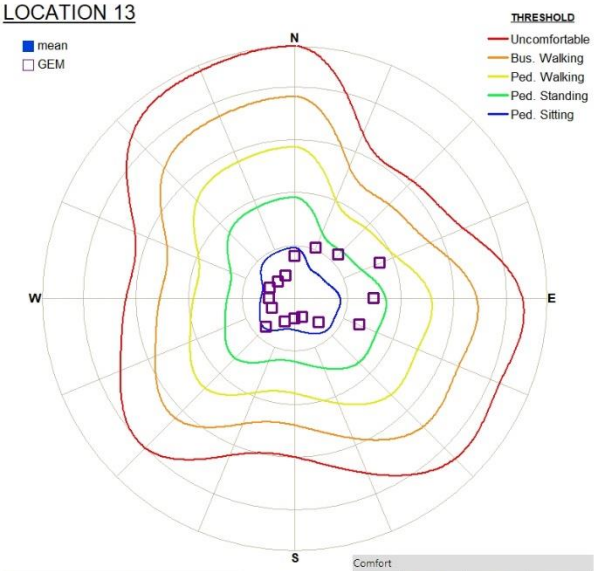
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.0	3.5	3.5
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.4	7.4	7.4
Rating	Pass	Pass	Pass

LOCATION 13



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	2.71	13.24	13.24
4	0.01	1.32	1.32
6	0.00	0.03	0.03
8	0.00	0.00	0.00
10	0.00	0.00	0.00

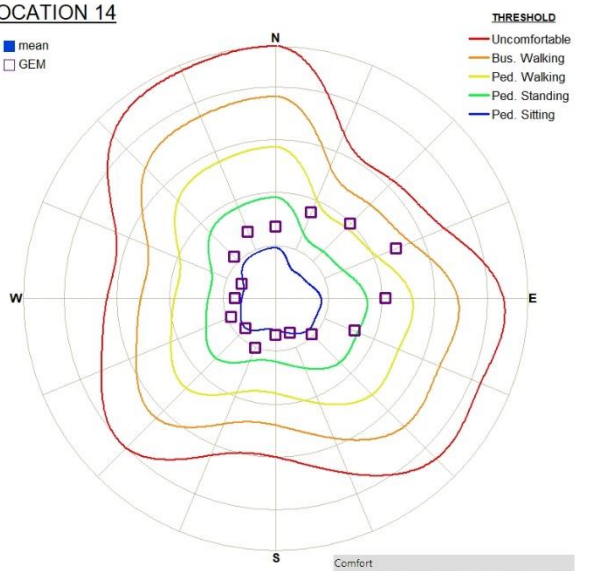
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	1.7	3.0	3.0
Rating	Outdoor Dining	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	3.7	6.1	6.1
Rating	Pass	Pass	Pass

LOCATION 14



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	12.39	28.65	28.65
4	0.74	8.20	8.20
6	0.01	1.45	1.45
8	0.00	0.09	0.09
10	0.00	0.01	0.01

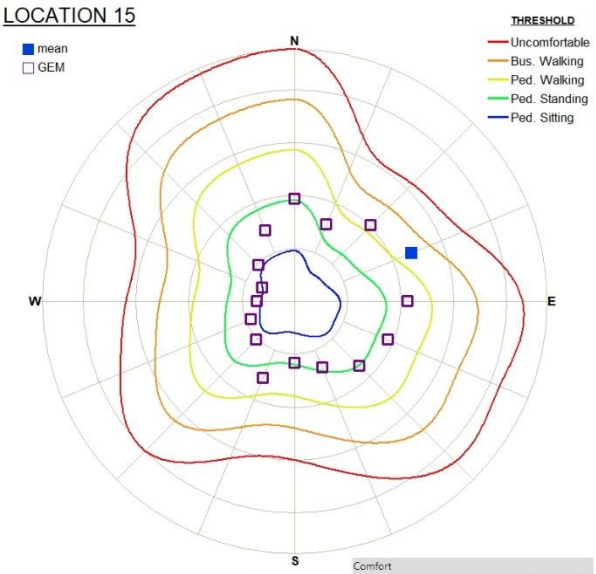
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.8	4.6	4.6
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.4	8.9	8.9
Rating	Pass	Pass	Pass

LOCATION 15



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	24.18	42.60	42.62
4	5.21	10.19	10.23
6	0.91	1.43	1.48
8	0.04	0.09	0.09
10	0.00	0.00	0.00

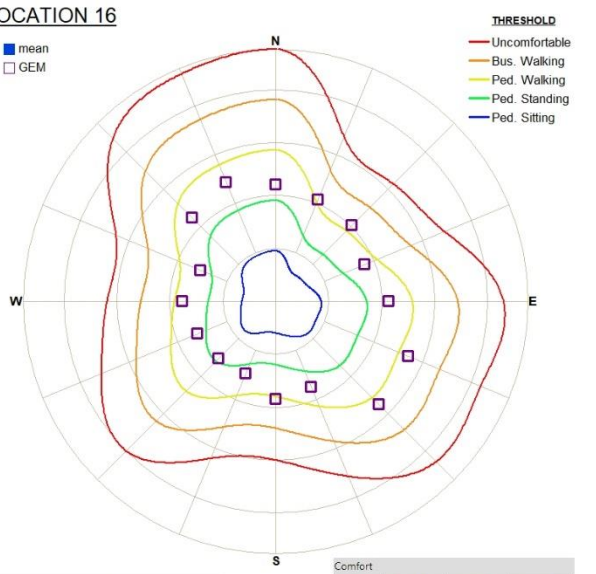
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	4.8	4.8
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.5	8.9	8.9
Rating	Pass	Pass	Pass

LOCATION 16



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	47.00	65.45	65.45
4	9.84	21.13	21.13
6	1.29	3.56	3.56
8	0.10	0.35	0.35
10	0.01	0.03	0.03

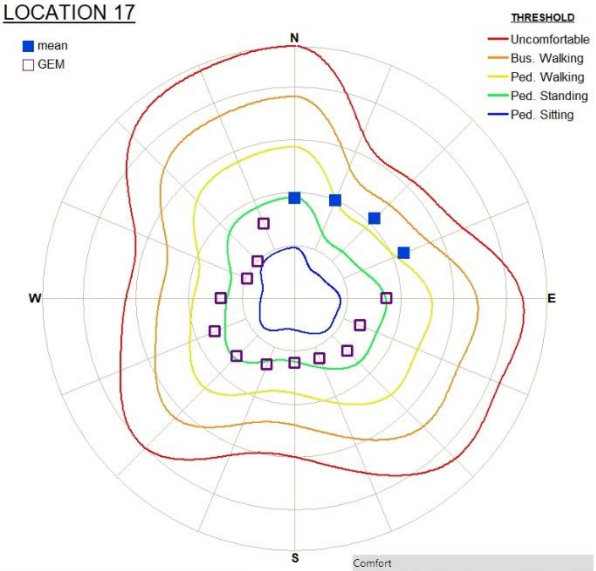
Comfort

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

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.1	10.2	10.2
Rating	Pass	Pass	Pass

LOCATION 17



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.08	46.93	47.57
4	8.87	10.15	11.15
6	1.66	1.09	1.76
8	0.14	0.05	0.14
10	0.00	0.00	0.00

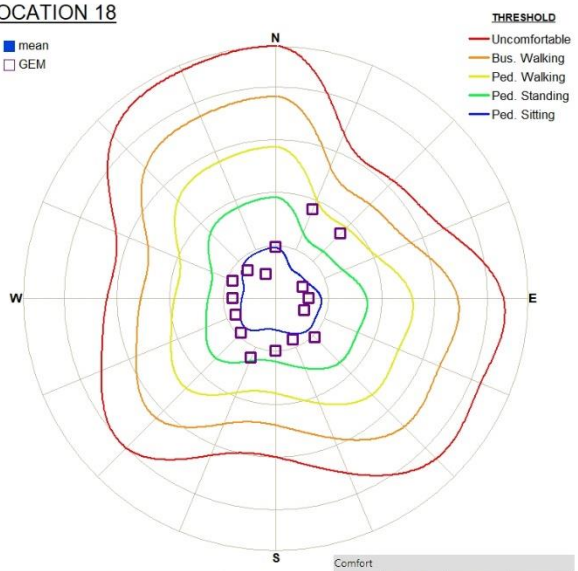
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.8	4.7	5.0
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.0	8.4	9.0
Rating	Pass	Pass	Pass

LOCATION 18



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	11.02	23.33	23.33
4	2.80	4.45	4.45
6	0.16	0.37	0.37
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort

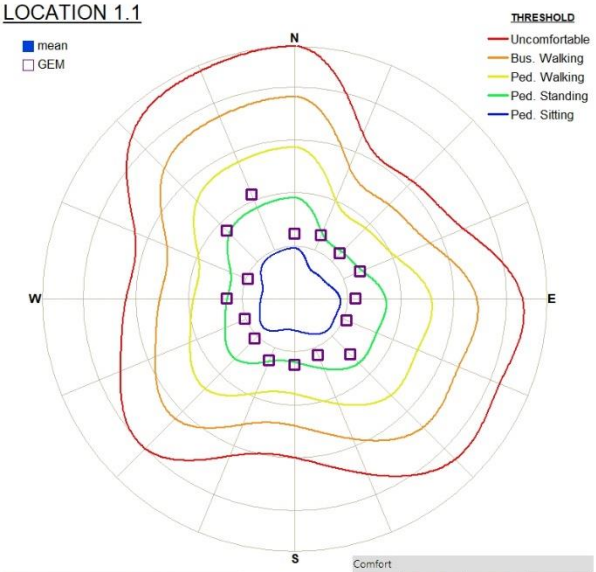
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.3	3.8	3.8
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.0	7.5	7.5
Rating	Pass	Pass	Pass

6.2 Proposed Development Site

LOCATION 1.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	19.38	41.22	41.22
4	0.96	3.25	3.25
6	0.05	0.27	0.27
8	0.00	0.03	0.03
10	0.00	0.00	0.00

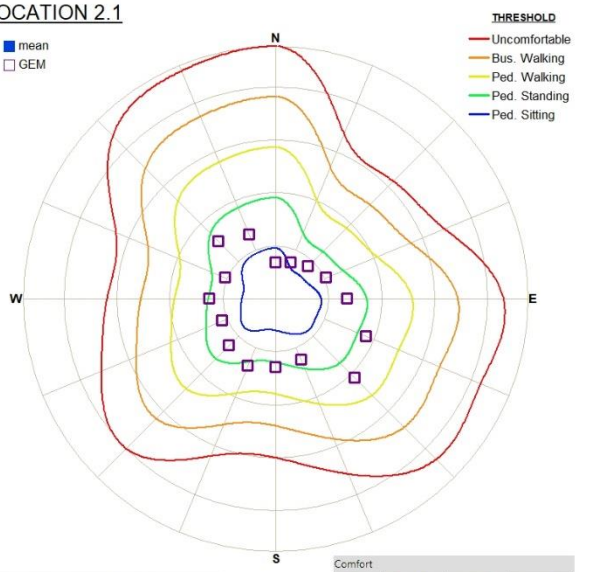
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.8	3.7	3.7
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.5	8.2	8.2
Rating	Pass	Pass	Pass

LOCATION 2.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	16.52	36.54	36.54
4	0.68	3.65	3.65
6	0.01	0.19	0.19
8	0.00	0.01	0.01
10	0.00	0.00	0.00

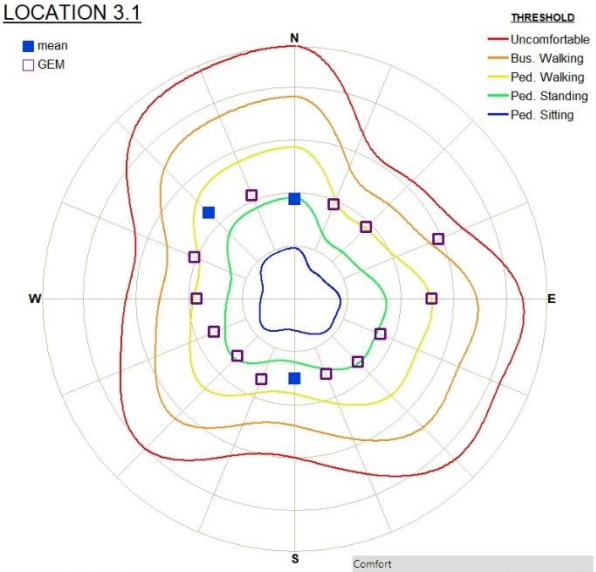
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.9	3.7	3.7
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.7	7.3	7.3
Rating	Pass	Pass	Pass

LOCATION 3.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	54.66	62.38	62.75
4	10.86	17.78	17.96
6	1.52	3.73	3.78
8	0.13	0.59	0.61
10	0.02	0.05	0.05

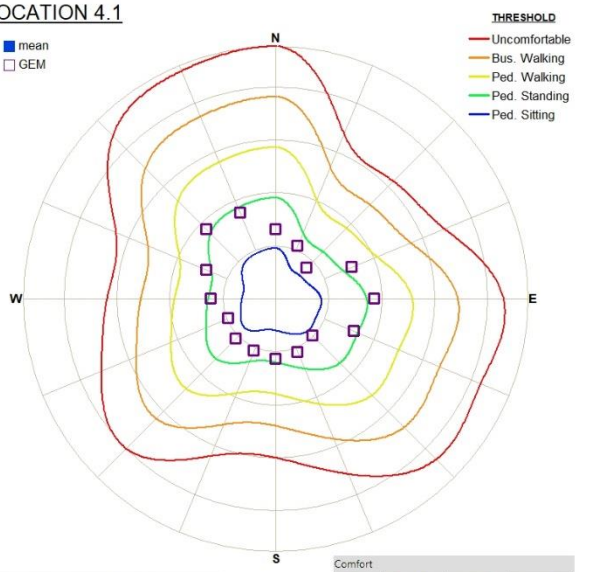
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.8	5.6	5.6
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.1	10.6	10.7
Rating	Pass	Pass	Pass

LOCATION 4.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	18.93	36.97	36.97
4	0.86	3.08	3.08
6	0.06	0.24	0.24
8	0.01	0.02	0.02
10	0.00	0.00	0.00

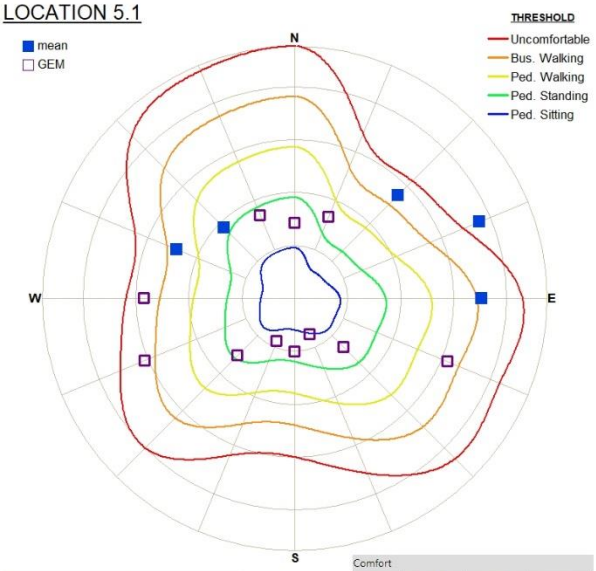
Comfort

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

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.8	8.0	8.0
Rating	Pass	Pass	Pass

LOCATION 5.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	39.34	52.45	52.81
4	17.24	21.34	22.28
6	7.86	9.03	10.34
8	2.68	2.40	3.53
10	0.68	0.47	0.89

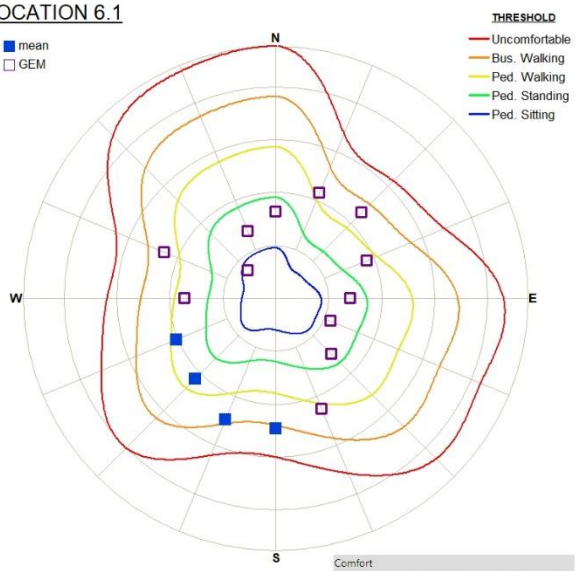
Comfort

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

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.2	12.9	13.7
Rating	Pass	Pass	Pass

LOCATION 6.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	48.53	56.46	57.12
4	21.34	24.08	25.54
6	5.50	5.85	7.00
8	1.00	1.01	1.31
10	0.13	0.11	0.18

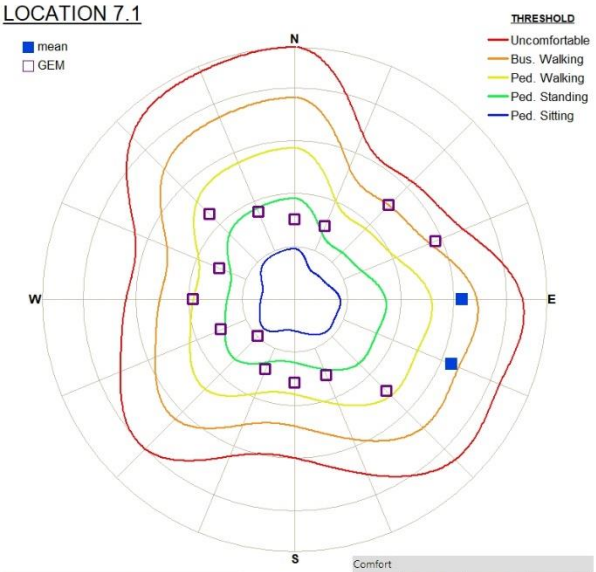
Comfort

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

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.9	11.3	11.9
Rating	Pass	Pass	Pass

LOCATION 7.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	45.54	60.20	60.35
4	13.15	19.44	19.93
6	3.59	5.53	6.11
8	0.46	0.98	1.08
10	0.07	0.11	0.13

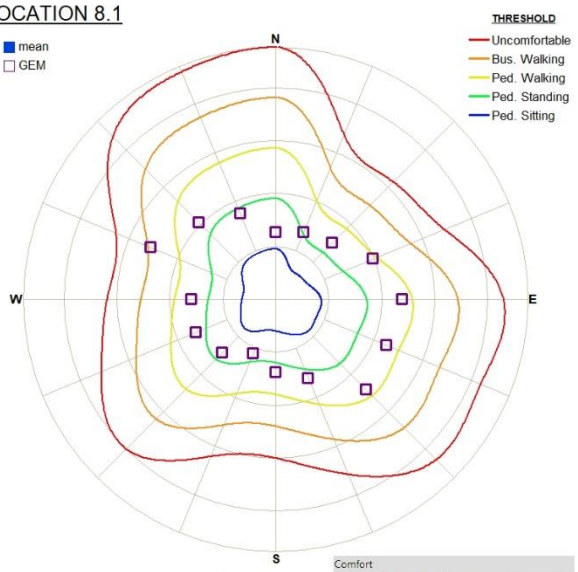
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.5	6.1	6.2
Rating	Ped Standing	Ped Walking	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.1	11.2	11.5
Rating	Pass	Pass	Pass

LOCATION 8.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	33.68	57.19	57.19
4	4.32	13.08	13.08
6	0.62	1.71	1.71
8	0.11	0.41	0.41
10	0.01	0.11	0.11

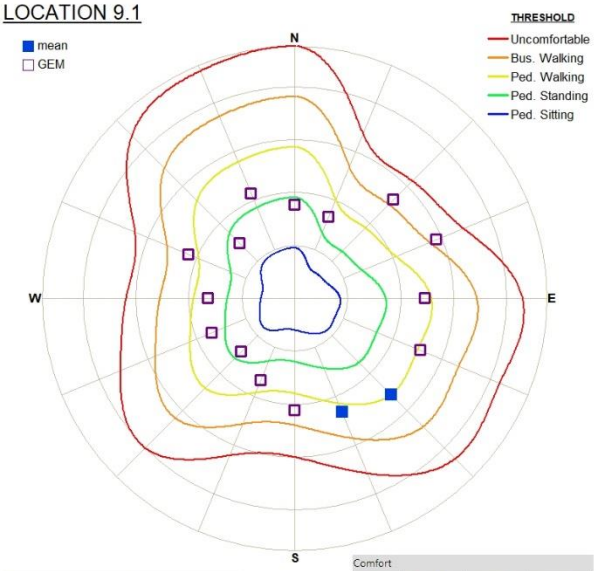
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.9	4.9
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.2	11.5	11.5
Rating	Pass	Pass	Pass

LOCATION 9.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	48.10	63.85	63.90
4	15.39	25.70	25.83
6	3.04	6.98	7.06
8	0.35	1.30	1.31
10	0.03	0.16	0.16

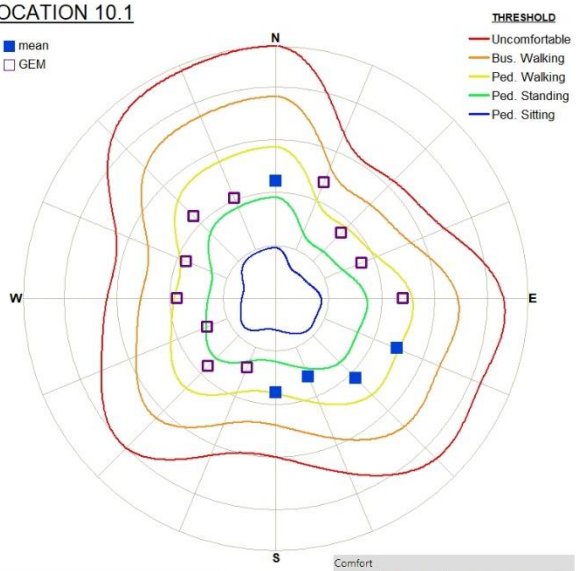
Comfort

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

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.1	11.4	11.4
Rating	Pass	Pass	Pass

LOCATION 10.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	51.68	64.14	64.58
4	11.62	18.13	18.93
6	1.52	2.95	3.15
8	0.10	0.30	0.33
10	0.00	0.02	0.03

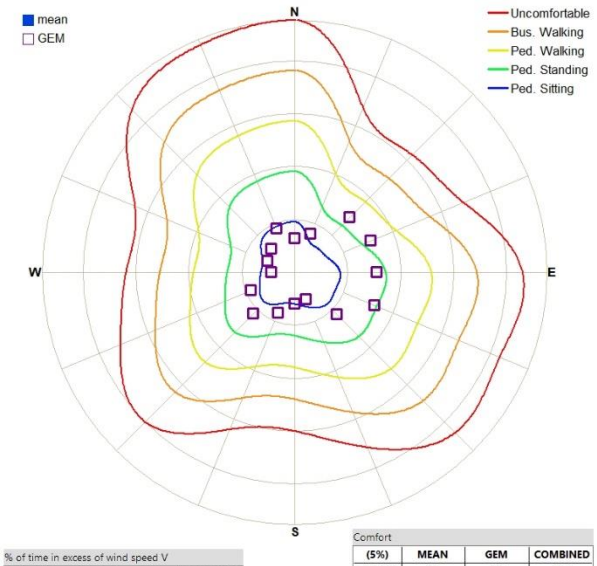
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.9	5.4	5.5
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.1	10.0	10.1
Rating	Pass	Pass	Pass

LOCATION 11.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	9.19	17.92	17.92
4	0.39	1.75	1.75
6	0.00	0.04	0.04
8	0.00	0.00	0.00
10	0.00	0.00	0.00

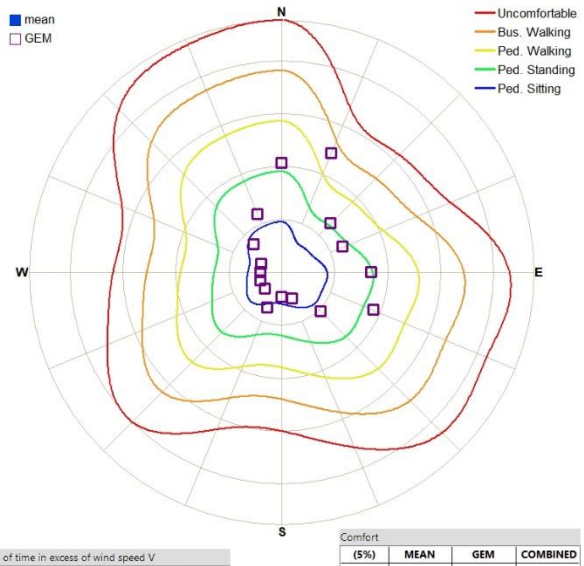
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.5	3.2	3.2
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.0	6.2	6.2
Rating	Pass	Pass	Pass

LOCATION 12.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	12.94	22.94	22.94
4	1.74	4.97	4.97
6	0.08	1.28	1.28
8	0.00	0.17	0.17
10	0.00	0.01	0.01

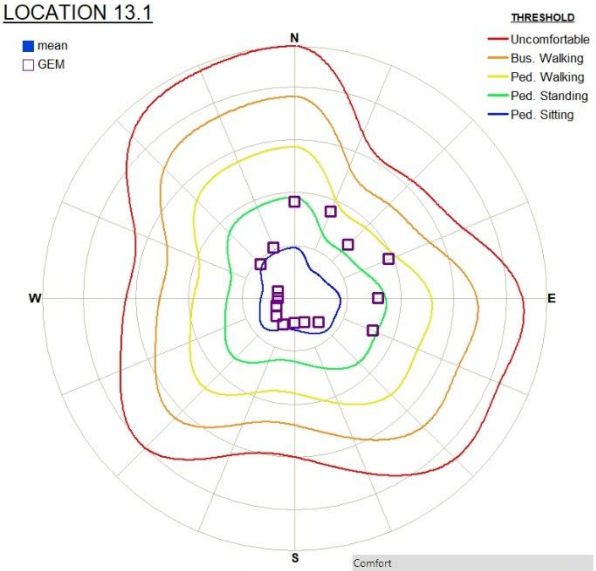
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.8	3.9	3.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.6	9.4	9.4
Rating	Pass	Pass	Pass

LOCATION 13.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	9.53	19.92	19.92
4	0.10	4.43	4.43
6	0.00	0.23	0.23
8	0.00	0.00	0.00
10	0.00	0.00	0.00

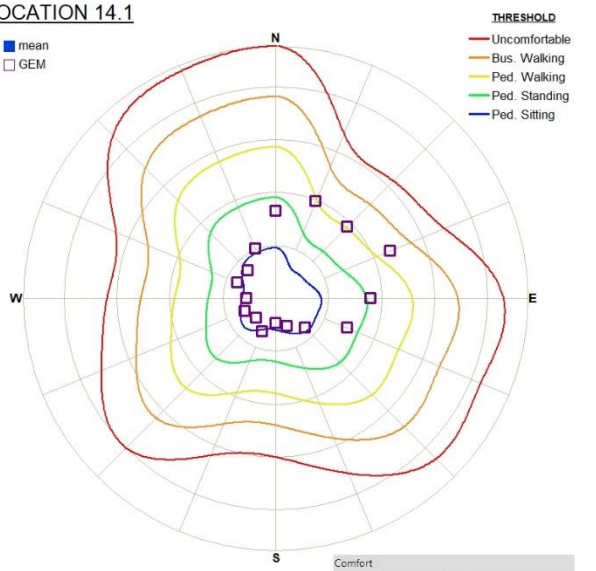
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.4	3.9	3.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.6	7.2	7.2
Rating	Pass	Pass	Pass

LOCATION 14.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	11.85	22.53	22.53
4	0.96	7.77	7.77
6	0.00	1.31	1.31
8	0.00	0.06	0.06
10	0.00	0.00	0.00

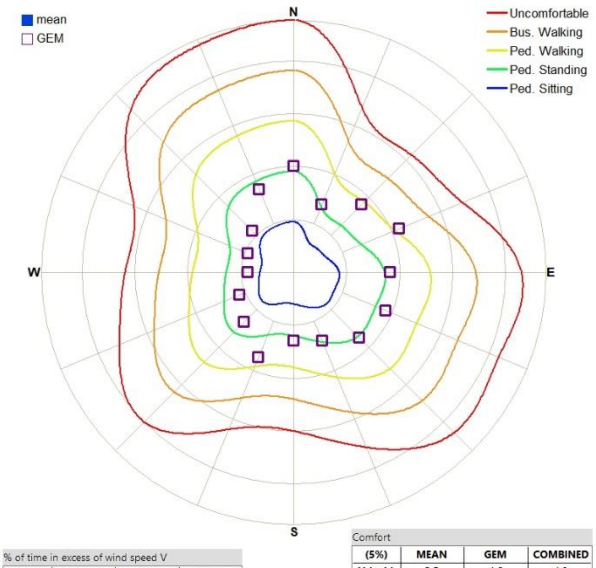
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.9	4.6	4.6
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.4	8.4	8.4
Rating	Pass	Pass	Pass

LOCATION 15.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	25.96	46.02	46.02
4	2.52	9.29	9.29
6	0.08	0.87	0.87
8	0.00	0.04	0.04
10	0.00	0.00	0.00

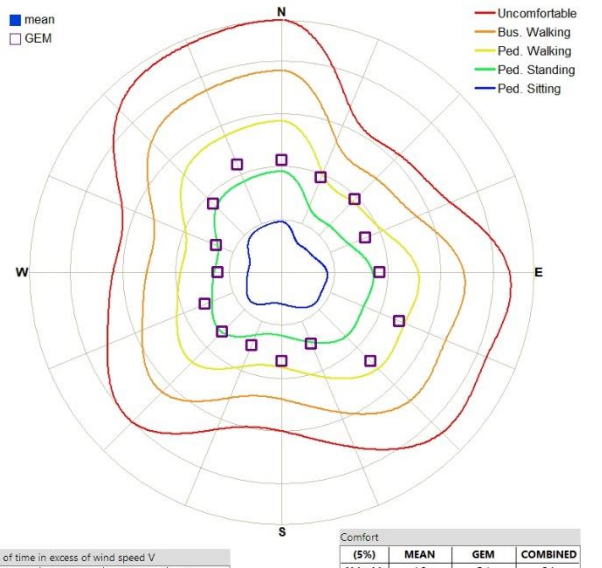
Comfort

(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)	6.8	8.3	8.3
Rating	Pass	Pass	Pass

LOCATION 16.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	38.62	59.37	59.37
4	7.19	15.60	15.60
6	0.80	1.79	1.79
8	0.04	0.13	0.13
10	0.00	0.01	0.01

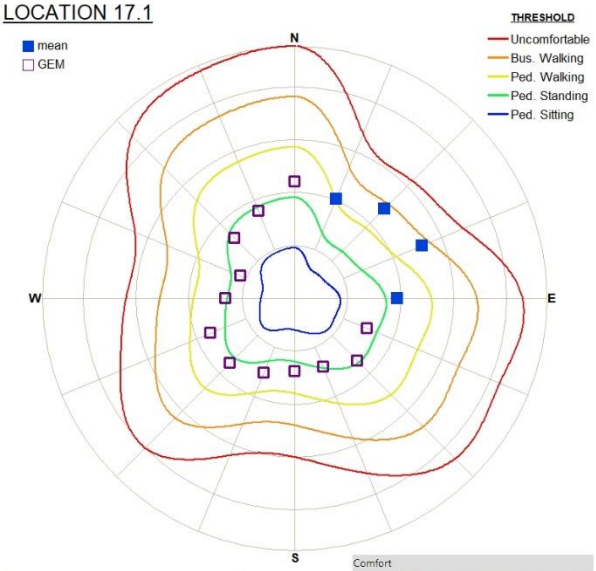
Comfort

(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)	8.2	9.0	9.0
Rating	Pass	Pass	Pass

LOCATION 17.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	38.09	54.57	55.12
4	10.96	13.93	14.80
6	3.06	2.51	3.33
8	0.44	0.26	0.46
10	0.03	0.01	0.03

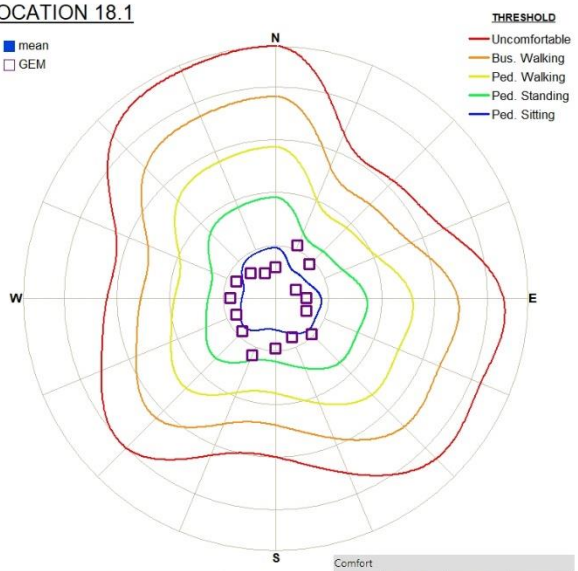
Comfort

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

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.1	9.6	10.2
Rating	Pass	Pass	Pass

LOCATION 18.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	3.12	16.45	16.45
4	0.00	0.29	0.29
6	0.00	0.00	0.00
8	0.00	0.00	0.00
10	0.00	0.00	0.00

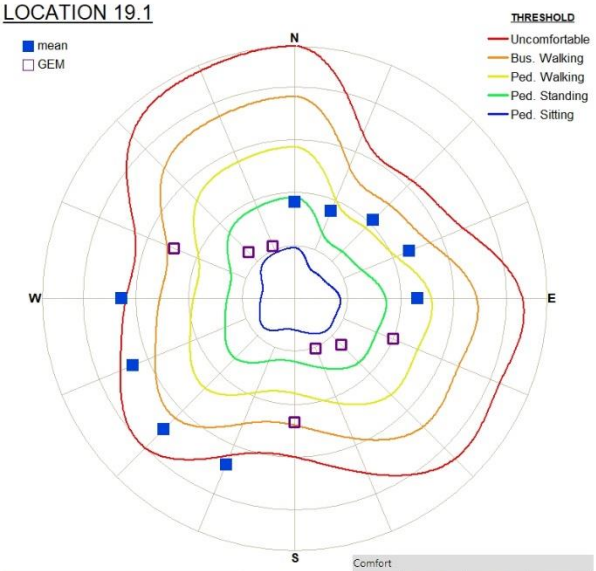
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	1.8	2.7	2.7
Rating	Outdoor Dining	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	3.4	5.2	5.2
Rating	Pass	Pass	Pass

LOCATION 19.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	54.93	58.47	60.53
4	27.90	27.79	30.61
6	10.84	9.06	12.03
8	3.54	2.46	4.00
10	1.13	0.60	1.24

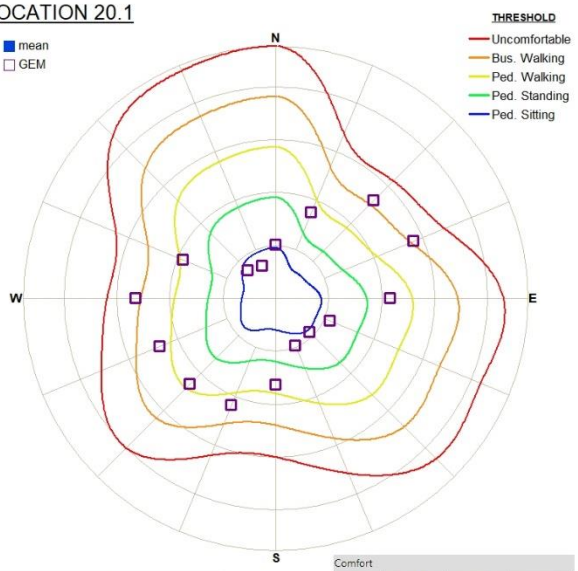
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	7.3	6.9	7.5
Rating	Ped Walking	Ped Walking	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	15.7	13.8	15.8
Rating	Able Body	Pass	Able Body

LOCATION 20.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	38.03	49.58	49.58
4	13.66	21.44	21.44
6	2.65	6.57	6.57
8	0.39	1.38	1.38
10	0.06	0.20	0.20

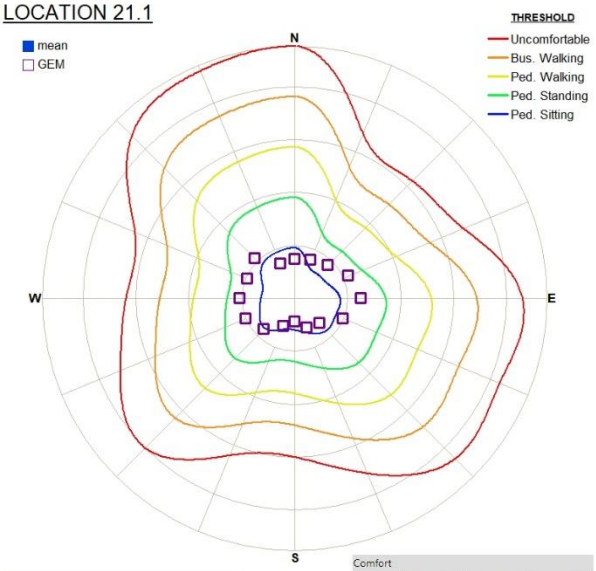
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	5.3	6.3	6.3
Rating	Ped Standing	Ped Walking	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.7	11.8	11.8
Rating	Pass	Pass	Pass

LOCATION 21.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	1.16	12.82	12.82
4	0.00	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

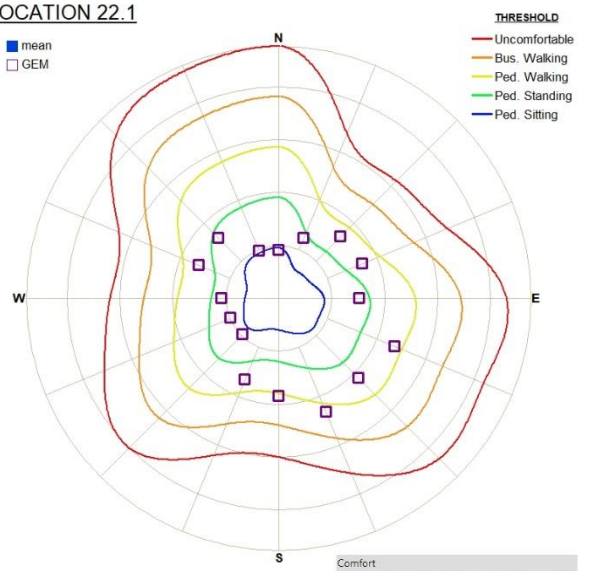
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	1.6	2.5	2.5
Rating	Outdoor Dining	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	3.1	4.9	4.9
Rating	Pass	Pass	Pass

LOCATION 22.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.62	49.01	49.01
4	2.59	13.66	13.66
6	0.12	1.76	1.76
8	0.00	0.16	0.16
10	0.00	0.02	0.02

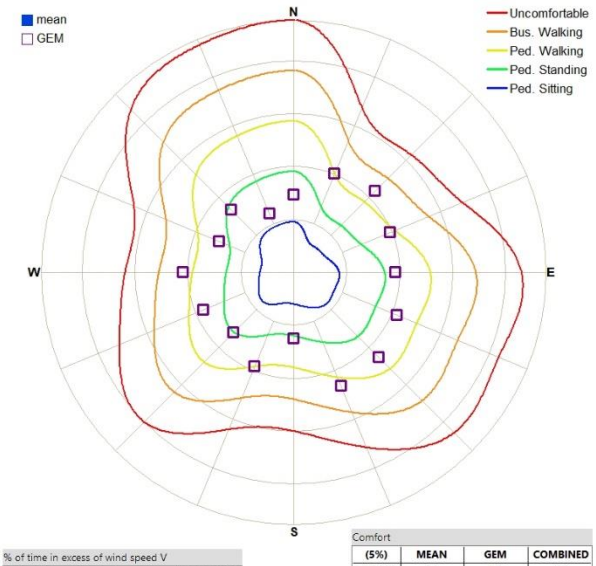
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	5.0	5.0
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.2	9.7	9.7
Rating	Pass	Pass	Pass

LOCATION 23.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	37.88	58.81	58.81
4	5.78	19.85	19.85
6	0.33	3.34	3.34
8	0.00	0.38	0.38
10	0.00	0.02	0.02

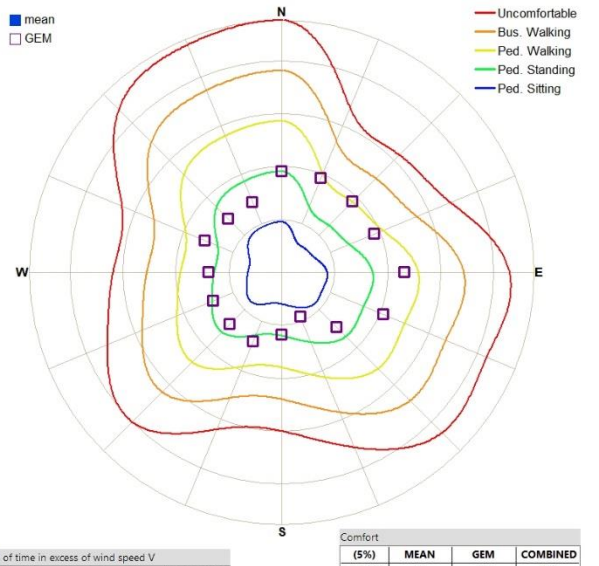
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	5.6	5.6
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.2	10.1	10.1
Rating	Pass	Pass	Pass

LOCATION 24.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.90	48.80	48.80
4	4.35	11.38	11.38
6	0.20	1.12	1.12
8	0.00	0.04	0.04
10	0.00	0.00	0.00

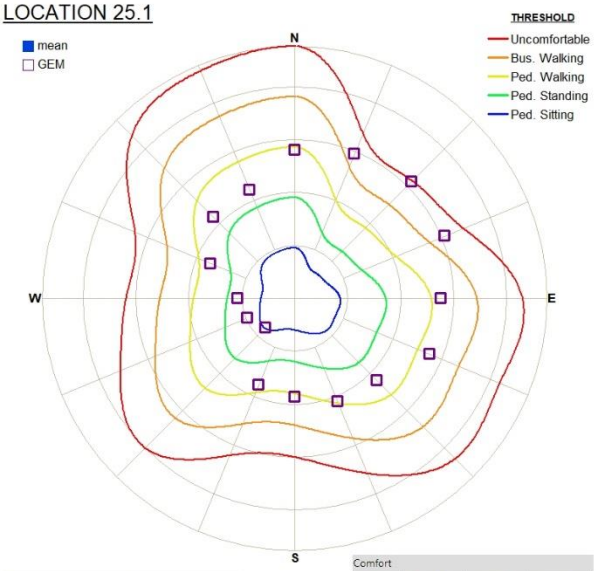
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.8	4.8
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.0	8.3	8.3
Rating	Pass	Pass	Pass

LOCATION 25.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	53.28	64.81	64.81
4	18.48	26.77	26.77
6	7.07	9.96	9.96
8	2.18	2.93	2.93
10	0.50	0.59	0.59

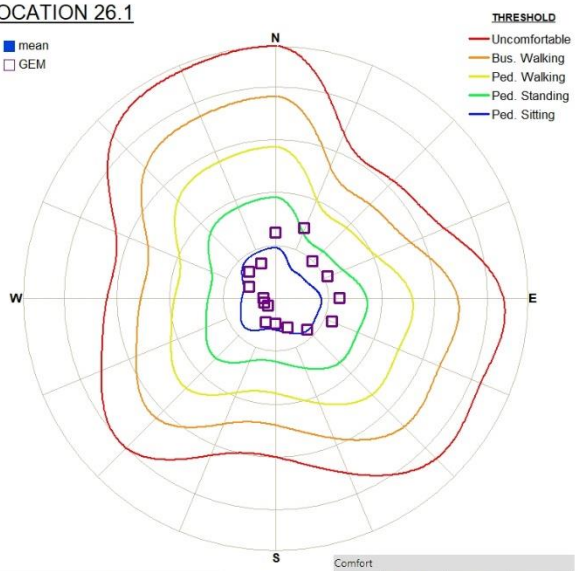
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	6.6	7.2	7.2
Rating	Ped Walking	Ped Walking	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.9	13.1	13.1
Rating	Pass	Pass	Pass

LOCATION 26.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	7.42	13.00	13.00
4	0.10	0.67	0.67
6	0.00	0.01	0.01
8	0.00	0.00	0.00
10	0.00	0.00	0.00

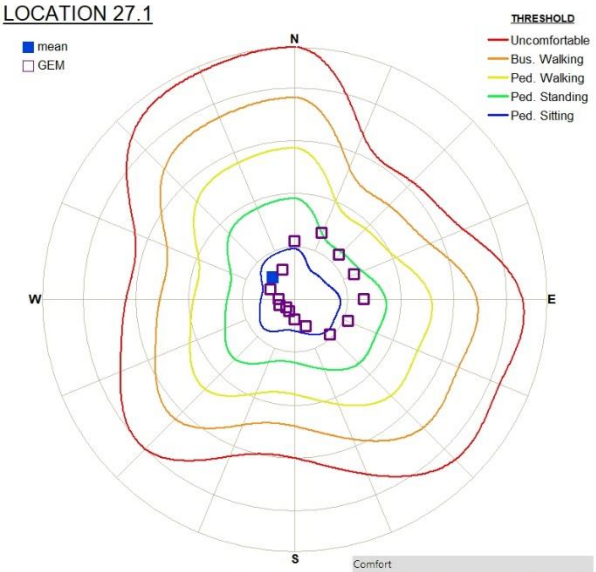
Comfort

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

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.5	5.5
Rating	Pass	Pass	Pass

LOCATION 27.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	9.96	13.70	13.71
4	0.14	0.76	0.76
6	0.00	0.00	0.00
8	0.00	0.00	0.00
10	0.00	0.00	0.00

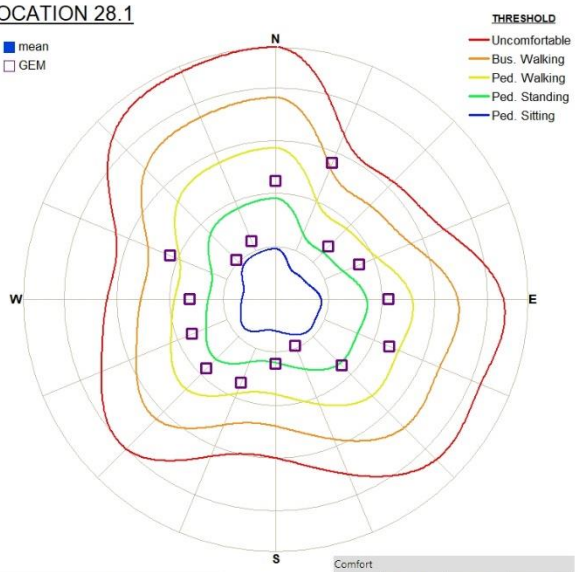
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.5	2.9	2.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.5	5.3	5.3
Rating	Pass	Pass	Pass

LOCATION 28.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	26.67	53.51	53.51
4	2.69	13.76	13.76
6	0.19	3.13	3.13
8	0.01	0.66	0.66
10	0.00	0.07	0.07

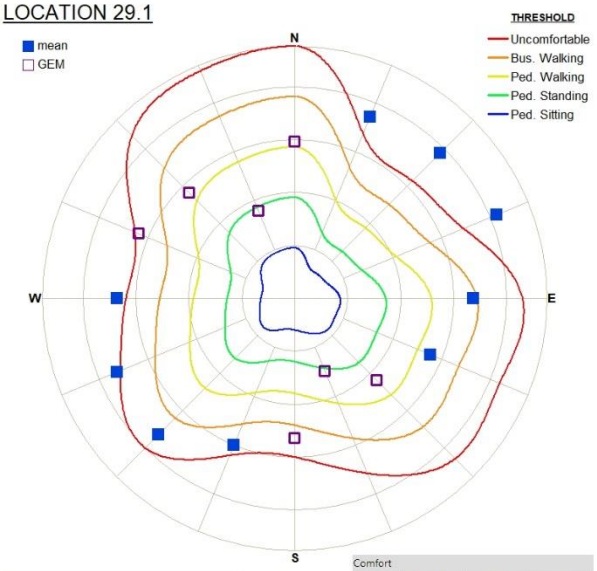
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.5	5.2	5.2
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.5	10.9	10.9
Rating	Pass	Pass	Pass

LOCATION 29.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	74.25	78.96	80.70
4	43.30	42.50	45.78
6	23.88	20.36	24.52
8	11.40	7.68	11.66
10	4.43	2.02	4.56

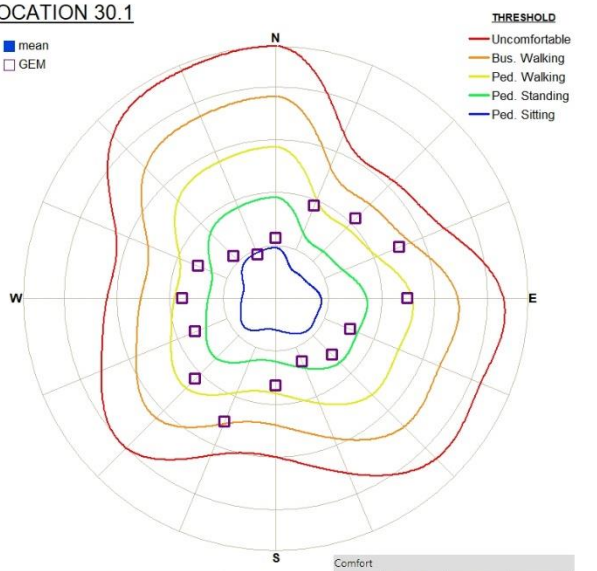
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	9.7	8.7	9.8
Rating	Bus Walking	Bus Walking	Bus Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	16.9	15.1	16.9
Rating	Able Body	Able Body	Able Body

LOCATION 30.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	39.59	53.12	53.12
4	10.82	18.69	18.69
6	1.81	4.21	4.21
8	0.16	0.56	0.56
10	0.02	0.07	0.07

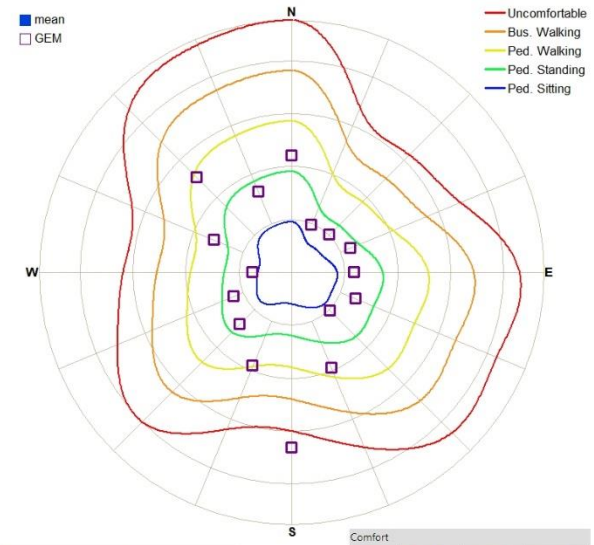
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.9	5.8	5.8
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.7	11.1	11.1
Rating	Pass	Pass	Pass

LOCATION 31.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	29.93	48.06	48.06
4	9.74	14.43	14.43
6	5.60	6.49	6.49
8	2.26	2.43	2.43
10	0.85	0.90	0.90

Comfort

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

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	15.5	15.6	15.6
Rating	Able Body	Able Body	Able Body