Appendix Q

Pedestrian Wind Assessment

Sydney Metro West

Sydney Olympic Park Over and Adjacent Station Development Pedestrian Wind Assessment

Appendix Q

July 2022

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Contents

List of Tables

List of Figures

Glossary

Term	Definition
AS	Australian Standard
ASD	Adjacent Station Development
AWES	Australasian Wind Engineering Society
BOM	Bureau of Meteorology
CBD	Central business district
Concept and Stage 1 CSSI Approval	Application SSI-10038, including all major civil construction works between Westmead and The Bays, including station excavation and tunnelling, associated with the Sydney Metro West line
Concept SSDA	A concept development application as defined in section 4.22 of the EP&A Act, as *a* development application that sets out the concept for the development of a site, and for which detailed proposals for the site or for separate parts of the site are to be the subject of a subsequent development application or applications.
CSSI	Critical State Significant Infrastructure
DPE	Department of Planning and Environment
EP&A Act	*Environmental Planning and Assessment Act 1979*
GEM	Gust equivalent mean
GFA	Gross floor area
NZS	New Zealand Standard
OSD	Over Station Development
QAM	Quality Assurance Manual
SEARs	Secretary's Environmental Assessment Requirements
SOPA	Sydney Olympic Park Authority
SSD	State Significant Development
SSDA	State Significant Development Application
SSI	State Significant Infrastructure
Stage 2 CSSI Application	Application SSI-19238057, including major civil construction works between The Bays and Hunter Street Station
Stage 3 CSSI Application	Application SSI-22765520, including rail infrastructure, stations, precincts and operation of the Sydney Metro West line
Sydney Metro West	Construction and operation of a metro rail line and associated stations between Westmead and the Sydney CBD as described in section 1.1.
The site	The site which is the subject of the Concept SSDA

Executive summary

This Pedestrian Wind Assessment supports a Concept State Significant Development Application (Concept SSDA) submitted to the Department of Planning and Environment (DPE) pursuant to part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The Concept SSDA is made under section 4.22 of the EP&A Act.

Sydney Metro is seeking to secure concept approval for an over station development (OSD) and adjacent station development (ASD) on an area defined as Site 47 within the Central Precinct of Sydney Olympic Park (referred collectively as the 'proposed development'). The proposed development will comprise of one new commercial and retail building (Building 1) above the Sydney Olympic Park metro station and two residential accommodation buildings (Buildings 2 and 3) with retail and commercial space, adjacent to the Sydney Olympic Park metro station.

The Concept SSDA seeks consent for a building envelope and mixed-use purposes, maximum building height, a maximum gross floor area (GFA), pedestrian and vehicular access, circulation arrangements and associated car parking and the strategies and design parameters for the future detailed design of development.

This report responds specifically to the Secretary's Environmental Assessment Requirements (SEARs). The Sydney Olympic Park Authority (SOPA) have developed a master plan for 2030 which includes building development specifications. However, there are no specific wind criteria. The only mention of a wind assessment is in section 4.0 point 5 of the Sydney Olympic Park Master Plan 2030 (2018 Review) document which states:

> *"For south and west facing buildings over eight storeys high, setbacks and other treatments may be required to minimise wind turbulence. All developments over 25m high will require assessment by a wind consultant."*

Therefore, the wind tunnel results are assessed against the industry-standard Lawson comfort criteria. The wind tunnel model and test were undertaken in accordance with relevant Australian standards and industry best-practice guidelines.

The results demonstrate that wind conditions satisfying the Lawson comfort criteria are achieved throughout the majority of the proposed development. However, there are some areas that will require further mitigation to ensure that the wind conditions are suitable for their intended use. These areas of concern are around the proposed retail frontages on the northeast corners of Buildings 2 and 3. These areas may be intended to have outdoor dining for cafés/restaurants and do not meet the Lawson sitting criteria.

Design refinements, at the Detailed SDDA stage, will therefore be required to reduce wind speeds in these areas. These may include the introduction of fixed canopies or retractable awnings, architectural or landscape screening, the use of podium balustrades, and/or the use of banners as roughing elements. Future Detailed SSDA would include updated wind modelling and mitigation measures for the final building design. Overall, the building envelopes are capable of complying with the relevant comfort criteria through the introduction of mitigation measures during the future detailed design stage.

1 Introduction

1.1 Sydney Metro West

Sydney Metro West will double rail capacity between Greater Parramatta and the Sydney Central Business District (CBD), transforming Sydney for generations to come. The once in a century infrastructure investment will have a target travel time of about 20 minutes between Parramatta and the Sydney CBD, link new communities to rail services and support employment growth and housing supply.

Stations have been confirmed at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock, The Bays, Pyrmont and Hunter Street (Sydney CBD).

Sydney Metro West station locations are shown in Figure 1-1.

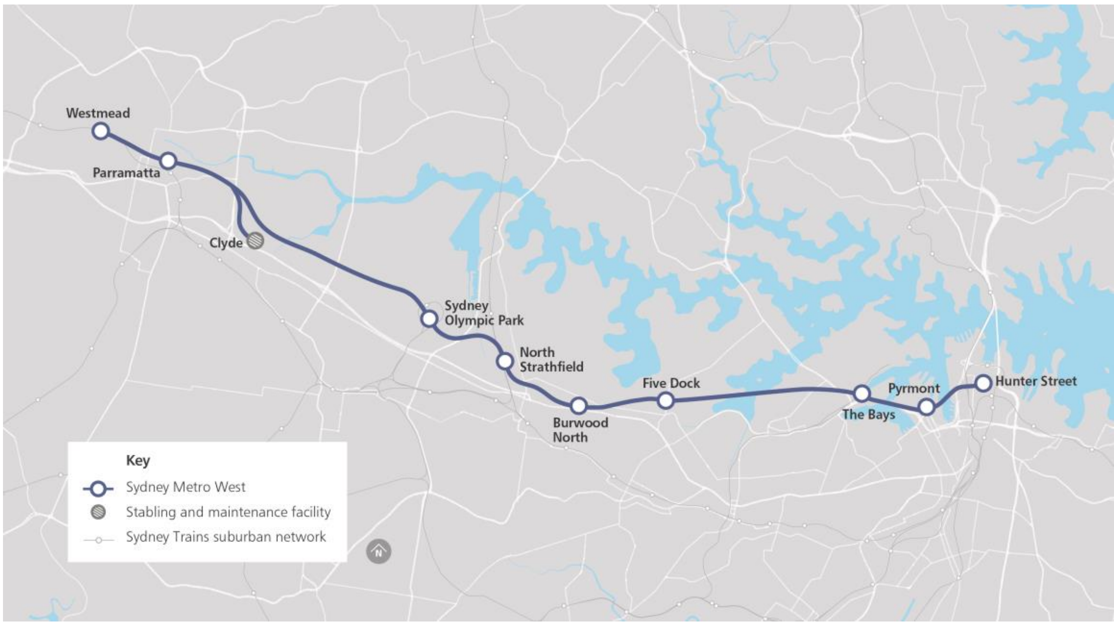


Figure 1-1 Sydney Metro West

1.2 Background and planning context

Sydney Metro is seeking to deliver Sydney Olympic Park metro station under a two-part planning approval process. The station fit-out infrastructure is to be delivered under a Critical State Significant Infrastructure (CSSI) application subject to provisions under Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act), while the over and adjacent station developments are to be delivered under a State Significant Development (SSD) subject to the provisions of Part 4 of the EP&A Act.

1.2.1 Critical State Significant Infrastructure

The State Significant Infrastructure (SSI) planning approval process for the Sydney Metro West metro line, including delivery of station infrastructure, has been broken down into a number of planning application stages, comprising the following:

- Concept and Stage 1 CSSI Approval (SSI-10038) – All major civil construction works between Westmead and The Bays including station excavation, tunnelling and demolition of existing buildings (approved 11 March 2021).

- Stage 2 CSSI Application (SSI-19238057) – All major civil construction works between The Bays and Hunter Street Station (under assessment).
- Stage 3 CSSI Application (SSI-22765520) – Tunnel fit-out, construction of stations, ancillary facilities and station precincts between Westmead and Hunter Street Station, and operation and maintenance of the Sydney Metro West line (under assessment).

1.2.2 State Significant Development Application

The SSD will be undertaken as a staged development with the subject Concept State Significant Development Application (Concept SSDA) being consistent with the meaning under section 4.22 of the EP&A Act and seeking conceptual approval for a building envelope, land uses, maximum building heights, a maximum gross floor area, pedestrian and vehicle access, vertical circulation arrangements and associated car parking. A subsequent Detailed SSD/s is to be prepared by a future development partner which will seek consent for detailed design and construction of the development.

1.3 Purpose of the report

This Pedestrian Wind Assessment supports a Concept SSDA submitted to the Department of Planning and Environment (DPE) pursuant to part 4 of the EP&A Act. The Concept SSDA is made under section 4.22 of the EP&A Act.

This report has been prepared to specifically respond to the Secretary's Environmental Assessment Requirements (SEARs) issued for the Concept SSDA on 18 February 2022 which states that the environmental impact statement is to address the following requirements:

SEARs requirement	Where addressed in report
4. Environmental amenity: • Assess amenity impacts on the surrounding locality, including lighting impacts, reflectivity, solar access, visual privacy, visual amenity, view loss and view sharing, overshadowing and wind impacts. A high level of environmental amenity for any surrounding residential or other sensitive land uses must be demonstrated.	Throughout this report.

This Pedestrian Wind Assessment report assesses the proposal for any wind impacts that may affect the environmental amenity of the area. It will assess the wind speeds for the existing site and the proposed development, using wind tunnel assessments, to determine the change in the local wind environment and the wind speeds across the site, and surrounds, based on the proposed development. These wind speeds are then assessed against the local and industry accepted wind criteria to determine the suitability of different areas of the site and to identify if any mitigation is required to ensure environmental amenity due to the proposed development.

2 The site and proposal

2.1 Site location and description

The site is located within Sydney Olympic Park and is situated within the City of Parramatta Local Government Area. The site is in the Central Precinct of Sydney Olympic Park and defined as Site 47 in the Draft SOP Master Plan (Interim Metro Review). The broader metro site is bound by Herb Elliot Avenue to the north, Olympic Boulevard to the west and Figtree Drive to the south as shown in Figure 2-1.

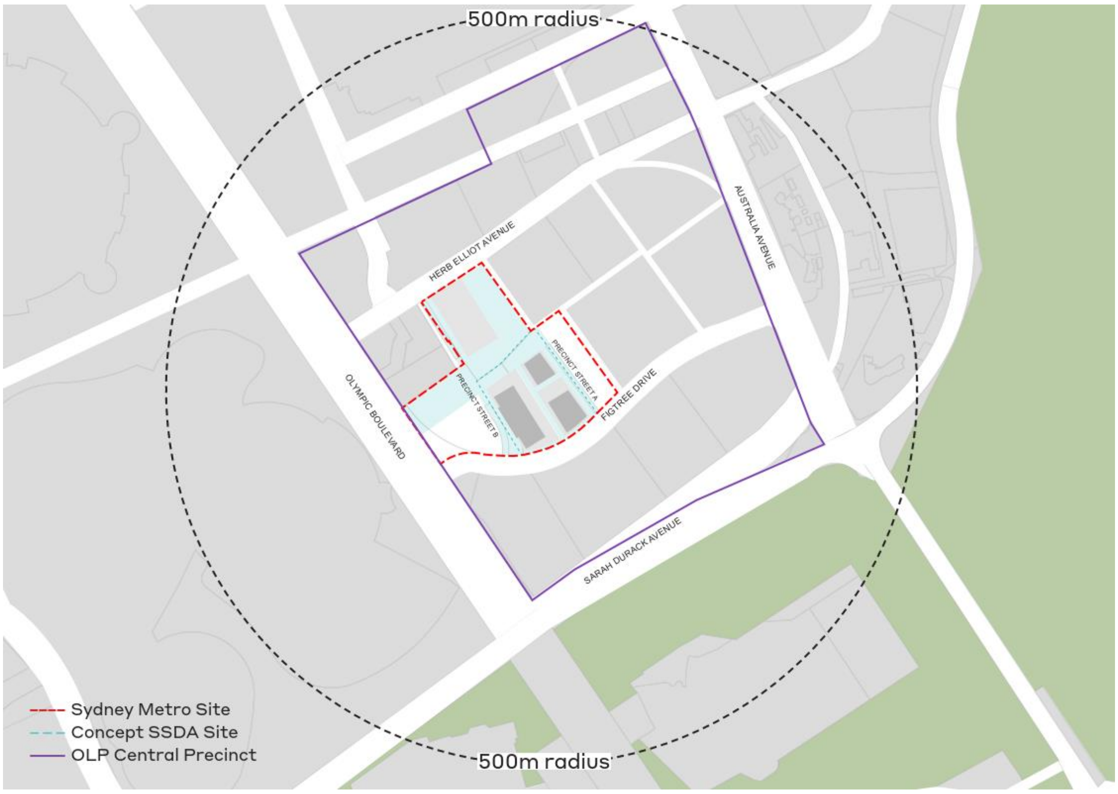


Figure 2-1 Sydney Olympic Park metro station location precinct

As described in Table 2-1, the site comprises part of Lot 59 in DP 786296 and Lot 58 in DP 786296, and comprises approximately 11,407m^2 of land.

Table 2-1 Site legal description

Street address	Legal description
5 Figtree Drive, Sydney Olympic Park	Lot 58 in DP 786296
7 Figtree Drive, Sydney Olympic Park	Lot 59 in DP 786296

2.2 Overview of this proposal

The Concept SSDA will seek consent for three building envelopes and the delivery of Precinct Street A as detailed in Table 2-2 and Figure 2-2.

Table 2-2 Sydney Olympic Park proposed development overview

Item	Description
Land use	**Building 1:** Commercial and retail **Building 2:** Commercial, retail and residential **Building 3:** Commercial, retail and residential
Building height (RL) / Number of storeys	**Building 1:** 120.20 / 21 storeys **Building 2**: 116.90 / 27 storeys **Building 3:** 171.50 / 45 storeys
Gross floor area (m^2)	**Building 1:** 28,517 **Building 2:** 12,089 **Building 3:** 27,384 **TOTAL: 68,000**
Car parking spaces	358

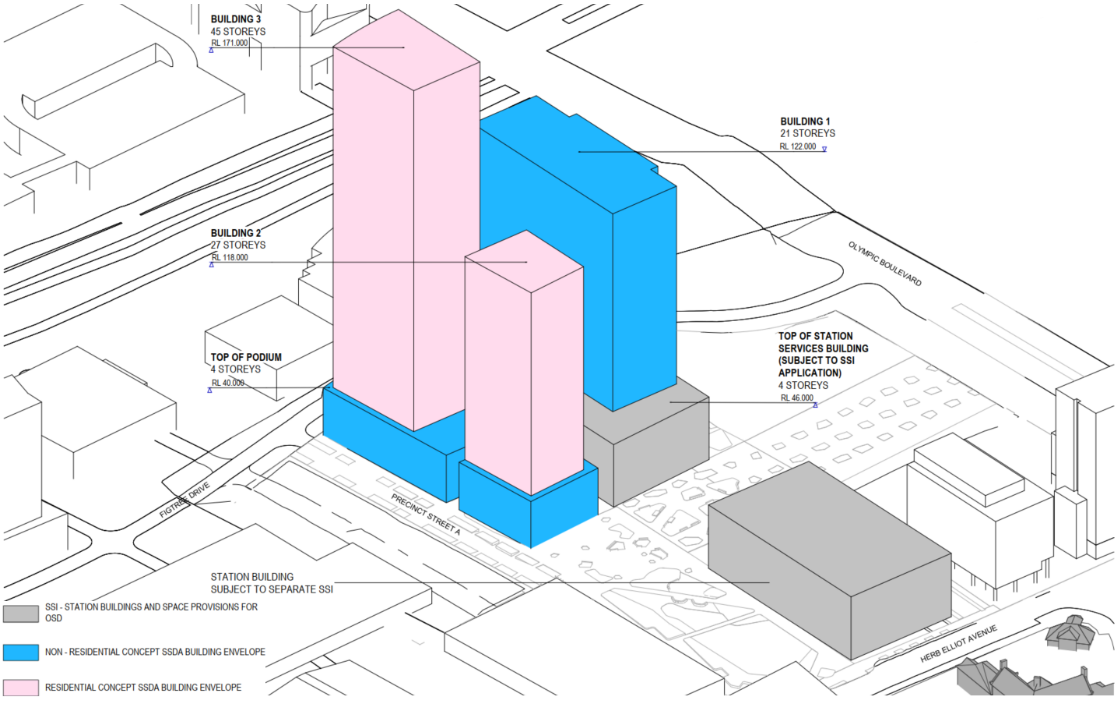


Figure 2-2 Proposed Concept SSDA development and CSSI approval

3 Methodology

3.1 Assessment criteria

Specific wind criteria are used to determine the acceptability of the measured wind environment to determine if it will be suitable for the intended use. This section outlines how the measured wind speeds were obtained, the criteria considered for the development, and the assessment locations.

3.1.1 State Environmental Planning Policy (Precincts – Central River City) 2021

Appendix 4 of the State Environmental Planning Policy (Precincts – Central River City) 2021 document outlines specific requirements for the Sydney Olympic Park site. Under section 30 (Design excellence) there is a provision for wind, relevant section is reproduced below. However, this does not outline any criteria or conditions that must be met in order to not have a negative impact on pedestrians within the precinct.

> ***"30 Design Excellence***
>
> *(2) In considering whether proposed development exhibits design excellence, the consent authority must have regard to the following matters –*
>
> > *(c) whether the building meets sustainable design principles in terms of sunlight, natural ventilation, wind, reflectivity, visual and acoustic privacy, safety and security and resource, energy and water efficiency."*

3.1.2 Sydney Olympic Park Authority

The Sydney Olympic Park Authority (SOPA) have developed a master plan for 2030 which includes building development specifications. However, there are no specific wind criteria. The only mention of a wind assessment is in section 4.0 point 5 of the Sydney Olympic Park Master Plan 2030 (2018 Review) document which states:

> *"For south and west facing buildings over eight storeys high, setbacks and other treatments may be required to minimise wind turbulence. All developments over 25m high will require assessment by a wind consultant."*

As the SOPA requirements do not provide specific wind criteria for the site, the Lawson Criteria (section 3.1.3), an industry-standard criteria, has been adopted.

3.1.3 Lawson Comfort Criteria

Assessment has been made against the Lawson (2001) criteria. The Lawson criteria for comfort, shown in Table 3-1, can be considered an industry-standard pedestrian comfort criteria.

Comfort wind speeds are defined as the exceedance of threshold wind speeds occurring less than 5% of the time (i.e., 95th percentile wind speeds). The value of 5% has been established as giving a reasonable allowance for extreme and relatively infrequent winds that are tolerable within each category. Note that the Lawson Criteria are defined in terms of gust equivalent mean (GEM) wind speeds, which account for the impact of turbulent/gusty conditions on comfort (refer to Appendix A.2).

Table 3-1 Lawson comfort criteria

Comfort rating	Description	GEM wind speed (m/s)	Appropriate usage	Description of wind effects
C1+ - Uncomfortable	Uncomfortable for all users	>10	Uncomfortable for all users	Umbrellas difficult to use. Hair blown straight
C1 - Fast walking	Fast or business walking	8-10	Areas where people are not expected to linger	Force of wind felt on body
C2 - Strolling	Leisurely walking	6-8	General walking or sightseeing	Dust and papers raised. Hair disarranged
C3 - Standing	Short period sitting/standing	4-6	Bus stops, building entrances	Light leaves and twigs in motion. Lightweight flags extend
C4 - Sitting	Long period sitting/standing	0-4	Reading a newspaper, eating a drinking	Light wind felt on face. Leaves rustle

Based on the Lawson Criteria, the region around the proposed development has been assigned a comfort rating of C3 (standing) since it is predominantly areas where pedestrians are expected to frequent and congregate. However, the ground level is designated as retail and therefore a comfort rating of C4 (sitting) is applied along the exterior of these buildings. Refer to Figure 3-1 for indicative ground floor layouts of the proposed development showing the building entrances and the retail and commercial spaces.

Figure 3-1 Proposed ground floor layout where red is retail, blue is commercial, orange is shared space and black is station

3.1.4 Safety Criteria

The Lawson (2001) safety criteria is based on an average recurrence interval of once a year. It states that a GEM wind speed which is greater than 20 m/s and occurs once per year can be considered as unsuitable for the public. This is equivalent to a 37 m/s 3-second gust wind speed. However, the City of Melbourne and Willington uses a 3-second gust wind speed of 20 m/s as a safety criterion. Thus, this criterion has been adopted for this assessment as it provides a more stringent assessment for the safety criteria (Table 3-2).

Table 3-2 Safety criteria

Comfort rating	Description	Gust wind speed (m/s)
S2	Suitable for general public	Less than 20
S1	Unsuitable for able bodied	Greater or equal to 20

3.2 Wind climate

Wind is a highly variable meteorological element, both in speed and direction. The selection of data and statistical representation of the wind climate can therefore have a large bearing on the outcome of a wind comfort assessment.

Historical weather data was used for the analysis and obtained from the Bureau of Meteorology (BOM) weather station at Bankstown Airport, which is situated 13km southwest of the site. Airport weather stations are generally the most reliable source of wind data as they are typically free from nearby obstructions and have uninterrupted, quality-controlled data for suitable time periods. While there are closer weather stations (notably the Sydney Olympic Park (Archery Centre)), the use of Bankstown Airport data ensures that there are no shielding effects which will impact the results of the pedestrian wind assessment.

From 2000 to 2019, 10-minute wind observations were converted to hourly means using methods outlined in Grange (2014). Scaling to correct for the difference in terrain roughness surrounding the site (i.e. due to buildings, trees, and other obstructions) was made and detailed in Appendix A.

Details of the statistical methods used and coefficients describing the wind probability distributions can also be found in Appendix A.

The scaled data is presented in the wind rose plot below, Figure 3-2. Here, the length and colour of the spoke sections represent the frequency and amplitude of recorded wind events, respectively.

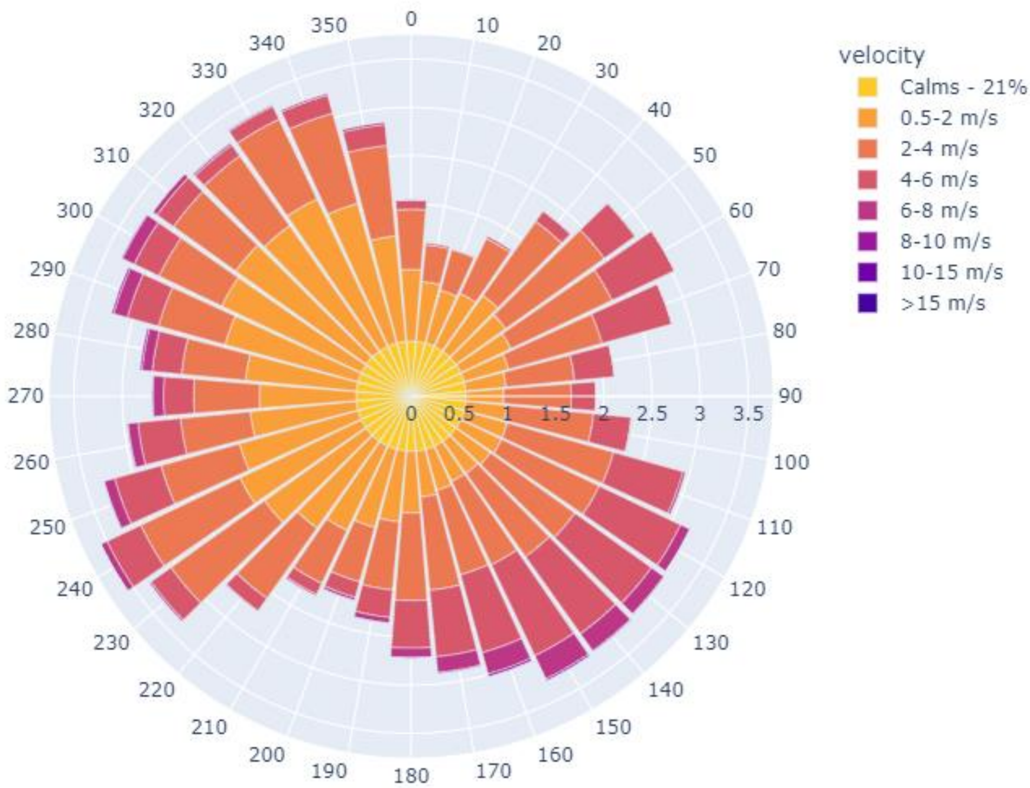


Figure 3-2 Wind rose plot of Bankstown Airport BOM data, 2000-2019

3.3 The wind tunnel model

Wind tunnel experiments were undertaken to determine the site-specific wind speeds for the existing buildings and proposed built form. Due to the nature of wind tunnel experiments, there are several factors that need to be considered (e.g. the wind tunnel configuration, approach flow, built environment, assessment locations, etc.).

3.3.1 Wind tunnel

Measurements were carried out using the atmospheric boundary layer wind tunnel at The University of Sydney. The tunnel has a test width of 2.5m, a turntable of diameter 2.4m, and a development length of approximately 15-20m. The turbulent boundary layer is established using a trip board, spires and roughness elements along the development length.

3.3.2 Establishment of the approach flow

The minimum requirements for an acceptable simulation of a neutrally stable atmospheric boundary layer are the modelling of:

- the variation of mean wind speed with height
- the variation of longitudinal component of turbulence with height
- the integral scale of turbulence
- a zero longitudinal pressure gradient.

The mean wind speed and turbulence intensity in the approach flow were modelled to within 10% of their target values. The integral length scale was within a factor of 3 of the value determined from the chosen geometric scaling ratio (1:400 in this case) (refer to Appendix B for the relevant scaling laws). Confirmation that the wind tunnel (using a trip board, turbulence elements and development length) adequately models the variation of mean wind speed with height and the variation of longitudinal component of turbulence with height for each terrain category is provided in Appendix B of this report.

3.3.3 Modelling of the near-field flow

Physical features such as significant buildings, structures, or topography, influence the near field flow and must be included as part of the local wind flow simulation. In general, all major structures and topographical features within a radius of 300m to 600m of the building site should be modelled to the correct scale, to an accuracy of 10% or better in accordance with the Australasian Wind Engineering Society Quality Assurance Manual AWES-QAM-1-2019.

A survey of the site shown in Figure 3-3 was carried out to acquire information on the footprint, form, and height of all buildings within a 450m radius of the site. Figure 3-4 to Figure 3-9 show the wind tunnel model and surroundings.

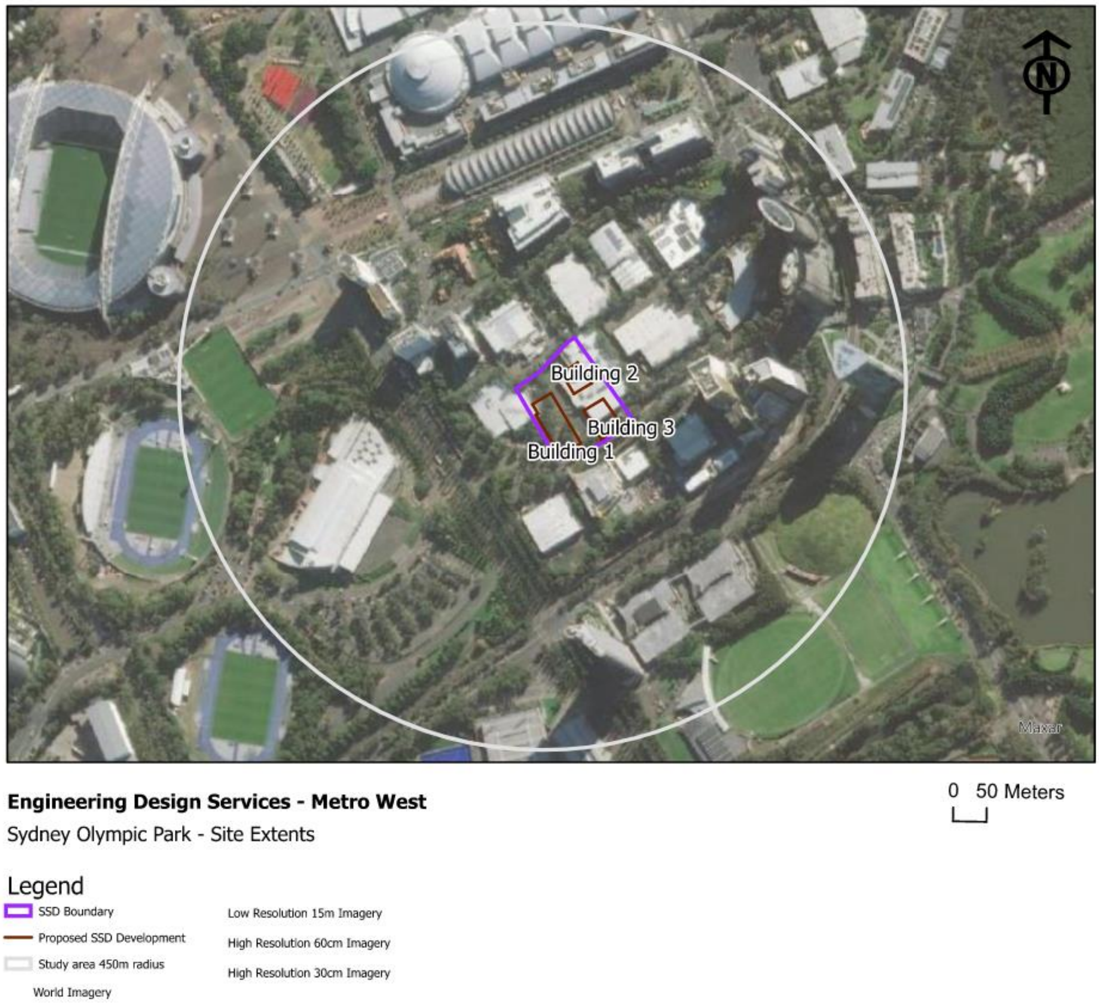


Figure 3-3 Existing buildings in the Sydney Olympic Park region with an overlay of the proposed site and the proposed development footprints

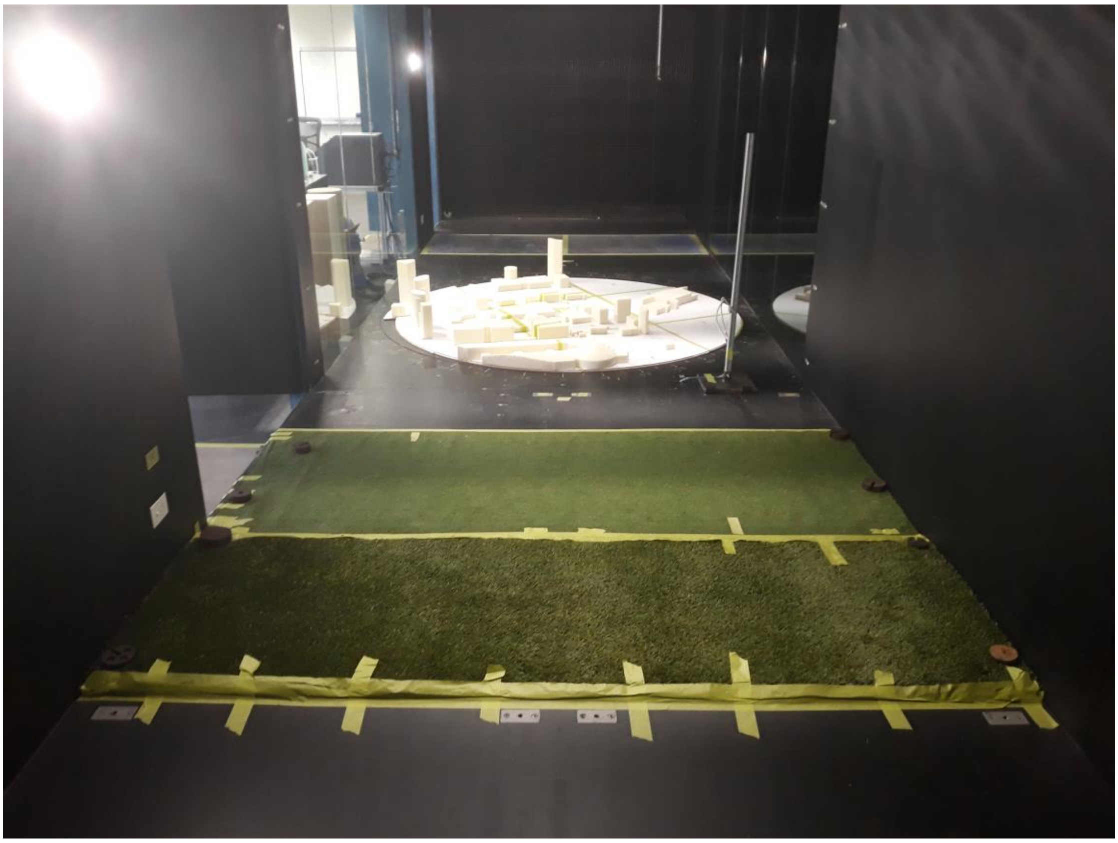


Figure 3-4 Wind tunnel model showing the approach region and overall modelled site

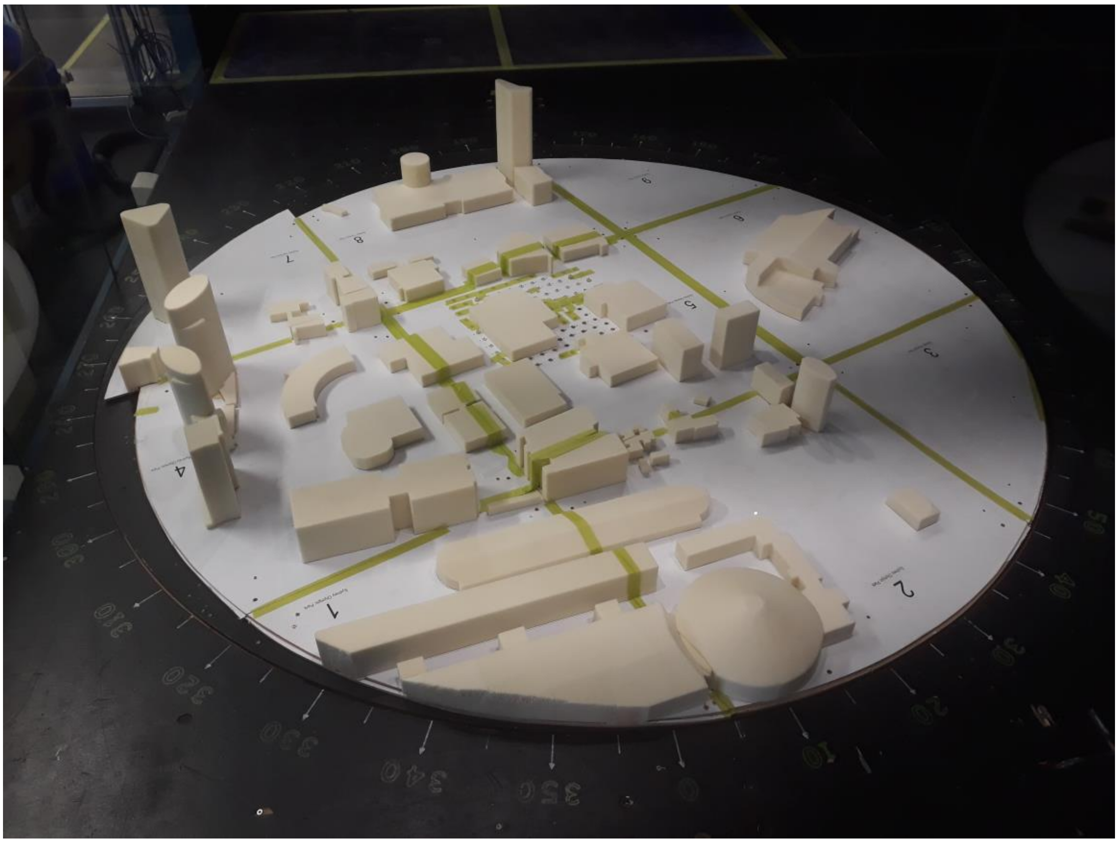


Figure 3-5 Wind tunnel model showing the existing buildings on the site

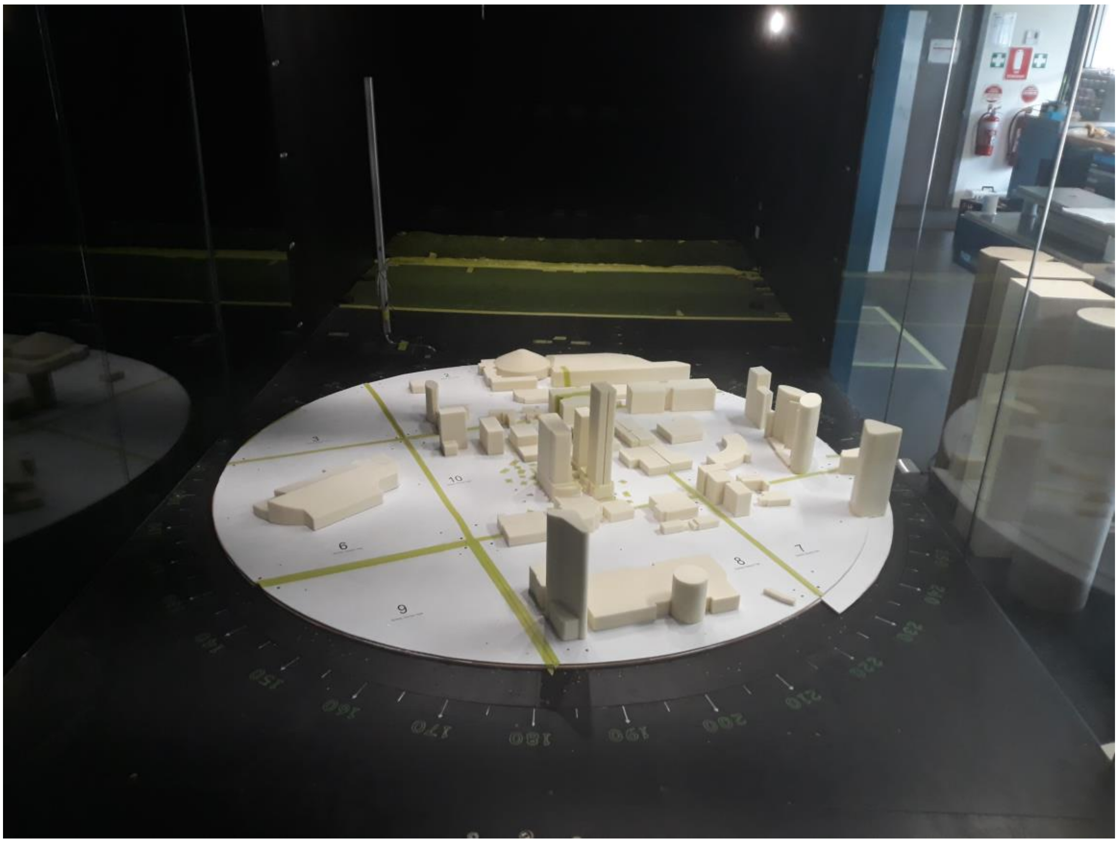


Figure 3-6 Wind tunnel model showing the existing surrounds and development buildings (viewed from the south)

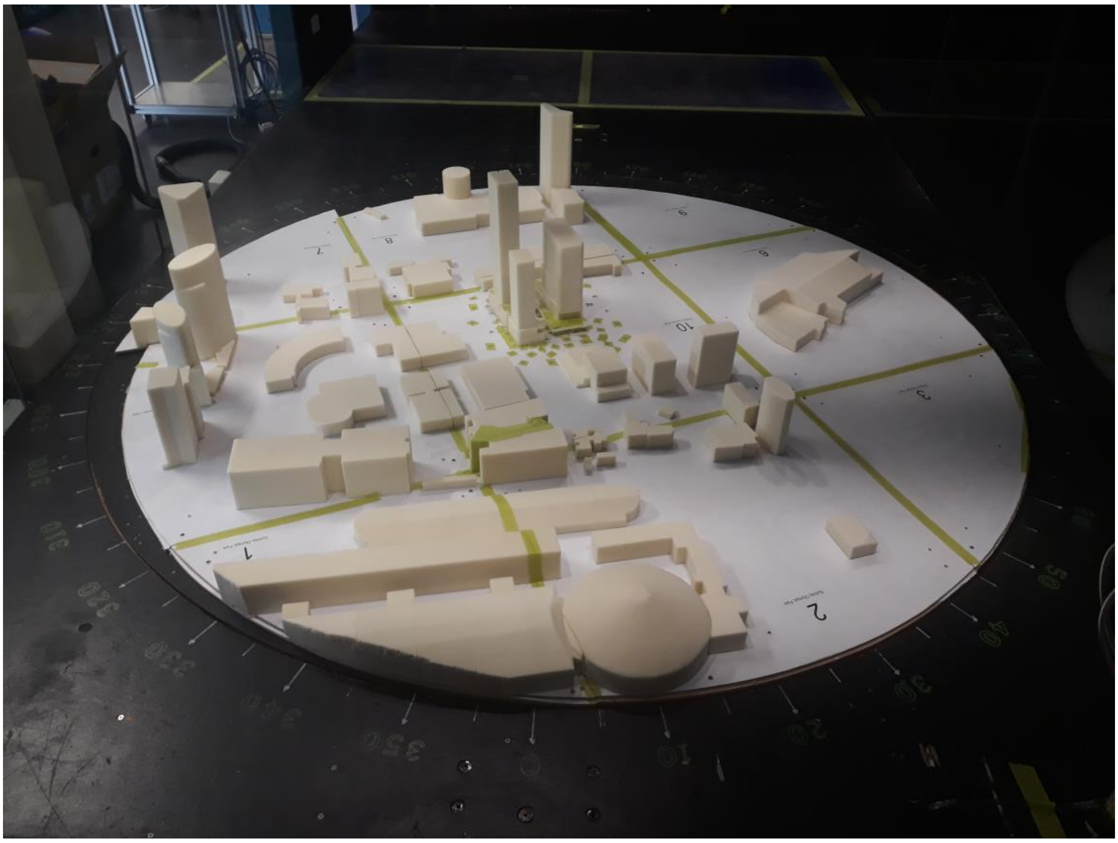


Figure 3-7 Wind tunnel model showing the existing surrounds and development buildings (viewed from the north)

Figure 3-8 Centre section showing the wind tunnel model for the development buildings

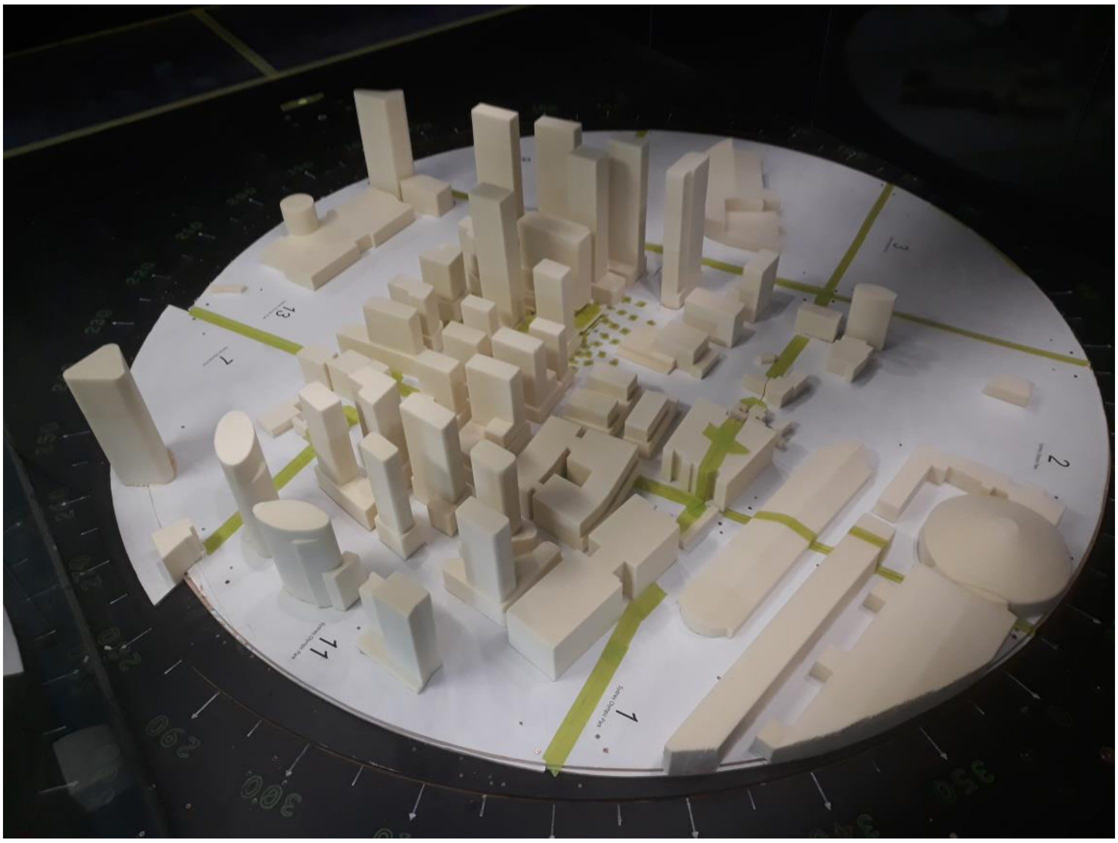


Figure 3-9 Wind tunnel model showing the masterplan surrounds

3.3.4 Test methodology

Measurements from the sensor array were taken for the full 360 degree azimuth range at 10 degree intervals, as required by AWES QAM. In addition to the local total and static pressures measured at each Irwin sensor, reference measurements of static and total pressure (measured using a pitot-static tube) were taken at the upstream edge of the turntable at a height of 0.38m (153m full-scale). This reference height is required to avoid interference with the flow over the model.

These measurements of ground-level wind speeds at the various locations are combined with the probability distribution of reference wind speed and direction to provide predictions of full-scale ground-level wind speeds. The following method was used for the analysis:

1. Time series of ground-level wind speeds were calculated from the Irwin sensor data using the calibration equation (refer to Appendix B of this report).
2. The maximum hourly 3-second gusts were calculated for each of these time series.
3. The gust wind speeds were converted to velocity ratios by dividing by the wind tunnel reference velocity (from the pitot-static tube) (refer to Appendix B for the sensor calibration and conversion from a pressure difference to a velocity).
4. Velocity ratios were then scaled to the 10m reference height of the BOM anemometer using Australian/New Zealand Standard AS/NZS 1170.2 gust profiles.
5. Comfort and safety wind speeds, representing the relative contributions of wind from all directions, were calculated using the statistical methods outlined in Appendix A. For each location, the probability of exceeding a certain wind speed was calculated using an iterative method, with the wind speed varied until the comfort exceedance probability was reached. This method was then repeated using the extreme value distribution and safety exceedance probability.
6. Gust wind speeds were converted to GEM wind speeds by dividing by a scaling factor of 1.85 (Lawson, 2001), to be used for comparison against the comfort criteria.

3.4 Assessment locations

The wind tunnel test is split in to three stages.

- Baseline investigations – assessing the existing buildings (pre-demolition) on the site to determine the existing wind climate.
- Proposed development – assessing the proposed development to determine the future wind climate.
- Masterplan developments – assessing the proposed development with the future master plan buildings based on the SOPA guidelines to determine the future wind climate.

3.4.1 Baseline investigations

For this study, a total of 66 ground level assessment locations within and around the proposed development site have been selected for analysis in the wind tunnel. The locations of the various assessment locations are presented in Figure 3-10 in the form of a marked-up plan drawing.

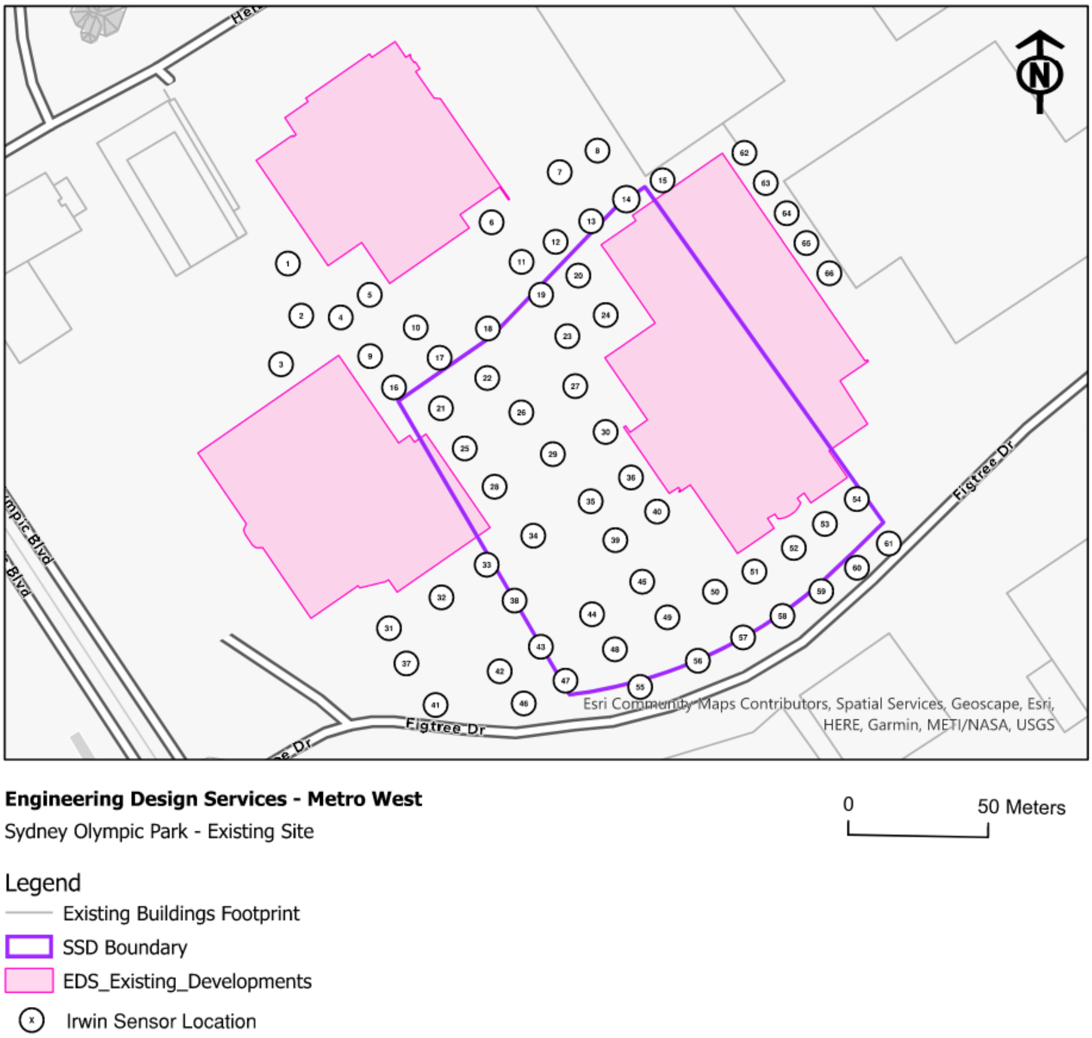


Figure 3-10 Irwin probe assessment locations for the existing built environment

3.4.2 Proposed development

For this study, a total of 52 ground level assessment locations within and around the proposed development site have been selected for analysis in the wind tunnel. The locations of the various assessment locations are presented in Figure 3-11 in the form of a marked-up plan drawing.

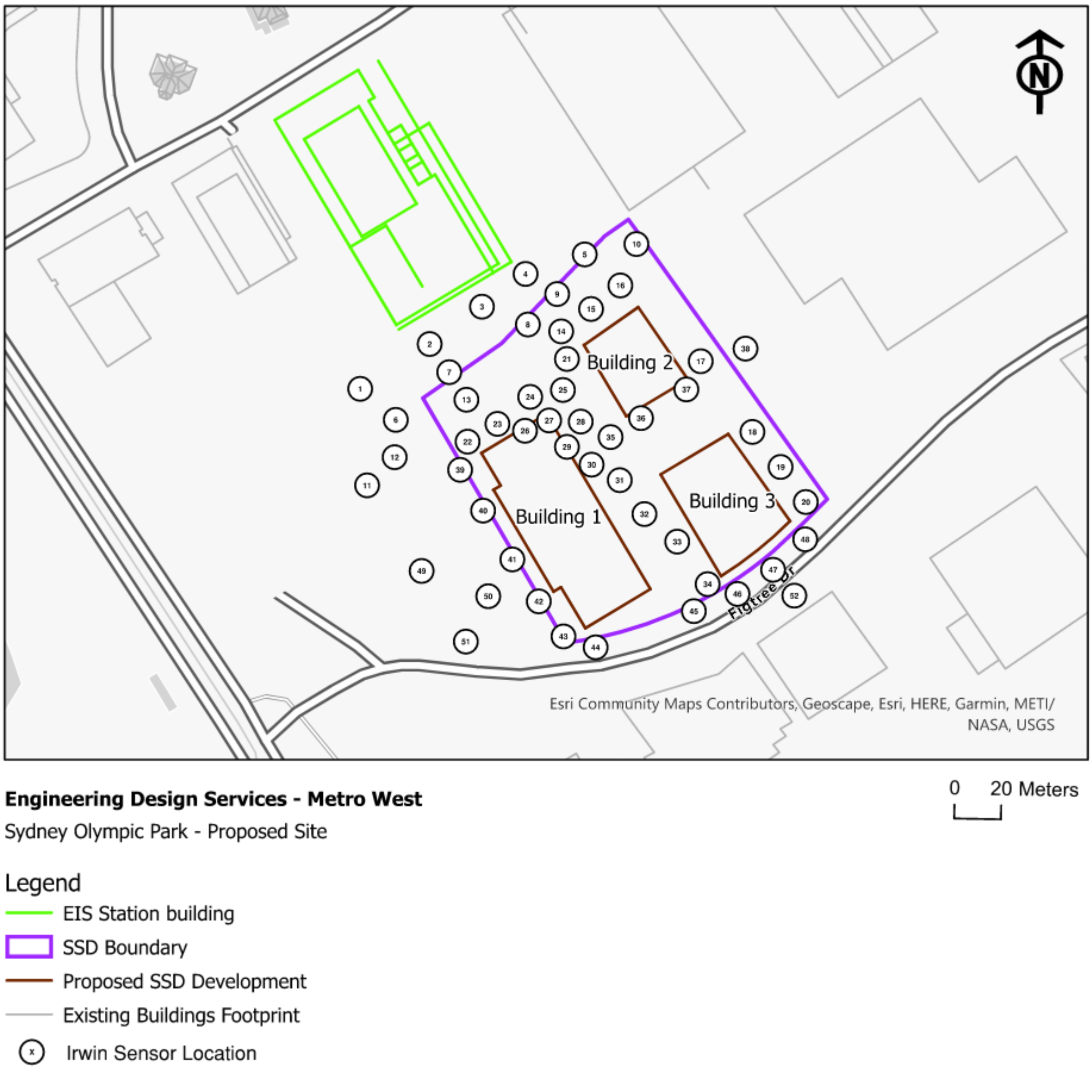


Figure 3-11 Irwin probe assessment locations for the proposed development

3.4.1 Masterplan developments

For this study, a total of 55 ground level assessment locations within and around the proposed development site have been selected for analysis in the wind tunnel. The locations of the various assessment locations are presented in Figure 3-12 in the form of a marked-up plan drawing.

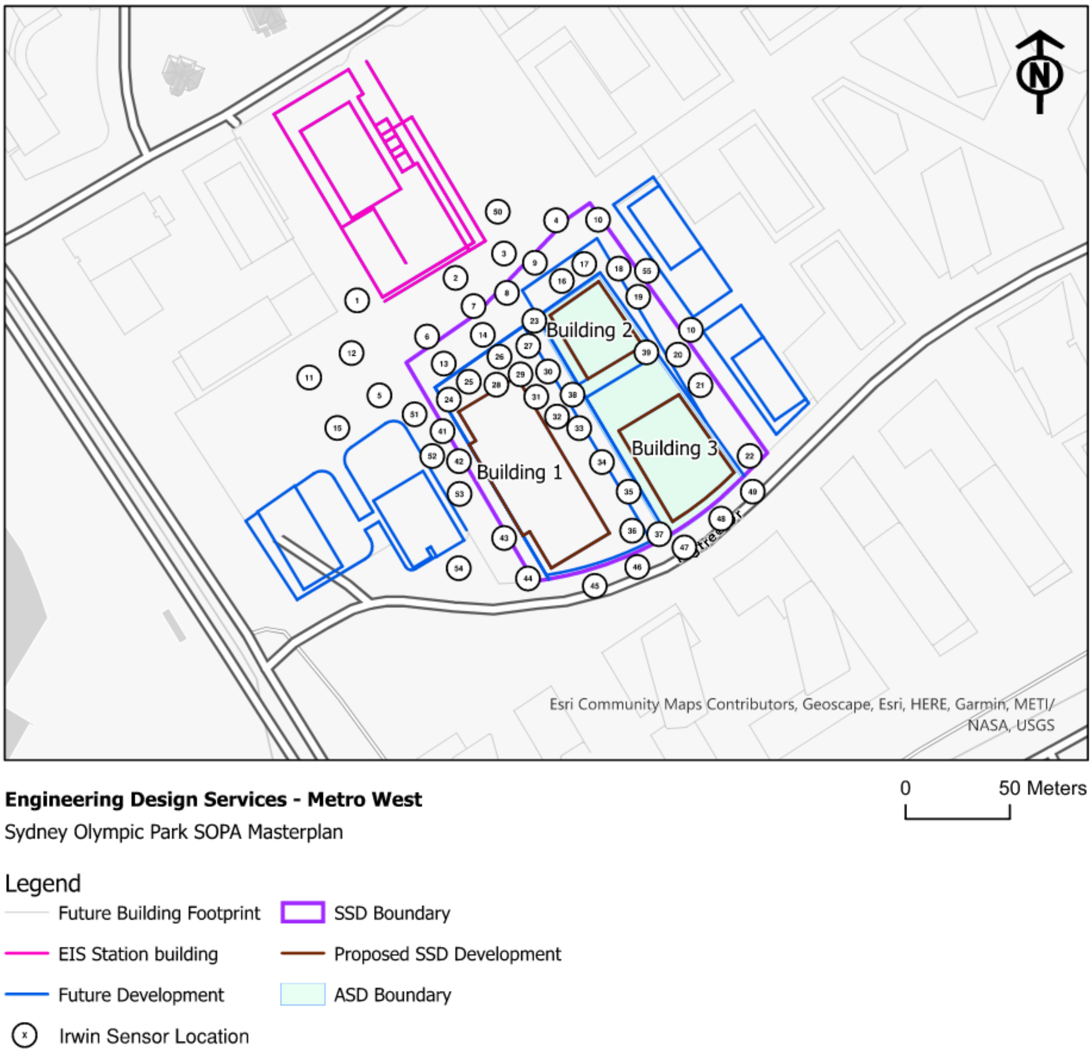


Figure 3-12 Irwin probe assessment locations for the proposed development with SOPA masterplan surrounds

4 Assessment

4.1 Baseline investigations

This assessment included 66 Irwin probes, located around the proposed development site, and their results are shown against the Lawson comfort and safety criteria in Figure 4-1 and Figure 4-2, respectively. Results are also tabulated in Table 4-1 to show the wind speeds and the achieved criteria.

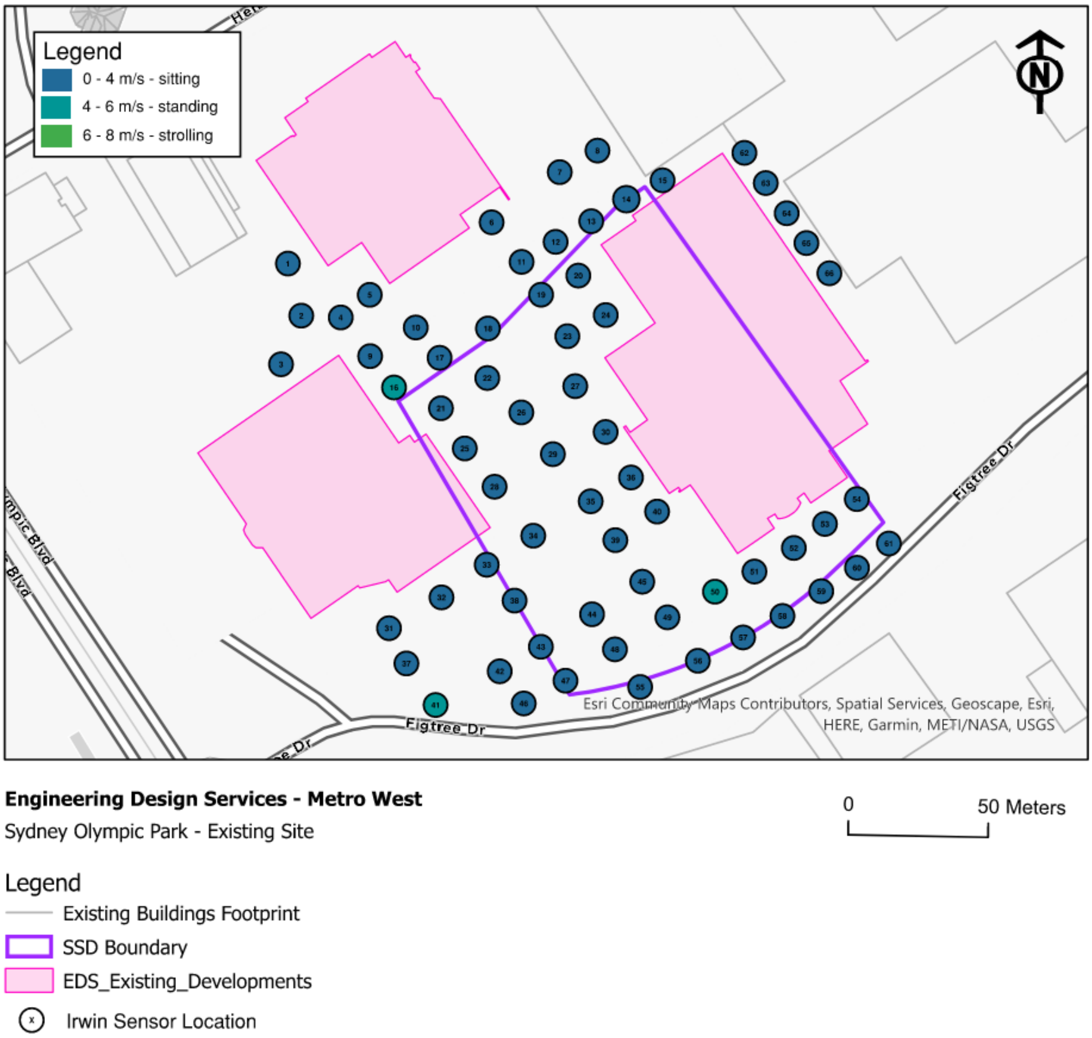


Figure 4-1 Irwin sensor Lawson comfort results for existing buildings

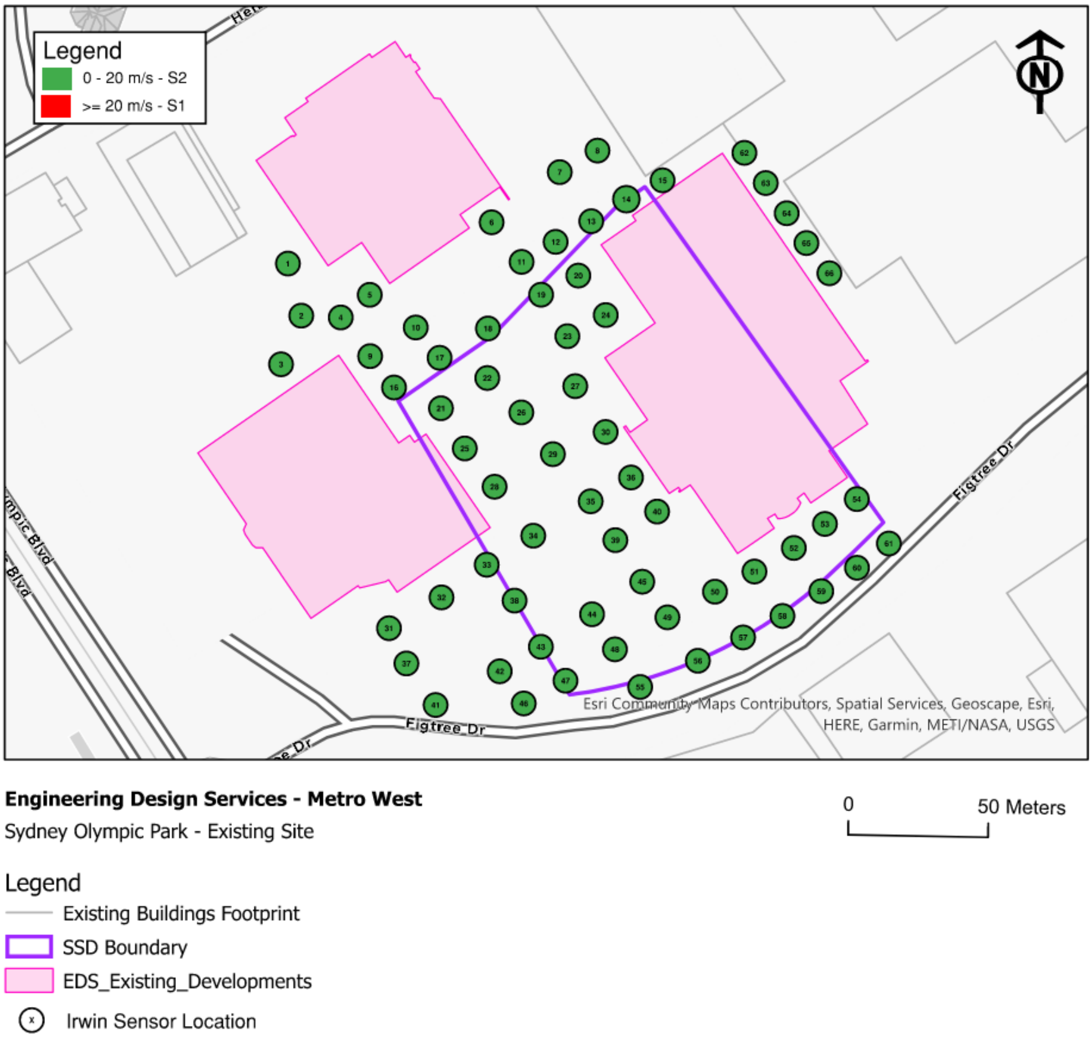


Figure 4-2 Irwin sensor Lawson safety results for existing buildings

Table 4-1 Irwin sensor wind speed results for existing buildings

Location	Comfort GEM wind speed (m/s)	Achieved comfort criteria	Safety gust wind speed (m/s)	Achieved safety criteria
1	3.0	Sitting	8.1	S2
2	3.6	Sitting	9.4	S2
3	3.1	Sitting	9.5	S2
4	3.4	Sitting	10.7	S2
5	2.6	Sitting	7.9	S2
6	3.5	Sitting	9.4	S2
7	2.8	Sitting	7.6	S2
8	3.1	Sitting	9.1	S2
9	2.8	Sitting	7.3	S2
10	3.0	Sitting	7.6	S2
11	2.4	Sitting	6.3	S2
12	3.3	Sitting	8.8	S2
13	2.6	Sitting	6.9	S2
14	2.5	Sitting	7.0	S2
15	2.2	Sitting	6.5	S2
16	4.1	Standing	10.4	S2
17	2.9	Sitting	7.6	S2
18	2.5	Sitting	7.2	S2
19	2.3	Sitting	8.3	S2
20	3.0	Sitting	8.1	S2
21	2.2	Sitting	6.0	S2
22	3.2	Sitting	8.4	S2
23	3.1	Sitting	10.1	S2

Location	Comfort GEM wind speed (m/s)	Achieved comfort criteria	Safety gust wind speed (m/s)	Achieved safety criteria
24	2.3	Sitting	7.5	S2
25	2.4	Sitting	6.1	S2
26	2.7	Sitting	6.8	S2
27	2.8	Sitting	7.7	S2
28	2.6	Sitting	7.3	S2
29	3.0	Sitting	8.2	S2
30	2.9	Sitting	8.0	S2
31	3.5	Sitting	9.8	S2
32	2.7	Sitting	7.3	S2
33	3.4	Sitting	9.1	S2
34	3.1	Sitting	8.7	S2
35	3.3	Sitting	9.0	S2
36	2.9	Sitting	8.0	S2
37	3.5	Sitting	10.5	S2
38	3.5	Sitting	12.3	S2
39	2.8	Sitting	10.1	S2
40	3.1	Sitting	8.5	S2
41	4.5	Standing	13.5	S2
42	2.9	Sitting	7.9	S2
43	3.0	Sitting	9.8	S2
44	2.4	Sitting	7.2	S2
45	3.8	Sitting	10.3	S2
46	3.4	Sitting	11.0	S2
47	2.8	Sitting	9.2	S2

Location	Comfort GEM wind speed (m/s)	Achieved comfort criteria	Safety gust wind speed (m/s)	Achieved safety criteria
48	4.0	Sitting	10.6	S2
49	3.5	Sitting	9.2	S2
50	4.2	Standing	11.3	S2
51	3.9	Sitting	11.2	S2
52	2.9	Sitting	7.8	S2
53	2.9	Sitting	8.0	S2
54	2.9	Sitting	8.2	S2
55	2.7	Sitting	9.9	S2
56	2.9	Sitting	7.7	S2
57	3.8	Sitting	10.6	S2
58	3.7	Sitting	10.8	S2
59	3.7	Sitting	11.3	S2
60	2.6	Sitting	7.1	S2
61	3.5	Sitting	10.0	S2
62	2.9	Sitting	8.1	S2
63	3.0	Sitting	8.1	S2
64	2.8	Sitting	7.5	S2
65	3.5	Sitting	9.5	S2
66	3.6	Sitting	9.9	S2

4.2 Proposed development

This assessment included 52 Irwin probes, located around the proposed development site, and their results are shown against the Lawson comfort and safety criteria in Figure 4-3 and Figure 4-4, respectively. Results are also tabulated in Table 4-2 to show the comparison between the target criteria and the achieved criteria, along with a pass/fail grade to determine if the wind speed is suitable for the intended use.

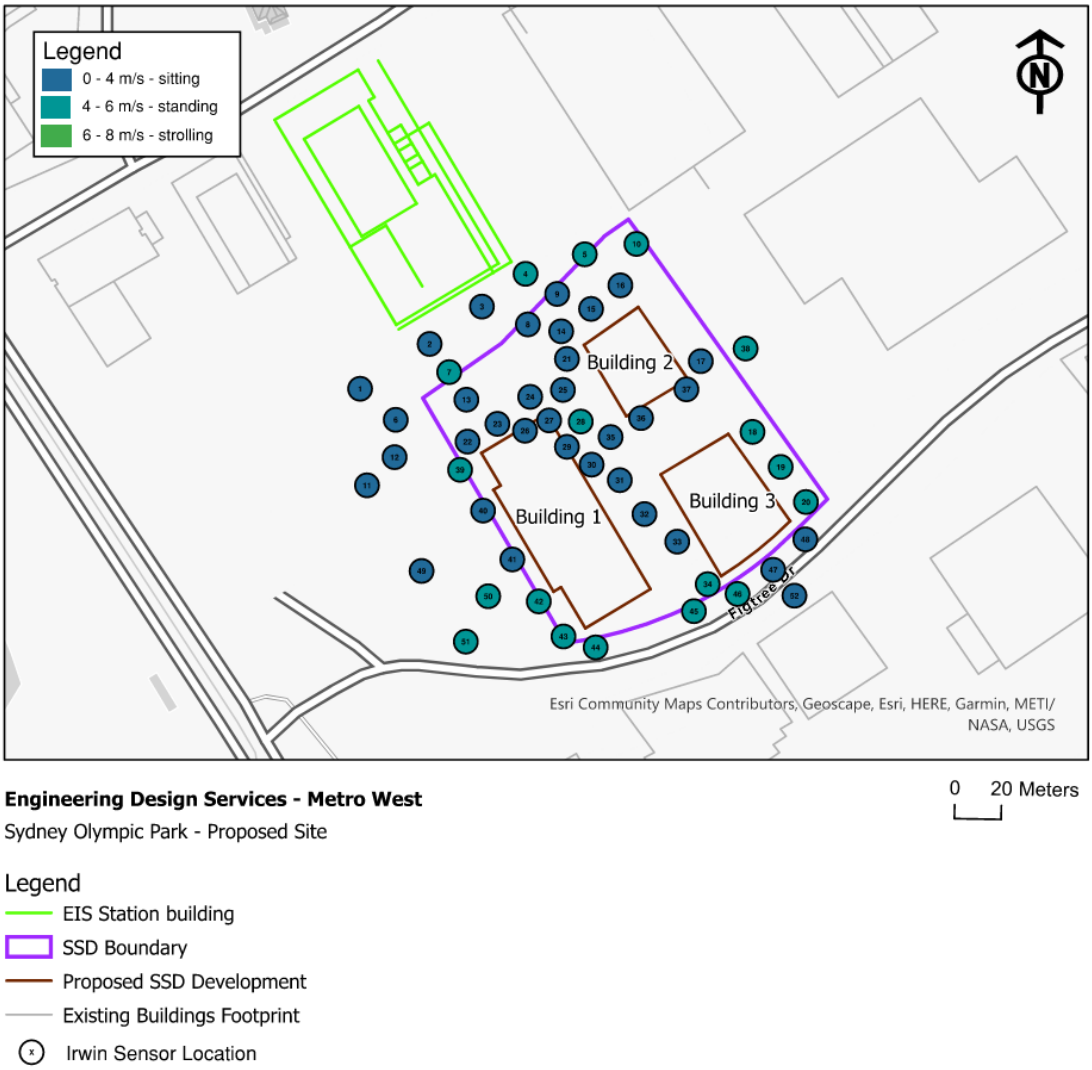


Figure 4-3 Irwin sensor Lawson comfort results for the proposed development

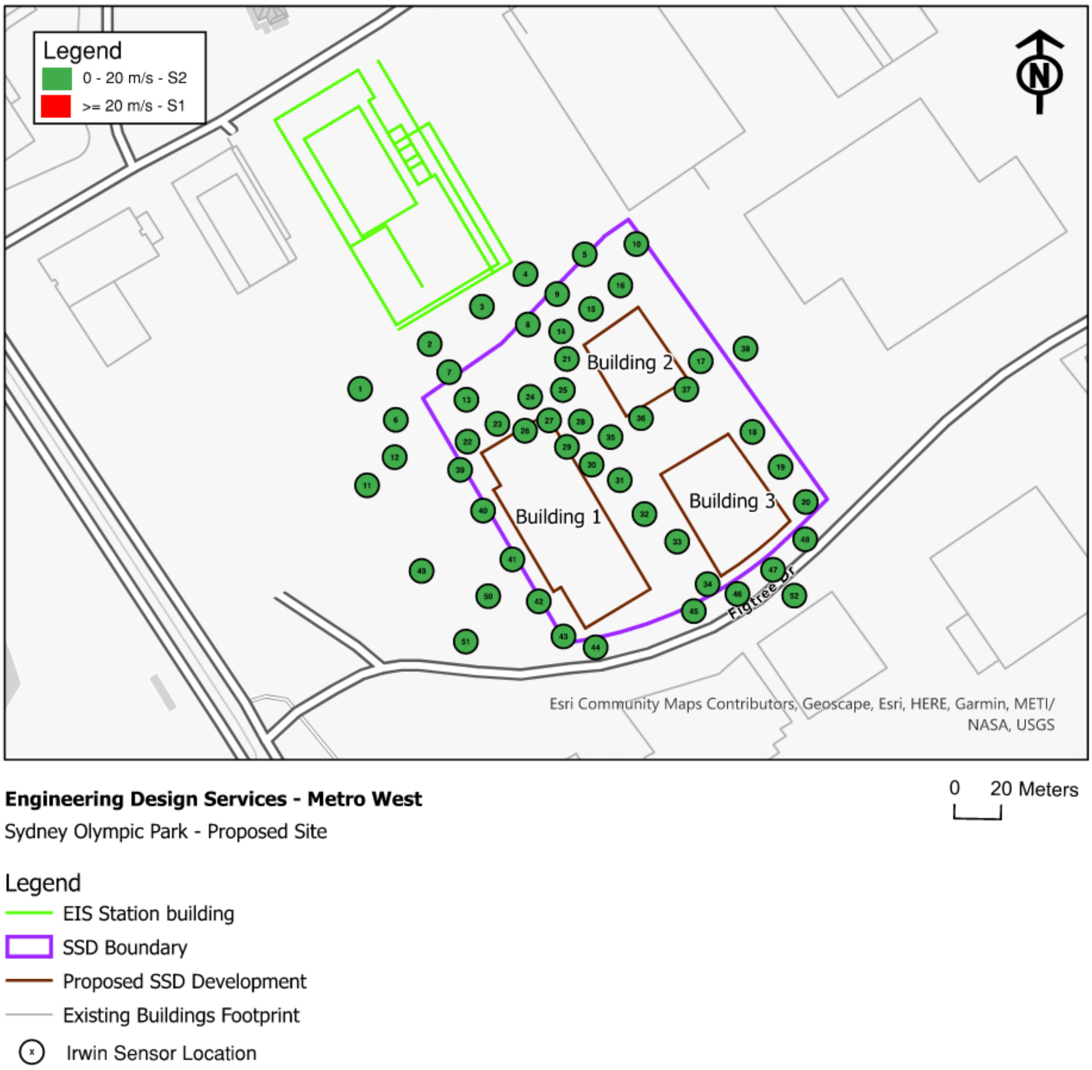


Figure 4-4 Irwin sensor safety results for the proposed development

Table 4-2 Irwin sensor wind speed results for the proposed development

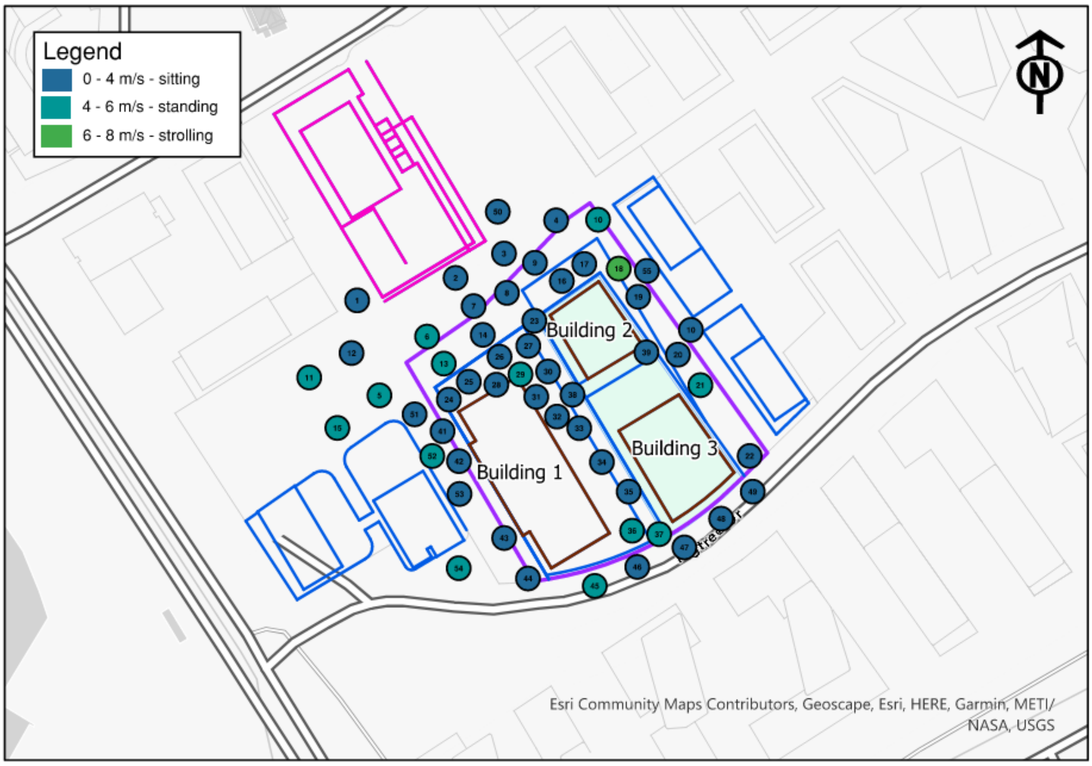
Location	Comfort GEM wind speed (m/s)	Achieved comfort criteria	Desired comfort criteria	Safety gust wind speed (m/s)	Achieved safety criteria	Pass/Fail
1	3.0	Sitting	Standing	9.3	S2	Pass
2	3.3	Sitting	Standing	10.9	S2	Pass
3	3.2	Sitting	Standing	10.0	S2	Pass
4	4.3	Standing	Standing	11.5	S2	Pass
5	5.5	Standing	Standing	16.2	S2	Pass
6	3.8	Sitting	Standing	12.6	S2	Pass
7	4.2	Standing	Standing	13.3	S2	Pass
8	3.3	Sitting	Standing	9.0	S2	Pass
9	2.9	Sitting	Standing	9.4	S2	Pass
10	4.9	Standing	Standing	13.4	S2	Pass
11	3.8	Sitting	Standing	10.8	S2	Pass
12	3.6	Sitting	Standing	11.9	S2	Pass
13	3.2	Sitting	Standing	14.2	S2	Pass
14	3.7	Sitting	Standing	11.1	S2	Pass
15	3.5	Sitting	Sitting	11.1	S2	Pass
16	3.7	Sitting	Sitting	10.9	S2	Pass
17	4.0	Sitting	Sitting	11.1	S2	Pass
18	4.9	Standing	Sitting	13.7	S2	Fail - Comfort
19	5.5	Standing	Standing	15.2	S2	Pass
20	4.2	Standing	Standing	12.1	S2	Pass
21	3.1	Sitting	Standing	9.1	S2	Pass
22	3.2	Sitting	Standing	10.5	S2	Pass
23	2.1	Sitting	Standing	7.8	S2	Pass

Location	Comfort GEM wind speed (m/s)	Achieved comfort criteria	Desired comfort criteria	Safety gust wind speed (m/s)	Achieved safety criteria	Pass/Fail
24	3.0	Sitting	Standing	8.1	S2	Pass
25	3.7	Sitting	Standing	10.4	S2	Pass
26	3.2	Sitting	Standing	8.9	S2	Pass
27	4.0	Sitting	Standing	11.0	S2	Pass
28	4.6	Standing	Standing	12.7	S2	Pass
29	2.1	Sitting	Standing	5.5	S2	Pass
30	3.2	Sitting	Standing	8.7	S2	Pass
31	4.8	Standing	Standing	13.2	S2	Pass
32	3.3	Sitting	Sitting	9.2	S2	Pass
33	2.9	Sitting	Sitting	8.0	S2	Pass
34	5.4	Standing	Standing	15.2	S2	Pass
35	4.0	Sitting	Standing	12.5	S2	Pass
36	3.1	Sitting	Sitting	9.0	S2	Pass
37	3.6	Sitting	Sitting	9.7	S2	Pass
38	4.1	Standing	Standing	11.4	S2	Pass
39	4.1	Standing	Standing	14.1	S2	Pass
40	3.0	Sitting	Standing	8.9	S2	Pass
41	3.2	Sitting	Standing	10.3	S2	Pass
42	4.7	Standing	Standing	14.5	S2	Pass
43	5.1	Standing	Standing	16.3	S2	Pass
44	5.2	Standing	Standing	16.9	S2	Pass
45	4.1	Standing	Standing	12.3	S2	Pass
46	4.4	Standing	Standing	12.8	S2	Pass
47	3.4	Sitting	Standing	10.0	S2	Pass

Location	Comfort GEM wind speed (m/s)	Achieved comfort criteria	Desired comfort criteria	Safety gust wind speed (m/s)	Achieved safety criteria	Pass/Fail
48	4.0	Sitting	Standing	12.4	S2	Pass
49	3.7	Sitting	Standing	11.1	S2	Pass
50	4.6	Standing	Standing	13.9	S2	Pass
51	4.2	Standing	Standing	13.3	S2	Pass
52	2.4	Sitting	Standing	6.8	S2	Pass

4.3 Masterplan developments

This assessment included 55 Irwin probes, located around the proposed development site, and their results are shown against the Lawson comfort and safety criteria in Figure 4-5 and Figure 4-6, respectively. Results are also tabulated in Table 4-3 to show the comparison between the target criteria and the achieved criteria, along with a pass/fail grade to determine if the wind speed is suitable for the intended use.



0 50 Meters

Engineering Design Services - Metro West
Sydney Olympic Park SOPA Masterplan

Legend
- Future Building Footprint
- SSD Boundary
- EIS Station building
- Proposed SSD Development
- Future Development
- ASD Boundary
- Irwin Sensor Location

Figure 4-5 Irwin sensor Lawson comfort results for the proposed development with SOPA masterplan surrounds

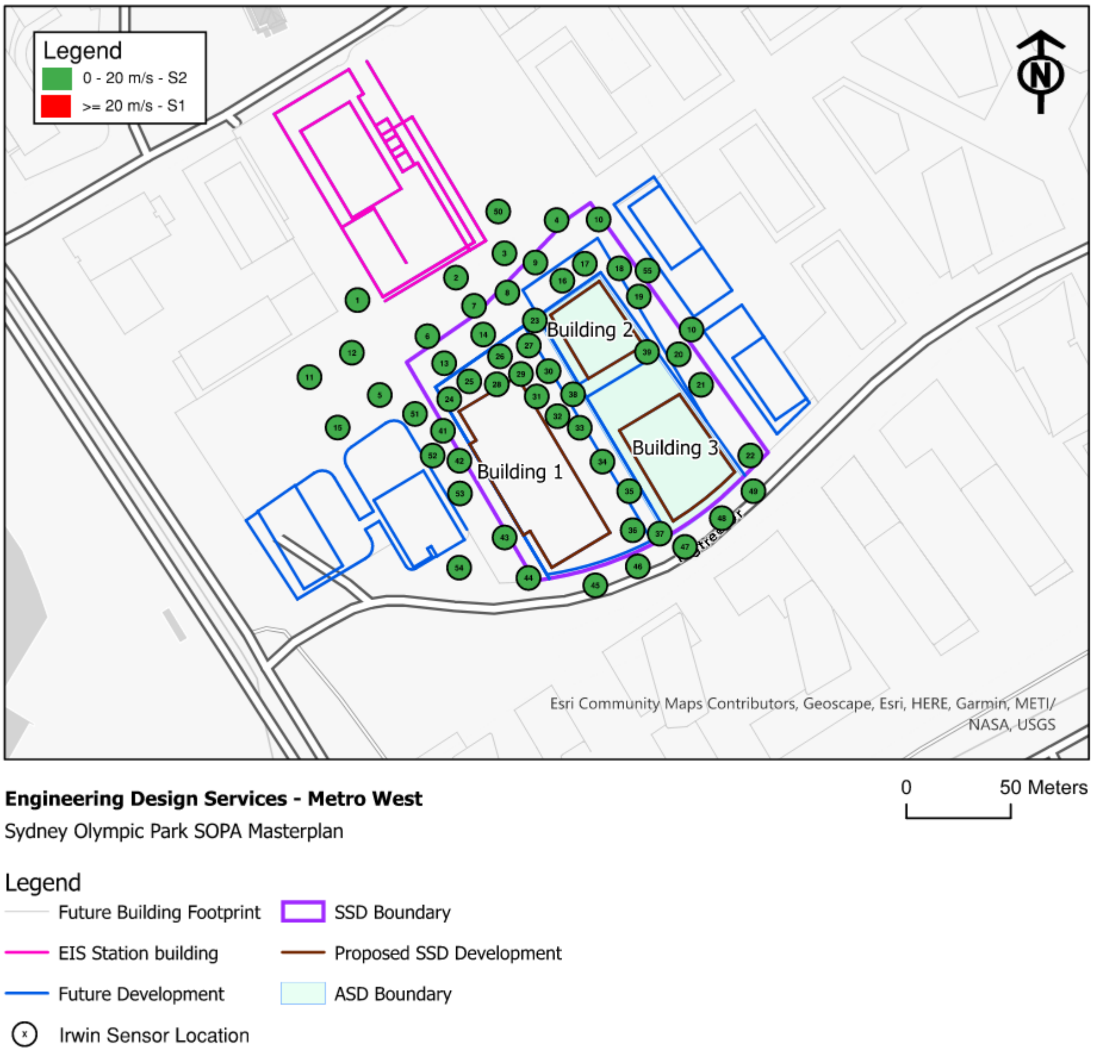


Figure 4-6 Irwin sensor safety results for proposed development with SOPA masterplan surrounds

Table 4-3 Irwin sensor wind speed results for the proposed development

Location	Comfort GEM wind speed (m/s)	Achieved comfort criteria	Desired comfort criteria	Safety gust wind speed (m/s)	Achieved safety criteria	Pass/Fail
1	3.9	Sitting	Standing	13.3	S2	Pass
2	3.6	Sitting	Standing	13.3	S2	Pass
3	2.5	Sitting	Standing	8.5	S2	Pass
4	3.6	Sitting	Standing	12.4	S2	Pass
5	4.4	Standing	Standing	14.7	S2	Pass
6	4.0	Sitting	Standing	14.7	S2	Pass
7	3.9	Sitting	Standing	14.3	S2	Pass
8	3.5	Sitting	Standing	11.9	S2	Pass
9	3.0	Sitting	Standing	10.6	S2	Pass
10	4.1	Standing	Standing	11.4	S2	Pass
11	4.7	Standing	Standing	14.0	S2	Pass
12	3.9	Sitting	Standing	13.1	S2	Pass
13	4.5	Standing	Standing	16.7	S2	Pass
14	2.5	Sitting	Standing	10.1	S2	Pass
15	4.1	Standing	Standing	14.2	S2	Pass
16	2.6	Sitting	Sitting	9.3	S2	Pass
17	2.4	Sitting	Sitting	9.0	S2	Pass
18	7.3	Strolling	Sitting	19.3	S2	Fail - Comfort
19	3.9	Sitting	Sitting	10.9	S2	Pass
20	4.0	Sitting	Sitting	11.1	S2	Pass
21	4.1	Standing	Sitting	11.4	S2	Fail - Comfort
22	3.3	Sitting	Standing	9.4	S2	Pass
23	1.9	Sitting	Standing	5.8	S2	Pass

Location	Comfort GEM wind speed (m/s)	Achieved comfort criteria	Desired comfort criteria	Safety gust wind speed (m/s)	Achieved safety criteria	Pass/Fail
24	2.5	Sitting	Standing	9.4	S2	Pass
25	3.0	Sitting	Standing	10.7	S2	Pass
26	3.4	Sitting	Standing	11.0	S2	Pass
27	3.6	Sitting	Standing	12.4	S2	Pass
28	2.0	Sitting	Standing	5.5	S2	Pass
29	4.3	Standing	Standing	11.6	S2	Pass
30	3.9	Sitting	Standing	11.8	S2	Pass
31	1.9	Sitting	Standing	6.2	S2	Pass
32	3.3	Sitting	Standing	9.8	S2	Pass
33	2.7	Sitting	Standing	9.1	S2	Pass
34	3.4	Sitting	Sitting	10.3	S2	Pass
35	3.6	Sitting	Sitting	10.3	S2	Pass
36	4.4	Standing	Standing	12.6	S2	Pass
37	5.2	Standing	Standing	14.1	S2	Pass
38	3.7	Sitting	Standing	12.0	S2	Pass
39	2.4	Sitting	Sitting	6.5	S2	Pass
40	2.9	Sitting	Standing	11.4	S2	Pass
41	3.8	Sitting	Standing	11.1	S2	Pass
42	3.8	Sitting	Standing	11.0	S2	Pass
43	3.3	Sitting	Standing	10.0	S2	Pass
44	4.0	Sitting	Standing	13.0	S2	Pass
45	4.6	Standing	Standing	13.3	S2	Pass
46	3.5	Sitting	Standing	9.7	S2	Pass
47	3.5	Sitting	Standing	9.3	S2	Pass

Location	Comfort GEM wind speed (m/s)	Achieved comfort criteria	Desired comfort criteria	Safety gust wind speed (m/s)	Achieved safety criteria	Pass/Fail
48	3.7	Sitting	Standing	10.5	S2	Pass
49	3.5	Sitting	Standing	9.9	S2	Pass
50	3.4	Sitting	Standing	8.9	S2	Pass
51	3.5	Sitting	Standing	9.7	S2	Pass
52	4.3	Standing	Standing	11.9	S2	Pass
53	3.4	Sitting	Standing	10.0	S2	Pass
54	4.1	Standing	Standing	11.6	S2	Pass
55	4.0	Sitting	Standing	11.9	S2	Pass

4.4 Discussion

The results of the assessment indicate that wind speeds are generally compliant with the intended usage of each area of the proposed development, when assessed against the Lawson comfort criteria. However, there are some areas that will require further mitigation to ensure that the wind conditions are suitable for their intended use. These areas are discussed below:

- Proposed development with existing surrounds:
  - Building 1 –
    - Ground level winds are satisfactory and achieve the C3 (standing) criterion.
    - Achieves S2 category around the base of the building for safety.
  - Building 2 –
    - Ground level winds are satisfactory and achieve the C4 (sitting) criterion in the northeast corner where a retail tenancy is likely and the C3 (standing) criterion in all other areas.
    - Achieves S2 category around the base of the building for safety.
  - Building 3 –
    - Ground level winds are generally satisfactory, achieving the C3 (standing) criterion around the entire building. However, there is likely to be a retail tenancy on the northeast corner which would be required to achieve the C4 (sitting) criterion which it does not currently.
    - Achieves S2 category around the base of the building for safety.
  - Precinct area –
    - Ground level winds are satisfactory and achieve the C3 (standing) criterion.
    - Achieves S2 category around the base of the building for safety.
- Proposed development with SOPA Masterplan surrounds:
  - Building 1 –
    - Ground level winds are satisfactory and achieve the C3 (standing) criterion.
    - Achieves S2 category around the base of the building for safety.
  - Building 2 –
    - Ground level winds are generally satisfactory, achieving the C4 (standing) criterion around most of the building. However, high wind speeds are predicted around the northeast corner, achieving a C2 (strolling) criterion, where a retail tenancy is likely to be located, and therefore mitigation measures will need to be considered.
    - Achieves S2 category around the base of the building for safety.
  - Building 3 –
    - Ground level winds are generally satisfactory, achieving the C3 (standing) criterion around the entire building. However, there is likely to be a retail tenancy on the northeast corner which would be required to achieve the C4 (sitting) criterion and therefore mitigation measures will need to be considered.

    - Achieves S2 category around the base of the building for safety.
  - Precinct area –
    - Ground level winds are satisfactory and achieve the C3 (standing) criterion.
    - Achieves S2 category around the base of the building for safety.

Refinements at a further design stage will be required to satisfy the Lawson comfort criteria around some of the retail frontages, particularly the northeast corner of Buildings 2 and 3. Future detailed SSDs will include updated wind modelling and mitigation measures for the final building design to ensure compliance.

4.5 Mitigation strategies

Based on the wind tunnel results, some areas will require some form of mitigation to ensure the desired comfort and safety criterion are achieved. Potential mitigation strategies include the introduction of:

- Fixed or retractable canopies or awnings to protect patrons.
- Architectural screening in critical positions such as:
  - Balustrading along the top of the podiums.
  - Landscape screening in critical positions. Such as an evergreen tree canopy can provide a wind break to the exposed facades. These trees will need to be mature and evergreen (i.e., have leaves all year round) to be an effective mitigation strategy.
- Roughing elements (e.g. banners, etc.) as a means of diffusing the energy contained in the wind.

These mitigation options can be considered throughout the future detailed design stage and incorporated into a future Detailed SSDA.

5 Conclusion

This Pedestrian Wind Assessment responds specifically to the SEARs. A wind tunnel study was conducted to provide assessment of wind conditions across the Sydney Olympic Park development site and nearby surrounding environment. Wind speeds have been assessed against the industry-standard Lawson comfort criteria. The development, surrounding terrain, local built environment and approach flow were modelled at the necessary accuracy to satisfy the AWES-QAM-1-2019. Atmospheric wind was simulated according to AS/NZS 1170.2:2011 profiles and the local wind environment modelled via statistical analysis of BOM historical weather data.

The results of the assessment indicate that wind speeds are generally compliant with the intended usage of each area of the proposed development, when assessed against the Lawson comfort criteria. However, there are some areas that will require further mitigation to ensure that the wind conditions are suitable for their intended use. These areas of concern are around the proposed retail frontages on the northeast corners of Buildings 2 and 3. These areas may be intended to have outdoor dining for cafés/restaurants and do not meet the Lawson sitting criteria.

Potential mitigation strategies include introducing canopies or retractable awnings, architectural or landscape screening in critical positions, or roughening elements to assist in diffusing the amount of energy contained in the wind. Future Detailed SSDAs should include updated wind modelling and mitigation measures for the final building design.

6 References

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Appendix A Statistical analysis of meteorological data

A.1 Scaling methods

Modelling of local wind effects requires accurate representation of the surrounding terrain and built environment. The influence of terrain and built environment over the development length is incorporated into AS/NZS 1170.2:2021 as different terrain categories. Based on the terrain category, a suitable model of the atmospheric boundary layer (change in velocity and turbulence intensity with height) is given, which accounts for nearby structures and terrain (roughness). This model uses a logarithmic law to describe the mean wind speed profile in terms of roughness length.

Wind data from Bankstown was corrected to open terrain (category 2) using methods outlined in Holmes, 2021. To scale to the terrain roughness surrounding the site (category 3), scaling was applied using mean wind speed terrain/height multipliers from AS/NZS 1170.2:1989; i.e. multiplying by 0.44/0.6 = 0.733.

A.2 Gust equivalent mean

Comfort conditions were assessed using the gust equivalent mean wind speeds, U_{GEM}, which were calculated using:

$$U_{GEM} = \max\left(\overline{\mathrm{U}}, \frac{\widehat{U}}{\mathrm{G}}\right)$$

Where:

- $\overline{U}$ is the mean wind speed
- $\widehat{U}$ is the gust wind speed
- G is the gust factor, taken as 1.85 based on the research published by Lawson (2001).

A.3 Weibull analysis

To accurately account for the relative contributions of wind events from different directions, comfort exceedance probabilities were defined using a Weibull distribution. The probability of the wind speed at a certain location, U_i, exceeding a speed, V, for any given direction, θ, is given by:

$$p(U_i > V, \theta) = A(\theta\,)e^{\left[-\left(\frac{V}{C(\theta)}\right)^{k(\theta)}\right]}$$

Here $k(\theta)$ and $C(\theta)$ are Weibull coefficients for the azimuth sector, θ, and $A(\theta)$ is the marginal probability of the wind direction being within the azimuth sector. Therefore, the sum of all the marginal probabilities will be equal to one and the following will hold true:

$$\sum_{all\ sectors} A(\theta) = 1$$

Consequently, the exceedance probability is given by:

$$p(U_i > V) = \sum_{all\ sectors} A(\theta)e^{\left[-\left(\frac{V}{C(\theta)}\right)^{k(\theta)}\right]}$$

The coefficients obtained from the Bankstown Airport BOM data are shown in Table A-1.

Table A-1 Weibull coefficients for all 36 assessment directions

Direction	A	C	k
0	0.015	2.59	2.00
10	0.010	2.27	2.28
20	0.010	2.15	2.50
30	0.013	2.57	2.53
40	0.018	2.78	2.41
50	0.023	3.33	2.54
60	0.025	3.78	2.66
70	0.022	4.05	2.78
80	0.016	3.77	2.50
90	0.013	3.34	2.48
100	0.017	3.78	2.55
110	0.024	4.31	2.69
120	0.026	4.69	2.59
130	0.027	4.86	2.55
140	0.027	5.03	2.49
150	0.027	5.14	2.45
160	0.025	4.88	2.25
170	0.023	4.47	2.19
180	0.021	3.82	1.99
190	0.018	3.28	1.82
200	0.016	2.79	1.75
210	0.017	2.50	1.86
220	0.022	2.58	1.98
230	0.028	2.77	2.00
240	0.030	2.94	1.81
250	0.027	3.17	1.68
260	0.024	3.20	1.65
270	0.021	3.18	1.61
280	0.023	3.07	1.57
290	0.027	3.00	1.54
300	0.028	2.80	1.58
310	0.027	2.54	1.74
320	0.027	2.41	1.83
330	0.028	2.33	1.85
340	0.027	2.53	1.87
350	0.023	2.72	1.89

A.4 Extreme value analysis

For analyses involving high return periods (e.g. safety wind speeds), infrequent wind events of high wind speed are considered. Such wind events have been described using a Type 1 Extreme Value Distribution (or Gumbel Distribution) with Gringorten's modification, which models infrequent events more accurately than the Weibull distribution. The probability of the wind speed at a given location, U_i, exceeding a speed, V, for any given direction, θ, is given by:

$$p(U_i > V, \theta) = 1 - e^{-e^{\left[\frac{V-u(\theta)}{a(\theta)}\right]}}$$

Where u(θ) and $a(\theta)$ are the calculated coefficients for each azimuth sector. The return period for exceedance velocity, V, for each sector is the inverse of the exceedance probability, i.e.:

$$R_\theta = \frac{1}{p(U_i > V, \theta)}$$

The overall exceedance probability for all wind directions is given by:

$$1 - \frac{1}{R} = \prod_\theta \left(1 - \frac{1}{R_\theta}\right)$$

$$1 - \frac{1}{R} = \prod_\theta e^{-e^{\left[\frac{V-u(\theta)}{a(\theta)}\right]}}$$

Therefore, the return period for winds from all directions is:

$$R = \frac{1}{1 - \prod_\theta e^{-e^{\left[\frac{V-u(\theta)}{a(\theta)}\right]}}}$$

The Extreme Value coefficients obtained from the Bankstown Airport BoM data, for all hours, are shown below in Table A-2.

Table A-2 Extreme Value coefficients for all 36 assessment directions

Direction	A	u	a
0	0.015	5.00	0.87
10	0.010	4.00	0.48
20	0.010	3.90	0.68
30	0.013	4.19	0.48
40	0.018	4.94	0.59
50	0.022	5.58	0.42
60	0.024	5.65	0.21
70	0.022	5.56	0.24
80	0.015	5.30	0.31
90	0.013	5.20	0.42
100	0.017	5.59	0.65
110	0.023	6.13	0.36
120	0.026	6.68	0.42
130	0.026	7.48	0.50
140	0.026	8.12	0.81

Direction	A	u	a
150	0.026	8.43	0.73
160	0.024	8.46	0.94
170	0.023	7.70	0.80
180	0.021	7.08	0.69
190	0.018	6.61	0.79
200	0.016	6.32	0.85
210	0.017	5.61	0.64
220	0.021	5.81	0.69
230	0.027	6.14	0.67
240	0.030	7.11	0.66
250	0.027	7.54	0.44
260	0.024	7.55	0.54
270	0.021	7.79	0.80
280	0.022	7.75	0.74
290	0.026	7.72	0.64
300	0.027	7.66	0.57
310	0.027	6.71	0.72
320	0.026	6.55	1.01
330	0.028	6.16	0.95
340	0.027	6.22	0.62
350	0.023	5.95	0.55

Appendix B Wind tunnel calibration

B.1 Scaling Laws

The fundamental concept is that the model of the structure and that the wind should be at approximately the same scale.

- Geometric Scale: The geometric scale was at 1:400, and affects the ratio of roughness length and integral scales of longitudinal turbulence:

$$L = \frac{(z_o)m}{(z_o)p} = \frac{(L_u)m}{(L_u)p} = 1{:}\,400$$

- Velocity Scale: The wind tunnel reference mean velocity was chosen as about 15 m/s to maximise the sensitivity of the measurement instrumentation. The velocity sale for the simulation was (with a design mean speed of about 30 m/s):

$$V = \frac{(V_{ref})m}{(V_{ref})p} = \frac{1}{2}$$

In addition, the following scales are necessary to determine wind tunnel instrumentation sampling and frequency response characteristics:

- Time Scale: $T = \frac{L}{V} = \frac{t_m}{t_p} = 1{:}\,200$
- Frequency Scale: $F = \frac{1}{T} = \frac{f_m}{f_p} = 200{:}\,1$

A sampling rate of 1000 Hz was used for the following reasons (consistent with the Australasian Wind Engineering Society Quality Assurance Manual):

- The rate corresponds to about 5 Hz in full-scale, which will allow pressure fluctuations with frequencies up to about 2.5 Hz (full-scale) to be determined without distortion or attenuation.

A sampling duration of 40 seconds was used as it ensures measured maximum and minimum wind speeds provide representative estimates of peaks encountered during a full-scale interval of about two hours, and a statistically stable estimate of the mean and RMS wind speeds.

B.2 Wind tunnel calibration

The wind tunnel approach flow was calibrated to match the AS 1170.2:2011 terrain category 3 approach flow, within a margin of 10% as per the Australasian Wind Engineering Society Quality Assurance Manual. The approach flow was normalised against a height of 153m (top of the tallest tower). The normalised approach flow and turbulence intensity are shown in Figure B-1 and Figure B-2, respectively.

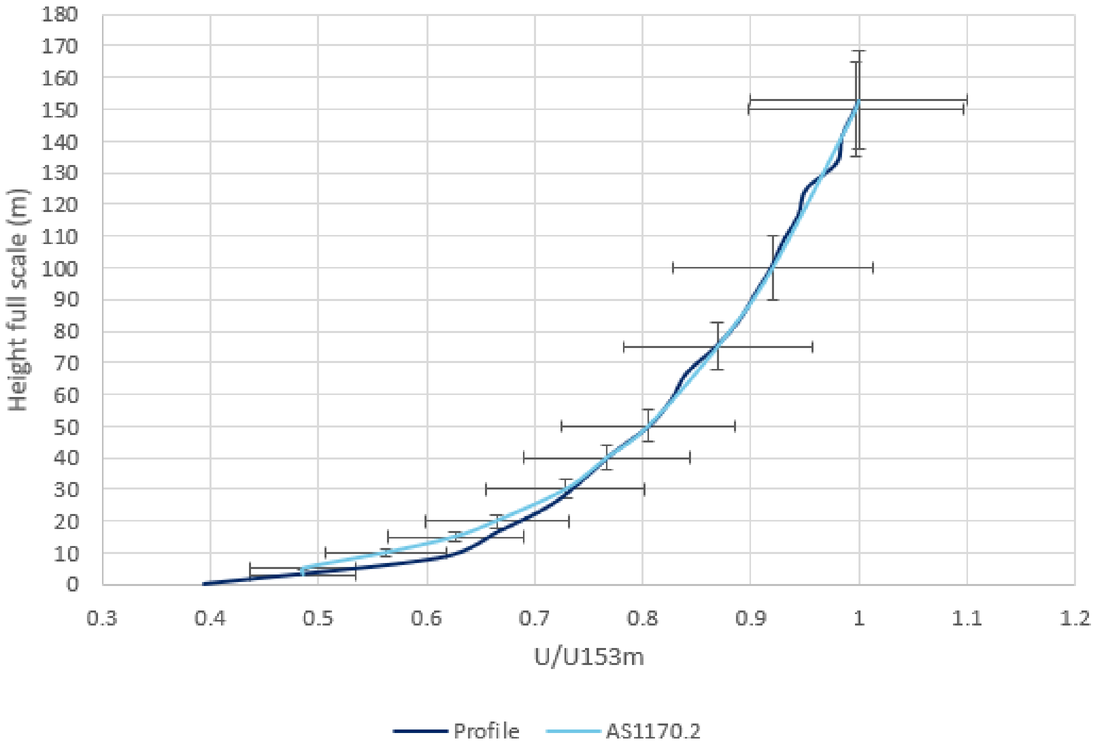

Figure B-1 Mean velocity profile comparison with AS1170.2:2011

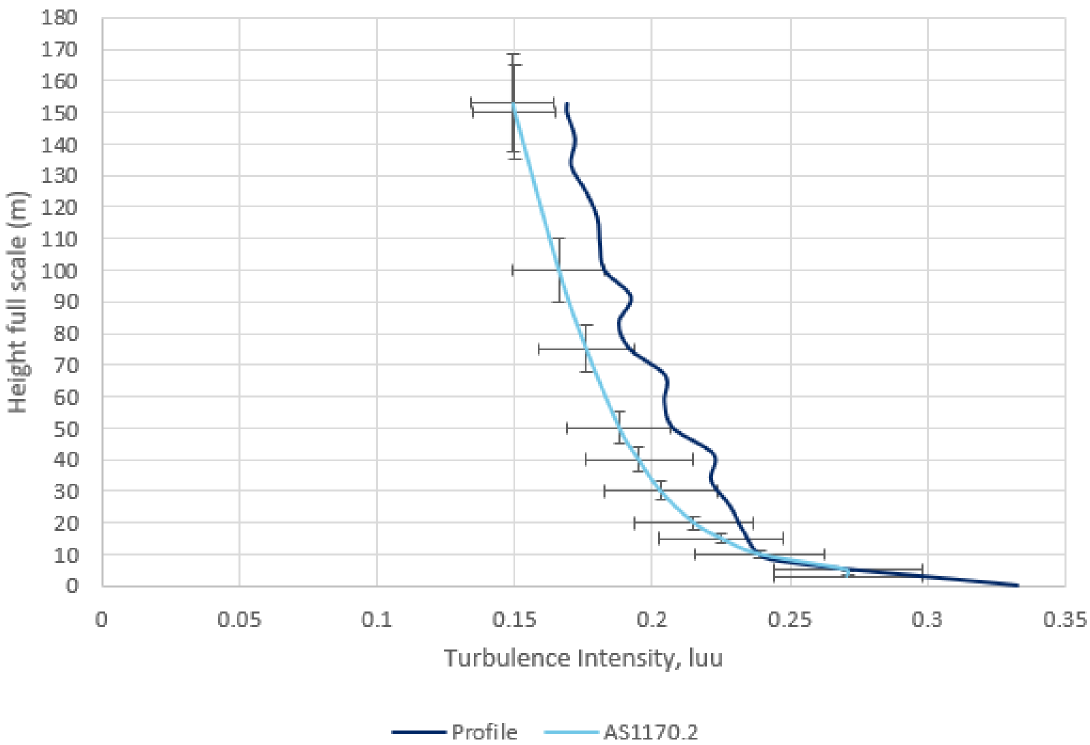

Figure B-2 Turbulence intensity profile comparison with AS1170.2:2011

B.3 Sensor calibration

Sensor calibration was conducted to ensure the accuracy and validity of measurements taken.

All pressure taps were zeroed (calibrated at zero tunnel speed) within 45 minutes of the tunnel being started.

Separate calibration adjustments are also made for each Irwin sensor. The relationship between the actual dynamic pressure and measured dynamic pressure for each sensor is linear, i.e. dynamic pressures can be calculated using the equation:

$$p_{dyn} = slope \times p_{dyn,measured} + intercept$$

With the calibration slope and intercept known for each sensor, i, the velocities were obtained using the below equation, where $p_{t,i}$ and $p_{s,i}$ are the measured total and static pressures from the Irwin sensor respectively.

$$v_i = \sqrt{\frac{2}{\rho}\left(slope_i \times \left(p_{t,i} - p_{s,i}\right) + intercept_i\right)}$$

where:

- $\boldsymbol{\rho}$ is the density of air, approximately 1.2 kg/m^3