Venues NSW

SSD 9835 Sydney Football Stadium Redevelopment Section 4.55 Modification

Precinct Village and Car Park (MOD 7) Environmental Wind Assessment

Wind

Issue 02 | 6 September 2021

Job number 282684-08

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Contents

Disclaimer

This assessment of the site environmental wind conditions is presented based on engineering judgement. In addition, experience from more detailed simulations have been used to refine recommendations. No detailed simulation, physical or computational study has been made to develop the recommendations presented in this report.

Executive summary

Arup has been commissioned by Venues NSW to provide an experienced-based impact assessment of the proposed SSD 9835 Sydney Football Stadium Redevelopment Section 4.55 Modification development on the pedestrian level wind conditions for comfort and safety in and around the site. The site is located within the Moore Park Precinct, Sydney.

Qualitatively, integrating the expected directional wind conditions around the site with the wind climate, it is considered that wind conditions at the majority of locations around the site would be classified as suitable for pedestrian standing and walking. The relatively open nature of the site means that the wind conditions would be similar to the nearby parkland areas, which are classified as suitable for pedestrian standing and meeting the wind speed associated with the pedestrian sitting criterion (4 m/s, 11 kph) for about 80-90% of the time. Sitting classification is applicable for cafés that rely on outdoor patronage. Given this is the intended use of the space, to locally improve areas around the Precinct to meet the sitting criterion (less than 4 m/s for 95% of the time), additional permanent or temporary screening, or landscaping would be required. Calmer conditions would be experienced to the immediate north of the tennis pavilion.

The relatively low-level nature of the development means that there are no safety concerns within the development.

The project is not expected to change the wind conditions around the Moore Park Precinct. The wind speed affecting tennis is player dependent, however applying the standing comfort classification (95% of time the mean wind speed is less than 6 m/s, 22 kph) would be considered appropriate. This classification would be expected to be achieved on the tennis courts.

The qualitative advice in this report is based on the results from the previous wind-tunnel testing for the Stadium. The proposed low-rise structures would be expected to have a minimal impact on the wind environment, affecting only the areas in the immediate vicinity. To quantify the impact of the proposed building, numerical or physical modelling of the development would be required, which is best conducted during detailed design, but is not considered necessary due to the recent previous nearby testing and the low-rise nature of the development.

1 Introduction

This qualitative environmental wind assessment report has been prepared on behalf of Venues NSW in support of a Section 4.55(2) modification to SSD 9835 for the Sydney Football Stadium (SFS) Precinct Village and Car Park development (the site), located within the Moore Park Precinct, Sydney.

This report outlines the assessment and subsequent recommendations for wind engineering services related to pedestrian wind comfort and safety on the ground level.

2 Precinct Village and Car Park

2.1 Introduction

On 6 December 2018, the then Minister for Planning approved a concept development application and concurrent early works package (SSD 9249) to facilitate redevelopment of the Sydney Football Stadium.

The concept approval established the maximum building envelope, design and operational parameters for a new stadium with up to 45,000 seats for patrons and allowing for 55,000 patrons in concert mode. The concurrent Stage 1 works, which were completed on 28 February 2020, facilitated the demolition of the former SFS and associated buildings.

Stage 2 of the Sydney Football Stadium (SFS) Redevelopment (SSD 9835) was approved by the Minister for Planning and Public Spaces on 6 December 2019. Stage 2 provides for:

- construction of the stadium, including:
    - 45,000 seats (additional 10,000 – person capacity in the playing field in concert mode) in four tiers including general admission areas, members seating and corporate / premium seating;
    - roof cover over all permanent seats and a rectangular playing pitch;
    - a mezzanine level with staff and operational areas;
    - internal pedestrian circulation zones, media facilities and other administration areas on the seating levels;
    - a basement level (at the level of the playing pitch) accommodating pedestrian and vehicular circulation zones, 50 car parking spaces, facilities for teams and officials, media and broadcasting areas, storage and internal loading areas;
    - food and drink kiosks, corporate and media facilities; and
    - four signage zones.
- construction and establishment of the public domain within the site, including:
    - hard and soft landscaping works;
    - publicly accessible event and operational areas;
    - public art; and
    - provision of pedestrian and cycling facilities.

    - wayfinding signage and lighting design within the site;
    - reinstatement of the existing Moore Park Carpark 1 (MP1) upon completion of construction works with 540 at-grade car parking spaces and vehicular connection to the new stadium basement level;
    - operation and use of the new stadium and the public domain areas within the site for a range of sporting and entertainment events; and
    - extension and augmentation of utilities and infrastructure.
- SSD 9835 has been modified on five previous occasions:
    - MOD 1 amended Conditions B14 and B15 to satisfy the regulatory requirements of the Contaminated Land Management Act 1997;
    - MOD 2 approved the design, construction and operation of the Stadium Fitness Facilities;
    - MOD 3 approved design refinements to the western mezzanine and introduced a new condition to facilitate approval of signage details within the approved signage zones;
    - MOD 4 relocated the approved photovoltaic array from the SFS roof to the Level 5 plant room roofs and revised the approved sustainability strategy; and
    - MOD 5 updated plan references and dates in the Instrument of Consent.

A sixth modification which seeks approval for the fit out and operation of the SFS’ eastern mezzanine for the Sydney Roosters Centre of Excellence (MOD 6) was placed on public exhibition by the Department of Planning, Industry, and Environment between 19 August and 1 September 2021.

2.2 Precinct Village and Car Park

2.2.1 Vision

Venues NSW (VNSW) is proposing to introduce a village community space, event plaza and multi level car park to complement the SFS and adjoining Moore Park and Centennial Parklands. The proposed development will facilitate the permanent closure of the EP2 on-grass parking areas within Moore Park opposite the MP1 car park and enable its use for open space purposes consistent with the Moore Park Masterplan.

The vision for the Precinct Village and Car Park is set out below:

The Precinct Village and Car Park provides a platform and canvas for an exceptional community asset and iconic design, that visually and physically connects to the adjacent Moore Park East and Kippax Lake. It provides patrons with quality café and dining experiences in an idyllic parkland setting and well-being play and relaxation nodes which engage with all ages. An event plaza, connected to the Stadium plaza provides a seamless opportunity for greater patron and community engagement through non-event and event day functions (Architectural Design Statement, Cox August 2021).

2.2.2 Location

The Precinct Village and Car Park is proposed to be located on the land west of the SFS, currently approved under SSD 9835 as the MP1 Car Park. It will extend to Moore Park and Driver Avenue and will adjoin the existing UTS, Rugby Australia and NRL Central buildings, all of which are to be retained and do not form part of the project site. A Location Plan is provided in Figure 1.

Figure 1: Precinct Village and Car Park Location

2.2.3 Development Description

The Precinct Village and Car Park has been designed to align with the conditions and commitment established within SSD 9835, particularly relating to delivering a LEED Gold rated sustainable precinct, and will include:

- Up to a maximum of 1,500 space multilevel carpark below ground level with the following access arrangements:
    - 1 x egress point onto Moore Park Road to be used on event days only;
    - 1 x two-lane access point from Driver Ave to be used on event and non-event days; and
    - dedicated area within the car park for operation/servicing vehicles.
- Reconfiguration of the currently approved drop off requirements for the elderly and mobility impaired.
- Free flow level pedestrian access to and from the SFS concourse from Driver Ave and Moore Park Road.
- Electric car charging provision.
- A versatile and community public domain, comprising:
    - provision for 4 x north-south orientated tennis courts on non-event days with the potential to become an event platform on event days;
    - children's playground;
    - 1,500 m^2 cafe / retail / restaurants with associated amenities in a single storey pavilion (6 m high) low level;
    - customer service office and ticket window; and

    - vertical transport provisions.
- Utilities provision augmentation.

Figure 2 illustrates the proposed Precinct Village and Car Park concept. Refer to the architectural within the Architectural Design Statement (Cox, August 2021) and landscape plans (Aspect, August 2021) for further details.

Figure 2: Precinct Village and Car Park Development

2.2.4 Proposed Operation

The Precinct Village is proposed to be accessible from 8 am to 11 pm to align with the approved operating hours for the SFS.

The tennis court operating hours are proposed to be the same as the approved operating hours for the Stadium Fitness Facilities.

The car park will be automated, replicating the existing arrangements at the nearby Entertainment Quarter and will be accessible 24 hours a day, 7 days a week.

The public domain is proposed to be curated as a series of distinct, flexible and purpose specific settings for event day patrons and the general public. These inviting public places will offer rich, engaging and shared experiences. An indication of the activity types, frequencies and durations proposed within the public domain is provided in the Architectural Design Statement (Cox Architecture, August 2021) and Planning Statement (Ethos Urban, August 2021).

2.2.5 Delivery

The Precinct Village and Car Park is proposed to be delivered in two stages:

- Stage 1, herein referred to as the East Car Park, consists of the area between the Rugby Australia and NRL Central buildings, immediately adjacent to the SFS concourse.

- Stage 2, herein referred to as the West Car Park, consists of the residual area immediately adjacent to the proposed East Car Park, bounded by Driver Ave and Moore Park Road.

The East Car Park is proposed to be delivered ahead of the opening of the SFS in 2022. The West Car Park is proposed to be delivered after the SFS opening, sometime in 2023.

2.3 Proposed Modifications

To facilitate the Precinct Village and Car Park, SSD 9249 and SSD 9835 are required to be modified. The proposed modification to SSD 9249 (concept development application) has been submitted under separate cover. SSD 9835 is proposed to be modified to facilitate construction, fit-out and operation of Precinct Village and Car Park as described above.

2.4 Purpose of this Report

This wind assessment report has been prepared to support the Precinct Village and Car Park modification. This Report specifically addresses the Secretary's Environmental Assessment Requirements (SEARs) issued in respect of SSD 9825 and as relevant to the Precinct Village and Car Park project, Table 1.

Table 1: Applicable SEARs

Secretary's Environmental Assessment Requirements	Report Section
12. Wind Effects	
• Provide a Wind Effects Report based on the conclusions and recommendations in the preliminary *Wind Considerations for Stadium Design* prepared by Arup dated 27 April 2018 (SSD 9249).	The report has been prepared by suitably qualified wind engineers: • Dr. Graeme Wood, PhD BEng • Lauren Boysen, BaeroEng(Hons)
• The report is to be prepared by a suitably qualified engineer and is to:	
• be based on wind tunnel testing, which compares and analyses the current wind conditions and the wind conditions created by the proposed stadium and any other ancillary buildings;	Section 4.3
• report the impacts of wind on the pedestrian environment at the footpath level within the site and the public domain; and	Section 4.3
• provide design solutions to minimise the impact of wind on the public and private domain.	Section 4.3
• Assess the potential wind impacts on the ground level environment having regard to Section 3.2.6 (wind effects) of Sydney Development Control Plan 2012 (Sydney DCP).	Section 4.1

This Environmental Wind Report is to be read in conjunction with the following reports and documents:

- Planning Statement prepared by Ethos Urban (August, 2021);
- Architectural plans/elevations/sections and Architectural Design Statement, prepared by Cox Architecture (August, 2021);
- Design Integrity Assessment Report prepared by Cox Architecture (August, 2021);
- Landscape plans and Landscape Design Report prepared by Aspect (August, 2021);
- Transport Assessment prepared by JMT (August, 2021);
- Noise and Vibration Assessment prepared by Arup (August, 2021);
- Stormwater and Flooding Assessment prepared by Arup (August, 2021);
- Visual Impact Assessment prepared by Ethos Urban (August, 2021);
- Social/Economic Statement prepared by Ethos Urban (August, 2021);
- Heritage Impact Statement prepared by Artefact (August, 2021);
- Sustainability Assessment prepared by LCI (August, 2021);
- Security Statement/CPTED prepared by Intelligent Risks (August, 2021);
- Contamination Assessment prepared by Douglas Partners (August, 2021);
- Aboricultural Assessment prepared by Tree IQ (August, 2021);
- Infrastructure Services Strategy prepared by Arup (August, 2021);
- Geotechnical Assessment prepared by Arup (August, 2021);
- Public Domain Lighting Assessment prepared by Arup (August, 2021);
- Accessibility Statement prepared by Before Compliance (August, 2021); and
- BCA Assessment prepared by Blackett Maguire Goldsmith (August 2021).

3 Site description

The proposed site is located on the north-west corner of the Moore Park Precinct at the corner of Moore Park Road and Driver Avenue, Figure 3.

Figure 3: Site location and local context

As per Section 2.2.5, the proposed development consists of Stage 1 and Stage 2, Figure 4 and Figure 5. The relative heights are shown in Figure 6.

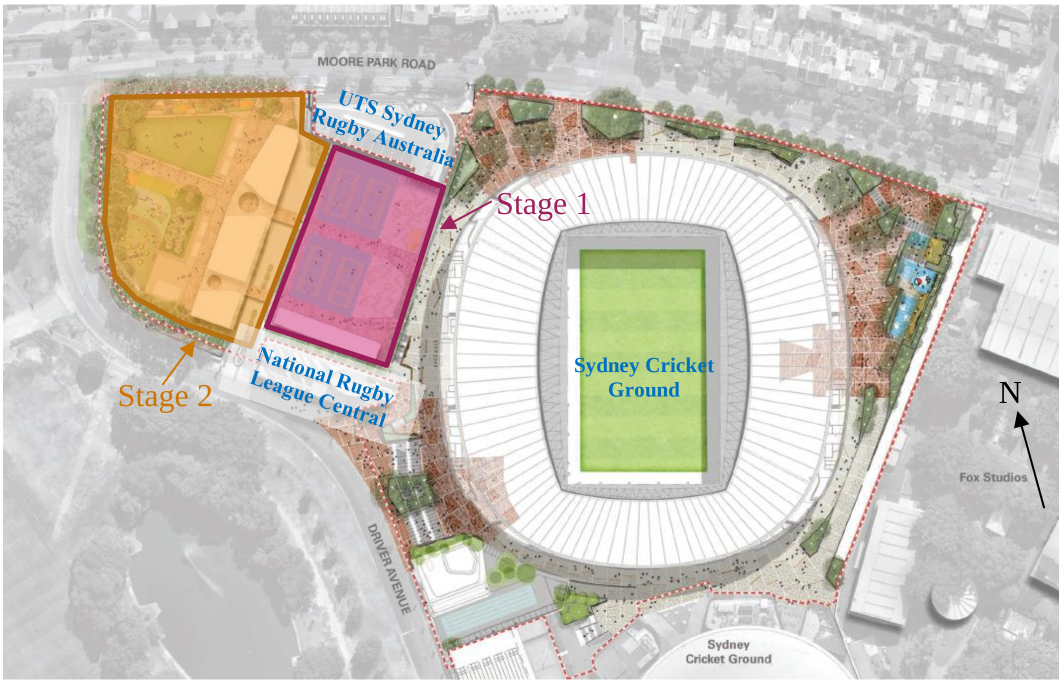


Figure 4: Site context

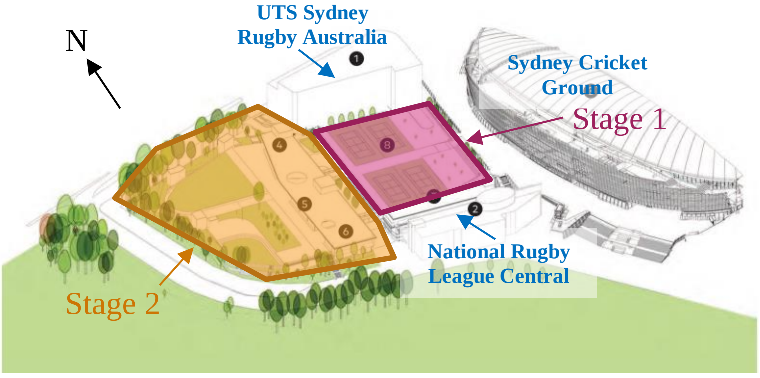


Figure 5: Site massing (view from south-west)

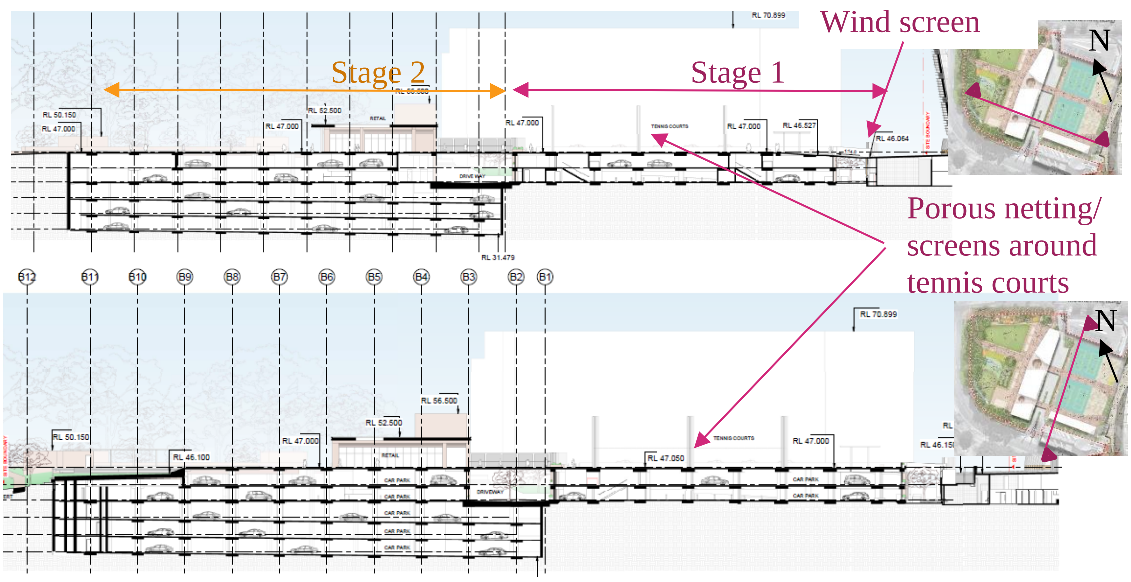


Figure 6: Sections looking north-east (T) and south-east (B)

4 Wind assessment

4.1 Local wind climate

Weather data recorded at Sydney Airport by the Bureau of Meteorology has been analysed for this project. The anemometer is located about 8 km to the south of the site. The arms of the wind rose point in the direction from where the wind is coming from. The directional wind speeds measured here are considered representative of the incident wind conditions at the site, due to close proximity to the site and similar distance from the coast.

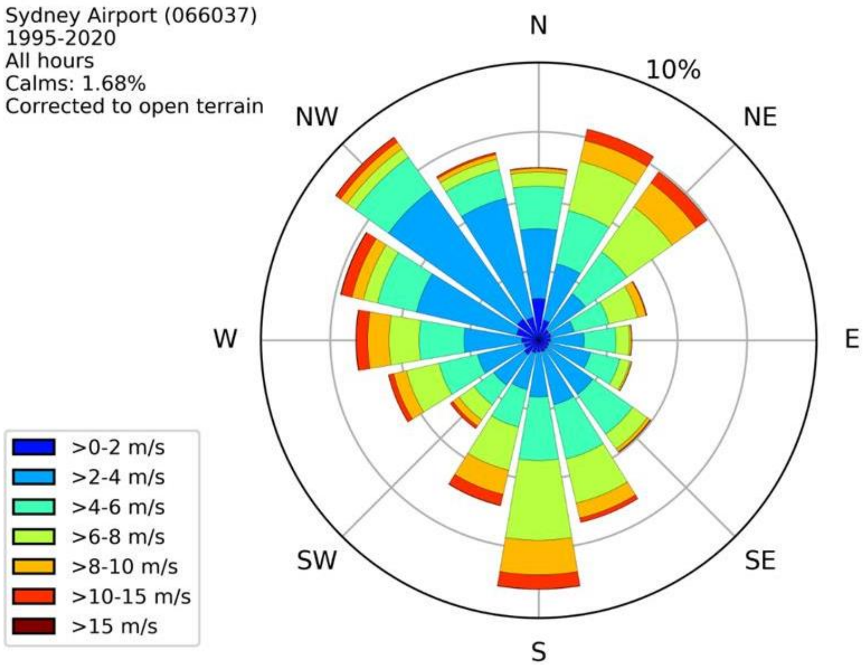


Figure 7: Wind rose showing probability of time of wind direction and speed

It is evident from Figure 7 that the prevailing wind directions are from the north-east, south, and north-west quadrants with stronger winds from these directions. The measured mean wind speed is 4.5 m/s, and the 5% exceedance mean wind speed is 9.5 m/s.

Strong summer winds occur mainly from the south and north-east quadrants. Winds from the south are associated with large synoptic frontal systems and generally provide the strongest gusts during summer. Moderate intensity winds from the north-east tend to bring cooling relief on hot summer afternoons typically lasting from noon to dusk. These are small-scale temperature driven effects; the larger the temperature differential between land and sea, the stronger the wind.

Winter and early spring strong winds typically occur from the north-west, and west quadrants. West quadrant winds provide the strongest winds affecting the area throughout the year and tend to be associated with large scale synoptic events that can be hot or cold depending on inland conditions.

A general description on flow patterns around buildings is given in Appendix 1.

4.2 Specific wind controls

Wind comfort is generally measured in terms of wind speed and rate of change of wind speed, where higher wind speeds and gradients are considered less comfortable. Air speed has a large impact on thermal comfort and are generally welcome during hot summer conditions. This assessment is focused on wind speed in terms of mechanical comfort.

There have been many wind comfort criteria proposed, and a general discussion is presented in Appendix 2.

This assessment has been conducted in accordance with the current draft Central Sydney Planning Strategy 2016-2036 wind controls, which are based on the work of Lawson (1990), as described in Figure 24 and Table 2. The safety criterion in the Central Sydney Planning Strategy 2016-2036 is based on a 0.5 s gust wind speed of 24 m/s occurring once per annum during daylight/business hours (6 am to 10 pm) or 0.0171% of the time. The comfort criteria are based on a 5% of the time exceedance during daylight hours. The comfort conditions for active sporting activities such as tennis would be similar to the standing classification.

Table 2: Lawson pedestrian comfort criteria for various activities

Comfort (max. of mean or GEM wind speed exceeded 5% of the time)	
<2 m/s	Dining
2-4 m/s	Sitting
4-6 m/s	Standing (or sporting activities)
6-8 m/s	Walking
8-10 m/s	Objective walking or cycling
>10 m/s	Uncomfortable
Safety (max. of mean or GEM wind speed exceeded 0.022% of the time)	
<15 m/s	General access
<20 m/s	Able-bodied people (less mobile or cyclists not expected)

Transferring the measured 5% of the time wind speed to an open location at ground level around the site would result in a mean wind speed of about 6 m/s. Form Table 2 these conditions would be classified as on the border of pedestrian standing and walking. From knowledge of the wind conditions in the locale, this would be a considered a correct classification for the area.

4.3 Predicted wind conditions on ground plane

This section of the report outlines the predicted wind conditions in and around the site based on the local climate, topography, and building form.

The proposed low-rise development is expected to have minimal impact on the local wind conditions making some areas calmer and other areas slightly windier depending on the incident wind direction as discussed below. In general, the proposed development of a courtyard protected by perimeter single storey structures around the raised deck area is good from a wind perspective.

Previous quantitative testing conducted for the SFS Redevelopment project by Wacker Ingenieure (2020) and MEL Consultants (2019) has been reviewed.

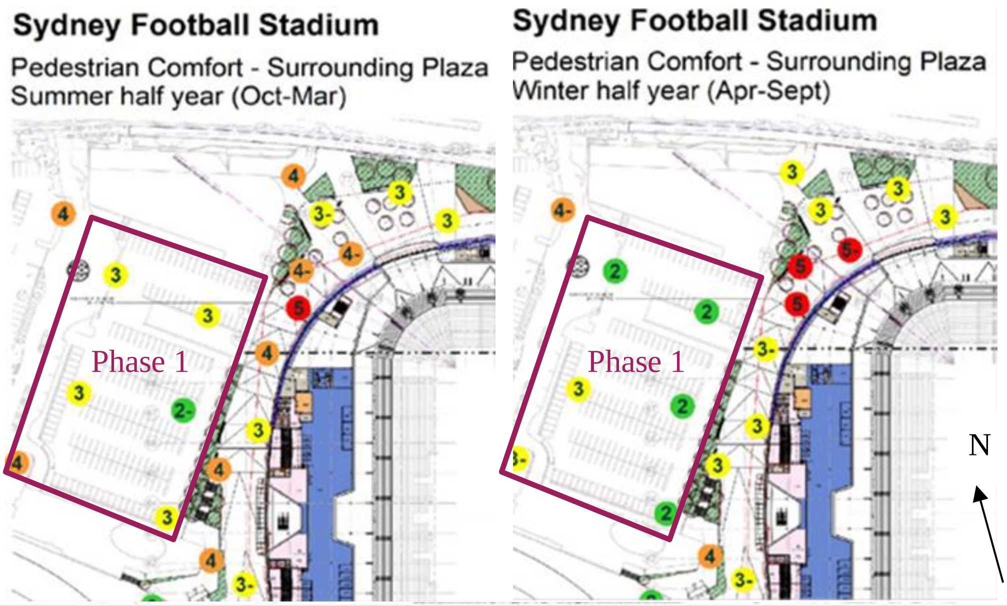
The MEL Consultants testing (MEL Consultants, 2019) does not extend as far as the subject site. The nearest test points (Locations 26, 26A, 27, Figure 8), located to the north-west of the SFS, indicate that wind conditions were estimated to exceed the walking comfort. This assessment was based on the City of Sydney 2012 Development Control Plan (DCP), which is based on the work of Melbourne (1978). The classifications would be similar to the City of Sydney classifications as evidenced in Figure 24.

Figure 8: Excerpt – SFS Redevelopment project quantitative testing (MEL Consultants, 2019)

Although not directly comparable to the applicable Sydney wind controls, the quantitative testing for the SFS by Wacker Ingenieure (2020) indicates that locations across the subject site are estimated to be suitable for standing/walking type activities and pass the safety criterion, Figure 9. The findings are similar to MEL consulting confirming that the area would not be classified as suitable for outdoor sitting. Note that this does not mean that the area can't be used for sitting for a large portion of the time, and most park areas in Sydney would be similarly classified, with areas meeting the wind speed associated with the sitting criterion for about 80-90% of the time. The areas marked poor in Figure 9 were addressed by Wacker Ingenieure in the SFS development with the inclusion of wind barriers to the west of the precinct.

The site is most exposed to winds from the south where the existing National Rugby League Central building would offer protection to the precinct in the closest 10-15 m to the north of the building.

The proposed perimeter buildings rise a maximum of 5.5 m above the central event deck offering minimal wind protection to the central space except when close to the leeward side of the structures.



Quality Class	Activity			Example for possible usage
	Traversing	Strolling	Sitting	
1	Good	Good	Good	cafes, sitting areas
2	Good	Good	Moderate	waiting areas, parks
3	Good	Moderate	Poor	shopping areas, entrance areas
4	Moderate	Poor	Poor	side walks
5	Poor	Poor	Poor	wind shelter recommended
6	Potential Risk			wind shelter necessary

Figure 9: Excerpt – SFS Redevelopment project quantitative testing (Wacker Ingenieure, 2020)

Winds from the north-east

Winds from the north-east will be undisturbed on reaching the site, approaching over low-rise residential areas. The flow will accelerate between the north-west corner of the SFS and the UTS Rugby Australia building, Figure 10. This channelling causes windy conditions in this area as shown in Figure 8 and Figure 9. The wind screens highlighted in Figure 6 offers local protection to people on the SFS forecourt, but would not offer protection to the event deck beyond the gully. The wind speed would decrease as the flow expands to the south. The wind conditions in the areas remote from the buildings would be similar to the incident flow.

Incident winds will impinge on the north-east corner of the existing UTS Sydney Rugby Australia building, offering some protection to the precinct. Existing windy conditions are expected to remain around the north-west corner of the UTS Sydney Rugby Australia. The northern part of the tennis courts/events space plaza and the area to the west of the events plaza is expected to experience reasonably calm conditions, Figure 10.

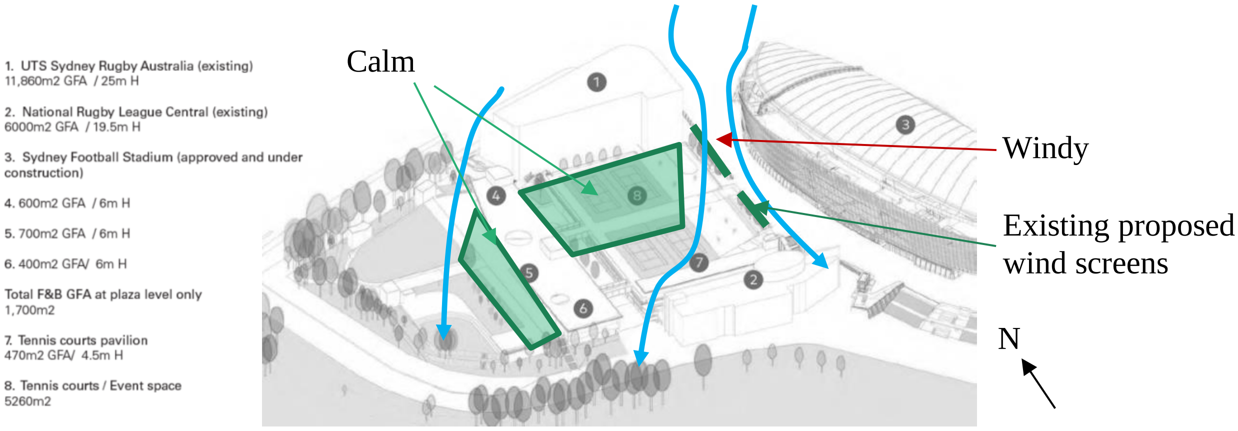


Figure 10: Flow patterns for winds from the north-east (viewed from the south-west)

Winds from the south

Winds from the south will approach the site fairly undisturbed. The existing National Rugby League Central building to the south of Phase 1 will offer little protection to the village precinct except close to the tennis court pavilion, Figure 11.

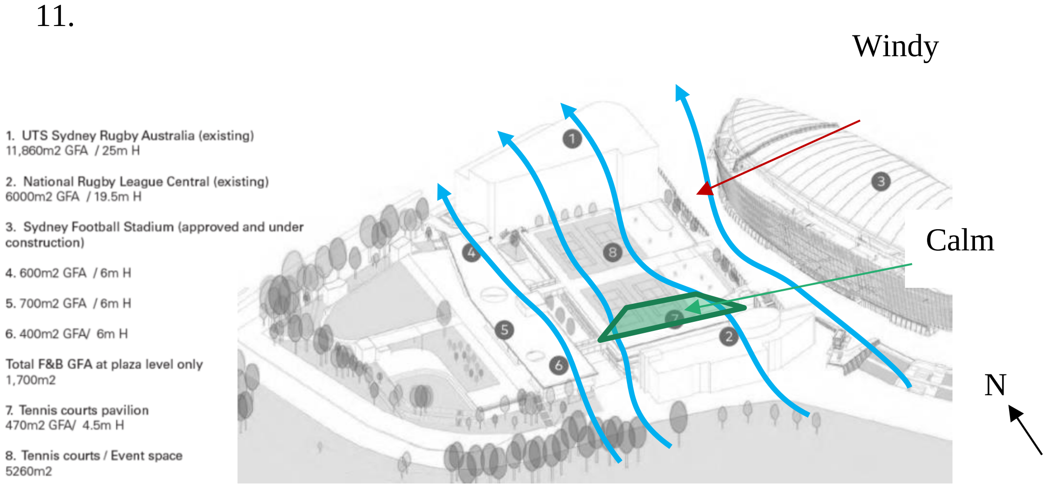


Figure 11: Winds from the south – expected wind behaviour (view from south-west)

The small buildings to the west will raise the incident flow and would be expected to improve the wind conditions around the western side of the existing UTS Sydney Rugby Australia building.

The wind conditions in the central events level would be similar to the incident flow, neither improved nor made windier by the proposed structures. Conditions could be improved if the perimeter buildings were taller, or central events deck was lower than the surrounding area to the west and south. The courts will be screened with mesh fencing, Figure 12, which would require about 15-20% solidity to have any beneficial measurable impact on the downstream wind speed. The more solid the fence the better the protection to the courts and across the event deck.

Figure 12: Central events level – perimeter screens (view from north-east)

The proposed layout of the walkways is slightly skewed to the prevailing wind direction, which is a good design feature. Channelled flow will occur when the incident wind direction aligns with the walkway. The bridge balustrades will offer protection to pedestrians and there are no wind concerns with the design.

Figure 13: Walkways alignment to prevailing wind directions (blue lines)

Similarly, wind conditions in the canyon through the carpark will experience pressure driven flow, Figure 14, but will be of lower speed than at ground level.

Figure 14: Carpark Level 0 (pressure driven flow indicated by blue line)

Winds from the west

Winds from the west are expected to be unimpeded when crossing the northern precinct of Moore Park before slightly accelerating up the rise to the site. Winds will impinge on the western aspects of the proposed low-rise Phase 2 buildings, creating some calmer conditions immediately upstream and downstream of the buildings, Figure 15, with some pressure driven flow between the buildings.

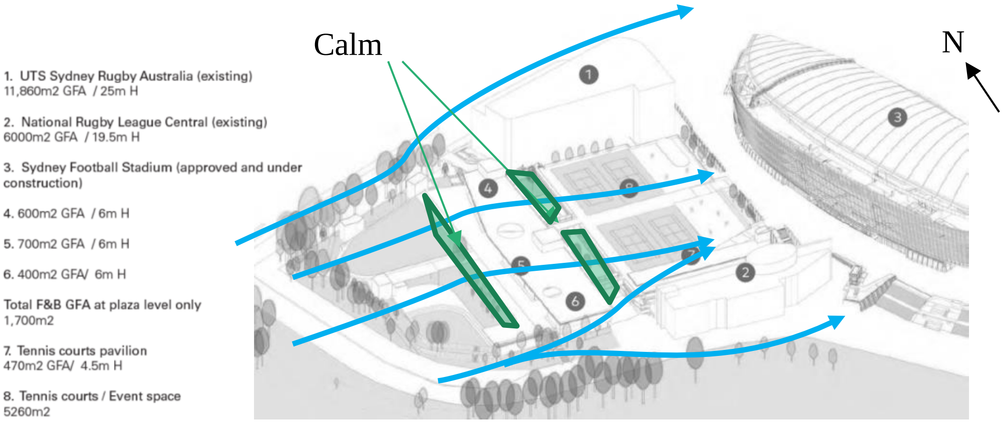


Figure 15: Winds from the west – expected wind behaviour (view from south-west)

As with winds from the south, the walkways between the buildings to the tennis courts/events space do not align with the prevailing wind direction from the west, Figure 13, but do align with winds form the north-west. The walkway orientation is considered generally good from a wind perspective.

Summary

Qualitatively, integrating the expected directional wind conditions around the site with the wind climate, it is considered that wind conditions at the majority of locations around the site would be similar to the existing conditions and classified as suitable for pedestrian standing and walking. The relatively open nature of the site means that the wind conditions would be similar to the nearby parkland areas, which are classified as suitable for pedestrian standing and meeting the wind speed associated with the pedestrian sitting criterion (4 m/s, 11 kph) for about 80-90% of the time. Sitting classification is applicable for cafés that rely on outdoor patronage.

The zones immediately close to the perimeter buildings would have an improved wind climate approaching the sitting classification, particularly the area to the immediate north of the tennis pavilion. The use of any area in the Precinct for commercial purposes relying on outdoor patronage, would require temporary or permanent screening to improve the local wind conditions for patrons.

With suitable screening as proposed, the tennis courts would be expected to meet the standing comfort classification, which is appropriate for sporting activities.

The relatively low-level nature of the development means that there are no safety concerns within the development.

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Appendix 1: Wind flow mechanisms

An urban environment generates a complex wind flow pattern around closely spaced structures, hence it is exceptionally difficult to generalise the flow mechanisms and impact of specific buildings as the flow is generated by the entire surrounds. However, it is best to start with an understanding of the basic flow mechanisms around an isolated structure.

Isolated building

When the wind hits an isolated building, the wind is decelerated on the windward face generating an area of high pressure, Figure 16, with the highest pressure at the stagnation point at about two thirds of the height of the building. The higher pressure bubble extends a distance from the building face of about half the building height or width, whichever is lower. The flow is then accelerated down and around the windward corners to areas of lower pressure, Figure 16. This flow mechanism is called **downwash** and causes the windiest conditions at ground level on the windward corners and along the sides of the building.

Rounding the building corners or chamfering the edges reduces downwash by encouraging the flow to go around the building at higher levels. However, concave curving of the windward face can increase the amount of downwash. Depending on the orientation and isolation of the building, uncomfortable downwash can be experienced on buildings of greater than about 6 storeys.

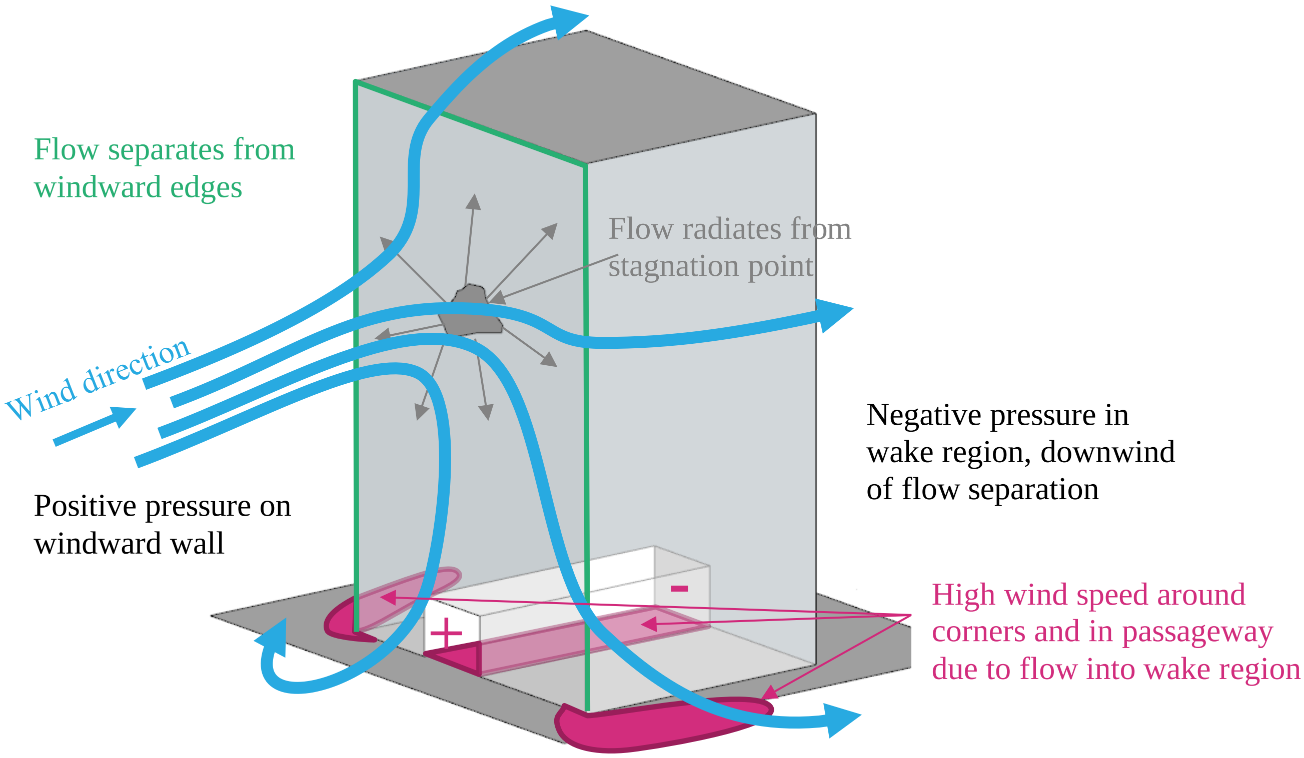

Figure 16 Schematic wind flow around tall isolated building

Techniques to mitigate the effects of downwash winds at ground level include the provision of horizontal elements, the most effective being a podium to divert the downward flow away from pavements and building entrances, but this will generate windy conditions on the podium roof, Figure 11. Generally, the lower the podium roof and deeper the setback from the podium edge to the tower improves the ground level wind conditions. The provision of an 8 m setback on an isolated building is generally sufficient to improve ground level conditions, but is highly dependent on the building isolation, orientation to prevailing wind directions, shape and width of the building, and any plan form changes at higher level.

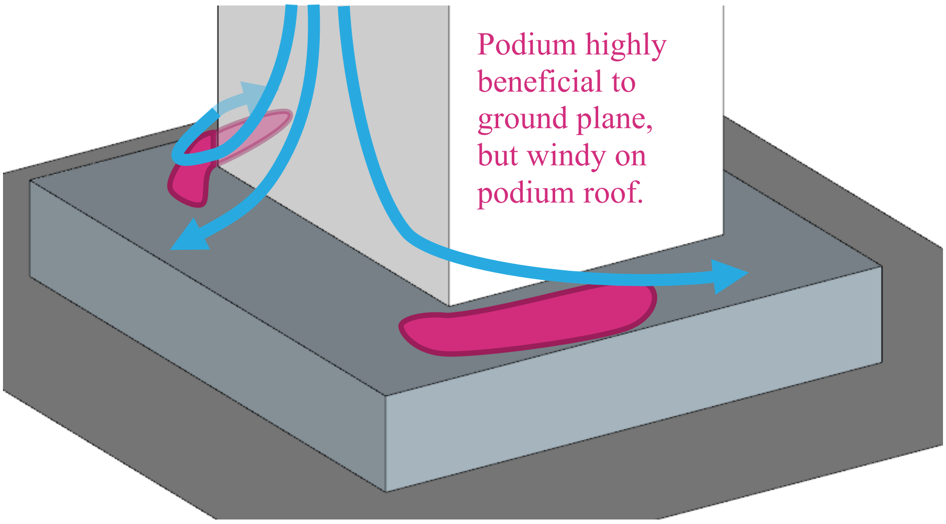

Figure 17 Schematic flow pattern around building with podium

Awnings along street frontages perform a similar function as a podium, and generally the larger the horizontal projection from the façade, the more effective it will be in diverting downwash flow, Figure 18. Awnings become less effective if they are not continuous along the entire façade, or on wide buildings as the positive pressure bubble extends beyond the awning resulting in horizontal flow under the awning.

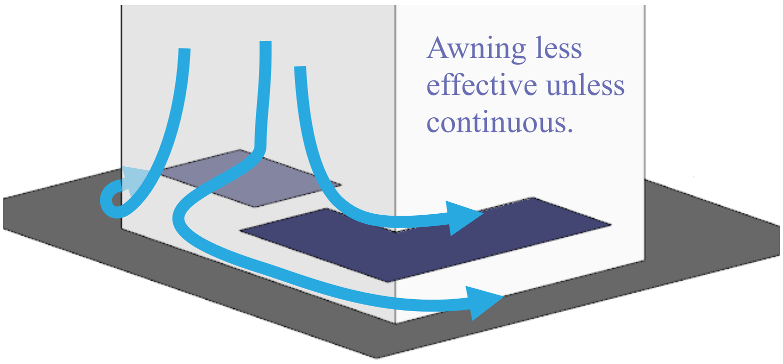

Figure 18 Schematic flow pattern around building with awning

It should be noted that colonnades at the base of a building with no podium generally create augmented windy conditions at the corners due to an increase in the pressure differential, Figure 19. Similarly, open through-site links through a building cause wind issues as the environment tries to equilibrate the pressure generated at the entrances to the link, Figure 16. If the link is blocked, wind conditions will be calm unless there is a flow path through the building, Figure 20. This area is in a region of high pressure and therefore the is the potential for internal flow issues. A ground level recessed corner has a similar effect as an undercroft, resulting in windier conditions, Figure 20.

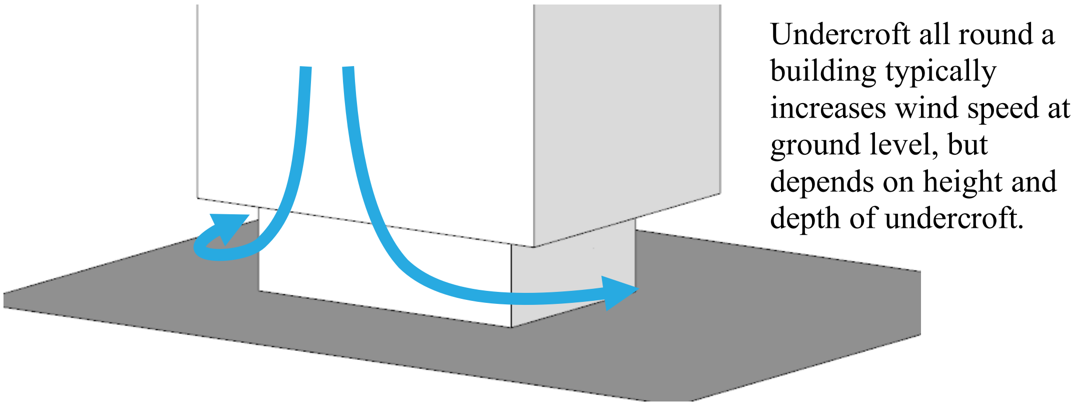

Figure 19 Schematic of flow patterns around isolated building with undercroft

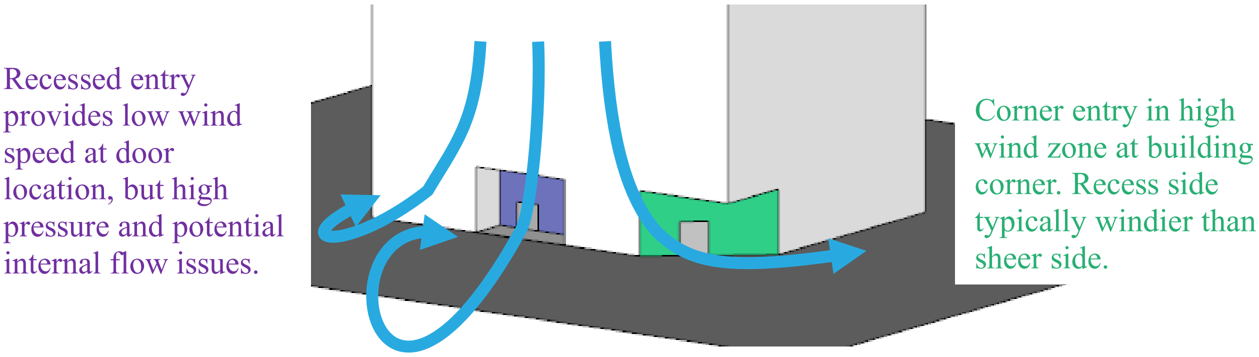

Figure 20 Schematic of flow patterns around isolated building with ground articulation

Multiple buildings

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 21. If the building is taller, more of the wind impacting on the exposed section of the building is likely to be drawn to ground level by the increase in height of the stagnation point, and the additional negative pressure induced at the base. If the upwind buildings are of similar height then the pressure around the building will be more uniform hence downwash is typically reduced with the flow passing over the buildings.

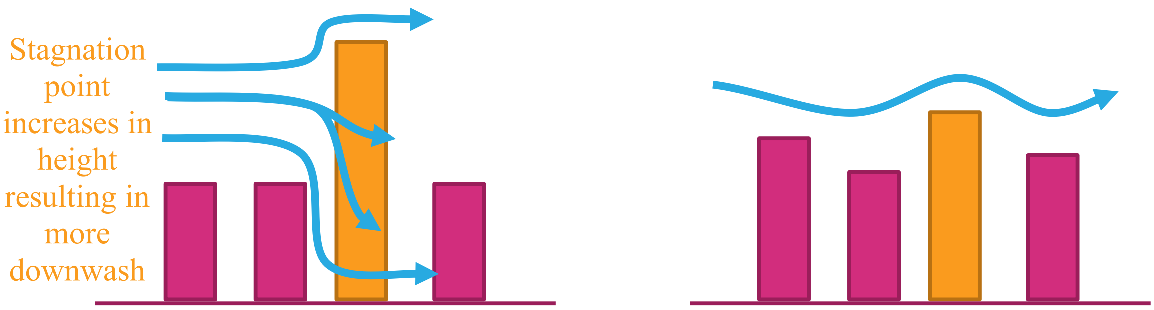

Figure 21 Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 22.

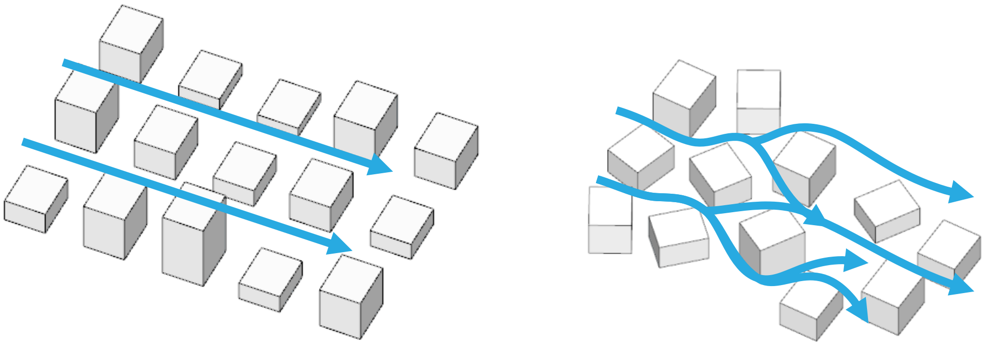

Figure 22 Schematic of flow patterns through a grid and random street layout

Channelling occurs when the wind is accelerated between two buildings, or along straight streets with buildings on either side, Figure 22(L), particularly on the edge of built-up areas where the approaching flow is diverted around the city massing and channelled along the fringe by a relatively continuous wall of building facades. This is generally the primary mechanism driving the wind conditions for this perimeter of a built-up area, particularly on corners, which are exposed to multiple wind directions. The perimeter edge zone in a built-up area is typically about two blocks deep. Downwash is more important flow mechanism for the edge zone of a built-up area with buildings of similar height.

As the city expands, the central section of the city typically becomes calmer, particularly if the grid pattern of the streets is discontinued, Figure 22(R). When buildings are located on the corner of a central city block, the geometry becomes slightly more important with respect to the local wind environment.

Single barriers and screens

The wind flow pattern over a vertical barrier is illustrated in Figure 23, showing there will be recirculation zones near the windward wall and in the immediate lee of the barrier. The typical extent of these recirculation zones relative to the height of the barrier, h, is illustrated in Figure 23. These regions are not fixed but fluctuate in time. The mean wind speed in the wake areas drops significantly compared with the incident flow. With increasing distance from the barrier the flow pattern will resort to the undisturbed state. Typically the mean velocity and turbulence intensity at barrier height would be expected to be within 10% of the free stream conditions at 10 times the height of the structure downwind from the barrier.

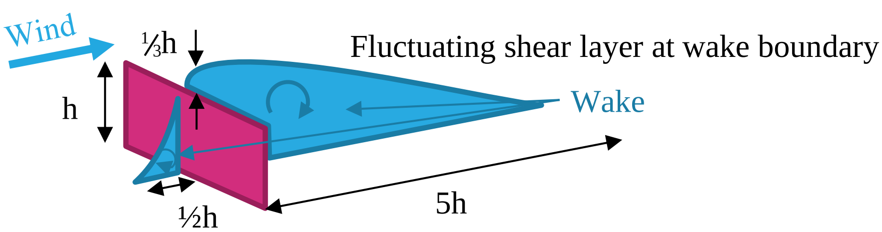

Figure 23: Sketch of the flow pattern over an isolated structure

Appendix 2: Wind speed criteria

General discussion

Primary controls that are used in the assessment of how wind affects pedestrians are the wind speed, and rate of change of wind speed. A description of the effect of a specific wind speed on pedestrians is provided in Table 3. It should be noted that the turbulence, or rate of change of wind speed, will affect human response to wind and the descriptions are more associated with response to mean wind speed.

Table 3 Summary of wind effects on pedestrians

Description	Speed (m/s)	Effects
Calm, light air	0–2	Human perception to wind speed at about 0.2 m/s. Napkins blown away and newspapers flutter at about 1 m/s.
Light breeze	2–3	Wind felt on face. Light clothing disturbed. Cappuccino froth blown off at about 2.5 m/s.
Gentle breeze	3–5	Wind extends light flag. Hair is disturbed. Clothing flaps.
Moderate breeze	5–8	Raises dust, dry soil. Hair disarranged. Sand on beach saltates at about 5 m/s. Full paper coffee cup blown over at about 5.5 m/s.
Fresh breeze	8–11	Force felt on body. Limit of agreeable wind on land. Umbrellas used with difficulty. Wind sock fully extended at about 8 m/s.
Strong breeze	11–14	Hair blown straight. Difficult to walk steadily. Wind noise on ears unpleasant. Windborne snow above head height (blizzard).
Near gale	14–17	Inconvenience felt when walking.
Gale	17–21	Generally impedes progress. Difficulty with balance in gusts.
Strong gale	21–24	People blown over by gusts.

Local wind effects can be assessed with respect to a number of environmental wind speed criteria established by various researchers. These have all generally been developed around a 3 s gust, or 1 hour mean wind speed. During strong events, a pedestrian would react to a significantly shorter duration gust than a 3 s, and historic weather data is normally presented as a 10 minute mean.

Despite the apparent differences in numerical values and assumptions made in their development, it has been found that when these are compared on a probabilistic basis, there is some agreement between the various criteria. However, a number of studies have shown that over a wider range of flow conditions, such as smooth flow across water bodies, to turbulent flow in city centres, there is less general agreement among. The downside of these criteria is that they have seldom been benchmarked, or confirmed through long-term measurements in the field, particularly for comfort conditions. The wind criteria were all developed in temperate climates and are unfortunately not the only environmental factor that affects pedestrian comfort.

For assessing the effects of wind on pedestrians, neither the random peak gust wind speed (3 s or otherwise), nor the mean wind speed in isolation are adequate. The gust wind speed gives a measure of the extreme nature of the wind, but the mean wind speed indicates the longer duration impact on pedestrians. The extreme gust wind speed is considered to be suitable for safety considerations, but not necessarily for serviceability comfort issues such as outdoor dining. This is because the instantaneous gust velocity does not always correlate well with mean wind speed, and is not necessarily representative of the parent distribution. Hence, the perceived ‘windiness’ of a location can either be dictated by strong steady flows, or gusty turbulent flow with a smaller mean wind speed.

To measure the effect of turbulent wind conditions on pedestrians, a statistical procedure is required to combine the effects of both mean and gust. This has been conducted by various researchers to develop an equivalent mean wind speed to represent the perceived effect of a gust event. This is called the ‘gust equivalent mean’ or ‘effective wind speed’ and the relationship between the mean and 3 s gust wind speed is defined within the criteria, but two typical conversions are:

$$\mathrm{U_{GEM}} = \frac{(\mathrm{U_{1\ hour\ mean}} + 3 \cdot \sigma_\mathrm{u})}{1.85} \text{ and } \mathrm{U_{GEM}} = \frac{1.3 \cdot (\mathrm{U_{1\ hour\ mean}} + 2 \cdot \sigma_\mathrm{u})}{1.85}$$

It is evident that a standard description of the relationship between the mean and impact of the gust would vary considerably depending on the approach turbulence, and use of the space.

A comparison between the mean and 3 s gust wind speed criteria from a probabilistic basis are presented in Figure 24 and Figure 26. The grey lines are typical results from modelling and show how the various criteria would classify a single location. City of Auckland has control mechanisms for accessing usability of spaces from a wind perspective as illustrated in Figure 24 with definitions of the intended use of the space categories defined in Figure 25.

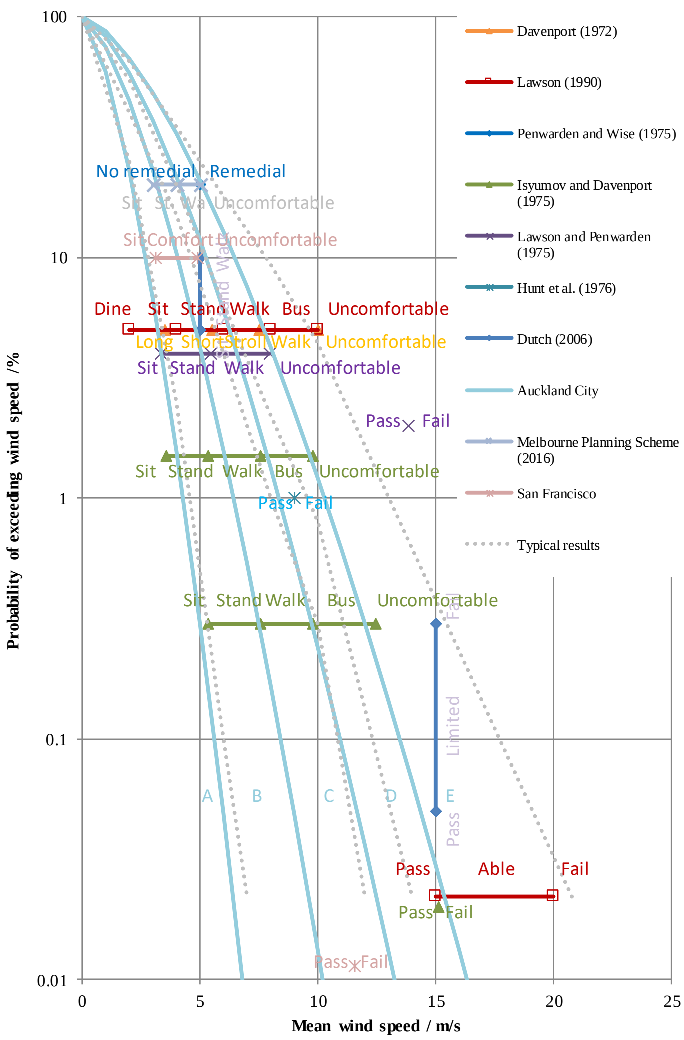

Figure 24 Probabilistic comparison between wind criteria based on mean wind speed

Category A	Areas of pedestrian use or adjacent dwellings containing significant formal elements and features intended to encourage longer term recreational or relaxation use i.e. public open space and adjacent outdoor living space
Category B	Areas of pedestrian use or adjacent dwellings containing minor elements and features intended to encourage short term recreation or relaxation, including adjacent private residential properties
Category C	Areas of formed footpath or open space pedestrian linkages, used primarily for pedestrian transit and devoid of significant or repeated recreational or relaxational features, such as footpaths not covered in categories A or B above
Category D	Areas of road, carriage way, or vehicular routes, used primarily for vehicular transit and open storage, such as roads generally where devoid of any features or form which would include the spaces in categories A - C above.
Category E	Category E represents conditions which are dangerous to the elderly and infants and of considerable cumulative discomfort to others, including residents in adjacent sites. Category E

Figure 25: Auckland Utility Plan (2016) wind categories

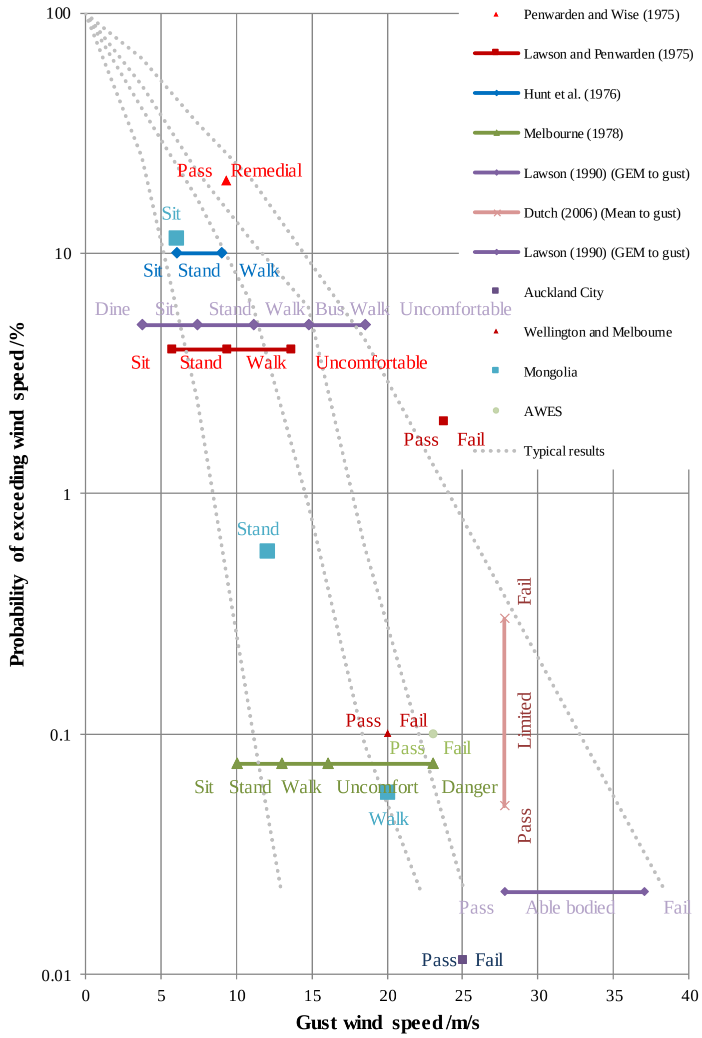

Figure 26 Probabilistic comparison between wind criteria based on 3 s gust wind speed

Appendix 3: Reference documents

In preparing the assessment, the following documents have been referenced to understand the building massing and features.

The Precinct village and Carpark drawings received are dated 02 September 2021.

- A04.00.00[A].pdf
- A10.SP.10[A].pdf
- A10.SP.20[A].pdf
- A10.SP.30[A].pdf
- A13.B1.01[B].pdf
- A13.B2.01[B].pdf
- A13.B3.01[B].pdf
- A13.L0.02[C].pdf
- A13.L0M.01[C].pdf
- A13.L1.03[E].pdf
- A30.EW.02[B].pdf
- A30.NS.02[B].pdf
- A30.NS.03[B].pdf
- A40.00.02[B].pdf
- A40.00.03[B].pdf
- A42.00.20[A].pdf
- A42.00.21[A].pdf
- A42.00.25[A].pdf
- A54.00.10[A].pdf
- A54.00.011[A].pdf

The Precinct village and Carpark Architectural Statement is dated August 2021.

- SFS Stage 2 DA_Architectural Design Statement Report.pdf