Infrastructure NSW

Stadium Australia Redevelopment Project

Environmental Wind Assessment

Wind

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Executive summary

Arup have been commissioned by Infrastructure NSW to provide an experienced-based impact assessment of the proposed Stadium Australia Redevelopment Project on the wind conditions in and around the site for pedestrian comfort and safety. This wind assessment report addressed the SEARs environmental amenity requirement for wind impact for application SSD 10342.

Arup have provided qualitative advice for the impact of the proposed redevelopment on pedestrian wind comfort and safety around the Stadium. The wind flow patterns in the Sydney Olympic Park precinct are governed by the overall massing of the large structures. From a wind perspective, the building massing is not changing significantly, hence the wind conditions in the immediate vicinity to the north and south stands would be expected to change marginally. From a wind comfort perspective, the wind conditions at the majority of locations around the site would be expected to remain classified as suitable for pedestrian standing and walking type activities. All locations in and around the precinct would be expected to continue meeting the safety criterion. These conditions are considered suitable for the intended use of the space.

To quantify the qualitative advice provided in this report, numerical or physical modelling of the Stadium and surrounds would be required. This modelling is not considered necessary for the current changes, which would have a relatively minor impact on the wind conditions.

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.

1 Introduction

Infrastructure NSW have engaged Arup to provide a qualitative environmental wind assessment for the Stadium Australia Redevelopment Project. This report outlines the pedestrian level wind assessment for comfort and safety in and around the development to address SEAR Key Issue No.6 Environmental Amenity in relation to wind impact.

2 Wind assessment

2.1 Local wind climate

Weather data recorded at Bankstown Airport by the Bureau of Meteorology (BoM) have been analysed for this project. The analysis is summarised in Appendix 1. This is considered the best weather station as the anemometer is located a similar distance from the coast in a flat exposed location, unlike the BoM anemometer on the Sydney Olympic Park precinct located on a hill surrounded by large trees next to a large building that changes the local wind direction. Winds come from all directions at Bankstown Airport with the strong prevailing wind directions being from the south-east and west quadrants. A general description on flow patterns around buildings is given in Appendix 2.

2.2 Specific wind controls

Wind comfort is generally measured in terms of wind speed and rate of change of wind speed with distance or time, 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 3. The current wind criteria in the City of Parramatta Council DCP 2011 are:

‘To ensure public safety and comfort the following maximum wind criteria are to be met by new buildings:

- 10 m/s in retail streets
- 13 m/s along major pedestrian streets, parks and public places
- 16 m/s in all other streets’

These wind criteria do not include the duration of the wind event, nor the probability of time that they occur. These are considered to be based on the work of Melbourne (1978), which represent a peak 3 s gust event occurring in an hour for 0.1% of time from any wind direction. The applicable 13 m/s limit for this site, is a comfort criterion appropriate for pedestrian standing activities. With reference to the wind rose for mean wind speed in Figure 6, there are few exposed locations in Parramatta that would meet this criterion without additional shielding to improve the wind conditions. This wind speed criterion is used as an estimator of the general wind conditions at a site, which may be more relevant. To combat this limitation, as well as the once per annum gust wind speed, the wind controls used in this wind assessment are based on the work of Lawson (1990) as described in Figure 14 and Table 1. These have both a comfort and safety component and tend to better describe the usage of the space from a comfort perspective. Converting the wind climate to the site location, the mean wind speed exceeded 5% of the time would be approximately 5 m/s at pedestrian level. With reference to Table 1, this wind condition is suitable for standing type activities and from our knowledge of the environs would be considered realistic.

Table 1 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
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)

2.3 Site description

Stadium Australia, completed in 1999, is located in Sydney Olympic Park, Figure 1. The entire precinct surrounding the stadium is open for pedestrian access. The open space around the Stadium is mainly used as a transient thoroughfare to and from the Stadium and is predominantly used during match times. The Stadium, being of greater size than the surrounding buildings, is exposed to winds from all directions with surrounding low- to medium- rise building and open parkland on all sides. The site is essentially flat from a wind perspective.

Figure 1: Aerial view of the proposed redevelopment (Google Map, 2018)

The redevelopment plan includes the demolition and redesign of the north and south stands enabling a rectangular stadium format. As such, the proposed north and south elevations of the external envelope move inwards. The east and west elevations of the external envelope do not change, Figure 2. The existing and proposed designs are highlighted in red and green colours respectively in Figure 3. The proposed roof structure for the north and south segment of the stadium, shown in Figure 3(T) and Figure 4(R), cantilevers over a large terrace level. There is a significant gap between the terrace level and roof structure to allow flow through the stadium. Additional roof is included along the entire length of the main trusses on the east and west stands, Figure 3(B) and Figure 4(R).

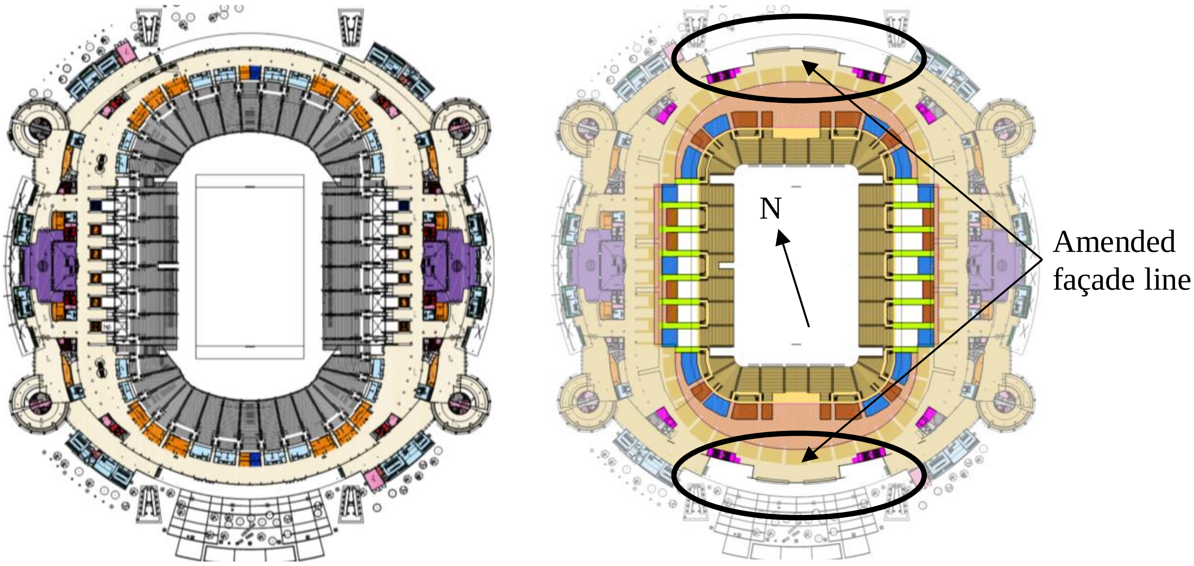

Figure 2: Ground floor plan view of existing (L) and proposed design (R)

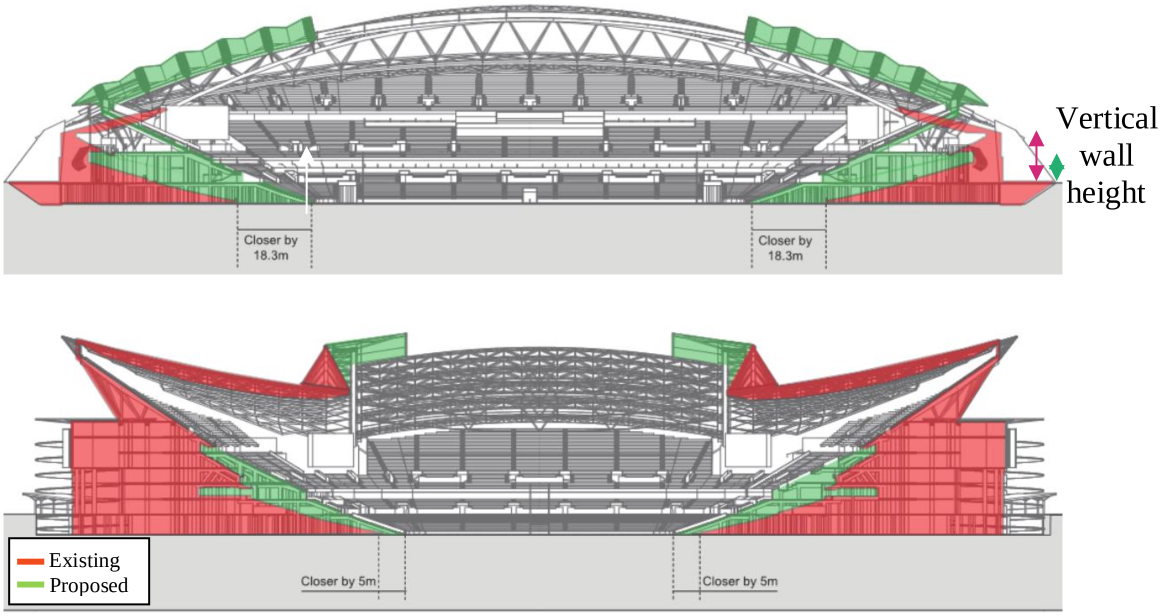

Figure 3: Comparative north-south (T) and west-east (B) sections

Figure 4: Photograph and rendered view of existing (L) and proposed (R) design

2.4 Predicted wind conditions on ground plane

This section of the report outlines the predicted wind conditions in and around the site based on local wind climate, topography, and building form. The height and massing of the Stadium is greater than the surrounding buildings, and therefore creates the local wind environment.

Integrating the expected directional wind conditions around the site with the wind climate, the wind speed at typical site location would be around 5 m/s which would be suitable for standing type activities, with some areas calmer and others windier depending on the location relative to the stadium and the incident wind direction. The change in the design is not expected to change the local wind conditions around the Stadium significantly, and hence the comfort and safety of pedestrians would be expected to be very similar to existing conditions.

Winds from the south-east

Winds from the south-east would pass over and around the low- to mid-rise buildings before reaching the site. Upon reaching the site, the wind would impinge on the broad curved face of the stadium and travel horizontally around the stadium. The fastest wind conditions would be around the north-east, and south-west pedestrian access ramps. Compared with the existing condition, the proposed additional articulation around the south façade would be expected to slightly improve the wind conditions, especially in the insets. Being in the leeward side and shielded by the stadium, the wind conditions to the north and west sides of the stadium would be unaffected by winds from this direction.

For winds more from the south impinging on the south stand, the reduction in height of the vertical stand wall height, and the opening of the flow path under the roof, Figure 3(T), would be expected to improve the wind conditions on ground level with more flow going into the terrace and through the Stadium rather than downwash, Figure 5.

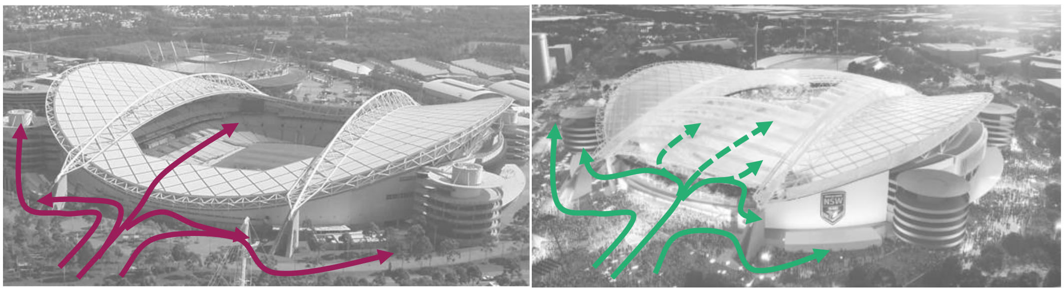

Figure 5: Flow patterns around south stand for winds from the south

Winds from the west

The strong winds from the west quadrant passing over the suburban area and low-rise buildings would impinge on the west stand and travel horizontally around the stadium. Due to the oval form of the Stadium, the flow mechanism would be similar to that described for winds from south-east except that the greater height of the west stand would encourage more downwash causing windy conditions around the west access ramps and the north and south stands. The wind speed would be fastest on the north and south stands near the west main truss buttresses entrances. The proposed design changes to the Stadium would have minimal impact on the wind conditions around the site.

Summary

Qualitatively, integrating the expected directional wind conditions around the site with the wind climate, it is considered that wind conditions around the proposed design would be very similar to the existing conditions. From a wind comfort perspective, the wind conditions at the majority of locations around the site would be expected to be classified as suitable for pedestrian standing and walking type activities. As the accessible areas around the stadium are primarily used for pedestrians moving to and from the stadium and surrounding venues, the wind conditions would be considered suitable for intended use of space.

The local amelioration would be required if the area around the site is intended to be activated for pedestrian sitting type activities such as café, or to further activate the precinct for outdoor events. Local wind mitigation measures would be typically in form of vertical screens perpendicular to the façade.

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Appendix 1: Wind climate

The mean wind speed frequency and direction information measured by the Bureau of Meteorology anemometer at a standard height of 10 m at Bankstown Airport has been used in this analysis, Figure 6. The arms of the wind rose point in the direction from where the wind is coming from. The station is located about 11 km to the south-west of the site. The site and Bankstown Airport anemometer station are located a similar distance from the coast to the east, and the mountains to the west and therefore considered to be representative of the wind conditions at the site.

Cold and hot winds tend to come from the west and east quadrants respectively. Typically, mornings tend to have lighter winds increasing in intensity through the day.

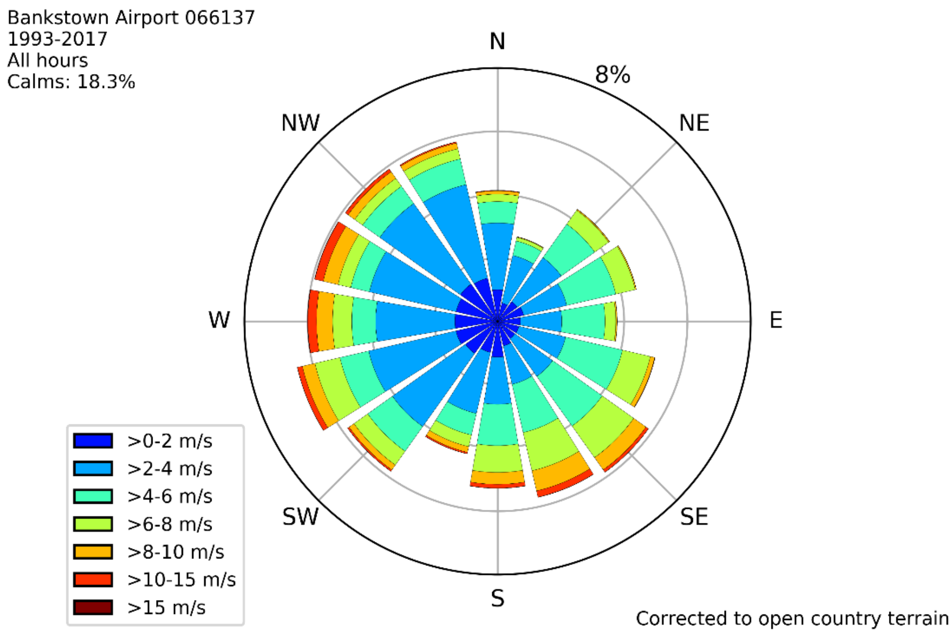

Figure 6: Wind rose showing probability of time of wind direction and speed

Appendix 2: 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 7, 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 7. 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.

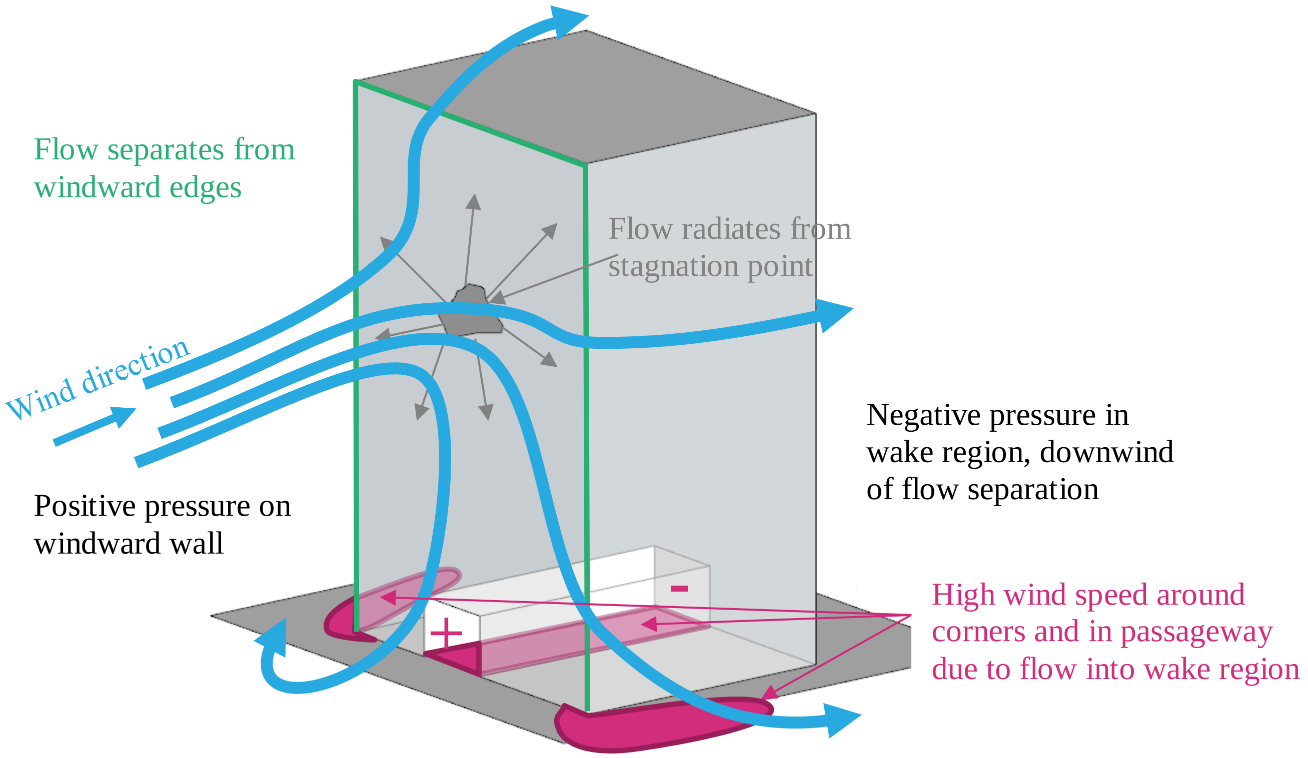

Figure 7 Schematic wind flow around tall isolated building

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 8. 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.

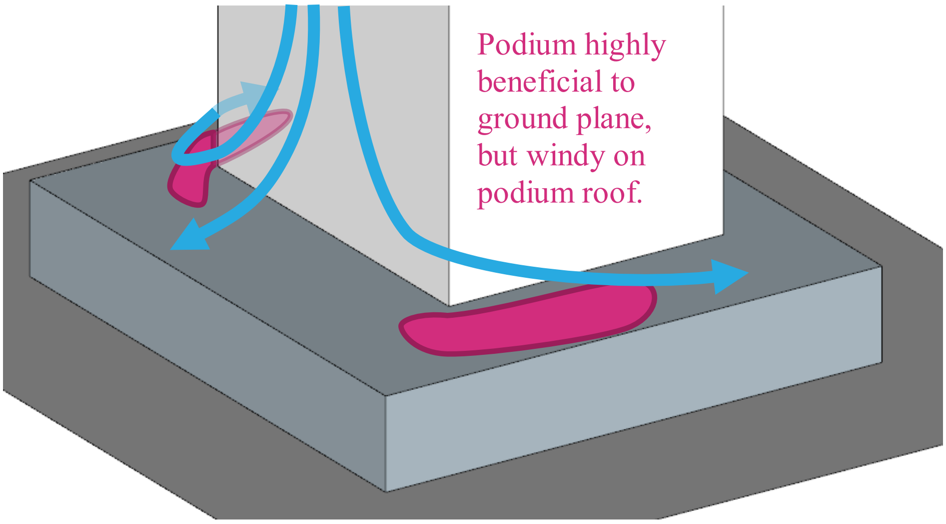

Figure 8 Schematic flow pattern around building with podium

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 9. 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.

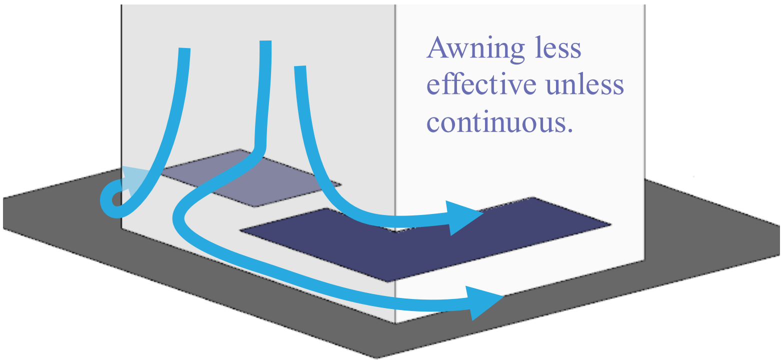

Figure 9 Schematic flow pattern around building with awning

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 10. 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 7. If the link is blocked, wind conditions will be calm unless there is a flow path through the building, Figure 11.

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 11.

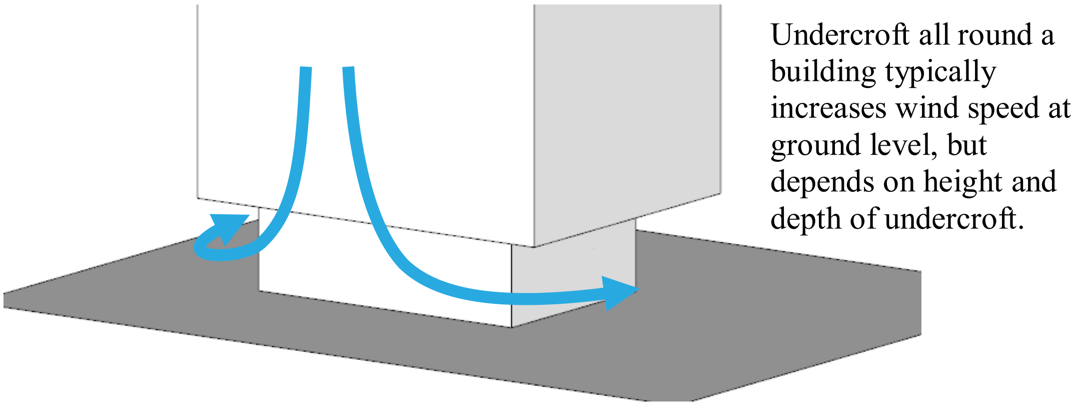

Figure 10 Schematic of flow patterns around isolated building with undercroft

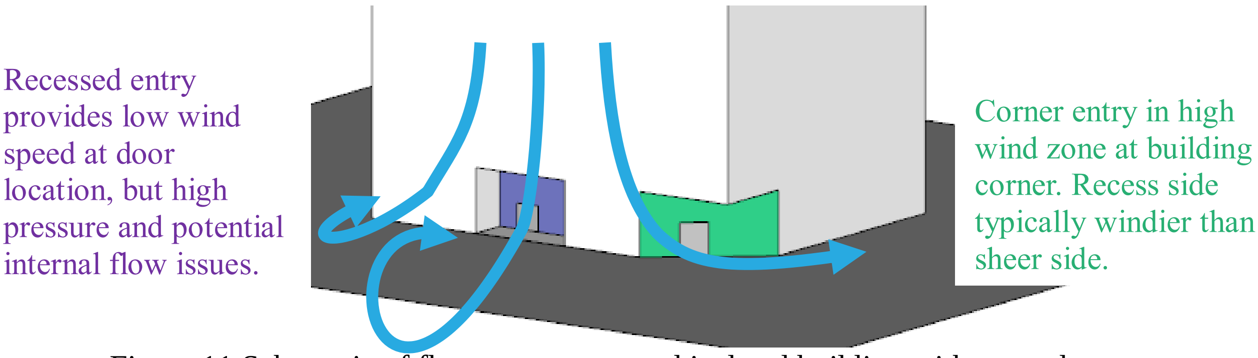

Figure 11 Schematic of flow patterns around isolated building with ground articulation

Multiple buildings

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 12. 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.

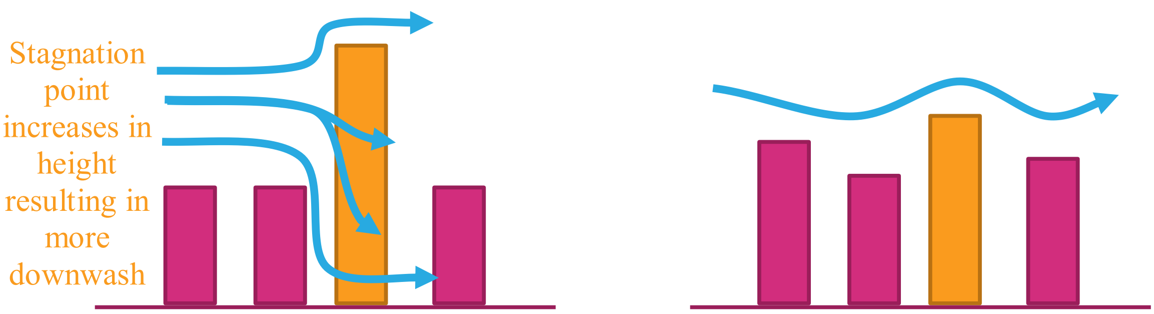

Figure 12 Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 13.

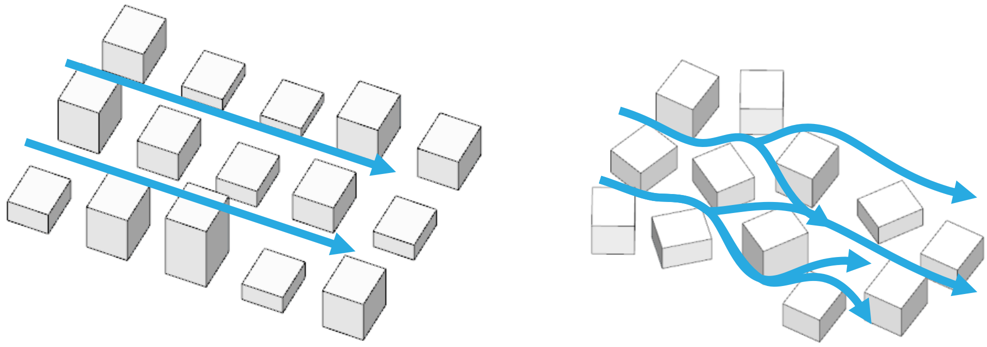

Figure 13 Schematic of flow patterns through a grid and random street layout

Channelling occurs when the wind is accelerated between two buildings, or along straight streets with buildings on either side, Figure 13(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 13(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.

Appendix 3: 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 2. 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 2 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:

$$U_{GEM} = \frac{(U_{mean} + 3 \cdot \sigma_u)}{1.85} \text{ and } U_{GEM} = \frac{1.3 \cdot (U_{mean} + 2 \cdot \sigma_u)}{1.85}$$

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 14 and Figure 16. 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 14 with definitions of the intended use of the space categories defined in Figure 15.

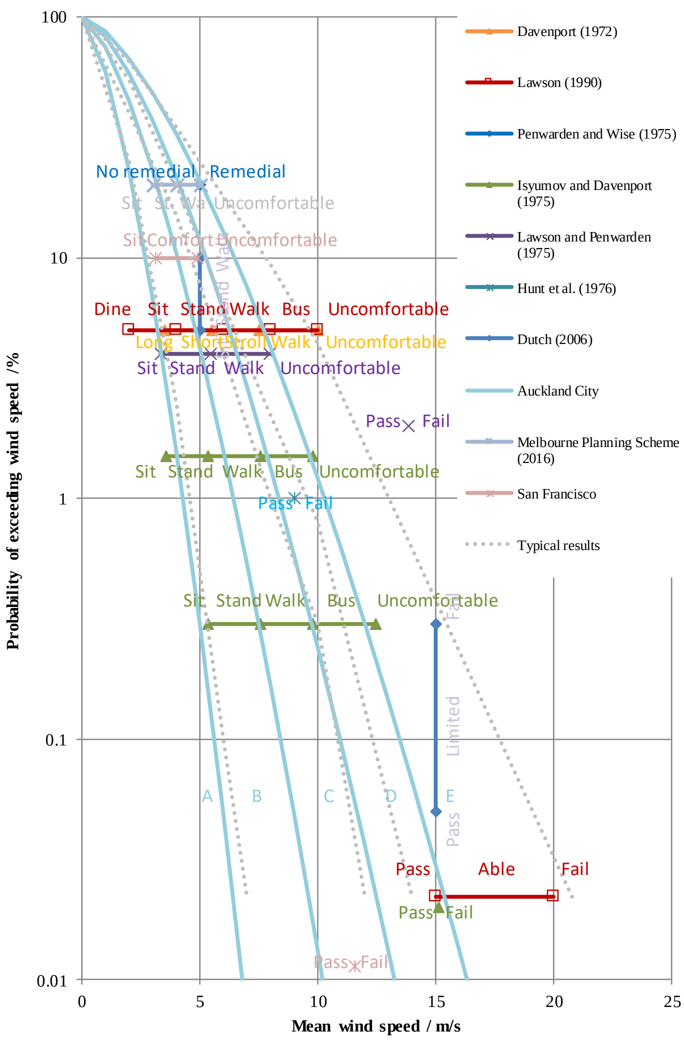

Figure 14 Probabilistic comparison between wind criteria based on mean wind speed

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 15: Auckland Utility Plan (2016) wind categories

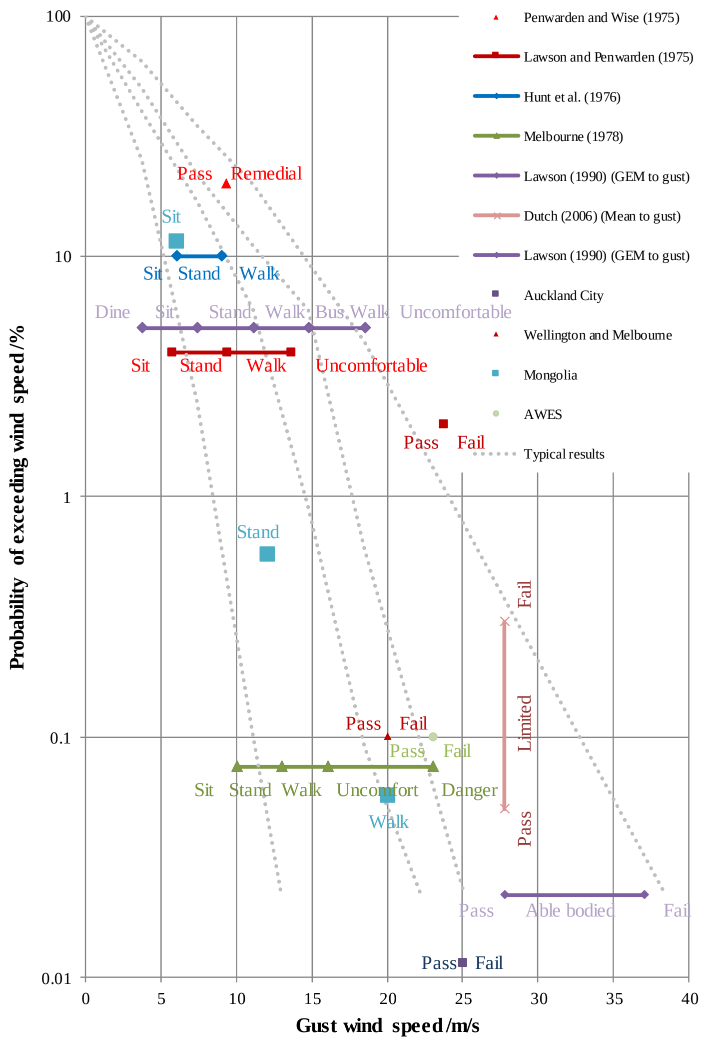

Figure 16 Probabilistic comparison between wind criteria based on 3 s gust wind speed

Appendix 4: Reference documents

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

- Render 2.pdf
- Render 4.pdf
- sections.pdf

- EX_PLOTSHEET LEVEL-00.pdf
- EX_PLOTSHEET LEVEL-01.pdf
- EX_PLOTSHEET LEVEL-02.pdf
- EX_PLOTSHEET LEVEL-03.pdf
- EX_PLOTSHEET LEVEL-04.pdf
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- EX_PLOTSHEET LEVEL-06.pdf
- EX_PLOTSHEET LEVEL-07.pdf
- EX_PLOTSHEET LEVEL-ROOF.pdf

- ELEVATIONS.pdf
- MAJOR SECTIONS Model (1).pdf
- Project Option - Proposed plans scope and areas.pdf