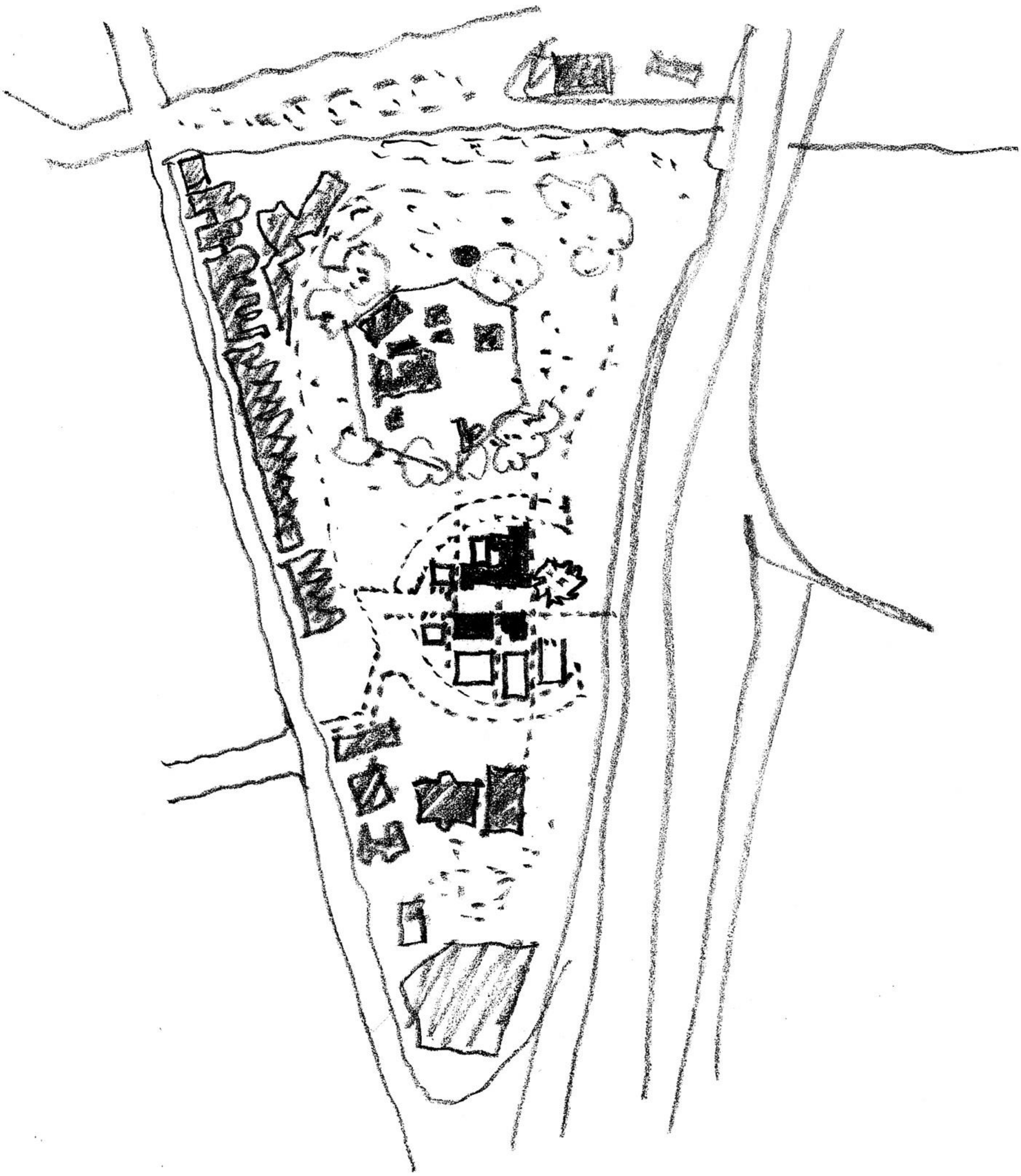
Fort Street Public School Environmental Wind Assessment

SSD 10340
Prepared by Arup
For School Infrastructure NSW
14 January 2020



Department of Education NSW

Fort Street Primary School

Environmental Wind Assessment

Wind

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Executive summary

Arup have been commissioned by the NSW Department of Education to provide an experienced-based impact assessment of the proposed redevelopment of the Fort Street Primary School on the pedestrian level wind conditions for comfort and safety in and around the site. This report addresses SEARs requirement 5. Environment Amenity for the impact of the development on wind amenity.

From a wind perspective, the building massing has not changed significantly from the existing conditions and there is a better protective wall of buildings to the south of the site shielding the prevailing winds from this quadrant. The large outdoor area in the north-east quadrant is well located.

It is Arup's opinion that from a wind comfort perspective, the wind conditions at the majority of locations around the development would be expected to be classified as suitable for pedestrian standing with locations closer to the buildings suitable for sitting and walking activities. These classifications match the intended use of the precinct. All locations within the proposed development would meet the safety criterion.

To quantify the qualitative advice provided in this report, numerical or physical modelling of the development would be required, which is best conducted during detailed design.

Contents

Tables

Figures

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

Department of Education NSW have engaged Arup to provide a qualitative environmental wind assessment for the proposed redevelopment of Fort Street Primary School. This report outlines the assessment and subsequent recommendations related to pedestrian wind comfort and safety on the ground level in and around the site. The report addresses SEARs requirement 5. Environment Amenity for the impact of the development on wind amenity

2 Wind assessment

2.1 Local wind climate

Weather data recorded at Sydney Airport by the Bureau of Meteorology has been analysed for this project. The Bureau of Meteorology anemometer mounted on Observatory Hill was decommissioned in 1992 when the impact of the city massing was interfering significantly with the measurements. The analysis of the Sydney Airport anemometer is summarised in Appendix 1, which is considered appropriate for the wind conditions at the site location. Strong prevailing winds for the site are from the north-east, south, and west quadrants. This wind assessment is based on these wind directions. 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. Wind 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 wind controls used in this wind assessment are based on the work of Lawson (1990) as described in Figure 15 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 data from the wind climate to the typical site location, the mean wind speed exceeded 5% of the time would be approximately 6 m/s. With reference to Table 1, this wind speed is on the boundary of pedestrian standing and walking conditions and from our knowledge of the environs would be considered appropriate.

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

Fort Street Primary School is located on the top of Observatory Hill to the north of Sydney CBD, Figure 1. The immediate surrounds are low-rise buildings and reasonably mature trees in all directions. Observatory hill rise about 40 m above sea level and is exposed to wind from most directions. From a wind perspective, the topography drops down from the site in all directions.

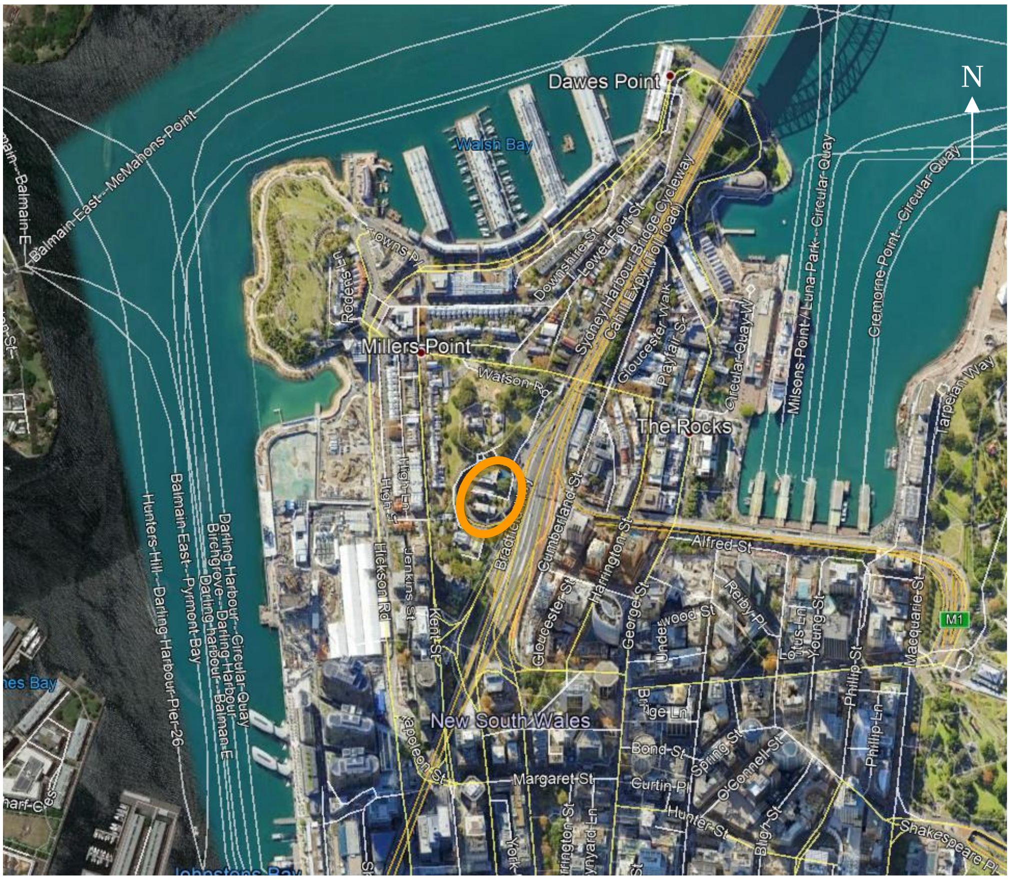

Figure 1 Site location (source: Google Earth 2018)

A comparison between the existing and proposed multiple low-rise buildings is illustrated in Figure 2. The proposed buildings are spread across the site, rising to a height of 3 levels as shown in Figure 3 to Figure 5.

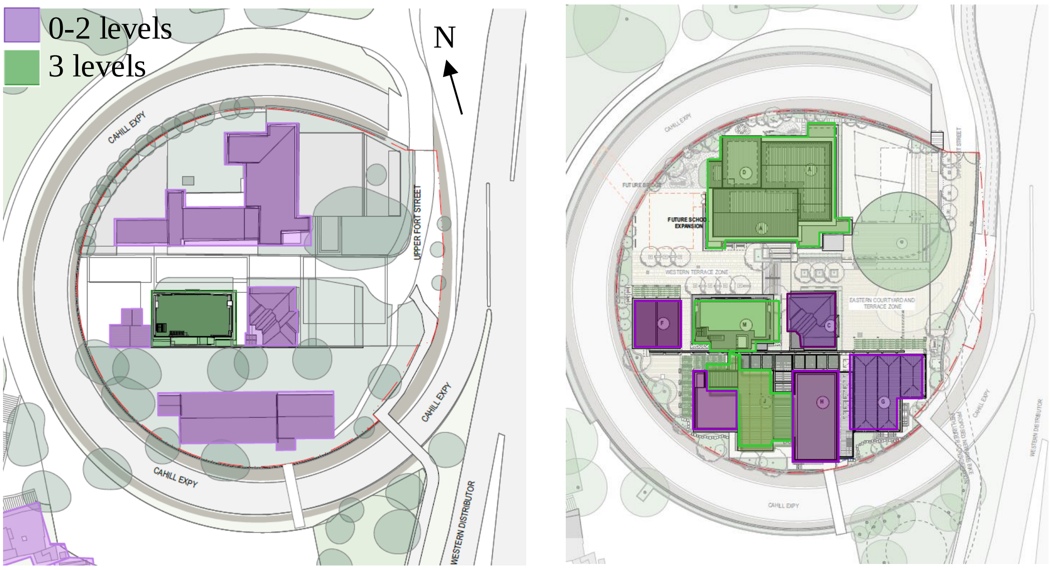

Figure 2: Existing site plan (L), proposed plan (R)

Figure 3: North elevation

Figure 4: South elevation

Figure 5: West elevation

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 the local climate, topography, and building form. The height, massing, proximity, and orientation of the proposed buildings has a small impact on the wind conditions compared with the exposure, topography, and landscaping, Figure 6. From a wind perspective, the buildings are close together and act as a compound shape.

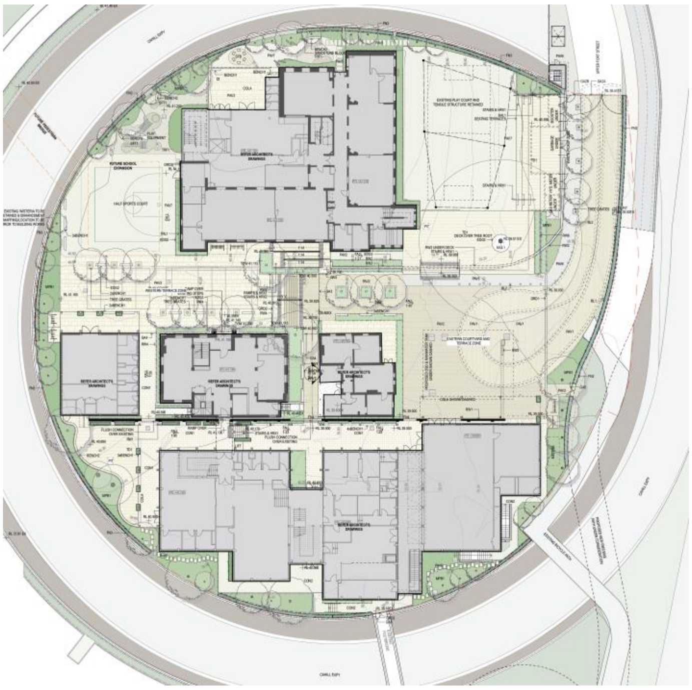

Figure 6: Ground floor landscaping plan

Winds from the north-east

The school is exposed to winds from the north-east and accelerates over the crest of Observatory Hill. The open area to the north-east of the site would be sheltered by the landscaping and would be relatively calm close to Building A caused by the back pressure. The low-rise nature of the buildings in the south-east corner of the site would offer further protection to this area with wind passing over these buildings rather than along the east-west gap between the buildings.

Winds from the south

Winds from the south are blocked by the city and the proposed buildings to the south of the site. The central passageway and outdoor area in the north-east and north-west corners are well-protected for winds from this direction.

Winds from the west

The site is exposed to winds from the west due to the location to the north of the city and the local topography. The slightly taller buildings to the west of the site would channel some flow between the buildings along the central passageway. For winds from slightly to the north of west, the wind would be channelled between the two slightly taller buildings and directed along the central passageway. The proposed landscaping would ameliorate the wind conditions in this area. The outdoor area in the north-east corner is well-protected for winds from this direction.

Final assessment of wind conditions

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. Closer to the building, conditions would be improved to sitting, or walking on the western corners. The wind conditions at all locations are expected to pass the safety criteria.

3 Summary

Arup have provided qualitative advice for the impact of the proposed development on pedestrian wind comfort. The building massing has not changed significantly from the existing conditions and there is a better protective wall of buildings to the south of the site shielding the prevailing winds from this quadrant. The large outdoor area in the north-east quadrant is well located.

It is Arup’s opinion that from a wind comfort perspective, the wind conditions at the majority of locations around the development would be expected to be classified as suitable for pedestrian standing with locations closer to the buildings suitable for sitting and walking activities depending on the location. These classifications match the intended use of the precinct. All locations within the proposed development would meet the safety criterion.

To quantify the qualitative advice provided in this report, numerical or physical modelling of the development would be required, which is best conducted during detailed design.

4 References

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Appendix 1: Wind climate

The wind frequency and direction information measured by the Bureau of Meteorology anemometer at a standard height of 10 m at Sydney Airport from 1995 to 2016 have been used in this analysis, Figure 7. The arms of the wind rose point in the direction from where the wind is coming from. The anemometer is located about 8 km to the east of the site. The directional wind speeds measured here are considered representative of the wind conditions at the site.

It is evident from Figure 7 that strong prevailing winds are organised into three main groups which centre at about the north-east, south, and west quadrants.

Strong summer winds occur mainly from the south quadrant and the north-east. 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 south-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.

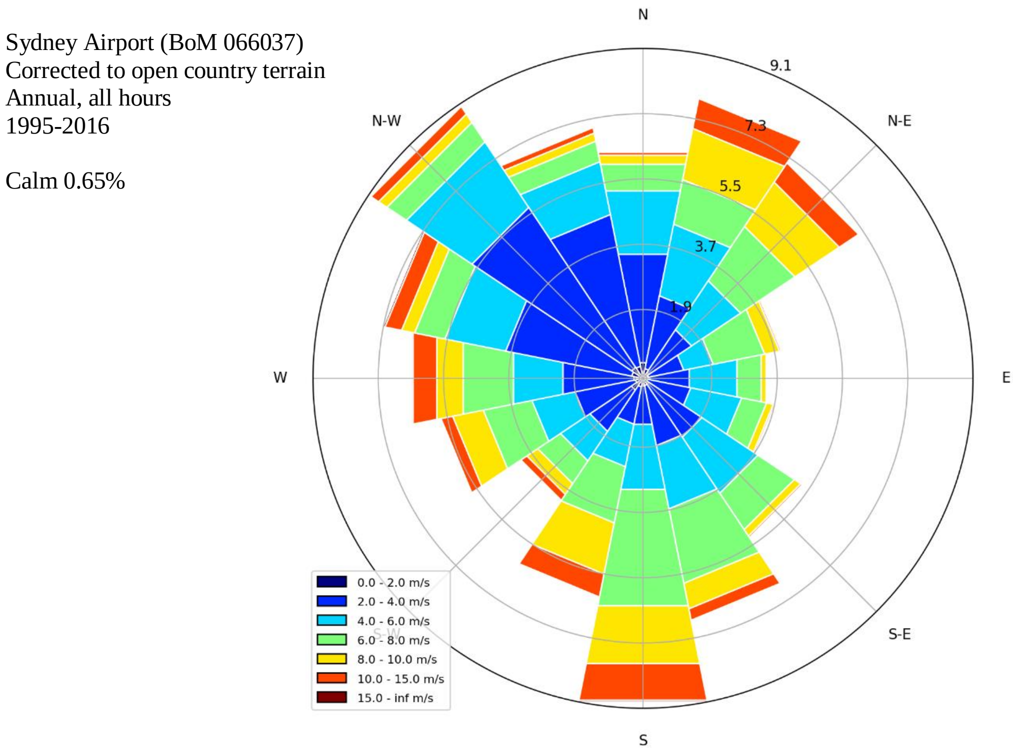

Figure 7 Wind rose showing probability of time of wind direction and speed

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 8, 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 8. 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.

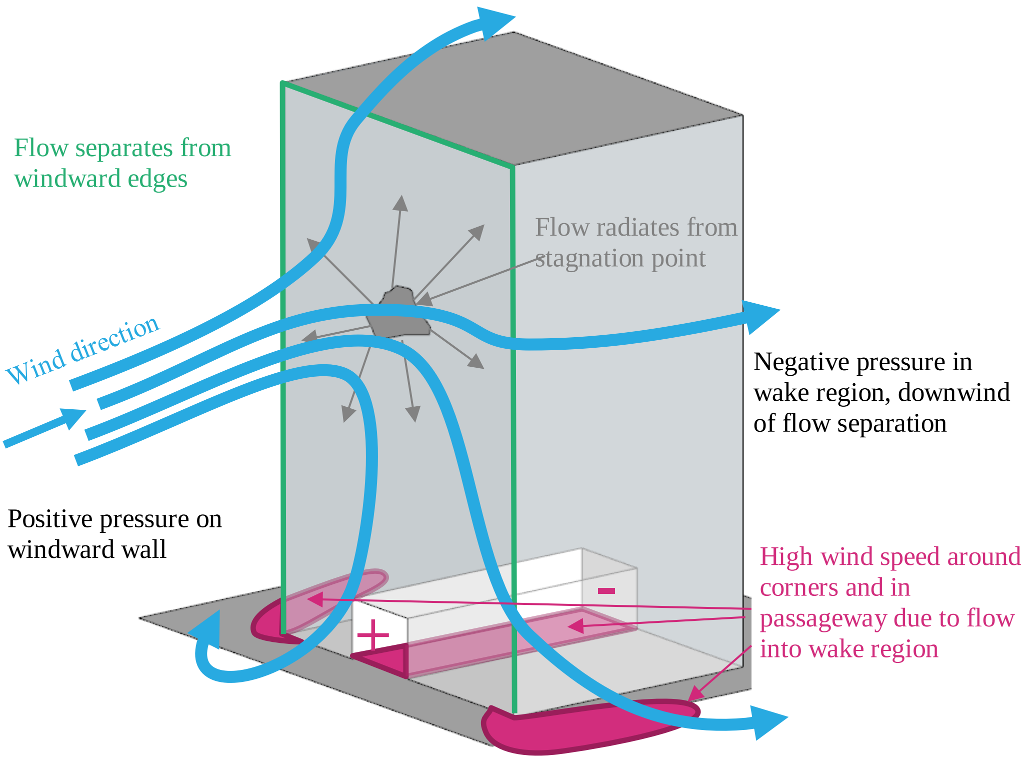

Figure 8 Schematic wind flow around tall isolated building

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 9. 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.

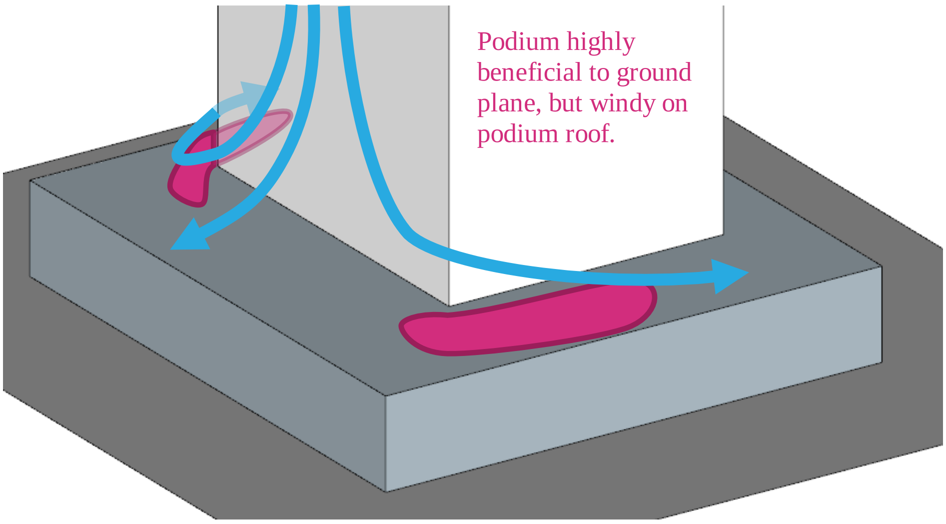

Figure 9 Schematic flow pattern around building with podium

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 10. 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.

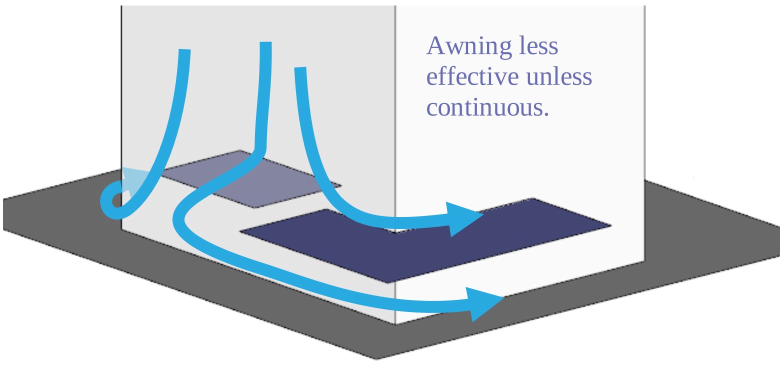

Figure 10 Schematic flow pattern around building with awning

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 11. 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 8. If the link is blocked, wind conditions will be calm unless there is a flow path through the building, Figure 12. 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 12.

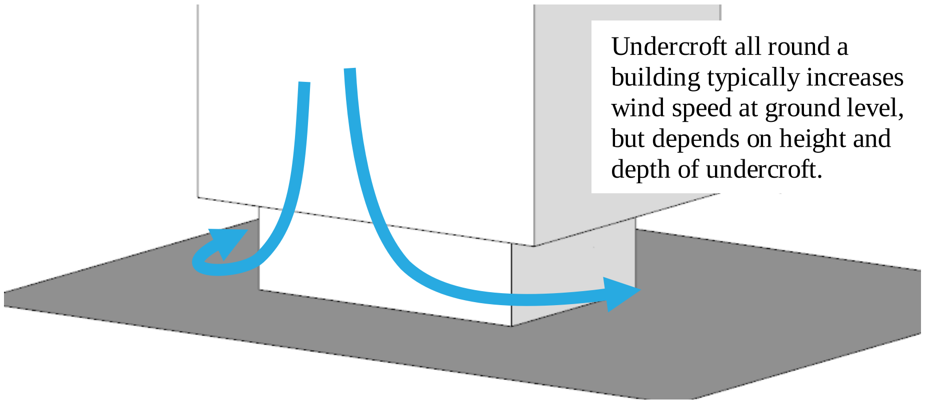

Figure 11 Schematic of flow patterns around isolated building with undercroft

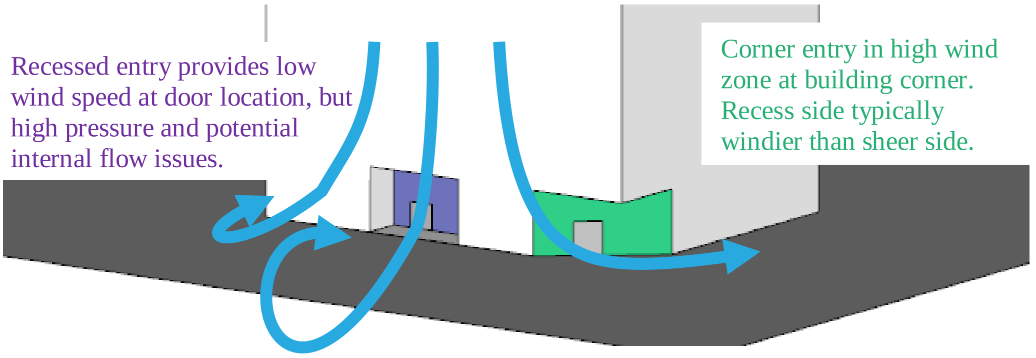

Figure 12 Schematic of flow patterns around isolated building with ground articulation

Multiple buildings

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 13. 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.

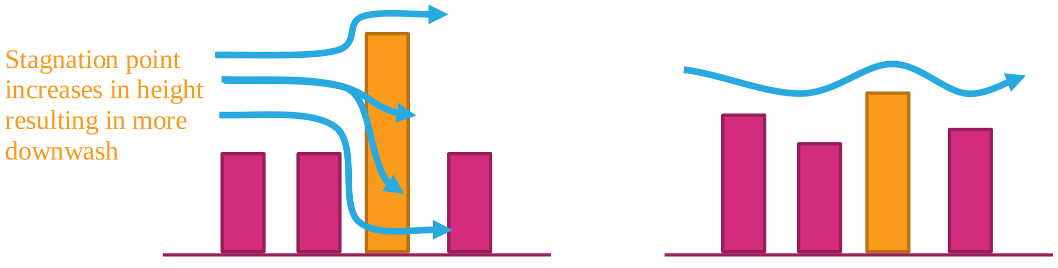

Figure 13 Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 14.

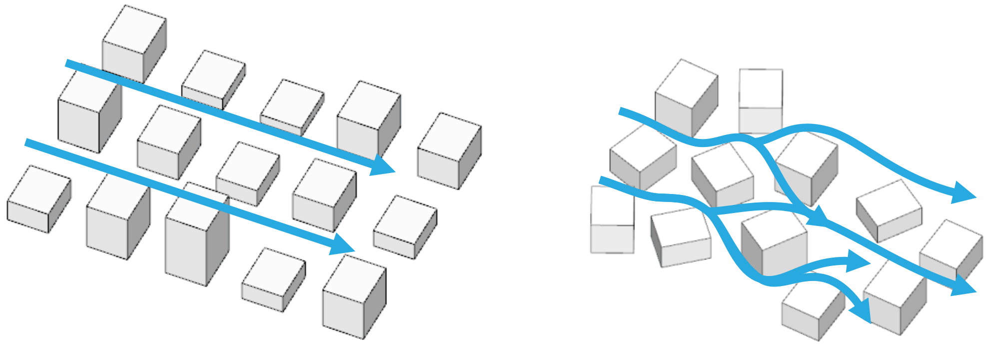

Figure 14 Schematic of flow patterns through a grid and random street layout

Channelling occurs when the wind is accelerated between two buildings, or along straight streets with buildings on either side, Figure 14(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 14(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:

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

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 15 and Figure 17. 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 15 with definitions of the intended use of the space categories defined in Figure 16.

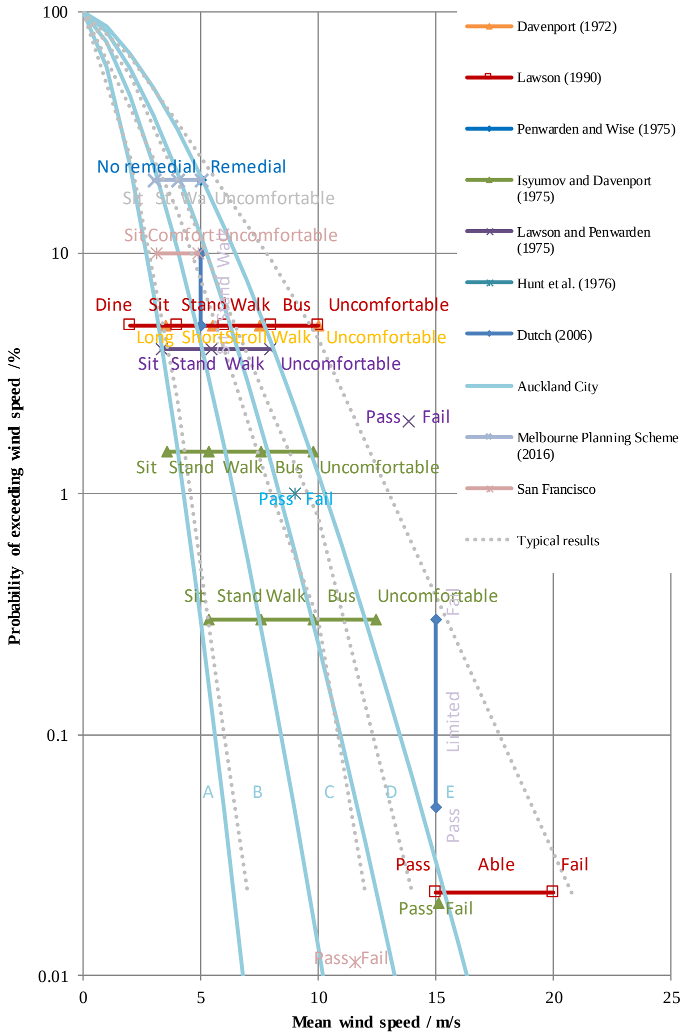

Figure 15 Probabilistic comparison between wind criteria based on mean wind speed

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 16: Auckland Utility Plan (2016) wind categories

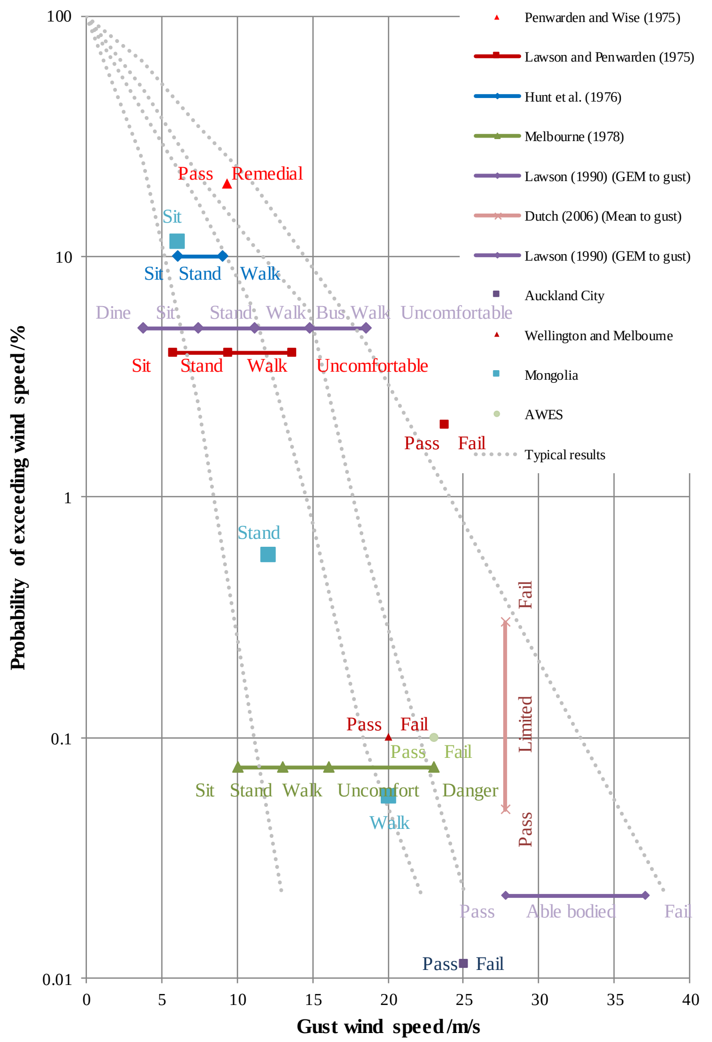

Figure 17 Probabilistic comparison between wind criteria based on 3 s gust wind speed

Appendix 4: Reference documents

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

- DA-1101 Location Plan - Existing.pdf
- DA-1201 Site Plan Existing.pdf
- DA-1202 Site Analysis.pdf
- DA-1211 Site Plan Proposed.pdf
- DA-2001 Proposed Plan - Lower Ground 1.pdf
- DA-2002 Proposed Plan - Ground.pdf
- DA-2003 Proposed Plan - Level 1.pdf
- DA-2004 Proposed Plan - Level 2.pdf
- DA-2005 Proposed Plan - Roof.pdf
- DA-2101 Demolition Plan - Ground.pdf
- DA-2102 Demolition Plan - Level 1.pdf
- DA-2103 Demolition Plan - Level 2.pdf
- DA-2104 Demolition Plan - Roof.pdf
- DA-2105 Services Excavation On Demolition Plan.pdf
- DA-3001 Elevations North East.pdf
- DA-3002 Elevations South West.pdf
- DA-4001 Sections 1.pdf
- DA-4002 Sections 2.pdf
- DA-4003 Sections 3.pdf
- DA-4004 Sections 4.pdf
- DA-5001 Detailed Areas - Heritage Wall.pdf
- DA-5002 Detailed Areas - Heritage Wall Details.pdf
- DA-5003 Detailed Areas - Bradfield Mechanical Exhaust.pdf
- DA-5004 Detailed Areas - Surgeon's Cottage.pdf
- DA-5005 Detailed Areas - MET Elevator shaft.pdf
- DA-5006 Detailed Areas - FSPS Existing Hall Skylight.pdf
- DA-5901 FT01 _ FT02 Building A.pdf
- DA-5902 FT03 Building D.pdf
- DA-5903 FT04 N _ FT04 W Building D.pdf
- DA-5904 FT05 _ FT06 Building C.pdf
- DA-5905 FT07 Building F_G.pdf
- DA-5906 FT08 _ FT09 _ FT13 N Building M.pdf
- DA-5907 FT10 Building J_H.pdf
- DA-5908 FT11 C.O.L.A..pdf
- DA-5909 FT12 Services Enclosure.pdf
- DA-5910 FT13 Glass Infill Building J_HG.pdf
- DA-8001 Landscape Design Plan.pdf
- DA-8002 Landscape Ground Floor.pdf
- DA-8003 Landscape Roof Plan.pdf
- DA-8004 Tree Management Plan.pdf
- DA-8101 Landscape Sections.pdf
- DA-9011 Exterior Finishes Samples.pdf