Cranbrook School

Cranbrook School Redevelopment

Wind Desktop Study

Wind

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Executive Summary

Cranbrook School have engaged Arup to provide an environmental wind assessment for the proposed development at Cranbrook School, 5 Victoria Road, Bellevue Hill. The local wind climate, surrounding topography, and building form have been analysed. It is Arup's opinion that the redevelopment would have minimal impact on the surrounding wind environment. It is shielded by local topography and surrounding buildings for two of the three prevailing winds and has similar massing to the existing building.

It is Arup's opinion that all areas are expected to pass the safety requirements and external wind conditions would be classified as suitable for pedestrian standing. This aligns with the intended use of outdoor spaces, hence, no ameliorations have been recommended.

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1 Introduction

Arup has been engaged by Cranbrook School to provide a qualitative environmental wind assessment for the proposed development at Cranbrook School, 5 Victoria Road Bellevue Hill, Figure 1. This report assesses the impact of the proposed development on the pedestrian level wind environment in and around the site.

Figure 1 - Aerial view showing urban context (Google Earth 2016)

2 Assessment

2.1 Site Description

Cranbrook School is undertaking a major redevelopment of the Cranbrook Senior School situated in Bellevue Hill, New South Wales. The Cranbrook School redevelopment aims to update and redevelop the existing infrastructure to create dynamic and adaptive social, learning facilities that will help facilitate Cranbrook in its vision of being a world class school.

An aerial view of the surrounding area is shown in Figure 1. The local topography shields the site to winds from the south and to a lesser extent from the west. To the north-east is Sydney Harbour which does not offer any shielding from prevailing winds.

The Aquatic and Fitness Centre (AFC) building, Figure 2 to Figure 4, is proposed to be constructed beneath what is currently the school oval. It will consist of two swimming pools and a gym with associated facilities as well as a car park. The new WMH will replace the existing WMH, it will consist of a theatre, sports hall, dining, and teaching spaces. The massing of the new WMH is similar to the existing building. The northern façade of the WMH would be exposed with the majority of other facades being underground, the top level will consist of a green roof and a chapel.

Figure 2 - Render of the proposed redevelopment viewed from the north-east (provided by Architectus 2017)

Figure 3 - Render of proposed war memorial hall viewed from the north (provided by Architectus 2017)

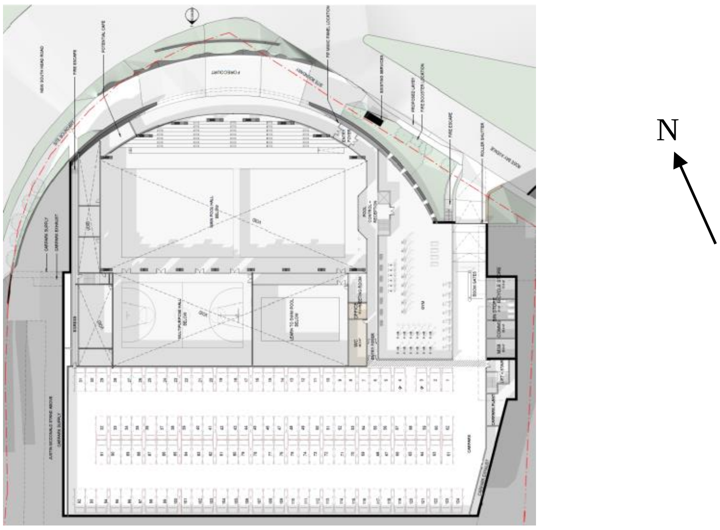

Figure 4 – Aeriel view and plan of underground aquatics and recreation centre (provided by Architectus 2018)

2.2 Local Wind Climate

Weather data recorded at Sydney Airport by the Bureau of Meteorology has been analysed. The analysis is summarised in Appendix A.

The prevailing strong wind directions for the Sydney region are from the north-east, south and west. This wind assessment is focused on these prevailing wind directions.

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

2.3 Wind Comfort Criteria

Wind comfort is generally measured in terms of mean air speed and fluctuations (or gusts), where higher wind speeds are considered less comfortable. Air speeds have a large impact on thermal comfort and are generally welcome during hot summer conditions. This assessment is focused on air speeds in terms of mechanical comfort.

There have been many wind comfort criteria developed in the 20th century and many jurisdictions take different approaches. The relevant standards for environmental wind comfort are discussed in Appendix C.

The Woollahra Development Control Plan 2015 has no specific requirements or regulations focused on the impact on wind conditions in and around the site. In the absence of explicit requirements, the research of Lawson (1990), which has been adopted in the Central Sydney Planning Strategy 2016-2036, Table 2, will be adopted as it contains appropriate targets for the Sydney region. Based on these targets, mean wind speeds above 4 m/s for more than 5% of the time in sitting areas are considered uncomfortable, and wind speeds above 8 m/s in other outdoor areas are considered uncomfortable. The corresponding mean wind speed for pedestrian safety is 20 m/s for 0.022% of the time. The wind assessment of individual spaces are assessed under the criteria outlined in Appendix C.

Note that there is general agreement between the criteria and the assessment criteria used in this report closely matches the standards discussed in Appendix C. All recommendations made in this report aim to minimise the risks that the wind speed criteria are exceeded.

2.4 Predicted Wind Conditions

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 development massing of the WMH and AFC does not protrude above the local surrounding buildings and is shielded by topography for winds from the south and west. As such, the proposed development is not expected to increase the local airspeeds in the public areas surrounding the site. The wind conditions are expected to be similar to typical residential areas and be similar to the current conditions. The wind conditions are expected to pass the safety criteria, and classified as suitable for pedestrian standing from a comfort perspective.

Winds from the south

Topography shields winds from the south. It is expected that the wind conditions at the site will be similar to typical residential areas at street level. The development is unlikely to perceptibly elevate wind speeds at the site above existing conditions.

Winds from the west

The site is shielded from winds from the west, due to local topography, existing buildings, and landscaping including the mature trees along New South Head Road. These benefits would result in the wind flow pattern staying similar to the existing conditions.

Winds from the north-east

The site is exposed to winds from the north-east. As such, the sports field, entry to the AFC, Figure 5, and isolated corner areas around the WMH would be expected to experience elevated wind speeds.

Figure 5 – Entrance to the AFC viewed from the north-east

Winds from the north-east would accelerate over the top and around the west side of the new WMH as shown in Figure 6 and Figure 7. Some outdoor areas may experience wind speeds, under these wind conditions, that are too high for activities such as studying or generally seating to be considered comfortable.

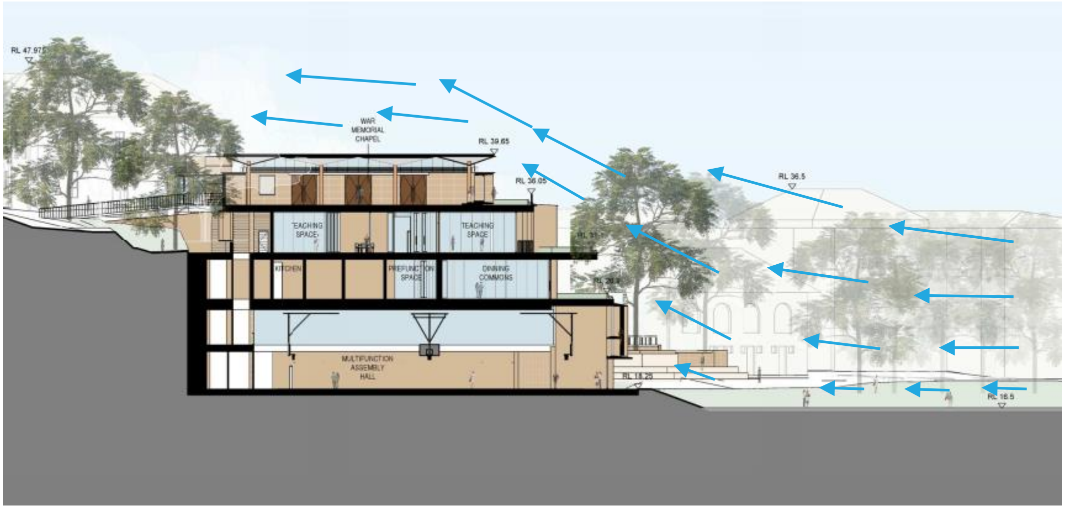

Figure 6 - Section view of north-east wind flows looking north-west

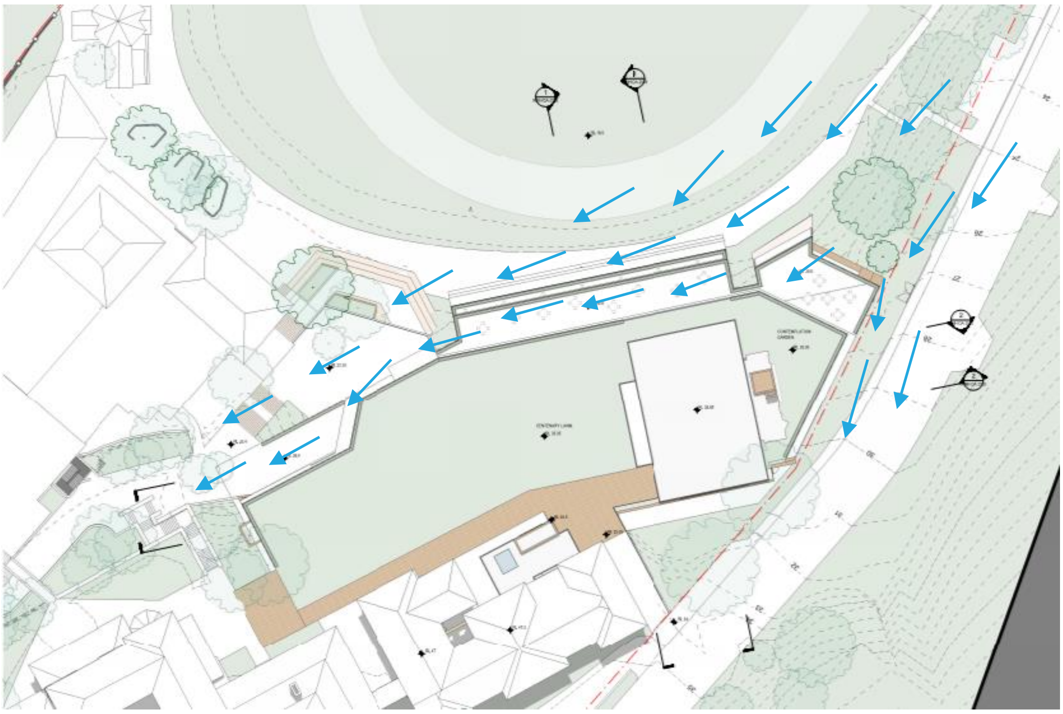

Figure 7 - Plan view of north-east wind flows

Summary

As the massing of the proposed building is similar to the existing buildings, the wind conditions around the site are expected to stay similar to the existing 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. All locations would meet the safety criterion.

Internal Flow Paths

The north facing façade of the WMH is exposed to winds form the west and north-east. As such there will be increased pressures on the north façades. Since there are some openings to the south from the same internal volume, this has the potential to cause increased air flows through the internal spaces when there are multiple openings.

Two areas worth highlighting are the WMH chapel, and level 3 of the WMH. The potential air flow paths are shown in Figure 8 and Figure 9 respectively. As multiple openings are required to generate the internal flows, management procedures can be adopted to mitigate the effects.

It is worth noting that the external façade pressures may drive air through the natural ventilation path at the basketball court at rates much greater than if driven by the stack affect alone.

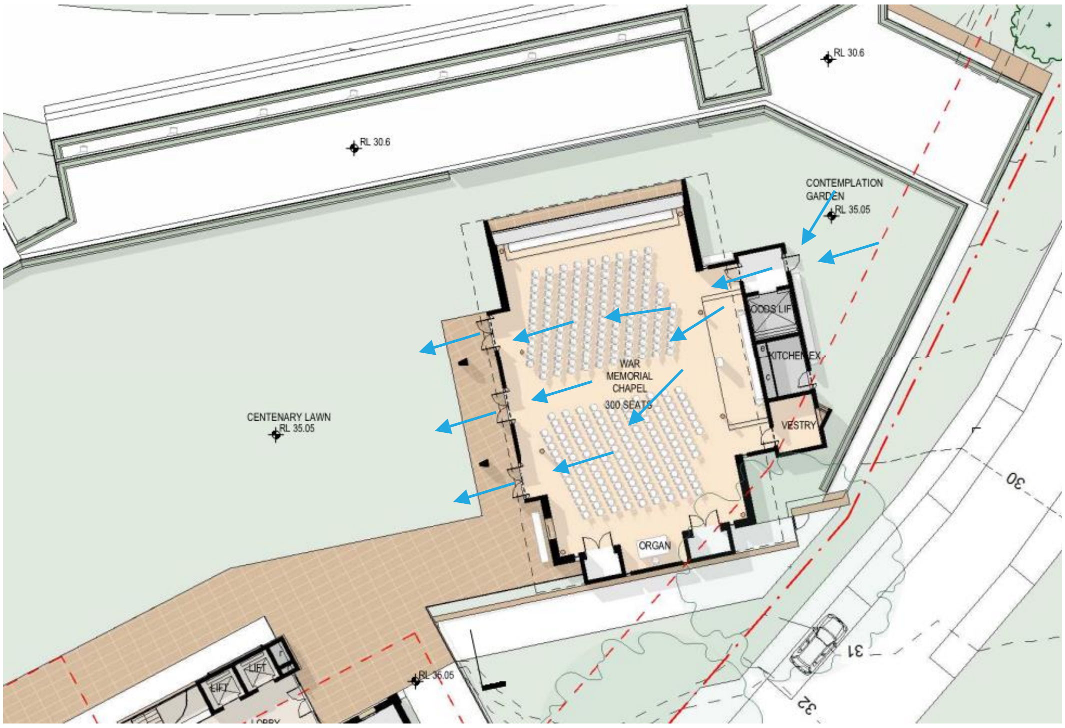

Figure 8 - Plan view of internal wind flows in chapel

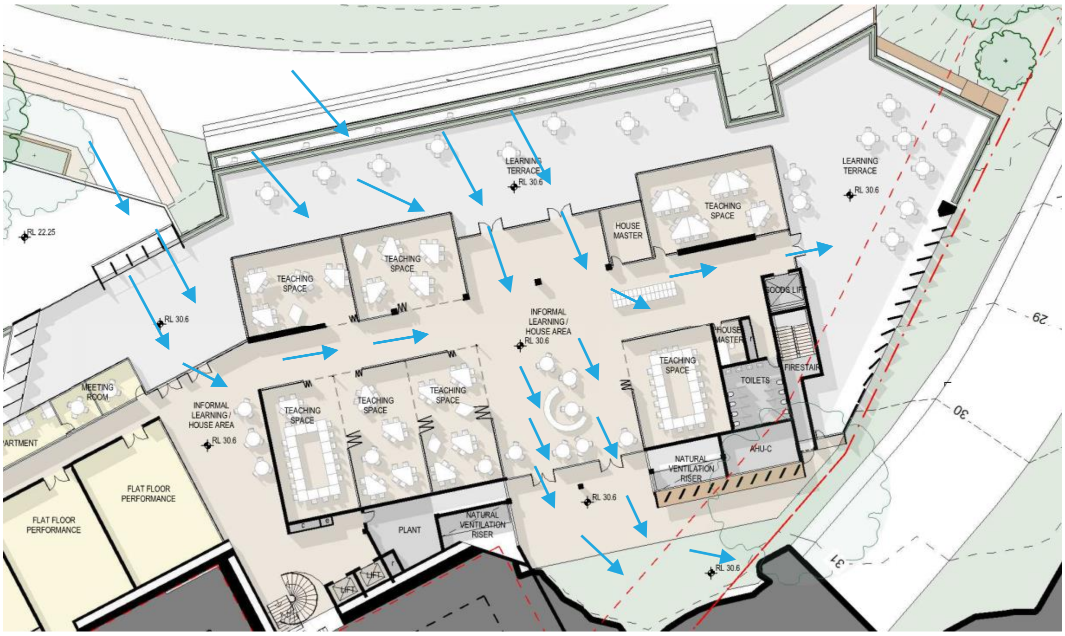

Figure 9 - Plan view of internal wind flows level 3

3 Recommended Ameliorations

As discussed in the previous section the external wind conditions are expected to be similar to existing conditions. It is considered that the majority of external wind conditions would be classified as suitable for pedestrian standing and all locations would meet the safety criterion. As such, no recommended ameliorations are being suggested.

It is recommended that an internal draft assessment be conducted on the natural ventilation flow path to ensure air speeds are acceptable. Alternatively control systems can be installed to reduce the flow rate when specified limits are exceeded.

4 Summary

It is Arup’s opinion that all locations within the proposed development would meet the safety criterion. The external wind conditions would be classified as suitable for pedestrian standing. It has been recommended that an internal air flow study be conducted to predict natural ventilation rates and internal draughts.

The wind speeds at the site could be quantified using computational fluid dynamics or wind tunnel tests. However, it is Arup’s opinion that this level of assessment is not required for this re-development.

References

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Appendices

Appendix A: 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 10. 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 wind conditions at the site.

It is evident from Figure 10 that strong prevailing winds are organised into three main groups which centre at about the north-east, south, and west directions.

Strong summer winds occur mainly from the north-east and south quadrant. Winds from the south are associated with large synoptic frontal systems and generally provide the strongest gusts during summer. North-east winds often improve thermal comfort on hot summer days.

Winter and early spring strong winds typically occur from the 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.

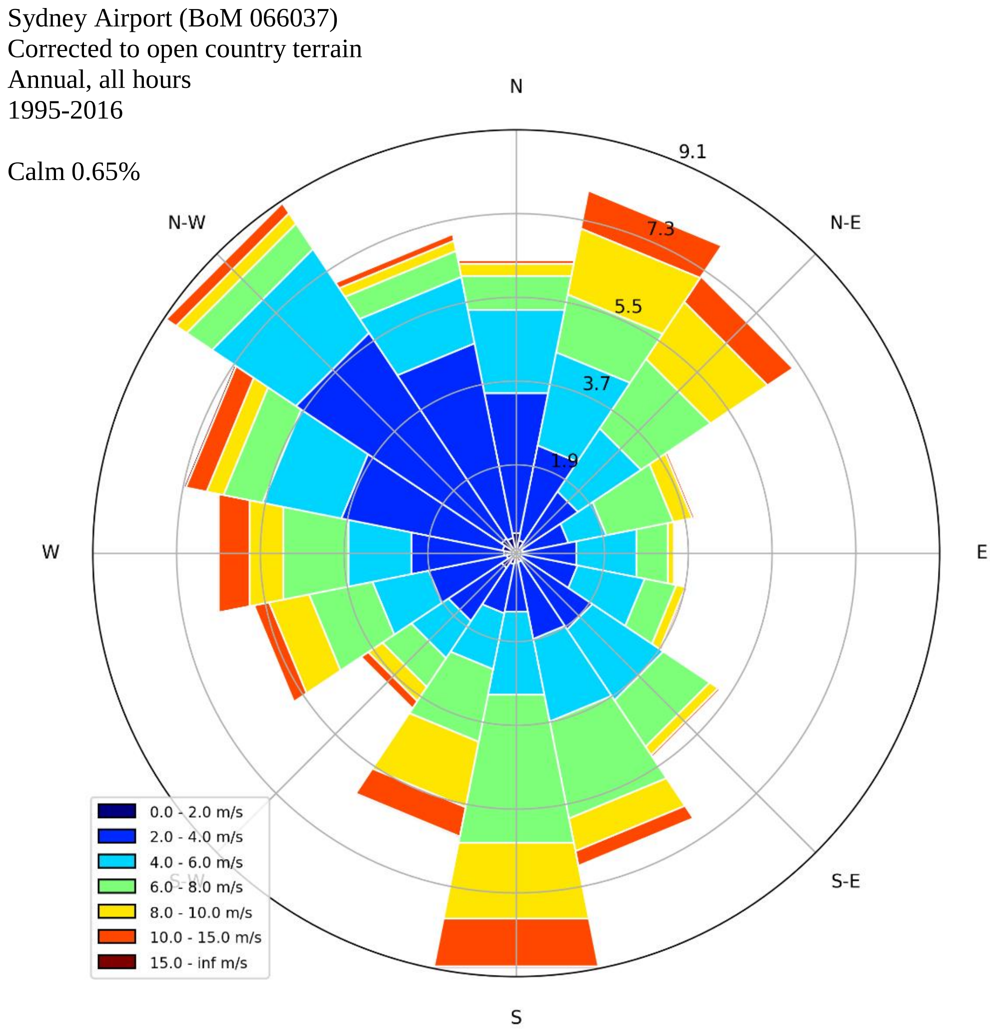

Figure 10 - Sydney airport wind rose

Appendix B: 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 11, 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 11. 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.

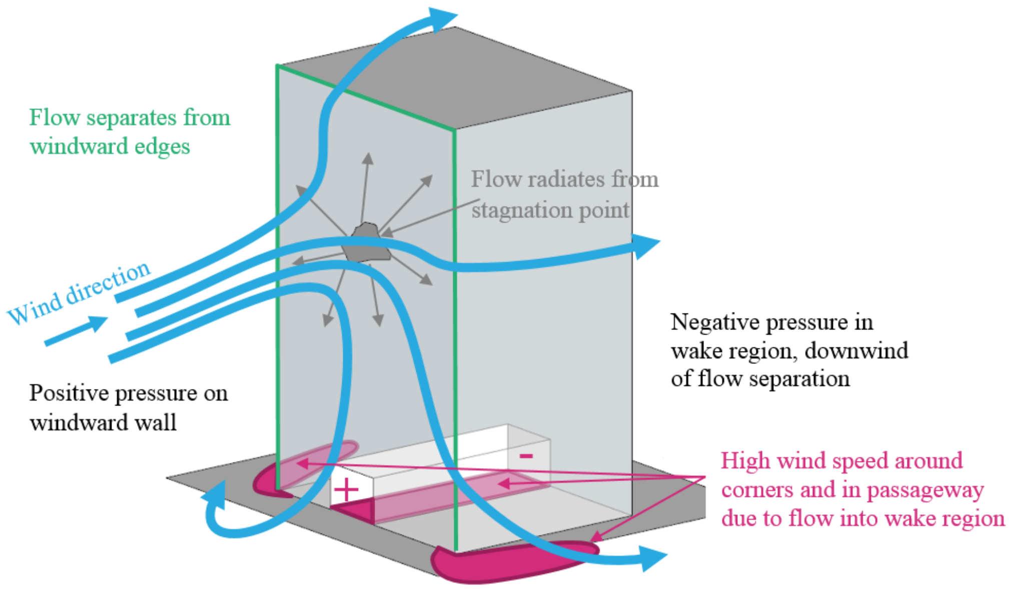

Figure 11 - Schematic wind flow around tall isolated building

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 12. 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.

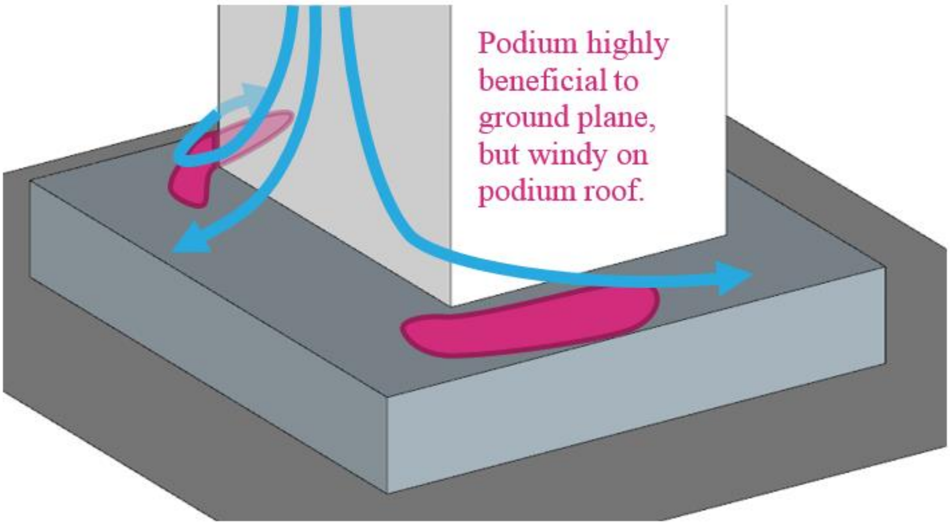

Figure 12 - Schematic flow pattern around building with podium

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 13. 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.

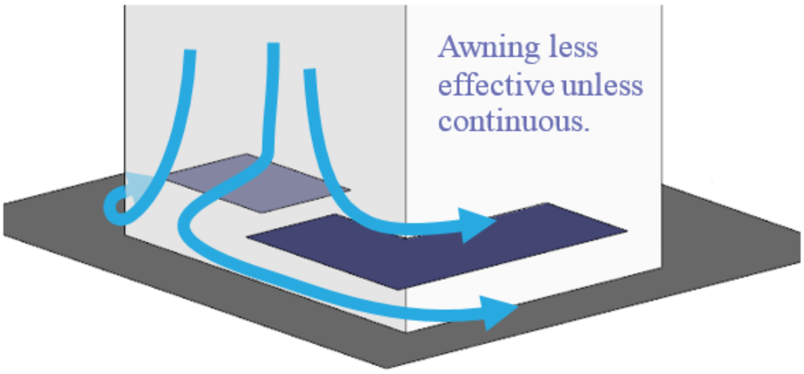

Figure 13 - Schematic flow pattern around building with awning

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 14. 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 11. If the link is blocked, wind conditions will be calm unless there is a flow path through the building, Figure 15. 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 15.

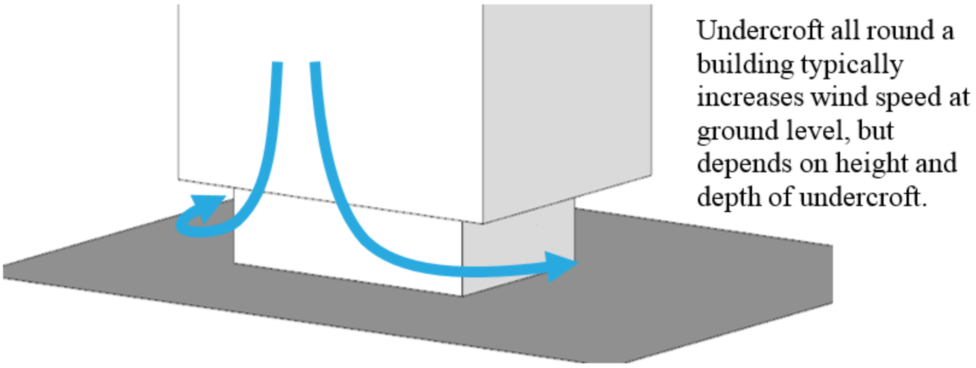

Figure 14 - Schematic of flow patterns around isolated building with undercroft

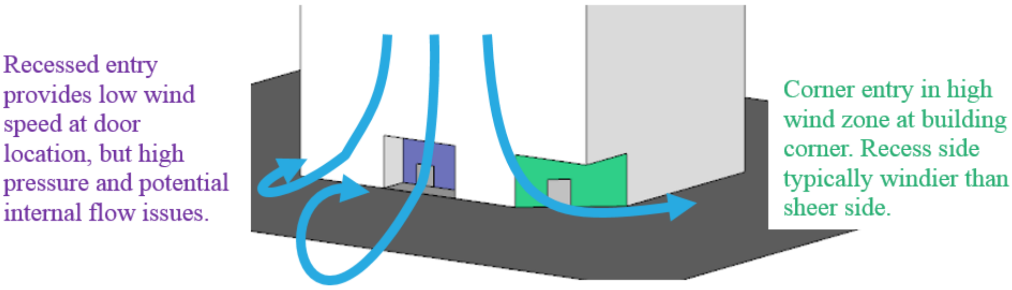

Figure 15 - Schematic of flow patterns around isolated building with ground articulation

Multiple Buildings

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative Figure 16. 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.

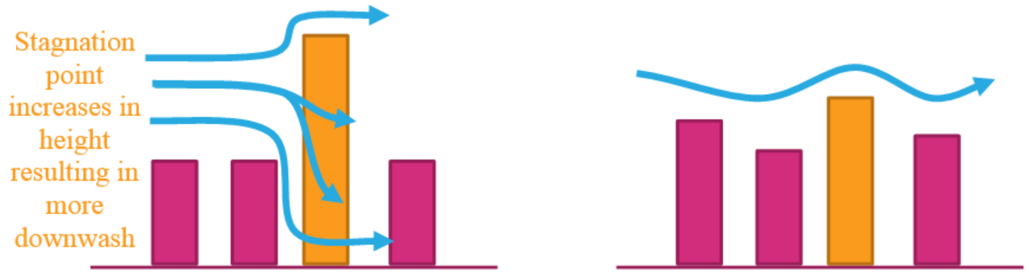

Figure 16 - Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 17.

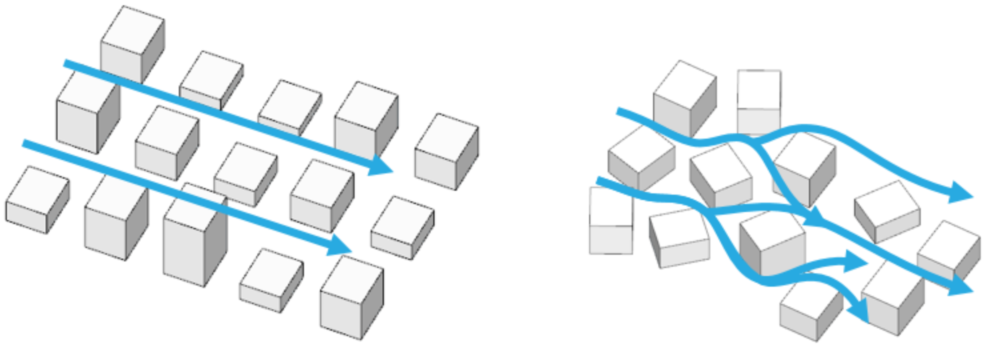

Figure 17 - Schematic of flow patterns through a grid and random street layout

Channelling occurs when the wind is accelerated between two buildings, or along straight streets with buildings on either side, Figure 17(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 17(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 C: 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 1. 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 1 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:

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

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 18 and Figure 20. The grey lines are typical results from modelling and show how the various criteria would classify a single location.

Figure 18 Table 2Table 2 Pedestrian comfort criteria for various activities

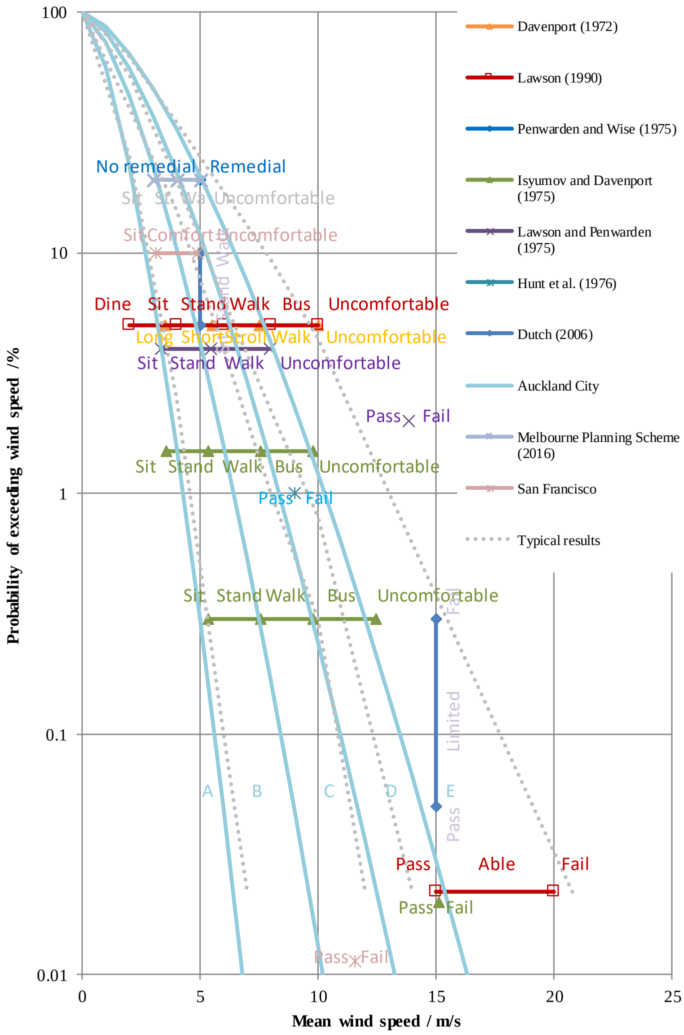

Figure 18 - Probabilistic comparison between wind criteria based on mean wind speed

City of Auckland has control mechanisms for accessing usability of spaces from a wind perspective as illustrated in Figure 20 with definitions of the intended use of the space categories defined in Figure 19.

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 19 - Auckland Utility Plan (2016) wind categories

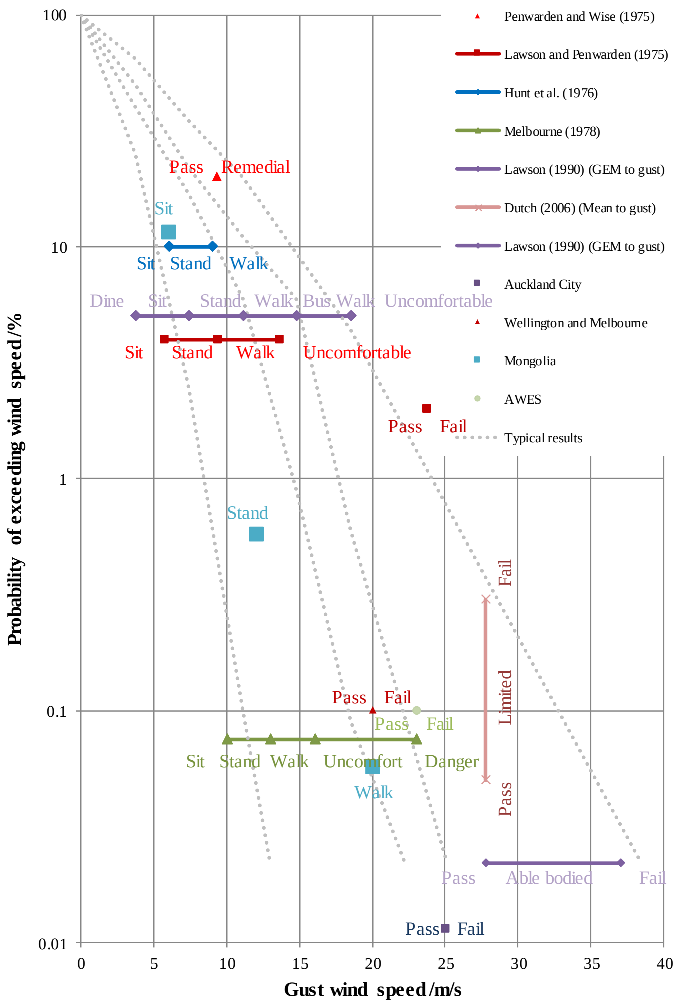

Figure 20 - Probabilistic comparison between wind criteria based on 3 s gust wind speed

Appendix D: Reference Documents

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

- 170608 CBK Study 1A and 2_COMBINED.pdf
- 170609-WMH-Study 1A.pdf
- 170609-WMH-Study 2.pdf
- 170609-WMH-Study 4 Option B.pdf
- 170609-ARC-2016 Scheme Variation.pdf
- 170609-ARC-Option A.pdf
- 180316_Final VE Issue_Aquatic and Fitness Centre.pdf