Stockland

Stockland Piccadilly Complex

Environmental Wind Assessment

Wind

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Executive summary

This report for Planning Proposal provides discussion around wind equivalence for the proposed Stockland Piccadilly Complex development at 133-145 Castlereagh Street, Sydney on the measured wind conditions for comfort and safety around the site. The wind tunnel testing was conducted by Windtech, with the data analysed by Arup.

The inclusion of any large building in the City alters the local wind environment. The effect is greater on the fringe of the City, or on exposed corner sites, and generally decreases with larger surrounding buildings, or remote from the corners of a City block. With the site being in the middle of a block on the eastern fringe of the City, the impact of the building on the local wind environment is expected to be minimal.

The equivalence testing between the Draft DCP compliant and Proposed building envelopes illustrate minimal difference in the wind conditions with the average 5 percentile wind speed across all locations being lower for the Proposed configuration. This indicates that the Proposed scheme meets the Wind Equivalence criteria described in Schedule 11, Section 5.1.1.4, Procedure B of Draft Sydney DCP 2012, dated February 2020. The majority of the area is classified as suitable for pedestrian standing type activities, with four locations being classified as suitable for pedestrian walking, thereby meeting the target criteria as transient space. Location 1 on the corner of Market and Castlereagh Streets marginally exceeds the walking criterion in the DCP compliant configuration, and is slightly below the walking criterion in the Proposed configuration.

From a safety perspective all locations pass the safety criterion in both configurations.

The current tests have shown that the wind conditions around the site are suitable for the intended use of the spaces.

Contents

1 Introduction

This wind assessment report has been prepared by Arup on behalf of Stockland. It accompanies a planning proposal seeking to initiate the preparation of a Local Environmental Plan amendment for the land known as 'Stockland Piccadilly Complex' located at 133-145 Castlereagh Street, Sydney (the site) legally described as Lot 10 in DP828419, Figure 1.

Figure 1: City of Sydney Development Control Plan (DCP) 2012, Active frontages map Sheet 015

The planning proposal seeks to amend the floor space ratio development standard applicable to the site, under the Sydney Local Environmental Plan 2012 (the LEP), in accordance with Section 3.33 of the Environmental Planning and Assessment Act 1979 (EP&A Act).

In accordance with Clause 7.20 of the LEP, this planning proposal also seeks amendments to the Sydney Development Control Plan 2012 (the DCP) to establish site specific provisions to guide the future development, including establishing a building envelope for the site as well as other key assessment criteria.

The intended outcome of the proposed amendments to the LEP and DCP is to facilitate the redevelopment of the site for a commercial office tower development above a retail podium, including Wesley Mission facilities at lower ground level, together with basement car parking and associated facilities. Such a proposal aligns with the draft Central Sydney Planning Strategy to facilitate additional commercial floor space capacity in Central Sydney while also delivering improved public domain outcomes.

The planning proposal is supported by a conceptual reference design, but the final details of the development will be subject to a future design excellence process and a future detailed development application.

This report summarises the wind conditions around the site with a Maximum permissible Draft DCP (with existing buildings and bridges), hereafter called the Draft DCP envelope, and Proposed building envelope on the site.

2 Wind assessment

Arup has been engaged to provide a quantitative environmental wind assessment for the proposed Stockland Piccadilly development at 133-145 Castlereagh Street, Sydney. This report discusses the relevant results of the wind-tunnel testing study conducted, and interpretive discussion on the impact of the proposed development on the pedestrian-level wind comfort and safety.

2.1 Modelling

Wind-tunnel testing was conducted by Windtech in two configurations: Maximum permissible Draft DCP Envelope (with existing buildings and bridges), hereafter called Draft DCP envelope, and Proposed envelope. The major differences between the envelopes from a wind perspective are the existing bridges across Pitt and Castlereagh Streets, and the rounded tower corners in the Draft DCP configuration. Additional differences are in the podium height with 25 and 35 m in the Draft DCP envelope, and 20 to 45 m in the Proposed envelopes, and differences in the tower setback from Castlereagh Street of 8.0 m in the Draft DCP, and 4.8 m Proposed envelopes, Figure 2.

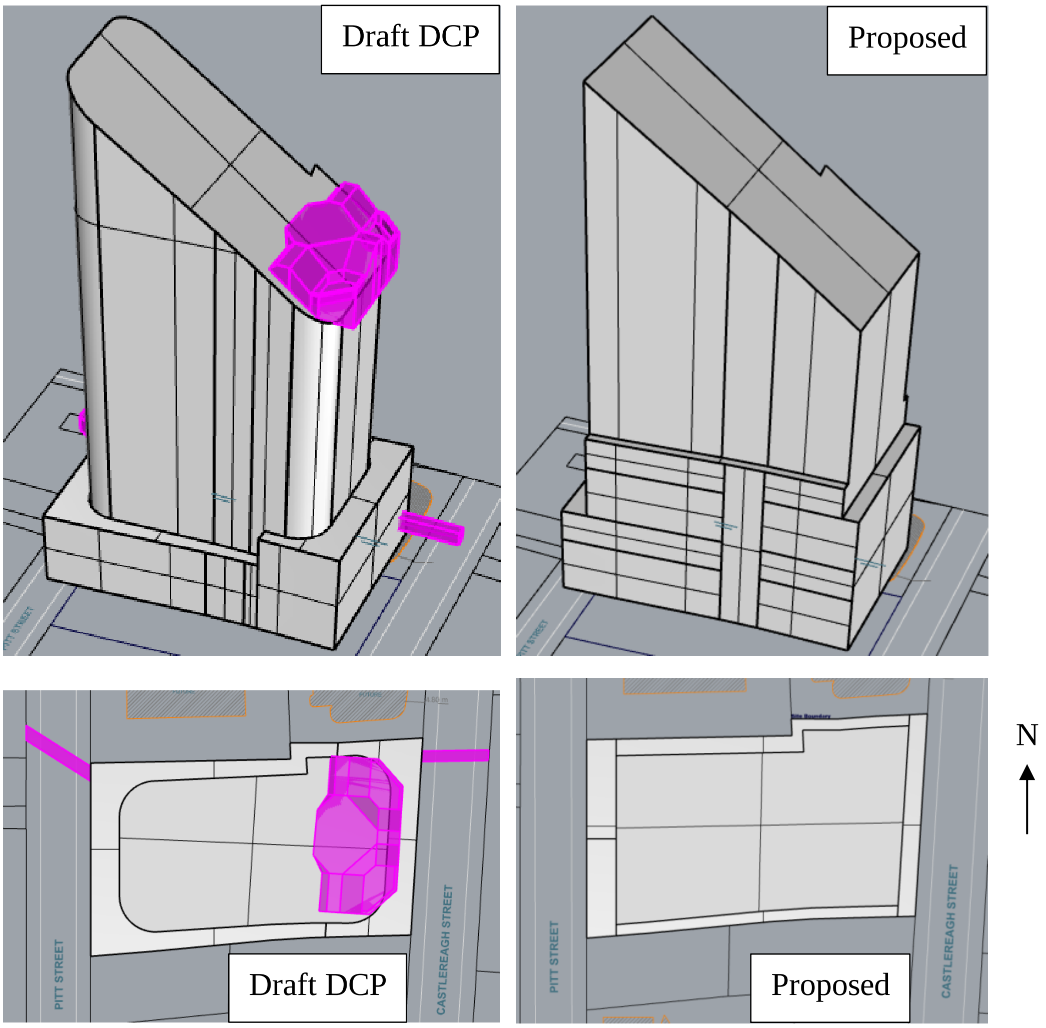


Figure 2: Perspective views from south-east, and plan view of both envelopes

Photos of the wind-tunnel models in the two configurations are shown in Figure 3.

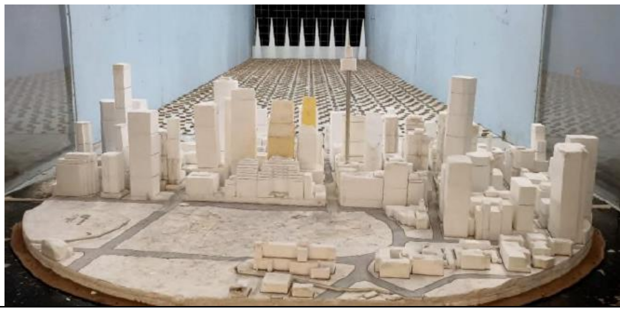
Draft DCP	
Proposed	 

Figure 3: Photographs of tested models

The construction of the physical models was based on the 3d model provided by 3XN. No landscaping was included in the models as this cannot be relied on for pedestrian safety in strong winds. Generally, any landscaping would tend to slightly improve the wind comfort conditions. All approved buildings in the vicinity were included in the model and the same surround model was used in both configurations.

The wind-tunnel testing programme conducted by Windtech was in accordance with the requirements of AWES (2019) and appropriate for the investigation. Appropriate wind speed and turbulence profiles, and test locations were used in the testing. Testing was conducted for 16 wind directions. The testing methodology to leave the test probes in location between building configurations to minimise the impact of probe placement between configurations is good.

2.2 Local wind climate

The wind results were analysed by Arup using weather data recorded at Sydney Airport by the Bureau of Meteorology. The climate analysis is summarised in Appendix 1.

A general description on flow patterns around buildings is given in Appendix 2.

2.3 Specific wind controls

The wind comfort and safety criteria used in the assessment were taken from the Draft City of Sydney Planning Strategy 2016-2036. The criteria are:

For pedestrian **safety** the annual maximum 0.5 s gust wind speed occurring in an hour between 6 am and 10 pm should be less than 24 m/s. This represents a 0.017% probability of occurrence.

For pedestrian **comfort** the greater of the hourly mean or gust equivalent mean wind speed occurring for 5% of the time, i.e. no more than 292 hours per annum between 6 am and 10 pm should be less than:

- 8 m/s for transient spaces such walking
- 6 m/s for more leisurely standing type activities such as window shopping or waiting for public transport
- 4 m/s for more sedentary activities such as pedestrian sitting, but not outdoor dining

The intended use of all locations in this part of the city would be considered to be for transient activities.

2.4 Discussion of results

Pitt and Castlereagh Streets

For ease of comparison, the primary findings of the equivalence study for the two configurations are summarised in Figure 4, which list the locations selected for investigation, shown in Figure 5, along with the target and measured comfort and safety classifications. The values presented in Figure 4 are the wind speed associated with the criterion probability of time, and the colour represents the classification associated with the criterion. A similar colour notation is used in the visual summary for the two schemes in Figure 5, where the central and outer colour represent the comfort and safety classification respectively.

It is evident from the results that the majority of locations around the site are classified as suitable for pedestrian standing type activities from a comfort perspective. Higher wind conditions are experienced at Locations 1 and 17 on the corners of Market Street and Pitt and Castlereagh Streets, and Locations 9 and 15 on Pitt Street. Sample statistical and directional results for Locations 1 and 9 with larger differences between the configurations results are presented in Figure 6 showing that conditions are generally similar between both configurations.

In terms of comfort equivalence between the Draft DCP compliant and proposed configurations, the average difference of the results (Draft DCP-Proposed) is provided in Figure 4 and is +0.1 m/s. The wind conditions are marginally improved, within the accuracy of testing and the discrete nature of the test locations.

Description / identifier		Wind-tunnel results: Comfort Target	Comfort DCP	Comfort Prop	Safety Target	Safety DCP	Safety Prop
Castlereagh St (numbered north to south)	1	>6 to 8	8.2	7.8	24	21	20
	2	>6 to 8	5.3	4.8	24	13	13
	3	>6 to 8	4.9	5.1	24	12	13
	4	>6 to 8	5.2	5.2	24	15	14
	5	>6 to 8	5.2	5.4	24	14	14
	6	>6 to 8	5.3	4.8	24	15	13
	7	>6 to 8	4.6	4.8	24	13	15
	8	>6 to 8	5.2	4.9	24	15	15
Pitt St (numbered south to north)	9	>6 to 8	6.2	6.5	24	16	17
	10	>6 to 8	4.9	5.1	24	14	16
	11	>6 to 8	3.8	4.4	24	11	14
	12	>6 to 8	4.8	5.3	24	16	17
	13	>6 to 8	5.0	4.3	24	15	15
	14	>6 to 8	5.8	5.8	24	19	19
	15	>6 to 8	6.3	6.5	24	18	18
	16	>6 to 8	6.3	5.7	24	18	17
	17	>6 to 8	7.6	7.4	24	21	20
		Average	**5.6**	**5.5**	Max	**21**	**20**

LEGEND Comfort

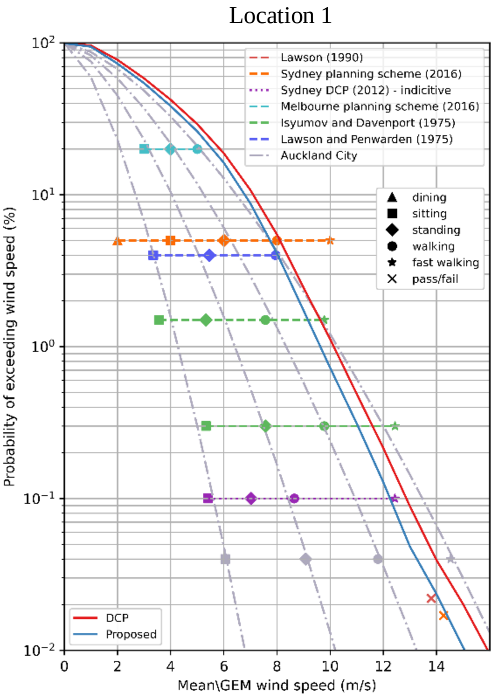
- Dining
- Sitting
- Standing
- Walking
- >Walking
- Uncomfortable

LEGEND Safety

- ≤24 Pass
- >24 Fail

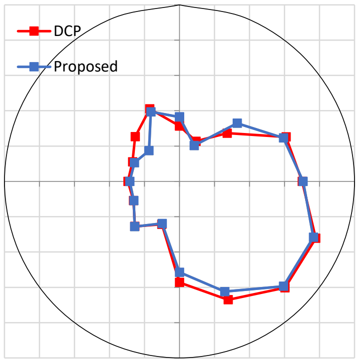
Figure 4: Summary of wind tunnel results along Pitt and Castlereagh Streets

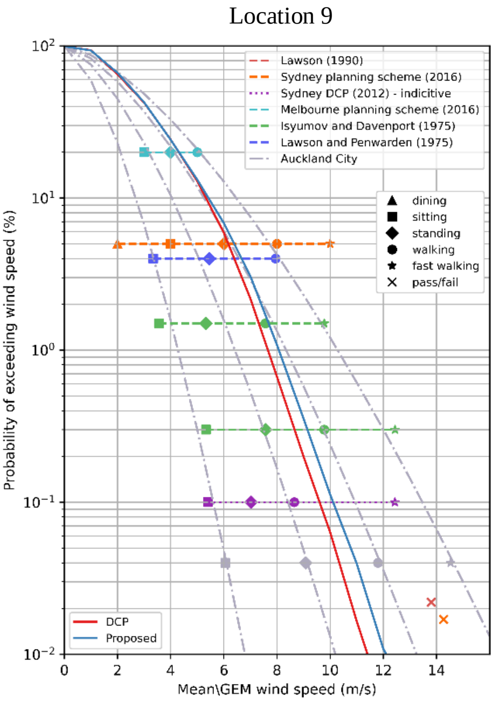
Figure 5: Measurement locations and classification



1995-2017, 6 am to 10 pm
% of time wind speeds occur

	<2 m/s (Dining)	<4 m/s (Sitting)	<6 m/s (Standing)	<8 m/s (Walking)
DCP	23%	58%	81%	95%
Proposed	27%	62%	84%	96%





1995-2017, 6 am to 10 pm
% of time wind speeds occur

	<2 m/s (Dining)	<4 m/s (Sitting)	<6 m/s (Standing)	<8 m/s (Walking)
DCP	35%	76%	94%	99%
Proposed	33%	76%	93%	99%

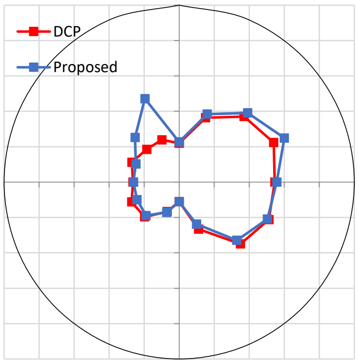


Figure 6: Directional wind results for Locations 1 and 9

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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 2017 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 10 km to the south-south-west 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 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-scales 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.

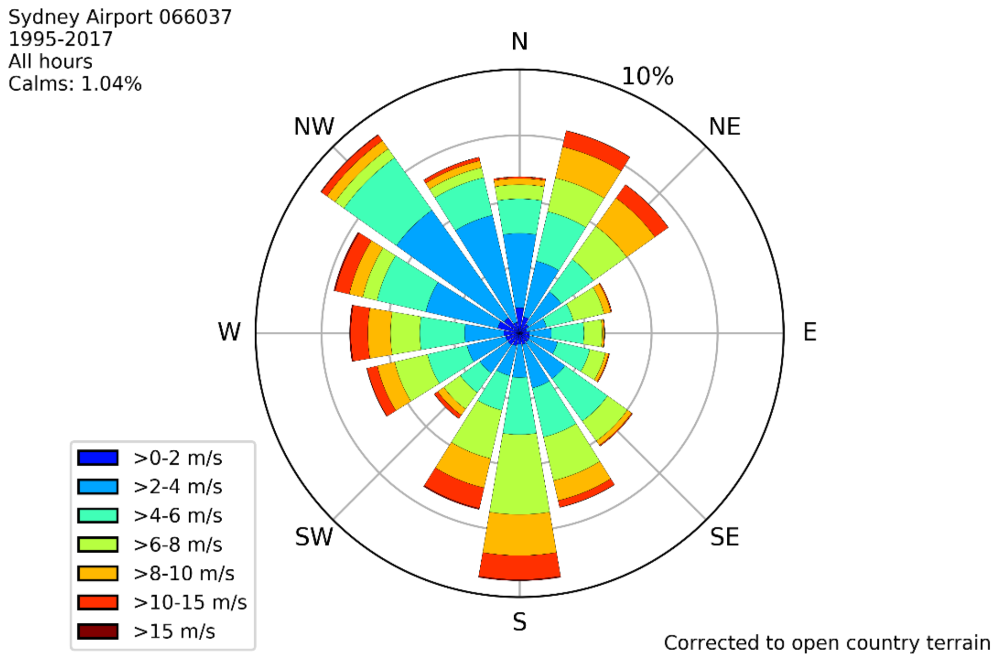

Figure 7: Wind rose showing probability of time of wind direction and speed

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.

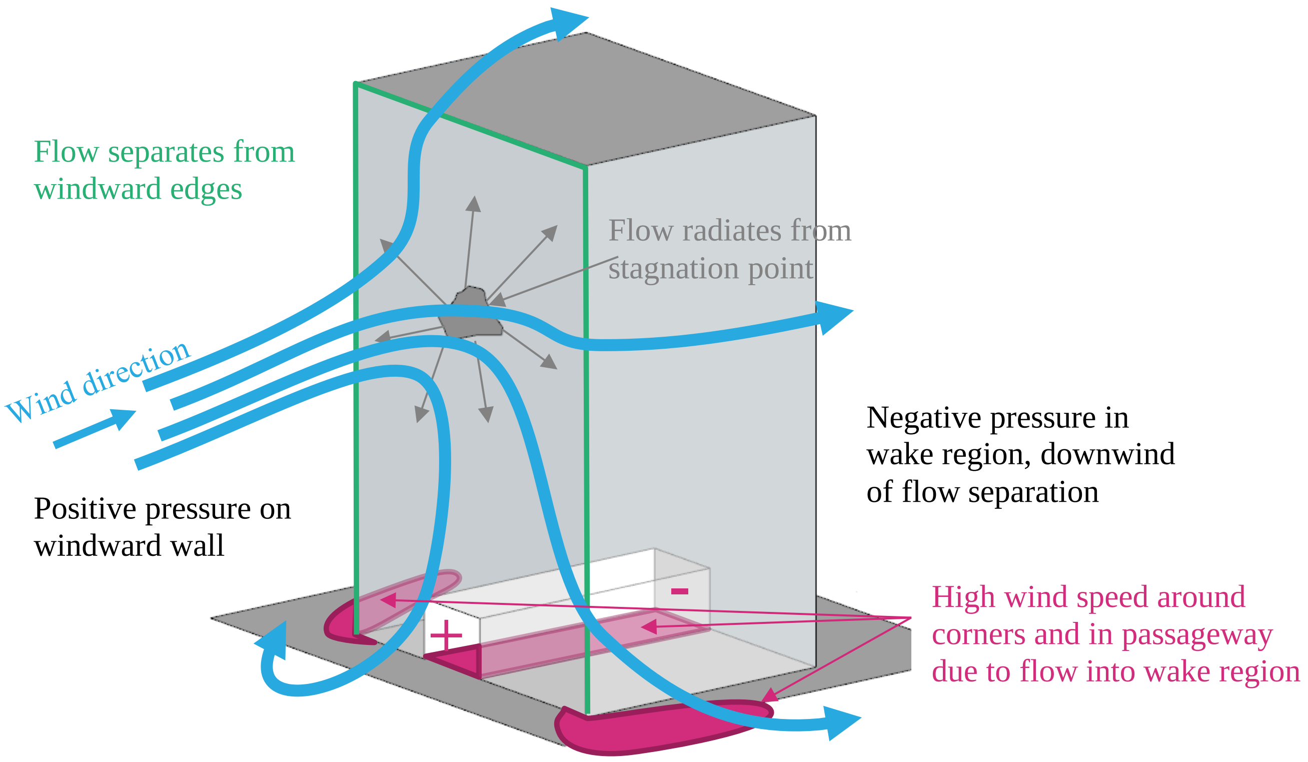

Figure 8: Schematic wind flow around tall isolated building

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 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.

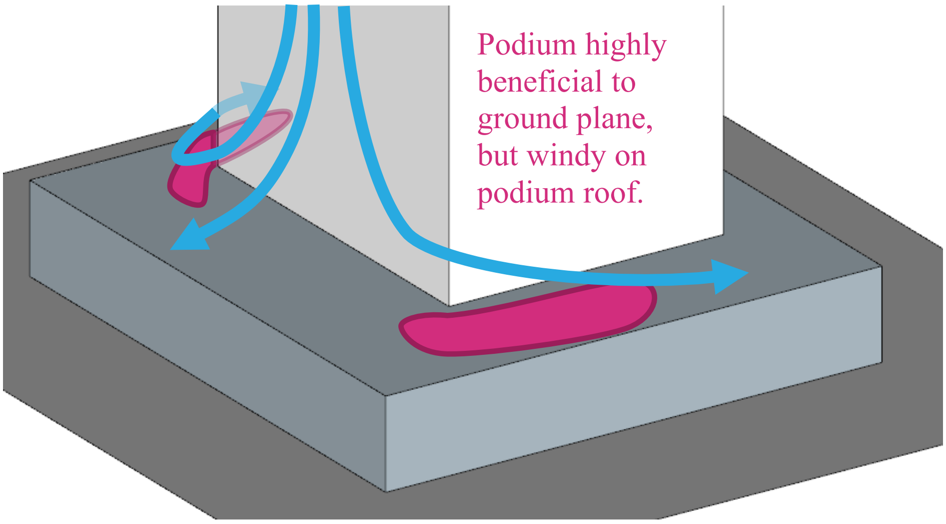

Figure 9: Schematic flow pattern around building with podium

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.

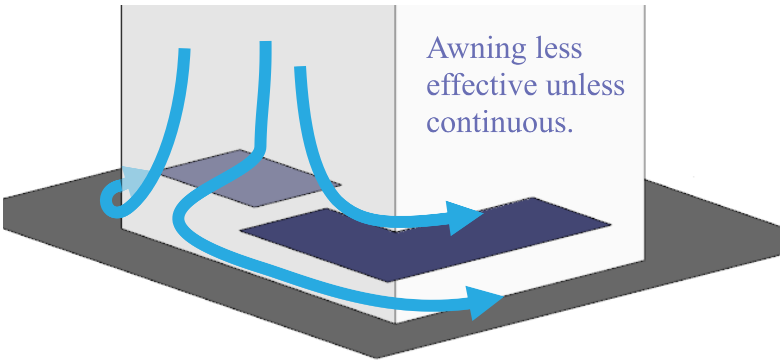

Figure 10: Schematic flow pattern around building with awning

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.

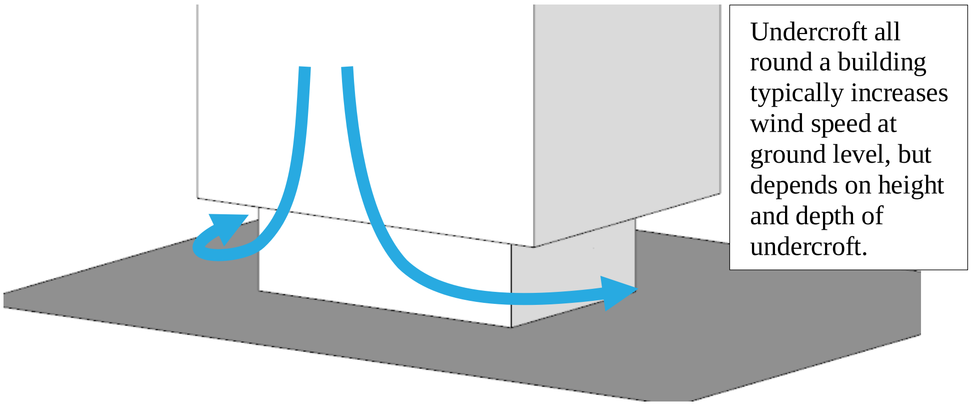

Figure 11: Schematic of flow patterns around isolated building with undercroft

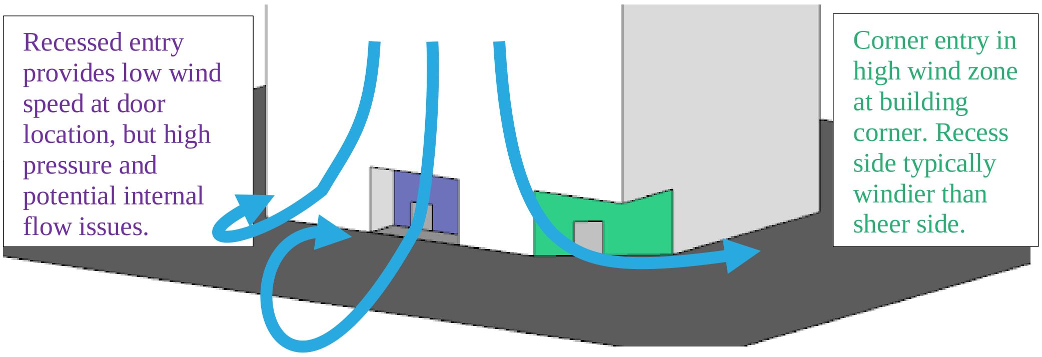

Figure 12: Schematic of flow patterns around isolated building with ground articulation

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.

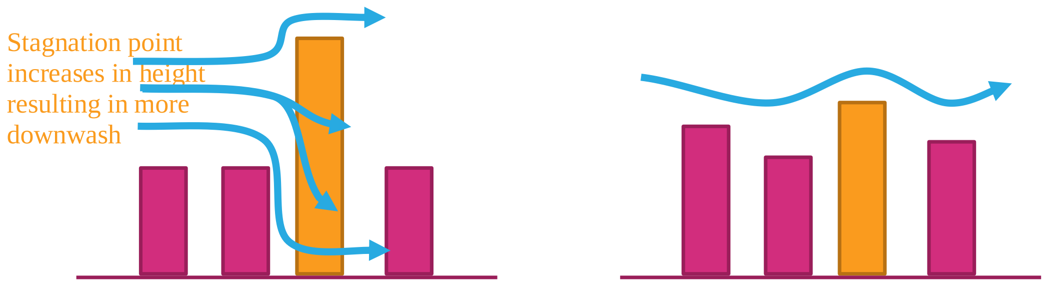

Figure 13: Schematic of flow pattern interference from surrounding buildings

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.

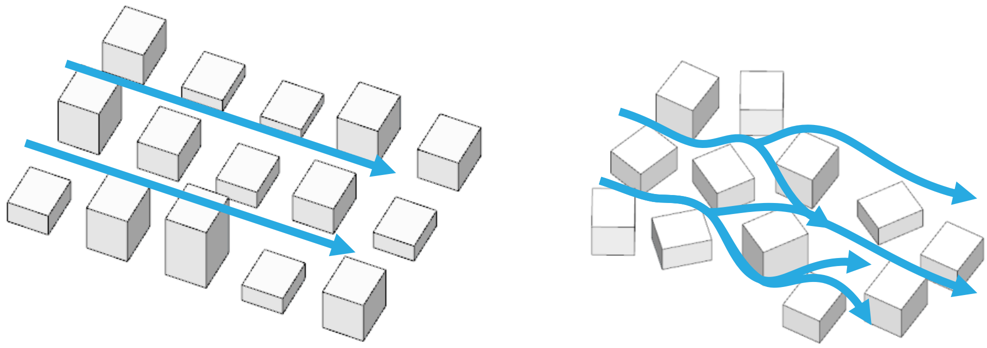

Figure 14: Schematic of flow patterns through a grid and random street layout

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

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:

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

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 15 and

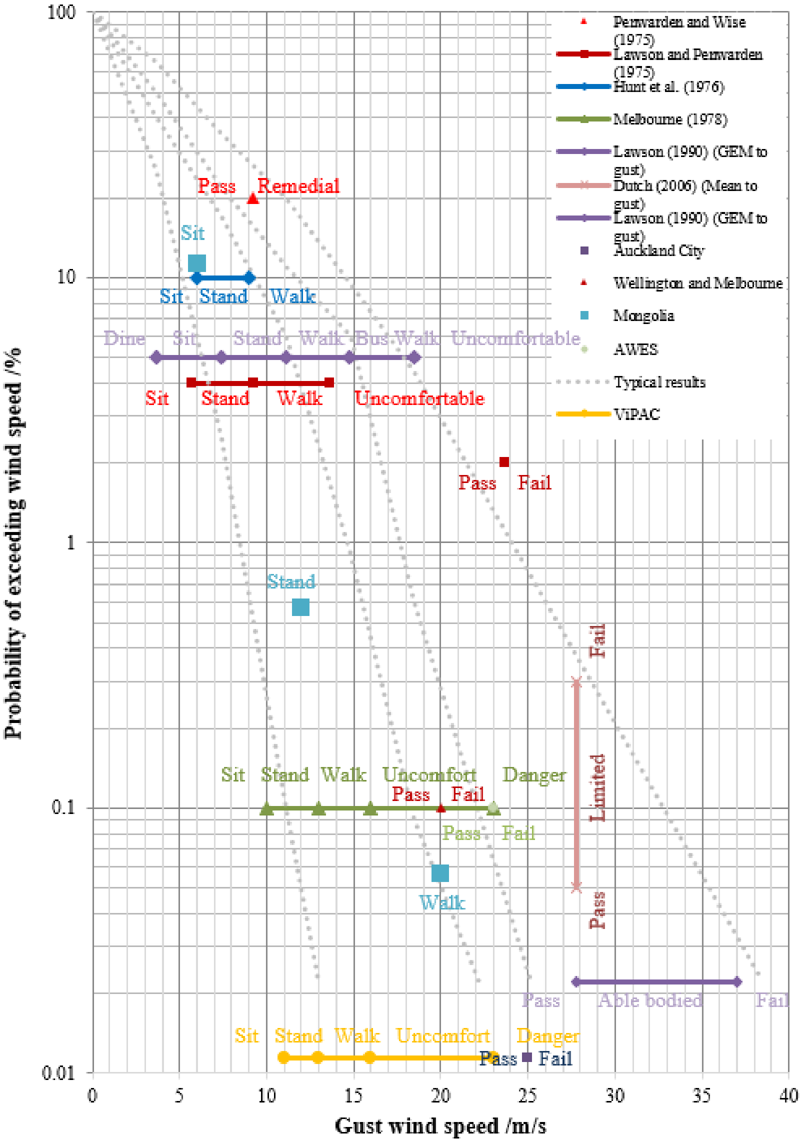

Figure 17. The grey lines are typical results from modelling and show how the various criteria would classify a single location. City of Auckland has control mechanisms for accessing usability of spaces from a wind perspective as illustrated in Figure 15 with definitions of the intended use of the space categories defined in Figure 16.

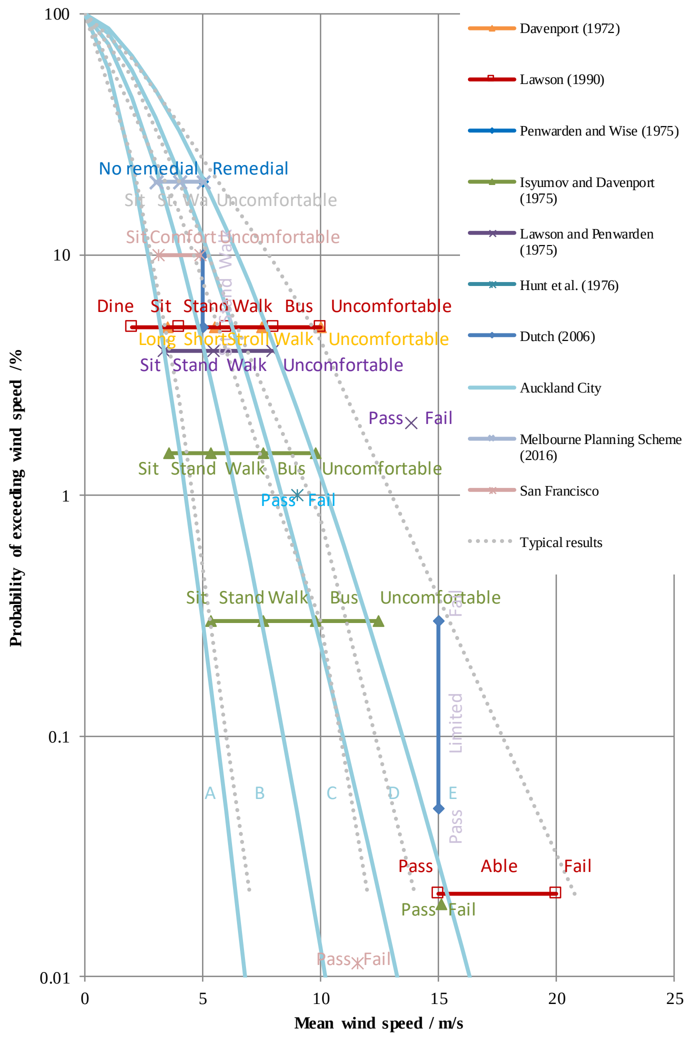

Figure 15: Probabilistic comparison between wind criteria based on mean wind speed

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

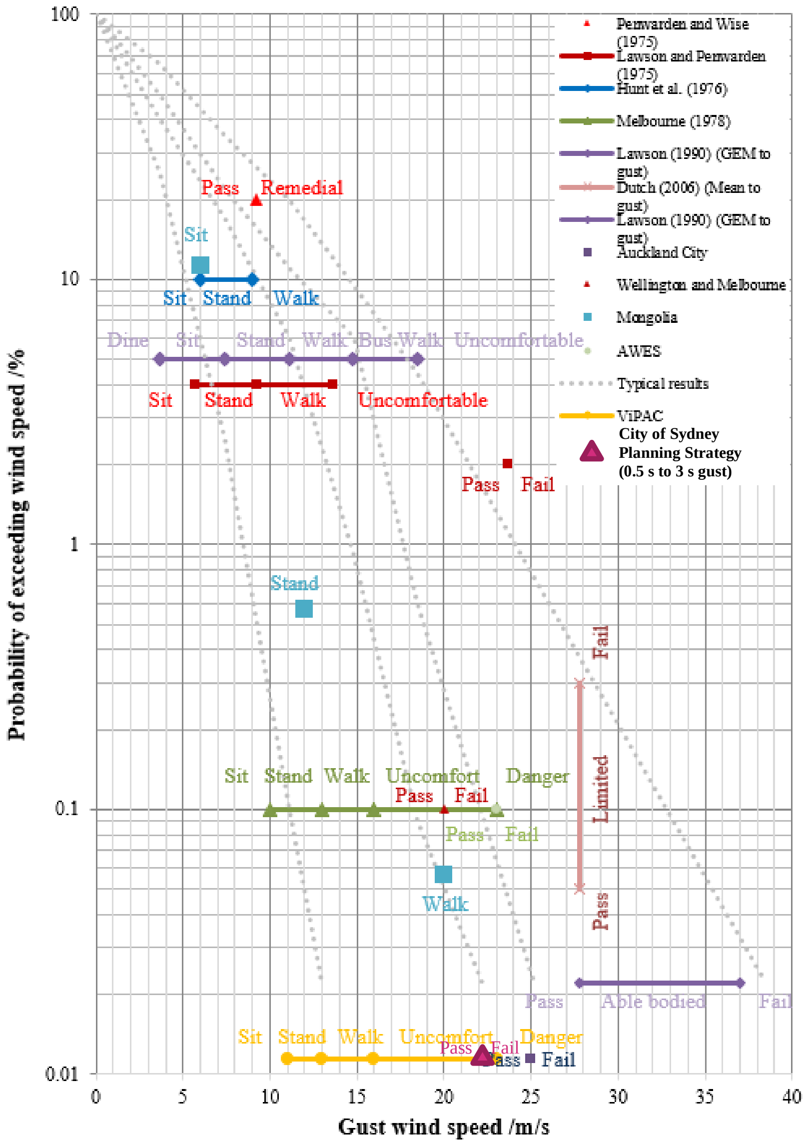

Figure 17: Probabilistic comparison between wind criteria based on 3 s gust wind speed