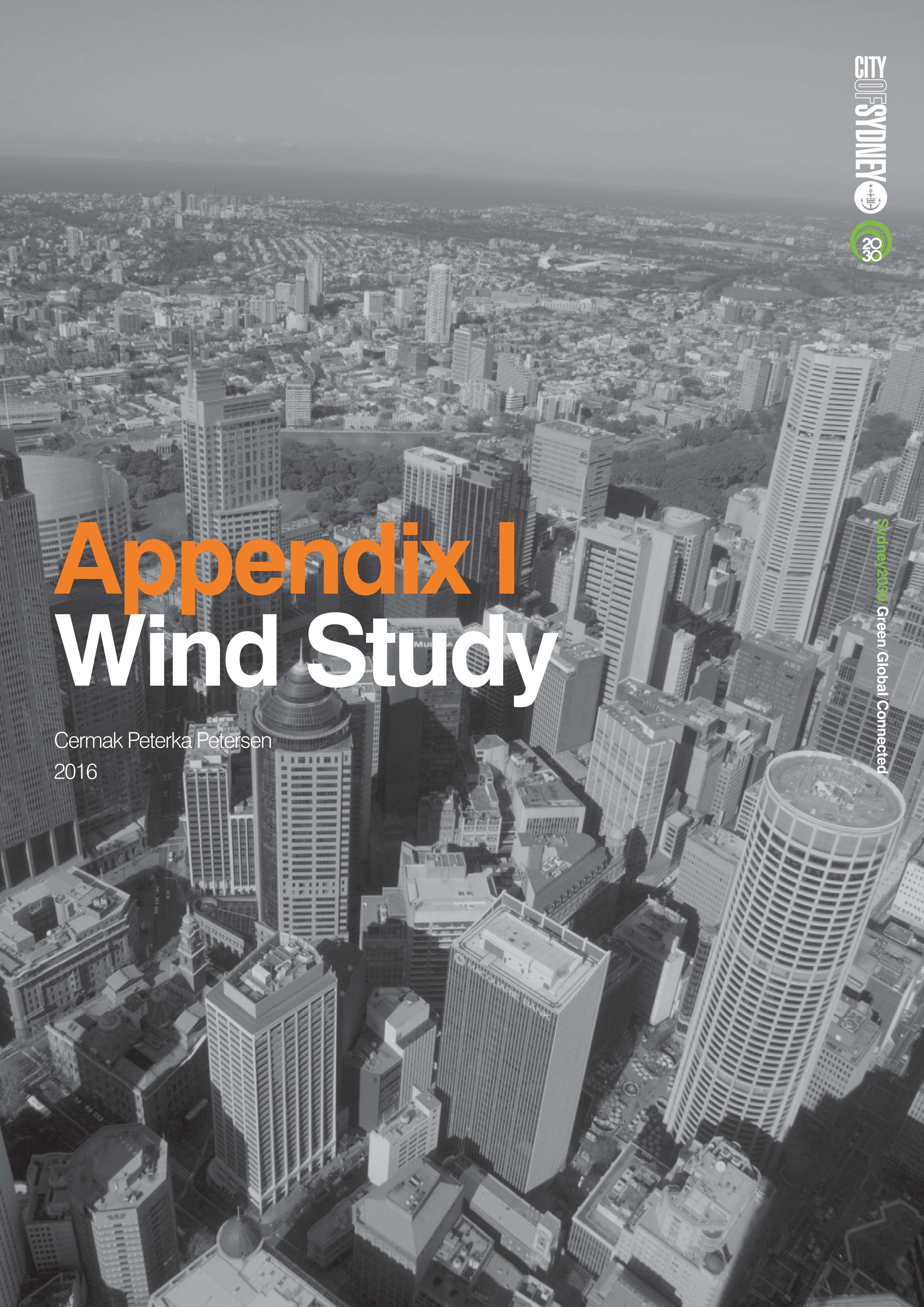

CITY OF SYDNEY

Appendix I
Wind Study

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2016

Sydney2030 Green/Global/Connected

Preface

This report discusses the complexities of measuring wind speed, analysing wind patterns and turbulence, and assessing their effects in relation to densely built-up areas of urban landscape such as Central Sydney and has been used to inform development of improved wind controls that increase clarity of intent and match industry standards for relating wind speed and frequency of occurence.

Different phenomena of wind patterns combine to have a dynamic impact on the habitability of the public domain in the city. Peak wind gust speeds may impact on pedestrian safety while average wind speeds affect comfort and use of open space at street level. The effects of downwash – deflection of wind down to street level by tall buildings – and channelling – the ‘canyoning’ effect of city streets on horizontal wind speeds – exacerbate turbulence conditions and the impact of wind-driven rain.

Ameliorating these effects calls for differing and at times conflicting design solutions. In general the recommendation is for provision of a podium with a setback tower form above.

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Draft Report

Wind Assessment for:

CITY OF SYDNEY

Sydney, Australia

June 2013

CPP Project 7224

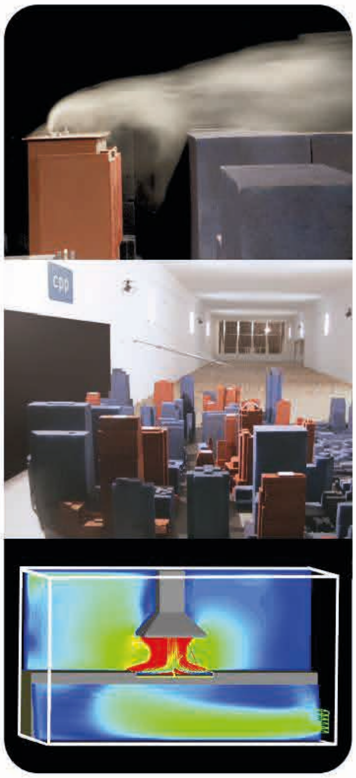

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Wind is measured by its speed and direction, but humans perceive the action as a wind force, which is proportional to wind speed squared, therefore it is difficult to gauge wind speed without taking measurements using an anemometer, or by subjectively comparing the observed effects against a table, such as the Beaufort scale, Table 1. Wind speed is typically expressed by engineers in metres per second, m/s; the conversion to more generally used units for sailing and driving terminology is 1 m/s = 1.944 knots = 2.24 mph = 3.6 kph. With a variety of different units in common usage confusion is generally the result.

Table 1: Summary of wind effects on people, Penwarden (1973)

Description	Beaufort Number	Wind speed (m/s)	Effects
Calm, light air	0, 1	0–2	Calm, no noticeable wind.
Light breeze	2	2–3	Wind felt on face.
Gentle breeze	3	3–5	Wind extends light flag. Hair is disturbed. Clothing flaps
Moderate breeze	4	5–8	Raises dust, dry soil, and loose paper. Hair disarranged.
Fresh breeze	5	8–11	Force of wind felt on body. Drifting snow becomes airborne. Limit of agreeable wind on land.
Strong breeze	6	11–14	Umbrellas used with difficulty. Hair blown straight. Difficult to walk steadily. Wind noise on ears unpleasant. Windborne snow above head height (blizzard).
Near gale	7	14–17	Inconvenience felt when walking.
Gale	8	17–21	Generally impedes progress. Great difficulty with balance in gusts.
Strong gale	9	21–24	People blown over by gusts.

Due to natural and structure-induced turbulence in wind flow, wind speeds vary considerably in time and space; Figure 1 presents a typical anemograph with a wind speed averaged over 0.5 s. This variability is further influenced by where the wind speeds are measured, data sampling techniques, and the measuring instrument employed. The Bureau of Meteorology tends to measure wind speeds at a standard height of 10 m above ground level. The most useful siting location is in a flat isolated location with few surroundings to influence both the wind speed and direction, such as close to an airport. Less useful typical locations are on a headland where topographical effects can accelerate the wind speed over the feature, and near the middle of a constantly developing built-up environment; this is one of the main reasons why the anemometer on Observatory Hill in Sydney was decommissioned in 1994 and relocated to Fort Denison in the harbour, which is still affected by topography and the city building massing. Measured mean wind speeds in these ideal open locations are typically higher than would be experienced by a pedestrian at ground level in an urban street by typically up to a factor of four. The wind flow effects in an urban area are exceptionally complex, but it is important to appreciate that forecast wind speeds based on isolated anemometer locations should be treated with scepticism depending on their intended usage.

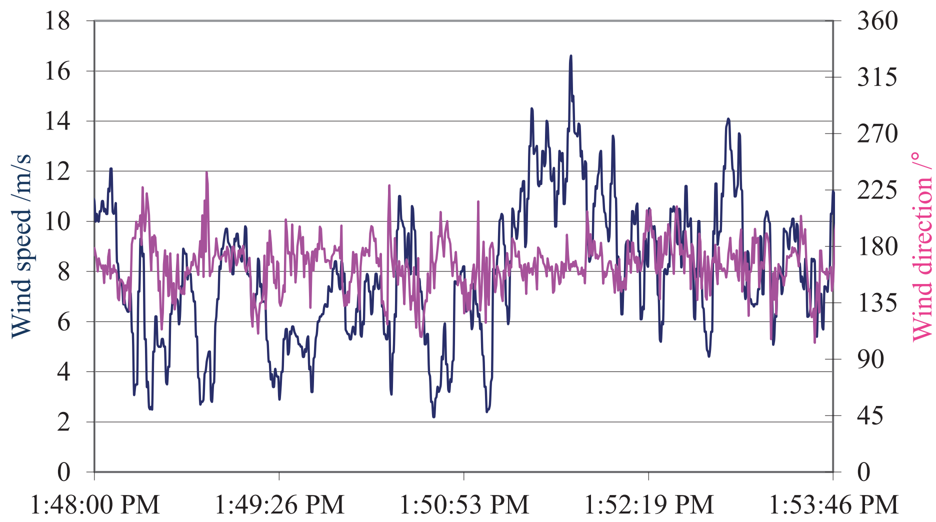

Figure 1: Anemograph for wind flow in a suburban environment

Unfortunately there are few measurements of full-scale wind speed in the urban environment correlated to the measurements in open country, such as airports, so it is difficult to appreciate the effects of the surrounding buildings on the local wind environment. Various researchers have measured the wind speed and related them to pedestrian activities for both pedestrian safety and pedestrian comfort for the intended use of the space. To account for the effects of turbulence, field measurements typically average the wind speed over a short period of time, typically 3 s, although a pedestrian can be influenced by a much smaller gust of wind. This standardisation is to account for the varying response times for reference anemometers, which would measure different values for instantaneous wind speeds. When the measured wind speed is averaged over 3 s, a more consistent measurement is obtained. The 3 s gust is adopted by the World Meteorological Organisation as standard. This standard averaging time implicates that wind comes in gusts that last for 3 s, which is incorrect and evident if you stand on a windy corner and experience the turbulence in the wind. It is a feature of very high gust speeds that they are often immediately preceded by a lull in the wind. It should be noted that the 3 s averaging makes a substantial difference to the measured wind speed; for example in open country a 0.2 s gust would typically be about 10-15% faster than a 3 s gust resulting in a 20-30% increase in wind force that would be felt by a pedestrian. Hence, it is important to understand the response time of an anemometer, any averaging that has been applied to the wind speed measurements, and what wind speed has been adopted for the development of pedestrian safety and comfort environmental criteria.

In some extreme field measurements, an increase in wind speed of 20 m/s has been measured in less than half a second. For a pedestrian, this increase is essentially instantaneous resulting in a significant increase in wind force. These extreme gusty conditions can blow pedestrians over, particularly the elderly and disabled, which is evidently dangerous if the pedestrian could be blown into traffic. In a city environment, this sudden change in wind speed is more often experienced with distance, such as turning a corner, rather than a temporal fluctuation at a particular location. In these cases preventing pedestrians from walking through such localised step changes in wind speed can be more effective than altering the building generating the problem.

2. SYDNEY WIND CLIMATE

The general wind conditions for the Sydney region are seasonal with sea breezes occurring in the summer and cold winds from the north-west in winter. Due to the relative openness of the site, the anemometer at Sydney Airport is the most reliable for establishing the historic wind climate and is located about 10 km to the south-south-west of the city.

The weather data used for the analysis was provided by the Bureau of Meteorology (BoM) for the Sydney Airport anemometer, BoM station number 066037. The BoM does not quality check its wind data. The data includes the period from 10 October 1948 to 31 December 2012. The data includes a date and time stamp, and the 10 minute mean wind speed and direction prior to the time stamp. It is understood that the BoM wind monitoring system samples at 2 Hz and is time averaged over a 3 s period. Automatic weather station data are typically recorded for the 10 minutes period prior to the hour and half hour. A 10 minute to 1 hour sample is needed to capture the micro-meteorological peak of relevance known to atmospheric scientists and engineers. Additional readings are taken during windy events, but since this additional data skews the probability distribution has been separated for this analysis. A plot of the annual average wind speed for the reduced data set is presented in Figure 2. From the BoM metadata for the weather station, the anemometer installed 1973 was replaced in June 1994 with a 3-cup anemometer and has been replaced in 1999, 2003, 2006, and 2009. It is evident that the sudden change in wind speed occurs at the same time as the replacement of the anemometer, but it is unknown whether the anemometer was relocated at this time. Wind direction provided by the BoM is the direction from which the wind blows, in terms of clockwise from true north. In Sydney, magnetic north is approximately 12° to the east of true north.

As the output is for general serviceability information, only the analysis for the years post-1995 have been presented herein. The wind data for these years presented in Figure 2 shows a suitable level of consistency.

The 10 minute mean wind speed data are presented for the entire year, Figure 3, as well as the seasonal contributions in Figure 4 to Figure 7. Each figure has two wind roses for all hours and nominal daylight hours from 6 am to 8 pm. The arms of the wind rose point in the direction from where the wind is blowing from, the width and colour of the arm represent the wind speed, and the length of the arm indicates the percent of the time that the wind blows for that combination of speed and direction.

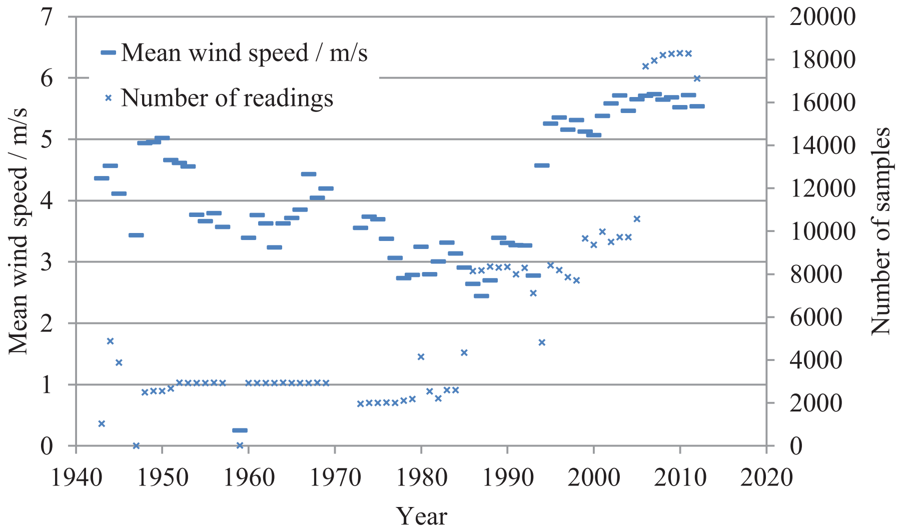

Figure 2: Annual distribution of average wind speeds

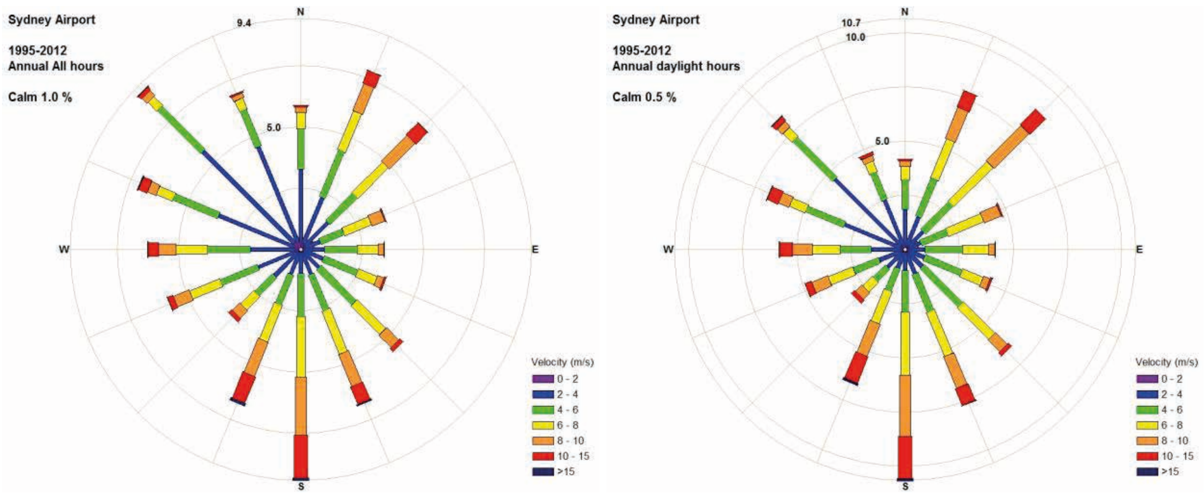

Figure 3: Sydney Airport annual wind rose for all hours (L) and daylight (6am-8pm) hours (R)

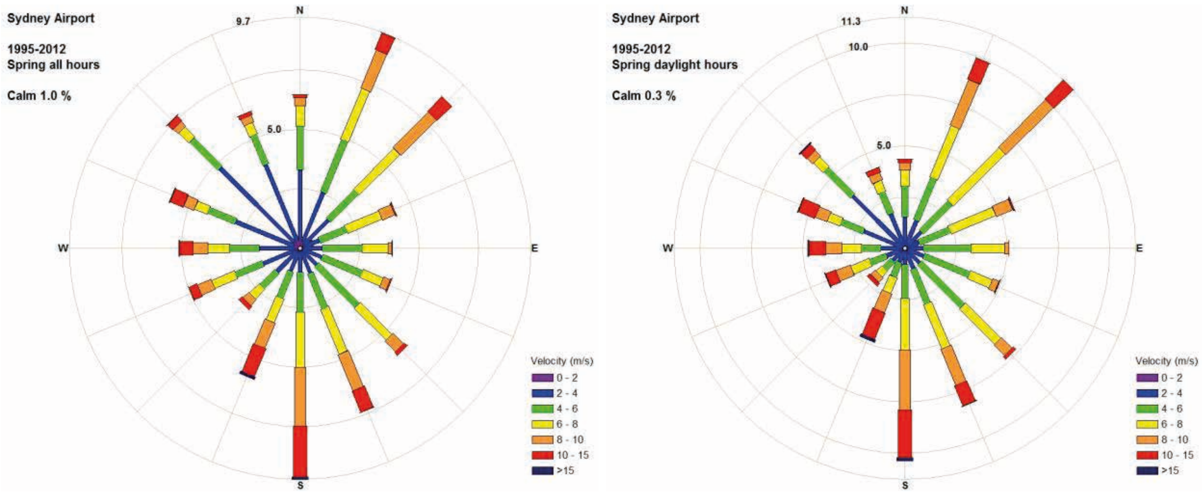

Figure 4: Sydney Airport spring wind rose for all hours (L) and daylight (6am-8pm) hours (R)

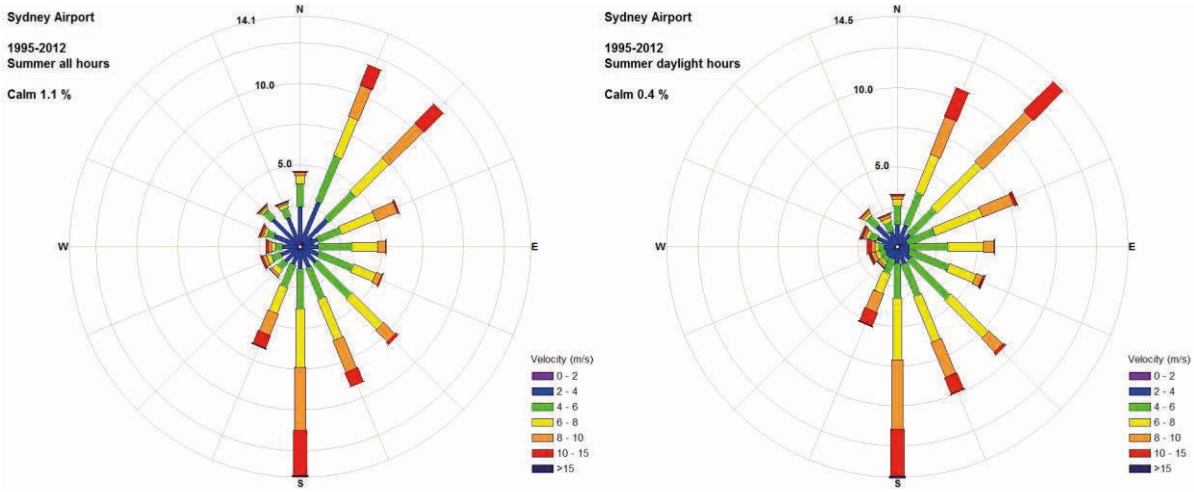

Figure 5: Sydney Airport summer wind rose for all hours (L) and daylight (6am-8pm) hours (R)

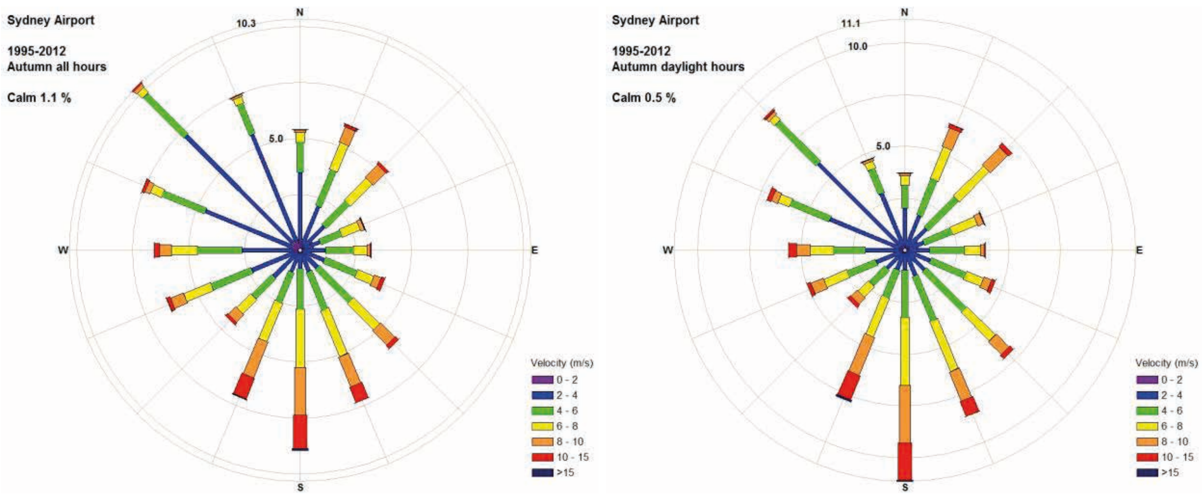

Figure 6: Sydney Airport autumn wind rose for all hours (L) and daylight (6am-8pm) hours (R)

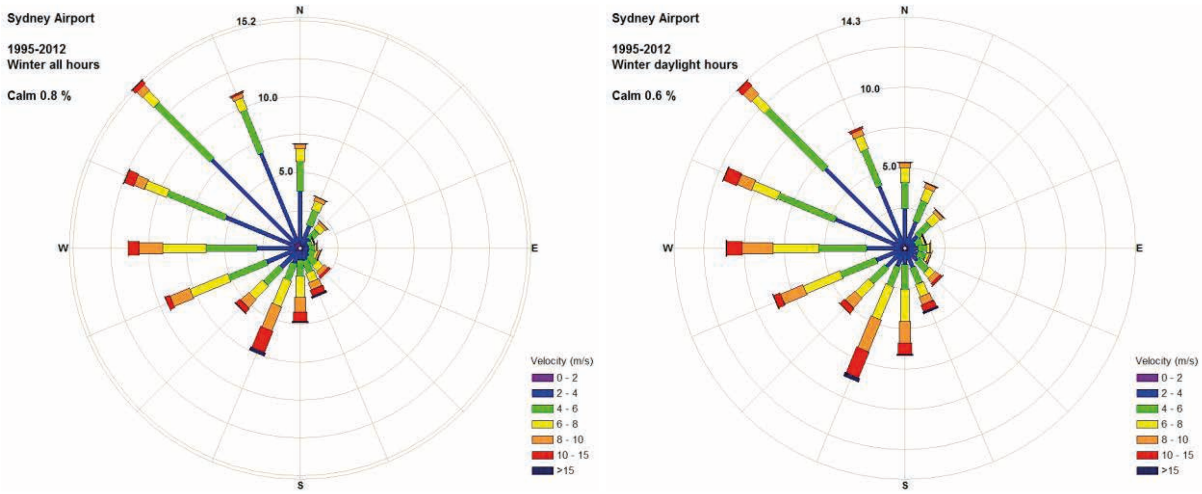

Figure 7: Sydney Airport winter wind rose for all hours (L) and daylight (6am-8pm) hours (R)

It is evident from Figure 3 that the prevailing winds from coastal Sydney come from the north-east, south, and west. Summer winds consist of sea breezes from the north-east that tend to bring welcome relief on hot summer days and frontal southerly busters associated with frontal systems, which can last several days. Winter winds tend to be the strongest of the year and are associated with winds from the west quadrant. Winds from the west are driven by the inland conditions and can be warm or cold depending on the time of year. Winds in spring and autumn tend to be variable and pick up elements of the flanking seasonal weather patterns.

3. WIND DRIVEN RAIN

In Sydney rain occurs for approximately 5% of the time. Directional wind driven rain statistics recorded at Sydney Airport are presented in Table 2 for rainfall intensity and in Table 3 for wind speed. It is evident that about 45% of the rain comes from the south quadrant, and the remaining 55% is evenly distributed around the other quadrants.

The rain associated wind speed at 10 m height at Sydney Airport is typically above 2 m/s. About 80% of the associated wind speed is spread evenly between 2 and 10 m/s, with a decreasing percentage at higher velocities. The combined wind speed and rainfall intensity distribution of rain events is presented in Table 4 showing that the majority of rain events have low rainfall intensity with a relatively high wind speed. There is a relatively constant distribution of time for medium intensity rainfall and mean wind speed.

Due to the increased density of the buildings in the Sydney CBD compared with the airport, for all wind directions the mean wind speed at a city site would be expected to be lower than recorded at the airport, even for the channelled winds from the south, but the turbulence of the wind will be higher. The mean wind speed governs the constant wetting of an area, whereas the turbulence leading to peak gusts will govern the maximum extent of rain ingress.

Wind driven rain ingress depends on the rainfall intensity, and the local wind speed and direction; these parameters control the particle size distribution, and the particle velocities in both the vertical and horizontal directions. The relationship between rainfall intensity and particle size distribution is described by Best (1950), which is based on an average from various researchers in warmer climates, which is applicable to rain events experienced in Sydney. The cumulative particle distribution for various rainfall intensities is shown in Figure 8. The terminal velocity of individual rain particles is dependent on their size. When the local wind speed is in excess of the terminal velocity the shape of the rain particle will change, reducing the terminal velocity, and forcing the rain particle to move more with the wind. Small lighter particles accelerate quickly reaching terminal velocity, or the local wind speed, from stationary in under 5 s.

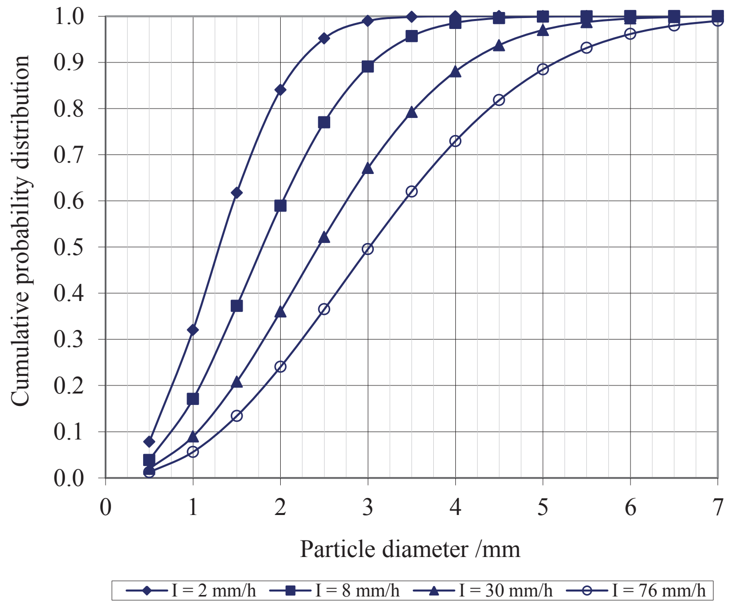

Figure 8: Cumulative rain particle size distribution (after Best, 1950)

When rain particles hit a solid surface they rebound and break into smaller particles, which are then easier to transport on the wind. The percentage of total rainfall that would be available for transportation is a function of the roof contact area, the angle of impact, and the method of rain discharge from surfaces. The main output from any wind driven rain analysis is the ingress distance into spaces perceived to be enclosed. Whenever there is airflow through a building there is the potential for small particle rain ingress, which will be carried on the breeze as a mist. For the benefit of pedestrians, it is also of significant benefit to maintain a continuous awning along a street to avoid wet patches. The awning can change in height, but a vertical element to seal the awning would be strongly recommended as overlapping awnings is not an effective solution to wind driven rain.

Table 2: Distribution of Sydney Airport rainfall rate with wind direction expressed as a percent of time

Rainfall rate	Wind direction																
mm/30 mins	CALM	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0-1	0.7	5.4	3.3	2.4	2.0	3.6	3.2	3.9	5.9	13.7	9.4	4.6	3.3	4.1	2.5	2.7	2.3
1-2	0.1	0.8	0.5	0.5	0.5	0.7	0.9	1.0	1.4	2.7	1.8	0.9	0.7	0.6	0.4	0.3	0.3
2-4	0.0	0.3	0.2	0.3	0.4	0.7	0.4	0.6	0.8	1.7	0.8	0.5	0.4	0.3	0.2	0.2	0.2
5-10	0.0	0.2	0.1	0.2	0.1	0.3	0.2	0.2	0.4	0.7	0.3	0.2	0.2	0.2	0.1	0.1	0.1
>10	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
TOTAL	**0.8**	**6.8**	**4.1**	**3.5**	**3.0**	**5.4**	**4.9**	**5.8**	**8.6**	**18.9**	**12.4**	**6.2**	**4.7**	**5.2**	**3.2**	**3.4**	**2.9**

Table 3: Distribution of Sydney Airport rain events with wind speed and direction expressed as a percent of time

Wind speed	Wind direction																
/m/s	CALM	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0-2	0.8	0.5	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.2	0.3	0.2
2-4		2.7	1.1	1.0	0.7	1.1	0.7	0.7	0.9	1.5	1.2	1.2	1.4	1.9	1.8	1.8	1.5
4-6		2.3	1.3	0.9	0.9	1.5	1.2	1.3	1.4	2.9	2.2	1.5	1.6	1.5	0.6	0.9	0.8
6-8		0.9	0.8	0.9	0.7	1.4	1.5	1.6	2.0	4.1	2.8	1.6	0.9	0.7	0.3	0.3	0.3
8-10		0.3	0.4	0.4	0.3	1.0	1.0	1.4	1.9	4.2	2.9	1.1	0.3	0.4	0.2	0.0	0.1
10-12		0.0	0.2	0.2	0.1	0.2	0.4	0.7	1.1	3.1	1.8	0.5	0.1	0.2	0.1	0.0	0.0
>12		0.0	0.0	0.0	0.1	0.0	0.1	0.2	1.1	2.9	1.3	0.2	0.1	0.1	0.0	0.0	0.0

Table 4: Distribution of Sydney Airport rain events with wind speed expressed as a percent of time

Wind speed	**Rainfall intensity /(mm/30 min)**					
/m/s	>0	≥ 1	≥ 3	≥ 6	≥ 15	**Total**
0	0.70%	0.052%	0.022%	0.0074%	0%	**0.78%**
≤ 2	2.8%	0.46%	0.16%	0.12%	0.0074%	**3.5%**
≤ 4	17%	2.4%	1.4%	0.73%	0.13%	**21%**
≤ 6	17%	3.3%	1.8%	0.84%	0.24%	**23%**
≤ 8	15%	2.9%	1.9%	0.78%	0.19%	**21%**
≤ 10	11%	2.4%	1.4%	0.63%	0.10%	**16%**
≤ 12	6.1%	1.4%	1.0%	0.33%	0.074%	**8.9%**
> 12	3.8%	1.3%	0.70%	0.33%	0.089%	**6.2%**
Total	**73%**	**14%**	**8.3%**	**3.8%**	**0.82%**	**100%**

4. 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 generate by the massing of the entire city. However, it is best to start with an understanding of the basic flow mechanisms around an isolated tall structure.

When the wind hits an isolated building, the wind is decelerated on the windward face generating an area of high pressure, Figure 9, which is then accelerated down and around the windward corners to areas of lower pressure, Figure 10. 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. In Figure 10 smoke is being released into the wind flow to allow the wind speed, turbulence, and direction to be visualised. The image on the left shows smoke being released across the windward face, and the image on the right shows smoke being released into the flow at about third height in the centre of the face. The observed downward flow is called downwash. Rounding the building corners or chamfering the edges reduces downwash, but concave curving of a façade 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.

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 podium level, Figure 11. The provision of an 8 m setback is generally sufficient to improve ground level conditions sufficiently, but is highly dependent on the building isolation, orientation to prevailing wind directions, shape and width of the building, and any setbacks at higher level. Awnings along street frontages perform a similar function as a podium, and the larger the horizontal projection from the façade, the more effective it will be in diverting downwash flow. 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 12. Similarly open, through-site links through an isolated building cause wind issues as the environment tries to equilibrate the pressure generated at the entrances to the link, Figure 13. If the link is blocked conditions will be calm unless there is a flow path through the building.

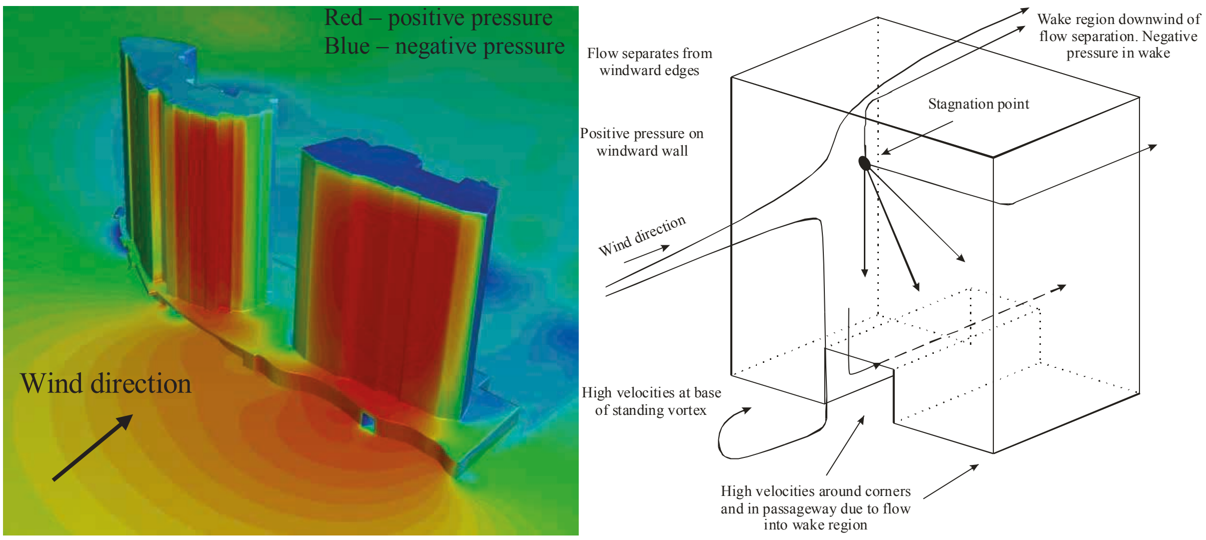

Figure 9: Pressure and flow schematic around tall buildings

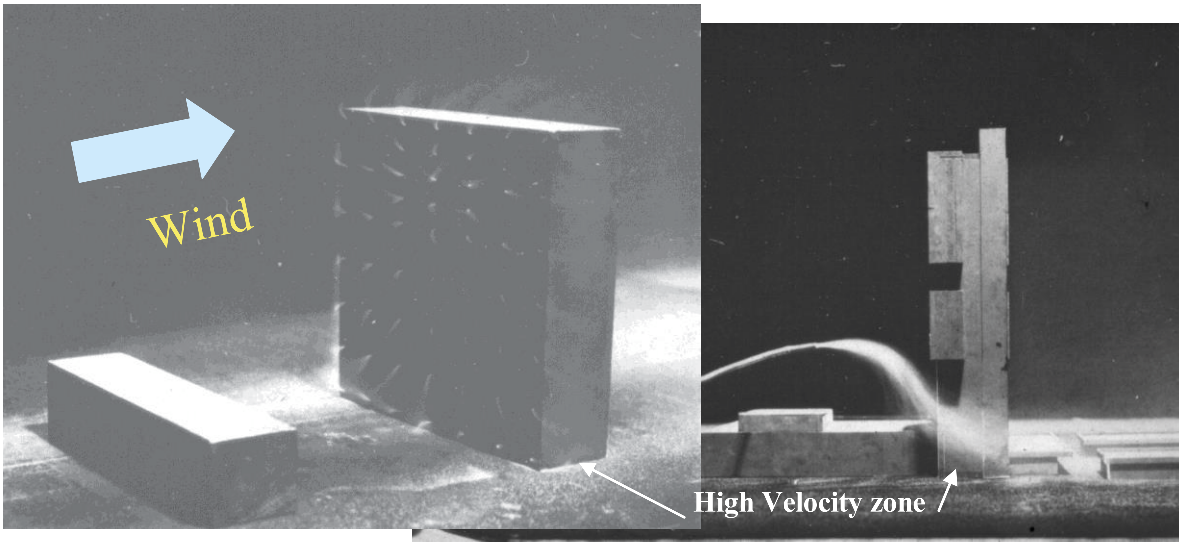

Figure 10: Flow visualisation around a large isolated building

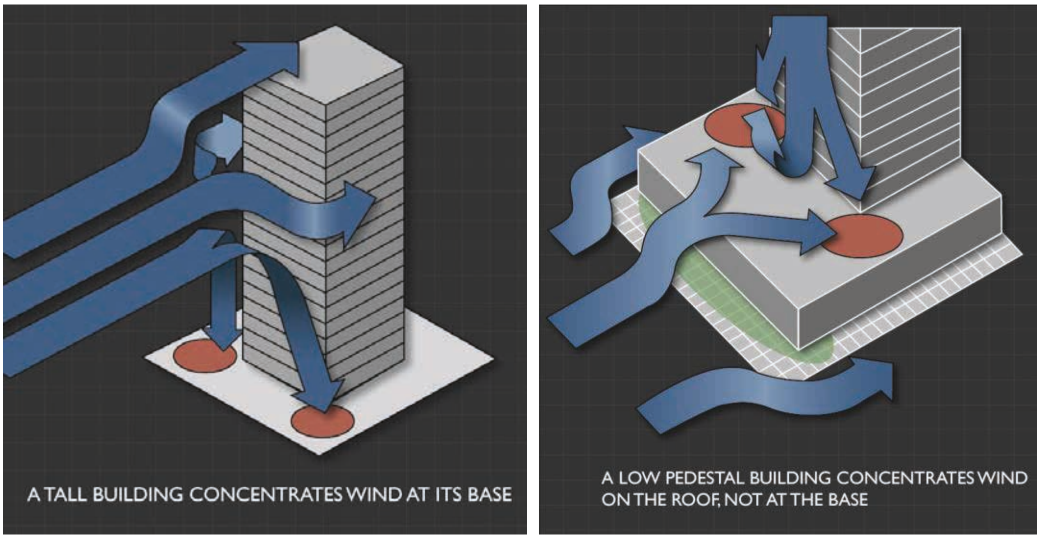

Figure 11: Schematic showing flow pattern around building with podium

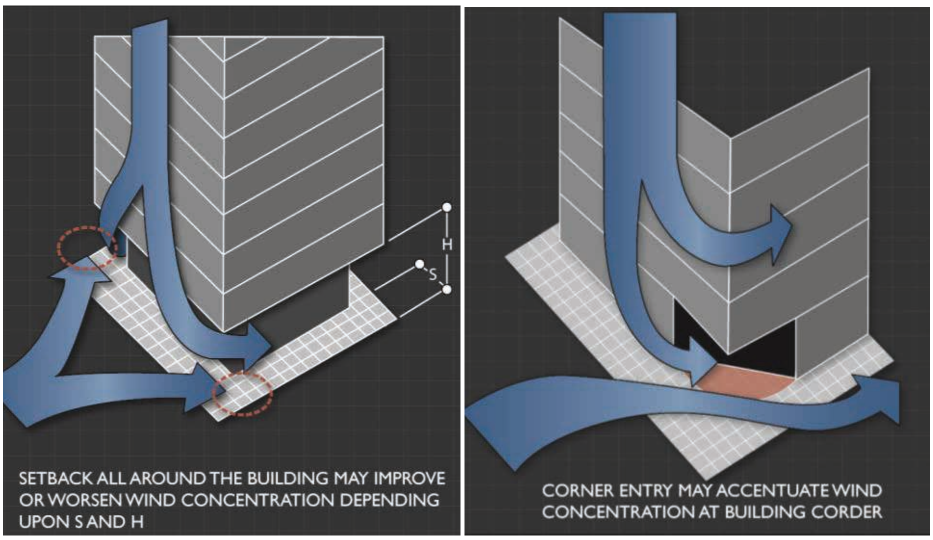

Figure 12: Schematic of buildings with colonnades and corner entries

12

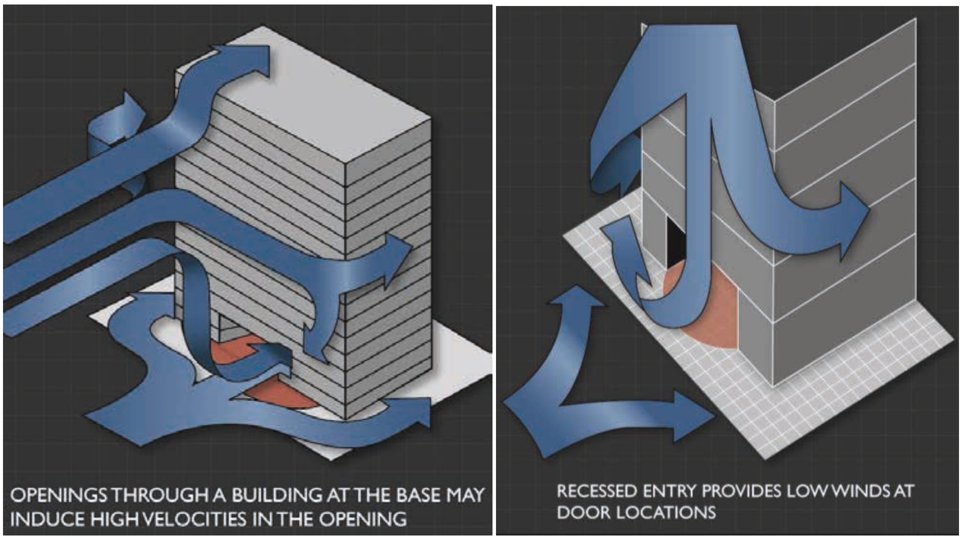

Figure 13: Schematic of flow at openings at base of building

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 14. If the building is taller, more of the wind impacting on the exposed section of the building will be drawn to ground level by the 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 will be reduced.

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

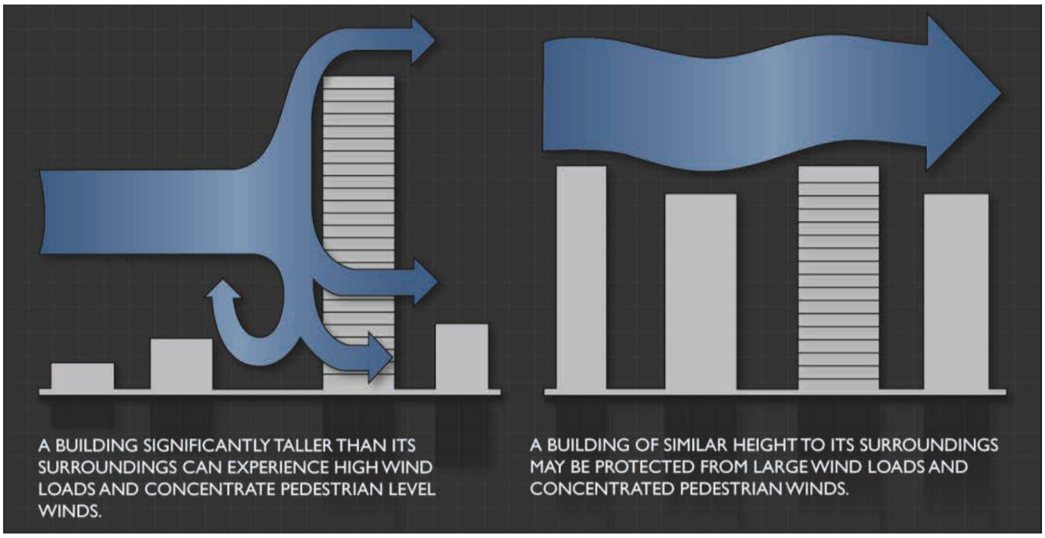

Figure 14: Schematic of interference of flow from surrounding buildings

Channelling occurs when the wind is accelerated between two buildings, or along straight streets with buildings on either side, Figure 15, particularly on the edge of the Sydney CBD such as Macquarie Street for winds from the north-east or south where the approaching flow is diverted around the city massing and channelled along the fringe by the relatively continuous wall of building facades. This is generally the primary mechanism driving the wind conditions for the central part of the city. As the city expands the central section of the city typically becomes calmer, particularly if the grid pattern of the streets is discontinued. Downwash is a more important mechanism for the fringes of the city.

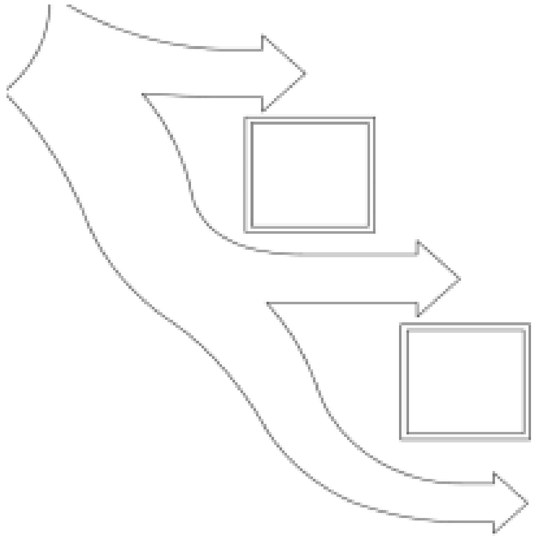

Figure 15: Wind channelling between buildings

When buildings are located on the corner of a city block their geometry becomes more important with respect to the local wind environment.

5. ENVIRONMENTAL WIND COMFORT CRITERIA

It is generally accepted that wind speed and the rate of change of wind velocity are the primary parameters that should be used in the assessment of how wind affects pedestrians. Local wind effects can be assessed with respect to a number of environmental wind speed criteria established by various researchers, which have all generally been developed around a 3 s gust, or 1 hour mean wind speed. 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 reasonable agreement. However, a number of studies have shown that over a wider range of flow conditions, such as smooth flow across water bodies, such as the harbour, to turbulent flow in city centres, there is less general agreement among the various criteria. The failing of these criteria is that they have seldom been benchmarked, or confirmed through long-term measurements in the field, particularly for comfort conditions. Although these criteria were all developed in similar temperate climates to Sydney, there is an assumption that the local population will generally subjectively agree with the criterion.

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 fluctuating turbulent nature of the wind, but the mean wind speed indicates the longer duration impact on pedestrians. The gust wind speed may be suitable for safety considerations, but not necessarily for serviceability comfort issues such as dining comfort. 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.

An example location where both gusty and strong steady flows is experienced is Gas Lane to the north of the city, well known as a windy location in the city for all prevailing wind directions. Winds from the north-east and west tend to generate strong smooth steady flow in this area with reduced turbulence. For winds from the north-east, downwash flow from Observatory Tower is accelerated down Gas Lane, and winds from the west are compressed as the smooth flow from crossing the harbour is accelerated up the local topography. Wind from the south is channelled along Kent Street, but is more turbulent due to the articulation of the upstream façade line and building heights producing turbulence. 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 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.

A comparison between the mean and 3 s gust wind speed criteria from a probabilistic basis are presented in Figure 16 and Figure 18. The grey lines are typical results from wind tunnel testing and show how the various criteria would classify a single location. City of Auckland has control mechanisms for assessing usability of spaces from a wind perspective as illustrated in Figure 16 with definitions of the intended use of the space defined in Figure 17.

Further criticisms of the existing environmental wind criteria include that only one environmental condition is assessed so the impact of temperature, humidity, and solar radiation are not included in the assessment, however there is no known criterion that combines all these effects.

The current wind criteria in the City of Sydney (2012) state
"Wind effects caused by development are not to exceed:
(a) 10 m/s for active frontages as shown on the Active frontages map; and
(b) 16 m/s for all other streets."

It is understood that these are the once per annum gust wind speed to define pedestrian comfort based on the criterion of Melbourne (1975), however this is not explicitly stated in the DCP.

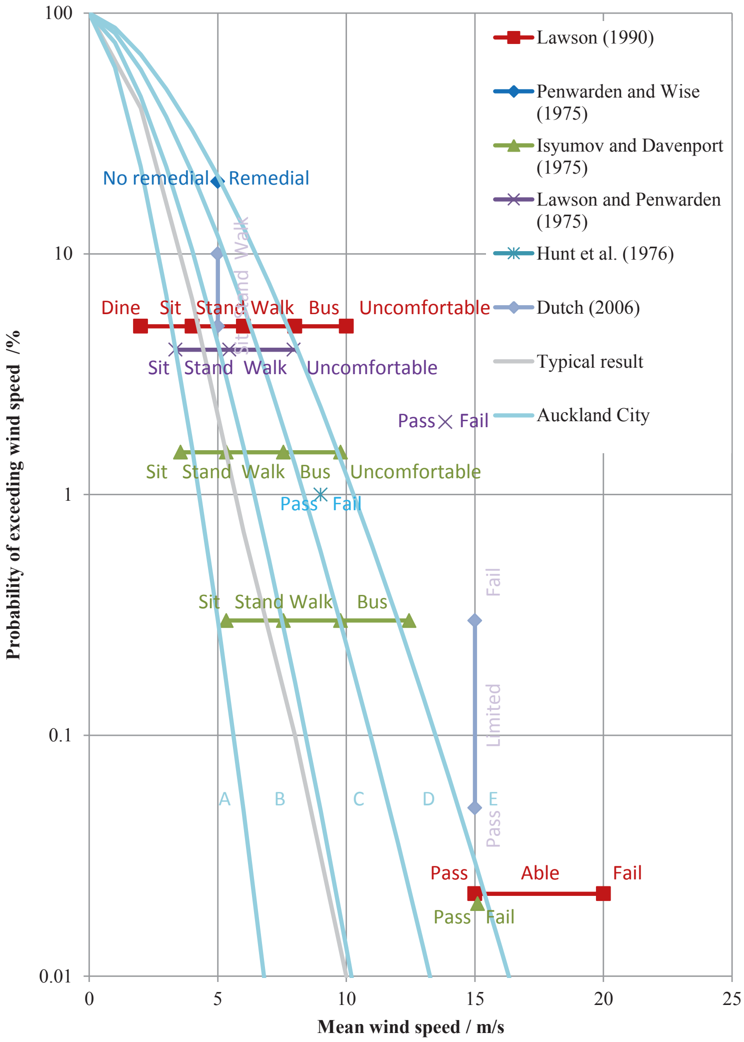

Figure 16: Probabilistic comparison between environmental criteria based on mean wind speed

16

Category A :	Areas of pedestrian use containing significant formal elements and features intended to encourage longer term recreational or relaxation use, ie, major and minor public squares, parks and other public open spaces - e.g. Aotea Square, Queen Elizabeth Square, Albert Park, Myers Park, St Patricks Square, Freyberg Place.
Category B:	Areas of pedestrian use containing minor elements and features intended to encourage short term recreation or relaxation, ie, minor pedestrian open spaces, pleasance areas in road reserves, streets with significant groupings of landscaped seating features e.g. Khartoum Place, Mayoral Drive pleasance areas, Queen Street.
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 where 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. Category E conditions are unacceptable and are not allocated to any physically defined areas of the city.
Note: All through-site links and other private land given over to public use as bonus features, or subject to public access easements, shall be subject to the Wind Environmental Categories.	

Figure 17: Auckland City District Plan comfort descriptions

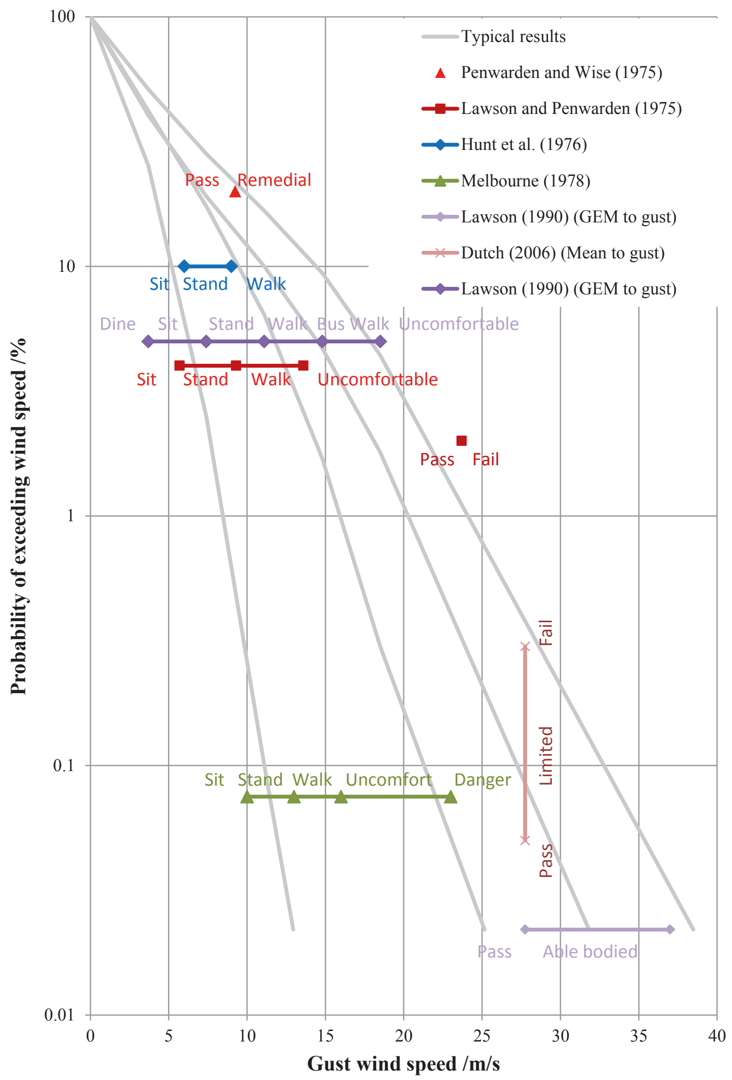

Figure 18: Probabilistic comparison between environmental criteria based on gust wind speed

For the limited amount of full-scale work conducted and compared with wind tunnel test results, the Lawson (1990) criterion have been found to be suitable. A snapshot of wind conditions across a section of the city as determined from CPP wind tunnel testing with respect to the Lawson criterion is presented in Figure 19. There is anecdotal experience supporting the Lawson ratings at these locations as discussed further below.

6. POTENTIAL MITIGATION STRATEGIES

It is evident from Figure 19, that the wind conditions on the fringes of the high-rise section of the city experience stronger winds than within the central zone of the city, Figure 20. This is partly due to shielding and in some cases the break up of the street grid pattern. This windy fringe area tends to extend about 200 m from the edge of the city, or about two-three times the width of the edge buildings. In these exposed areas downwash, channelling, and topographical effects combine to generate the windier conditions. The windiest conditions occur about one building width inbound form the edge of the city where the downwash is most concentrated at ground level. If the building is adjacent to a row of buildings of similar height the downwash generated will be a function of the compound building shape as discussed earlier.

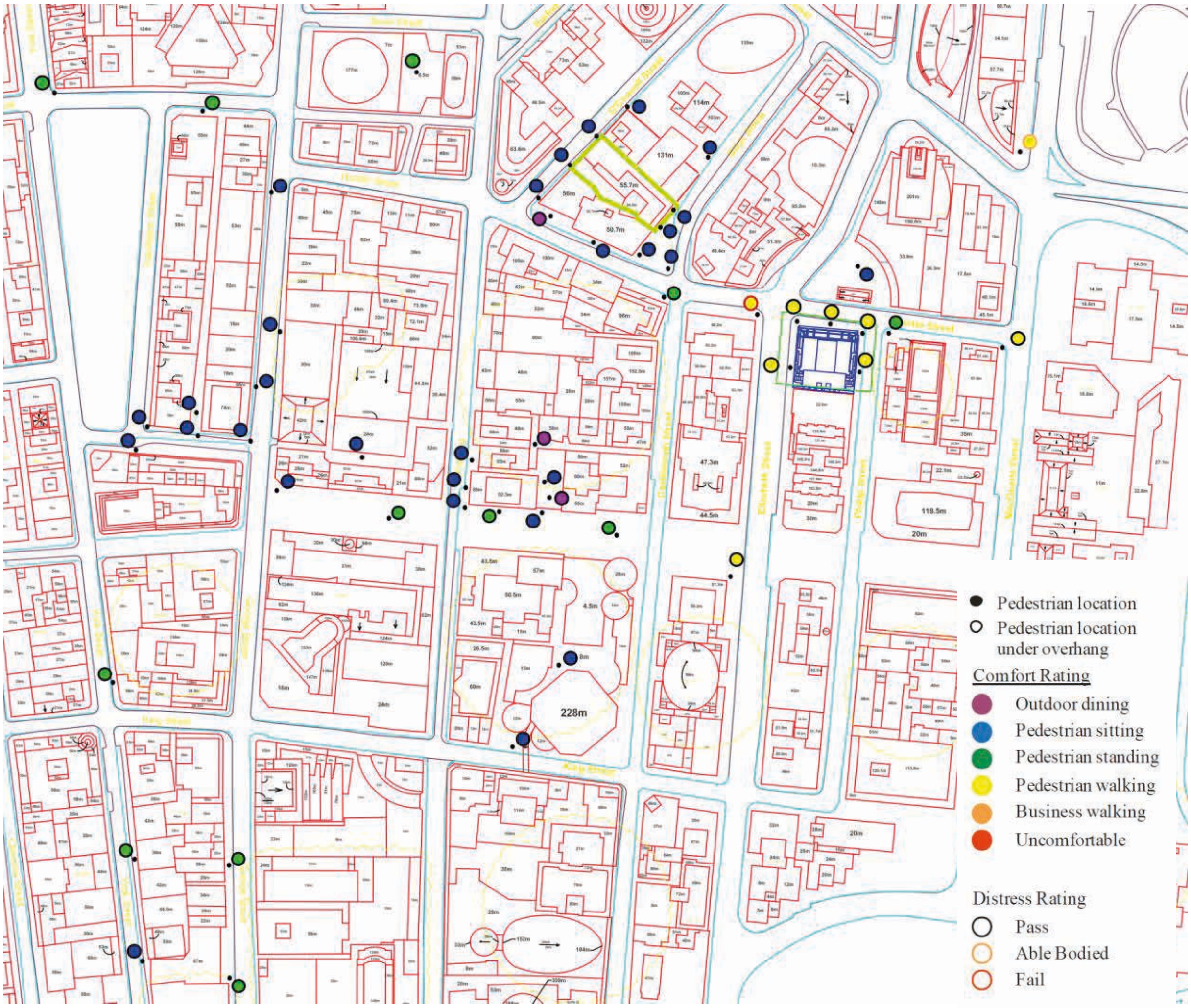

Figure 19: Snapshot of Sydney City showing wind conditions relative to the Lawson criterion

In this perimeter fringe region, or for new isolated buildings or groups of buildings outside the CBD massing, such as One Central Park on Broadway, it is recommended that any proposed tall building located on the corner of a block facing outward toward the fringe of the city should have a podium around the base to deflect downwash from pedestrians at ground level. The size of the tower setback will depend on the size, shape, and orientation of the tower, but should be in the order of at least 8 m on the windward and side faces. This does depend on the orientation and shape of the building relative to the wind climate. The horizontal disruption to downwash flow, could be a combination of podium and awning, but would need to occur at the same level. The podium should ideally be about 4 storeys above ground level. The provisions outlined in section 2.3 of the Central Sydney DCP 1996 are considered suitable for buildings within the 200 m fringe zone from the edge of the city, or for isolated individual towers, or groups of towers greater than about 50 m in height. For a proposed building in the central zone of the city, or in the fringe away from the corners of a continuous block, the requirement for a setback is reduced unless it is classified as an isolated building.

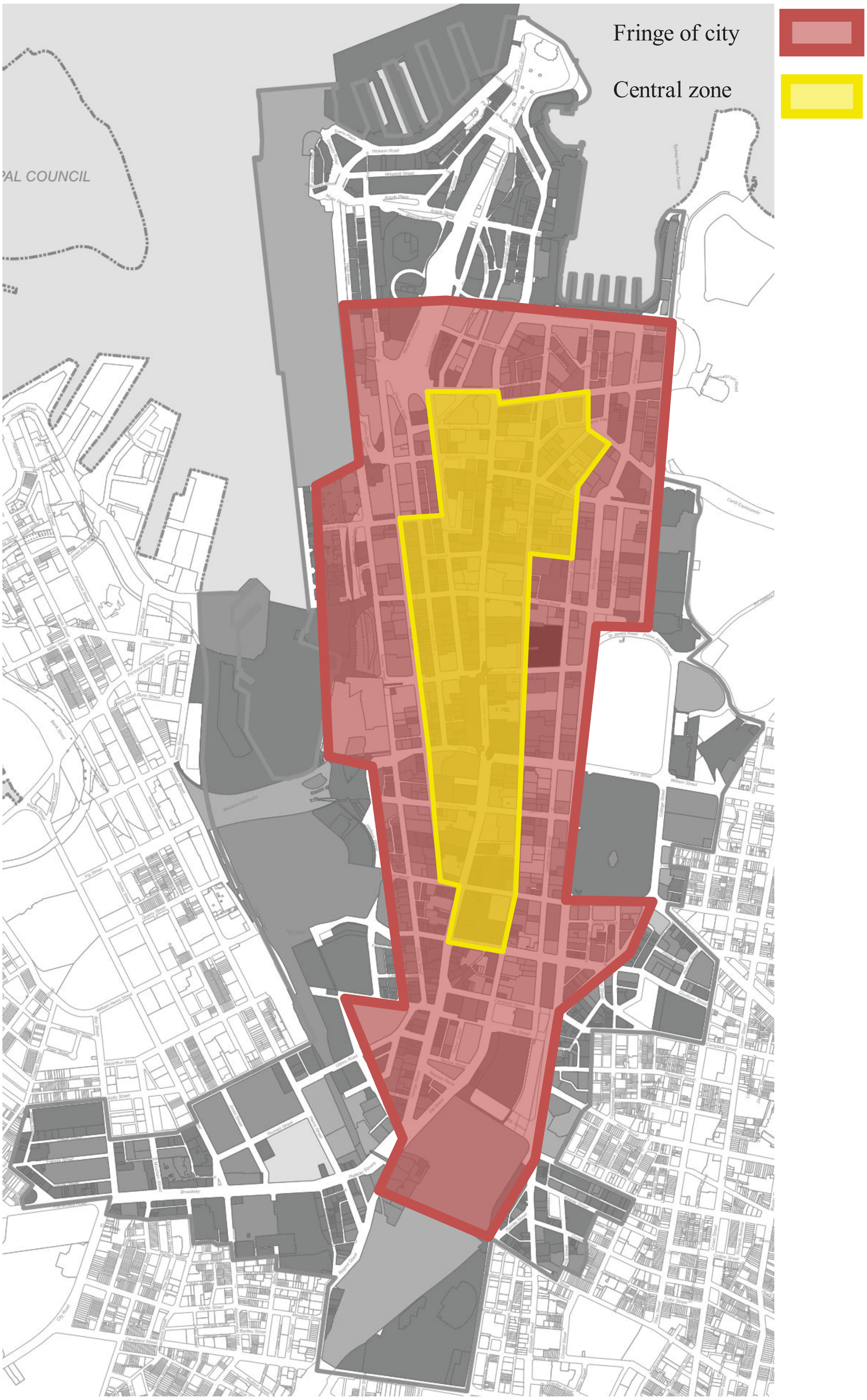

Figure 20: Wind zone diagram for the city

For concentrated channelled horizontal flow, vertical elements are required to ameliorate stronger wind conditions. These elements are most effective they are porous rather than solid, which tend to create a sudden local change in wind speed at the edge of the screen.

An open structural area at podium level such as a car park is an effective way to reduce the pedestrian level wind speed by allowing horizontal flow to pass through the building rather than down to ground level. This requires large openings on at least two faces of the building and a continuous flow path through the building. In this situation consideration need be given to the potential to induce strong internal building flows; in a carpark these can be beneficial from a flushing air quality perspective.

A single open floor above the ground floor produces only a small reduction in wind speeds. At least two fully open floors are required to have a significant effect on the wind conditions such as 8 Chifley Square, and if necessary a horizontal awning can be included in the open space to trap the wind between the top of the awning and the soffit of the space.

The use of large isolated trees or dense shrubs to reduce exceedances of the safety criterion is not always successful. Experience has shown that trees planted in windy locations tend to experience wind speeds at the height of the tree canopy capable of destroying or causing severe damage to many species. Falling limbs have the potential to generate a different sort of pedestrian hazard. Trees planted in regularly windy locations rarely mature to their normal full height due to loss of limbs, the drying effect of the wind, and the natural tendency of trees to remain stunted in such windy locations for the best chance of survival. Where landscaping is being considered to ameliorate stronger winds it is recommended evergreen species should be adopted with dense foliage. The other aspect of trees on footpaths is the disturbance to pedestrians, the impact of the roots on the subterranean services, and the ongoing maintenance in a built-up area.

For more open sites it may be possible to incorporate a landscaped zone, such as a raised planter bed, adjacent to the building façade rather than amend the building geometry. The landscaped zone would be impassable to pedestrian traffic. Similarly a solid or porous wall remote from the building could be used to provide local protection to pedestrians.

7. REFERENCES

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