WIND ENGINEERING
CONSULTANTS

QUALITATIVE WIND ASSESSMENT
CPP PROJECT 21556
14 AUGUST 2025

10 Missenden Road

Camperdown, NSW

CPP Wind Engineering Consultants
Unit 2, 500 Princes Highway
St Peters NSW 2044
Info-syd@cppwind.com

cppwind.com

PREPARED FOR:

ISPT.
c/- Pier Property Corporation
Suite 305, Level 3, 25 Lime Street
King Street Wharf, NSW 2000

Scott Egleton
Director
scott@pierproperty.com.au

PREPARED BY:

Joe Paetzold, PhD
Engineering Manager
jpaetzold@cppwind.com

Graeme Wood, PhD
Associate Principal
gwood@cppwind.com

Executive Summary

This environmental wind assessment report has been prepared to accompany a Concept State Significant Developments Application (SSDA) for a private hospital and associated ancillary uses. The legal description of the site is 10 Missenden Road, Camperdown, NSW 2050, title Lot 2 in DP 1124852.

For abundant clarity, when referring to the site this is reference to the legal property allotment for 10 Missenden Road, Camperdown. Separately, when referring to the Concept Development Area this is reference to part of the allotment to which the concept proposal relates.

This report has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) issued for the project (SSD-79888213).

A qualitative assessment was conducted to determine the impact of the proposed development at 10 Missenden Road, Camperdown on the surrounding pedestrian wind environment. The assessment was based on the local wind climate, CPP's experience in the region and comparable projects, and the characteristics of the proposed development.

The proposed concept development seeks to establish a built form envelope at the Concept Development Area which is expected to affect the local wind conditions in and around the Concept Development Area. However, the future detailed development design as demonstrated in the indicative reference scheme, can include measures to minimise the wind impact such as facade articulation, building orientation, and a stepped profile form west to east.

Qualitatively, integrating the expected directional wind conditions around the Concept Development Area with the wind climate, it is considered that wind conditions at the majority of locations around the Concept Development Area would be classified as suitable for pedestrian standing in accordance with the Lawson criteria, which is similar to the existing conditions. Wind conditions around the eastern corners of the development to the walkway between the Charles Perkins Centre are expected to be windier and be classified as suitable for pedestrian walking. These wind conditions are considered suitable for the intended use of the areas around the Concept Development Area, which is primarily for transient activities.

All locations would be expected to pass the safety criterion.

This report concludes that the proposed Concept Proposal relevant to the private hospital and associated uses is suitable and warrants approval subject to the implementation of the following mitigation measure:

- the wind conditions at the outdoor seating area on Missenden Road would be expected to be classified as Pedestrian Standing, meeting the wind speed associated with outdoor sitting for 80% of the time. Depending on the necessity to have this area operational at all times, the wind conditions could be improved with local amelioration such as temporary or permanent vertical screens, or planter boxes around the seating area.

This report is a high-level qualitative assessment based on basic features of the local wind climate and proposed built environment. To quantify the qualitative advice provided in this report, numerical or physical modelling of the development would be required and is recommended for the current large design in a complex flow environment.

Document Tracking and Version Control

REVISION	RELEVANT INFORMATION	
R00	Date Issued:	22/05/2025
	Prepared by:	Graeme Wood, PhD
	Reviewed by:	Joe Paetzold, PhD
	Approved by:	Graeme Wood, PhD
	Document Name:	CPP21556 _10 Missenden Road_REP_DS_PW_R00.pdf
R01	Date Issued:	6/06/2025
	Prepared by:	Joe Paetzold, PhD
	Reviewed by:	Graeme Wood, PhD
	Approved by:	Graeme Wood, PhD
	Document Name:	CPP21556 _10 Missenden Road_REP_DS_PW_R01.pdf
R02	Date Issued:	13/06/2025
	Prepared by:	Joe Paetzold, PhD
	Reviewed by:	Graeme Wood, PhD
	Approved by:	Graeme Wood, PhD
	Document Name:	CPP21556 _10 Missenden Road_REP_DS_PW_R02.pdf
R03	Date Issued:	5/08/2025
	Prepared by:	Joe Paetzold, PhD
	Reviewed by:	Graeme Wood, PhD
	Approved by:	Graeme Wood, PhD
	Document Name:	CPP21556 _10 Missenden Road_REP_DS_PW_R03.pdf
R04	Date Issued:	14/08/2025
	Prepared by:	Joe Paetzold, PhD
	Reviewed by:	Graeme Wood, PhD
	Approved by:	Graeme Wood, PhD
	Document Name:	CPP21556 _10 Missenden Road_REP_DS_PW_R04.pdf

CPP WIND ENGINEERING CONSULTANTS

Contents

1. Introduction

CPP have been engaged to provide an experienced-based wind impact assessment report for the proposed 10 Missenden Road development in Camperdown. This report outlines the assessment and subsequent recommendations for wind engineering services related to pedestrian wind comfort and safety on the ground level.

The Concept SSDA seeks development consent for a Concept Proposal for:

- development of a private hospital, including the provision of ancillary health and research uses, ancillary retail and commercial office space and carparking,
- a building envelope comprising a stepped building form, with dual setbacks and cantilevered elements which responds to the surrounding heritage and context.
- a building envelope which includes:
    - three (3) basement levels to a maximum depth of RL 13 m,
    - five (5) storey terraced podium with a maximum height of RL 56.4 m,
    - a 10-storey tower, plus roof plant level, with a maximum height of RL 85.5 m,

The concept proposal anticipates the private hospital development will provide:

- vehicular access from Missenden Road,
- 33,253 m^2 gross floor area,
- a maximum of 264 basement car parking spaces and three (3) ground floor, hospital drop-off parking spaces,
- associated tree removal and tree transplanting, site landscaping, public art and public domain upgrades within and adjacent to the site.
- accommodation of approximately 90 ward beds, 26 ICU/CCU beds and 8 Theatre rooms. Additionally, spaces for ancillary uses, such as:
    - radiology,
    - pathology,
    - clinical suites,
    - research / technology,
    - education,
    - retail food and beverage, and
    - pharmacy.

This Concept SSDA is being sought pursuant to Division 4.4 of the EP&A Act. No physical works are proposed as part of this Concept SSDA. The Concept SSDA seeks development consent for the proposed concept envelope and private hospital land use only, further detailed design in the submission of staged DAs will determine the exact use and operation of these spaces.

All physical works will be the subject of detailed proposals as part of a future required detailed DA. An indicative reference scheme has been prepared by Architectus which provides a proof of concept that the proposed built form outcome is able to sensitively respond and integrate within the existing heritage fabric of the surrounding sites while accommodating the intended land use operations.

The proposal will provide a private hospital that is co-located to the RPA and supports the broader Camperdown Health, Education and Research Precinct ecosystem by providing for contributory health and life science land uses.

This report has been prepared in response to the requirements contained within the Secretary's Environmental Assessment Requirements (SEARs) dated 5 March 2025 and issued for the SSDA (SSD-

79888213). Specifically, this report has been prepared to respond to the SEARs requirement as detailed in Table 1.

Table 1: Relevant SEARs requirements for the project

PROJECT SEARs SSD-79888213	
5. Environmental amenity Assess amenity impacts on the surrounding locality, including lighting impacts, solar access, visual privacy, visual amenity, view loss and view sharing, overshadowing and **wind** impacts (**including the preparation of a wind assessment where the concept built form has a height above four storeys**). A high level of environmental amenity for any surrounding residential or other sensitive land uses must be demonstrated.	Entire report
City of Sydney Advice on SEARs	
2. Urban Design A wind study report is to be provided to ensure that circulation, entries and outdoor areas are safe for standing, walking, seating during all times of the year and designed to optimise areas based on their conditions.	Entire report
4 Landscape *Environmental Amenity* Wind testing at ground level for sitting and upper-level accessible terraces the establish the wind impacts and address how the envelope and building articulation is modified to minimise impacts. A reliance on tree and shrub planting to mitigate wind impacts is not supported	Entire report

THE SITE

The site is located at 10 Missenden Road, Camperdown, within the Sydney Local Government Area (LGA), outlined in red in Figure 1 and Figure 2.

For abundant clarity, when referring to the site this is reference to the legal property allotment for 10 Missenden Road, Camperdown. Separately, when referring to the Concept Development Area this is reference to part of the allotment to which the concept proposal relates.

The Concept Development Area comprises 7.329m^2. The bulk of the Concept Development Area is currently comprised of at-grade, outdoor carparking (public paid car park) with scattered tree plantings and a driveway/access point from Missenden Road. At the south-west corner, fronting Missenden Road, is a sing-storey retail building, known as the Benning Building, which current accommodates three retail tenancies, a post-office, a “7/11” convenience store and an office.

The Concept Development Area has a prevailing topography characterised by a moderate slope from Missenden Road to the east of the Concept Development Area located along John Hopkins Drive.

The Concept Development Area is located within the Camperdown Health, Education and Research Precinct (CHERP), which contains a mixture of healthcare services, medical research and education institutions. Surrounding land uses include the Royal Prince Alfred Hospital (RPAH), University of Sydney and ancillary student accommodation, and mixed-use buildings comprising commercial and residential activity.

St Johns College is identified under the Sydney Local Environmental Plan 2012 (SLEP 2012) as a local heritage item (no. 67). The Concept Development Area has been assessed as having medium to low archaeological significance, with a potential for Aboriginal archaeological materials to be present in the area. However, it is noted by the St Johns College Conservation Management Plan 2020 that based on the level of continued site disturbance, it is highly unlikely that any deposits or materials would be in situ or undisturbed. The Concept Development Area is also situated within the "University of Sydney" Heritage Conservation Area, which is listed under the SLEP 2012 (C5), and is within the curtilage of the State Heritage Register listing for the Sydney University campus (SHR #01974). Further, the Concept Development Area is located in proximity to the "Admission Block" and "Victoria & Albert Pavilions" of the RPAH to the south of the area, which are listed on the state heritage register (listing numbers 00830 and 00829, respectively).

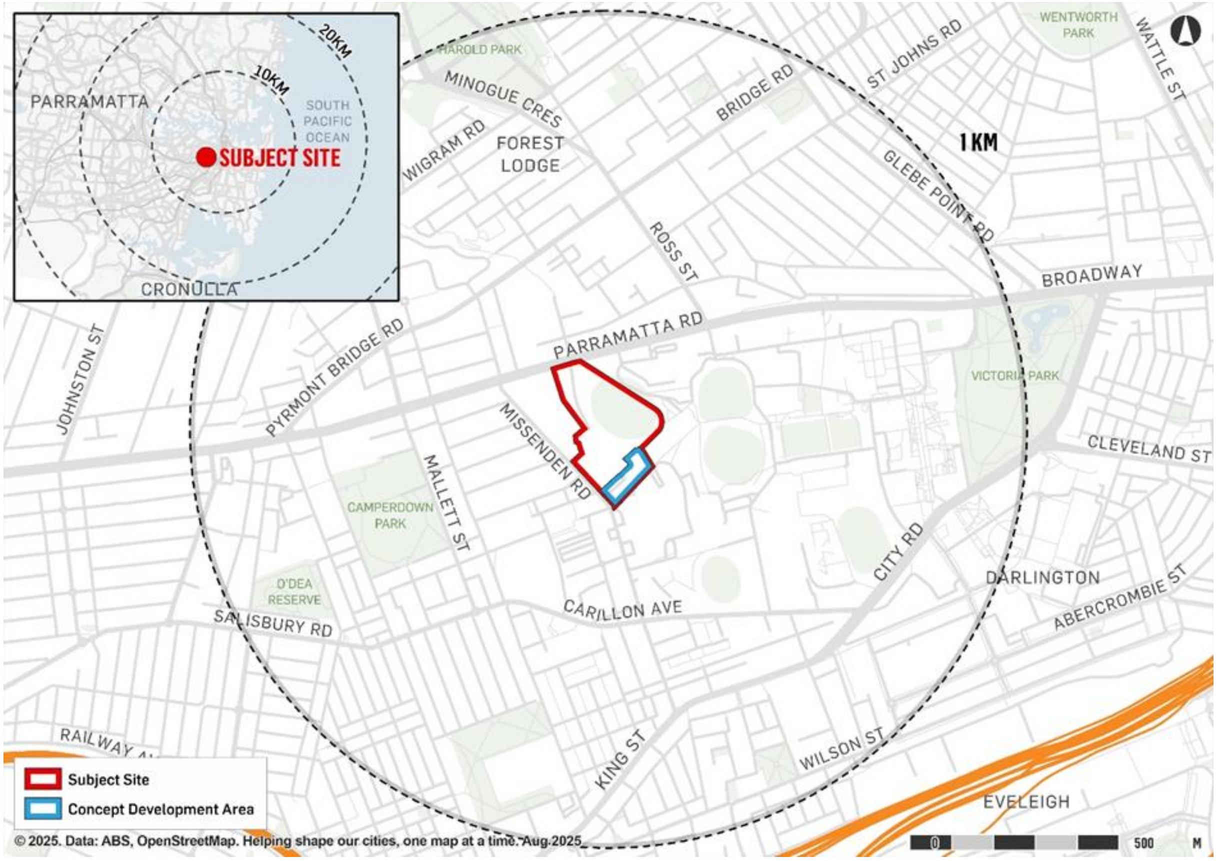

Figure 1: Location Plan (Source: Urbis Spatial, 2025)

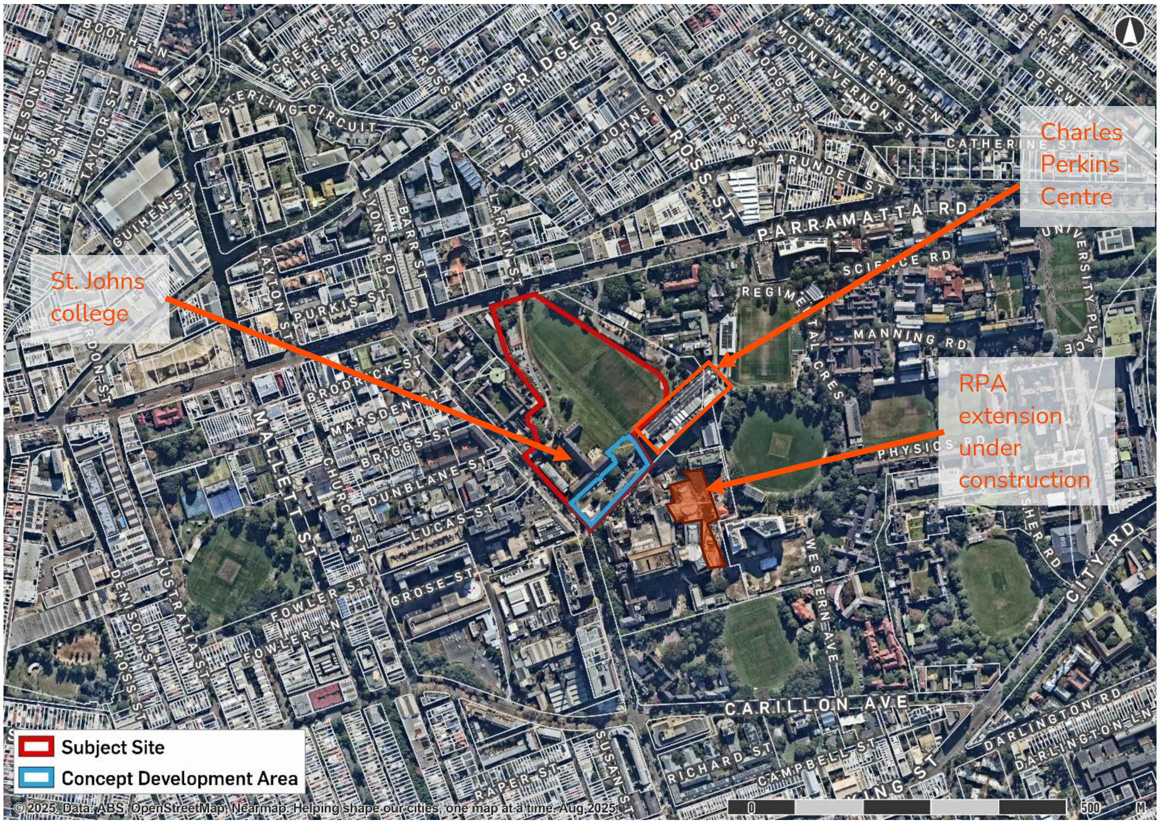

Figure 2: Aerial photograph (Source: Urbis Spatial, 2025)

CPP WIND ENGINEERING CONSULTANTS

2. Wind Assessment

WIND CLIMATE

The proposed development lies approximately 8 km to the north of the Sydney Airport Bureau of Meteorology anemometer, which provides the best source of historical wind data for the project. The wind rose is shown in Figure 3. The arms point in the direction from where the wind is blowing, 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. It is evident from Figure 3 that prevailing winds come from the north-east, south, and west quadrants. This wind assessment is structured around these prevailing wind directions.

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 cooler conditions and contain 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 sunset. 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 clockwise to north-west. 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.

The measured mean, 5%, and 0.1% exceedance wind speeds are 4.5, 10, and 16 m/s respectively. A general description of wind flow patterns around buildings is provided in Appendix A.

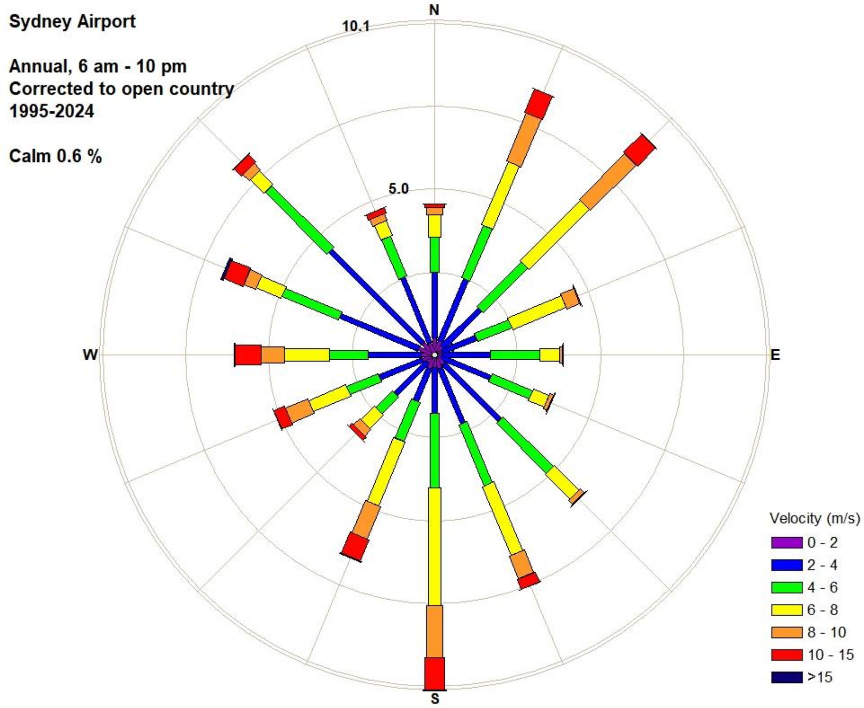

Figure 3: Wind rose for Sydney Airport

WIND ASSESSMENT CRITERIA

A number of researchers have suggested quantitative methods for assessing wind comfort and safety based on estimated wind speeds and local climate statistics. These criteria provide a means of evaluating the wind amenity of location based on the frequency of threshold wind speeds, noting that pedestrians will tolerate higher wind speeds for a shorter time period than lower speeds. The comfort criteria allows planners to assess the usability, with respect to the wind environment, of different locations for various purposes. A discussion on various criteria is presented in Appendix B.

There are no specific controls for wind comfort or safety for this site. CPP uses a modified form of the widely-accepted pedestrian-level wind criteria developed by Lawson (1990). Lawson's criteria are divided into separate categories of comfort and distress (safety).

Lawson's comfort criteria are based on wind speeds exceeded 5% of the time, and are described as categories for comfort ranging from 'Pedestrian Sitting' to 'Business Walking', allowing planners to judge the usability of locations for various intended purposes. The criteria include a distress rating, for safety assessment, which is based on occasional (once or twice per year) wind speeds, to identify locations where wind speeds may be hazardous to pedestrians. The categories and criteria are specified in Table 2. In general, wind conditions comfortable for Sitting and Standing are considered appropriate for areas such as entrances where pedestrians are likely to gather for longer durations, while wind conditions comfortable for Casual Walking and Business Walking are more appropriate for sidewalks where pedestrians are actively in transit. Locations rated as Uncomfortable are generally less suitable for most pedestrian activities and wind control solutions are often sought. Whether mitigation is needed at a location depends upon the intended pedestrian use of the location.

Satisfaction of the safety rating is generally required for areas accessible to the general public. A rating of 'Able-Bodied' may be acceptable for areas with managed access or where pedestrians are unlikely to be present under adverse conditions.

Assessment using the Lawson criteria is preferred to methods based on once per annum gust speeds such as Melbourne (1978) as it is based on more regularly occurring wind speeds relevant to perception by pedestrians and uses a combined probability integrated over all directions. In addition, it is less susceptible to variations in turbulence levels in urban environments while still considering the impact of short-duration gusts.

The perception of wind is subjective and varies depending on regional difference in wind climate and thermal conditions, as well as by individual. Calibration to the local wind environment should be taken into account when evaluating predicted wind comfort conditions. Note that the ratings of 'Uncomfortable' and 'Safety' are the words of the published wind criteria and applicability may vary by project and location.

Converting the wind climate to the site location, the mean wind speed at pedestrian level exceeded 5% of the time would be approximately 5.5 m/s, which would be classified as suitable for pedestrian standing activities. From knowledge of the site, this is considered representative of the area.

Table 2: Wind Comfort and Safety criteria (after Lawson, 1990)

COMFORT RATING	U_{EQUIV}*	DESCRIPTION
Dining**	≤2 m/s	outdoor restaurant uses, semi-enclosed spaces.
Sitting	>2-4 m/s	long duration seating areas, café areas, and other amenities.
Standing	>4-6 m/s	main entrances and bus stops where pedestrians may linger, recreational parks, and sitting for shorter periods.
Pedestrian Walking	>6-8 m/s	window shopping and strolling along a downtown street, or park.
Business Walking	>8-10 m/s	less frequented areas, areas with objective walking, or running.
Uncomfortable	>10 m/s	unacceptable for all pedestrian activities; wind mitigation is typically required.

*U_{Equiv} = Max (U_{Mean}, U_{Gust} / 1.85). Criterion based on an annual exceedance of 5% (~8 hours / week) assessed over all hours.
** For regular outdoor dining, commercial tenancies, and in semi-enclosed spaces, it has been the experience of CPP that the comfort rating of Sitting may be windier than desired and a comfort criterion of 2 m/s or less may be more applicable.

SAFETY RATING	U_{EQUIV}*	DESCRIPTION
Pass	≤15 m/s	Meets wind safety criterion.
Able-Bodied	>15-20 m/s	Acceptable where only able-bodied people would be expected; not acceptable for frail persons or cyclists
Fail	>20 m/s	Excessive wind speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation required.

* U_{Equiv} = Max (U_{Mean}, U_{Gust} / 1.85). Criterion based on an annual exceedance of 0.022% (~2 / year or 1 / season) assessed over all hours.

CONCEPT DEVELOPMENT AREA DESCRIPTION

The Concept Development Area is located on the northern corner of Missenden Road and John Hopkins Drive, which has an existing single-storey convenience store, café, and car park, Figure 2. The Concept Development Area is surrounded by medium-rise buildings of the RPA Hospital including the Charles Perkins Centre to the north-east, the RPA extension building currently under construction to the east, and St John's College to the north-west. The development overlooks the St John's College playing fields to the north. The existing buildings to the north-west of the Concept Development Area are low to mid-rise. Topography surrounding the Concept Development Area drops to the east by about 7 m.

Winds in such surrounds tend to experience less channelling than areas with many tall structures, with local effects instead being dictated by exposed buildings and their relation to prevailing strong wind directions. Several wind flow mechanisms such as downwash and channelling flow are described in Appendix A including the effectiveness of some common wind mitigation measures.

The proposed development has an irregular floor plan, Figure 4, rising to a height of about 15 and 60 m above local ground level to the west and east respectively, Figure 5. As the proposed building massing is large, and taller than surrounding buildings, it is expected to have some impact on the local wind conditions, and the extents are discussed in this report.

Figure 4: Various plans

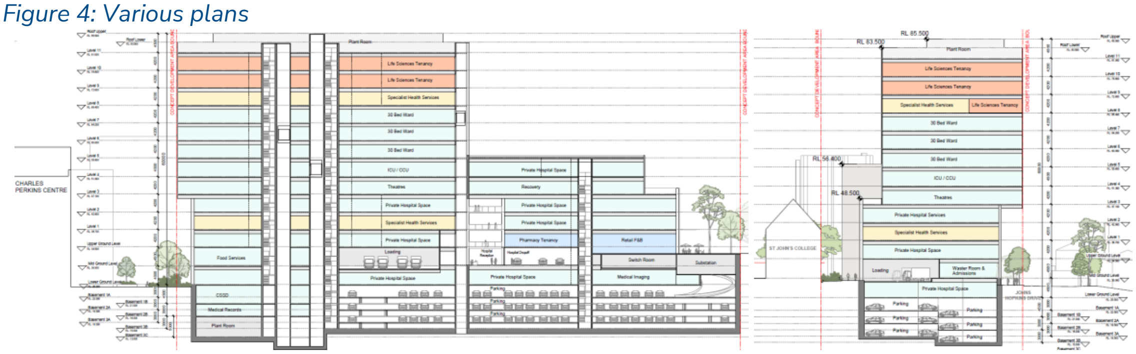

Figure 5: Sections looking south (L) and east (R)

PREDICTED WIND CONDITIONS ON THE GROUND PLANE

The following sections of the report outline the predicted wind conditions in and around the Concept Development Area based on the local wind climate, topography, and changes to the building form. The initial sections look at specific wind directions before being combined to compare the findings against the comfort and safety criteria.

The wind conditions in this area are known to be relatively benign with the majority of locations being classified as suitable for pedestrian standing type activities, increasing to walking around the corners of larger buildings, such as the Charles Perkins Centre.

The roof of the proposed building is about 25 m higher than the Charles Perkins Centre, and about 5 m shorter than the RPA extension building currently under construction.

WINDS FROM THE NORTH-EAST

The Camperdown Health, Education and Research Precinct is relatively exposed to winds from the north-east as the flow approaches over medium-rise buildings and open playing fields. The winds would be redirected by the Charles Perkins Centre before reaching the Concept Development Area, as illustrated in Figure 6. The flow would accelerate along the north façade and up the topography to the west. The decrease in building height to the west, allows the flow to expand before accelerating around the corners along Missenden Road.

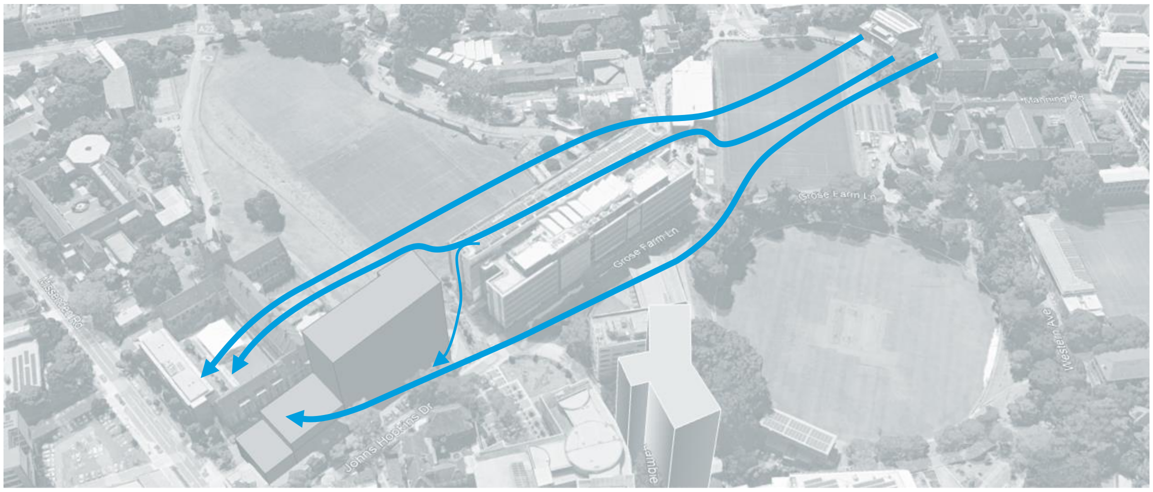

Figure 6: Flow patterns for winds from the north-east (Google Earth, 2025)

Wind with a direction more from the north would cause windier conditions along the north façade of the Chrles Perkins Centre before being redirected along the laneway between the buildings. A component of the accelerated flow along the north façade would expand across the low-rise component of the building to the west before reaching Missenden Road.

WINDS FROM THE SOUTH

Winds from the south approach the Concept Development Area over suburbia and the medium-rise RPA hospital buildings. These upstream buildings tend to channel the flow along the main surrounding streets. The ground floor coverage and irregular layout of the hospital buildings, with complex topography between the buildings is beneficial to the local wind conditions by encouraging wind flow around and over the surrounding massing rather than directing it to ground level. The large existing RPA hospital building to the south is orientated to direct winds from the south to the east and over the building, Figure 7. The lifting of the flow and orientation of the building to the incident wind is expected to further reduce the amount of downwash generated from the proposed taller building. The flow would be encouraged to stay at a higher level,

The low-rise nature of the building adjacent to Missenden Road and the significant landscaping along Missenden Road would encourage the flow to pass over the roof rather than descent to ground level. Relatively windy conditions can be expected in the laneway between the proposed building and Charles Perkins Centre.

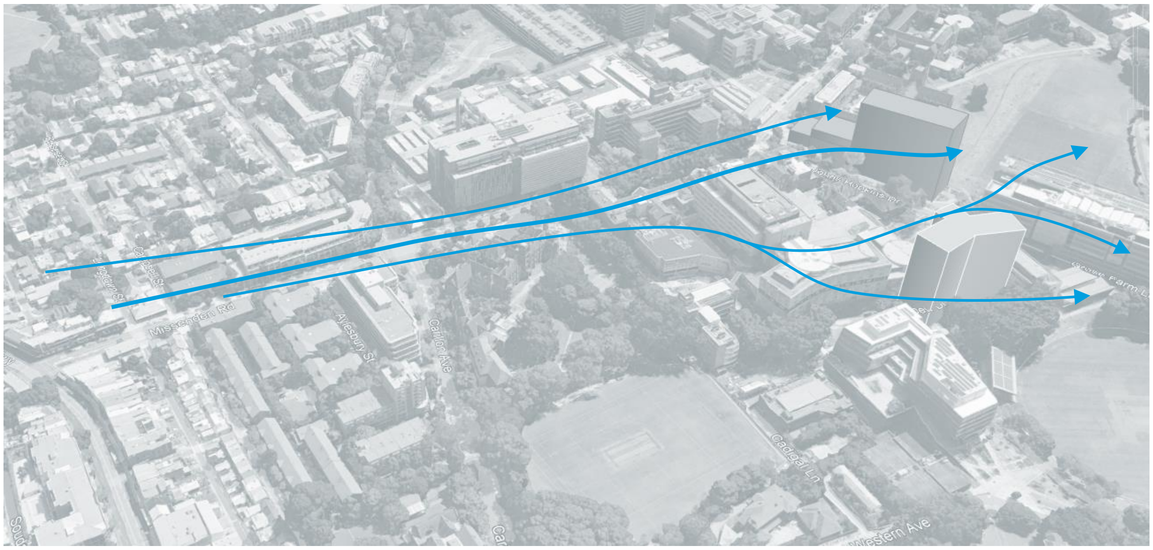

Figure 7: Flow patterns for winds from the south (Google Earth, 2025)

WINDS FROM THE WEST

The Concept Development Area is relatively exposed to winds from the west approaching over the suburbia. The stepped nature of the building form the west is a benefit to lift the flow above ground level. Winds from the west would impinge on the corner of the proposed building encouraging horizontal flow thereby reducing the among of downwash reaching ground level, Figure 8. Winds would be accelerated along the north-west façade, but the wind conditions at ground level benefit from the drop in topography to the east.

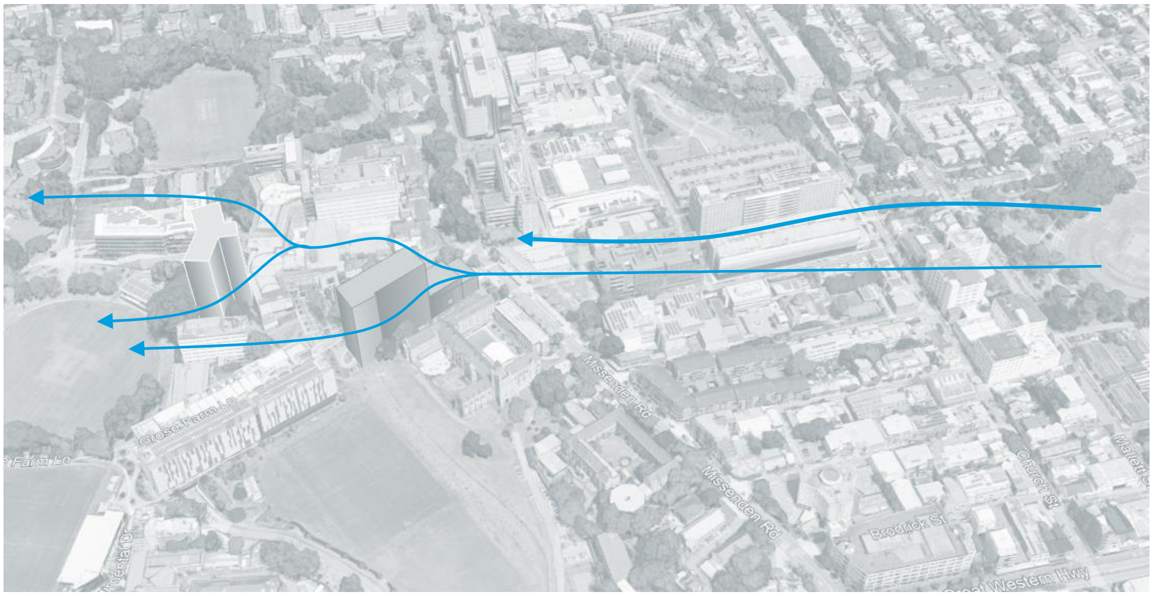

Figure 8: Flow patterns for winds from the west (Google Earth, 2025)

Wind from the north-west would impinge on the broad face of the building. These winds would be directed to the west over the Level 5 roof protecting the ground level conditions on Missenden Road, and channelled to the east between the proposed building and the Charles Perkins Centre.

DISCUSSION – PUBLIC DOMAIN

The proposed concept development seeks to establish a built form envelope at the Concept Development Area which is expected to affect the local wind conditions in and around the Concept Development Area. The Concept Development Area is relatively well orientated to the prevailing wind directions and receives beneficial shielding from the existing and future RPA hospital buildings, and the Charles Perkins Centre. The irregular nature of the pedestrian accessways and street layout in the area reduces the potential for strong channelled flows. Ther irregular shape of the proposed developed, and the low-rise nature of the building to Missenden Road are beneficial for the ground plane wind conditions. There is no access to elevated terraces indicated in the reference scheme though an area around the south-western part of the building on Level 3 is considered for an outdoor terrace. The C-shaped form of this space would ensure that there would be some portion that would experience mild wind conditions independent of the wind direction. However the wide western section facing Missenden Road would likely be subject to relatively windy conditions frequently. To avoid issue with the door operations, it is recommended to avoid outward swinging doors to the terrace, unless there is a management plan not to operate the doors during windy conditions. Inset terraces away from the corners of the building would be preferable from a wind comfort perspective.

Qualitatively, integrating the expected directional wind conditions around the Concept Development Area with the wind climate, it is considered that wind conditions would be generally classified as suitable for pedestrian standing to the Lawson comfort criteria, rising to pedestrian walking at the corners to the laneway between the Charles Perkins Centre. For most locations around the Concept Development Area, wind conditions are expected to remain similar to the existing wind conditions with some areas getting windier and others calmer depending on the incident wind direction. The predicted environmental wind conditions are considered to be suitable for the intended use of the areas in and around the Concept Development Area.

All locations would be expected to satisfy the safety/distress limiting annual maximum gust criterion.

The main entrances to the building are well located in the middle of the building face and remote from the high wind speed zones around the corners. The wind conditions at the outdoor seating area on Missenden Road would be expected to be classified as suitable for pedestrian standing, meeting the wind speed associated with the sitting criterion for about 80% of the time. Although landscaping is not encouraged for wind mitigation by the City of Sydney, the presence of the mature landscaping in the area would significantly improve the local wind conditions in these areas. Wind conditions at the café area fronting Missenden Road could be improved with local amelioration such as temporary or permanent vertical screens around the seating area. These elements would only have to be employed during inclement environmental conditions.

References

Lawson, T.V. (1990), “The Determination of the Wind Environment of a Building Complex before Construction” Department of Aerospace Engineering, University of Bristol, Report Number TVL 9025.

Appendix A – 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 9, 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 9. 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.

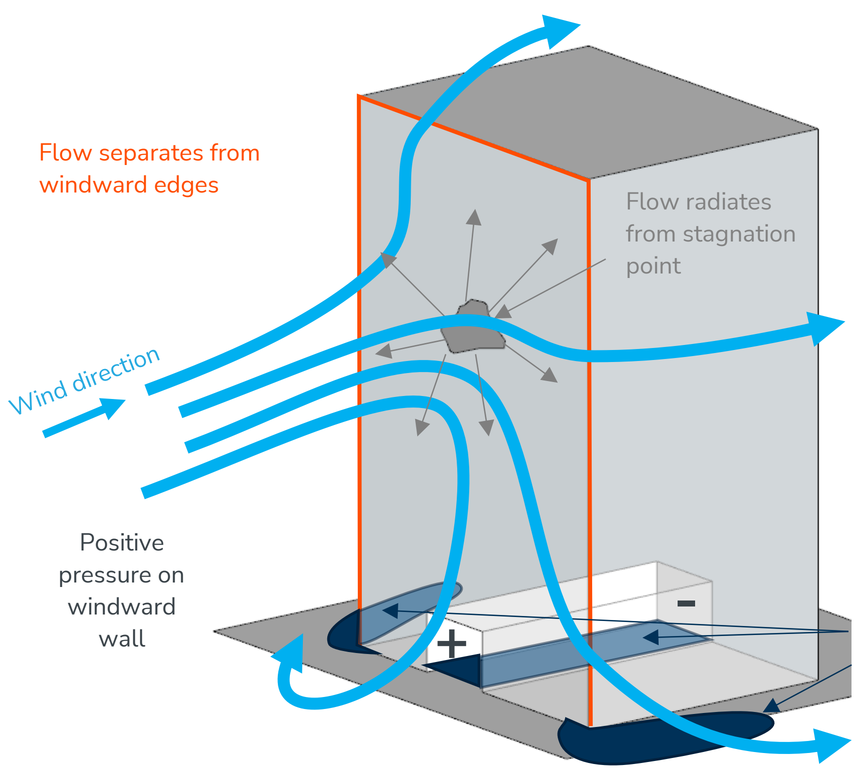

Figure 9: Schematic wind flow around tall isolated building

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 10. 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.

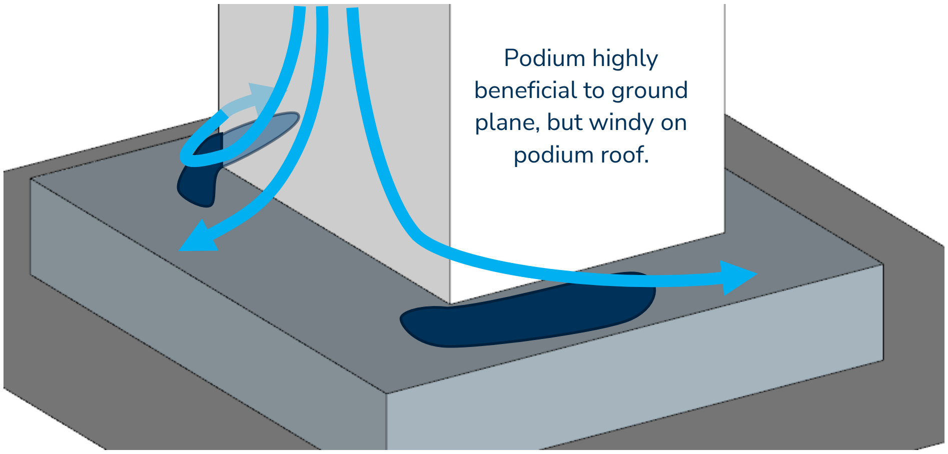

Figure 10: Schematic flow pattern around building with podium

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 11. 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.

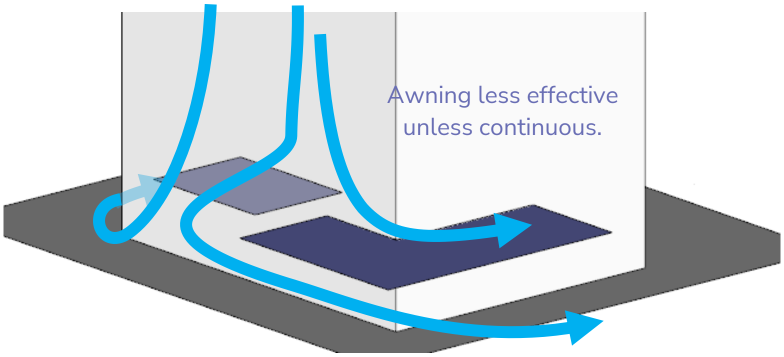

Figure 11: Schematic flow pattern around building with awnings

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 a building cause wind issues as the pressure tries to equilibrate between the entrances to the link causing strong flow, Figure 9. If the link is blocked, wind conditions will be relatively calm, Figure 13. This area is in a region of high pressure and therefore there is the potential for internal flow issues. A ground level recessed corner has a similar effect as an undercroft, resulting in windier conditions, Figure 13.

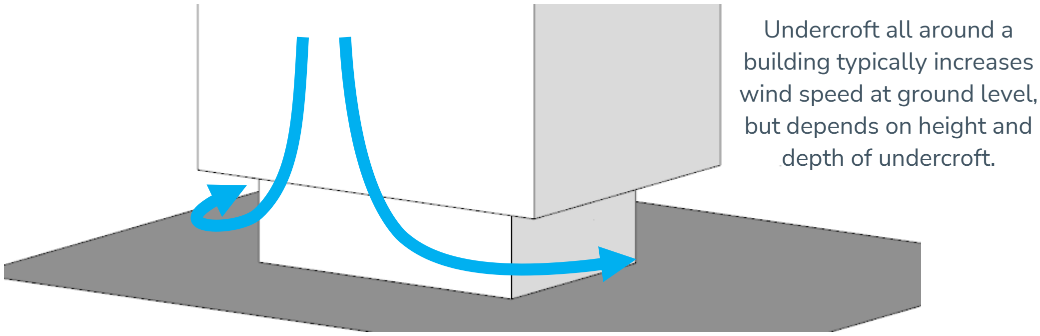

Figure 12: Schematic of flow patterns around isolated building with undercroft

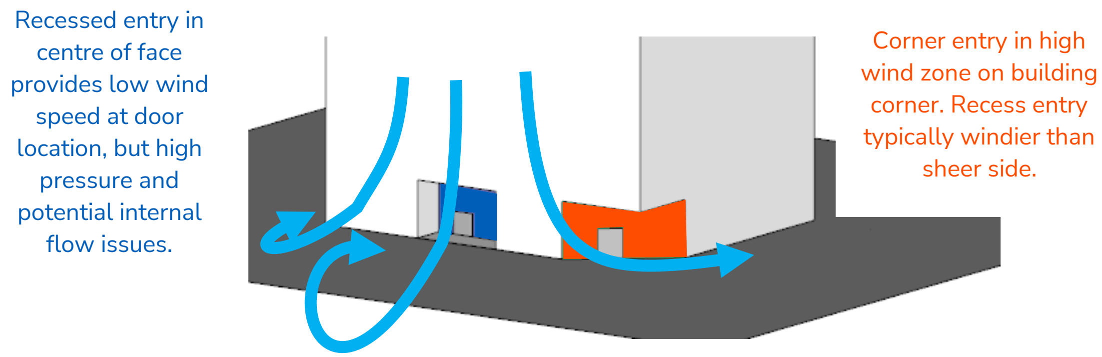

Figure 13: Schematic of flow patterns around isolated building with ground articulation

MULTIPLE BUILDINGS

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 14. 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 by the surrounding buildings. 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.

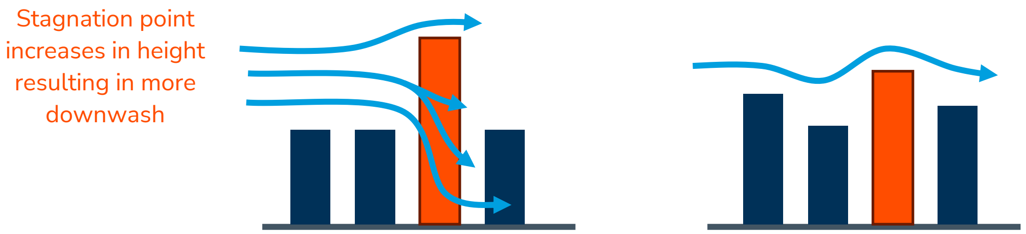

Figure 14: Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 15.

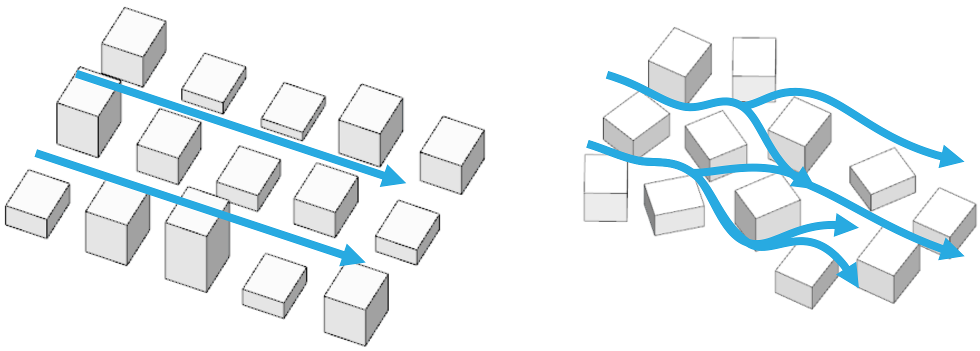

Figure 15 Schematic of flow patterns through a grid and random street layout

On the fringe of a city, the compound shape of neighbouring buildings instigates the flow pattern through the city. The overall massing causes an obstruction to the flow causing a slowing of the incident flow and increasing the windward pressure. Pressure driven flow is produced between the buildings, Figure 16. The vertical component in pressure driven flow is lower than downwash flow.

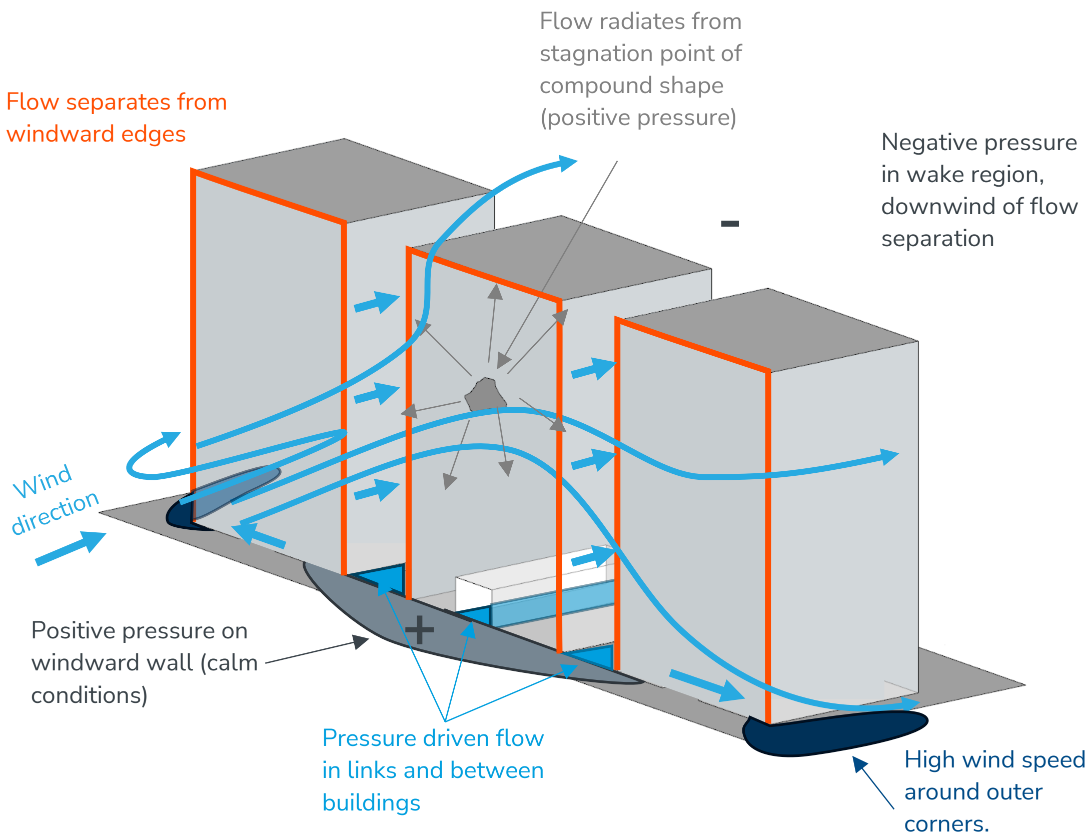

Figure 16: General flow pattern around multiple buildings

Channelling is instigated when pressure driven flow accelerates between two buildings, and continues along straight streets with buildings on either side, Figure 15(L). This occurs on the edge of large built-up areas where the approaching flow is diverted around the overall massing and channelled along the fringe by a relatively continuous wall of building facades. This is generally the primary mechanism producing strong wind conditions on the perimeter of a built-up area, particularly on corners, which can be exposed to multiple prevailing wind directions. The perimeter edge zone in a built-up area is typically about two blocks deep. Downwash is the 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 15(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.

BARRIERS AND SCREENS

The wind flow pattern over a vertical barrier is illustrated in Figure 17, showing there will be recirculation zones near the windward wall and in the immediate lee of the barrier. The typical extent of these recirculation zones relative to the height of the barrier, *h*, is illustrated in Figure 17. These regions are not fixed but fluctuate in time. The mean wind speed in the wake areas drops significantly compared with the incident flow. With increasing distance from the barrier, the flow pattern will resort to the undisturbed state. Typically, the mean velocity and turbulence intensity at barrier height would be expected to be within 10% of the free stream conditions at 10 times the height of the structure downwind from the barrier.

Multiple barriers offer improved wind conditions between the barriers by preventing the flow from reattaching to the surface.

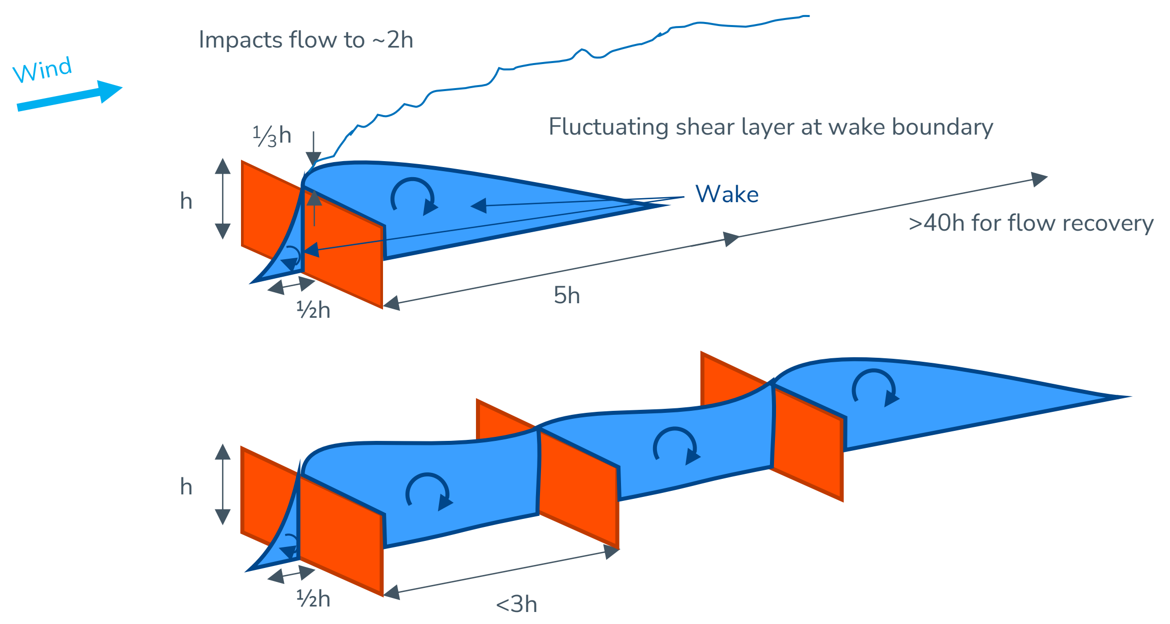

Figure 17: Sketch of the flow pattern over vertical elements

Appendix B – 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 3. 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 3: 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 peak 3 s gust in an hour, 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 less agreement over a wider range of flow conditions. 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 wind speed 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:

$$U_{GEM} = \frac{(U_{1\,hour\,mean} + 3 \cdot \sigma_u)}{1.85} \text{ and } U_{GEM} = \frac{1.3 \cdot (U_{1\,hour\,mean} + 2 \cdot \sigma_u)}{1.85}$$

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 18 and Figure 19. 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 18 with definitions of the intended use of the space categories included in this Figure.

REFERENCES

City of Auckland, (2016), Auckland Unitary Plan Operative.

City of Sydney (2016), Central Sydney Planning Strategy 2016-2036.

City of Melbourne (2017), Melbourne Planning Scheme.

Hunt, J.C.R., Poulton, E.C., and Mumford, J.C., (1976), The effects of wind on people; new criteria based on wind tunnel experiments, Building and Environment, Vol.11.

Isyumov, N. and Davenport, A.G., (1975), The ground level wind environment in built-up areas, Proc. 4th Int. Conf. on Wind Effects on Buildings, Cambridge University Press, U.K.

Lawson, T.V., and Penwarden, A.D., (1975), The effects of wind on people in the vicinity of buildings, Proc. 4th Int. Conf. on Wind Effects on Buildings, Cambridge University Press, U.K.

Lawson, T.V., (1990), The Determination of the wind environment of a building complex before construction, Department of Aerospace Engineering, University of Bristol, Report Number TVL 9025.

Melbourne, W.H., (1978), Criteria for environmental wind conditions, J. Wind Engineering and Industrial Aerodynamics, Vol.3, No.2-3, pp.241-249.

Netherlands Standardization Institute, NEN, (2006). Wind comfort and wind danger in the built environment, NEN 8100 (in Dutch) Dutch Standard.

Penwarden, A.D. and Wise, A.F.E. (1975), Wind environment around buildings, Building Research Establishment Report, HMSO.

San Francisco Planning Department, (2015) San Francisco Planning Code Section 148.

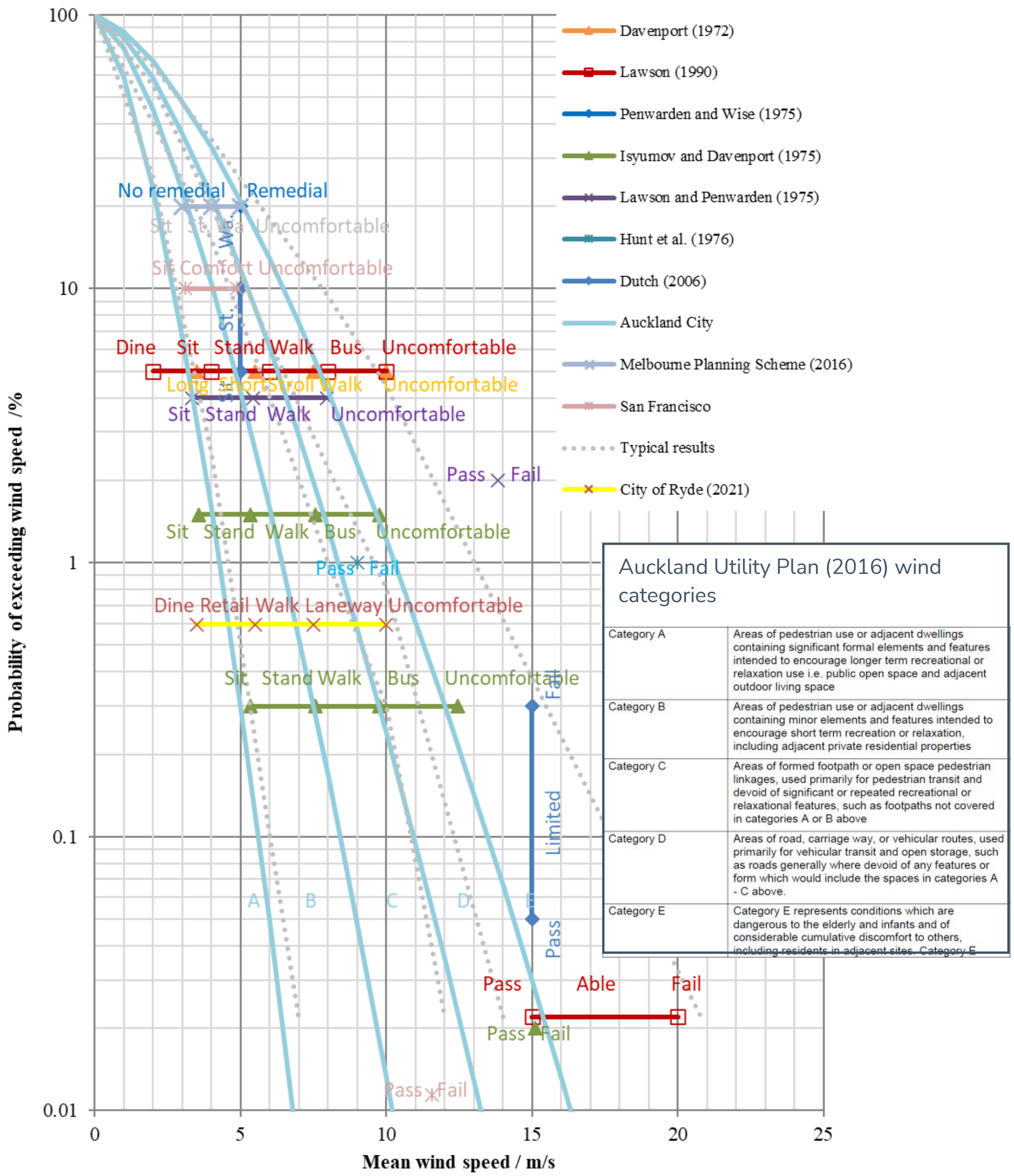

Figure 18: Probabilistic comparison between wind criteria based on mean wind speed

CPP WIND ENGINEERING CONSULTANTS

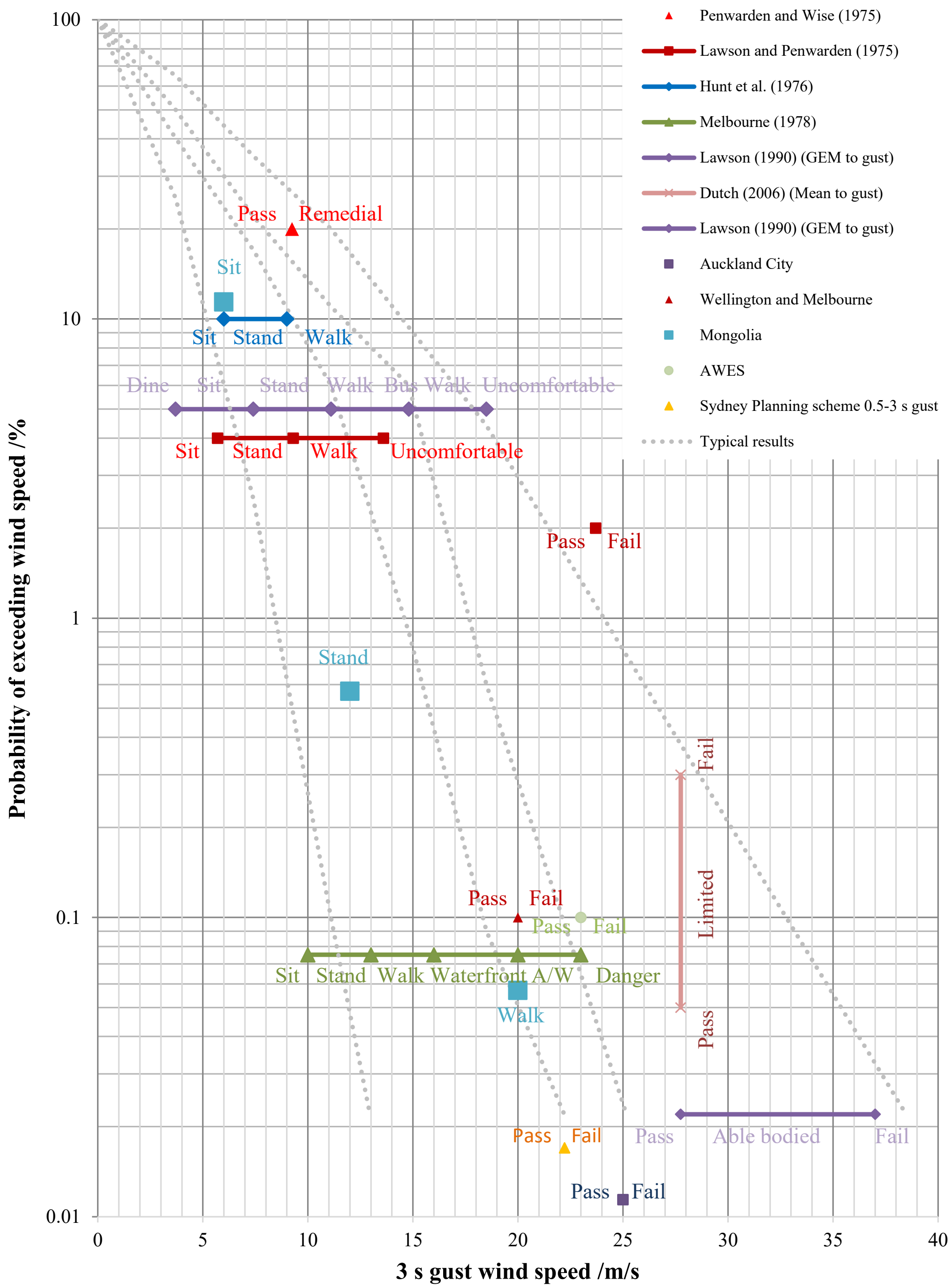

Figure 19: Probabilistic comparison between wind criteria based on 3 s gust wind speed