Sydney Metro City & Southwest:
Crows Nest
Over Station Development

Wind Impact Assessment Report

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Amendment Record

Changes made to this document since its last revision, which affect its scope or sense, are marked in the right margin by a vertical bar (|).

Date	Rev	Amendment Description	By
	P06	*Updates in response to SMA comments*	
	P05	*Revision In Progress*	
	P04	*Final Draft incorporating comments*	
	P03	*Revision In Progress*	

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Executive Summary

Cermak Peterka Petersen Pty. Ltd. has provided an opinion-based assessment of the wind conditions around the site of Sydney Metro – Crows Nest Station and within the indicative OSD. The wind advice provided herein includes for maximum development in the SEARS and is based on an assessment of the indicative OSD design submitted with the concept SSD Application.

The wind conditions at most locations around the proposed site following high-rise development would be expected to be similar to or marginally stronger than the existing wind conditions. Several locations are expected to experience higher wind speeds, namely along Clark Lane, Hume Street, and Pacific Highway. Overall, the wind conditions at most locations around the proposed development site are expected to be suitable for pedestrian standing/walking activities under the Lawson criterion. Several amelioration measures have been proposed to mitigate downwash flows from the buildings of the proposed development onto the ground level.

Wind conditions around most locations on the podium, and on the rooftops of buildings of the proposed development, are expected to be suitable for pedestrian walking activities from a Lawson comfort perspective. To maximise usage of the outdoor spaces within the proposed development, several amelioration measures have been proposed to divert flow over the space and to mitigate downwash flows from the buildings of the proposed development.

Wind tunnel testing is ultimately required during detailed design to verify the findings of this qualitative report. However, as the current designs are only indicative concepts and still in its early stages, wind tunnel testing should be delayed until the detailed SSD application stage. For the purposes of this concept SSD application, the initial qualitative assessment provided is considered sufficient for the indicative design concepts.

This report has been prepared to outline the wind impacts of the OSD and to specifically respond to and address the SEARs dated 26 September 2018.

1.0 Introduction

1.1 Purpose of this report

This report supports a concept State Significant Development application (concept SSD Application) submitted to the Department of Planning and Environment (DPE) pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The concept SSD Application is made under Section 4.22 of the EP&A Act.

Sydney Metro is seeking to secure concept approval for a mixed use development comprising four buildings above the Crows Nest Station, otherwise known as the over station development (OSD). The concept SSD Application seeks consent for building envelopes and land uses, maximum building heights, maximum gross floor areas, pedestrian and vehicular access, circulation arrangements and associated car parking and the strategies and design parameters for the future detailed design of the development.

Sydney Metro proposes to procure the construction of the OSD as part of an Integrated Station Development package, which would result in the combined delivery of the station, OSD and public domain improvements. The station and public domain elements form part of a separate planning approval for Critical State Significant Infrastructure (CSSI) approved by DPE on 9 January 2017.

As the development is within a rail corridor, is associated with railway infrastructure and is for commercial premises and residential accommodation with a Capital Investment Value of more than $30 million, the project is identified as State Significant Development (SSD) pursuant to Schedule 1, 19(2)(a) of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). The development is therefore, State significant development for the purposes of Section 4.36 of the EP&A Act.

This report has been prepared to specifically respond to the Secretary's Environmental Assessment Requirements (SEARs) issued for the concept SSD Application on 26 September 2018 which states that the Environmental Impact Statement (EIS) is to address the following requirements:

Table 1: SEARS issued on 26 September 2018

Reference	SEARs Requirement	Where Addressed in Report
8	Provide wind analysis (including wind tunnel modelling) outlining the impacts, in particular any impacts to existing and proposed public domain areas and open space. The wind impact assessment must identify the existing wind characteristics of the site and its locality, significant locations for wind sensitivity and mitigating measures.	Section 4.0: Environmental Wind Assessment
Plans & Documents	Wind Impact Assessment (including wind tunnel testing)	Section 5.0: Conclusion

1.2 Overview of the Sydney Metro in its context

Sydney Metro is Australia's biggest public transport project. A new standalone metro railway system, this 21st century network will deliver 31 metro stations and 66km of new metro rail for Australia's biggest city — revolutionising the way Sydney travels. Services start in the first half of 2019 on Australia's first fully-automated railway.

Sydney Metro was identified in *Sydney's Rail Future*, as an integral component of the *NSW Long Term Transport Master Plan*, a plan to transform and modernise Sydney's rail network so it can grow with the city's population and meet the future needs of customers. In early 2018, *the Future Transport Strategy 2056* was released as an update to *the NSW Long Term Transport Master Plan* and *Sydney's Rail Future*. Sydney Metro City & Southwest is identified as a committed initiative in the *Future Transport Strategy 2056*.

Sydney Metro is comprised of three projects, as illustrated in **Figure 1**:

- **Sydney Metro Northwest** — formerly the 36km North West Rail Link. This $8.3 billion project is now under construction and will open in the first half of 2019 with a metro train every four minutes in the peak.
- **Sydney Metro City & Southwest** — a new 30km metro line extending the new metro network from the end of Sydney Metro Northwest at Chatswood, under Sydney Harbour, through the CBD and south west to Bankstown. It is due to open in 2024 with an ultimate capacity to run a metro train every two minutes each way through the centre of Sydney.
- **Sydney Metro West** – a new underground railway connecting the Parramatta and Sydney central business districts. This once-in-a-century infrastructure investment will double the rail capacity of the Parramatta to Sydney CBD corridor and will establish future capacity for Sydney's fast growing west. Sydney Metro West will serve five key precincts at Westmead, Parramatta, Sydney Olympic Park, The Bays and the Sydney CBD. The project will also provide an interchange with the T1 Northern Line to allow faster connections for customers from the Central Coast and Sydney's north to Parramatta and the Sydney CBD.

Sydney's new metro, together with signalling and infrastructure upgrades across the existing Sydney suburban rail network, will increase the capacity of train services entering the Sydney CBD – from about 120 an hour currently to up to 200 services beyond 2024. That's an increase of up to 60 per cent capacity across the network to meet demand.

Sydney Metro City & Southwest includes the construction and operation of a new metro rail line from Chatswood, under Sydney Harbour through Sydney's CBD to Sydenham and on to Bankstown through the conversion of the existing line to metro standards.

The project also involves the delivery of six (6) new metro stations, including at Crows Nest, together with new underground platforms at Central. Once completed, Sydney Metro will have the ultimate capacity for a train every two minutes through the CBD in each direction - a level of service never seen before in Sydney.

Figure 1: Sydney Metro alignment map

On 9 January 2017, the Minister for Planning (the Minister) approved the Sydney Metro City & Southwest - Chatswood to Sydenham application lodged by TfNSW as a Critical State Significant Infrastructure project (reference SSI 15_7400), hereafter referred to as the CSSI Approval.

The CSSI Approval includes all physical work required to construct the CSSI, including the demolition of existing buildings and structures on each site. Importantly, the CSSI Approval also includes provision for the construction of below and above ground structures and other components of the future OSD (including building infrastructure and space for future lift cores, plant rooms, access, parking and building services, as relevant to each site). The rationale for this delivery approach, as identified within the CSSI application is to enable the OSD to be more efficiently built and appropriately integrated into the metro station structure.

The EIS for the Chatswood to Sydenham alignment of the City & Southwest project identified that the OSD would be subject to a separate assessment process.

Since the CSSI Approval was issued, Sydney Metro has lodged five modification applications to amend the CSSI Approval as outlined below:

- **Modification 1** - Victoria Cross and Artarmon Substation which involves the relocation of the Victoria Cross northern services building from 194-196A Miller Street to 50 McLaren Street together with the inclusion of a new station entrance at this location referred to as Victoria Cross North. The modification also involves the relocation of the substation at Artarmon from Butchers Lane to 98 – 104 Reserve Road. This modification application was approved on 18 October 2017.

- **Modification 2 -** Central Walk which involves additional works at Central Railway Station including construction of a new eastern concourse, a new eastern entry, and upgrades to suburban platforms. This modification application was approved on 21 December 2017.

- **Modification 3** - Martin Place Station which involves changes to the Sydney Metro Martin Place Station to align with the Unsolicited Proposal by Macquarie Group Limited (Macquarie) for the development of the station precinct. The proposed modification involves a larger reconfigured station layout, provision of a new unpaid concourse link and retention of the existing MLC pedestrian link and works to connect into the Sydney Metro Martin Place Station. It is noted that if the Macquarie proposal does not proceed, the original station design remains approved. This modification application was approved on 22 March 2018.

- **Modification 4** - Sydenham Station and Sydney Metro Trains Facility South which incorporated Sydenham Station and precinct works, the Sydney Metro Trains Facility South, works to Sydney Water’s Sydenham Pit and Drainage Pumping Station and ancillary infrastructure and track and signalling works into the approved project. This modification application was approved on 13 December 2017.

- **Modification 5** - Blues Point acoustic shed modification which involves the installation of a temporary acoustic shed at Blues Point construction site and retrieval of all parts of the tunnel boring machines driven from the Chatswood dive site and Barangaroo through the shaft at the Blues Point temporary site. This modification application was approved on 2 November 2018.

The CSSI Approval as modified allows for all works to deliver Sydney Metro between Chatswood and Sydenham Stations and also includes upgrade of Sydenham Station.

The remainder of the City & Southwest alignment (Sydenham to Bankstown) proposes the conversion of the existing heavy rail line from west of Sydenham Station to Bankstown to metro standards. This part of the project, referred to as the Sydenham to Bankstown upgrade, is the subject of a separate CSSI Application (Application No. SSI 17_8256) for which an EIS was exhibited between September and November 2017, and a Submissions and Preferred Infrastructure Report was exhibited in June and July 2018. This application is currently being assessed by DPE.

1.3 Planning relationship between Crows Nest Station and the OSD

While Crows Nest Station and the OSD will form an Integrated Station Development, the planning pathways defined under the *Environmental Planning & Assessment Act 1979* require separate approval for each component of the development. In this regard, the approved station works (CSSI Approval) are subject to the provisions of Part 5.1 of the EP&A Act (now referred to as Division 5.2) and the OSD component is subject to the provisions of Part 4 of the EP&A Act.

For clarity, the approved station works under the CSSI Approval included the construction of below and above ground structures necessary for delivering the station and also enabling construction of the integrated OSD. This includes but is not limited to:

- demolition of existing development
- excavation
- integrated station and OSD structure (including concourse and platforms)
- lobbies
- retail spaces within the station building
- public domain improvements
- pedestrian through-site link
- access arrangements including vertical transport such as escalators and lifts
- space provisioning and service elements necessary to enable the future development of the OSD, such as lift cores, plant rooms, access, parking, retail, utilities connections and building services.

The vertical extent of the approved station works above ground level is defined by the 'transfer level' level, above which would sit the OSD. This delineation is illustrated in **Figure 2**.

The CSSI Approval also establishes the general concept for the ground plane of Crows Nest Station including access strategies for commuters, pedestrians, workers, visitors and residents.

Since the issue of the CSSI Approval, Sydney Metro has undertaken sufficient design work to determine the space planning and general layout for the station and identification of those spaces within the station area that would be available for the OSD. In addition, design work has been undertaken to determine the technical requirements for the structural integration of the OSD with the station. This level of design work has informed the concept proposal for the Crows Nest OSD. It is noted that ongoing design development of the works to be delivered under the CSSI Approval would continue with a view to developing an Interchange Access Plan (IAP) and Station Design Precinct Plan (SDPP) for Crows Nest Station to satisfy Conditions E92 and E101 of the CSSI Approval.

All public domain improvement works around the site would be delivered as part of the CSSI Approval.

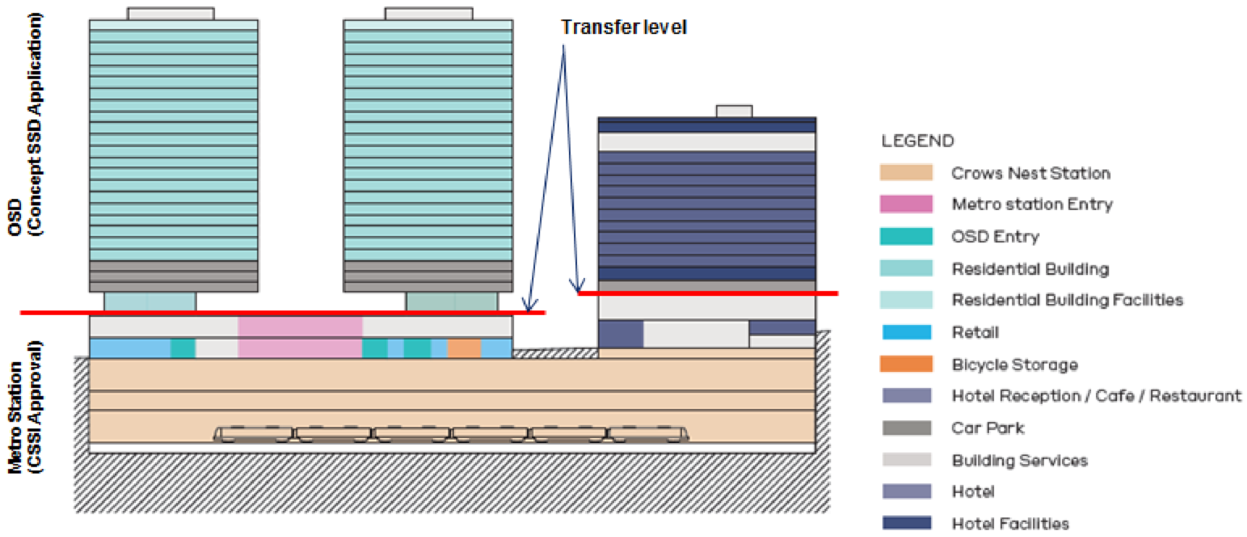

Figure 2: Delineation between the Metro station and OSD (based on indicative OSD design)

1.4 The strategic planning context

DPE is currently undertaking strategic planning investigations into revitalising the area surrounding St Leonards railway station and the metro station at Crows Nest. In August 2017, DPE released the *St Leonards and Crows Nest Station Precinct Interim Statement* and in October 2018 DPE released the *St Leonards and Crows Nest 2036 Draft Plan* (2036 Draft Plan) and supporting documents which detail recommended changes to land use controls in the precinct. These documents recommend new developments be centred around the Pacific Highway corridor and the Crows Nest Station while protecting the amenity of Willoughby Road.

In October 2018, DPE also placed on public exhibition the *Crows Nest Sydney Metro Site Rezoning Proposal* (Planning Proposal). The Planning Proposal outlines the State led rezoning of the subject site, on the basis that the current planning controls in the *North Sydney Local Environmental Plan 2013* do not reflect the opportunities for improved accessibility associated with the new metro station enabling people to live, work and spend time close to public transport. This concept SSD Application is aligned with the planning controls proposed in the Planning Proposal.

1.5 The site

Crows Nest Station precinct is located between the Pacific Highway and Clarke Street (eastern side of the Pacific Highway) and Oxley Street and south of Hume Street, Crows Nest (**Figure 3**).

The site is located within the North Sydney Local Government Area.

The Crows Nest Station precinct is divided into three separate sites as illustrated in **Figure 4** and described below:

- **Site A:** Six lots in the block bound by the Pacific Highway, Hume Street, Oxley Street and Clarke Lane (497-521 Pacific Highway, Crows Nest)
- **Site B:** Three lots on the southern corner of Hume Street and Pacific Highway (477-495 Pacific Highway, Crows Nest)
- **Site C:** One lot on the north-western corner of Hume Street and Clarke Street (14 Clarke Street, Crows Nest).

Sites A, B and C have a combined site area of 6,356 square metres.

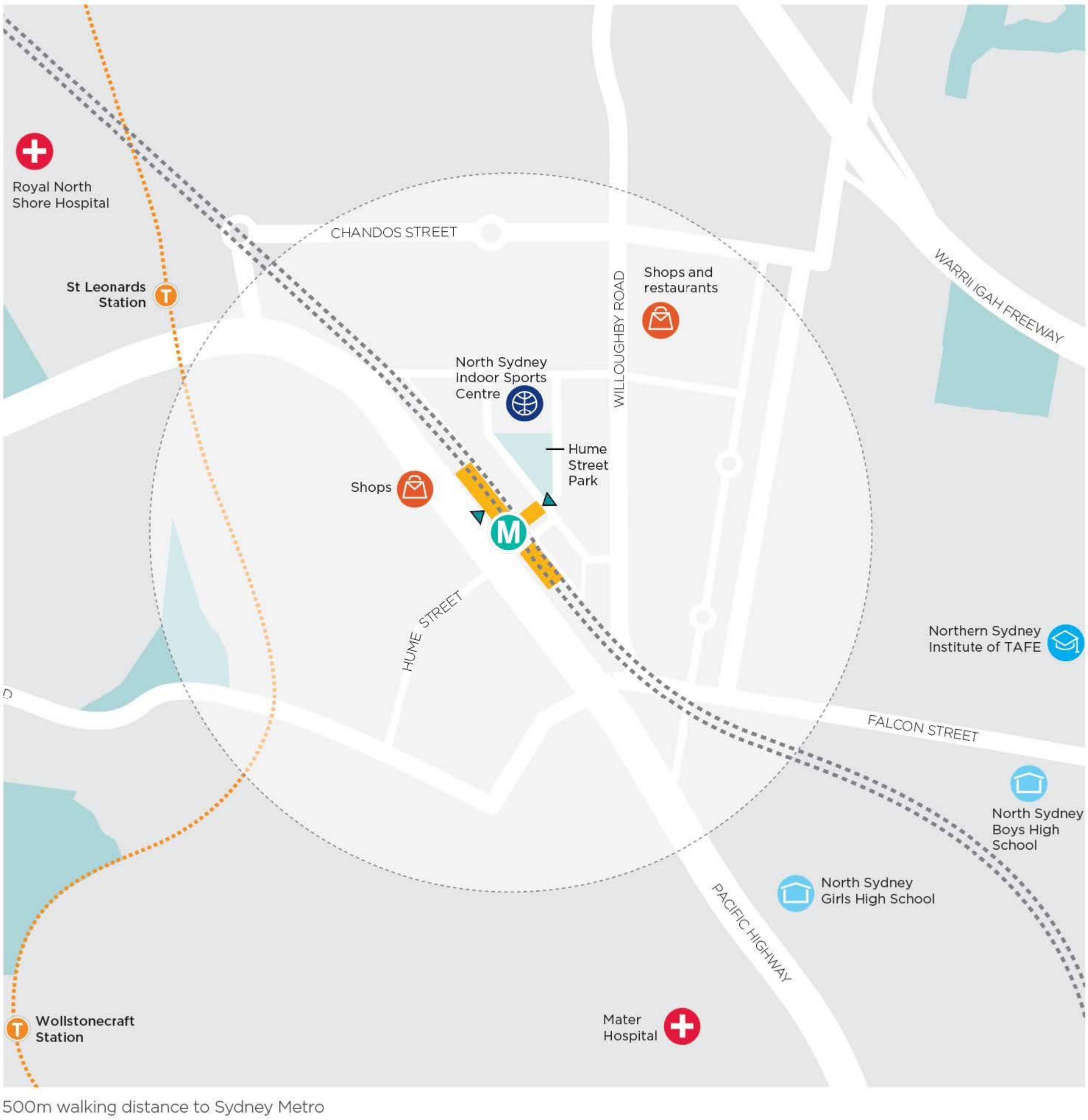

Figure 3: Crows Nest Station location plan

Figure 4: The subject site

The site comprises the following properties:

- **Site A:**
  - 497 Pacific Highway (Lot 2 in DP 575046)
  - 501 Pacific Highway (Lot 1 in DP 575046)
  - 503-505 Pacific Highway (Lot 3 in DP 655677)
  - 507-509 Pacific Highway (Lot 4 in DP 1096359)
  - 511-519 Pacific Highway (SP 71539)
  - 521-543 Pacific Highway (Lot A and Lot B in DP 374468)
- **Site B:**
  - 477 Pacific Highway (Lot 100 in DP 747672)
  - 479 Pacific Highway (Lot 101 in DP 747672)
  - 491-495 Pacific Highway (Lot 100 in DP 442804)
- **Site C:**
  - 14 Clarke Street (Lot 1 in SP 52547)

1.6 Overview of the proposed development

This concept SSD Application comprises the first stage in the Crows Nest OSD project. It will be followed by a detailed SSD Application for the design and construction of the OSD to be lodged by the successful contractor who is awarded the contract to deliver the Integrated Station Development.

This concept SSD Application seeks approval for the planning and development framework and strategies to inform the future detailed design of the Crows Nest OSD.

The concept SSD Application specifically seeks approval for the following:

- maximum building envelopes for Sites A, B and C, including street wall heights and setbacks as illustrated in the plans prepared by Foster + Partners for Sydney Metro
- maximum building heights:
  - **Site A:** RL 183 metres or equivalent of 27 storeys (includes two station levels and conceptual OSD space in the podium approved under the CSSI Approval)
  - **Site B:** RL 155 metres or equivalent of 17 storeys (includes two station levels and conceptual OSD space approved under the CSSI Approval)
  - **Site C:** RL 127 metres or 8 storeys (includes two station levels and conceptual OSD space approved under the CSSI Approval)

    Note 1: the maximum building heights defined above are measured to the top of the roof slab and exclude building parapets which will be resolved as part of future detailed SSD Application(s)
  - maximum height for a building services zone on top of each building to accommodate lift overruns, rooftop plant and services:
    - **Site A:** RL 188 or 5 metres
    - **Site B:** RL 158 or 3 metres
    - **Site C**: RL 132 or 5 metres

    Note 1: the use of the space within the building services zone is restricted to non-habitable floor space.

    Note 2: for the purposes of the concept SSD Application, the maximum height of the building envelope does not make provision for the following items, which will be resolved as part of the future detailed SSD Application(s):
    - communication devices, antennae, satellite dishes, masts, flagpoles, chimneys, flues and the like, which are excluded from the calculation of building height pursuant to the standard definition in NSLEP 2013
    - architectural roof features, which are subject to compliance with the provisions in Clause 5.6 of NSLEP 2013, and may exceed the maximum building height, subject to development consent.
- maximum gross floor area (GFA) of 55,400sqm for the OSD comprising the following based on the proposed land uses:
  - **Site A:** Residential accommodation - maximum 37,500 square metres (approximately 350 apartments)
  - **Site B:** Hotel / tourist accommodation and associated conference facilities or commercial office premises GFA - maximum of 15,200 square metres (approximately 250 hotel rooms)
  - **Site C:** Commercial office premises GFA - maximum of 2,700 square metres
  - **Site A or C**: social infrastructure GFA inclusive of the GFA figures nominated above for each site, with provision optional as follows:
    - Site A: podium rooftop (approximately 2,700 square metres)

- Site C: three floors and rooftop (approximately 1,400 square metres)

Note 1: GFA figures exclude GFA attributed to the station and station retail space approved under the CSSI Approval

- a minimum non-residential floor space ratio (FSR) for the OSD across combined Sites A, B and C of 2.81:1 or the equivalent of 17,900 square metres
- the use of approximate conceptual areas associated with the OSD which have been provisioned for in the Crows Nest station box (CSSI Approval) including areas above ground level (i.e. OSD lobbies and associated spaces)
- a maximum of 150 car parking spaces on Sites A and B associated with the proposed commercial, hotel and residential uses
- loading, vehicular and pedestrian access arrangements
- strategies for utilities and services provision
- strategies for managing stormwater and drainage
- a strategy for the achievement of ecological sustainable development
- a public art strategy
- indicative signage zones
- a design excellence framework
- the future subdivision of parts of the OSD footprint, if required.

As this is a staged development pursuant to section 4.22 of the EP&A Act, future approval would be sought for the detailed design and construction of the OSD.

The proposed location of the buildings on the site is illustrated in the location plan provided at **Figure 5**.

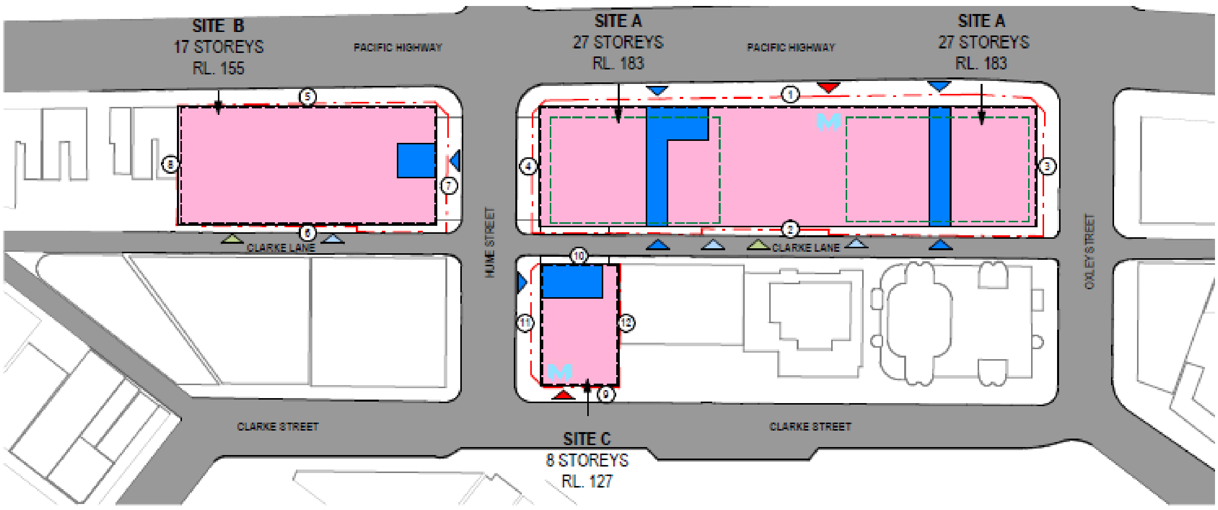

Figure 5 – Proposed location of buildings on the

The total GFA for the integrated station development, including the station GFA (i.e. retail, station circulation and associated facilities) and the OSD GFA is 60,400 square metres, equivalent to a floor space ratio (FSR) of 9.5:1.

The concept proposal includes opportunities for community uses in the development on either Site A or Site C. This space has the potential to be used for a range of uses including community facilities, child care centre, recreational area/s, library, co-working space, which can take advantage of the sites accessibility above the metro station.

Through design development post the CSSI Approval, pedestrian access to the metro station is proposed from the Pacific Highway and from Clarke Street, opposite the Hume Street Park. Vehicular access to the site including separate access to the loading docks and parking is proposed from Clarke Lane.

Public domain works around the site would be delivered as part of the CSSI Approval. Notwithstanding, the OSD will be appropriately designed to complement the station and activate the public domain. Provision for retail tenancies to activate the public domain are included in the ground floor of Sites A, B and C, as part of the CSSI Approval. Future detailed development applications will seek approval for the fitout and specific use of this retail space.

Drawings illustrating the proposed building envelopes are provided in Figures 6A and 6B. The concept SSD Application includes an indicative design for the OSD to demonstrate one potential design solution within the proposed building envelope (refer to Figure 7).

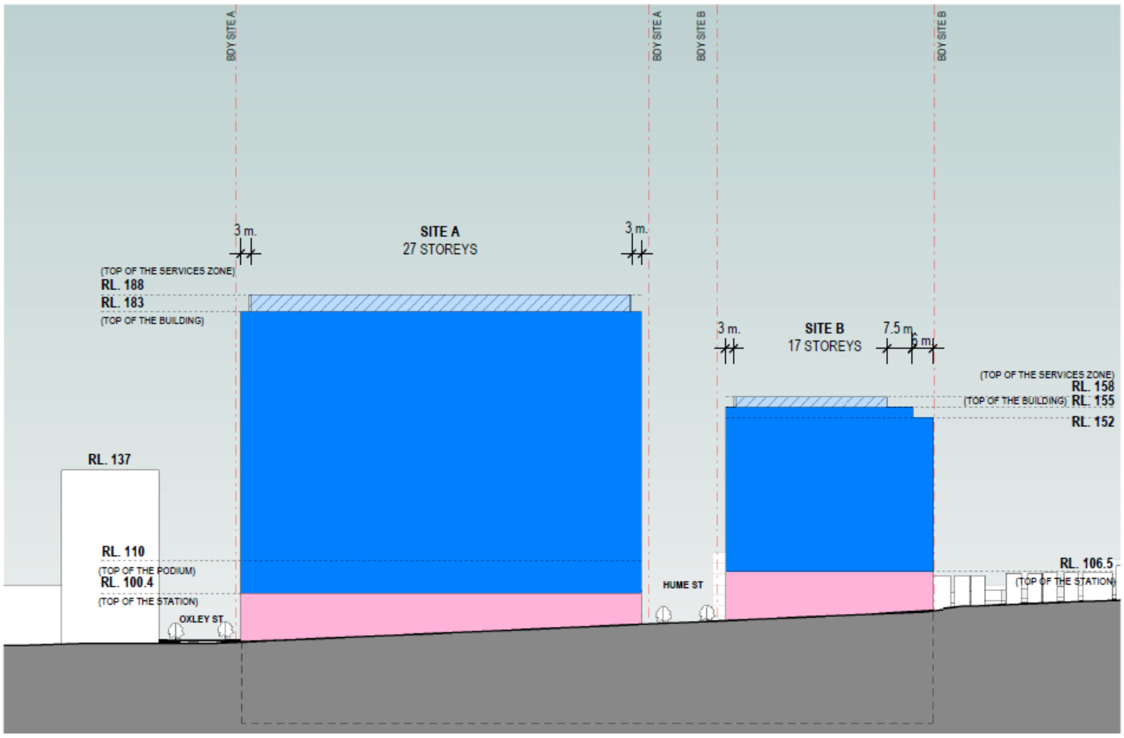

Figure 6A: Proposed Crows Nest OSD building envelopes – west elevation (Pacific Highway)

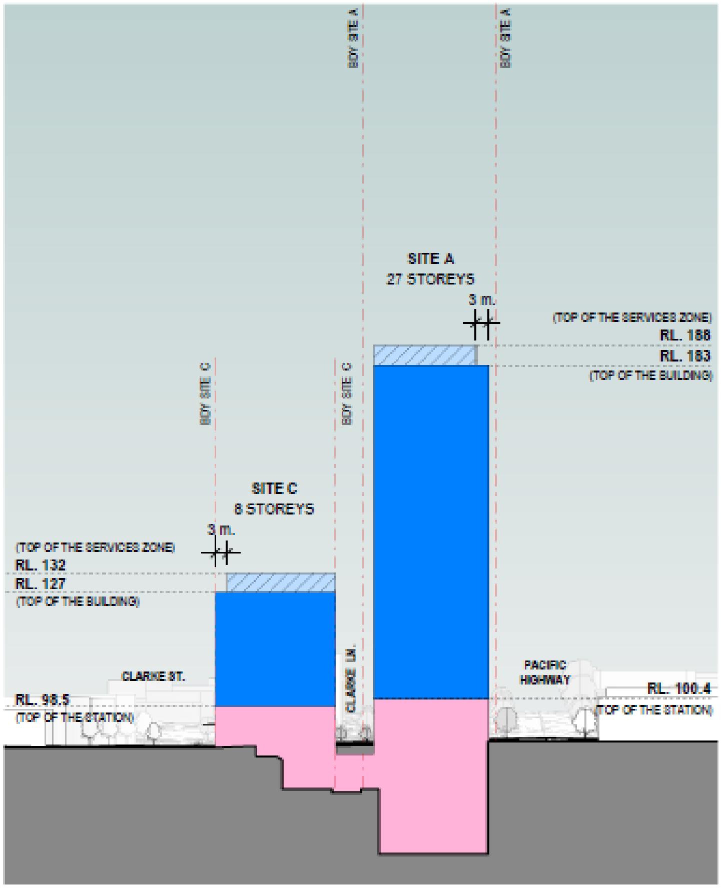

Figure 6B: Proposed Crows Nest OSD building envelopes – cross section through the site (east-west)

Figure 7: Crows Nest OSD indicative design

2.0 Sydney Wind Climate

To enable a qualitative assessment of the wind environment, the wind frequency and direction information measured by the Bureau of Meteorology at a standard height of 10 metres at Sydney Airport from 1995 to 2017 have been used in this analysis, **Figure 8**. The anemometer is located about 5 km to the south-west of the site and is considered representative of the wind conditions at the site. It is noted from **Figure 8** that strong prevailing winds are organised into three main groups which centre at about north-east, south, and west. This wind assessment is focused on these prevailing strong wind directions.

Strong summer winds occur mainly from the south quadrant and the north-east. Winds from the south are associated with large synoptic frontal systems and generally provide the strongest gusts during summer. Moderate intensity winds from the north-east tend to bring cooling relief on hot summer afternoons typically lasting from noon to dusk. These are small-scale temperature driven effects; the larger the temperature differential between land and sea, the stronger the breeze.

Winter and early spring winds typically occur from the south and west quadrants. West quadrant winds provide the strongest winds affecting the area throughout the year and are large scale synoptic events that can be hot or cold depending on inland conditions.

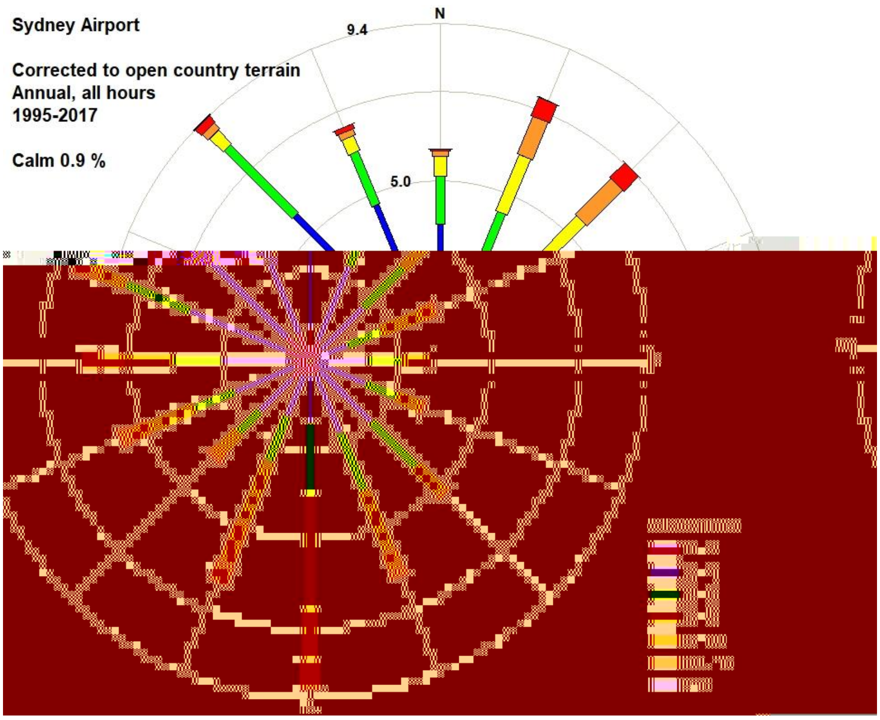

Figure 8: Wind rose showing probability of time of wind direction and speed for Sydney Airport

3.0 Environmental Wind Speed 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. Over the years, a number of researchers have added to the knowledge of wind effects on pedestrians by suggesting criteria for comfort and safety. Because pedestrians will tolerate higher wind speeds for a smaller period of time than for lower wind speeds, these criteria provide a means of evaluating the overall acceptability of a pedestrian location. A location can further be evaluated for its intended use, such as for an outdoor café or footpath.

North Sydney Development Control Plan 2013 (DCP) stipulates a minimisation of wind impact for new developments over 33 metres in height, and specifies wind effects not to exceed 13 metres per second (m/s), and 10 m/s along footpaths and accessible outdoor spaces. It is not clear whether this is a mean or gust wind speed nor the required frequency of occurrence throughout the year. It is expected that this metric is derived from the work of Melbourne (1978), which specifies that this is a maximum 3 second gust wind speed in an hour, occurring for 0.1% of the year from each direction. A location meeting this requirement would be suitable for pedestrian standing activities such as window shopping. The DCP wind speed is interpreted as a comfort rather than a safety criterion.

From **Figure 8**, the 0.1% mean wind speed measured at 10 m above ground for all directions is about 16.5 m/s. Converting this to a mean and gust wind event at pedestrian level in a built-up environment in accordance with Standards Australia (2011) would result in mean and gust wind speeds of 10.5 and 20.5 m/s respectively, which is evidently greater than the 13 m/s in the DCP. There are few locations in Sydney that would meet this criterion without some shielding to improve the wind conditions.

The work of Melbourne (1978), uses the infrequent (0.1%) gust wind event as basis of classification, which may not adequately characterise the general wind conditions at the site. To address this limitation, the current study is based upon the criteria of Lawson (1990), which are described in Table 2 below for both pedestrian comfort and distress. The limiting criteria are defined for both a mean and gust equivalent mean (GEM) wind speed. The criteria based on the mean wind speeds define when the steady component of the wind causes discomfort, whereas the GEM wind speeds define when the wind gusts cause discomfort.

Assessment using the Lawson criteria (Table 2) generally provides a classification of pedestrian walking at a similar wind speed to the DCP, however it also provides information regarding the serviceability of the wind climate.

Table 2: Pedestrian comfort criteria for various activities.

Comfort (maximum of mean or gust equivalent mean (GEM†.) wind speed exceeded 5% of the time)	
< 4 m/s	Pedestrian Sitting (considered to be of long duration)
4 - 6 m/s	Pedestrian Standing (or sitting for a short time or exposure)
6 - 8 m/s	Pedestrian Walking
8 - 10 m/s	Business Walking (objective walking from A to B or for cycling)
> 10 m/s	Uncomfortable
Distress (maximum of mean or GEM wind speed exceeded 0.022% of the time)	
<15 m/s	not to be exceeded more than two times per year (or one time per season) for general access
<20 m/s	not to be exceeded more than two times per year (or one time per season) where only able bodied people would be expected; frail or cyclists would not be expected

The wind speed is either a mean wind speed or a gust equivalent mean (GEM) wind speed. The GEM wind speed is equal to the 3 s gust wind speed divided by 1.85.

Source: Lawson, T.V., (1990)

4.0 Environmental Wind Assessment

Assessment of wind conditions throughout the public domain surrounding the site requires assessment of ambient wind statistics and how prevailing winds will interact with the building massing. Wind interaction with the built environment producing higher velocities at pedestrian level can be grouped into basic flow mechanisms commonly encountered. Some key flow mechanisms relevant to this development are explained in **Appendix A**.

Once the expected wind intensities throughout the site are determined, it is necessary to assess conditions against independently derived criterion. Wind tunnel testing will be ultimately required to quantify wind conditions at the site against these established criteria. However, as the current designs are indicative concepts and still in its early stages, wind tunnel testing is best conducted during the detailed SSD application stage. For the purposes of this concept SSD application, an initial qualitative assessment to estimate the level of wind intensity at different locations throughout the site based upon professional experience has been provided, and is considered sufficient for the indicative design concepts. The wind advice provided herein is based on an assessment of the building envelopes and the indicative OSD design illustrated in **Figure 6** and **Figure 7** above. Opinion based wind mitigation is suggested in this report with reference to **Appendix B**.

Four rectangular buildings are proposed in the concept proposal, which is separated into three sites: A, B, and C. Site A comprises 2 residential high-rise buildings atop a 12 metre podium, with both buildings rising approximately 95 metres above ground level, **Figure 10**. Site B comprises a single medium-rise hotel and rises approximately 65 metres above ground level. Site C consists of a single low-rise commercial building and rises approximately 40 metres above ground level. The ground-level domain of the development includes several station entrances, as well as potentially several outdoor café-style seating areas.

The analysis will firstly be conducted assuming no over station development, followed by a discussion of the effect of including the over station development.

4.1 Prior to high-rise building massing

The existing site is surrounded by primarily low- to medium-rise buildings, with several high-rise buildings scattered to the north in St Leonards, both existing and under construction. From a wind perspective, topography surrounding the site is relatively flat to the north-east, with a decline to the south-west. As a result, winds from the south-west quadrant will experience an acceleration up the incline. With reference to the Sydney Wind Climate, coastal summer winds from the north-east quadrant will pass through upstream zones of predominantly low-rise buildings, and are relatively unimpeded upon reaching the development site which is located on a high point on the ridgeline. Notwithstanding, the intensity of these coastal winds will have decreased upon reaching Crows Nest approximately 10 km inland.

Winds from the south and west quadrants will pass over predominantly low- and medium-rise buildings, with a small acceleration in the flow being generated by the rising topography. Given the exposure of the site to winds from the south-west quadrant; it is expected that the building massing will direct high level winds toward ground level in the form of downwash (**Appendix A**).

Results of previous CPP wind tunnel testing of numerous locations to the north-west of the site along Pacific Highway in St Leonards demonstrated that most outdoor public domain areas along Pacific Highway were suitable for pedestrian sitting/standing activities from a Lawson comfort perspective. Given the close proximity of the previously tested locations to the proposed development site, similar wind conditions are expected to exist around the Crows Nest Station development prior to any development still in the existing configuration.

4.2 Inclusion of high-rise building massing

The inclusion of medium-rise and high-rise buildings along Pacific Highway (**Figure 9**) will lead to increased volumes of downwash and channelling flows that can lead to undesirable ground-level wind conditions. The three buildings illustrated in the indicative OSD design on Site A and B are relatively exposed to the prevailing winds from the north-east, south, and west quadrants, and these winds will reach the site relatively unimpeded. Site C is partially shielded by Site A and B, as well as the surrounding developments, from several wind directions. The indicative rectangular plan form envelope of the high-rise buildings is expected to generate downwash for winds striking the buildings orthogonal to the façade, increasing the amount of flow reaching the ground plane. **Figure 9** illustrates the various quadrants of the wind directions.

Figure 9: Quadrants of the wind directions.

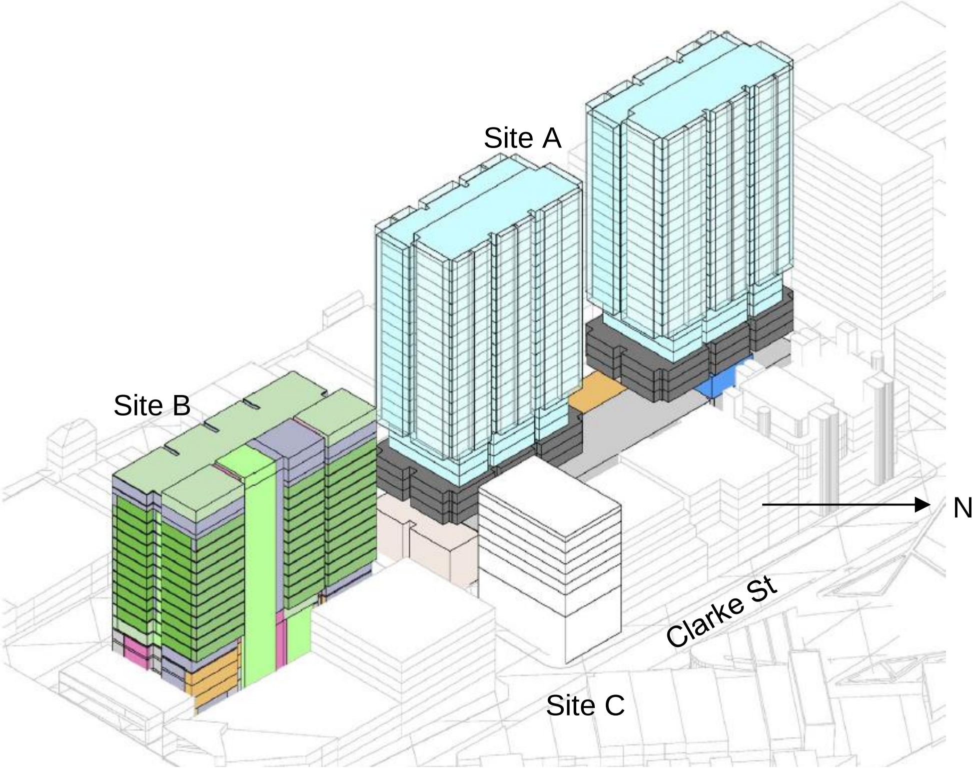

Figure 10: Indicative OSD design showing Sites A, B, and C viewed from the east

Winds from the north-east

Winds from the north-east quadrant will impact the north-east façades of all four buildings. Downwash from the north-east façade of Site C will impact Clark Street, before accelerating around the east corner of the building and discharging along Hume St. However, the amount and strength of the downwash will be limited given the relatively small mass and height of this building. As calm conditions around Site C are required given it provides a secondary entry to the station, it is recommended that a ground-level awning be installed along the north-east façade and extending around both corners of the Site C building.

Downwash from the north-east façade of the buildings on Site A and Site B will impact Clark Lane, which will channel along the narrow alleyway, with some of the downwash from the Site A buildings impacting the Site A podium (See *Wind conditions within the proposed development*). The laneway is likely to be acceptable for pedestrian walking activities (e.g. for station access) but likely too windy for longer term stationary type activities. A portion of this downwash will also likely accelerate around the corner of the east building of Site A, promoting channelling flow along Hume Street, and creating strong wind conditions along these corridors, **Figure 11**. It is recommended that the setback of the Site A buildings from the north-east podium edge be increased to deflect a portion of this downwash away from the ground plane. Alternatively, extending the ground-level awnings around the eastern corner of Site A as far outward as possible, combined with ground-level awnings around the northern corner of Site B, would assist in reducing wind speeds at the station entry. If locations along Hume Street are to be activated for outdoor café-style seating, then amelioration in the form of natural planting or local vertical screening can be implemented to create local areas of calm.

For winds from the north-east quadrant without any mitigation measures, conditions along Pacific Highway and Hume Street Park are expected to remain similar to the existing wind conditions. In contrast, Clark Lane and Hume Street are expected to experience stronger wind conditions, particularly around the eastern corner of Site A and the northern corner of Site B.

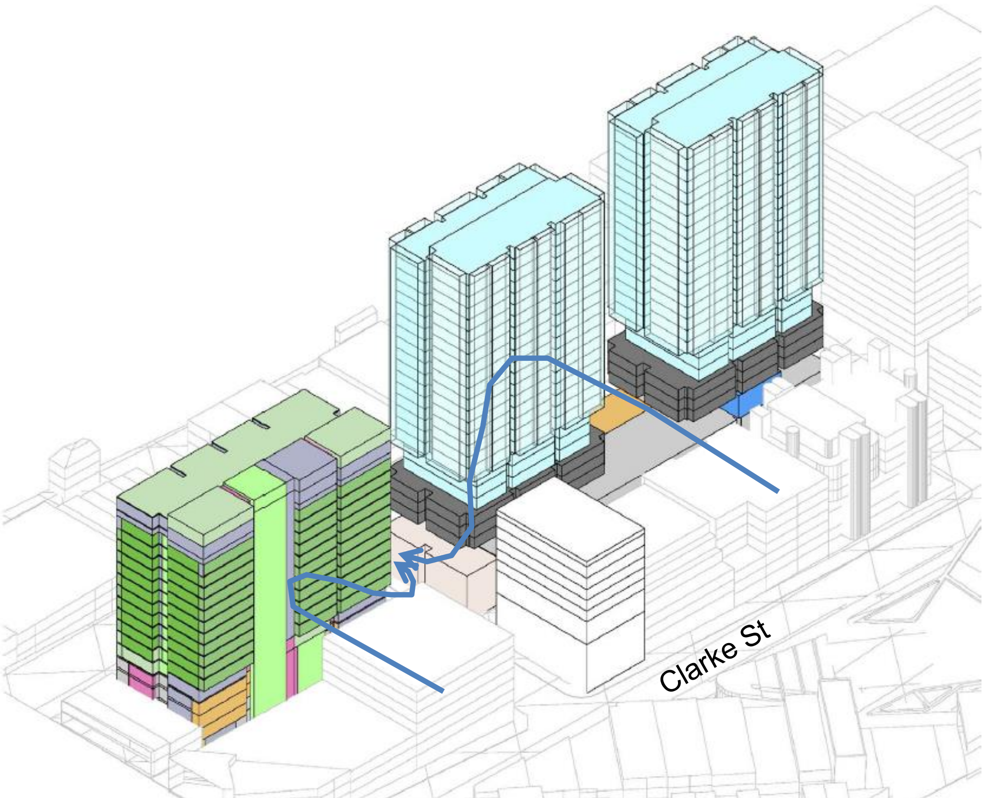

Figure 11: Winds from the north-east channelling down Hume Street, viewed from the east.

Winds from the south

The orientation of the buildings oblique to winds from the south will encourage winds from the south to flow horizontally around the buildings of Site A and B. Winds from the south-east will downwash off the south-east façades of the Site B building. Downwash from the south-east façade of the Site B building will impact the rooftop of the adjacent development to the south-east, with some flow also being discharged along Pacific Highway. It would be expected that the Site A buildings will receive some shielding from winds from the south-east from Site B. However, high level flow reaching the south-east façade of the southern building on Site A would direct some flow to ground level in the form of downwash, slightly impacting wind conditions along Hume Street and Pacific Highway. Increasing the building setback from the south-east podium edge, or including awnings along the south-east and south-west aspects at ground level, would be expected to improve wind conditions along Hume Street and Pacific Highway. Site C is relatively shielded from winds from the south quadrant by the Site A and B buildings.

For winds from the south quadrant without any mitigation measures, conditions around the proposed development site are expected to be similar to the existing wind conditions.

Winds from the west

The alignment of the buildings will encourage winds from the west to flow around the buildings of Site A and B. Winds from the south-west (**Figure 12**) will downwash off the south-west façade of the buildings on Site A and B. The presence of a ground-level awning along the south-west and south-east boundary of Site A would assist in deflecting most of this downwash away from the ground plane. As a result, the Site A station and OSD entrances are expected to be relatively calm. Downwash from the south-west façade of the Site B building will impact the ground plane, creating gusty wind conditions along Pacific Highway. Inclusion of a ground-level awning along the south-west and north-west aspects of the Site B building would be beneficial in reducing the impact of downwash flow on the Site B entrances, and would minimise the effect of downwash accelerating around the west corner of the building onto Hume Street. If locations along Pacific Highway are to be activated for outdoor café-style seating, then the ground-level awnings along Pacific Highway should be extended out as far outward as possible. Amelioration in the form of natural planting or local vertical screening can also be implemented along Pacific Highway to create local areas of calm. Site C is relatively shielded from winds from the west quadrant by the buildings on Site A.

For winds from the west without any mitigation measures, conditions at locations around the proposed development site are likely to be similar to the existing wind conditions, with higher wind speeds expected along the Site B portion of Pacific Highway.

Figure 12: Downwash caused by winds from the south-west impacting Site B, viewed from the west.

Summary of ground-level wind conditions around the proposed development without any amelioration measures

Wind conditions on the ground plane are expected to be dominated by winds from the north-east, south, and west quadrants. For winds from the north-east quadrant, conditions along Pacific Highway and Hume Street Park are expected to remain similar to the existing wind conditions. In contrast, Clark Lane, Hume Street, and Pacific Highway are expected to experience stronger wind conditions, particularly around the eastern and southern corner of Site A and the northern corner of Site B. For winds from the south quadrant, conditions around the proposed development site are expected to be similar to the existing wind conditions. For winds from the west, conditions at locations around the proposed development site are likely to be similar to the existing wind conditions, with higher wind speeds expected along the Site B portion of Pacific Highway. Ground-level areas that are likely to experience stronger wind speeds are shown in **Figure 13**.

Wind conditions along Clark Lane are expected to be suitable given their intended use of space. Strong wind conditions are expected along Hume Street, and the presence of ground-level awnings along the north-west boundary of Site B will assist in deflecting downwash away from the ground-plane (**Figure 14)**. The ground-level awning along the south-east boundary of Site A should also extend outward as far as possible. If outdoor café-style seating is to be activated along Pacific Highway and/or Hume Street, then amelioration in the form of natural planting or local vertical screening can also be implemented on windier days to create local areas of calm.

Overall, wind conditions at the Pacific Highway station entry and along Pacific Highway are expected to be suitable for pedestrian standing or walking activities from a Lawson comfort perspective. Wind conditions along Clark Lane, at the Hume Street station entry, and along Hume Street, are also expected to be classified as suitable for pedestrian walking activities, although these locations are expected to be near the upper limit of the pedestrian walking criterion (8 m/s).

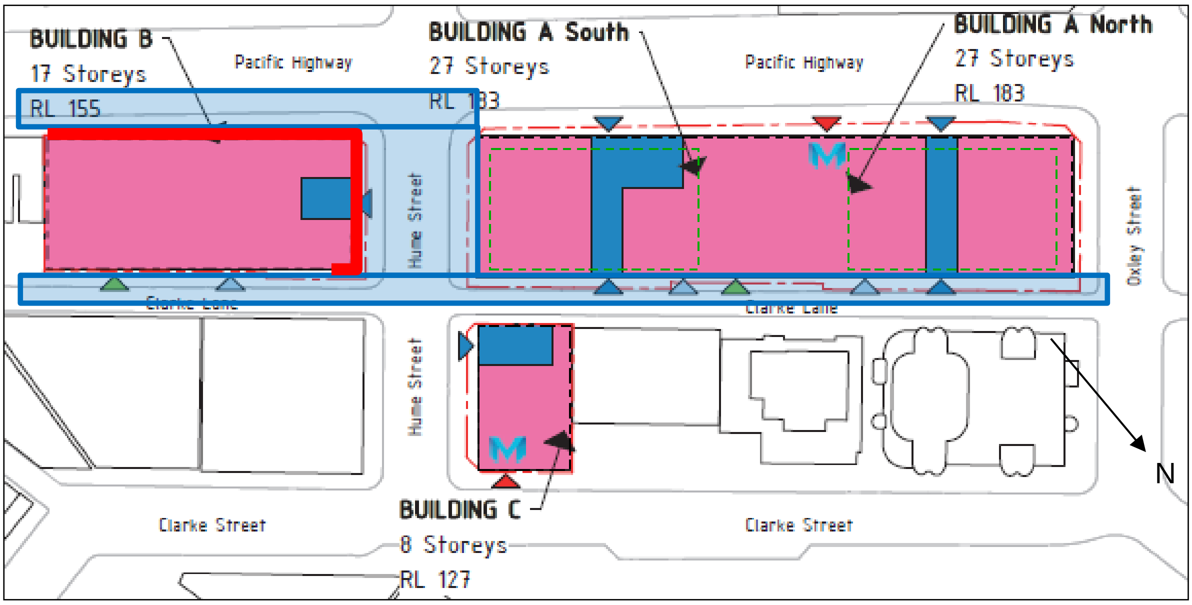

Figure 13: Proposed ground-level awning placements (red) with highlighted areas (blue) where higher wind speeds are expected.

Wind conditions within the proposed development

Some locations within the development may experience higher wind velocities at times, which may necessitate local amelioration depending on how these areas are to be used and based on the final building designs.

The Site A podium community roof may experience channelling flows from winds from the north-east and south-west, as well as downwash from the north-east and south-west building façades, **Figure 14**. The presence of significant planting, combined with full-height balustrades, would be expected to reduce wind speeds and divert the flow over this space rather than disperse within it. The inclusion of an overhead canopy to deflect downwash flows away from the podium will also be beneficial from a wind perspective, and will assist in significantly reducing wind speeds on the podium if outdoor café-style activities are desired.

Without any amelioration, the wind conditions around most locations on the podium are expected to be suitable for pedestrian walking activities from a Lawson comfort perspective.

The south-east boundary of the podium rooftop may experience stronger wind conditions due to downwash from the south-west and north-east façades accelerating into this undercut space, **Figure 14**. To reduce wind speeds in this area, it is recommended to install an awning above podium level that borders the entirety of this space. Further consideration should be given to wind mitigations measures relevant to the final use of the roof top of the podium of Building A at the detailed design stage. **Figure 15** illustrates one potential solution should the podium rooftop be used for a community use.

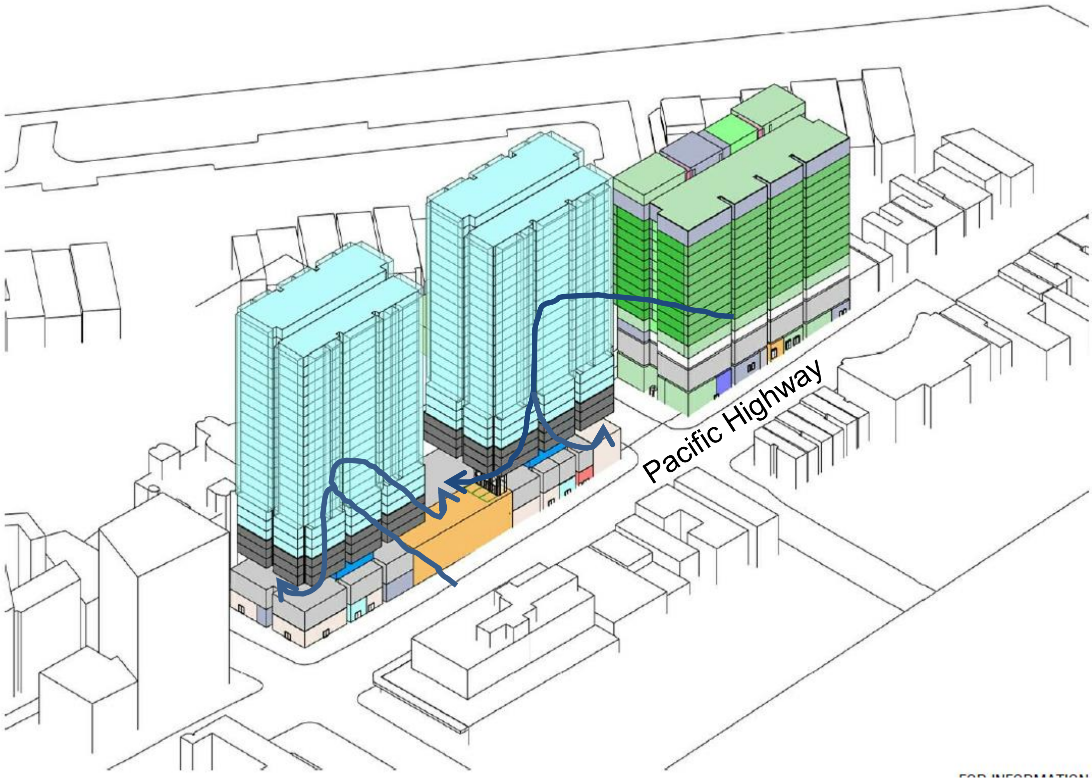

Figure 14: Downwash from the north-east façade flowing onto the podium and accelerating into the undercut space of the Site A podium, viewed from the west.

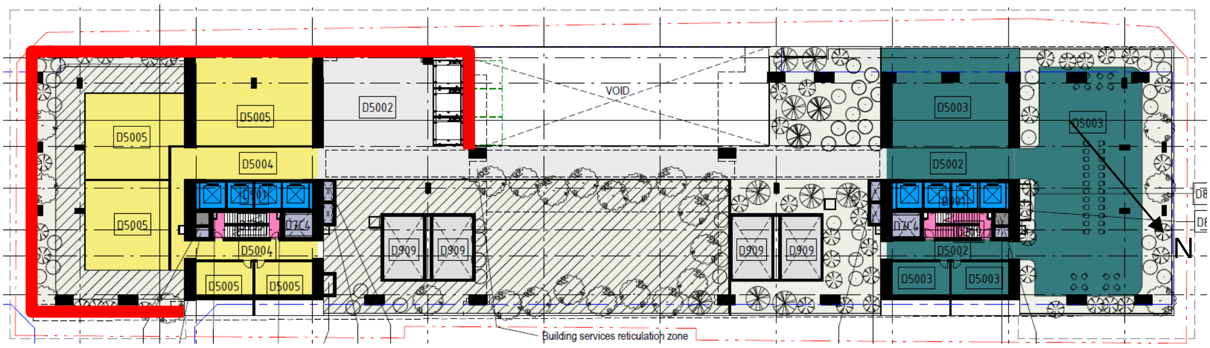

Figure 15: Indicative Site A podium community roof plan with proposed awning (red) around the south-east boundary.

The rooftops of the buildings on Site A and B in the indicative OSD design include several amenities, and are relatively exposed to winds from the south and west quadrants. The inclusion of full-height balustrades/screens around each rooftop boundary would assist in reducing wind speeds within these spaces. The rooftop of Site C is primarily exposed to winds from the north-east, and should therefore include full-height balustrades/screens along its north-east boundary. The effectiveness of such measures can be explored during detailed design.

Private balconies may potentially be located within the development particularly on Site A. Wind conditions within the balconies are expected to be mostly calm provided they are recessed within the façade. Balconies located on building corners or protruding from the façade are typically more exposed and can experience strong cross flows. For exposed corner balconies it would be recommended to include vertical fins and/or screens on one aspect, to allow calm areas to exist for a larger portion of time. Over time residents tend to learn to determine the usability of their balconies based on the seasonal weather conditions.

The station entrances may experience some pressure driven flow. This flow is a common attribute for many developments that have an open entrance leading to underground stations. Mitigation of preventing pressure driven flow into underground spaces can be achieved by sealing off station entrances.

Pressure differentials across the building envelope also have the potential to drive internal flows (**Appendix B**). More generally, the introduction of revolving doors at the OSD entrances to each building would also be beneficial in preventing pressure-driven wind flows into the lobby and associated areas. Alternatively, the mitigation of pressure-driven flow can be achieved by having sets of double sliding doors separated by several meters one after the other to create an airlock. Furthermore, sealing the building lobbies will assist in mitigating any potential stack effect flows through building lift cores associated with thermal stratification effects. The need for such building seals can be determined through wind tunnel testing of scale models during detailed design.

Further wind mitigation can be obtained using landscaping and screening elements, and these are best developed as a second-tier strategy behind the recommendations above.

5.0 Conclusion

This report presents the results of a qualitative wind assessment of the OSD above Crows Nest Station. The wind advice provided herein is based on an assessment of the indicative OSD design submitted with the concept SSD Application.

The wind conditions at most locations around the site based on the concept proposal would be expected to be similar to or marginally stronger than the existing wind conditions. Several locations are expected to experience higher wind speeds, namely along Clark Lane and at ground level around Site B. Overall, the wind conditions at most locations around the proposed development site are expected to be suitable for pedestrian standing/walking activities under the Lawson criterion. Several amelioration measures have been proposed to mitigate downwash flows onto the ground level as well as areas within the development.

Wind tunnel testing is ultimately required during detailed design to verify the findings of this qualitative report. However, as the current designs are only indicative concepts and still in its early stages, wind tunnel testing should be delayed until the detailed SSD application stage. For the purposes of this concept SSD application, the initial qualitative assessment provided is considered sufficient for the indicative design concepts.

A computational wind engineering assessment can quantify the comfort conditions around the proposed development site, and as a result, is often considered beneficial as a lead-up to the wind tunnel test as it can identify and address potential areas of concern around the proposed development. The results can then be used to aid the detailed design process.

This report has been prepared to outline the wind impacts of the OSD and to specifically address the SEARs issued for the concept SSD Application by DPE on 26 September 2018.

6.0 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.

Melbourne, W.H., (1978), Criteria for environmental wind conditions, J. Industrial Aerodynamics, 3, 241-249.

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Appendix A

Wind Flow Mechanisms

When the wind hits a large isolated building, the wind is accelerated down and around the windward corners, **Figure 16**; this flow mechanism is called downwash and causes the windiest conditions at ground level on the windward and sides of the building. Downwash will occur on buildings of all heights, but the vertical component is dictated by the height to width ratio of the building. In **Figure 16**, 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.

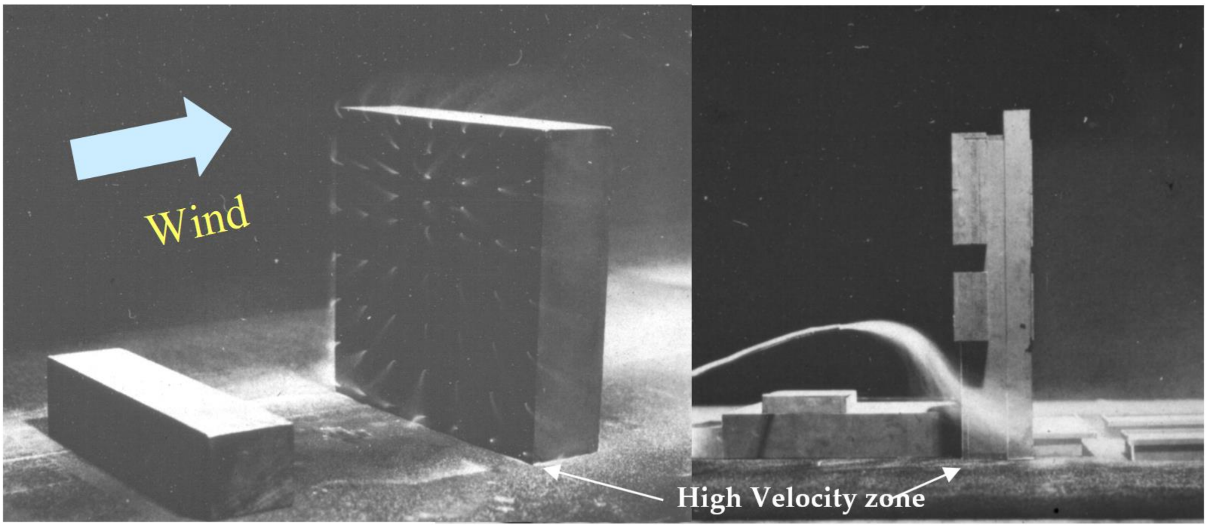


Figure 16: Flow visualisation around a tall building

Techniques to mitigate the effects of downwash winds on pedestrians include the provision of horizontal elements, the most effective being a podium to divert the flow away from pavements and building entrances. Awnings along street frontages perform a similar function. The deeper the horizontal element generally the more effective it will be in diverting the flow.

Channelling occurs when the wind is accelerated between two buildings or along straight streets with buildings on either side. For long buildings relative to their height the flow around the corners will generally be horizontal.

Appendix B

Wind Mitigation

It is well known that the design of a building will influence the quality of the ambient wind environment at its base. Below are some suggested wind mitigation strategies that should be adopted into precinct planning guidelines and controls.

Building form – Canopies

A large canopy may interrupt the flow as it moves down the windward face of the building. This will protect the entrances and sidewalk area by deflecting the downwash at the second storey level, **Figure 17**. However, this approach may have the effect of transferring the breezy conditions to the other side of the street. Large canopies are a common feature near the main entrances of major office buildings.

Downwash to street level may generate windy conditions for pedestrians. This is particularly true for buildings much taller than the surrounding buildings.

A large canopy is a common solution to this pedestrian-wind problem at street level.

Figure 17: Canopy windbreak treatment

Downwash to street level may generate windy conditions for pedestrians. This is particularly true for buildings much taller than the surrounding buildings. A large canopy is a common solution to this pedestrian-wind problem at street level.

The architect may elect to use an extensive podium for the same purpose if there is sufficient land and it complies with the design mandate, **Figure 18**. This is a common architectural feature for many major projects in recent years, but it may be counterproductive if the architect wishes to use the podium roof for long-term pedestrian activities, such as a pool or tennis court.

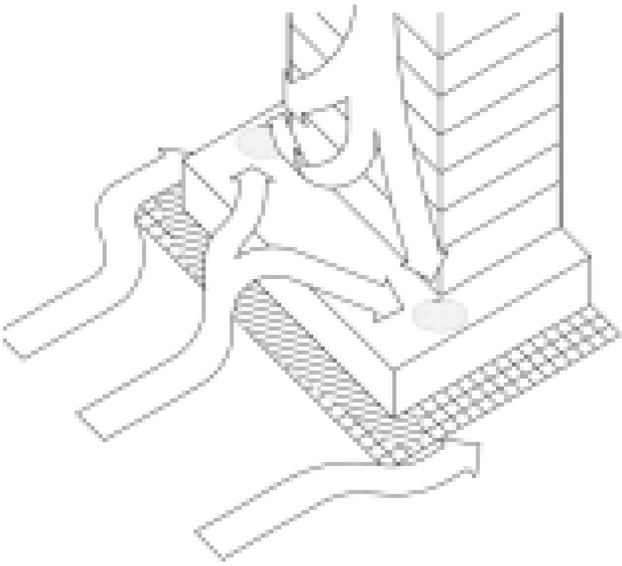


Figure 18: The building-on-podium massing often results in reasonable conditions at ground level, but the podium may not be useable

Building form – Arcades

Another massing issue, which may be a cause of strong ground-level winds, is an arcade or thoroughfare opening from one side of the building to the other. This effectively connects a positive pressure region on the windward side with a negative pressure region on the lee side; a strong flow through the opening often results, **Figure 19**. The uninvitingly windy nature of these open areas is a contributing reason behind the use of arcade airlock entrances (revolving or double sliding doors).

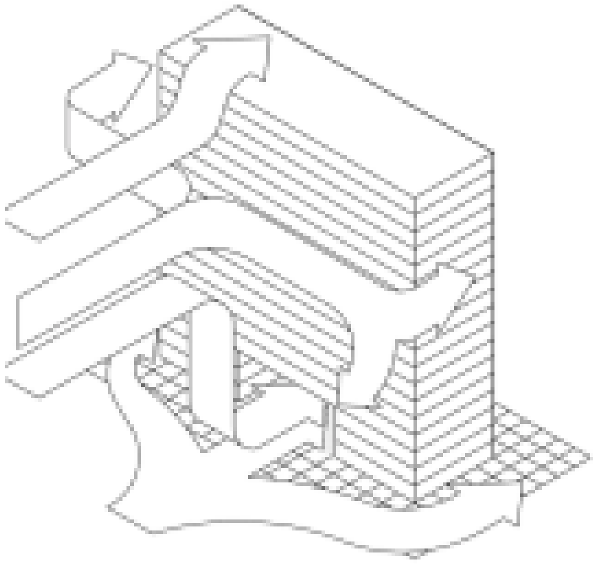
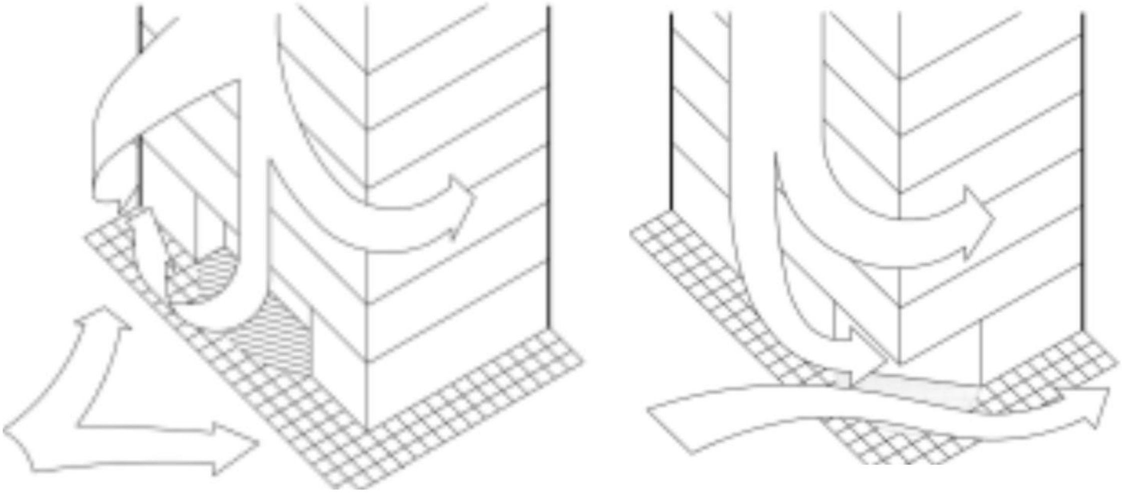


Figure 19: An arcade or open column plaza under a building frequently generates strong pedestrian wind conditions

Building form – Alcove

An entrance alcove behind the building line will generally produce a calmer entrance area at a mid-building location, **Figure 20**. In some cases, a canopy may not be necessary with this scenario, depending on the local geometry and directional wind characteristics. The same undercut design at a building corner is usually quite unsuccessful, **Figure 20**. This is due to the accelerated flow mechanism described in **Figure 16** and the ambient directional wind statistics. If there is a strong directional wind preference (e.g., northeast, southerly or westerly winds at the site), and the corner door is shielded from those common stronger winds, then the corner entrance may work. However, it is more common for a corner entrance to be adversely impacted by this local building geometry. The result can range from simply unpleasant conditions to a frequent inability to open the doors.



A mid-building alcove entrance usually results in an inviting and calm location.

Accelerated corner flow from downwash often yields an unpleasant entrance area.

Figure 20: Alcove windbreak treatment

Building form – façade profile and balconies

The way in which a building's vertical line is broken up may also have an impact. For example, if the floor plans have a decreasing area with increased height the flow down the stepped windward face may be greatly diminished. To a lesser extent the presence of many balconies can have a similar impact on ground level winds, although this is far less certain and more geometry dependent. Apartment designs with many elevated balconies and terrace areas near building ends or corners often attract a windy environment to those locations. Mid-building balconies, on the broad face, are usually a lot calmer, especially if they are recessed. Corner balconies are generally a lot windier and so the owner is likely to be selective about when the balcony is used or endeavours to find a protected portion of the balcony that allows more frequent use, even when the wind is blowing.

Use of Canopies, trellises and high canopy foliage

Downwash Mitigation - As noted earlier, downwash off a building may be deflected away from ground-level pedestrian areas by large canopies or podium blocks. The downwash then effectively impacts the canopy or podium roof rather than the public areas at the base of the building, **Figure 18**. Provided that the podium roof area is not intended for long-term recreational use (e.g. swimming pool or tennis court), this massing method is typically quite successful. However, some large recreational areas may need the wind to be deflected away without blocking the sun (e.g. a pool deck), and so a large canopy is not an option. Downwash deflected over expansive decks like these may often be improved by installing elevated trellis structures or a dense network of trees to create a high, bushy canopy over the long-term recreational areas. Various architecturally acceptable ideas may be explored in the wind tunnel prior to any major financial commitment on the project site.

Horizontally accelerated flows between two tall buildings may cause an unpleasant, windy, ground-level pedestrian environment, which could also be locally aggravated by ground topography. Horizontally accelerated flows that create a windy environment are best dealt with by using vertical porous screens or substantial landscaping. Large hedges, bushes or other porous media serve to retard the flow and absorb the energy produced by the wind. A solidity ratio (i.e. proportion of solid area to total area) of about 60-70% has been shown to be most effective in reducing the flow's momentum (Rouse, 1950). These physical changes to the pedestrian areas are most easily evaluated by a model study in a boundary-layer wind tunnel.