Attachment B26(b)

Pedestrian Wind Environment Study Part 2 – Waterloo Estate (South) – Land and Housing Corporation

5 PEDESTRIAN WIND COMFORT AND SAFETY

The acceptability of wind conditions of an area is determined by comparing the measured wind speeds against an appropriate criteria. This section outlines how the measured wind speeds were obtained, the criteria considered for the development, as well as the critical trafficable areas that were assessed and their corresponding criteria designation.

5.1 Measured Wind Speeds

Wind speeds were measured using Dantec hot-wire probe anemometers, positioned to monitor wind conditions at critical outdoor trafficable areas of the development. The reference mean free-stream wind speed measured in the wind tunnel, which is at a full-scale height of 200m and measured 3m upstream of the study model.

Measurements were acquired for 16 wind directions at 22.5 degree increments using a sample rate of 1,024Hz. The full methodology of determining the wind speed measurements at the site from the Dantec Hot-wire probe anemometers is provided in Appendix D. Based on the results of the analysis of the boundary layer wind profiles at the site (see Section 4), and incorporating the regional wind model (see Section 5), the data sampling length of the wind tunnel test for each wind direction corresponds to a full-scale sample length ranging between 30 minutes and 1 hour. Research by A.W. Rofail and K.C.S. Kwok (1991) has shown that, in addition to the mean and standard deviation of the wind being stable for sample lengths of 15 minutes or more (full-scale), the peak value determined using the upcrossing method is stable for sample lengths of 30 minutes or more.

5.2 Wind Speed Criteria Used for This Study

For this study, the measured wind conditions for the various critical outdoor trafficable areas around the subject development are compared against the criteria presented in the Sydney Development Control Plan 2012 - Central Sydney Planning Review Amendment, which supersedes the criteria detailed in the City of Sydney Development Control Plan 2012 (SDCP2012).

For pedestrian comfort, the Sydney DCP 2012 requires that the hourly mean wind speed, or Gust-Equivalent Mean (GEM) wind speed (whichever is greater for each wind direction), must not exceed 8m/s for walking, 6m/s for standing, and 4m/s for sitting. These are based on a 5% probability of exceedance.

For pedestrian safety, the Sydney DCP 2012 defines a safety limit criterion of 24m/s, based on an annual maximum 0.5 second gust wind speed, which applies to all areas.

Furthermore, in accordance with the provisions of the Sydney DCP 2012, the existing conditions for the pedestrian footpaths around the site are also analysed as part of this study to determine the impact of the subject development. If it is found that the existing conditions exceed the relevant criteria, then the target wind speed for that area with the inclusion of the proposed development is to at least match the existing site conditions.

In accordance with the provisions of the Sydney DCP 2012, the wind speed assessment is undertaken for winds occurring between 6am and 10pm (AEST). A more detailed comparison of published criteria for pedestrian wind comfort and safety is provided in Appendix C. For this study the measured wind conditions of the selected critical outdoor trafficable areas are compared against two sets of criteria; one for pedestrian safety, and one for pedestrian comfort. The safety criterion is applied to the annual maximum gust winds, and the comfort criteria is applied to Gust Equivalent Mean (GEM) winds. In accordance with ASCE (2003), the GEM wind speed is defined as follows:

$$GEM = max\left(\bar{V}, \frac{\hat{V}}{1.85}\right) \quad (5.1)$$

Where:

$\bar{V}$ is the mean wind speed.

$\hat{V}$ is the gust wind speed.

The criteria considered in this study are summarised in Table 4 and

Table 5 for pedestrian comfort and safety, respectively. The results of the wind tunnel study are presented in the form of directional plots attached in Appendix A of this report. For each study point there is a plot of the GEM wind speeds using the comfort criteria, and a plot for the annual maximum gust wind speeds using the safety criterion.

Table 4: Pedestrian Comfort Criteria (Sydney DCP 2012)

Classification	Description	Maximum 5% Exceedance GEM Wind Speed (m/s)
Sitting	Outdoor areas that involve seating such as dining areas in restaurants, amphitheatres, etc.	4
Standing	Short duration stationary activities (generally less than 1 hour), including window shopping, waiting areas, etc.	6
Walking	For pedestrian thoroughfares, private swimming pools, most communal areas, private balconies and terraces, etc.	8

Table 5: Pedestrian Safety Criterion (Draft Sydney DCP 2012)

Classification	Description	Annual Maximum Gust Wind Speed (m/s)
Safety	Safety criterion applies to all trafficable areas.	24

6 BASELINE INVESTIGATIONS

This section will address study requirements 19.1 and 19.8 through the analysis of the existing site wind conditions via wind tunnel testing.

Testing of the entire Waterloo precinct was undertaken for the existing site conditions, based on the architectural drawing packages received May 2017. The results provide a baseline wind case for the existing site wind conditions for the proposed development site to be established, taking into account the prevailing wind directions for the region, as well as the local topographical effects of the terrain and the surrounding buildings of the proposed site.

6.1 Existing Site Wind Tunnel Model

The existing site study model incorporates all necessary architectural features on the development to ensure an accurate wind flow is achieved. The effect of nearby buildings and land topography has been accounted for through the use of a proximity model, which represents a radius of approximately 600m. Photographs of the wind tunnel model are presented below for the existing site in Figure 6a – 6d on the following pages. Figure 6e depicts a plan view of the proximity model.

The model of the proposed development was tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as screens, balustrades, awnings, etc., which are not already shown in the architectural drawings.

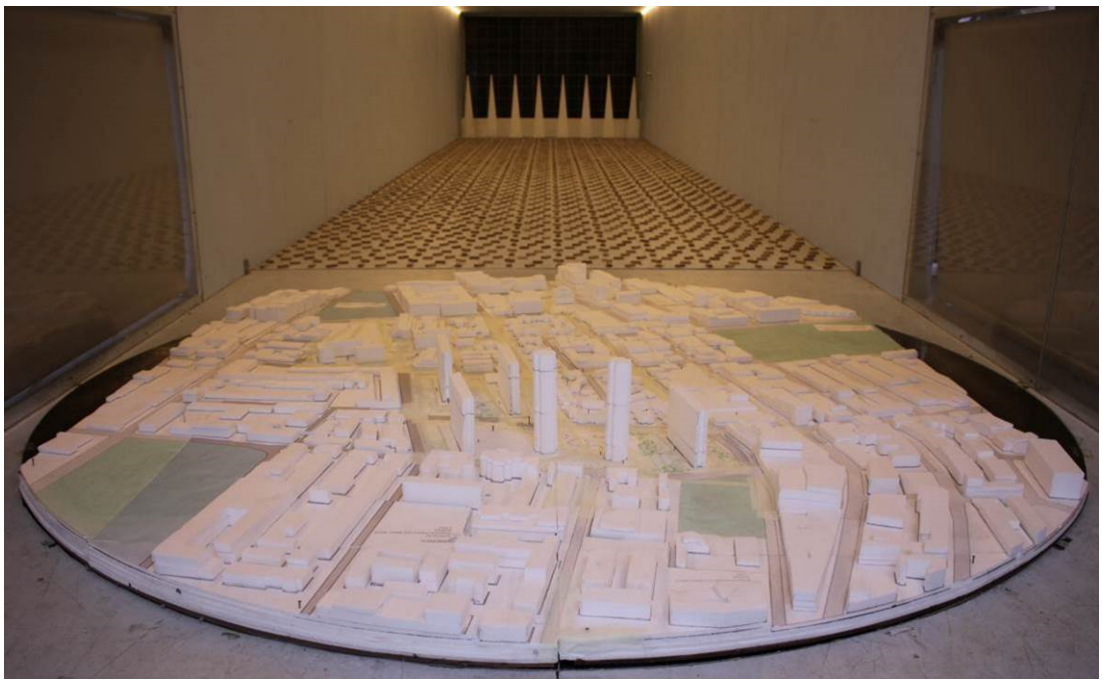

Figure 6a: Photograph of the Wind Tunnel Model – (View from the North)

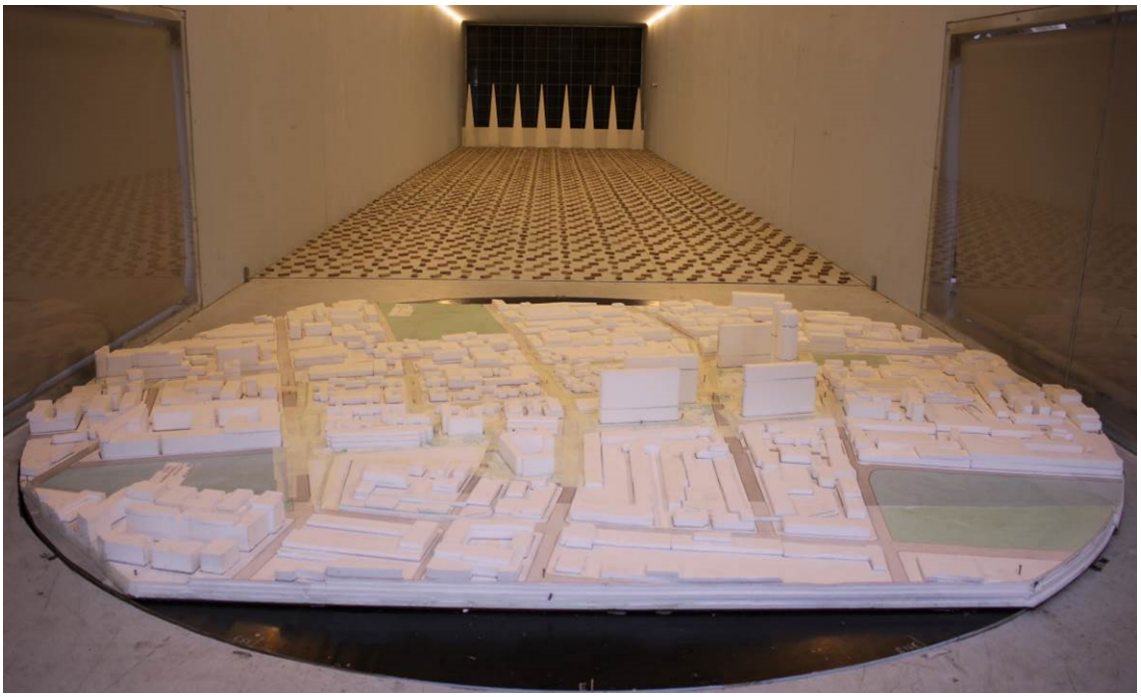

Figure 6b: Photograph of the Wind Tunnel Model – (View from the East)

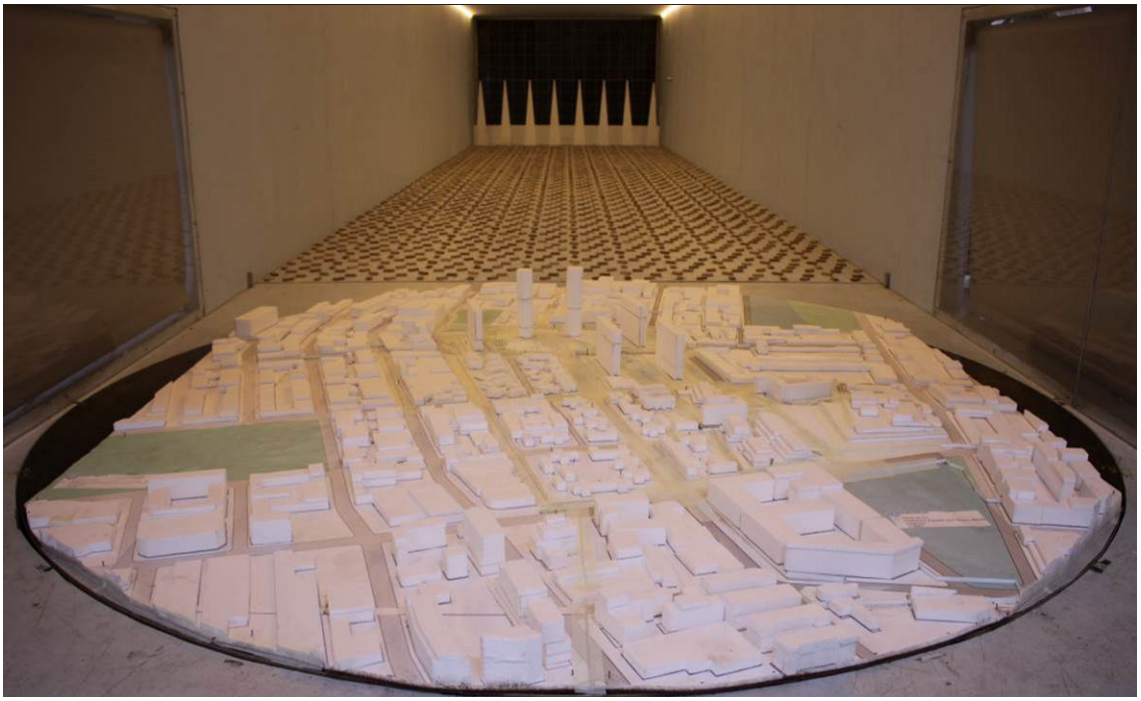

Figure 6c: Photograph of the Wind Tunnel Model – (View from the South)

Figure 6d: Photograph of the Wind Tunnel Model – (View from the West)

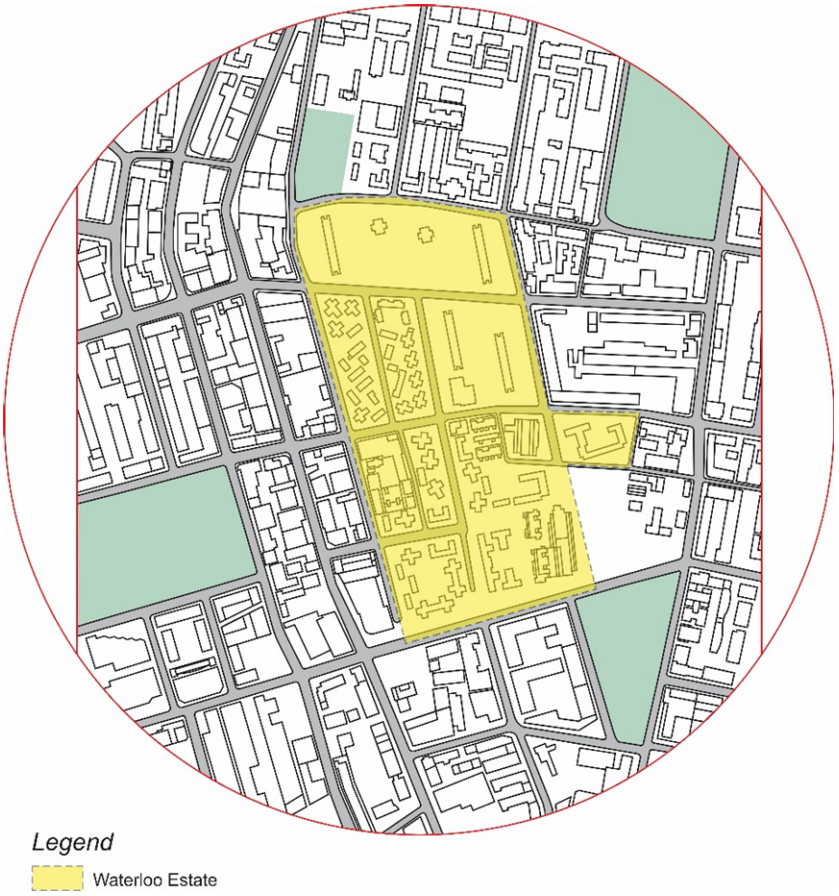

Figure 6e: Map of Proximity Model – Existing Site (Waterloo Estate Boundary)

6.2 Layout of Study Points

For this study a total of 81 ground level study points have been selected for analysis in the wind tunnel located within and around the proposed Waterloo Estate site boundary.

The locations of the various study points tested are presented in Figures 7a to 7d in the form of marked-up plan drawings. The target wind speed criteria for the outdoor trafficable areas within and around the development is also indicated in these figures.

The most critical outdoor locations of the development have been selected for analysis which will help with the masterplan design input. The areas for consideration are the corner areas of the proposed development site due to the alignment of the city street grid coinciding with two of the prevailing winds for the Sydney region, which are the southerly and westerly winds. These areas may be subject to adverse wind effects due to a combination of direct winds and corner accelerations.

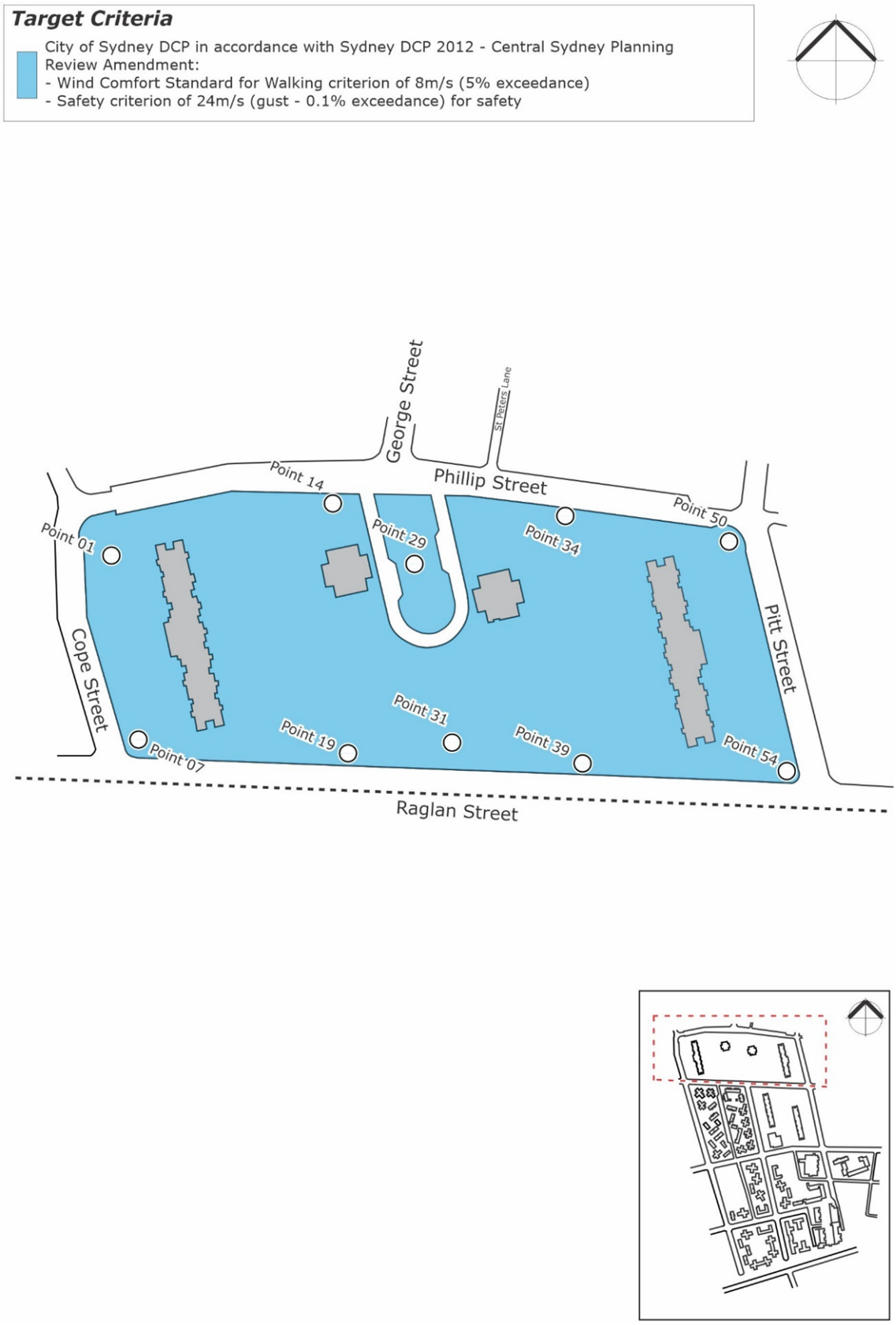

Figure 7a: Study Point Locations and Target Criteria – Phillip to Raglan Street - Existing Site of Waterloo Estate Masterplan

Figure 7b: Study Point Locations and Target Criteria – Raglan to Wellington Street- Existing Site of Waterloo Estate Masterplan

Figure 7c: Study Point Locations and Target Criteria – Wellington to McEvoy Street - Existing Site of Waterloo Estate Masterplan

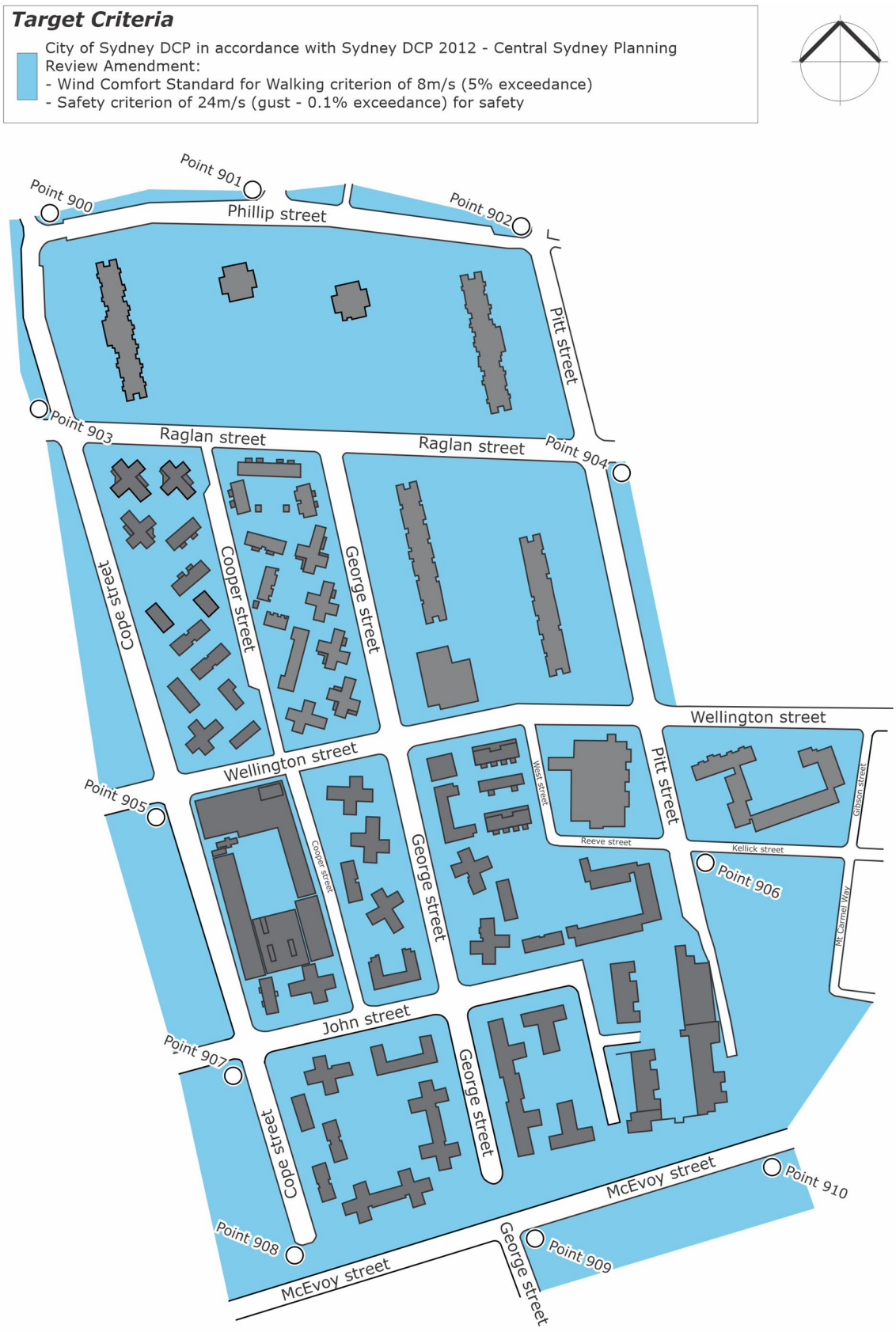

Figure 7d: Study Point Locations and Target Criteria – Surrounding Points - Existing Site of Waterloo Estate Masterplan

6.3 Results

The results for the existing site point locations are presented in the form of directional plots in Appendix A, summarised in Table 6, and shown on marked-up plans in Figures 8a – 8d below. The wind speed criteria for the existing site has been assessed against the walking criterion, as listed in Table 6 for each study point location, as well as shown in Figures 7a – 7d.

Table 6: Wind Tunnel Results Summary – Existing Site Conditions (Sydney DCP 2012)

Study Point	Wind Speed Criteria and Overall Rating			
	Weekly GEM (m/s)	Rating	Annual Peak (m/s)	Rating
Point 01	8.0	PASS	24.0	PASS
Point 07	8.0	PASS	24.0	PASS
Point 14	8.0	PASS	24.0	PASS
Point 19	8.0	PASS	24.0	PASS
Point 29	8.0	FAIL	24.0	PASS
Point 31	8.0	PASS	24.0	PASS
Point 34	8.0	PASS	24.0	PASS
Point 39	8.0	PASS	24.0	PASS
Point 50	8.0	PASS	24.0	PASS
Point 54	8.0	PASS	24.0	PASS
Point 60	8.0	PASS	24.0	PASS
Point 68	8.0	PASS	24.0	PASS
Point 70	8.0	PASS	24.0	PASS
Point 77	8.0	PASS	24.0	PASS
Point 79	8.0	FAIL	24.0	PASS
Point 81	8.0	PASS	24.0	PASS
Point 82	8.0	PASS	24.0	PASS
Point 85	8.0	PASS	24.0	PASS
Point 87	8.0	PASS	24.0	PASS
Point 89	8.0	PASS	24.0	PASS
Point 90	8.0	PASS	24.0	PASS
Point 96	8.0	PASS	24.0	PASS
Point 100	8.0	PASS	24.0	PASS
Point 104	8.0	PASS	24.0	PASS
Point 107	8.0	FAIL	24.0	PASS
Point 109	8.0	PASS	24.0	PASS
Point 110	8.0	FAIL	24.0	PASS
Point 111	8.0	PASS	24.0	PASS
Point 118	8.0	PASS	24.0	PASS

Study Point	Wind Speed Criteria and Overall Rating			
	Weekly GEM (m/s)	Rating	Annual Peak (m/s)	Rating
Point 119	8.0	FAIL	24.0	FAIL
Point 120	8.0	PASS	24.0	PASS
Point 122	8.0	PASS	24.0	PASS
Point 124	8.0	PASS	24.0	PASS
Point 125	8.0	PASS	24.0	PASS
Point 127	8.0	PASS	24.0	PASS
Point 131	8.0	PASS	24.0	PASS
Point 133	8.0	PASS	24.0	PASS
Point 136	8.0	PASS	24.0	PASS
Point 137	8.0	PASS	24.0	PASS
Point 143	8.0	PASS	24.0	PASS
Point 146	8.0	PASS	24.0	PASS
Point 147	8.0	PASS	24.0	PASS
Point 151	8.0	PASS	24.0	PASS
Point 153	8.0	PASS	24.0	PASS
Point 173	8.0	PASS	24.0	PASS
Point 156	8.0	PASS	24.0	PASS
Point 158	8.0	PASS	24.0	PASS
Point 179	8.0	PASS	24.0	PASS
Point 164	8.0	PASS	24.0	PASS
Point 166	8.0	PASS	24.0	PASS
Point 168	8.0	PASS	24.0	PASS
Point 170	8.0	PASS	24.0	PASS
Point 178	8.0	PASS	24.0	PASS
Point 181	8.0	PASS	24.0	PASS
Point 183	8.0	PASS	24.0	PASS
Point 184	8.0	FAIL	24.0	PASS
Point 187	8.0	PASS	24.0	PASS
Point 192	8.0	PASS	24.0	PASS
Point 193	8.0	PASS	24.0	PASS
Point 198	8.0	PASS	24.0	PASS
Point 202	8.0	PASS	24.0	PASS
Point 206	8.0	PASS	24.0	PASS
Point 207	8.0	PASS	24.0	PASS
Point 211	8.0	PASS	24.0	PASS
Point 215	8.0	PASS	24.0	PASS
Point 227	8.0	PASS	24.0	PASS
Point 232	8.0	PASS	24.0	PASS
Point 235	8.0	PASS	24.0	PASS

Study Point	Wind Speed Criteria and Overall Rating			
	Weekly GEM (m/s)	Rating	Annual Peak (m/s)	Rating
Point 238	8.0	PASS	24.0	PASS
Point 900	8.0	PASS	24.0	PASS
Point 901	8.0	PASS	24.0	PASS
Point 902	8.0	PASS	24.0	PASS
Point 903	8.0	PASS	24.0	PASS
Point 904	8.0	PASS	24.0	PASS
Point 905	8.0	PASS	24.0	PASS
Point 906	8.0	PASS	24.0	PASS
Point 907	8.0	PASS	24.0	PASS
Point 908	8.0	PASS	24.0	PASS
Point 909	8.0	PASS	24.0	PASS
Point 910	8.0	FAIL	24.0	FAIL

Note that when classifying a "Pass" or "Fail" for the weekly GEM wind speeds, the desired criterion is exceeded if the probability of exceedance is greater than 5% and hence awarded a "Fail".

The baseline conditions established from the pedestrian wind environment testing will be compared against the results of the wind tunnel testing of the Waterloo South masterplan, as summarised in Table 7. For the Waterloo South masterplan assessment it should be noted that certain study point locations will be assessed against stricter criteria. Similarly, point naming between the existing scenario and proposed scenarios are not the same. As such, comparison will be made for each existing site study point against the equivalent criteria and equivalent point.

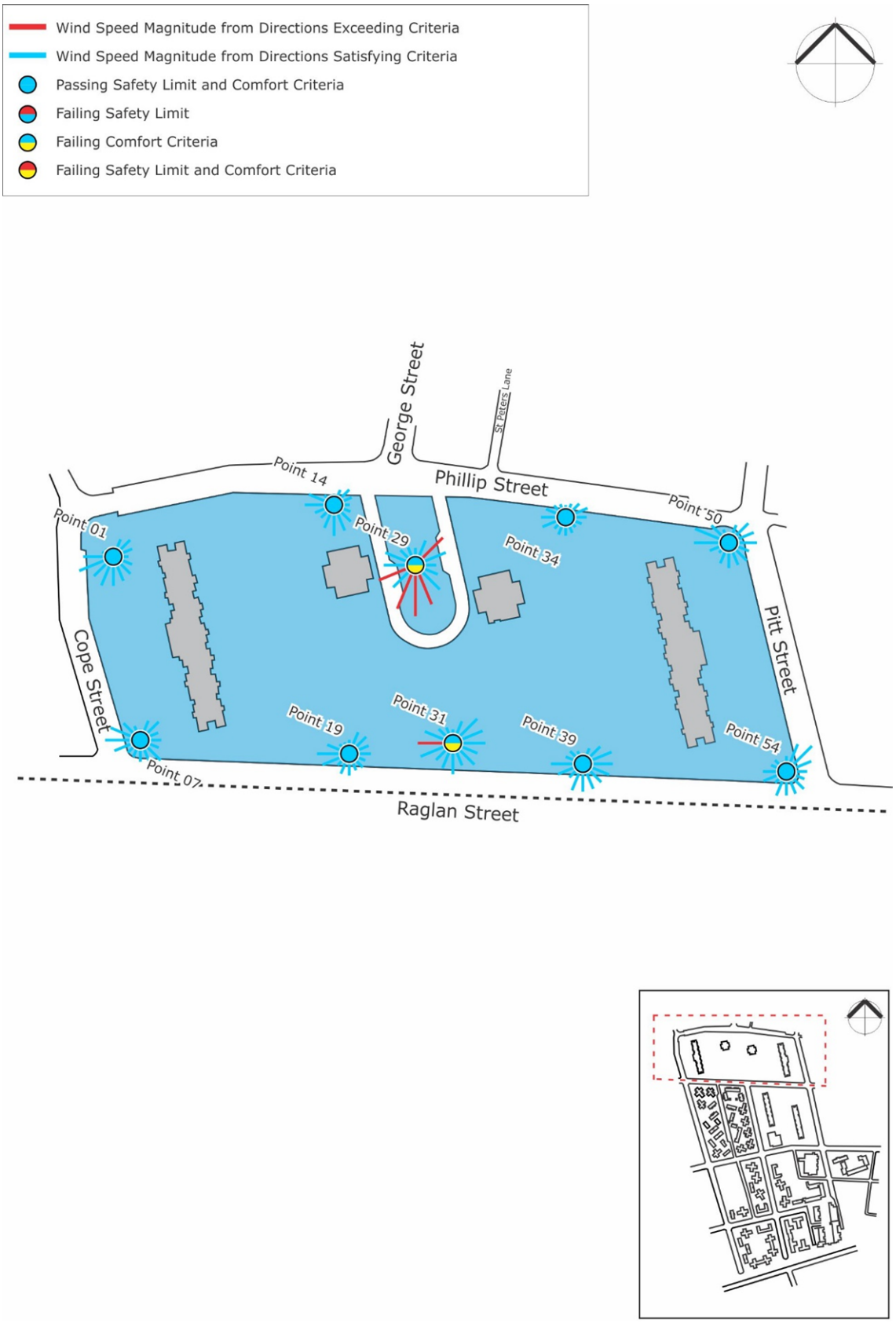

Figure 8a: Wind Directionality Plots – Ground Level - Existing Site of Waterloo Estate Masterplan

Figure 8b: Wind Directionality Plots – Ground Level - Existing Site of Waterloo Estate Masterplan

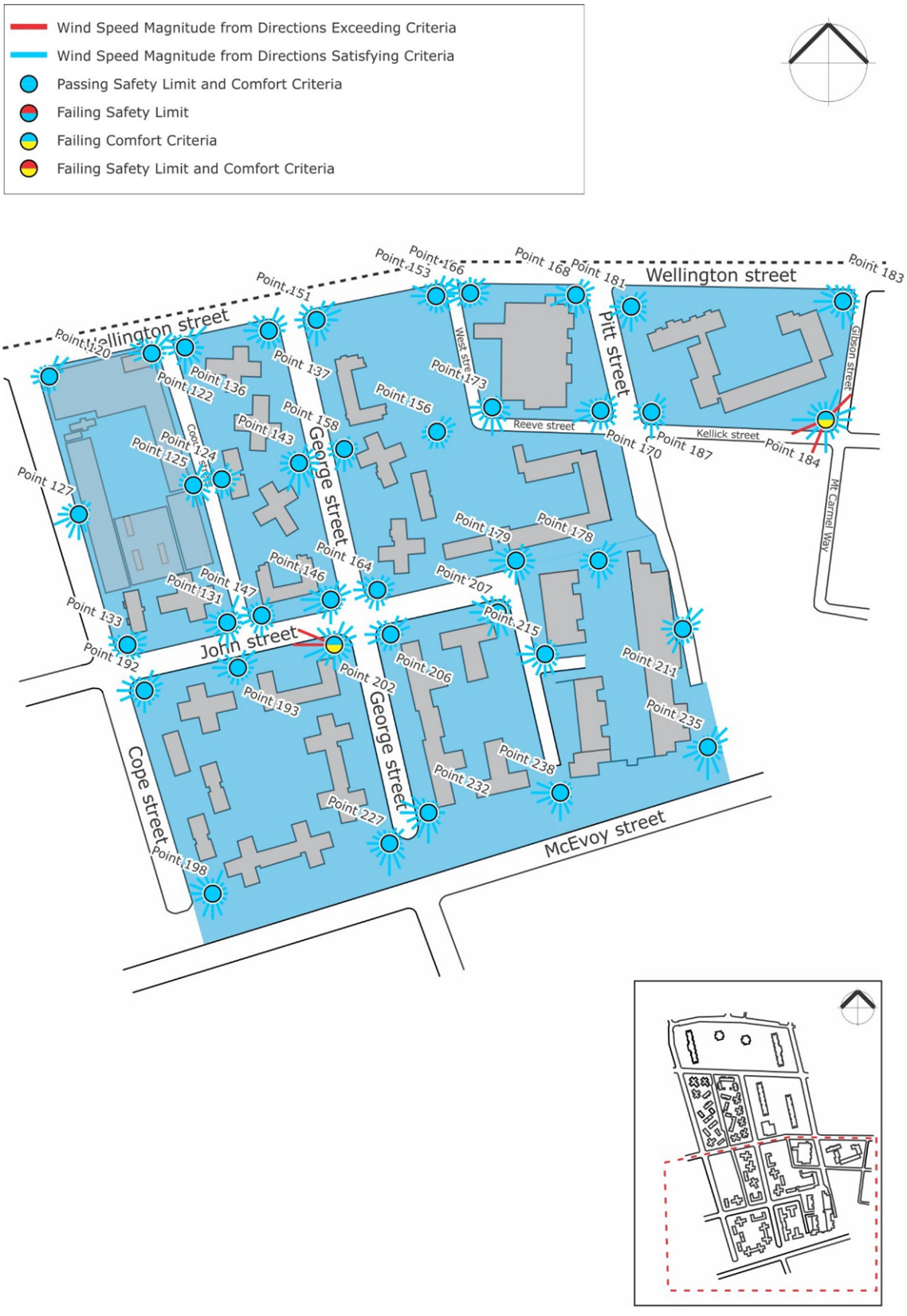

Figure 8c: Wind Directionality Plots – Ground Level - Existing Site of Waterloo Estate Masterplan

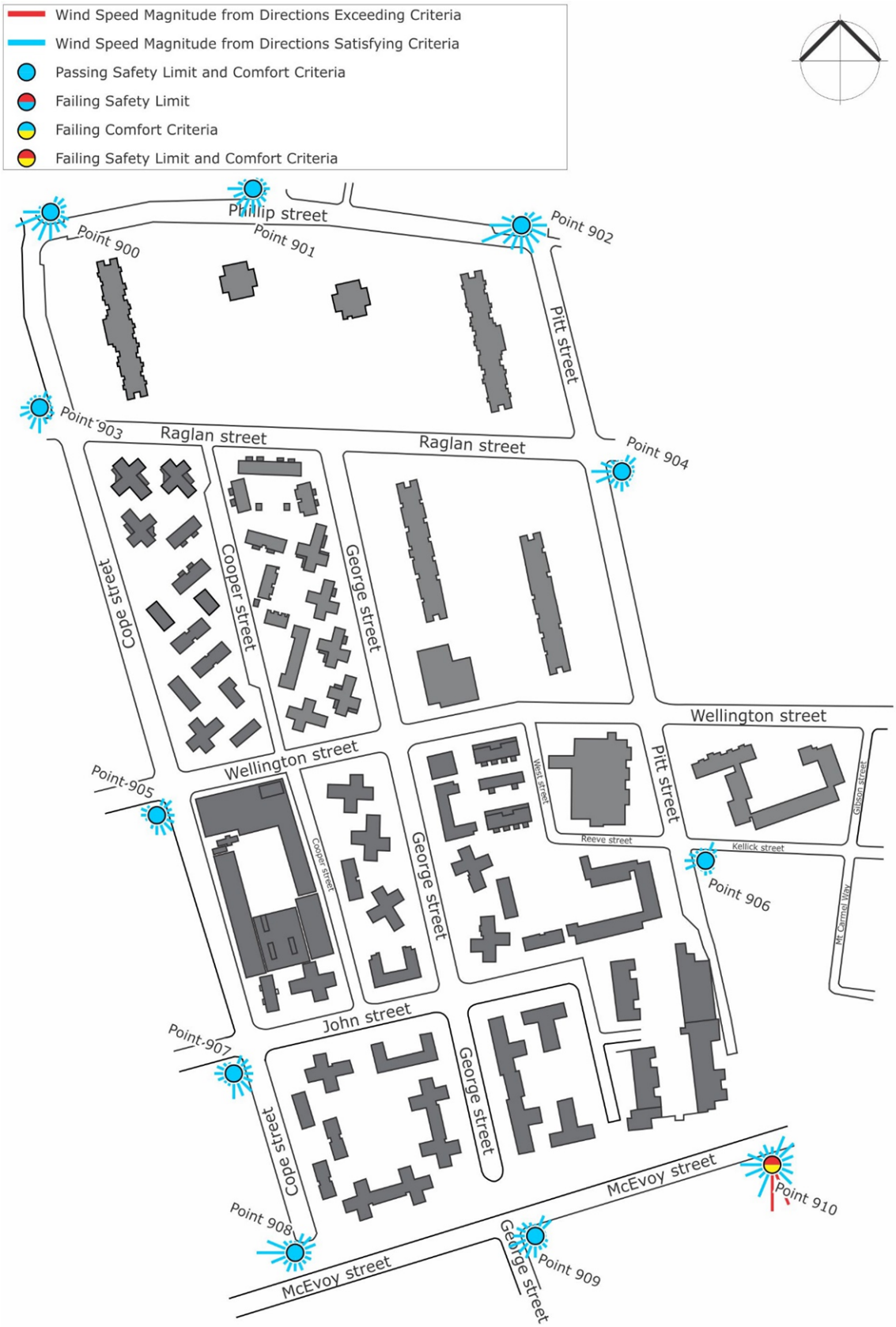

Figure 8d: Wind Directionality Plots – Ground Level - Existing Site of Waterloo Estate Masterplan

6.4 Discussion of Results

Wind tunnel testing was performed to determine the existing site wind conditions for the proposed Masterplan development. The prevailing wind directions for the region, as well as the local topographical effects of the terrain and the surrounding buildings of the proposed site were considered. The results allow for design guidance and comparison with the wind tunnel testing results of the proposed Waterloo South development.

It is important to note that due to the relatively low-rise and scattered nature of the existing buildings within and around the study site, the wind conditions from the wind tunnel test generally indicate the exposed nature of the site to the predominant wind directions for the Sydney region. However, due to the exposed nature of the overall site to the predominant winds, medium to high rise buildings have the potential to induce wind effects onto the surrounding streetscape, as discussed below.

Along the northern part of the proposed Waterloo Masterplan development site the study points along Phillip Street indicate exposure to the predominant westerly winds for the region. Similarly, along Raglan Street, the westerly winds are shown to impact the region spanning from Cope Street up until Pitt Street. This is a direct result of the exposure of the region to the predominant westerly winds in conjunction with a relatively uninterrupted low-rise region of developments to the west of the development site. The north-easterly winds are also observed to effect the corner of Pitt Street and Raglan Street, however this is seen to be a localised wind effect due to the proximity of the two mid-rise buildings on the north-eastern aspect of the site, resulting in the funnelling of the north-easterly winds. In a similar manner, the southerly winds are observed to funnel between the two mid-rise buildings adjacent to George Street.

Within the middle region of the development site, the area bounded by Raglan Street, Cope Street, Wellington Street and Pitt Street, the predominant wind directions are observed to effect the general streetscapes of the region. In particular, the north-easterly, westerly as well as the southerly winds are all observed to impact the streetscapes within and around the region. In particular, the westerly winds are seen to be prevalent along both Raglan Street and Wellington Street. This is a direct result of the orientation of these streetscapes to the westerly winds, in conjunction with their exposed nature due to the low-rise and scattered developments in the surrounding regions. The two medium-rise rectangular building forms to the west of Pitt Street are also shown to have a significant effect on the wind conditions around this region. As shown from the wind tunnel results, the westerly winds are observed to be further accentuated towards the eastern aspect of both Raglan Street and Wellington Street, highlighting the effect of the medium-rise rectangular building forms. Similarly, funnelling effects are observed between the two medium-rise rectangular buildings forms, as the westerly and southerly winds are accelerated between the two building forms. From this it is important to note the significant increase in wind speeds adjacent to the existing medium rise buildings which are causing the prevailing winds to downwash and side-stream around the built form. This is driven by the noted exposure upstream and hence should be accounted for during the design development of the masterplan.

Towards the southern aspect of the development site similar wind effects are observed throughout the streetscapes and surrounding areas. The predominant north-easterly, westerly and southerly winds are all seen to impact the various study point locations throughout the region, due to its' exposed topographical nature. In particular, the southerly winds are observed to be more dominant along the southern aspect of the development, in comparison to the regions further north. This is a result of the existing low-rise building forms baffling the southerly winds as they travel upstream towards the northern portion of the development site. Additionally, the streetscapes are once again observed to be governed by westerly and southerly winds, due to their orientation to the predominant winds. The effect of the medium-rise building forms is once again present, with the influence of the developments bounded by Wellington Street, Pitt Street, Kellick Street and Gibson Street apparent from the wind tunnel results. As observed, the westerly and southerly winds are further accentuated around this region due to the incoming winds being accelerated around this building form.

The noted reduction in the southerly winds at the northern end of the site compared to the southern end helps to verify the importance of controlling the rise in built form to encourage the winds to move up and over the precinct instead of funnelling between the built forms. The inclusion of a "wall" or buildings at the perimeter of the precinct will result in notable adverse conditions around these buildings due to the exposed upstream nature. Alternatively by aligning the perimeter tower forms to the respective prevailing winds will also help to minimise these effects while also allowing winds to pass through the precinct which will assist with natural ventilation and air quality outcomes.