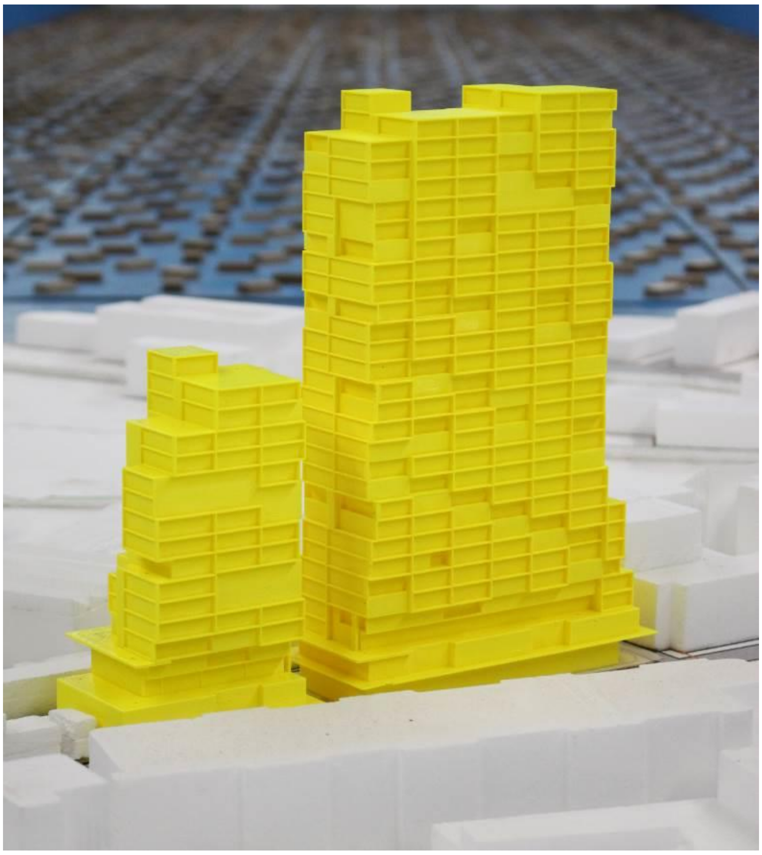

44-70 ROSEHILL STREET, REDFERN

PEDESTRIAN WIND ENVIRONMENT STUDY

WD516-02F02(REV0)- WE REPORT

MAY 2, 2018

Prepared for:

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DOCUMENT CONTROL

Date	Revision History	Issued Revision	Prepared By (initials)	Instructed By (initials)	Reviewed & Authorised by (initials)
May 2, 2018	Initial	0	NR	SWR	TD

The work presented in this document was carried out in accordance with the Windtech Consultants Quality Assurance System, which is based on International Standard ISO 9001.

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EXECUTIVE SUMMARY

This report presents the results of a detailed investigation into the wind environment impact of the Green Garden Development located at 44-70 Rosehill, Redfern. Testing was performed using Windtech's boundary layer wind tunnel, which has a 3.0m wide working section and has a fetch length of 14m. Measurements were carried out using a 1:300 scale detailed model of the development. 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 375m from the development site.

Peak gust and mean wind speeds were measured at selected critical outdoor trafficable locations within and around the subject development. Wind velocity coefficients representing the local wind speeds are derived from the wind tunnel and are combined with a statistical model of the regional wind climate (which accounts for the directional strength and frequency of occurrence of the prevailing regional winds) to provide the equivalent full-scale wind speeds at the site. These wind speed measurements are compared with criteria for pedestrian comfort and safety, based on gust wind speeds and Gust-Equivalent Mean (GEM) wind speeds.

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, etc. that are not already shown in the architectural drawings. Any proposed vegetation was also excluded from testing. If the results of the study indicate that any area was exposed to strong winds, in-principle treatments have been recommended. These treatments could be in the form of vegetation that is already proposed for the site, and/or additional trees, shrubs, screens, awnings, etc. The existing wind conditions for the pedestrian footpaths around the site have also been tested to determine the impact of the proposed development.

The results of the study indicate that treatments are required for certain locations to achieve the desired wind speed criteria for pedestrian comfort and safety. Based on the results observed from the wind tunnel testing, the treatments which have been deemed most appropriate have been suggested and are summarised as follows:

Ground Level (Levels N1 and S1):

- Inclusion of densely foliating evergreen planters capable of growing up to a height of 2m at the northwest corner of the North Tower along Margaret Street.
- Inclusion of densely foliating evergreen planters capable of growing up to a height of 2m and along the west wall of both towers near Cornwallis Lane.
- Inclusion of a louvered trellis or operable awning that encompasses the central area up to the heights and extents of the awnings at Rosehill Street and Cornwallis Lane. Note that the louvers should be aligned.

- Inclusion of full height porous screens in the communal area between the two towers, as well as on the northern end of the North Tower near Margaret Street.

North Tower

- Inclusion of 1.8m high impermeable parapets/screens along several balconies/terraces, for Levels 3, 9, 29 and 30.
- Inclusion of 1.8m high impermeable partitions for Level 3.
- Retention of the impermeable parapets along the western balconies of Levels 9, 13, 16, 21, 25 and 29.

South Tower

- Inclusion of 1.8m high impermeable parapets/screens along several balconies/terraces, for Levels 3, 5 and 16.
- Inclusion of 1.8m high impermeable partitions for Level 5.
- Inclusion of a full height screen along the south-west edge of the Level 3 balcony.
- Inclusion of 3m high impermeable screens along the perimeter of the terrace area, located on Level 18.

With the inclusion of these treatments to the final design, it is expected that wind conditions for all outdoor trafficable areas within and around the proposed development will be suitable for their intended uses.

CONTENTS

1 WIND CLIMATE FOR THE SYDNEY REGION

Details of the wind climate of the Sydney region have been determined from a detailed statistical analysis of measured mean wind speed data from the meteorological observation station located at Kingsford Smith airport (Sydney Airport). The data has been collected from this station from 1995 to 2016 between 6am to 10pm, and corrected so that it represents winds over standard open terrain at a height of 10m above ground. A plot of the regional wind speeds is presented in Figure 1, which are referenced to a height of 10m above ground in standard open terrain and converted to hourly means. The data is also presented in Table 1. Note that the recurrence intervals examined in this study are for exceedances of 5% for the comfort criteria and annual maximum for any 22.5 degree sector for the Safety Limit.

The data indicates that the southerly winds are by far the most frequent winds for the Sydney region, and are also the strongest. The westerly winds occur most frequently during the winter season for the Sydney region, and although they are typically not as strong as the southerly winds, they are usually a cold wind and hence can be a cause for discomfort for outdoor areas. North-easterly winds occur most frequently occur during the warmer months of the year for the Sydney region, and hence are usually welcomed within outdoor areas since they are typically not as strong as the southerly or westerly winds.

Table 1: Directional Mean and Gust Wind Speeds for the Sydney Region (referenced to 10m height above ground in standard open terrain)

Wind Direction	Reference Hourly Mean Wind Speeds (m/s)	
	5% Exceedance per 90deg sector	Annual Maximum per 22.5deg sector
N	5.9	9.9
NNE	9.9	12.9
NE	9.7	12.3
ENE	7.5	10.0
E	6.3	9.3
ESE	6.2	9.1
SE	7.0	10.1
SSE	8.5	12.2
S	10.3	13.9
SSW	10.0	14.1
SW	6.9	11.9
WSW	9.3	13.6
W	9.8	14.4
WNW	8.8	14.3
NW	6.7	12.6
NNW	5.5	10.7

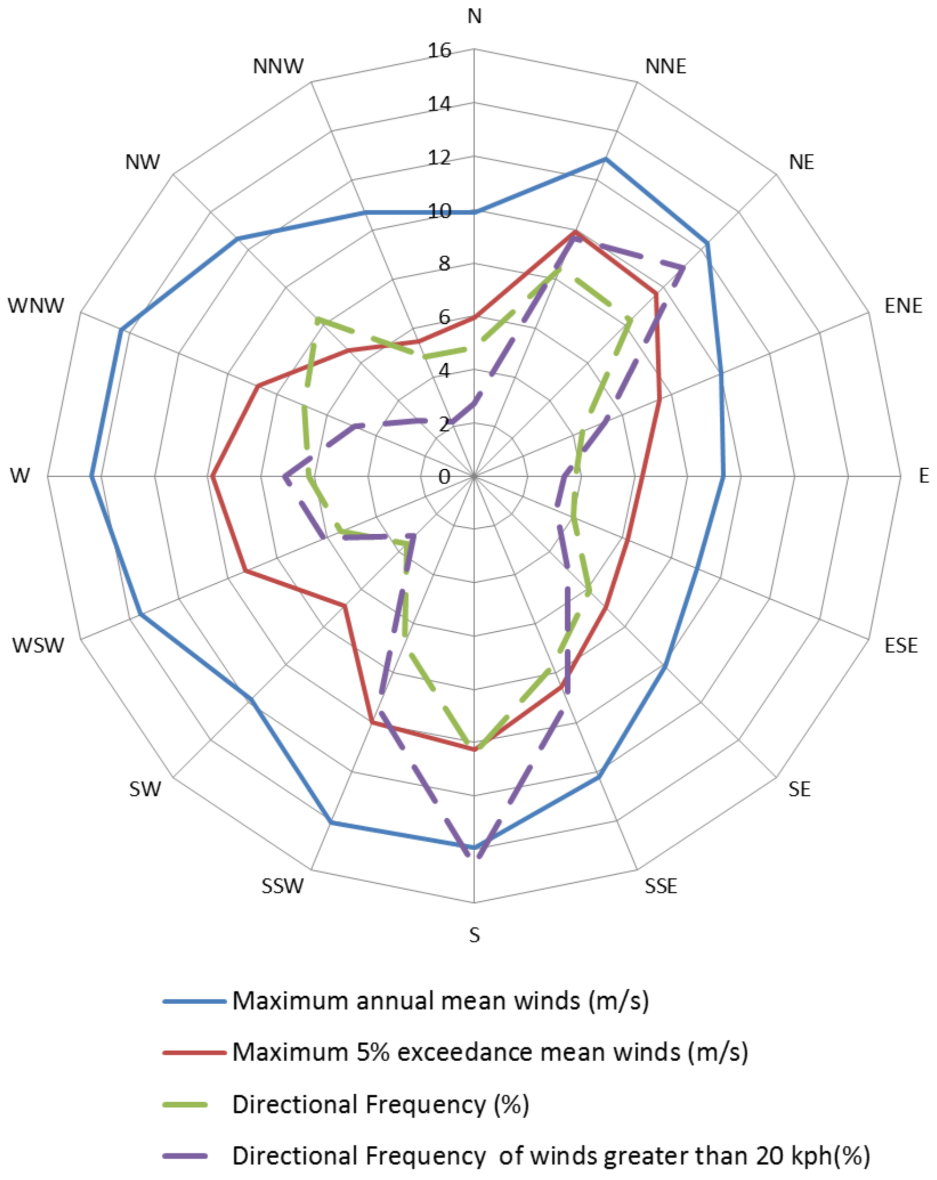


Figure 1: Directional Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Sydney Region (for annual and 5% probability exceedance winds, referenced to standard open terrain at a height of 10m above ground)

2 THE WIND TUNNEL MODEL

Wind tunnel testing was undertaken to obtain accurate wind speed measurements at selected critical outdoor locations within and around the development using a 1:300 scale model. The study model incorporates all necessary architectural features on the development to ensure an accurate wind flow is achieved around the model. A proximity model has also been constructed and represents the surrounding buildings and significant topographical effects within a radius of 375m, centred on the development site. Testing was also performed on the existing site as a comparison against the proposed development. Photographs of the wind tunnel model are presented in Figures 2a to 2f and Figure 2g for the proposed and existing configurations respectively. A map of the proximity model is shown in Figure 2h.

The model was tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as screens, balustrades, etc. that are not already shown in the architectural drawings. The effect of vegetation was also excluded from testing. If the results of the study indicate that any area is exposed to strong winds, in-principle treatments have been recommended. These treatments could be in the form of vegetation that is already proposed for the site, and/or additional trees, shrubs, screens, awnings, etc. Existing wind conditions have also been tested for the critical trafficable outdoor locations at street level and these results have been compared against the results with the proposed development in-place.

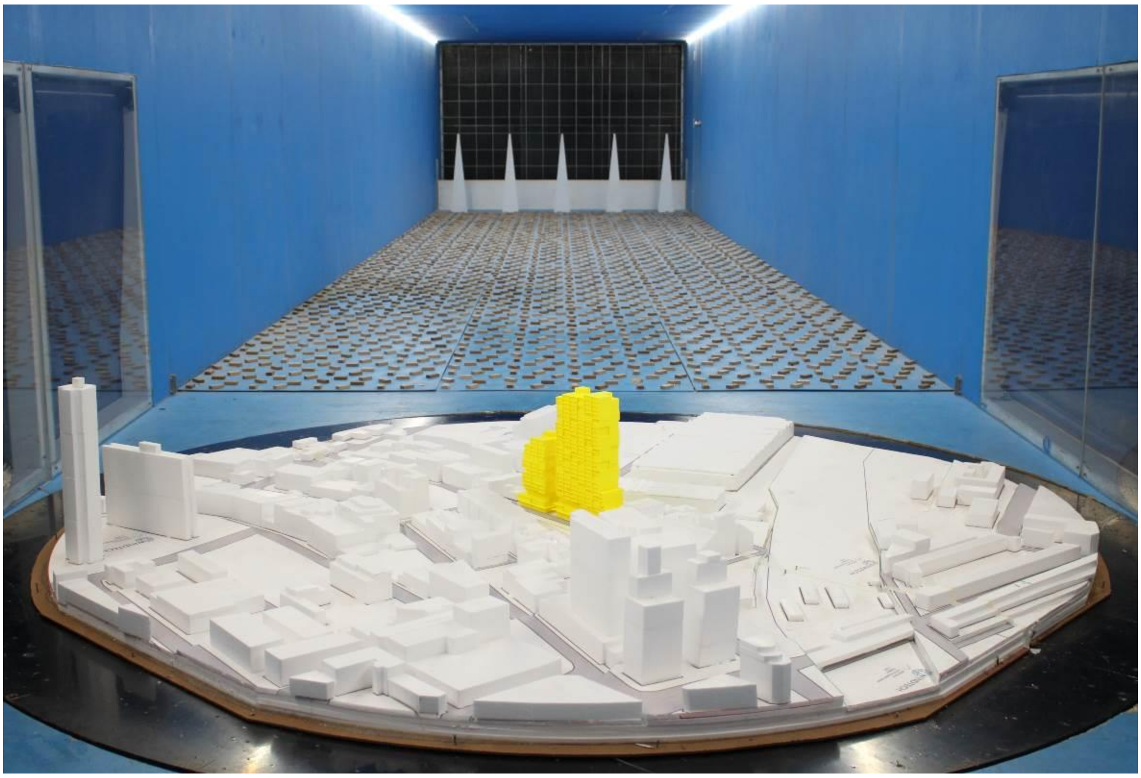


Figure 2a: Photograph of the Wind Tunnel Model – Proposed Scenario (view from the north-east)

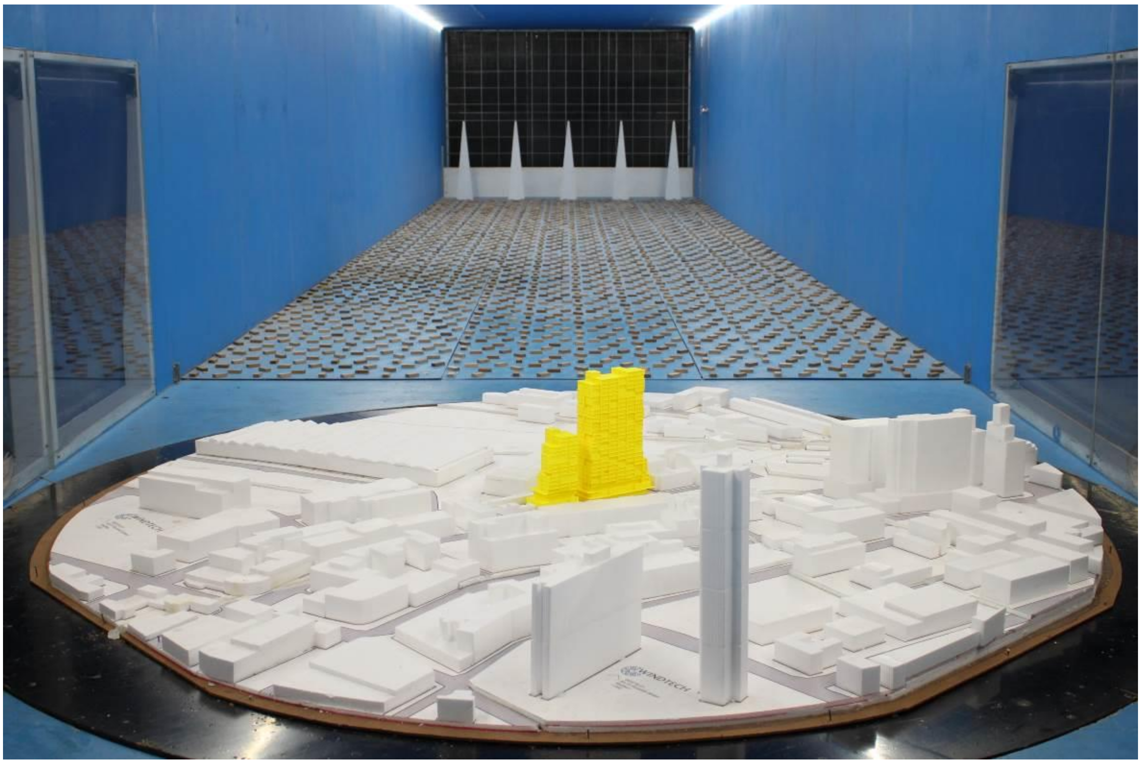


Figure 2b: Photograph of the Wind Tunnel Model– Proposed Scenario (view from the south-east)

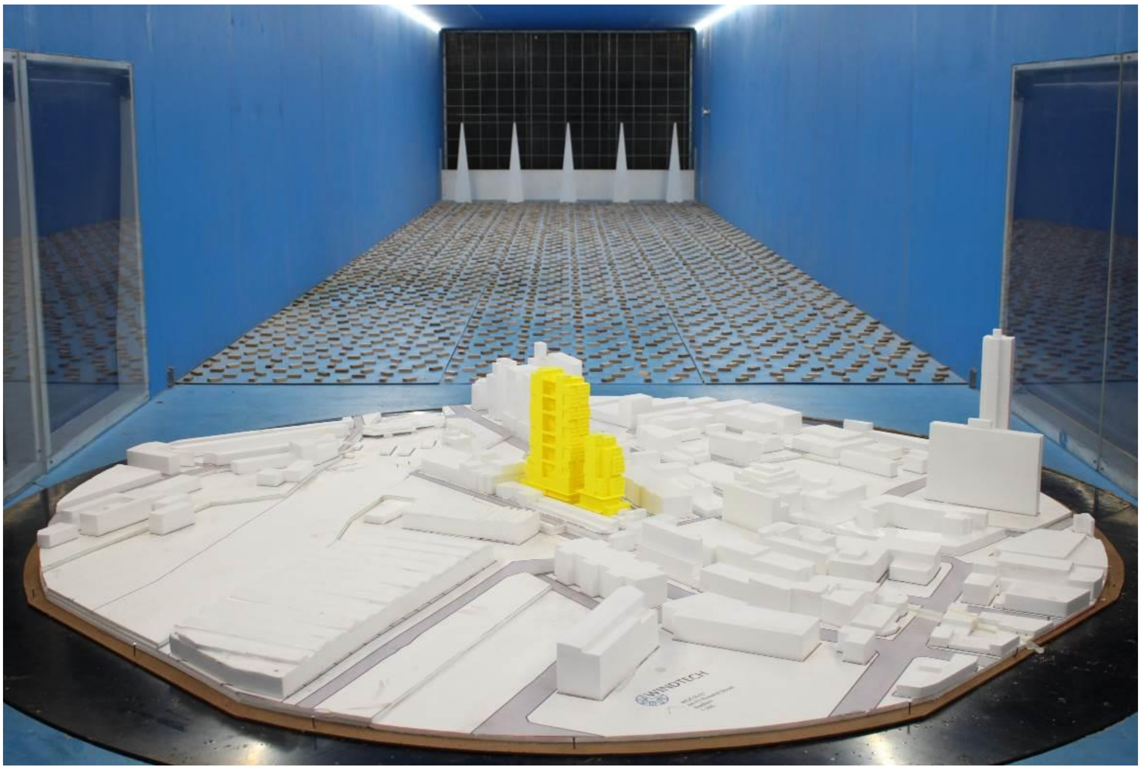


Figure 2c: Photograph of the Wind Tunnel Model – Proposed Scenario (view from the south-west)

Figure 2d: Photograph of the Wind Tunnel Model – Proposed Scenario (view from the north-west)

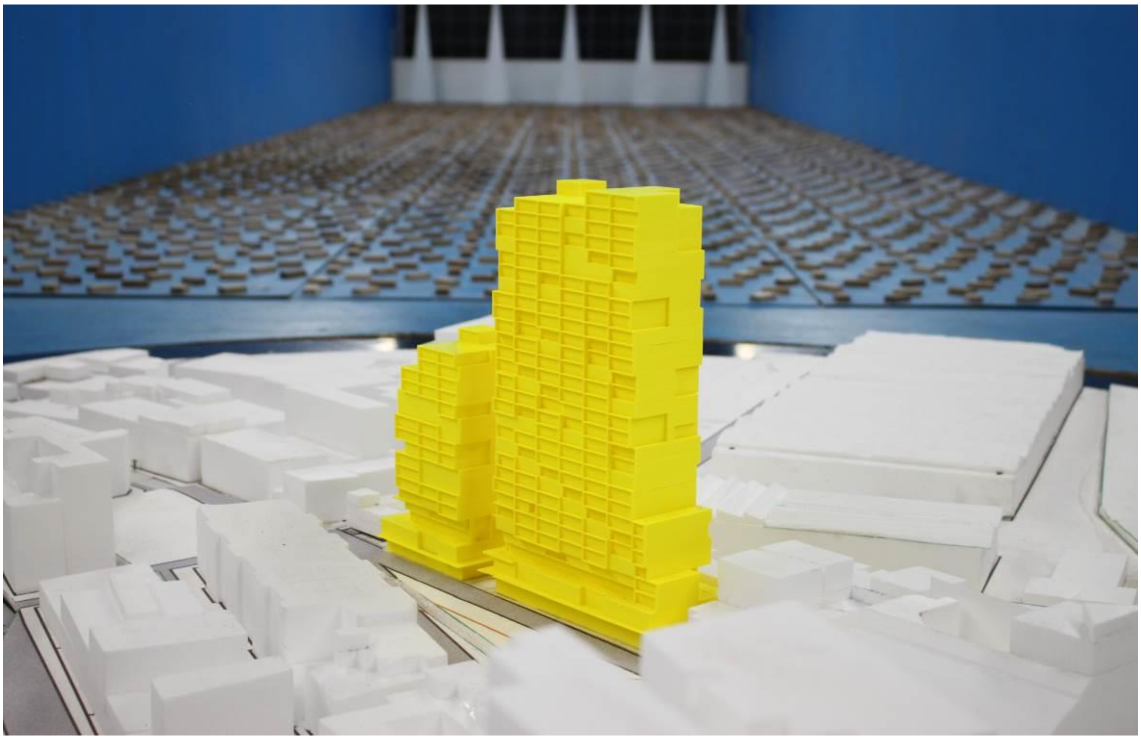


Figure 2e: Photograph of the Wind Tunnel Model – Proposed Scenario (view from the north-east)

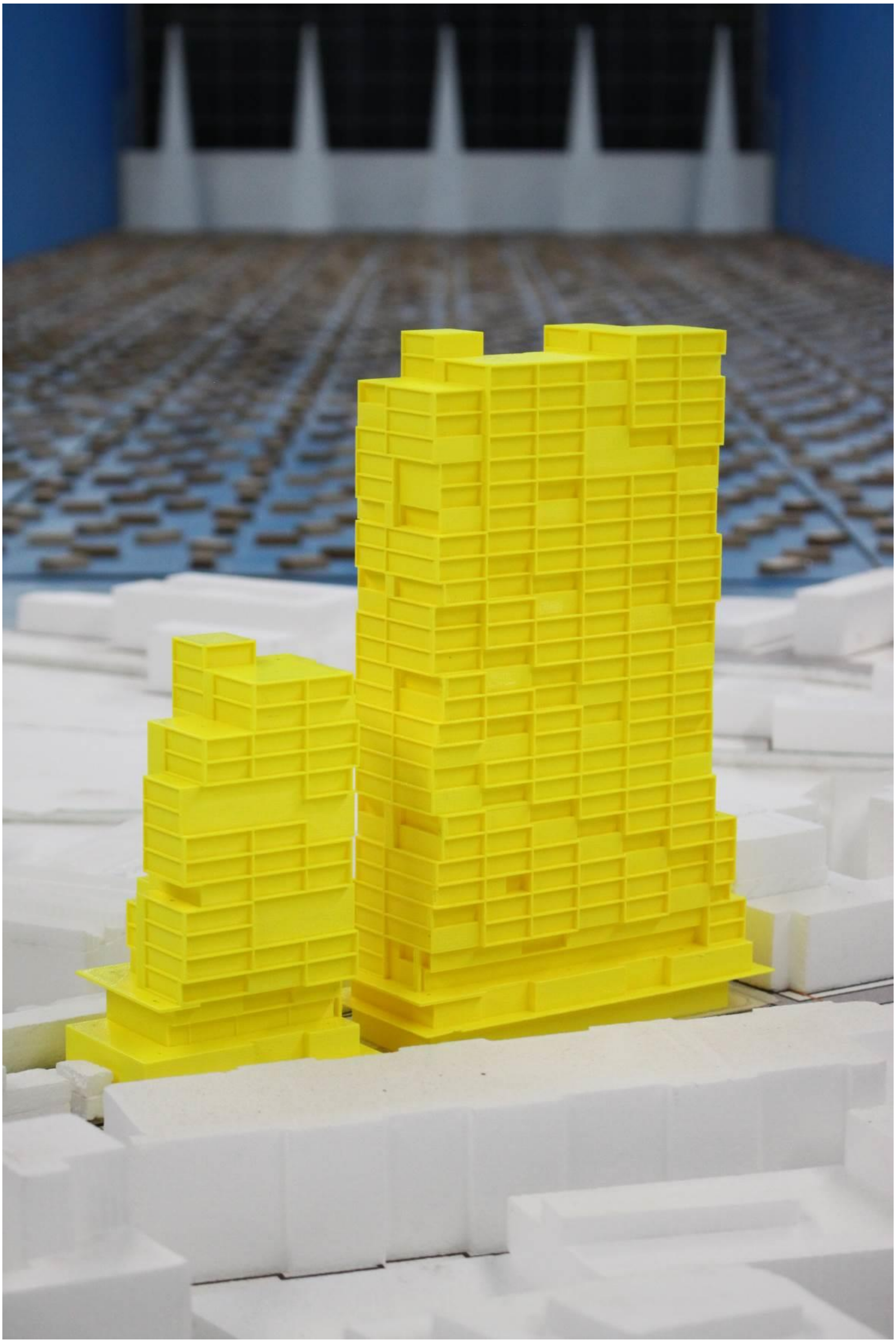


Figure 2f: Photograph of the Wind Tunnel Model – Proposed Scenario (view from the south-east)

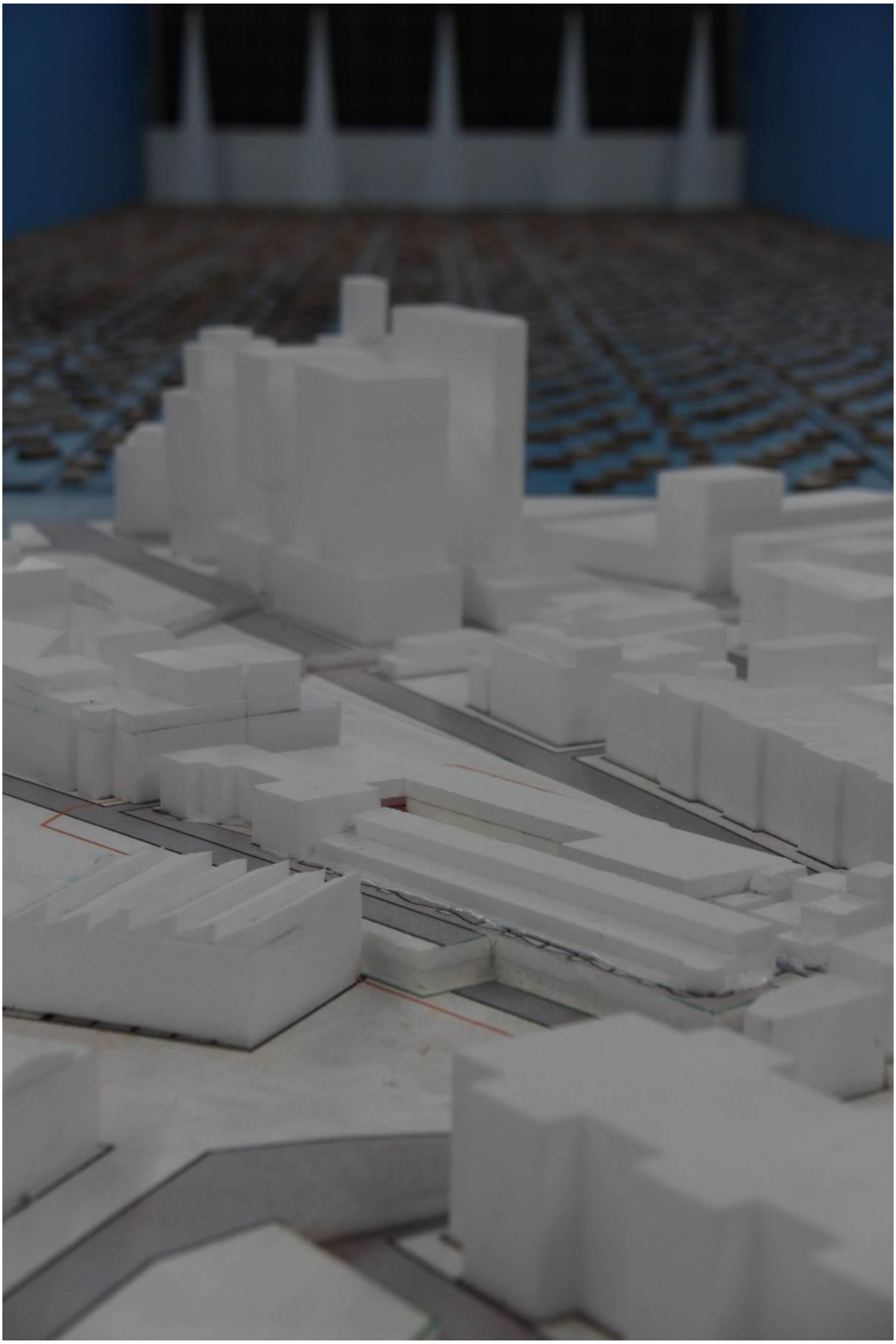


Figure 2g: Photograph of the Wind Tunnel Model – Existing Scenario (view from the south-west)

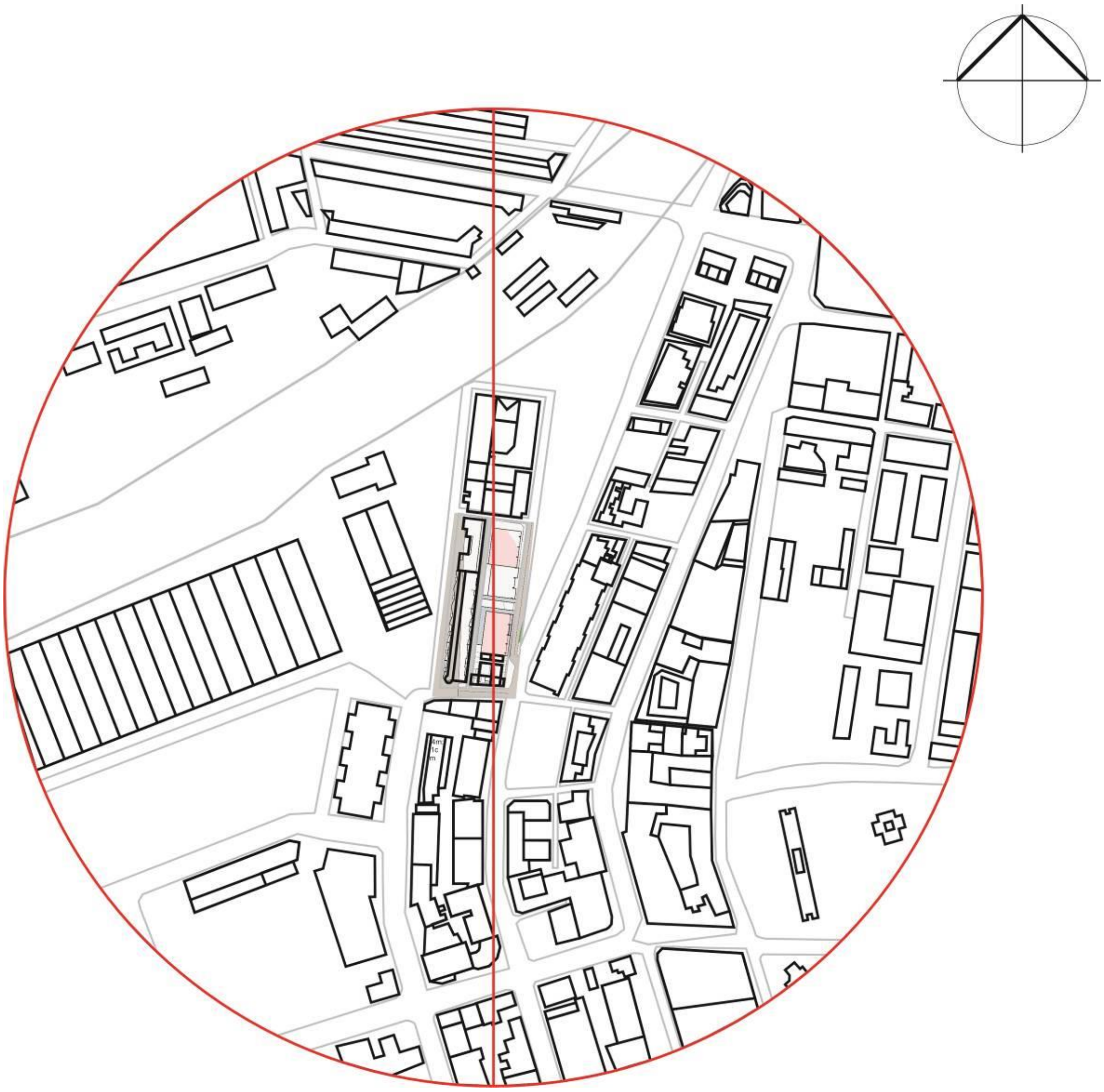


Figure 2h: Map of proximity model.

3 BOUNDARY LAYER WIND FLOW MODEL

Testing was performed using Windtech's boundary layer wind tunnel, which has a 3.0m wide working section and has a fetch length of 14m. The model was placed in the appropriate standard boundary layer wind flow for each of the prevailing wind directions for the wind tunnel testing. The type of wind flow used in a wind tunnel study is determined by a detailed analysis of the surrounding terrain types around the subject site. Details of the analysis of the surrounding terrain for this study are provided in the following pages of this report.

The roughness of the earth's surface has the effect of slowing down the prevailing wind near the ground. This effect is observed up to what is known as the *boundary layer height*, which can range between 500m to 3km above the earth's surface depending on the roughness of the surface (i.e. oceans, open farmland, dense urban cities, etc.). Within this range, the prevailing wind forms what is known as a *boundary layer wind profile*.

Various wind codes and standards classify various types of boundary layer wind flows depending on the surface roughness. However, it should be noted that the wind profile does not change instantly due to changes in the terrain roughness. It can take many kilometres (at least 100km) of a constant surface roughness for the boundary layer profile to achieve a state of equilibrium. Descriptions of the standard boundary layer profiles for various terrain types are summarised as follows (in accordance with AS/NZS1170.2.2011):

- **Terrain Category 1.0:** Extremely flat terrain. Examples include enclosed water bodies such as lakes, dams, rivers, bays, etc.
- **Terrain Category 1.5:** Relatively flat terrain. Examples include the open ocean, deserts and very flat open plains.
- **Terrain Category 2.0:** Open terrain. Examples include grassy fields and plains and open farmland (without buildings or trees).
- **Terrain Category 2.5:** Relatively open terrain. Examples include farmland with scattered trees and buildings and very low-density suburban areas.
- **Terrain Category 3.0:** Suburban and forest terrain. Examples include suburban areas of towns and areas with dense vegetation such as forests, bushland, etc.
- **Terrain Category 3.5:** Relatively dense suburban terrain. Examples include centres of small cities, industrial parks, etc.
- **Terrain Category 4.0:** Dense urban terrain. Examples include CBD's of large cities with many high-rise towers, and areas with many closely-spaced mid-rise buildings.

For this study, the shape of the boundary layer wind flows over standard terrain types is defined in accordance with Deaves & Harris (1978). These are summarised in Table 2, referenced to the study reference height of 47.8m above ground.

Table 2: Terrain and Height Multipliers, Turbulence Intensities, and Corresponding Roughness Lengths, for the Standard Boundary Layer Profiles (referenced to the study reference height)

Terrain Category	Terrain and Height Multipliers $k_{tr,T=3600s}$ (hourly)	$k_{tr,T=600s}$ (10-minute)	$k_{tr,T=3s}$ (3-second)	Turbulence Intensity I_v	Roughness Length (m) $z_{0,r}$
1.0	0.96	0.99	1.28	0.112	0.003
1.5	0.90	0.93	1.25	0.128	0.01
2.0	0.84	0.88	1.21	0.147	0.03
2.5	0.77	0.81	1.17	0.174	0.1
3.0	0.69	0.73	1.12	0.208	0.3
3.5	0.58	0.62	1.04	0.265	1
4.0	0.46	0.51	0.96	0.355	3

An analysis of the effect of changes in the upwind terrain roughness was carried out for each of the wind directions studied. This has been undertaken based on the method given in AS/NZS1170.2:2011, which uses a "fetch" length of 40 times the study reference height. However, it should be noted that this "fetch" commences *beyond* a "lag distance" area, which has a length of 20 times the study reference height (in accordance with AS/NZS1170.2:2011), so the actual "fetch" of terrain analysed is the area between 20 and 60 times the study reference height away from the site. An aerial image showing the surrounding terrain is presented in Figure 3 for a radius of 3.0km from the edge of the wind tunnel proximity model. The resulting mean and gust terrain and height multipliers at the site location are presented in Table 3, referenced to the study reference height.

Table 3: Directional Terrain and Height Multipliers at the Site (at the study reference height, as per the AS/NZS1170.2:2011 boundary layer transition methodology)

Wind Sector (degrees)	$k_{tr,T=3600s}$ (hourly mean)	$k_{tr,T=600s}$ (10-minute mean)	$k_{tr,T=3s}$ (3-second gust)
0	0.64	0.68	1.08
30	0.60	0.64	1.05
60	0.69	0.73	1.12
90	0.75	0.79	1.16
120	0.66	0.70	1.10
150	0.62	0.67	1.07
180	0.58	0.62	1.04
210	0.66	0.71	1.10
240	0.69	0.73	1.12
270	0.69	0.73	1.12
300	0.64	0.68	1.08
330	0.73	0.77	1.14

For each of the 16 wind directions tested in this study, the approaching boundary layer wind profiles modelled in the wind tunnel matched the model scale and the overall surrounding terrain characteristics beyond the 375m radius of the proximity model. Plots of the wind tunnel boundary layer wind profiles are presented in Appendix B of this report.

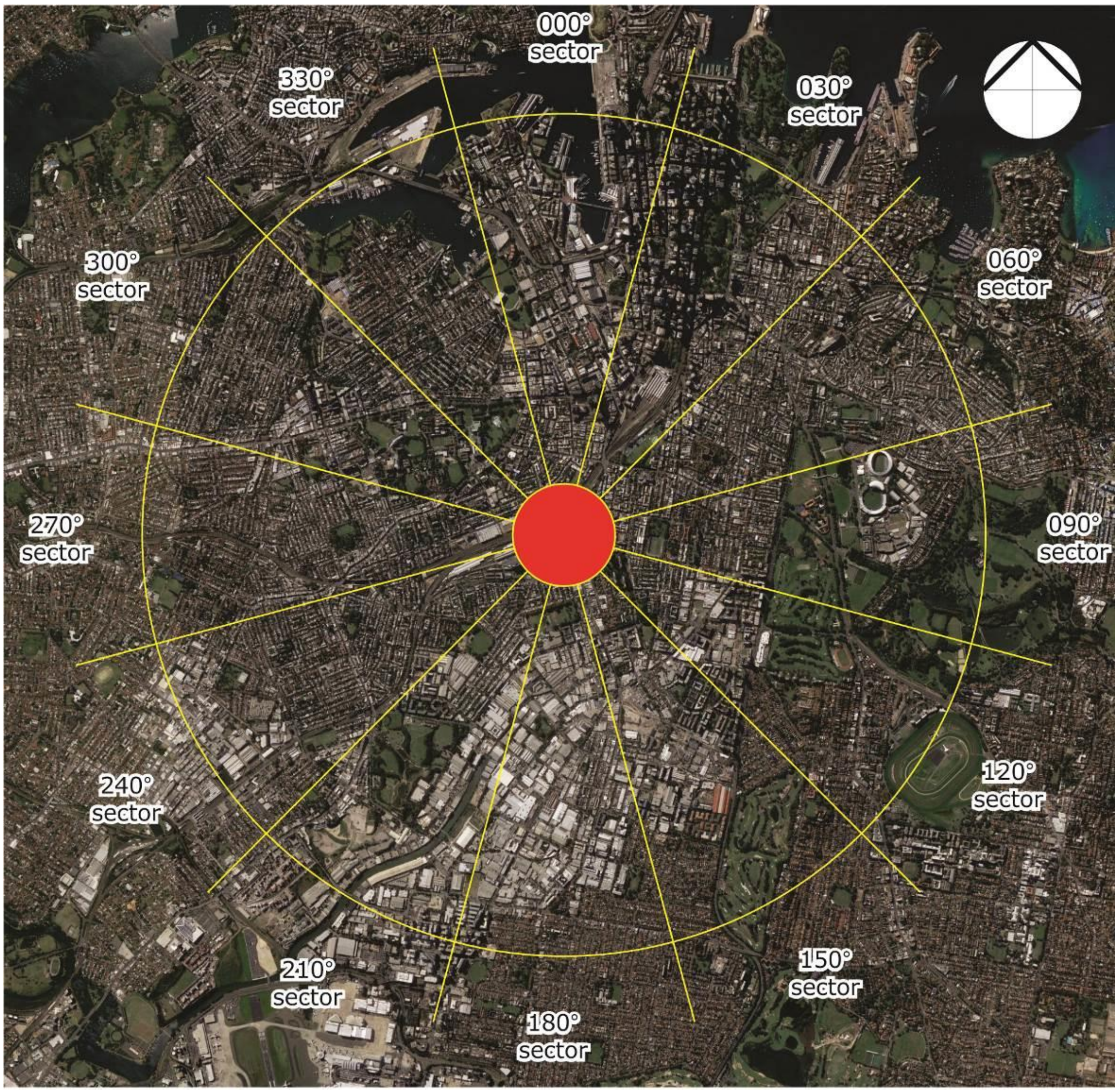


Figure 3: Aerial Image showing the Surrounding Terrain
(radius of 3.0km from the edge of the proximity model, which is coloured red)

4 ENVIRONMENTAL WIND SPEED CRITERIA

4.1 Wind Effects on People

The acceptability of wind in any area is dependent upon its use. For example, people walking or window-shopping will tolerate higher wind speeds than those seated at an outdoor restaurant. Various other researchers, such as A.G. Davenport, T.V. Lawson, W.H. Melbourne, A.D. Penwarden, etc., have published criteria for pedestrian comfort for pedestrians in outdoor spaces for various types of activities. These are discussed in the following sub-sections of this report.

4.1.1 A.D. Penwarden (1975) Criteria for Gust Wind Speeds

The following table developed by A.D. Penwarden (1975) is a modified version of the Beaufort Scale, and describes the effects of various wind intensities on people. Note that the applicability column related to wind conditions occurring frequently (a probability of exceedance of 5%). Higher ranges of wind speeds can be tolerated for rarer events.

Table 4: Summary of Wind Effects on People (after A.D. Penwarden, 1975)

Type of Winds	Beaufort Number	Mean Wind Speed (m/s)	Effects
Calm, light air	1	0 - 1.5	Calm, no noticeable wind
Light breeze	2	1.6 - 3.3	Wind felt on face
Gentle breeze	3	3.4 - 5.4	Hair is disturbed, Clothing flaps
Moderate breeze	4	5.5 - 7.9	Raises dust, dry soil and loose paper - Hair disarranged
Fresh breeze	5	8.0 – 10.7	Force of wind felt on body
Strong breeze	6	10.8 – 13.8	Umbrellas used with difficulty, Hair blown straight, Difficult to walk steadily, Wind noise on ears unpleasant.
Near gale	7	13.9 – 17.1	Inconvenience felt when walking.
Gale	8	17.2 - 20.7	Generally impedes progress, Great difficulty with balance.
Strong gale	9	20.8 – 24.4	People blown over by gusts.

4.1.2 A.G. Davenport (1972) Criteria for Mean Wind Speeds

A.G. Davenport (1972) had also determined a set of criteria in terms of the Beaufort Scale and for various return periods. The values presented in Table 5 below are based on a probability of exceedance of 5%.

Table 5: Criteria by A.G. Davenport (1972)

Classification	Activities	Maximum Mean (5% exceedance)
Walking Fast	Acceptable for walking, main public accessways.	7.5 m/s < $\overline{V}$ < 10.0 m/s
Strolling, Skating	Slow walking, etc.	5.5 m/s < $\overline{V}$ < 7.5 m/s
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	3.5 m/s < $\overline{V}$ < 5.5 m/s
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	$\overline{V}$ < 3.5 m/s

4.1.3 T.V. Lawson (1975) Criteria for Mean Wind Speeds

In 1973, T.V. Lawson quotes that A.D. Penwarden's Beaufort 4 wind speeds (as listed in Table 3) would be acceptable if it is not exceeded for more than 4% of the time; and a Beaufort 6 as being unacceptable if it is exceeded more than 2% of the time. Later, in 1975, T.V. Lawson presented a set of criteria very similar to those of A.G. Davenport's. These are presented in Tables 6 and 7.

Table 6: Safety Criteria by T.V. Lawson (1975)

Classification	Activities	Annual Maximum Mean
Safety (all weather areas)	Accessible by the general public.	15 m/s
Safety (fair weather areas)	Private outdoor areas (balconies, terraces, etc.)	20 m/s

Table 7: Comfort Criteria by T.V. Lawson (1975)

Classification	Activities	95 Percentile Maximum Mean
Business Walking	Objective Walking from A to B.	8 m/s < $\overline{V}$ < 10m/s
Pedestrian Walking	Slow walking, etc.	6 m/s < $\overline{V}$ < 8 m/s
Short Exposure Activities	Pedestrian standing or sitting for short times.	4 m/s < $\overline{V}$ < 6 m/s
Long Exposure Activities	Pedestrian sitting for a long duration.	$\overline{V}$ < 4 m/s

4.1.4 W.H. Melbourne (1978) Criteria for Gust Wind Speeds

W.H. Melbourne (1978) introduced a set of criteria for the assessment of environmental wind conditions, which were developed for a temperature range of 10°C to 30°C and for people suitably dressed for outdoor conditions. These criteria are based on maximum gust wind speeds with an annual probability of exceedance, and are outlined in Table 8 below. It should be noted that this criteria tends to be more conservative than criteria suggested by other researchers.

Table 8: Criteria by W.H. Melbourne (1978)

Classification	Human Activities	Annual Maximum Gust
Limit for safety	Completely unacceptable: people likely to get blown over.	$\hat{V}$ > 23m/s
Marginal	Unacceptable as main public accessways.	23 m/s > $\hat{V}$ > 16 m/s
Comfortable Walking	Acceptable for walking, main public accessways	16 m/s > $\hat{V}$ > 13 m/s
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	13 m/s > $\hat{V}$ > 10 m/s
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	10 m/s > $\hat{V}$

4.2 Comparison of the Various Wind Speed Criteria

The criteria by W.H. Melbourne (1978) mentioned in Table 8, and criteria from other researchers, are compared on a probabilistic basis in Figure 4. This indicates that the criteria by W.H. Melbourne (1978) are quite conservative. This was also observed by A.W. Rofail (2007) when undertaking on-site remedial studies, who concluded that the criteria by W.H. Melbourne (1978) generally overstates the wind effects in a typical urban setting, which is caused by the assumption by W.H. Melbourne of a fixed 15% turbulence intensity for all areas. This value tends to be at the lower end of the range of turbulence intensities, and the A.W. Rofail (2007) study found that, in an urban setting, the range of the *minimum* turbulence intensities is typically in the range of 20% to 60%.

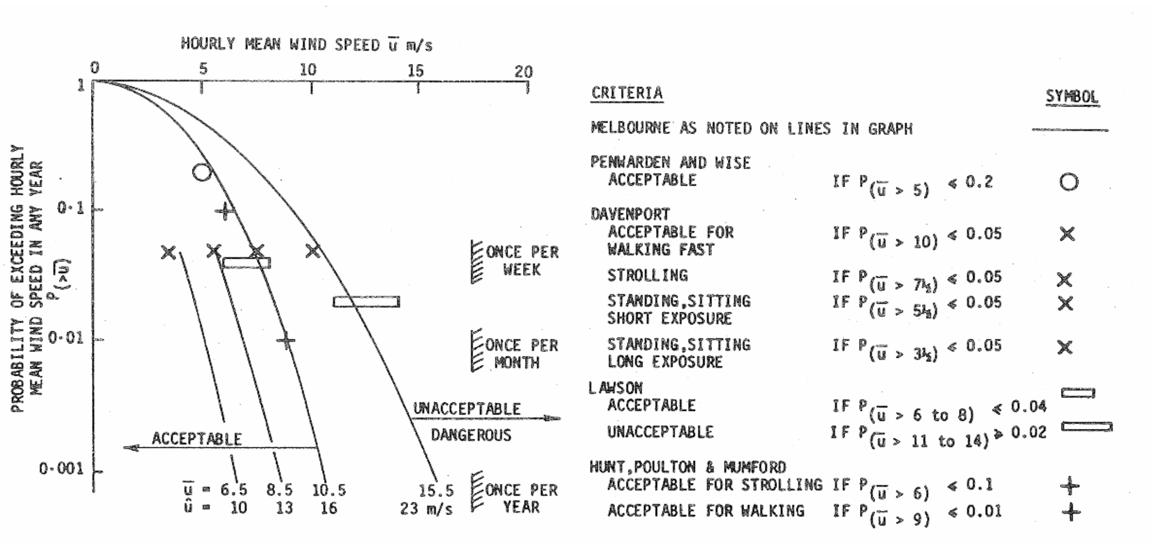


Figure 4: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (after W.H. Melbourne, 1978)

4.3 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 City of Sydney Development Control Plan 2012 (SDCP2012) in accordance with the Draft Sydney Development Control Plan 2012 - Central Sydney Planning Review Amendment. For comfort, the Draft Sydney DCP 2012 - Central Sydney Planning Review Amendment requires that the hourly mean wind speed, or gust equivalent mean wind speed (GEM), whichever is greater for each wind direction, must not exceed 8m/s for comfortable walking, 6m/s for standing and 4m/s for sitting based on 5% probability of exceedance.

In addition, the safety limit is based on an annual maximum 0.5 second gust wind speed of 24m/s is applied to all areas.

The existing conditions for the pedestrian footpaths around the site are also analyzed 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 with an upper limit bound of the safety limit criterion of 24m/s for the annual maximum 0.5 second gust wind speeds.

The basic criteria for a range of outdoor activities are described as follows:

- **City of Sydney DCP 2012 in accordance with the Draft Sydney DCP 2012 - Central Sydney Planning Review Amendment Requirement for Wind Comfort Standards for Comfortable Walking, Standing, Sitting and Safety:**
    - 8m/s gust equivalent mean wind speed for comfortable walking.
    - 6m/s gust equivalent mean wind speed for standing.
    - 4m/s gust equivalent mean wind speed for sitting.
    - Safety Limit: 24m/s maximum 0.5 second gust wind speeds.
- **Existing Conditions:** Where relevant, if the existing site conditions exceed the City of Sydney DCP (2012) criterion, then the target wind speed for that area with the inclusion of the proposed development is to at least match the existing site conditions, and should be less than the 24m/s safety limit criterion.

The results of the wind tunnel study are summarised in the following section, and presented in the form of directional plots attached in Appendix A of this report. Each study point has 2 plots: one comparing to the Draft Sydney DCP 2012 - Central Sydney Planning Review Amendment criteria for the maximum GEM wind speeds (5% probability of exceedance), and the other comparing to the Draft Sydney DCP 2012 - Central Sydney Planning Review Amendment criteria for the annual maximum 0.5 second gust wind speeds.

Note that Section 5.1.9 of the Draft Sydney DCP 2012 – Central Sydney Planning Review Amendment prevails over Section 3.2.6 in Sydney Development Control Plan 2012 - Section 3: General Provisions.

Notes:

- The GEM is defined as the maximum of the mean wind speed and the gust wind speed divided by a gust factor of 1.85.
- The gust wind speed is defined as 3.0 standard deviations from the mean for a 3 second gust duration, or 3.4 standard deviations from the mean for a 0.5 second gust duration.
- Sitting applies to outdoor areas that involve seating such as dining areas in restaurants, amphitheatres, etc as well as outdoor Public Spaces protected by Sun Access Planes and Overshadowing Controls.
- Standing applies typically to areas where short duration stationary activities are involved (less than 1 hour). This includes window shopping, waiting areas, etc.
- Walking applies typically to areas used mainly for pedestrian thoroughfares. This also includes private swimming pools, communal areas, and private balconies and terraces.
- In all areas, the wind conditions are also checked against the safety limit.

5 TEST PROCEDURE AND METHODOLOGY

5.1 Measurement of the Velocity Coefficients

Testing was performed using Windtech's boundary layer wind tunnel facility, which has a 3.0m wide working section and has a fetch length of 14m. The test procedures followed for the wind tunnel testing performed for this study generally adhere to the guidelines set out in the Australasian Wind Engineering Society Quality Assurance Manual (AWES-QAM-1-2017), ASCE 7-10 (Chapter C31), and CTBUH (2013) guidelines.

The model of the subject development was setup within the wind tunnel, and the wind velocity measurements were monitored using Dantec hot-wire probe anemometers at selected critical outdoor locations at a full-scale height of approximately 1.5m above ground/slab level. The probe support for each study location was mounted such that the probe wire was vertical as much as possible, which ensures that the measured wind speeds are independent of wind direction along the horizontal plane. In addition, care was taken in the alignment of the probe wire and in avoiding wall-heating effects. Wind speed measurements are made in the wind tunnel for 16 wind directions, at 22.5° increments. The output from the hot-wire probes was obtained using a National Instruments 12-bit data acquisition card. A sample rate of 1024Hz was used, which is more than adequate for the given frequency band.

The mean and the maximum peak gust velocity coefficients are derived from the wind tunnel test by the following relation:

$$\hat{C}_V = \overline{C}_V + g.\sigma_V \qquad (5.1)$$

where: $\hat{C}_V$ is the gust velocity coefficient.

$\overline{C}_V$ is the mean velocity coefficient.

g is the gust factor, which is taken to be 3.0 for a 3-second gust duration, or 3.4 for a 0.5-second gust duration..

σ_V is the standard deviation of the velocity measurement.

The mean free-stream wind speed measured in the wind tunnel for this study was approximately 9.6m/s. Note that the measurement location for the mean free-stream wind speed is at a height of 200m at the upwind edge of the proximity model. A sample length of 16 seconds was used for each wind direction tested, which is equivalent to a minimum sample time of approximately 39 minutes in full-scale for the maximum gust wind speeds, which is suitable for this type of study.

5.2 Calculation of the Full-Scale Results

To determine if the wind conditions at each study point location will satisfy the relevant criteria for pedestrian comfort and safety, the measured velocity coefficients need to be combined with information about the local wind climate. The aim of combining the wind tunnel measurements with wind climate information is to determine the probability of exceedance of a given wind speed at the site. The local wind climate is normally described using a statistical model, which relates wind speed to a probability of exceedance. Details of the wind climate model used in this study are outlined in Section 1.

A feature of this process is to include the impact of wind directionality, which includes any local variations in wind speed or frequency with wind direction. This is important as the wind directions which produce the highest wind speed events for a region may not coincided with the most wind exposed direction at the site.

The methodology adopted for the derivation of the full-scale results for the maximum gust and the GEM wind speeds are outlined in the following sub-sections.

5.2.1 Maximum Gust Wind Speeds

The full-scale maximum gust wind speed at each study point location is derived from the measured velocity coefficient using the following relationship:

$$V_{study} = V_{ref,RH} \left(\frac{k_{200m,tr,T=3600s}}{k_{RH,tr,T=3600s}} \right) C_V \qquad (4.2)$$

V_{study} is the full-scale wind velocity at the study point location, in m/s.

$V_{ref,RH}$ is the full-scale reference wind speed at the upwind edge of the proximity model at the study reference height. This value is determined by combining the directional wind speed data for the region (detailed in Section 1) and the upwind terrain and height multipliers for the site (detailed in Section 3).

$k_{200m,tr,T=3600s}$ is the hourly mean terrain and height multiplier at 200m for the standard terrain category setup used in the wind tunnel tests.

$k_{RH,tr,T=3600s}$ is the hourly mean terrain and height multiplier at the study reference height (see Table 3).

C_V is the velocity coefficient measurement obtained from the hot-wire anemometer, which is derived from the following relationship:

$$C_V = \frac{C_{V,study}}{C_{V,200m}} \qquad (4.3)$$

$C_{V,study}$ is the velocity coefficient measurement obtained from the hot-wire anemometer at the study point location.

$C_{V,200m}$ is the measurement obtained from the hot-wire anemometer at the free-stream reference location at 200m height upwind of the model in the wind tunnel.

The value of $V_{ref,RH}$ varies with each prevailing wind direction. Wind directions where there is a high probability that a strong wind will occur will have a higher directional wind speed than other directions. To determine the directional wind speeds, a probability level must be assigned for each wind direction. These probability levels are set following the approach used in AS/NZS1170.2:2011, which assumes that the major contributions to the combined probability of exceedance of a typical load effect comes from only two 45 degree sectors.

5.2.2 Maximum Gust-Equivalent Mean Wind Speeds

The contribution to the probability of exceedance of a specified wind speed (i.e. the desired wind speed for pedestrian comfort, as per the criteria) is calculated for each wind direction. These contributions are then combined over all wind directions to calculate the total probability of exceedance of the specified wind speed. To calculate the probability of exceedance for a specified wind speed a statistical wind climate model was used to describe the relationship between directional wind speeds and the probability of exceedance. A detailed description of the methodology is given by Lawson (1980).

The criteria used in this study, is referenced to a probability of exceedance of 5% of a specified wind speed.

5.3 Layout of Study Points

For this study a total of 44 study point locations have been selected for analysis in the wind tunnel. This includes the following It should be noted that only the most critical outdoor locations of the development have been selected for analysis.:

- 15 study points located on the Ground Level pedestrian footpath, potential seating areas and entrances
- 26 study points located on various terraces and balconies on Levels 3, 5, 9, 16, 18, N29 and N30.
- 3 study points located in surrounding areas further away from the proposed development site to determine any impact on these surrounding conditions.

The locations of the various study points tested for this study are presented in Figures 5a to 5i in the form of marked-up plan drawings, along with the wind speed criteria that each study point should satisfy.

Target Criteria

City of Sydney DCP in accordance with Draft Sydney DCP 2012- Central Planning Review amendment:
- Wind Comfort Standard for Walking of 8 metres per second.
- Safety Limit of 24m/s (gusts).

City of Sydney DCP in accordance with Draft Sydney DCP 2012- Central Planning Review amendment:
- Wind Comfort Standard for Standing of 6 metres per second.
- Safety Limit of 24m/s (gusts).

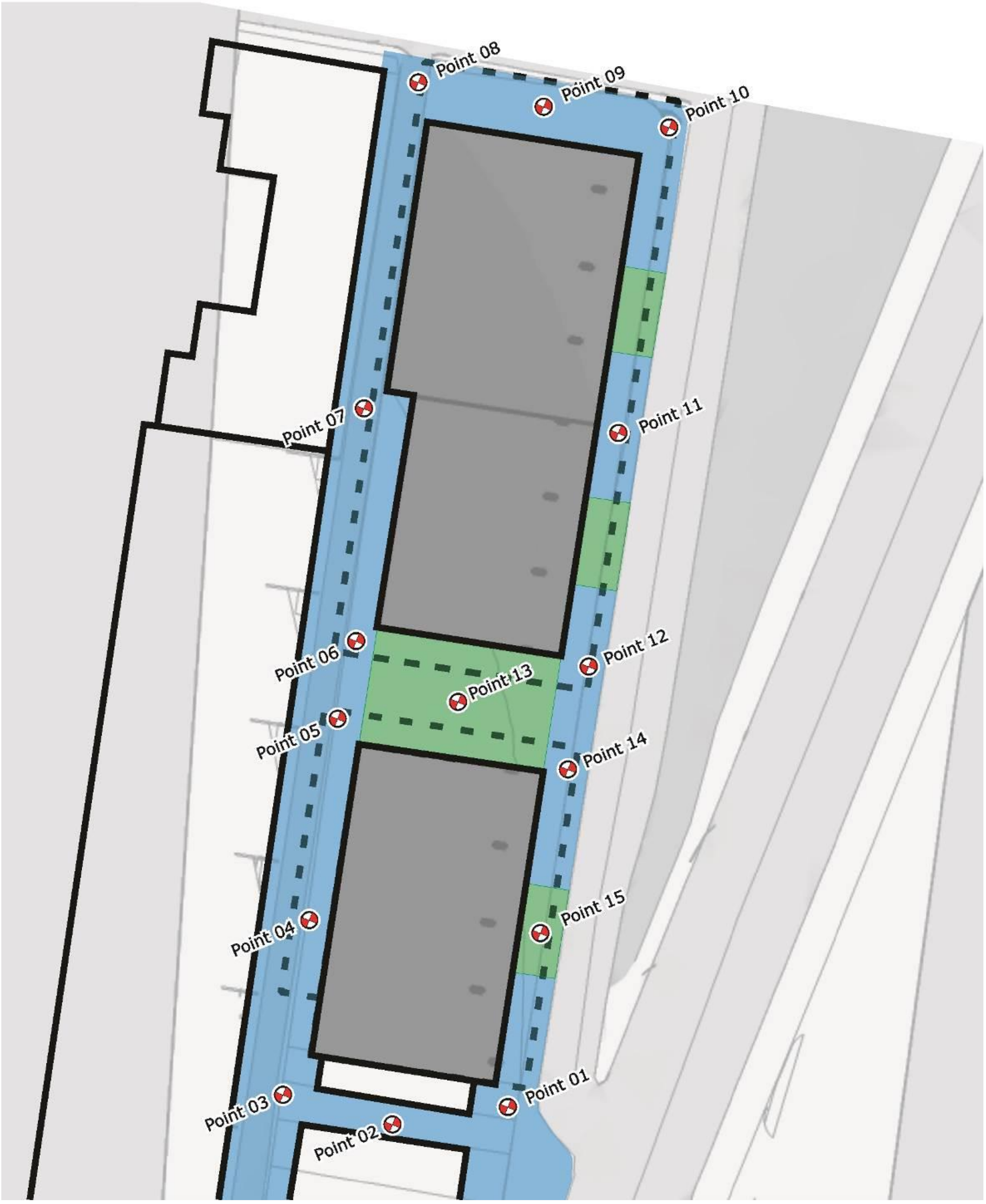


Figure 5a: Study Point Locations and Target Wind Speed Criteria – Level 1

Target Criteria

City of Sydney DCP in accordance with Draft Sydney DCP 2012- Central Planning Review amendment:
- Wind Comfort Standard for Standing of 6 metres per second.
- Safety Limit of 24m/s (gusts).

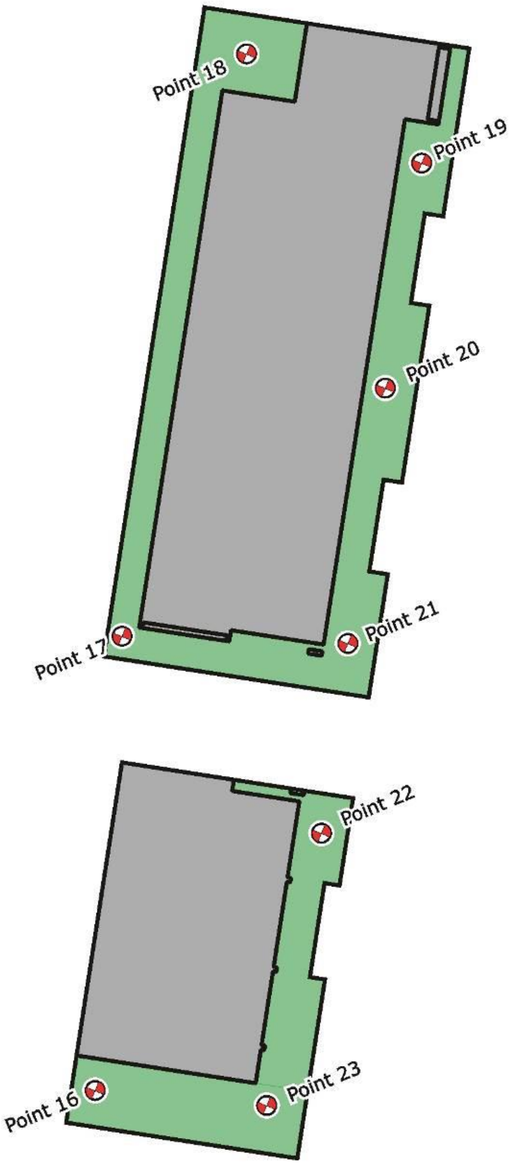


Figure 5b: Study Point Locations and Target Wind Speed Criteria –Level 3

Target Criteria

- (blue) City of Sydney DCP in accordance with Draft Sydney DCP 2012- Central Planning Review amendment:
  - Wind Comfort Standard for Standing of 8 metres per second.
  - Safety Limit of 24m/s (gusts).
- (green) City of Sydney DCP in accordance with Draft Sydney DCP 2012- Central Planning Review amendment:
  - Wind Comfort Standard for Standing of 6 metres per second.
  - Safety Limit of 24m/s (gusts).

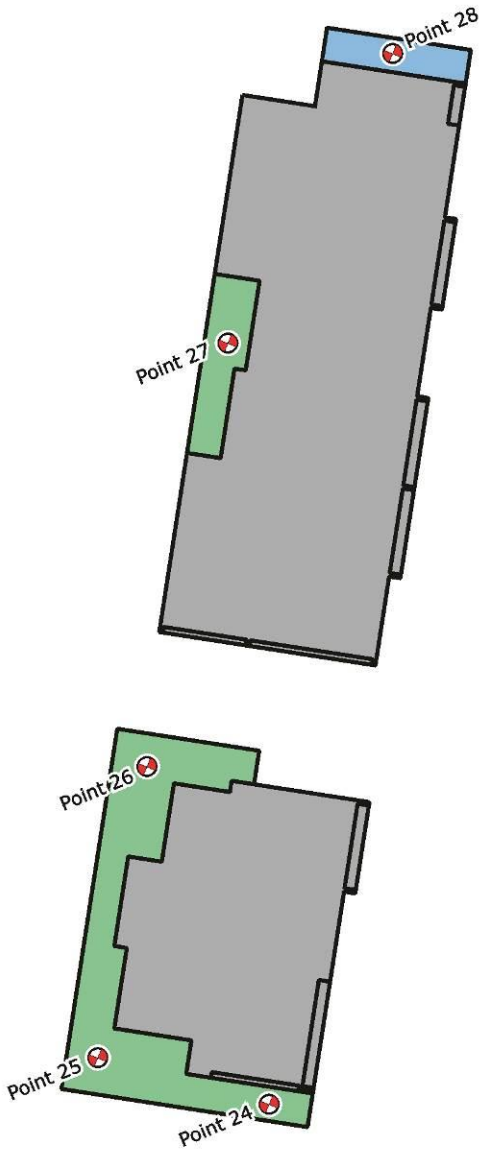
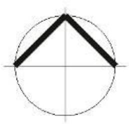


Figure 5c: Study Point Locations and Target Wind Speed Criteria – Level 5

Target Criteria

(blue)	City of Sydney DCP in accordance with Draft Sydney DCP 2012- Central Planning Review amendment: - Wind Comfort Standard for Standing of 8 metres per second. - Safety Limit of 24m/s (gusts).
(green)	City of Sydney DCP in accordance with Draft Sydney DCP 2012- Central Planning Review amendment: - Wind Comfort Standard for Standing of 6 metres per second. - Safety Limit of 24m/s (gusts).



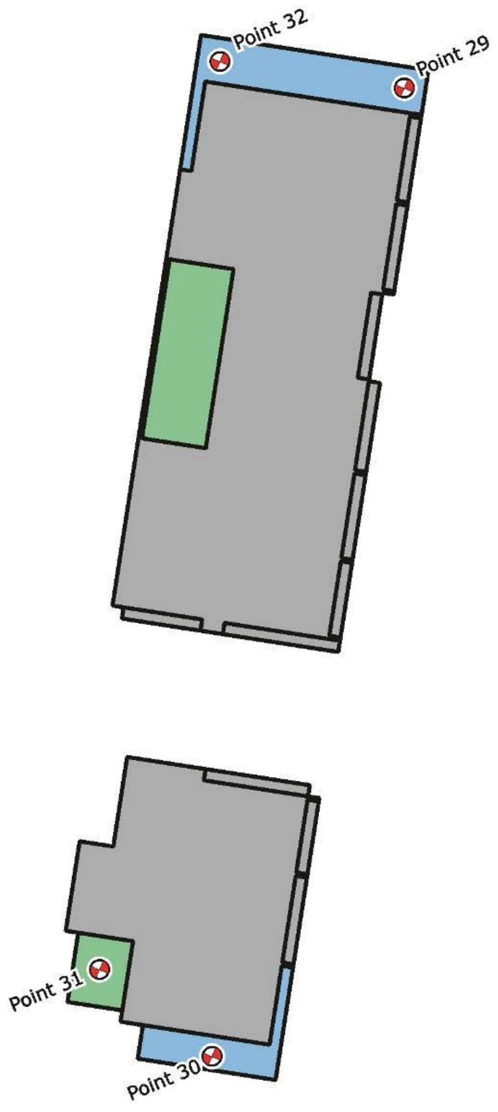


Figure 5d: Study Point Locations and Target Wind Speed Criteria –Level 9

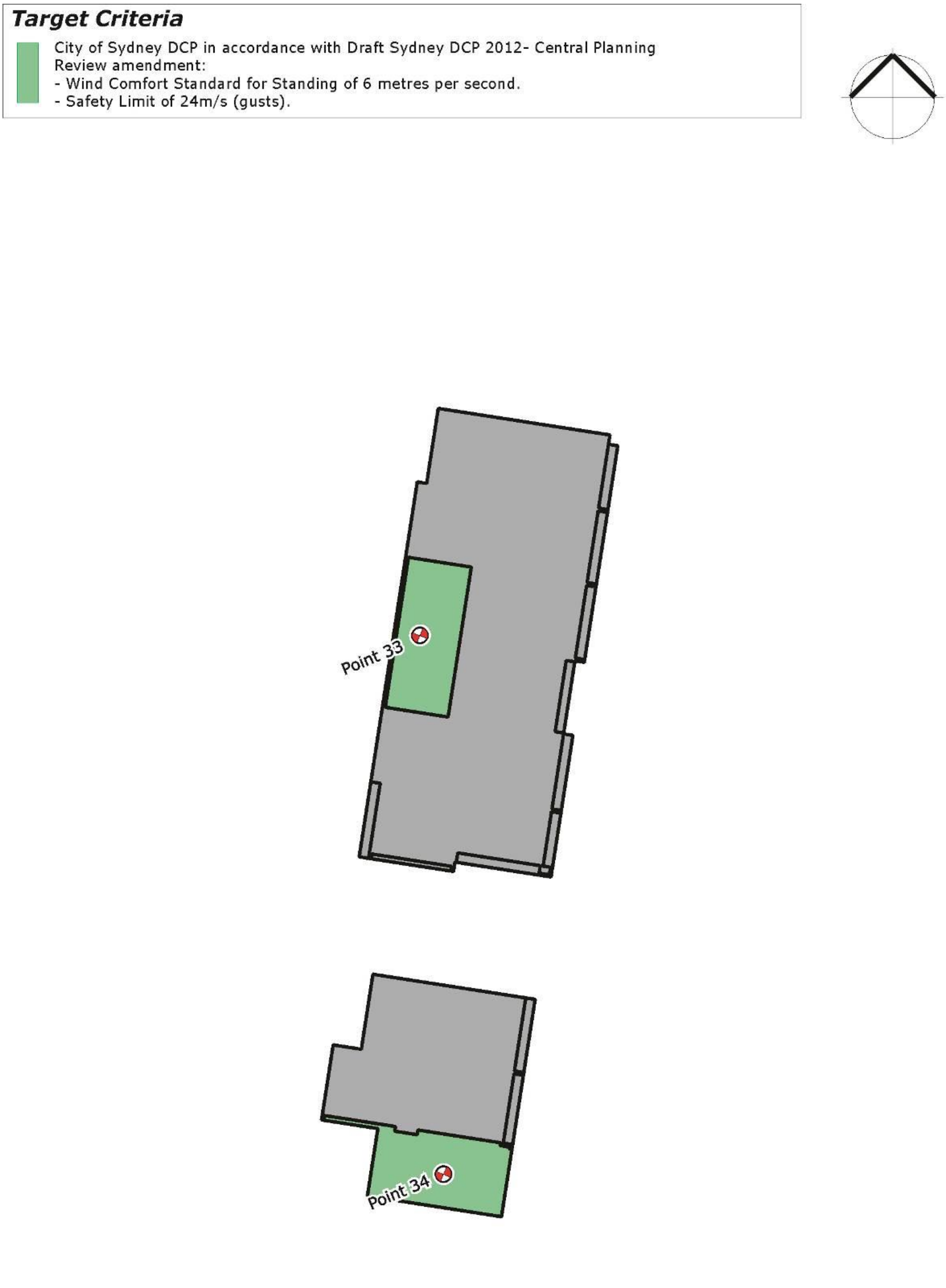


Figure 5e: Study Point Locations and Target Wind Speed Criteria –Level 16

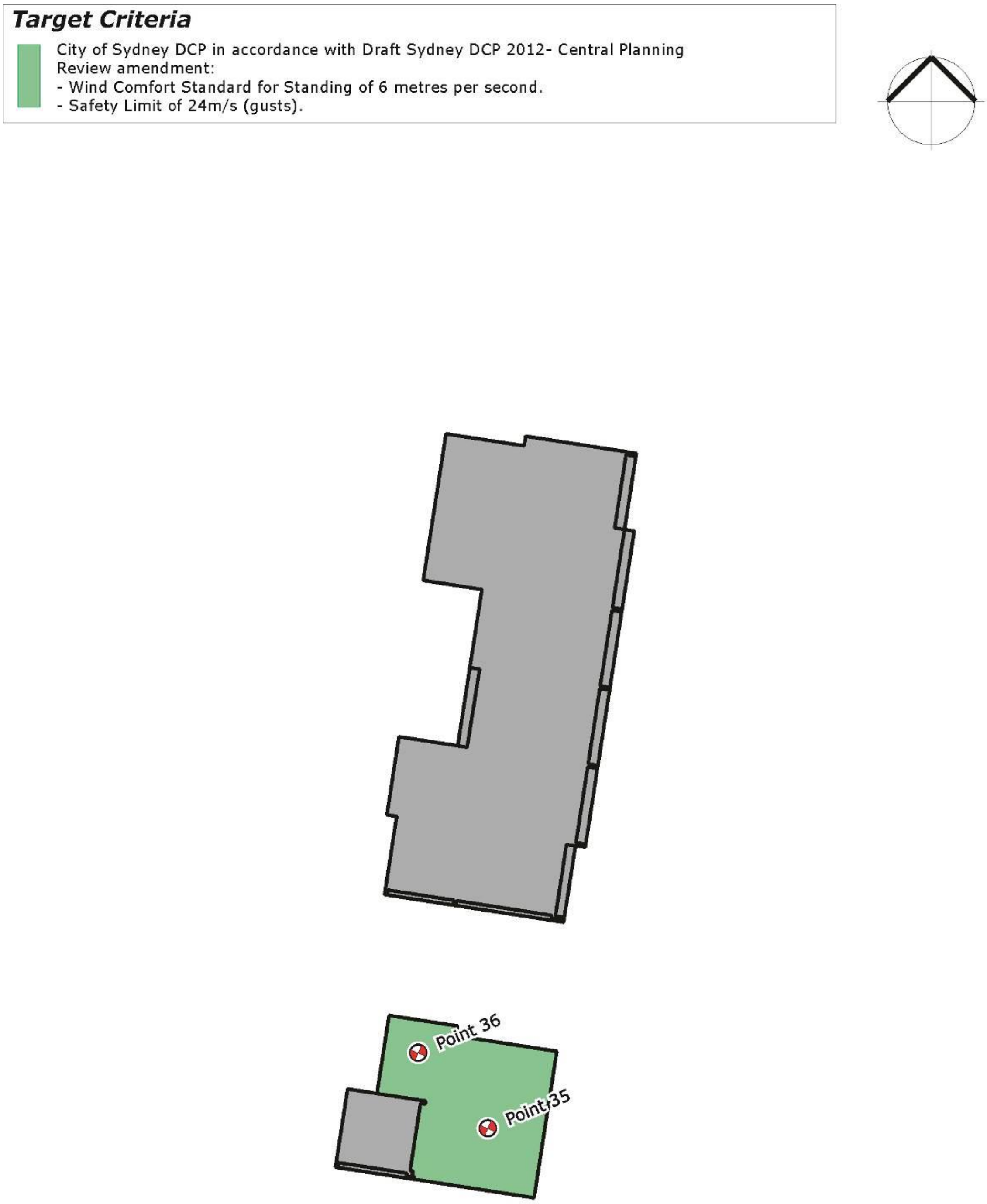


Figure 5f: Study Point Locations and Target Wind Speed Criteria –Level 18

Target Criteria

City of Sydney DCP in accordance with Draft Sydney DCP 2012- Central Planning Review amendment:
- Wind Comfort Standard for Standing of 6 metres per second.
- Safety Limit of 24m/s (gusts).

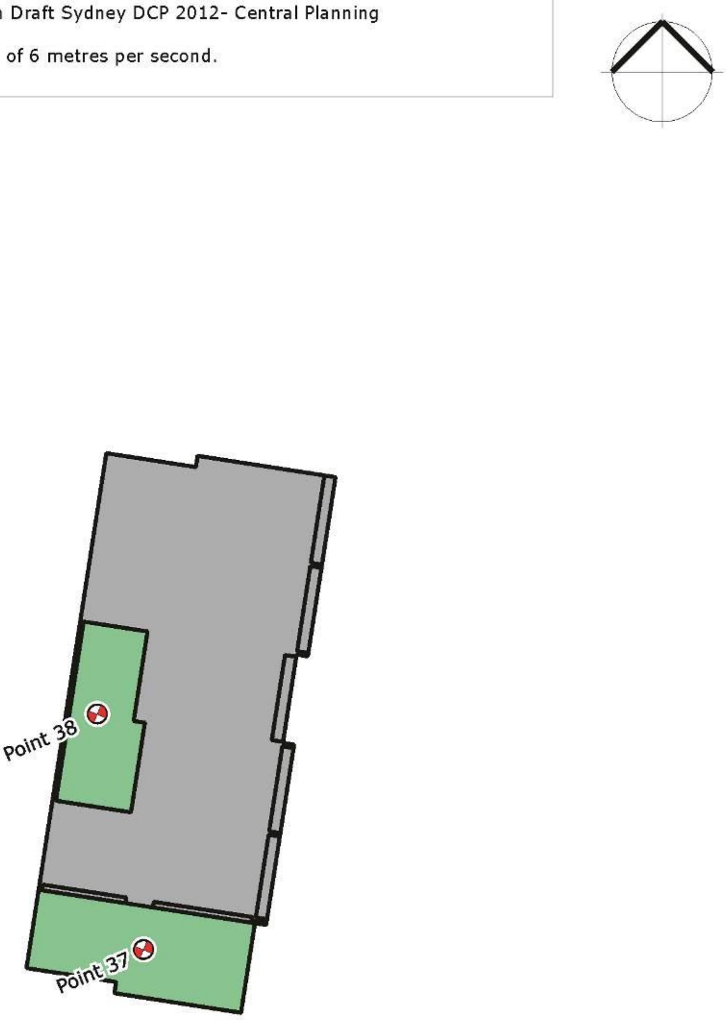
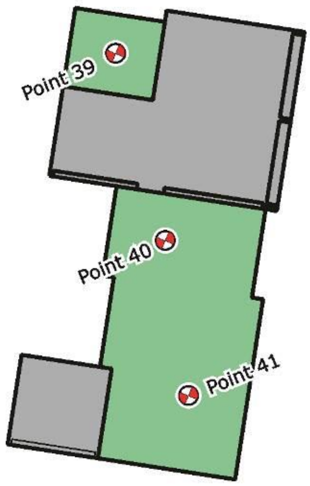


Figure 5g: Study Point Locations and Target Wind Speed Criteria –Level 29

Target Criteria

City of Sydney DCP in accordance with Draft Sydney DCP 2012- Central Planning Review amendment:
- Wind Comfort Standard for Standing of 6 metres per second.
- Safety Limit of 24m/s (gusts).



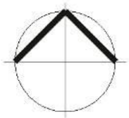


Figure 5h: Study Point Locations and Target Wind Speed Criteria –Level 30

Target Criteria

City of Sydney DCP in accordance with Draft Sydney DCP 2012- Central Planning Review amendment:
- Wind Comfort Standard for Walking of 8 metres per second.
- Safety Limit of 24m/s (gusts)

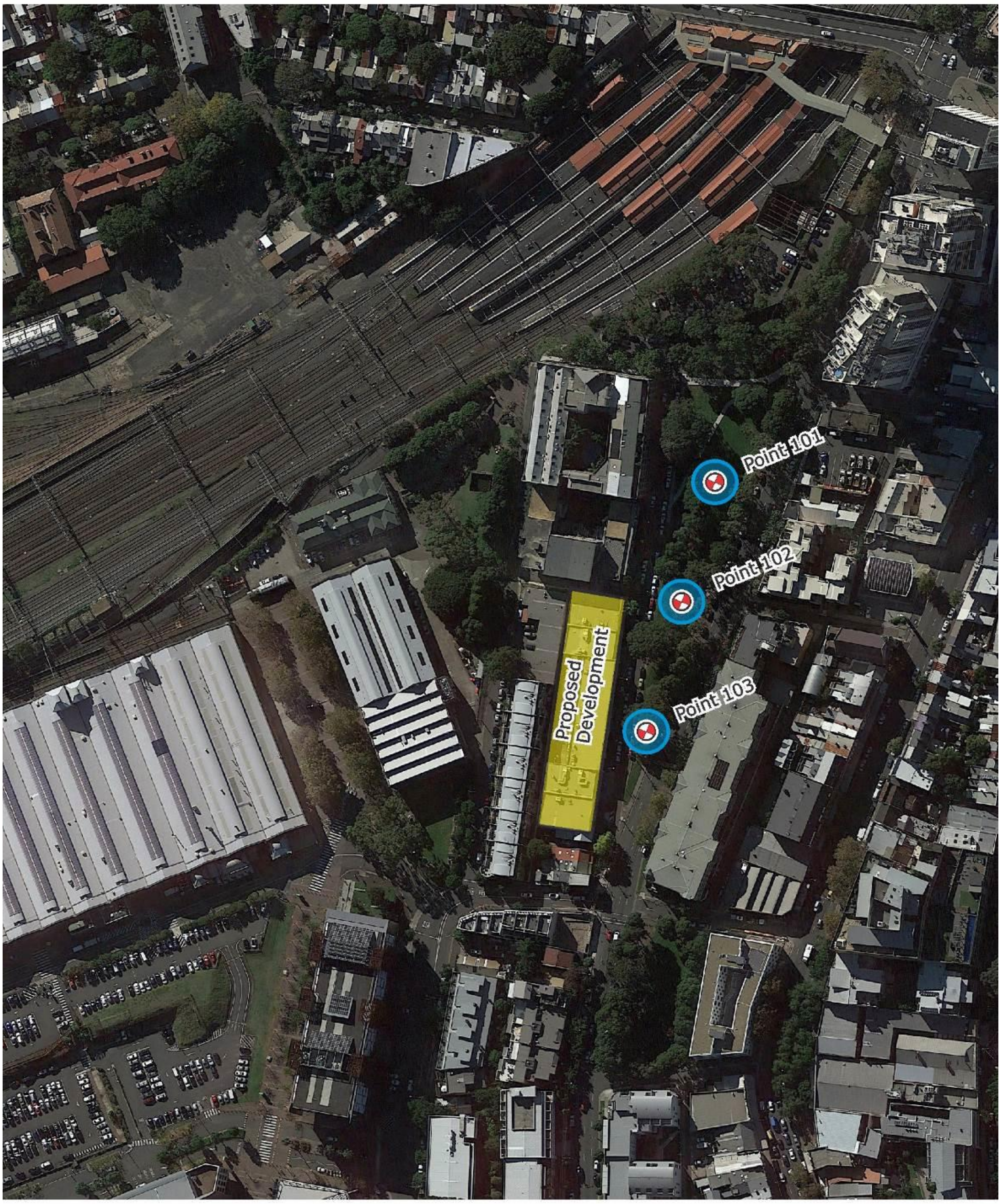


Figure 5i: Surrounding Study Points

6 RESULTS AND DISCUSSION

The model of the development was tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as screens, balustrades, etc., which are not already shown in the architectural drawings. The effect of vegetation was also excluded from the testing. If the results of the study indicate that any area is exposed to strong winds, in-principle treatments have been recommended.

The results for all study point locations are presented in the form of directional plots in Appendix A, and are summarised in Table 9 below and in Figures 6a to 6i. The wind speed criteria that the wind conditions should achieve are also listed in Table 9 for each study point location, as well as in Figures 5a to 5i.

The results of the study indicate certain locations around the site are experiencing adverse wind conditions and will require treatments to achieve the desired wind speed criteria for pedestrian comfort and safety. The main problems, occur due to the prevailing southerly and westerly winds combined with limited shielding from neighbouring buildings.

The areas subject to the adverse conditions on the Ground level include the pedestrian area along Margaret Street, the open communal area between the two towers and the south-west corner of the South building. The pedestrian area along Margaret Street as well as the communal area between the two towers are subject to the prevailing westerly winds funnelling through the narrow spaces. The area on the south-west corner of the South tower is exposed to the downwash from the prevailing westerly winds striking the ground and accelerating around the corner of the tower. This downwash also contributes to the funnelling through the communal area between the two towers.

For the elevated areas of the development, the corner balconies of the development located on both towers experience adverse wind conditions due to the prevailing winds accelerating around the corners of the buildings. Similarly, the exposed communal terraces on the upper two levels are exposed to the direct prevailing winds and consequently experience adverse conditions.

The aforementioned results of the study indicate that treatments are required for certain locations to achieve the desired wind speed criteria for pedestrian comfort and/or safety. The inclusion of the following in-principle ameliorative treatments are expected to be effective in enhancing the wind conditions. The suggested treatments are presented in Figures 7a to 7i and are also summarised as follows:

Ground Level (Levels N1 and S1):

- Inclusion of densely foliating evergreen planters capable of growing up to a height of 2m at the northwest corner of the North Tower along Margaret Street as indicated in Figure 7a.

- Inclusion of densely foliating evergreen planters capable of growing up to a height of 2m and along the west wall of both towers near Cornwallis Lane as indicated in Figure 7a.
- Inclusion of a louvered trellis or operable awning that encompasses the central area up to the heights and extents of the awnings at Rosehill Street and Cornwallis Lane. Note that the louvers should be aligned as indicated in the Figure 7a.
- Inclusion of full height porous screens in the communal area between the two towers, as well as on the northern end of the North Tower near Margaret Street. The positions of these screens is indicated in Figure 7a.

North Tower

- Inclusion of 1.8m high impermeable parapets/screens along several balconies/terraces, for Levels 3, 9, 29 and 30 as indicated in Figures 7b, 7d, 7g, and 7h.
- Inclusion of 1.8m high impermeable partitions for Level 3 as indicated in Figures 7b.
- Retention of the impermeable parapets along the western balconies of Levels 9, 13, 16, 21, 25 and 29 as indicated in Figures 7g and 7h.

South Tower

- Inclusion of 1.8m high impermeable parapets/screens along several balconies/terraces, for Levels 3, 5 and 16 as indicated in Figures 7b, 7c, 7e.
- Inclusion of 1.8m high impermeable partitions for Level 5 as indicated in Figure 7c.
- Inclusion of a full height screen along the south-west edge of the Level 3 balcony as indicated in Figure 7b.
- Inclusion of 3m high impermeable screens along the perimeter of the terrace area, located on Level 18 as indicated in Figure 7f.

With the inclusion of these treatments to the final design, it is expected that wind conditions for all outdoor trafficable areas within and around the proposed development will be suitable for their intended uses.

Table 9: Treatment Results Summary

Study Point	Desired Criterion (m/s)		Equivalent to or Better than Existing Site Wind Conditions?	Treatment Necessary to Pass?	Description of Suggested Treatment/ Notes
	GEM 5% exceedance	Safety Limit			
Point 01	8	24		NO	
Point 02	8	24	NO	NO	
Point 03	8	24	NO	YES	Dense foliating evergreen planters capable of growing up to 2m in height as indicated in Fig 7a.
Point 04	8	24		NO	
Point 05	8	24	NO	YES	Dense foliating evergreen planters capable of growing up to 2m in height and full height porous screens indicated in Fig 7a.
Point 06	8	24	NO	YES	
Point 07	8	24		NO	
Point 08	8	24	NO	YES	Dense foliating evergreen planters capable of growing up to 2m in height as indicated in Fig 7a.
Point 09	8	24	NO	YES	Full height porous screens indicated in Fig 7a.
Point 10	8	24	NO	YES	
Point 11	6	24	YES	NO	
Point 12	8	24		NO	
Point 13	6	24		YES	Full height porous screens and a trellis/ operable awning indicated in Figure 7a.
Point 14	8	24		NO	
Point 15	6	24		NO	
Point 16	6	24		YES	Impermeable 1.8m high screens along perimeter and full height screen at southwest edge of balcony indicated in Figure 7b.
Point 17	6	24		YES	Impermeable 1.8m high screens along perimeter and 1.8m high partition screens as indicated in Figure 7b.
Point 18	6	24		YES	
Point 19	6	24		YES	
Point 20	6	24		YES	
Point 21	6	24		YES	
Point 22	6	24		YES	
Point 23	6	24		YES	
Point 24	6	24		YES	Impermeable 1.8m high screens along perimeter and 1.8m high partition screens as indicated in Figure 7c.
Point 25	6	24		YES	
Point 26	6	24		YES	
Point 27	6	24		NO	
Point 28	8	24		NO	
Point 29	8	24		YES	Impermeable 1.8m high screens along perimeter of balconies indicated in Fig 7d.
Point 30	8	24		NO	

Study Point	Desired Criterion (m/s)		Equivalent to or Better than Existing Site Wind Conditions?	Treatment Necessary to Pass?	Description of Suggested Treatment/ Notes
	GEM 5% exceedance	Safety Limit			
Point 31	6	24		NO	
Point 32	8	24		YES	Impermeable 1.8m high screens along perimeter of balconies indicated in Fig 7d.
Point 33	6	24		NO	
Point 34	6	24		YES	Impermeable 1.8m high screens along perimeter of terrace indicated in Fig 7e.
Point 35	6	24		YES	Impermeable 3m high screens along perimeter of terrace indicated in Fig 7f.
Point 36	6	24		YES	
Point 37	6	24		YES	Impermeable 1.8m high screens along perimeter of terrace indicated in Fig 7g.
Point 38	6	24		NO	
Point 39	6	24		YES	Impermeable 1.8m high screens along perimeter of terrace indicated in Fig 7h.
Point 40	6	24		NO	
Point 41	6	24		YES	Impermeable 1.8m high screens along perimeter of terrace indicated in Fig 7h.
Point 101	8	24	NO	NO	
Point 102	8	24	NO	NO	
Point 103	8	24	NO	NO	

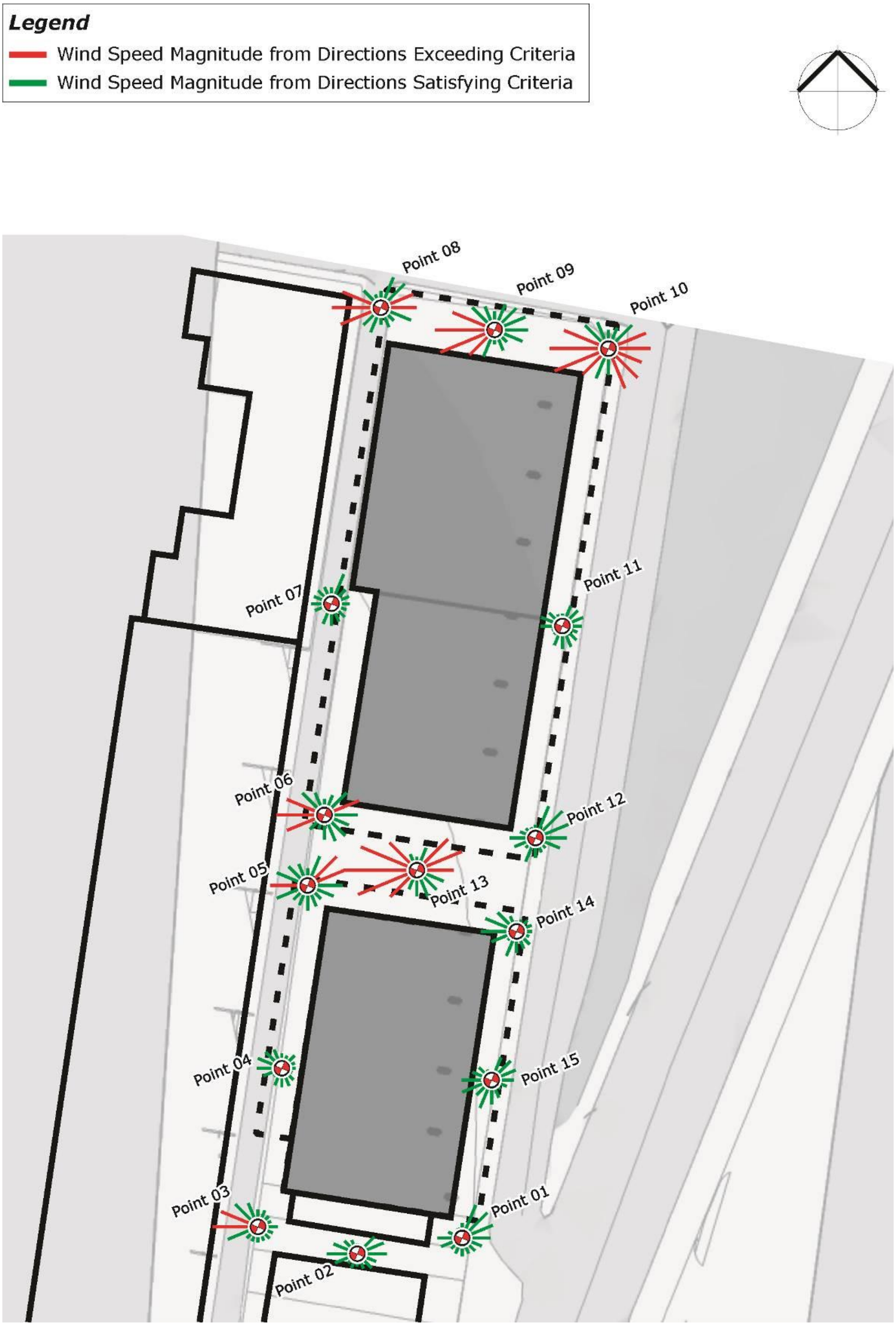


Figure 6a: Wind Direction Plots – Level 1

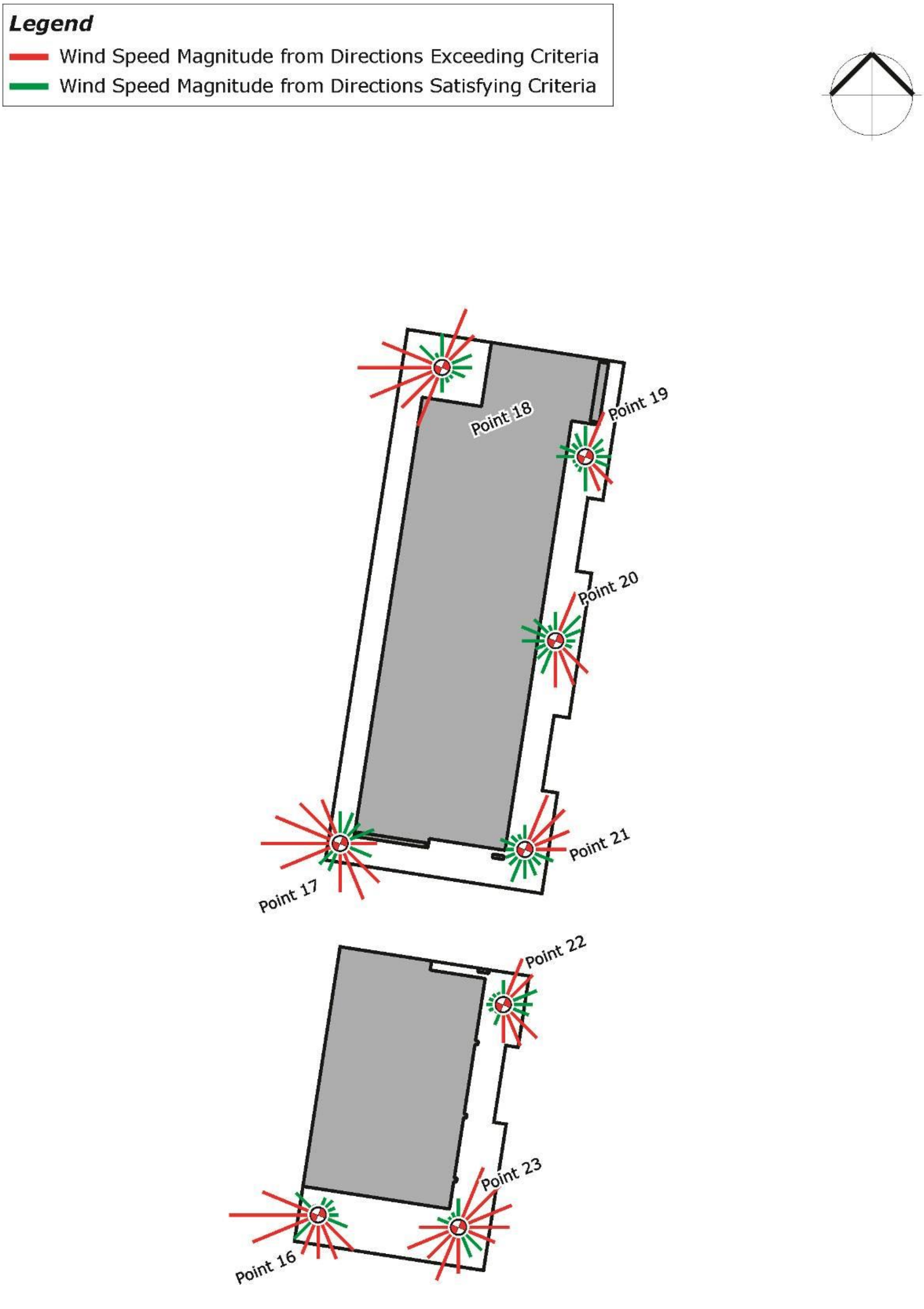


Figure 6b: Wind Direction Plots –Level 3

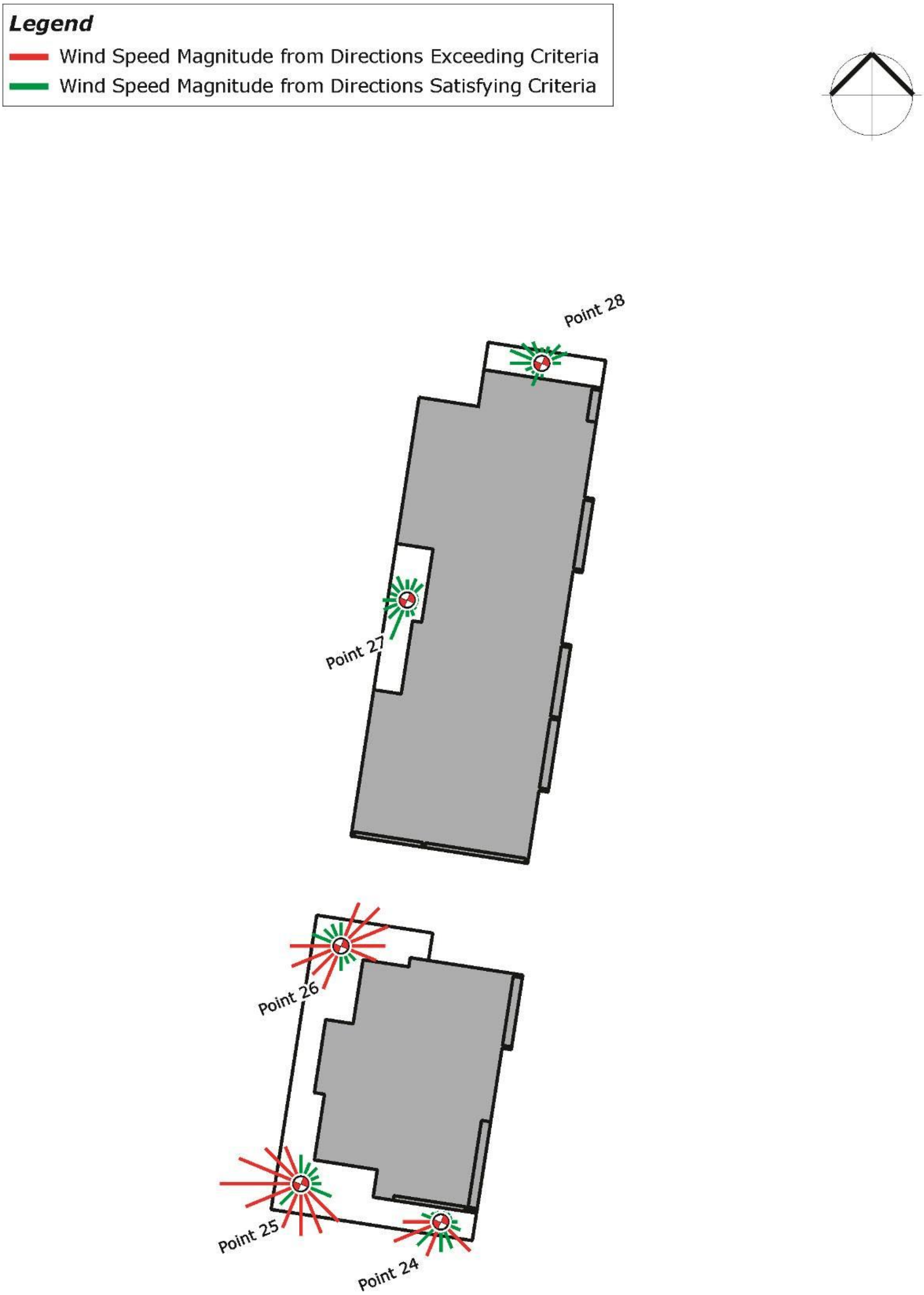


Figure 6c: Wind Direction Plots – Level 5

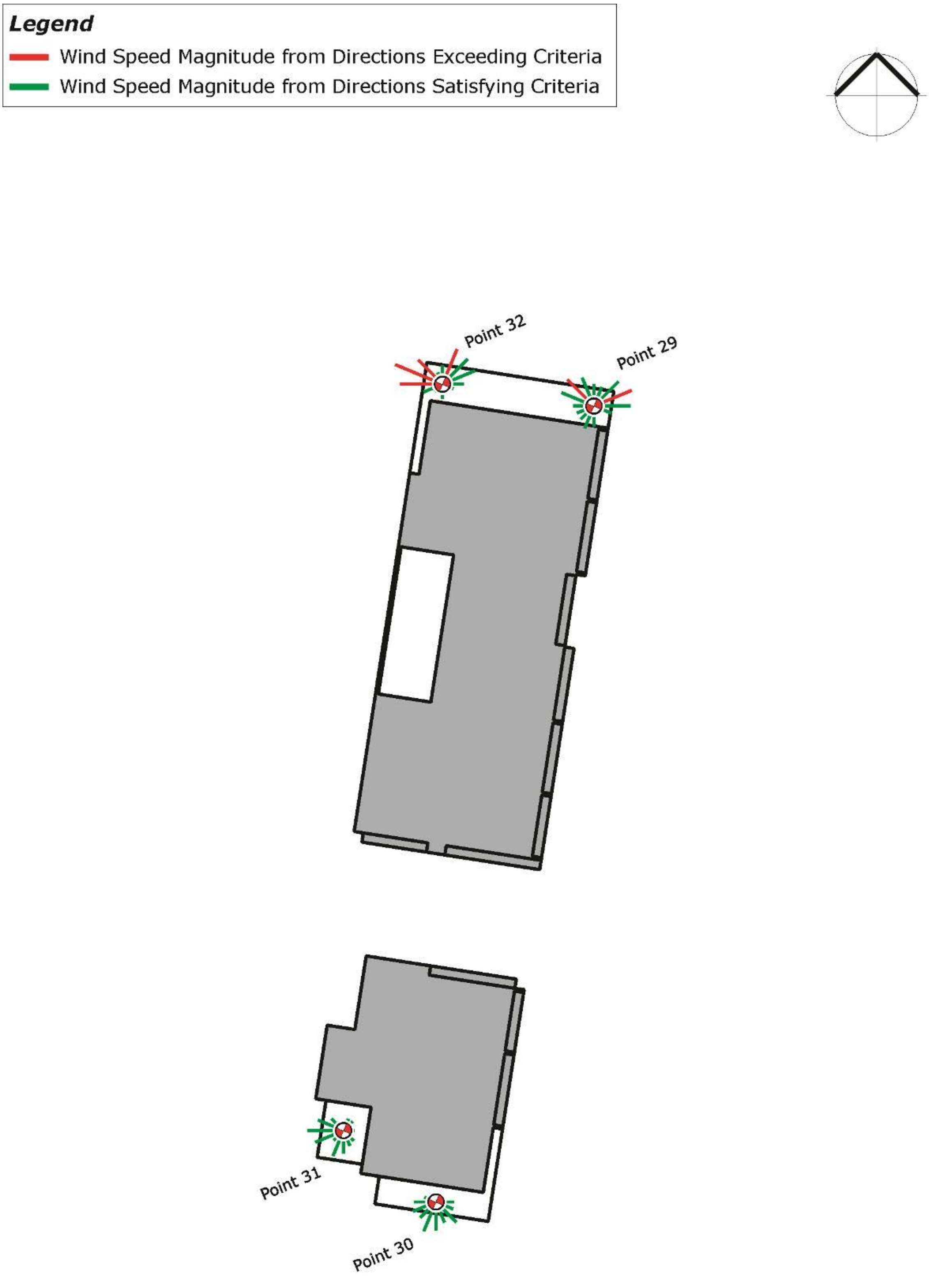


Figure 6d: Wind Direction Plots –Level 9

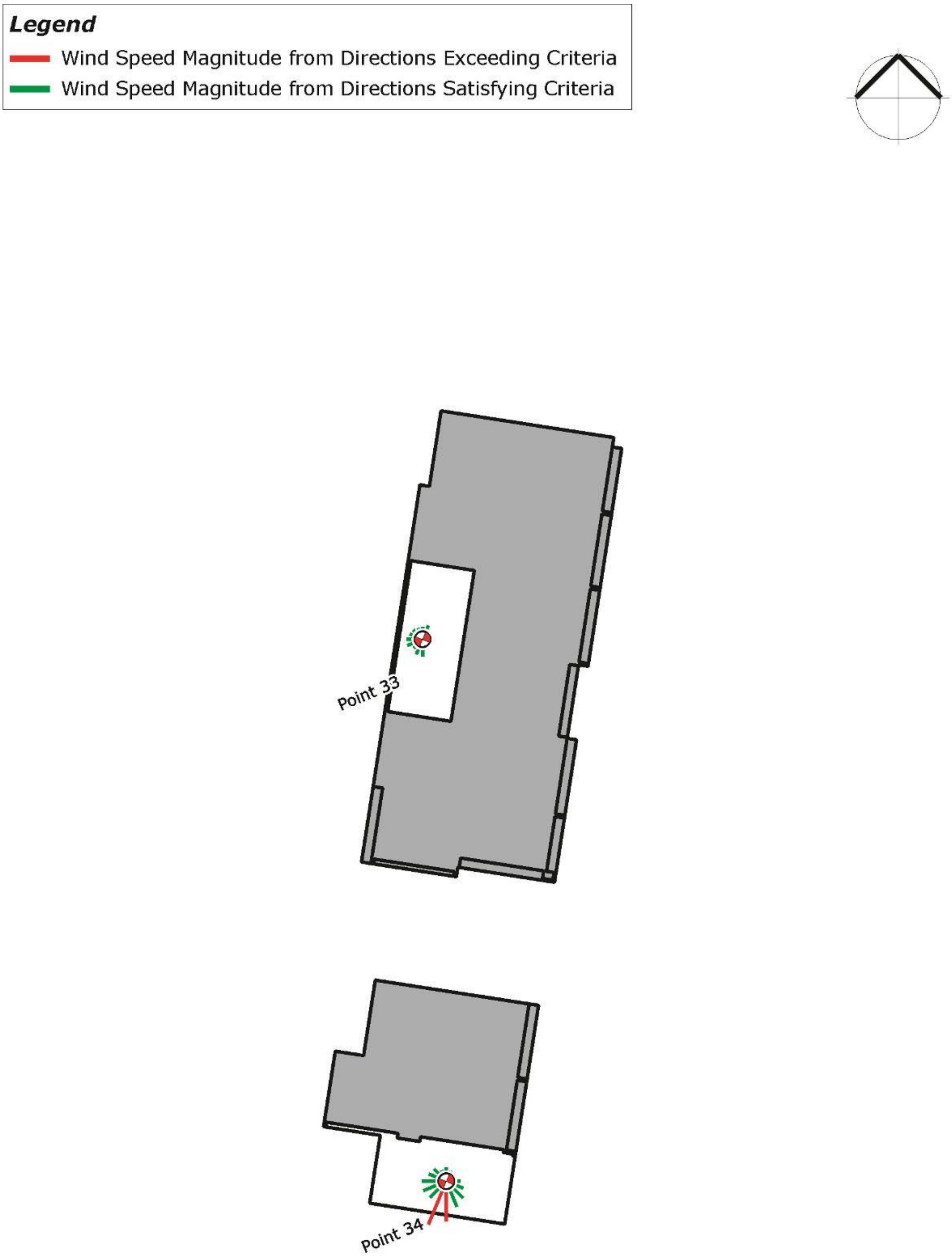


Figure 6e: Wind Direction Plots –Level 16

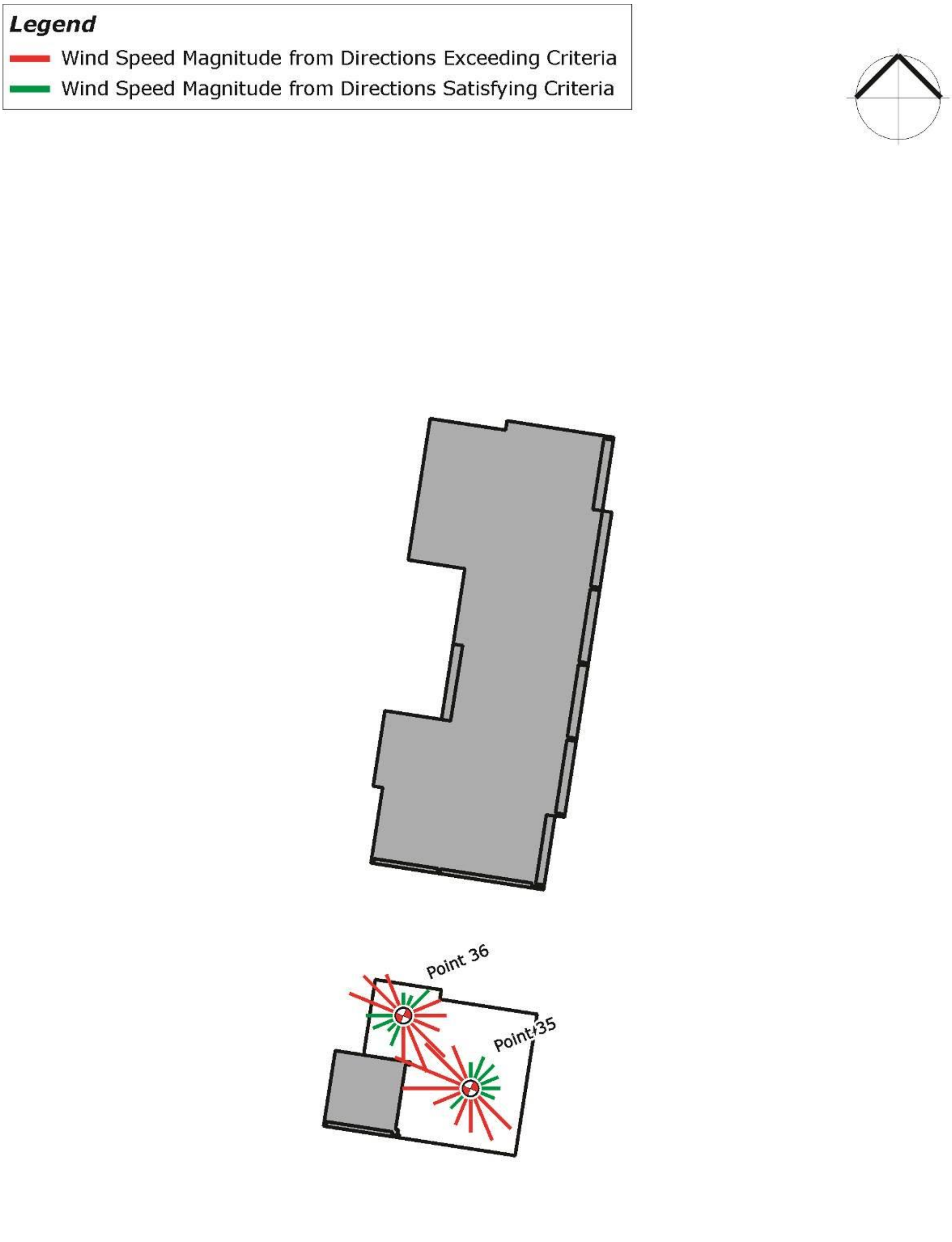


Figure 6f: Wind Direction Plots –Level 18

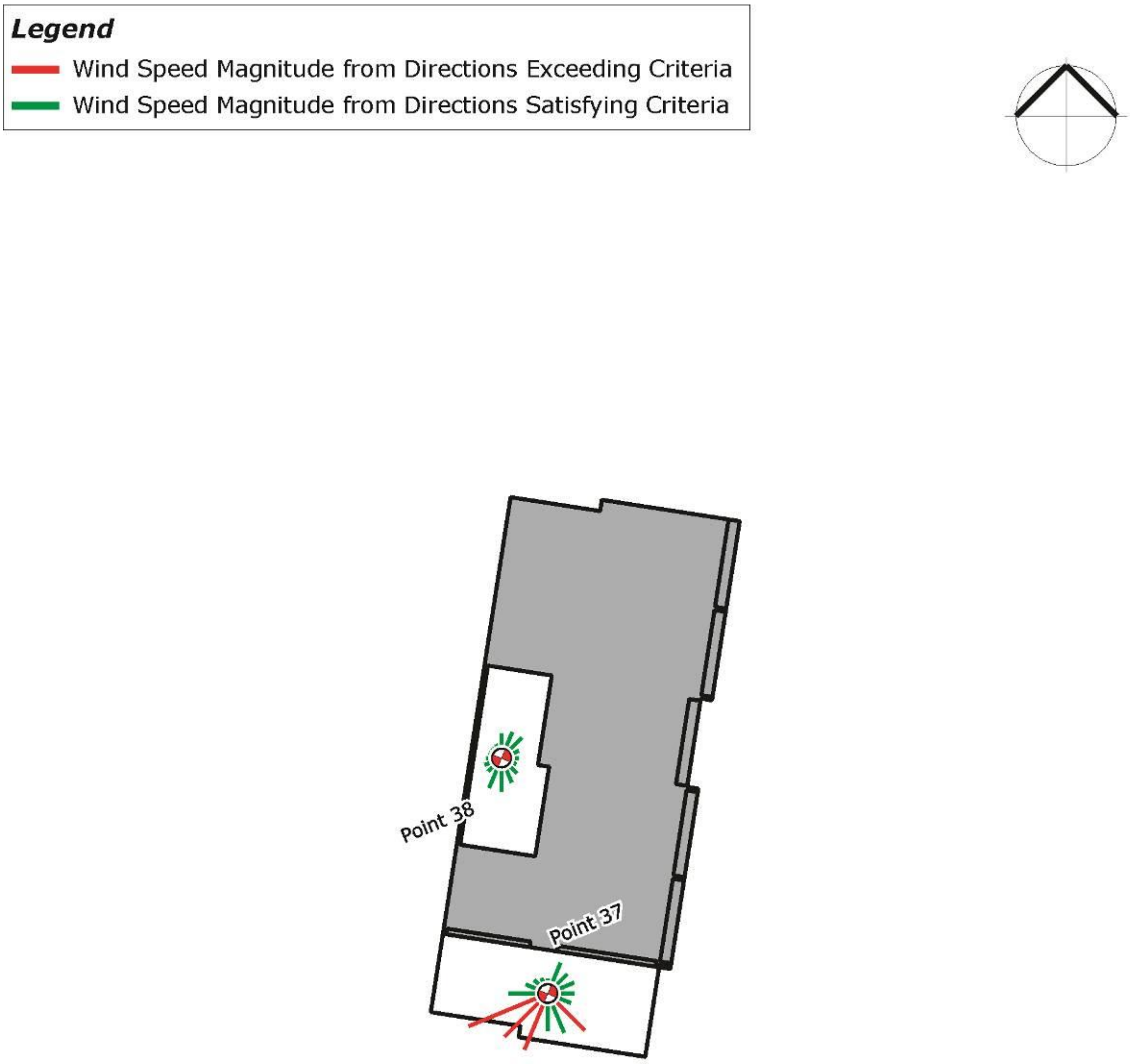


Figure 6g: Wind Direction Plots –Level 29

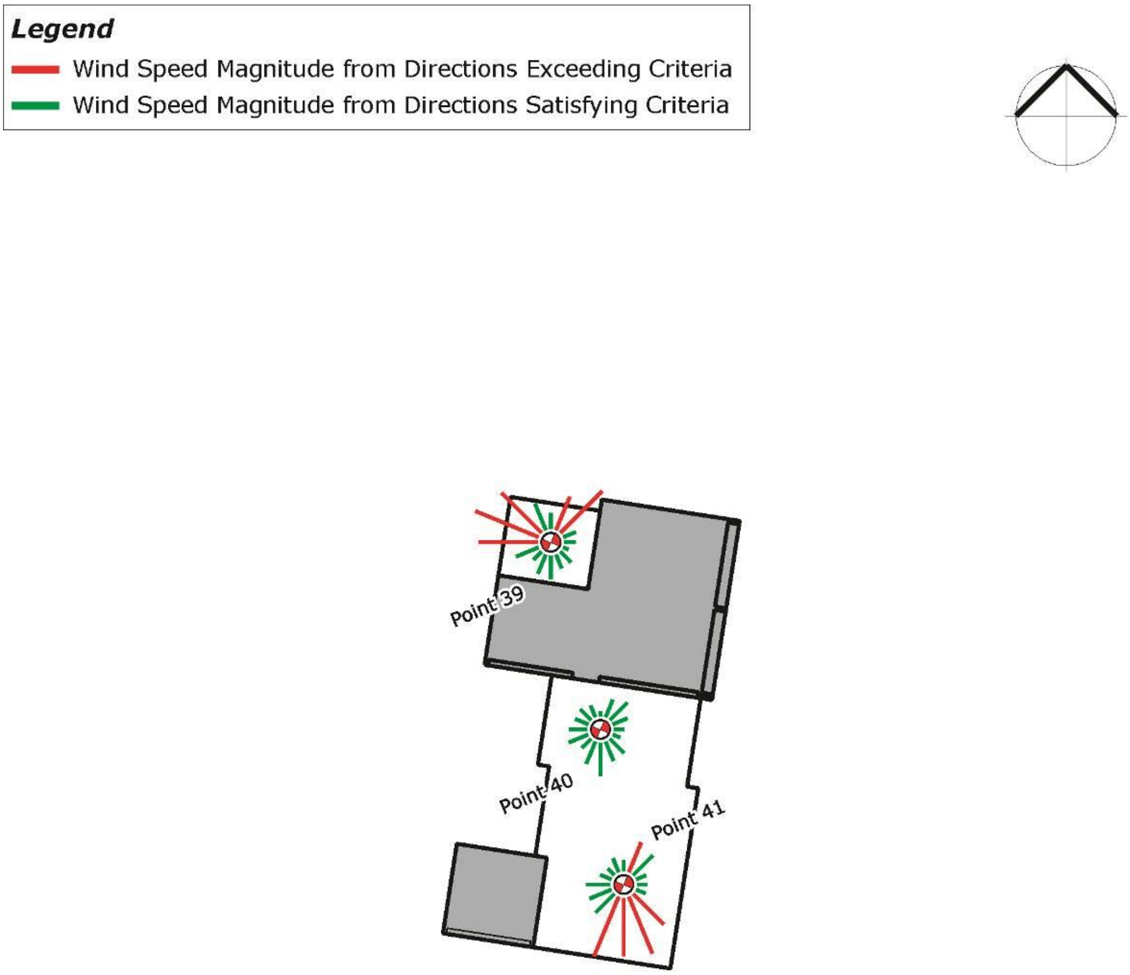


Figure 6h: Wind Direction Plots –Level 30

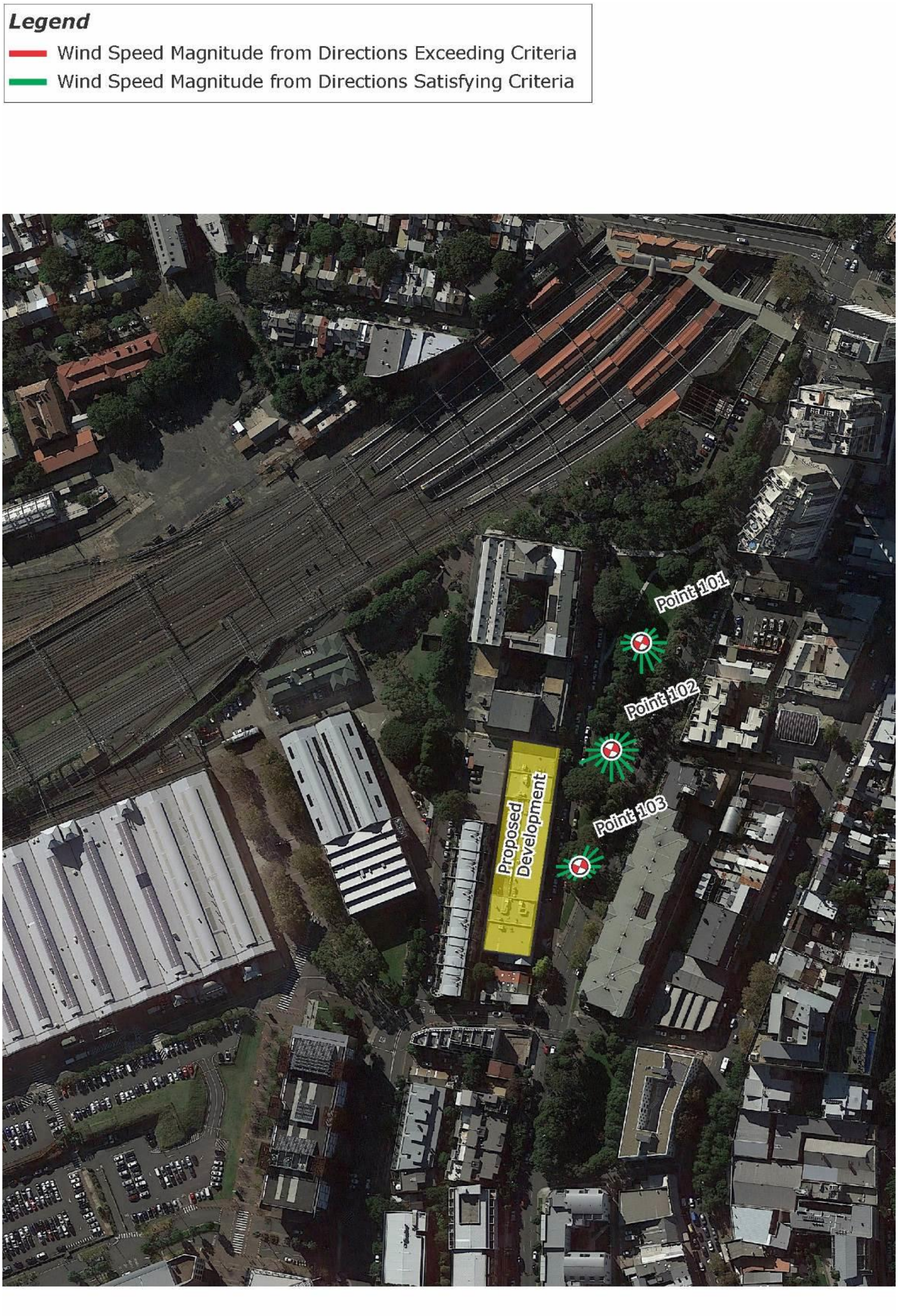


Figure 6i: Wind Direction Plots - Surrounding Study Points

Treatments Legend

Densely foliating evergreen planters capable of growing up to 2m high

Full height porous screens

Trellis or operable awning

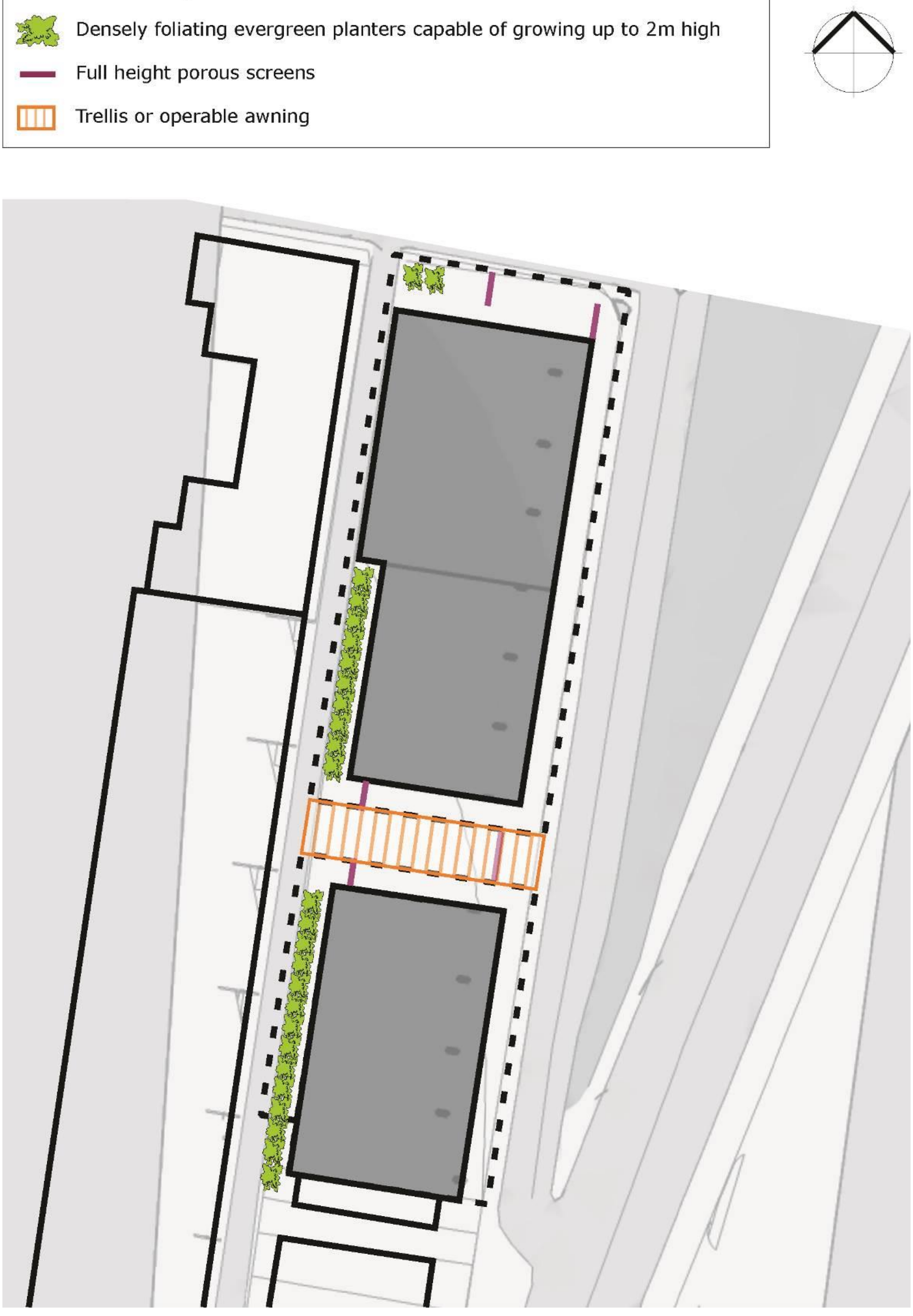


Figure 7a: Suggested Treatments – Level 1

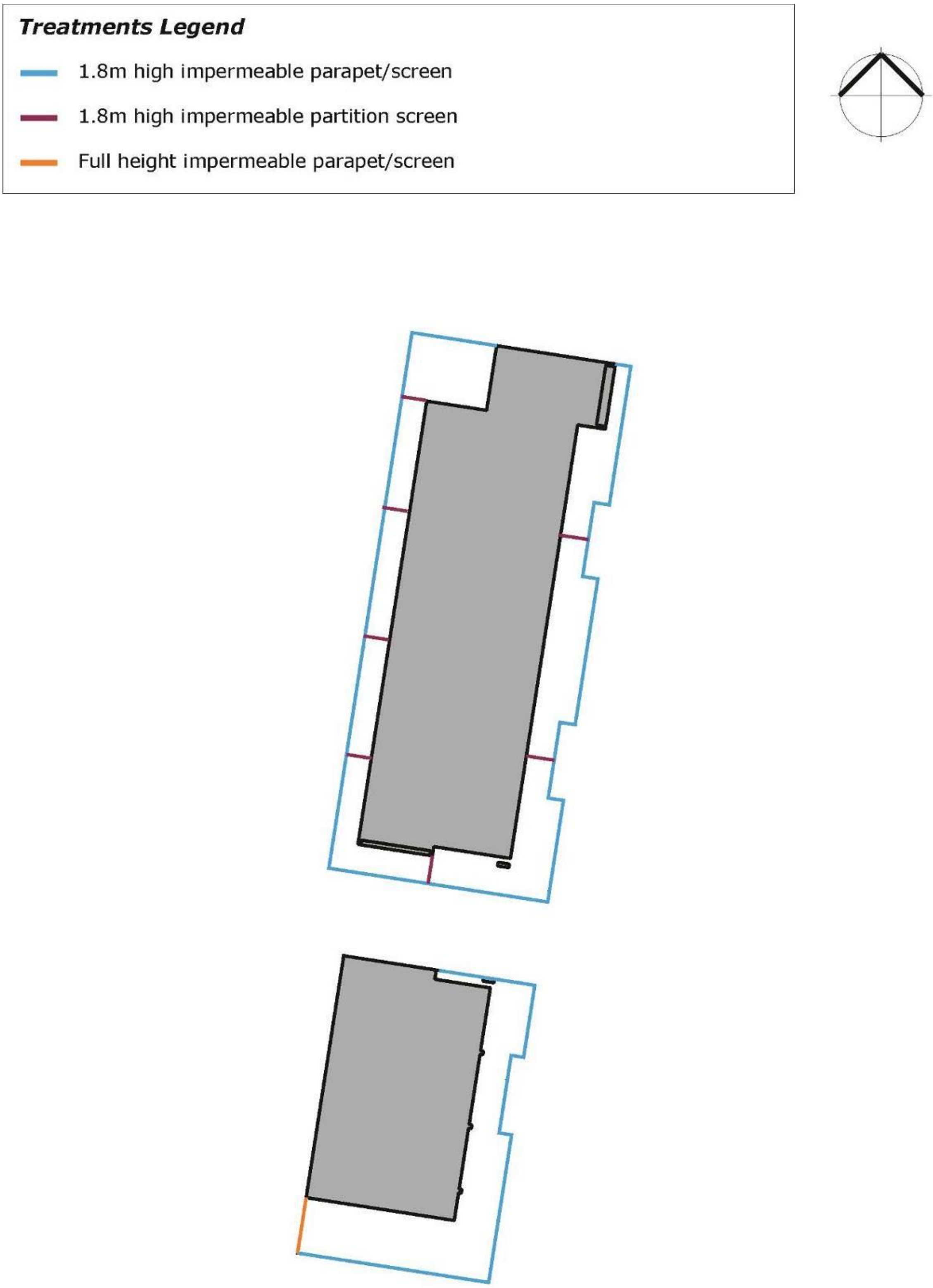


Figure 7b: Suggested Treatments – Level 3

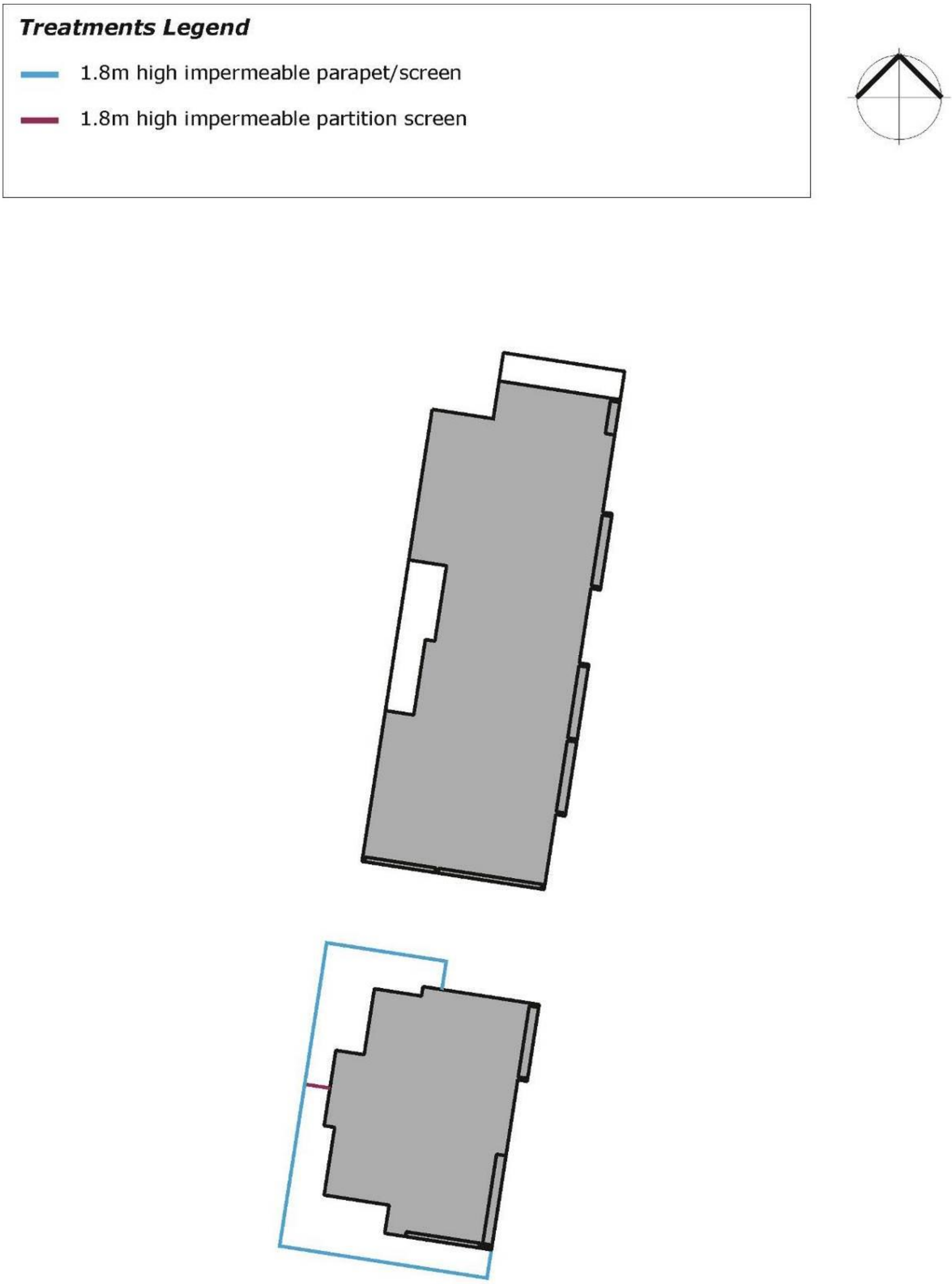
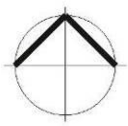


Figure 7c: Suggested Treatments – Level 5

Treatments Legend

1.8m high impermeable parapet/screen

Retain 1.8m high impermeable parapet/screen



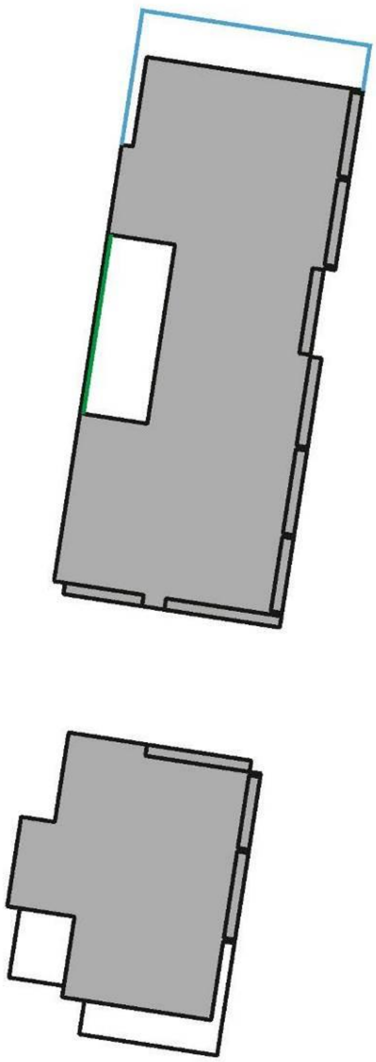


Figure 7d: Suggested Treatments – Level 9

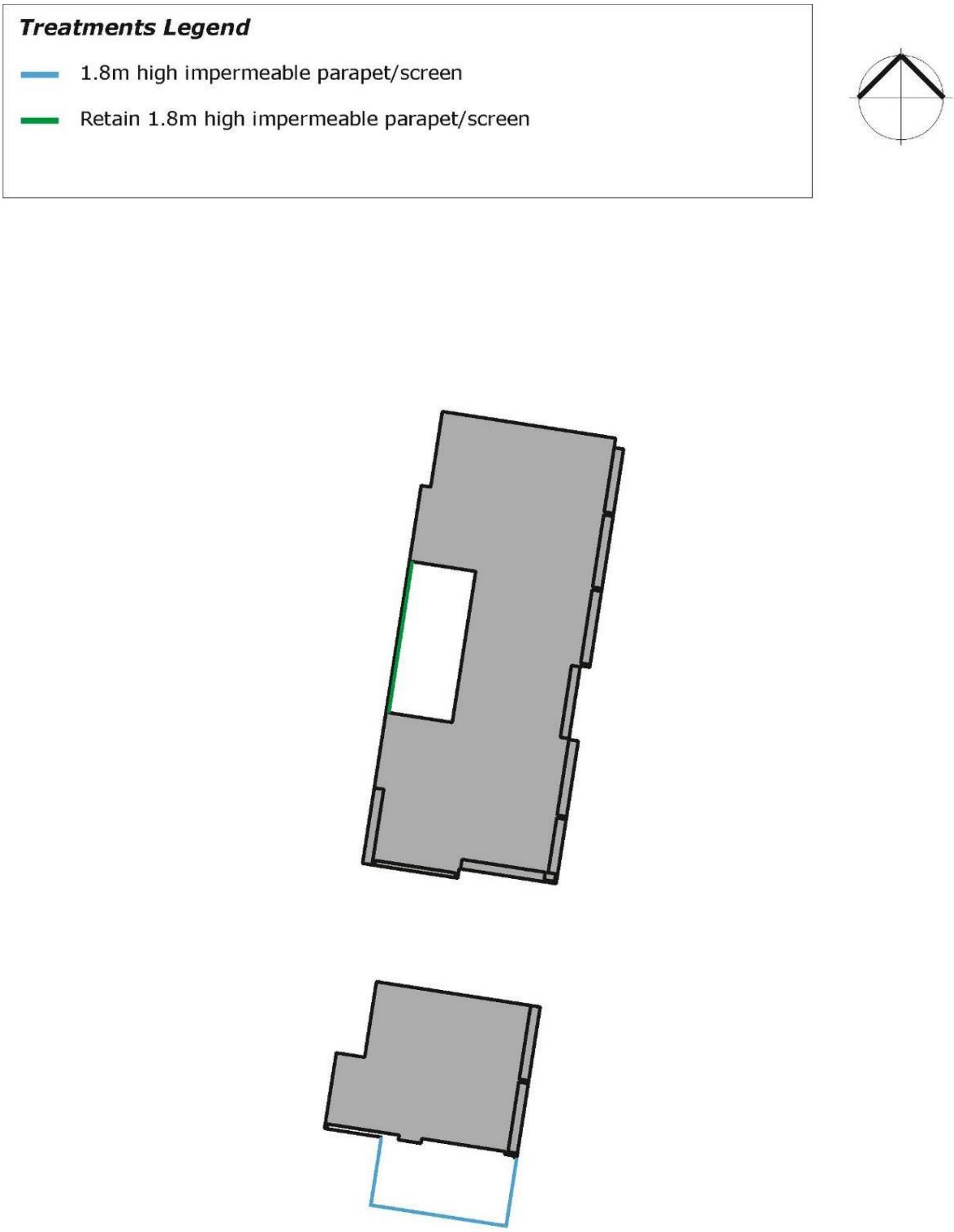


Figure 7e: Suggested Treatments – Level 16

Treatments Legend

3.0m high impermeable parapet/screen

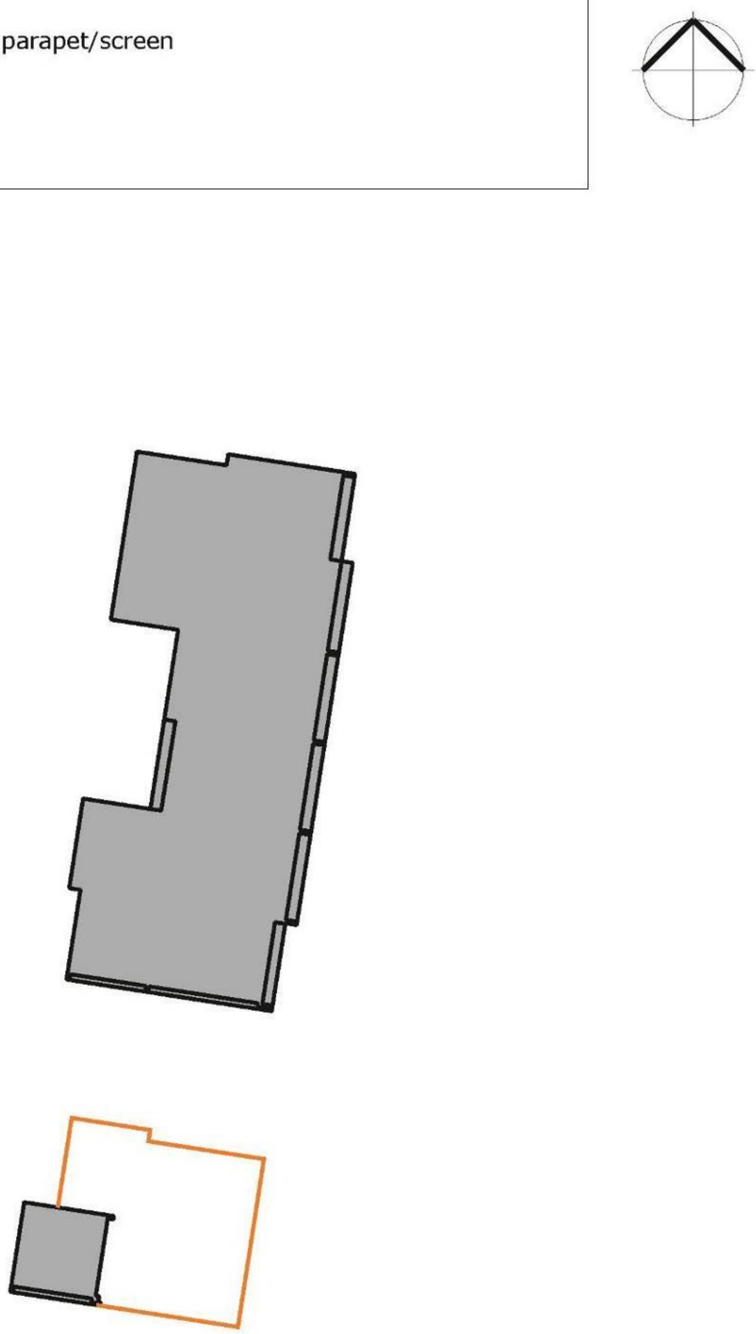


Figure 7f: Suggested Treatments – Level 18

Treatments Legend

1.8m high impermeable parapet/screen

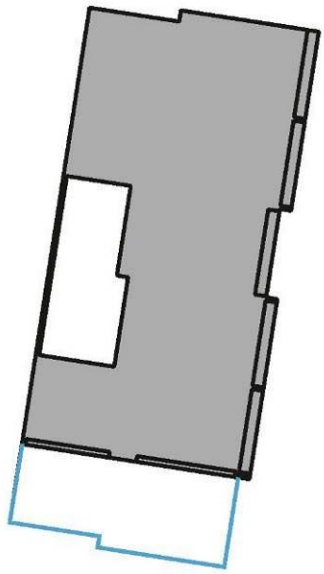


Figure 7g: Suggested Treatments – Level 29

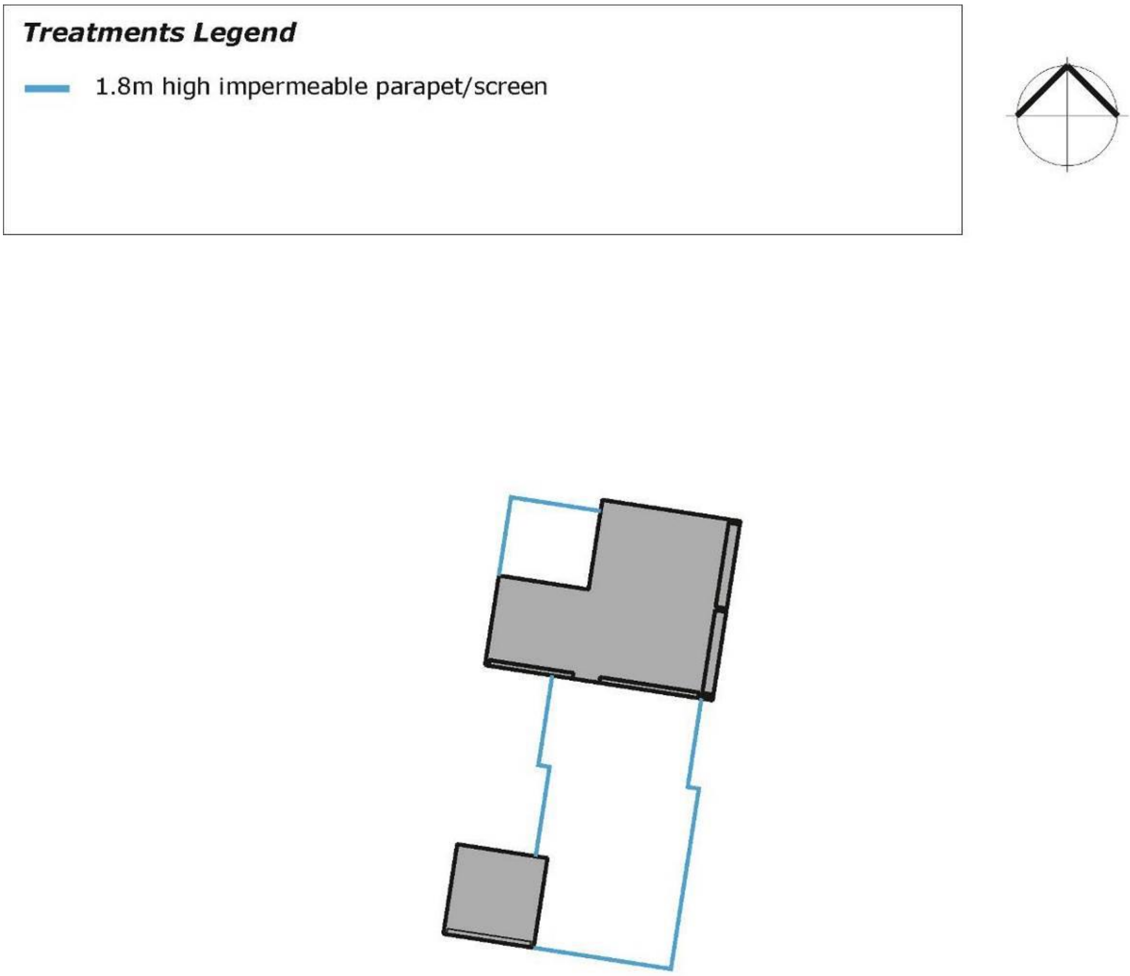


Figure 7h: Suggested Treatments – Level 30

REFERENCES

American Society of Civil Engineers, ASCE-7-10, 2010, "Minimum Design Loads for Buildings and Other Structures".

Australasian Wind Engineering Society, QAM-1, 2017, "Quality Assurance Manual".

Australasian Wind Engineering Society, 2014, "Guidelines for Pedestrian Wind Effects Criteria"

Aynsley, R.M., Melbourne, W.H., Vickery, B.J., 1977, "Architectural Aerodynamics". Applied Science Publishers.

City of Sydney Council, 2012, "City of Sydney Development Control Plan 2012"

City of Sydney Council, 2016, "City of Sydney Development Control Plan 2012: Central Sydney Planning Strategy Amendment"

Council on Tall Buildings and Urban Habitat (CTBUH), 2013, "Wind tunnel testing of high-rise buildings", CTBUH Technical Guides.

Davenport, A.G., 1972, "An approach to human comfort criteria for environmental conditions". Colloquium on Building Climatology, Stockholm.

Davenport, A.G., 1977, "The prediction of risk under wind loading", 2nd International Conference on Structural Safety and Reliability, Munich, Germany, pp511-538.

Deaves, D.M. and Harris, R.I., 1978, "A mathematical model of the structure of strong winds." Construction Industry and Research Association (U.K), Report 76.

Engineering Science Data Unit, 1982, London, ESDU82026, "Strong Winds in the Atmospheric Boundary Layer, Part 1: Hourly Mean Wind Speeds", with Amendments A to E (issued in 2002).

Engineering Science Data Unit, 1983, London, ESDU83045, "Strong Winds in the Atmospheric Boundary Layer, Part 2: Discrete Gust Speeds", with Amendments A to C (issued in 2002).

International Organisation for Standardisation, ISO4354, 2009, "Wind Actions on Structures".

Lawson, T.V., 1973, "The wind environment of buildings: a logical approach to the establishment of criteria". Bristol University, Department of Aeronautical Engineering.

Lawson, T.V., 1975, "The determination of the wind environment of a building complex before construction". Bristol University, Department of Aeronautical Engineering.

Lawson, T.V., 1980, "Wind Effects on Buildings - Volume 1, Design Applications". Applied Science Publishers Ltd, Ripple Road, Barking, Essex, England.

Melbourne, W.H., 1978, "Criteria for Environmental Wind Conditions". *Journal of Wind Engineering and Industrial Aerodynamics*, vol. 3, pp241-249.

Melbourne, W.H., 1978, “Wind Environment Studies in Australia”. *Journal of Wind Engineering and Industrial Aerodynamics*, vol. 3, pp201-214.

Penwarden, A.D., Wise A.F.E., 1975, “Wind Environment around Buildings”. Building Research Establishment Report, London.

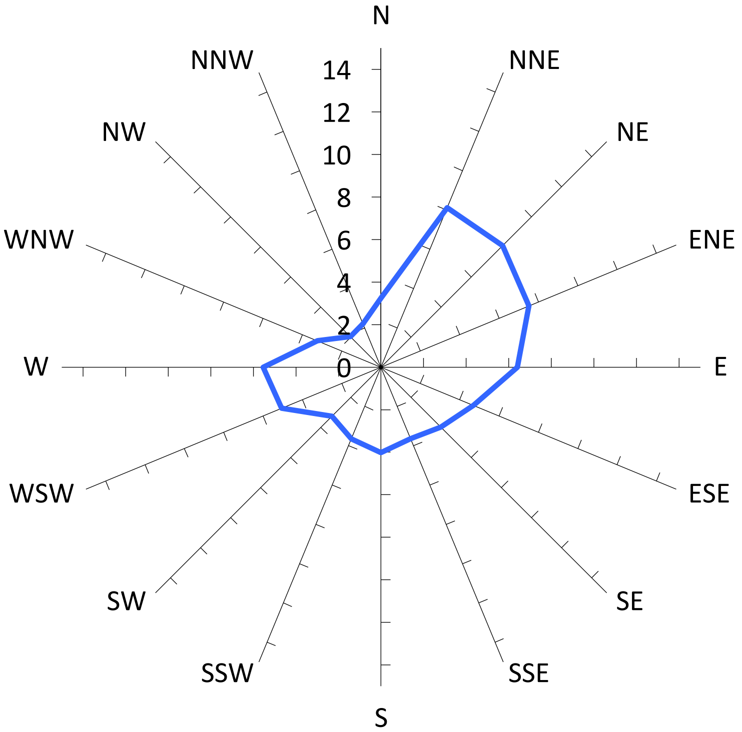
Rofail, A.W., 2007, “Comparison of Wind Environment Criteria against Field Observations”. 12th International Conference of Wind Engineering, Cairns, Australia.

Standards Australia and Standards New Zealand, AS/NZS 1170.2, 2011, “SAA Wind Loading Standard, Part 2: Wind Actions”.

APPENDIX A - DIRECTIONAL PLOTS OF WIND TUNNEL TREATMENT RESULTS

Measured Wind Speeds at Point 01

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
3%

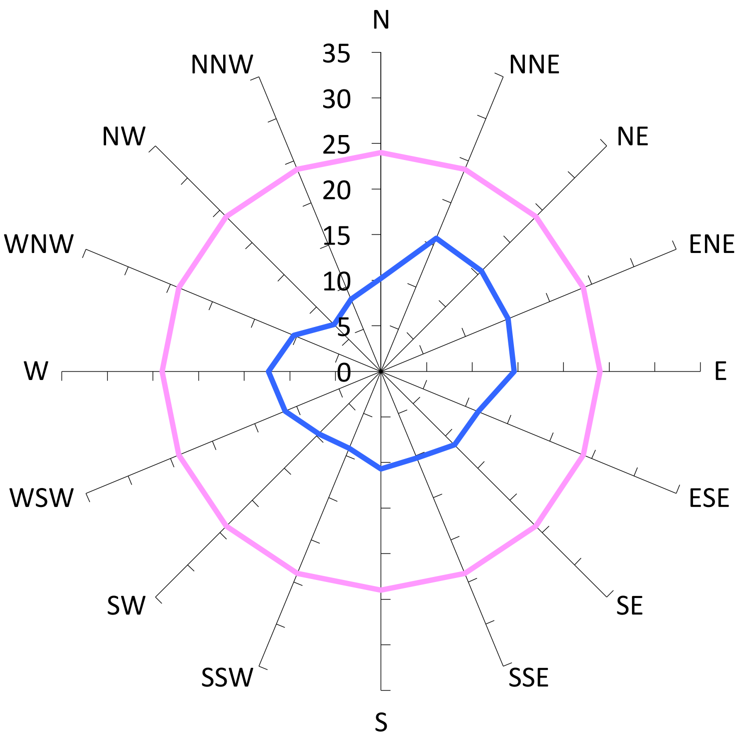
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

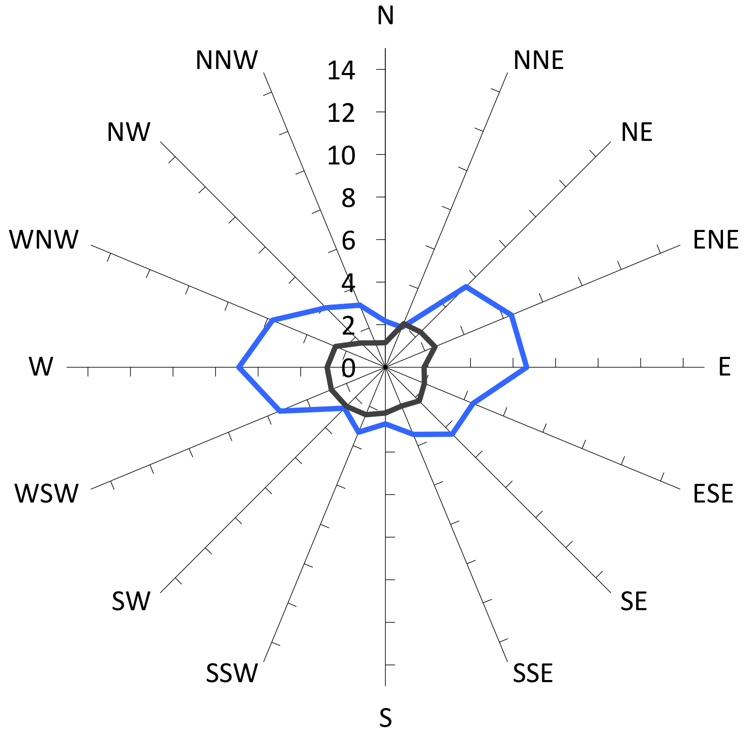
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 02

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
0%

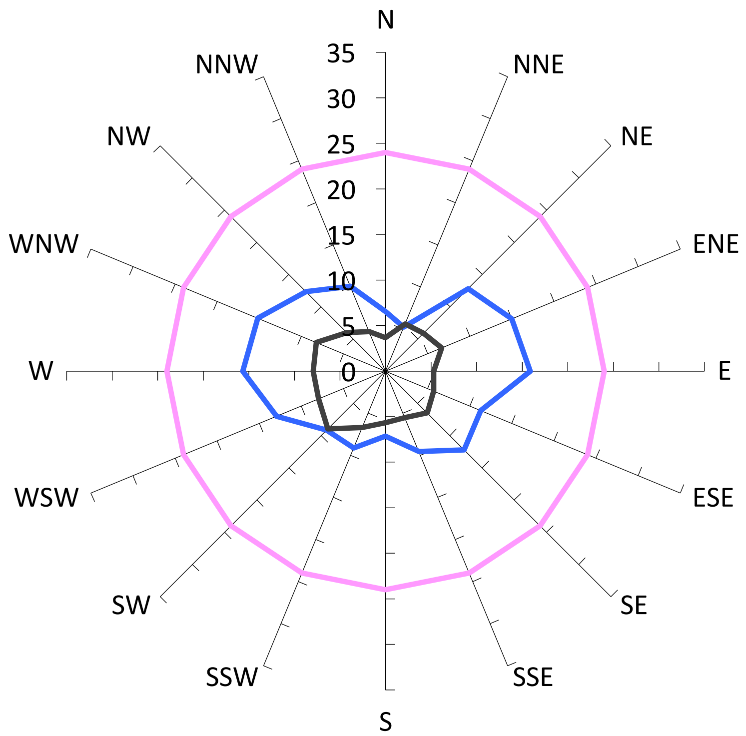
Probability of Criterion Exceedence (initial test)
2%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.
With development "as proposed", without proposed vegetation or other treatments.
With the existing site conditions

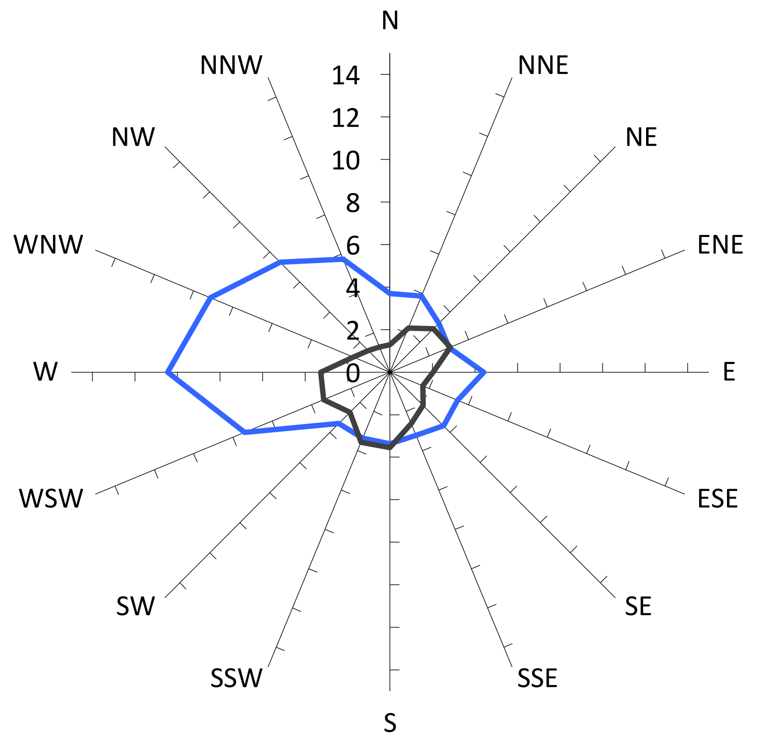
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 03

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
0%

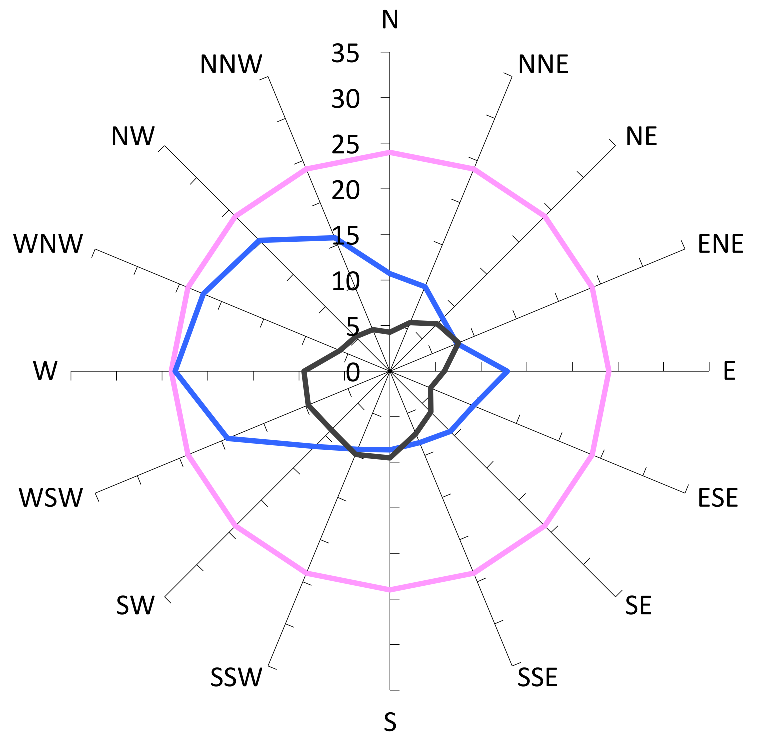
Probability of Criterion Exceedence (initial test)
8%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.
With development "as proposed", without proposed vegetation or other treatments.
With the existing site conditions

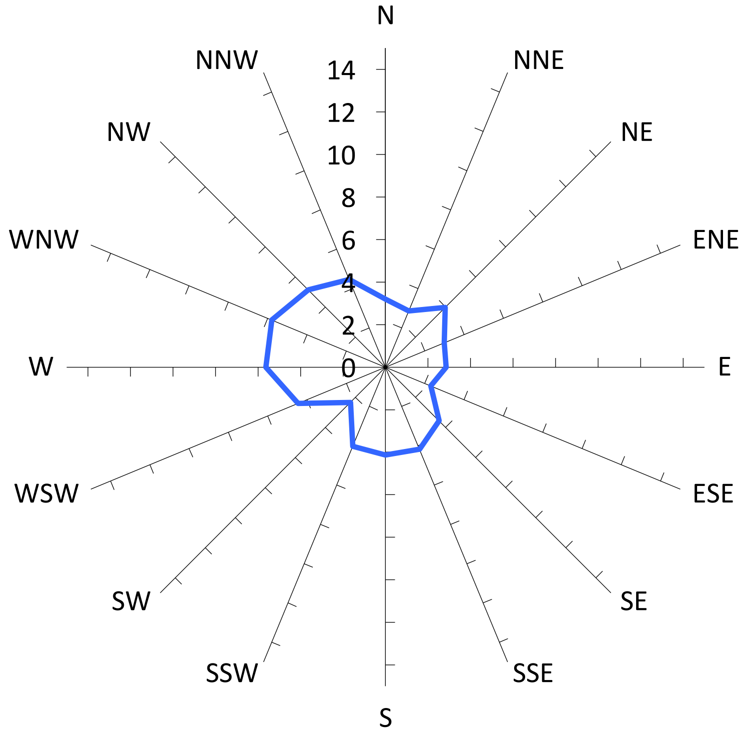
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 04

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

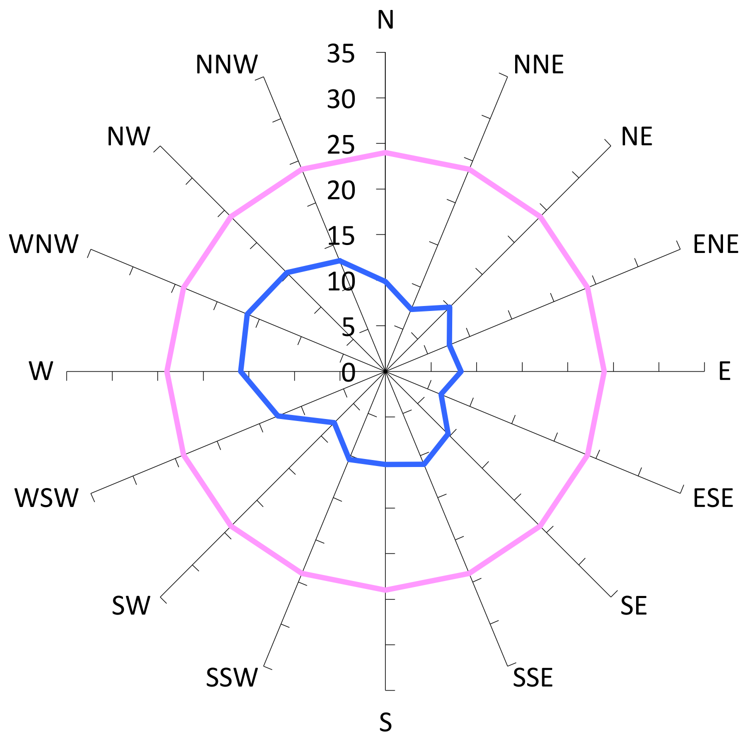
Probability of Criterion Exceedence (initial test)
1%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

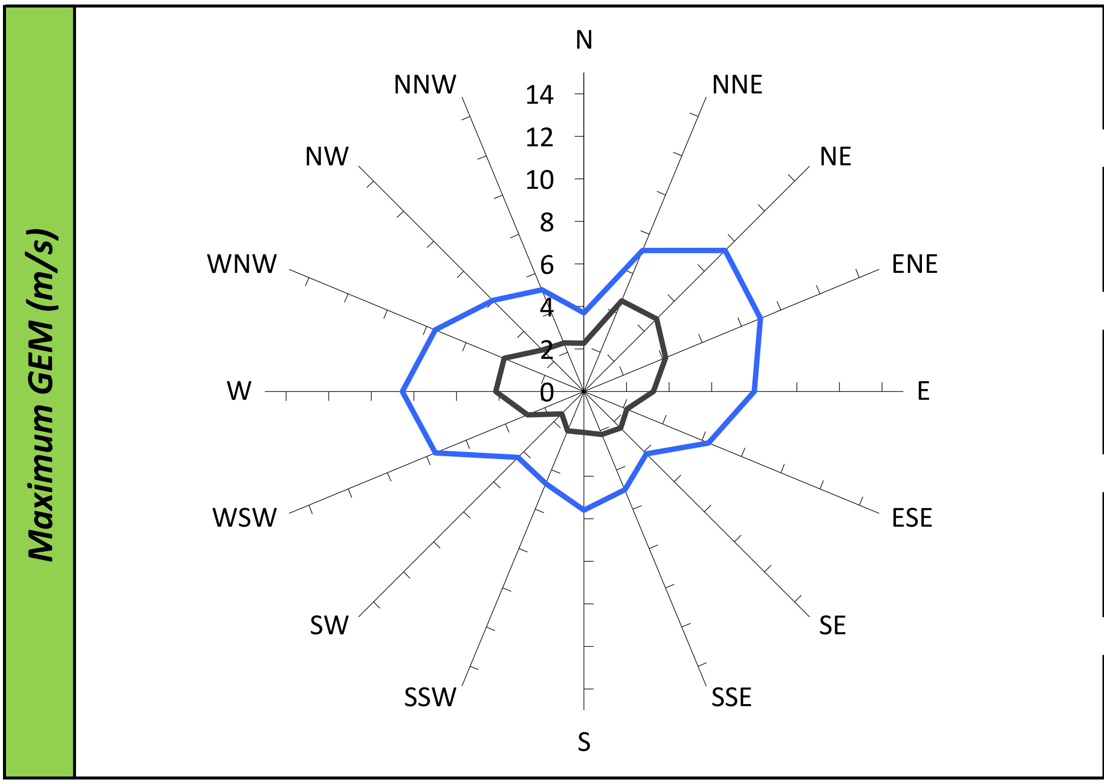
Criterion.
With development "as proposed", without proposed vegetation or other treatments.

Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 05



Desired Criterion
8m/s

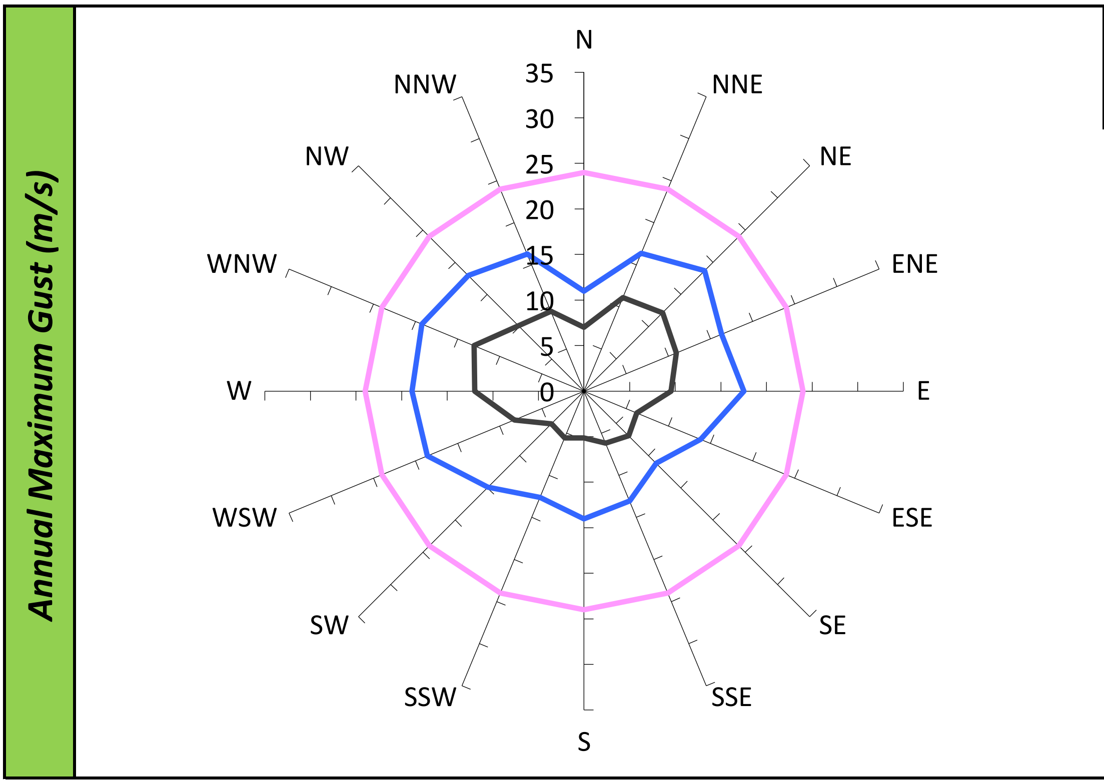
Prob. of Criterion Exceedence (existing site conditions)
0%

Probability of Criterion Exceedence (initial test)
12%

Probability of Criterion Exceedence (final retest)
N/A

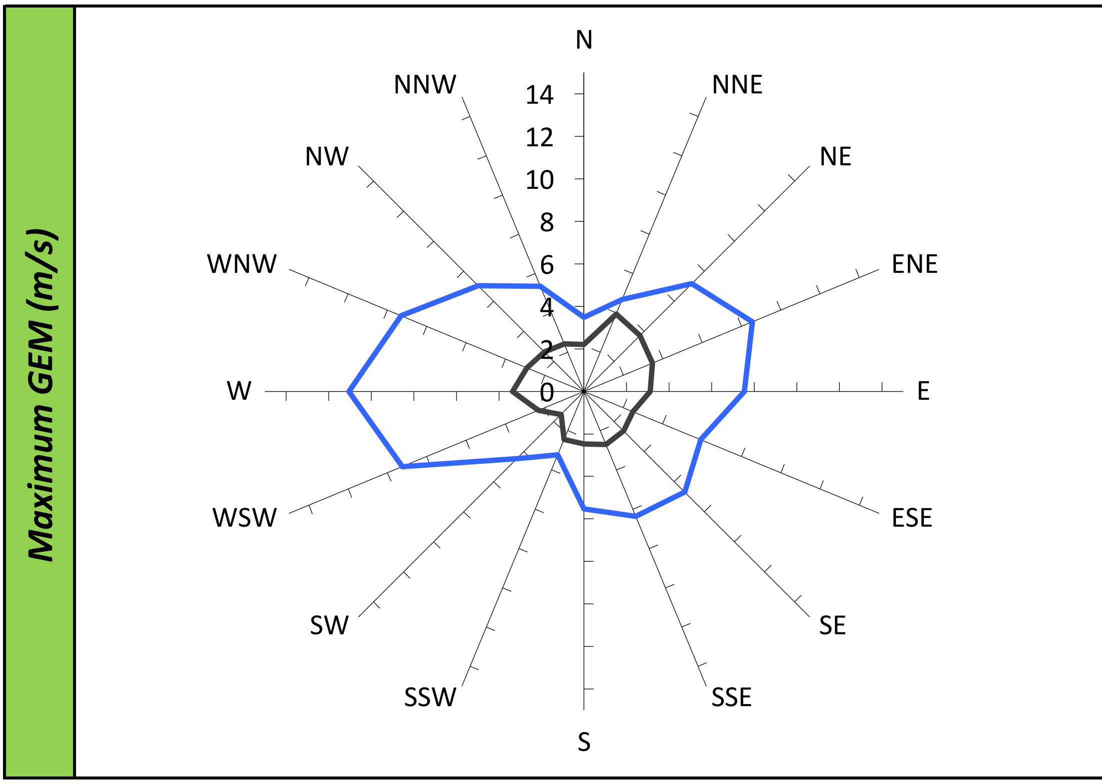
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.
With development "as proposed", without proposed vegetation or other treatments.
With the existing site conditions



Desired Criterion
24m/s

Measured Wind Speeds at Point 06



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
0%

Probability of Criterion Exceedence (initial test)
14%

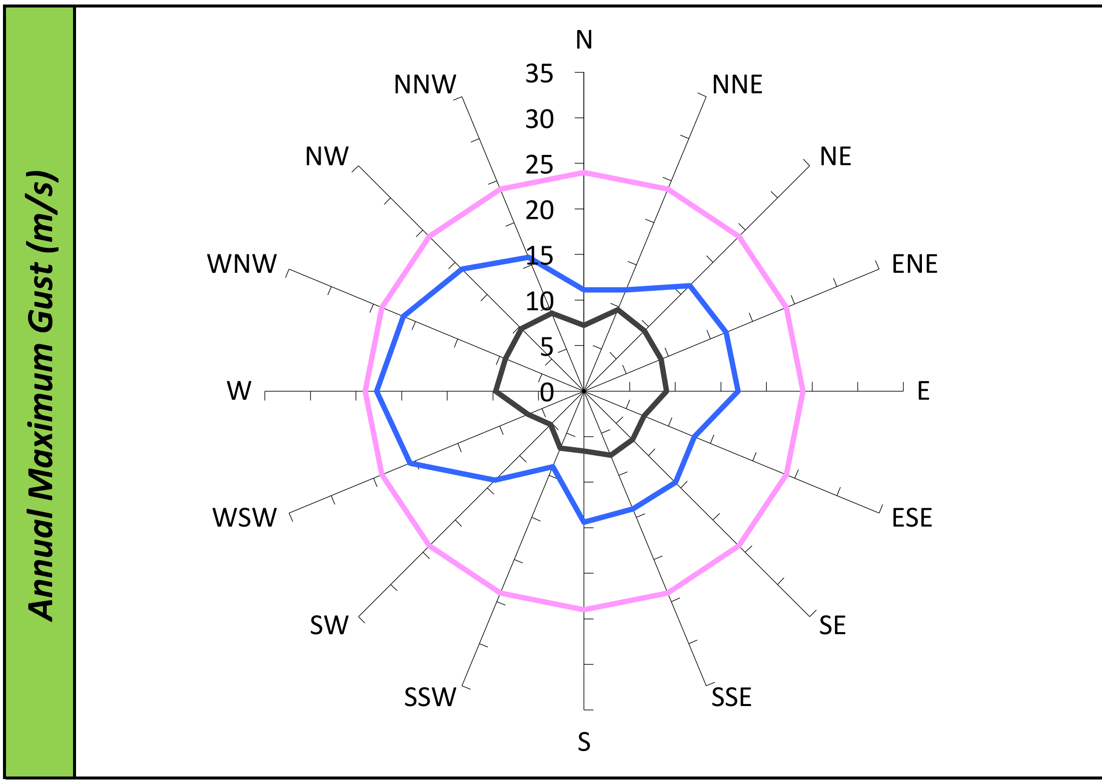
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

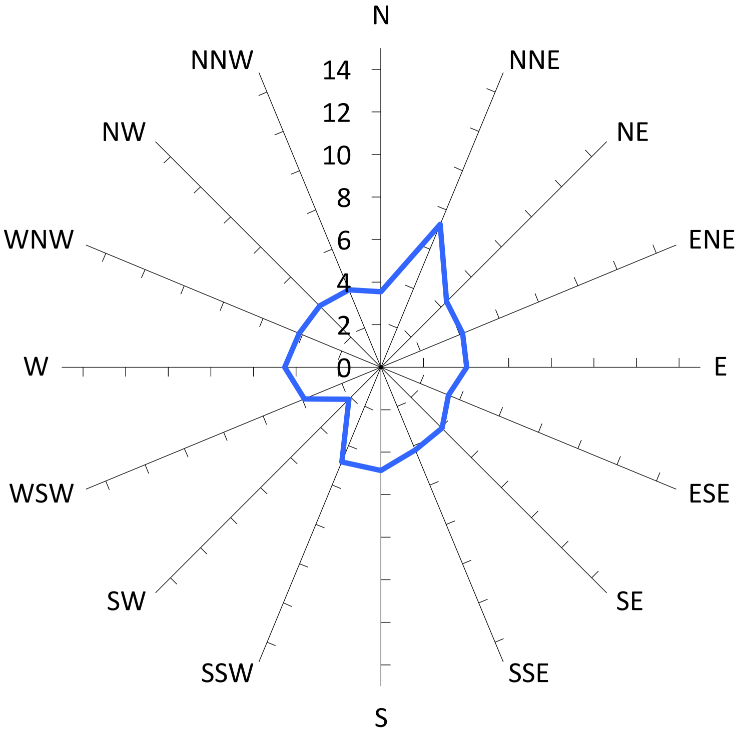
With the existing site conditions



Desired Criterion
24m/s

Measured Wind Speeds at Point 07

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
1%

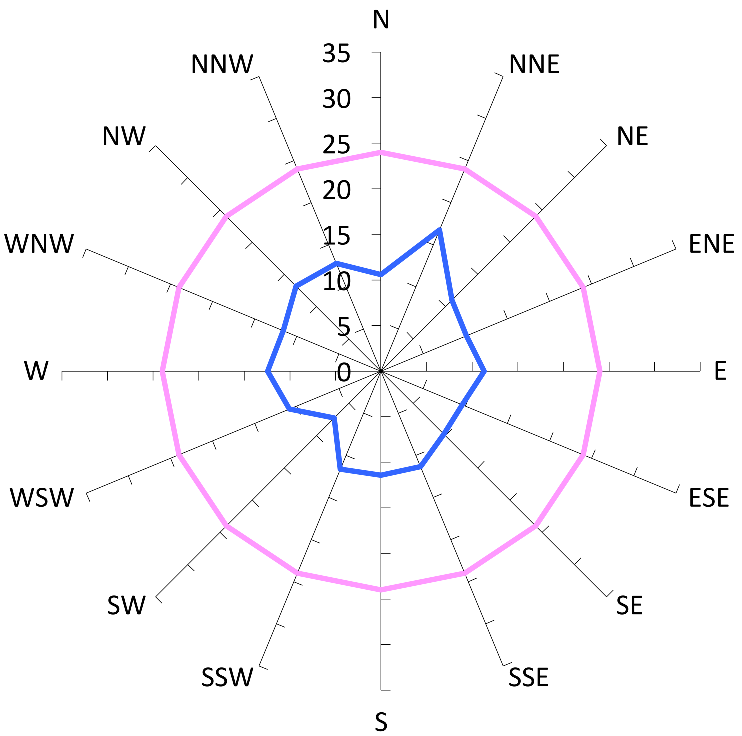
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

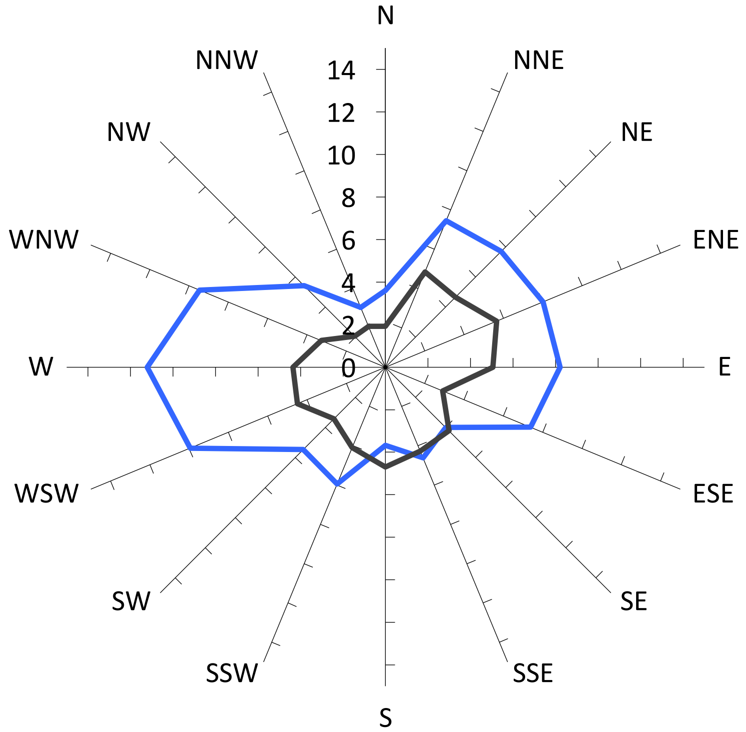
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 08

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
0%

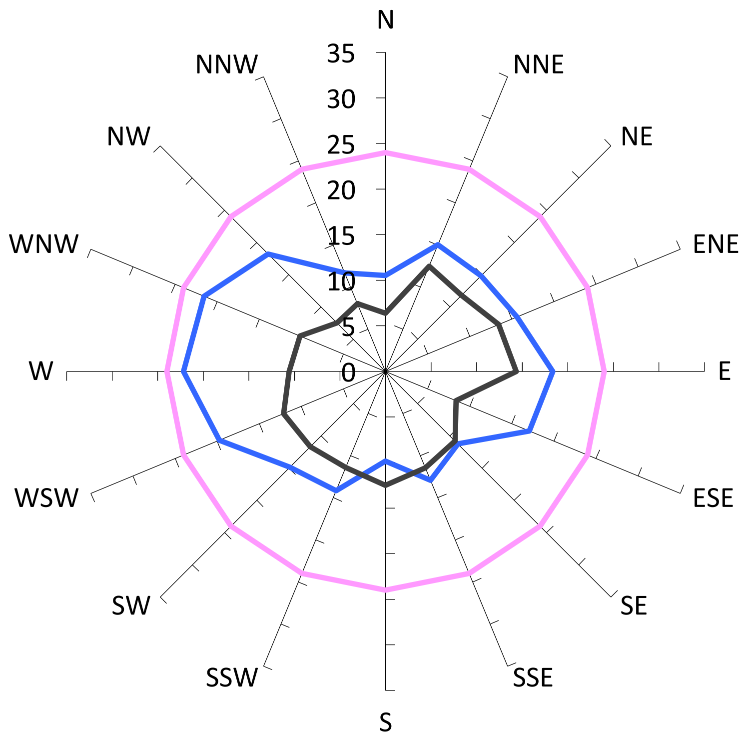
Probability of Criterion Exceedence (initial test)
15%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.
With development "as proposed", without proposed vegetation or other treatments.
With the existing site conditions

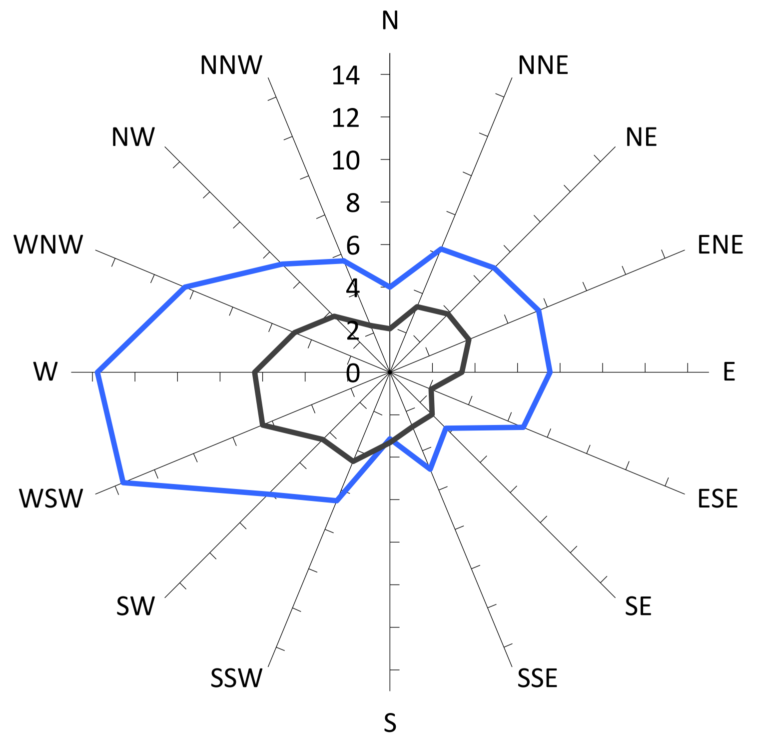
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 09

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
1%

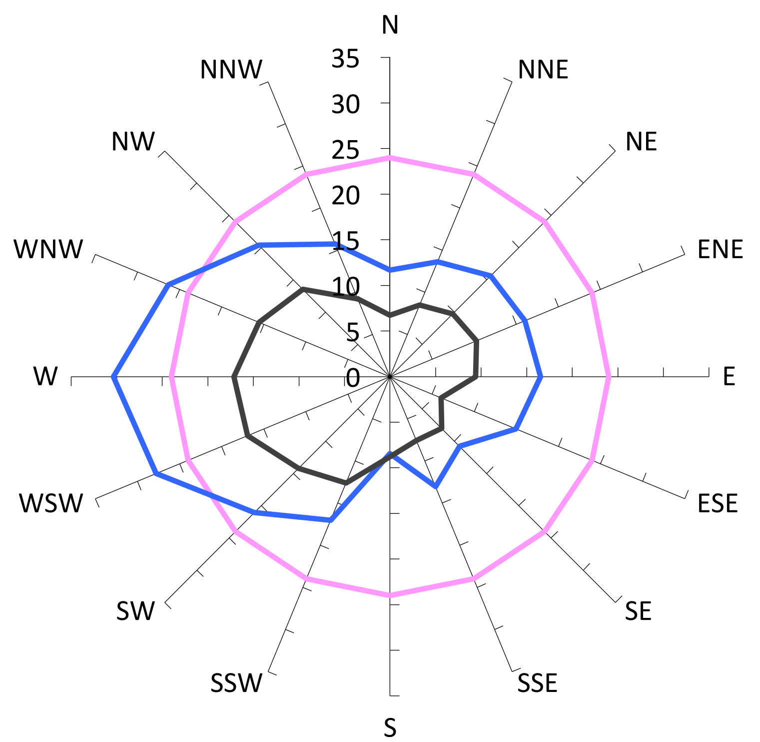
Probability of Criterion Exceedence (initial test)
18%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.
With development "as proposed", without proposed vegetation or other treatments.
With the existing site conditions

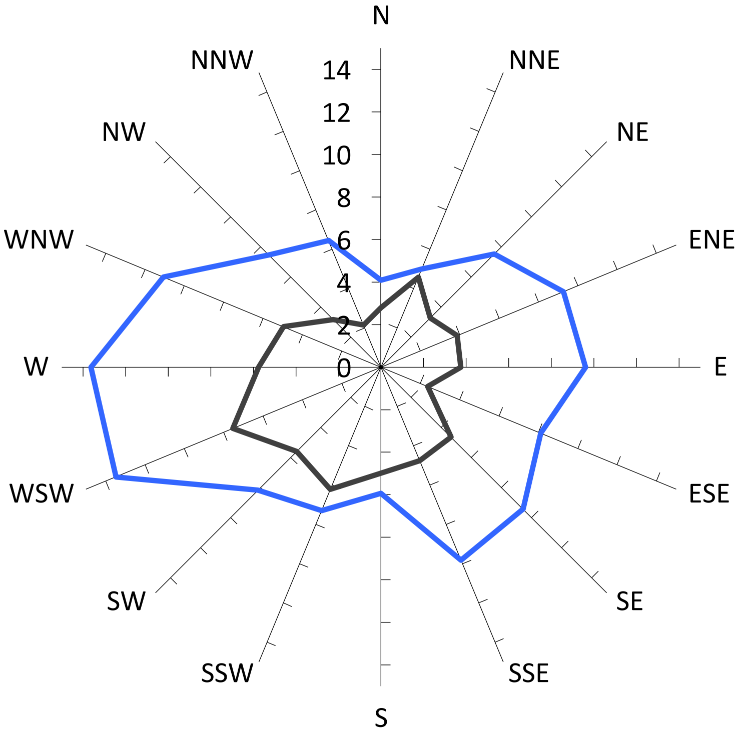
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 10

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
2%

Probability of Criterion Exceedence (initial test)
29%

Probability of Criterion Exceedence (final retest)
N/A

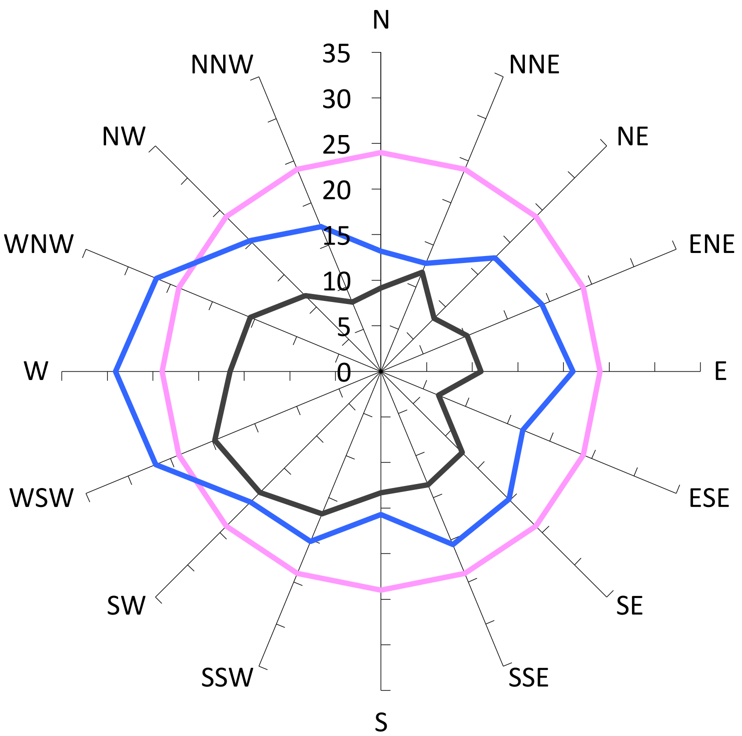
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

With the existing site conditions

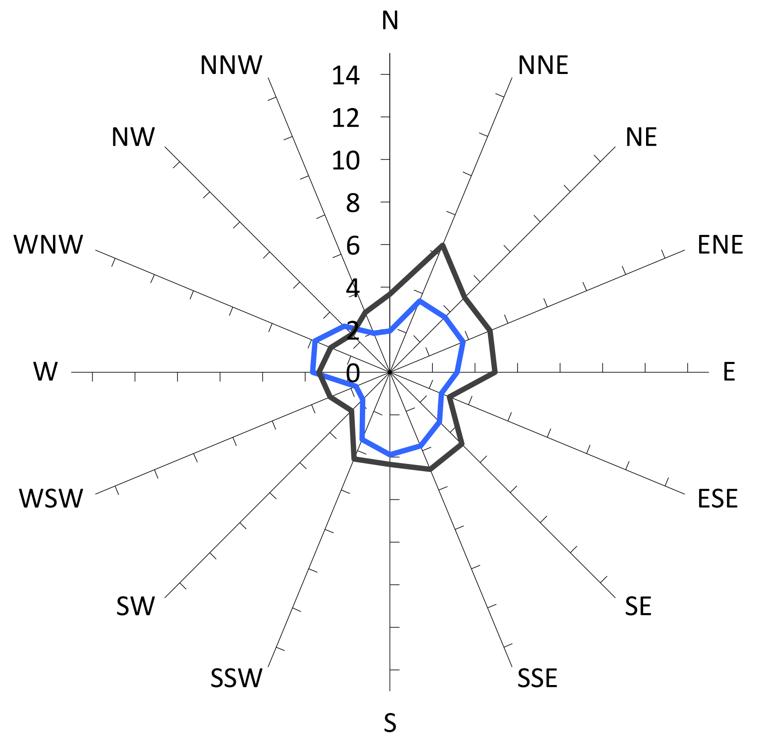
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 11

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
4%

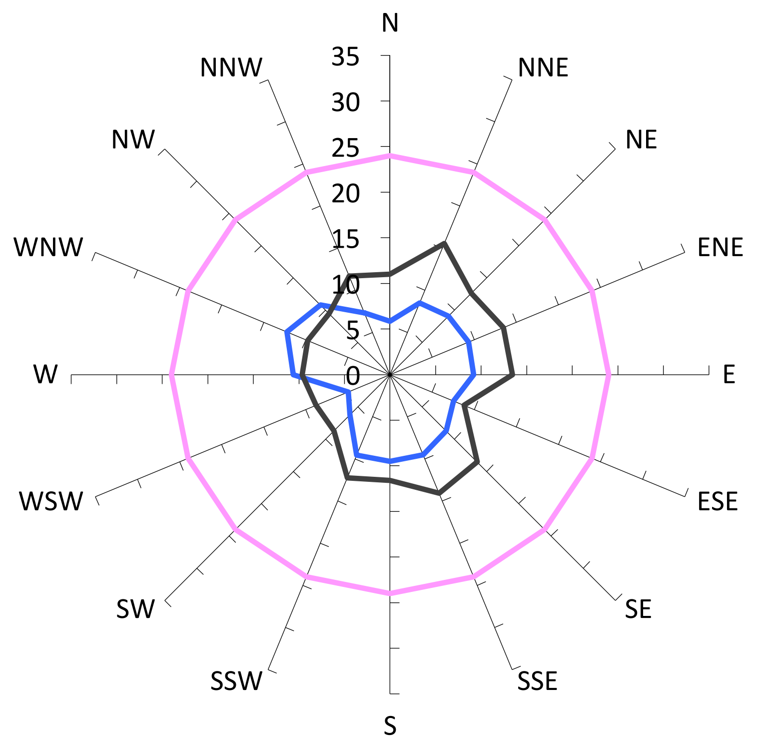
Probability of Criterion Exceedence (initial test)
0%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

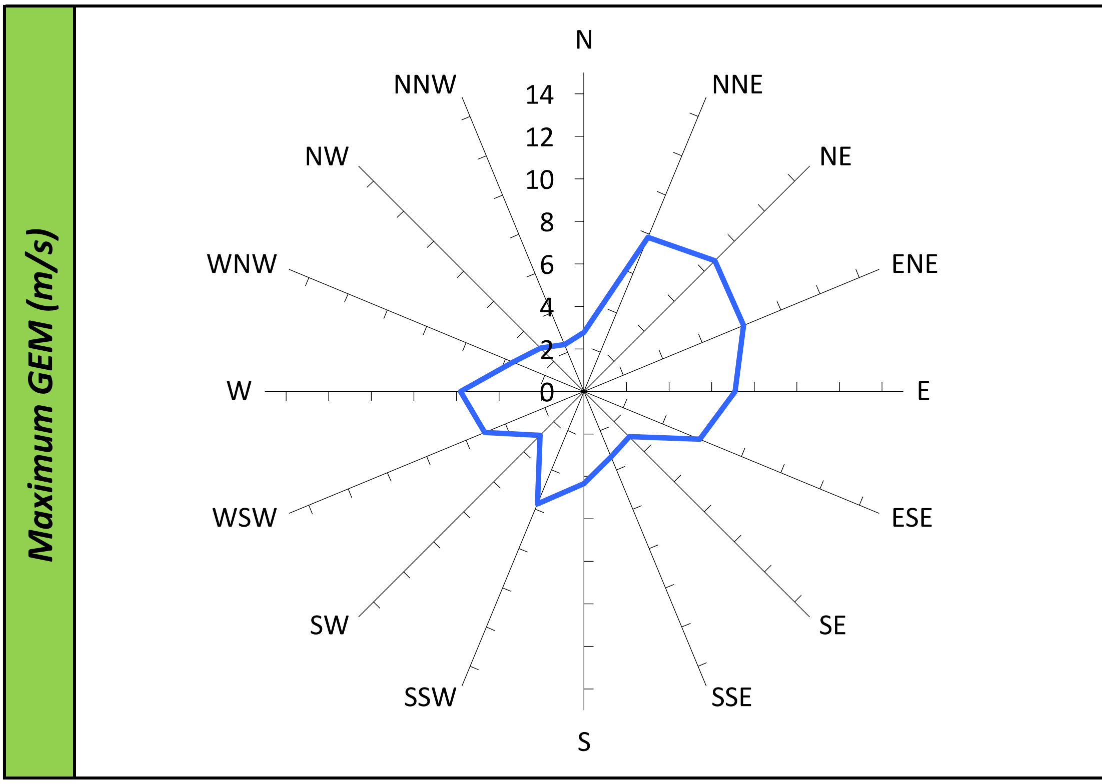
Criterion.
With development "as proposed", without proposed vegetation or other treatments.
With the existing site conditions

Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 12



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

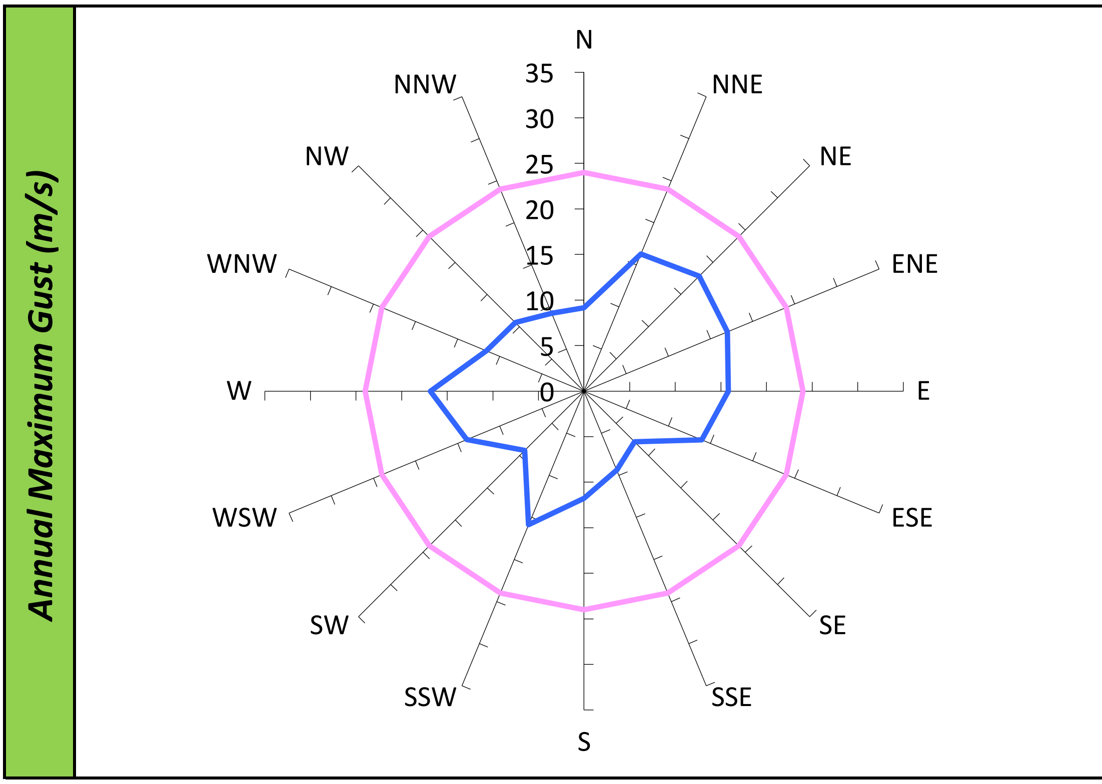
Probability of Criterion Exceedence (initial test)
5%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

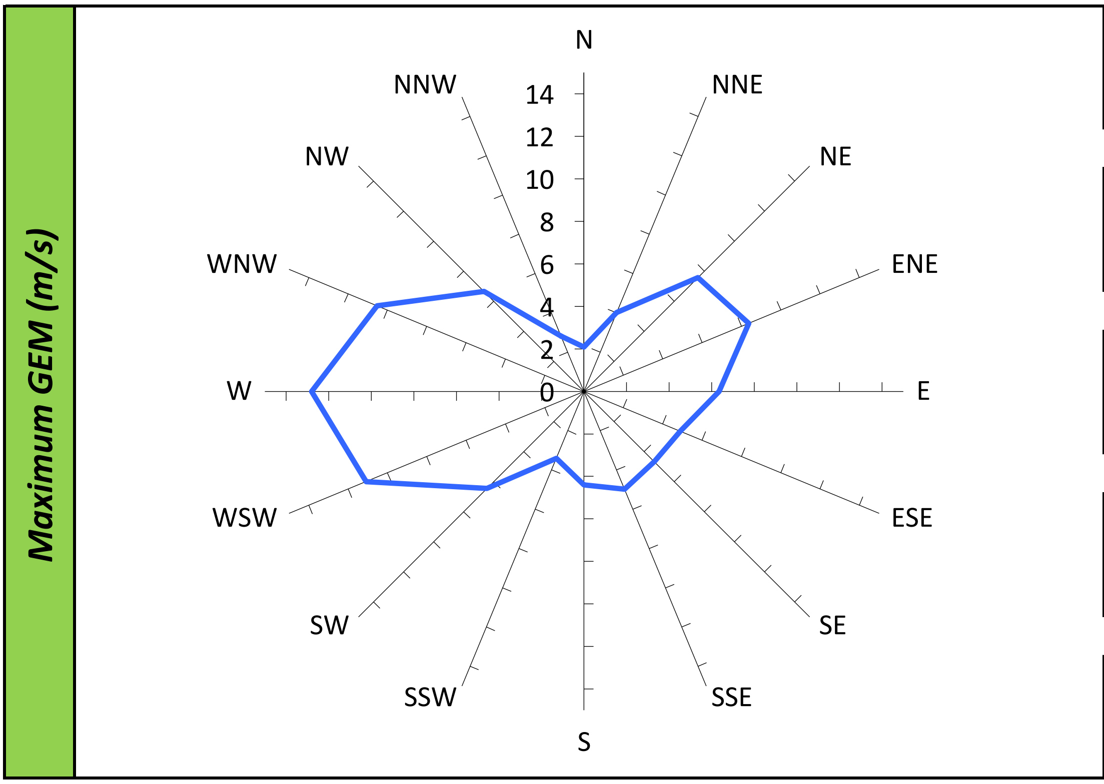
Criterion.

With development "as proposed", without proposed vegetation or other treatments.



Desired Criterion
24m/s

Measured Wind Speeds at Point 13



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

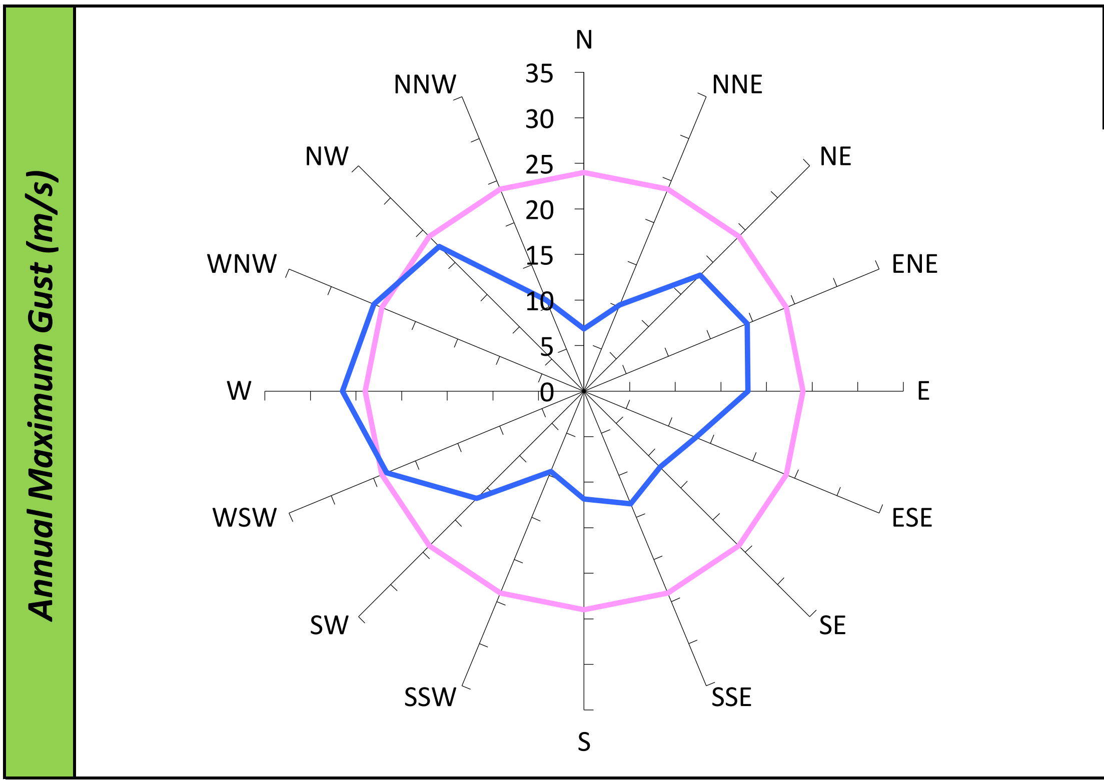
Probability of Criterion Exceedence (initial test)
28%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

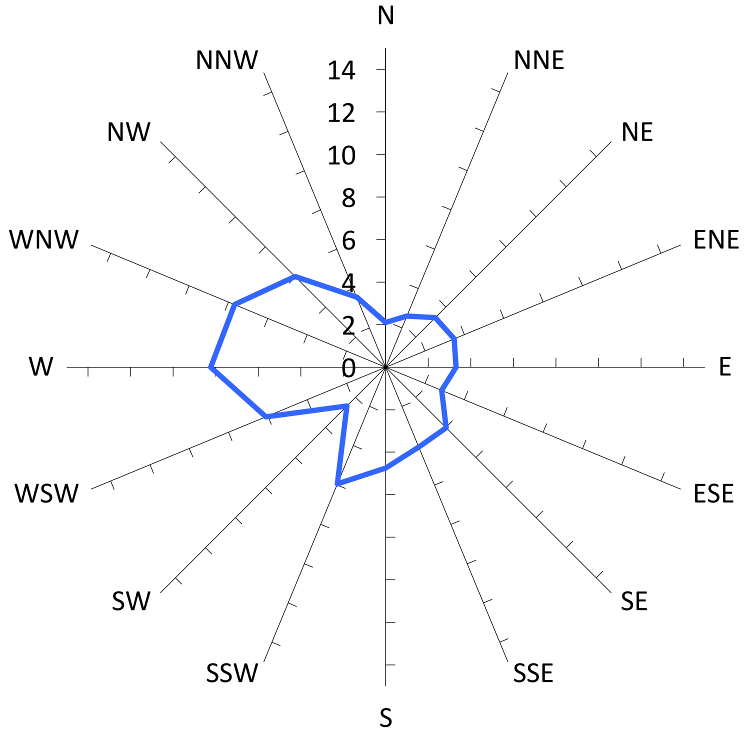
With development "as proposed", without proposed vegetation or other treatments.



Desired Criterion
24m/s

Measured Wind Speeds at Point 14

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
3%

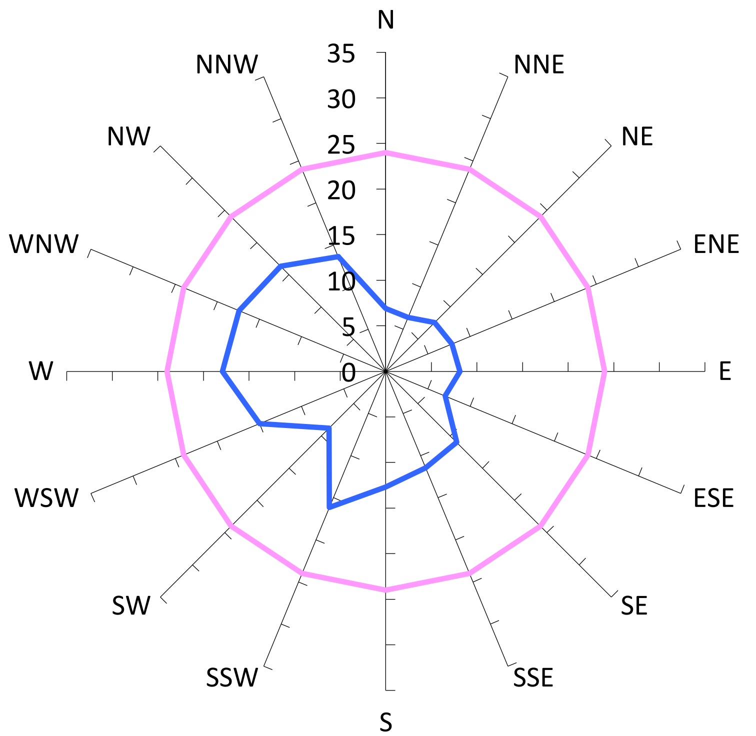
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

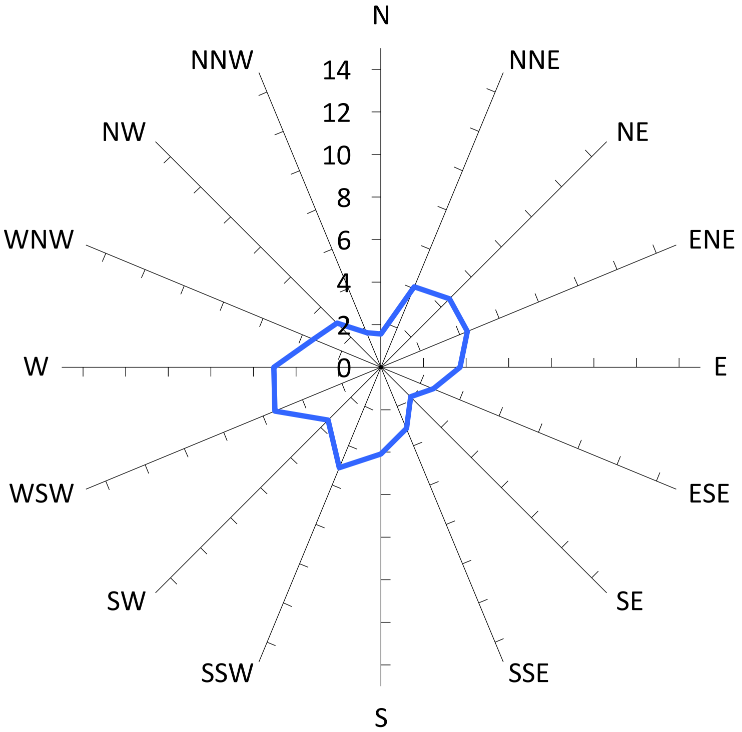
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 15

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
2%

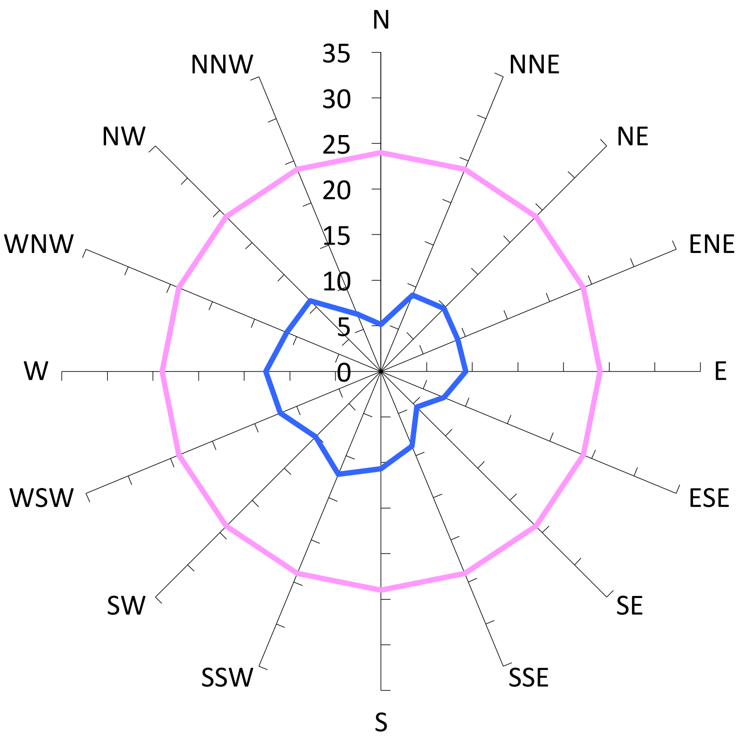
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

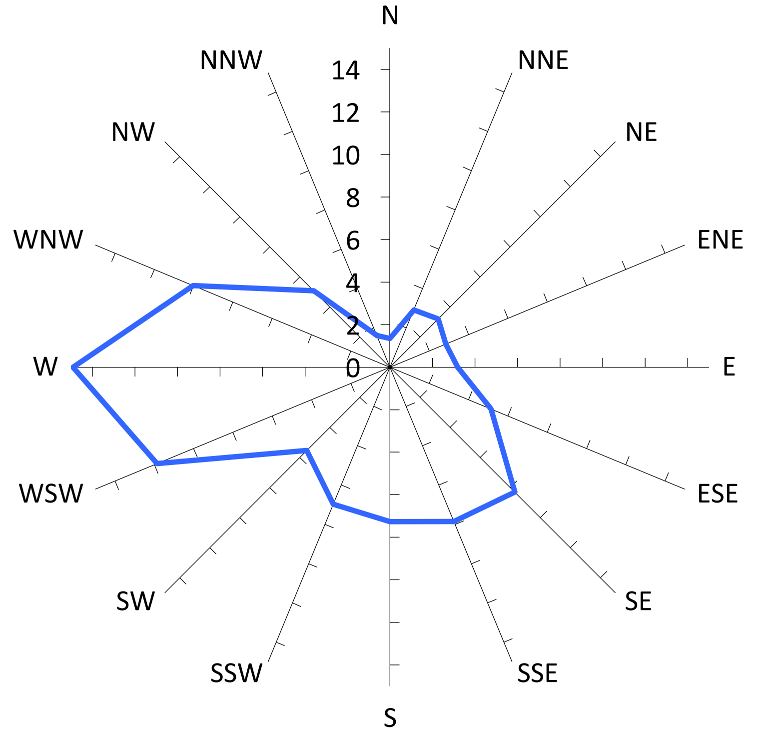
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 16

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
30%

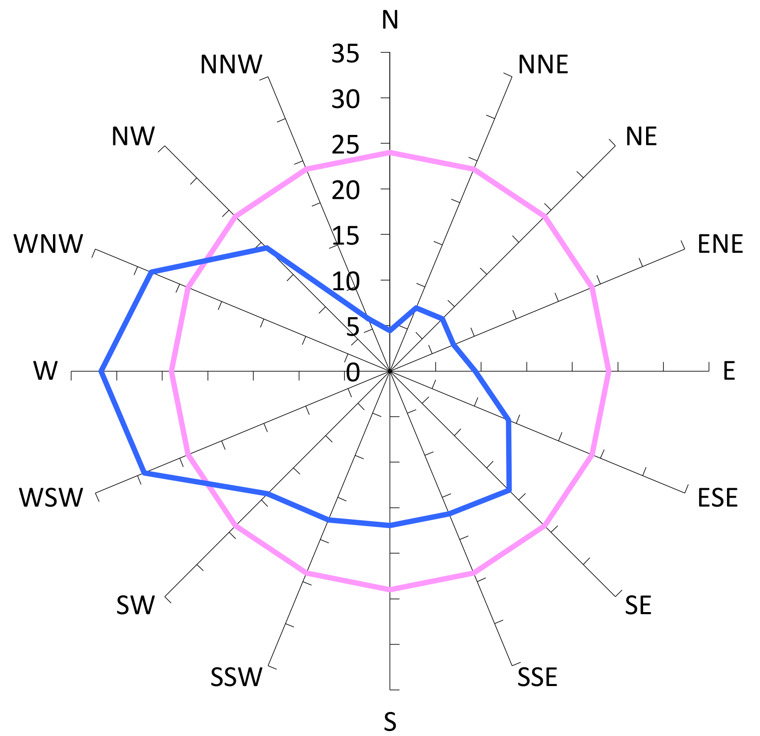
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

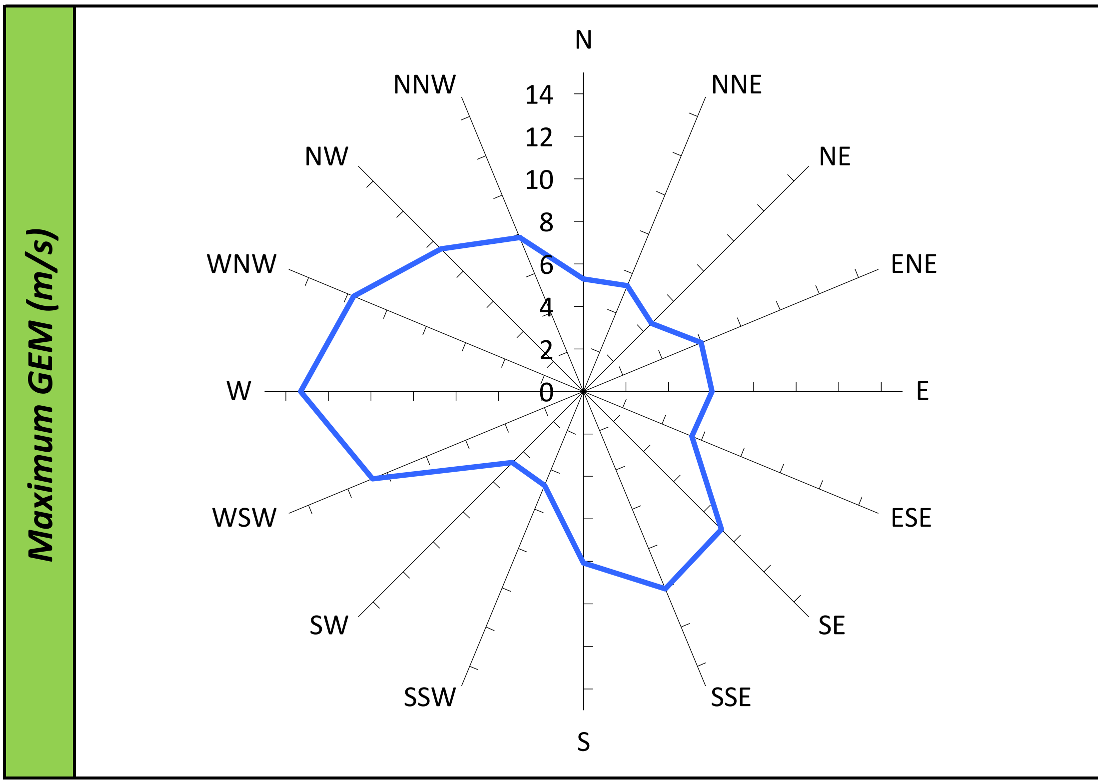
With development "as proposed", without proposed vegetation or other treatments.

Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 17



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

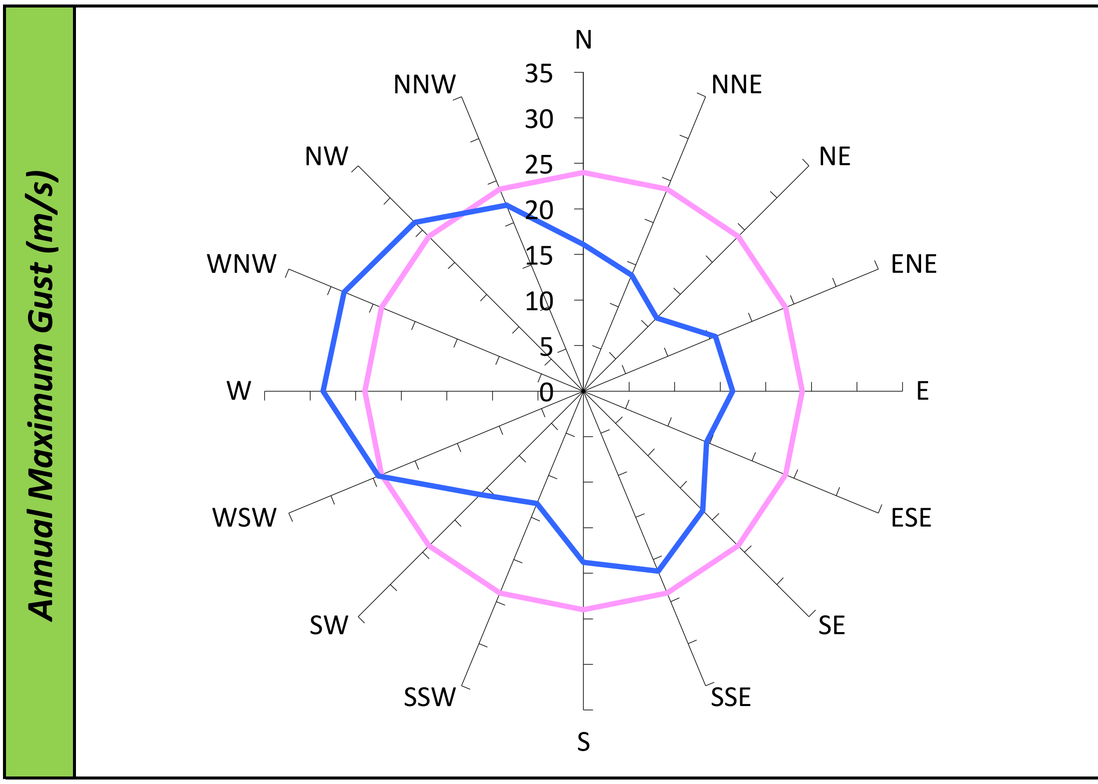
Probability of Criterion Exceedence (initial test)
39%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

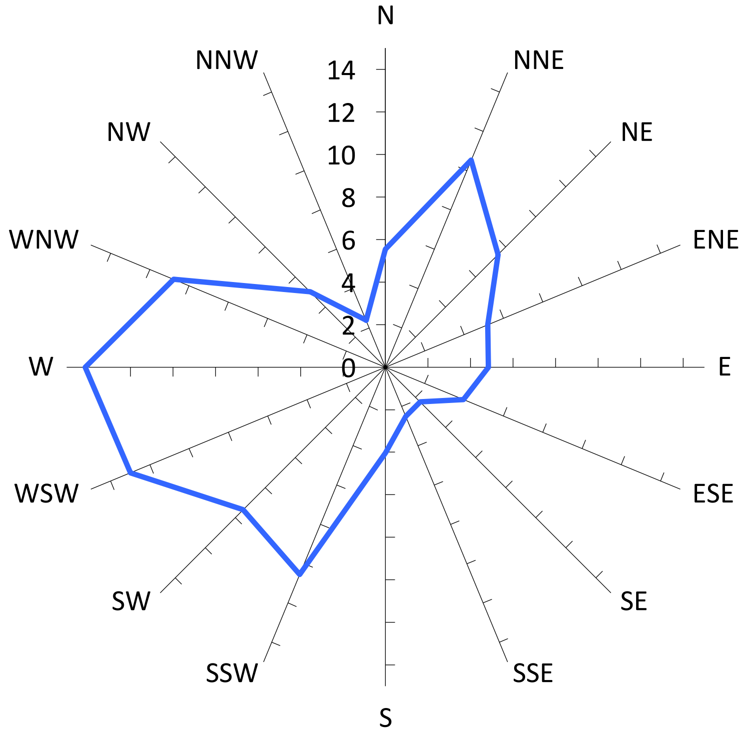
With development "as proposed", without proposed vegetation or other treatments.



Desired Criterion
24m/s

Measured Wind Speeds at Point 18

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

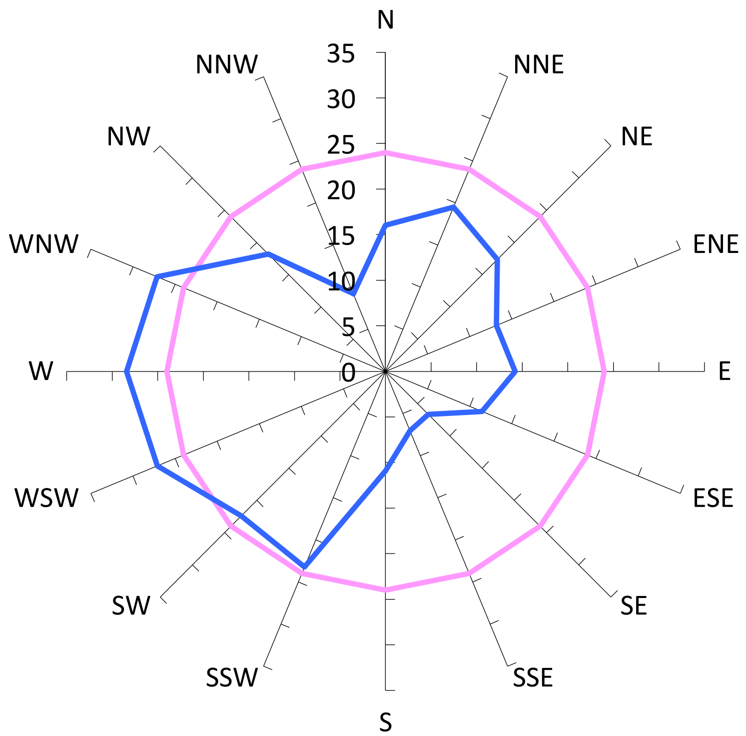
Probability of Criterion Exceedence (initial test)
32%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.
With development "as proposed", without proposed vegetation or other treatments.

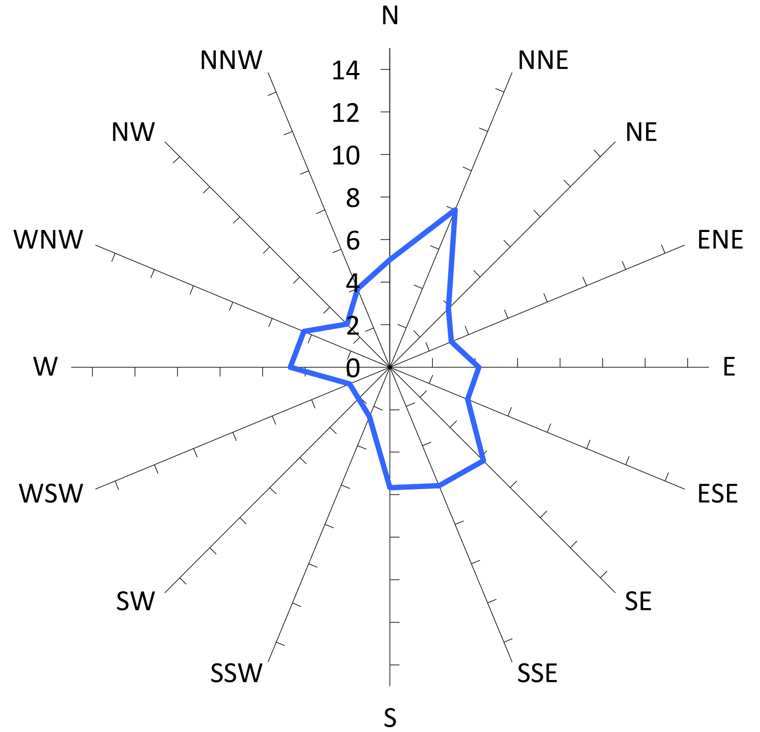
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 19

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
10%

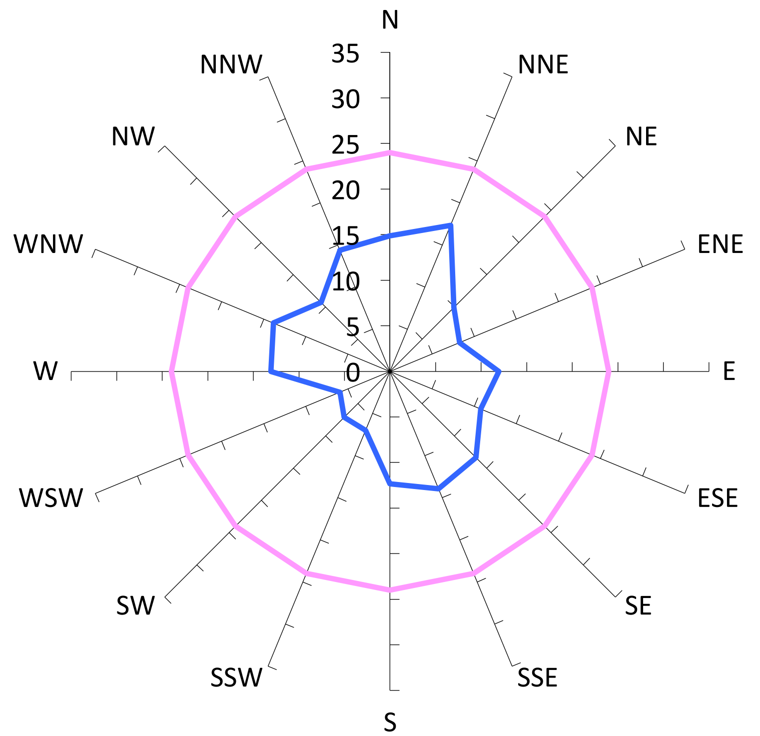
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

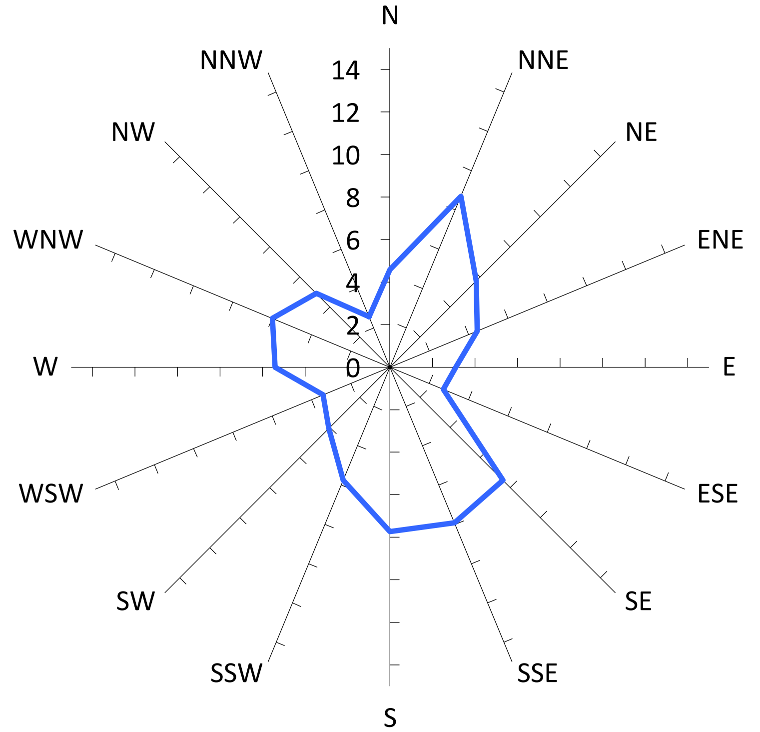
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 20

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
22%

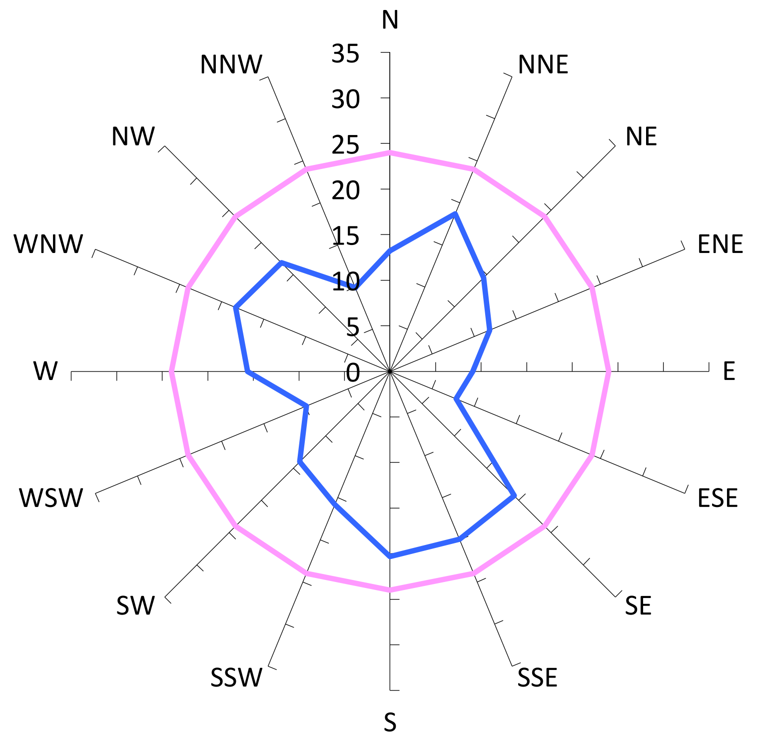
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

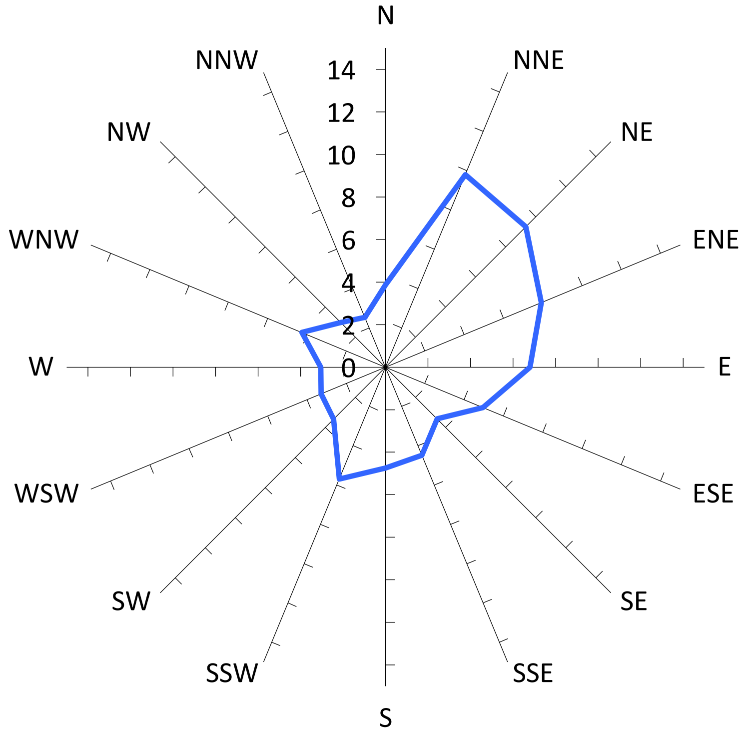
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 21

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
20%

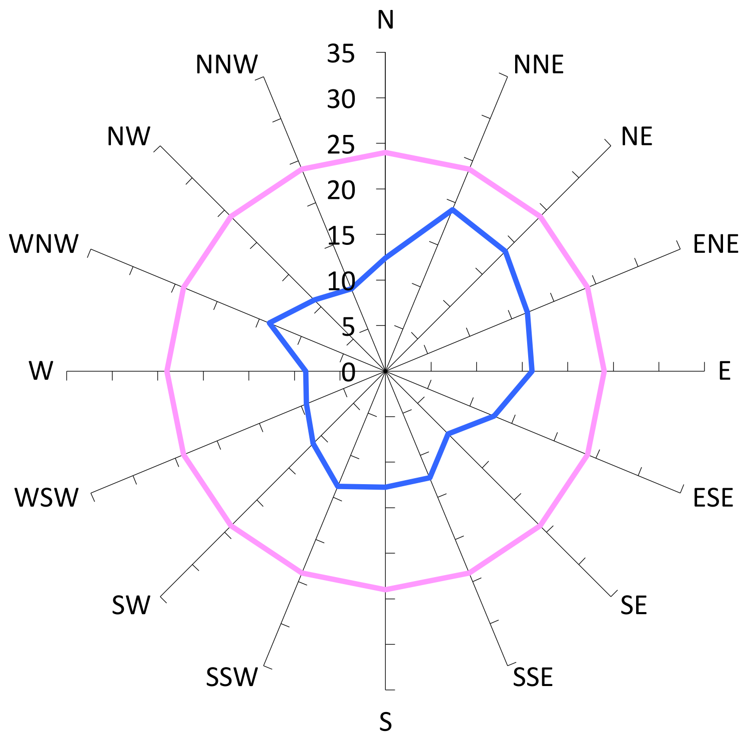
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

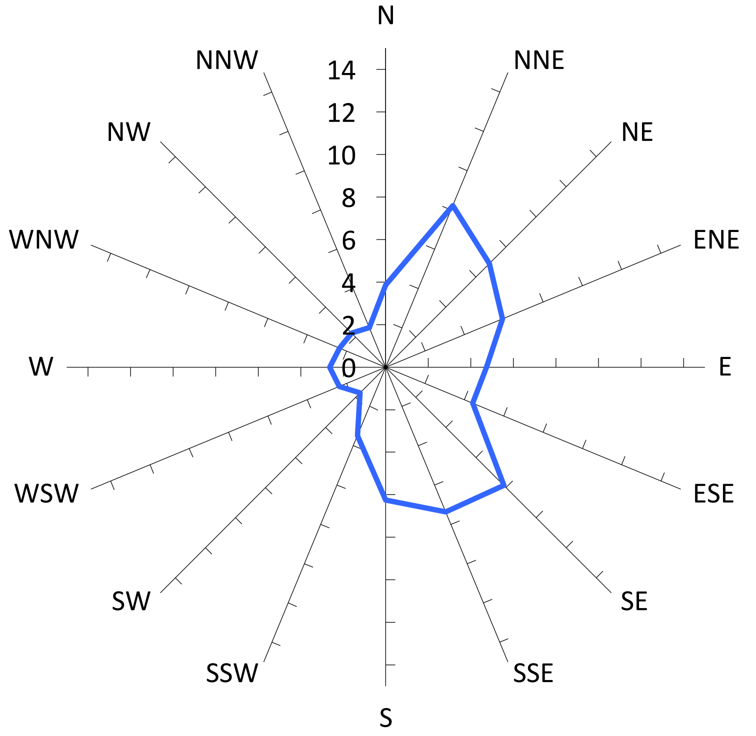
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 22

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
19%

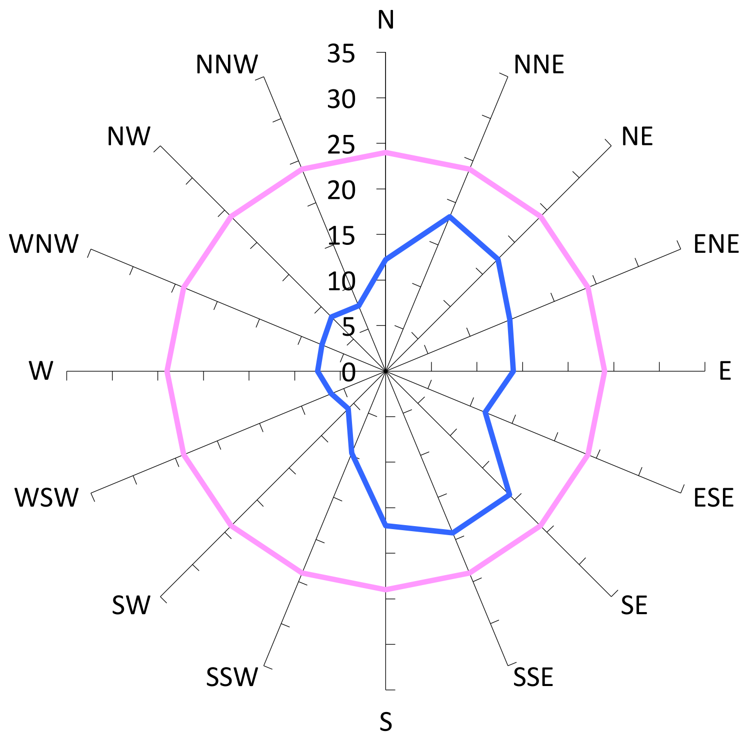
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

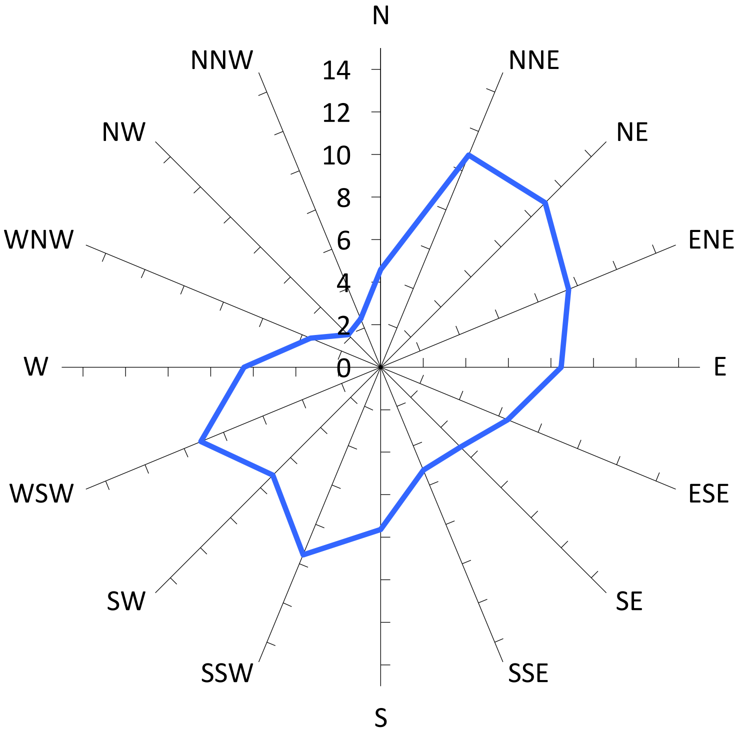
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 23

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
35%

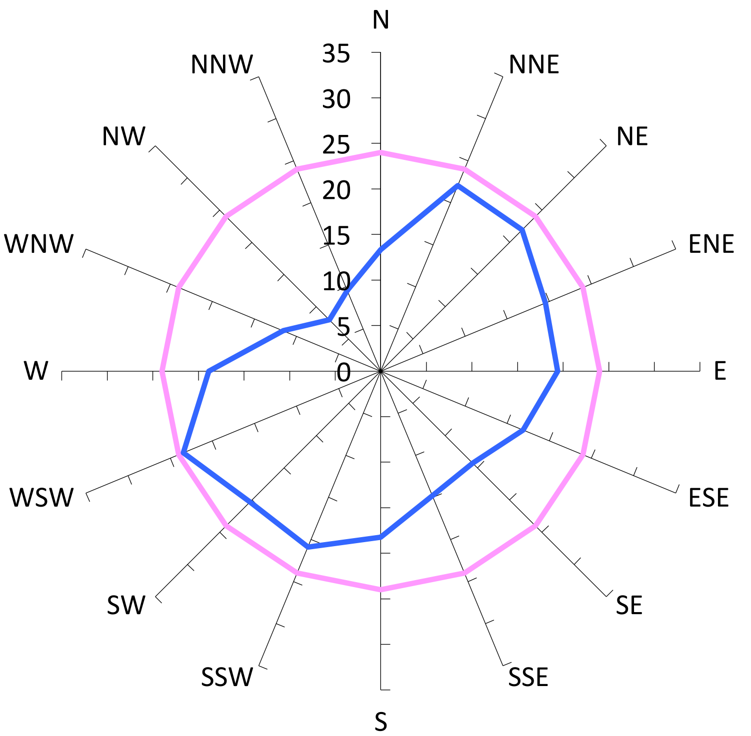
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

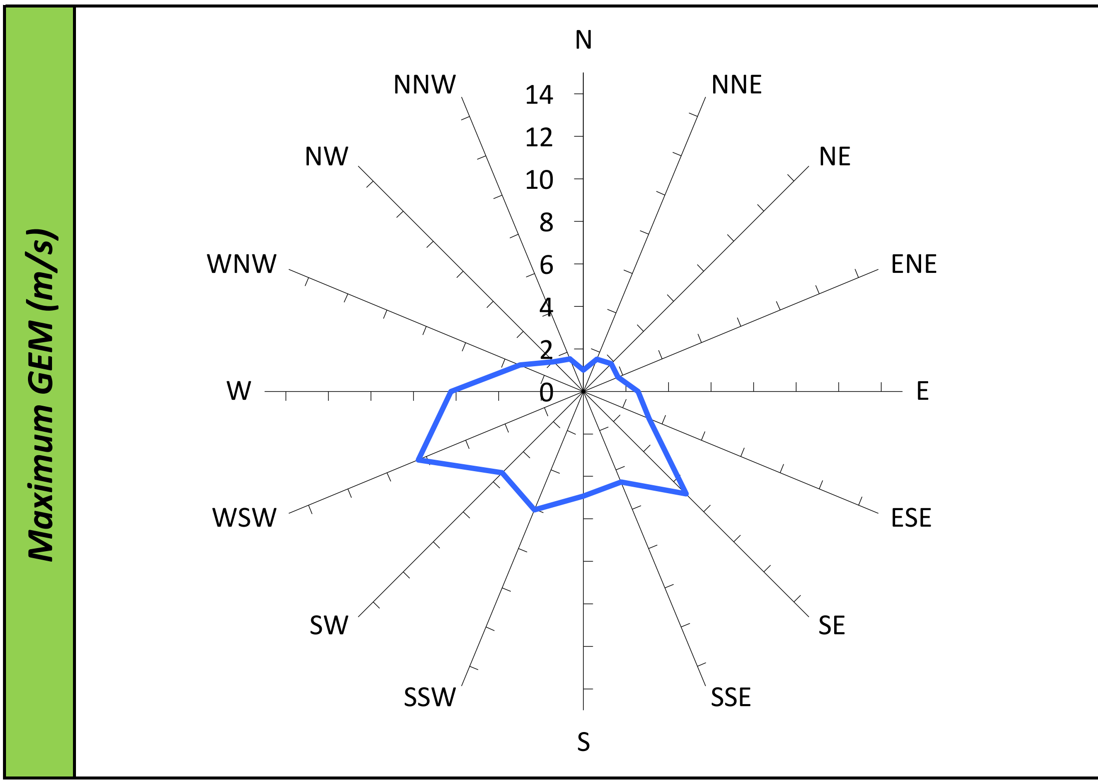
With development "as proposed", without proposed vegetation or other treatments.

Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 24



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

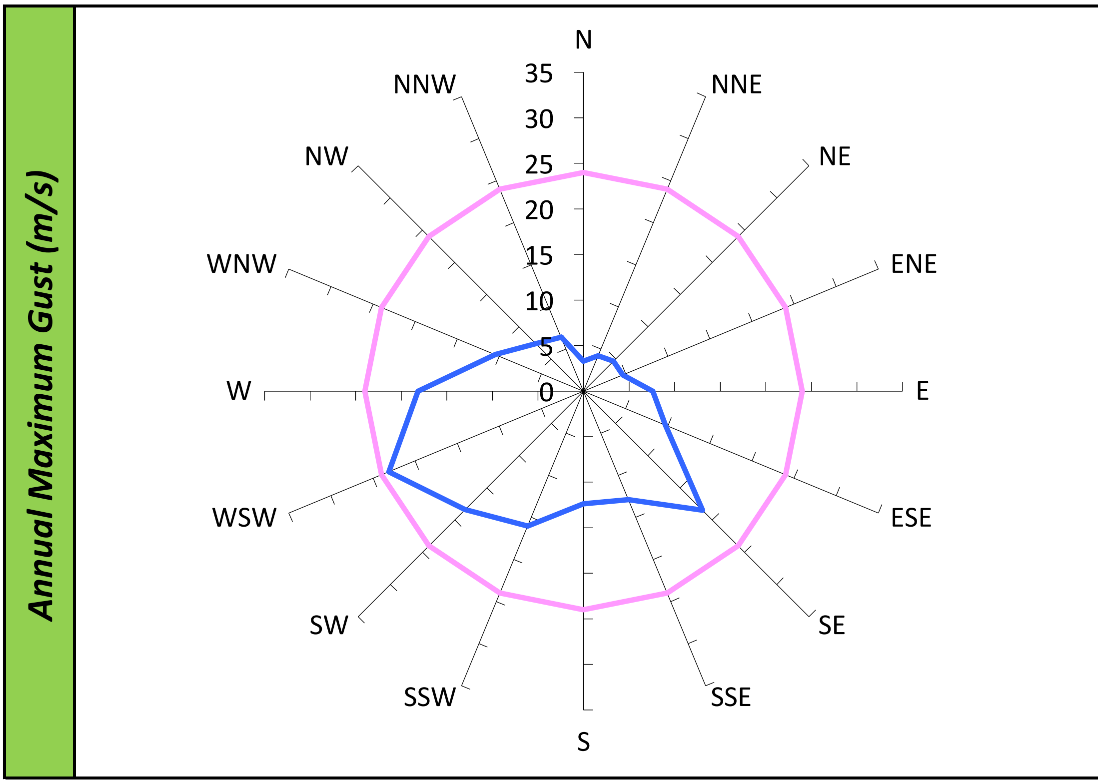
Probability of Criterion Exceedence (initial test)
11%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

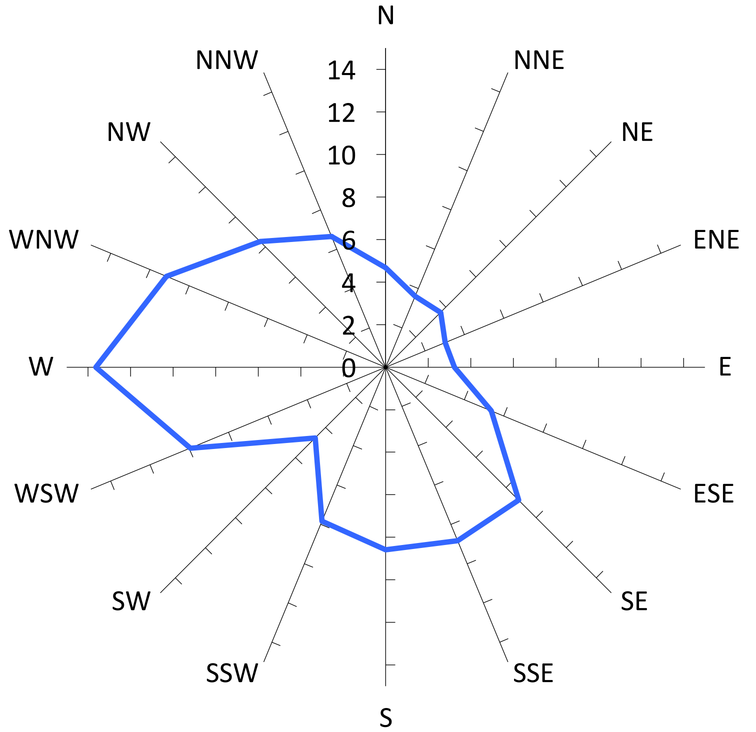
With development "as proposed", without proposed vegetation or other treatments.



Desired Criterion
24m/s

Measured Wind Speeds at Point 25

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
39%

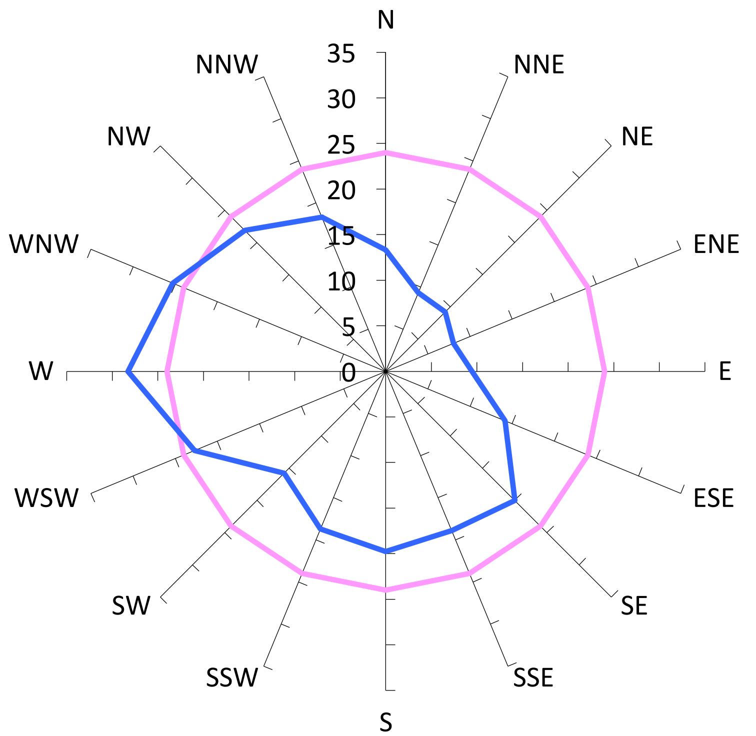
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

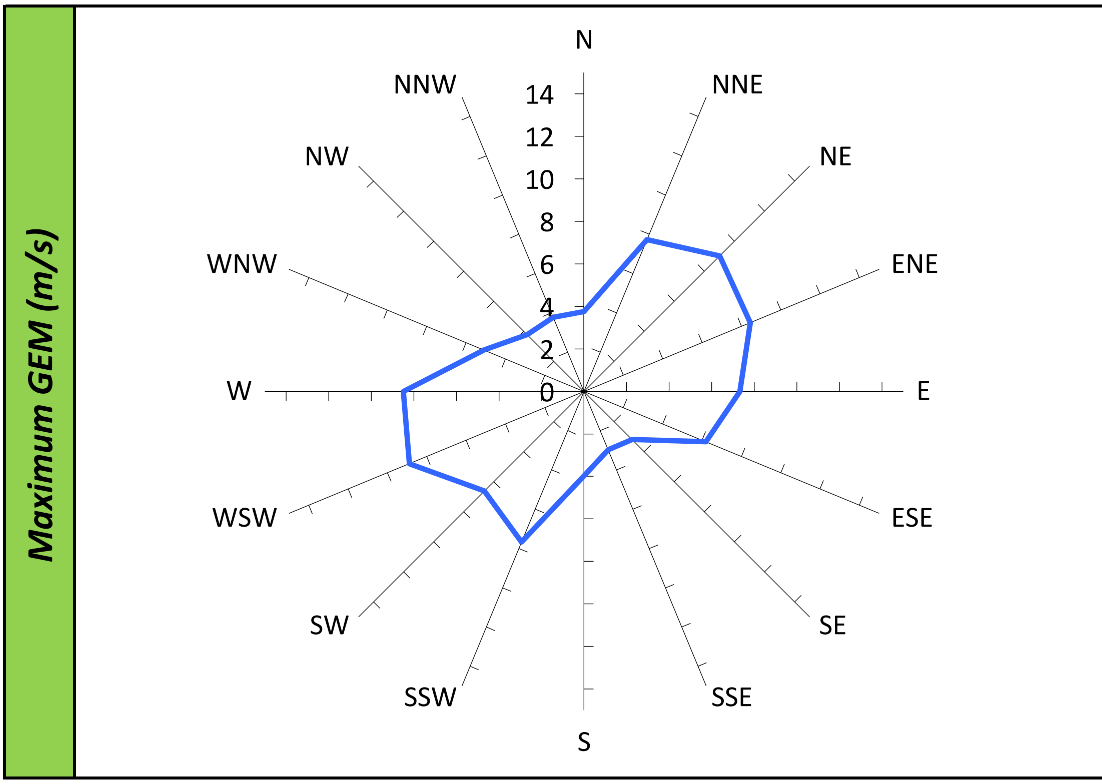
With development "as proposed", without proposed vegetation or other treatments.

Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 26



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

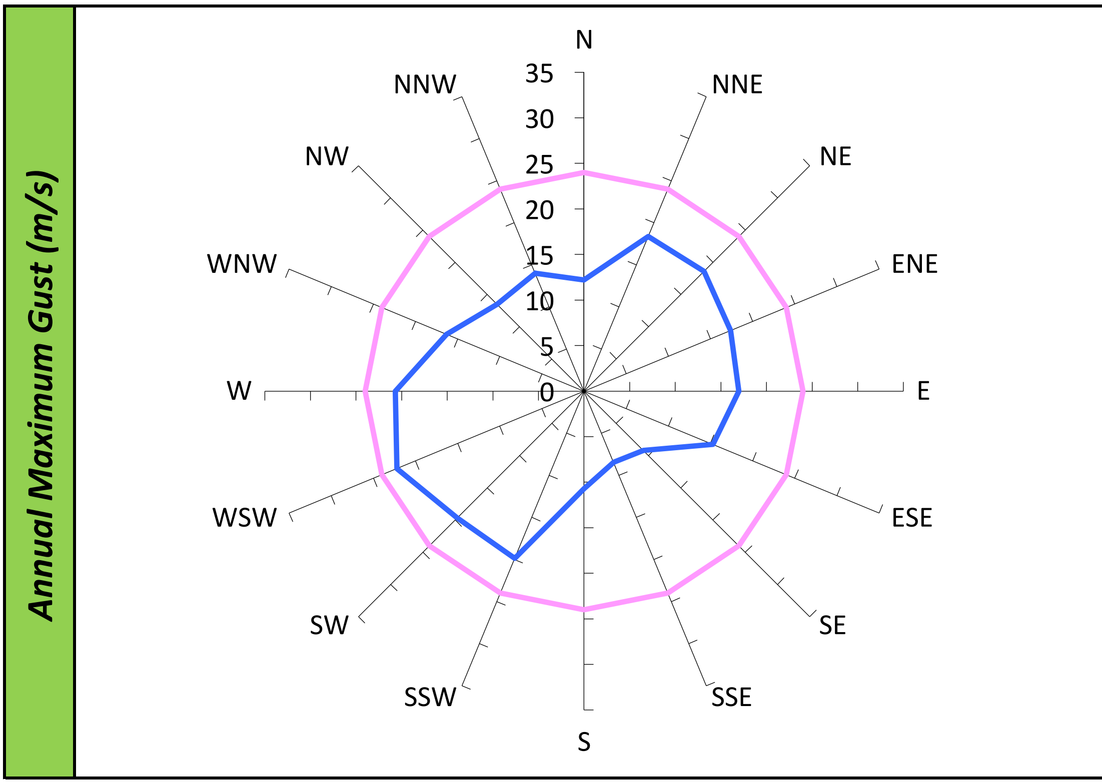
Probability of Criterion Exceedence (initial test)
32%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

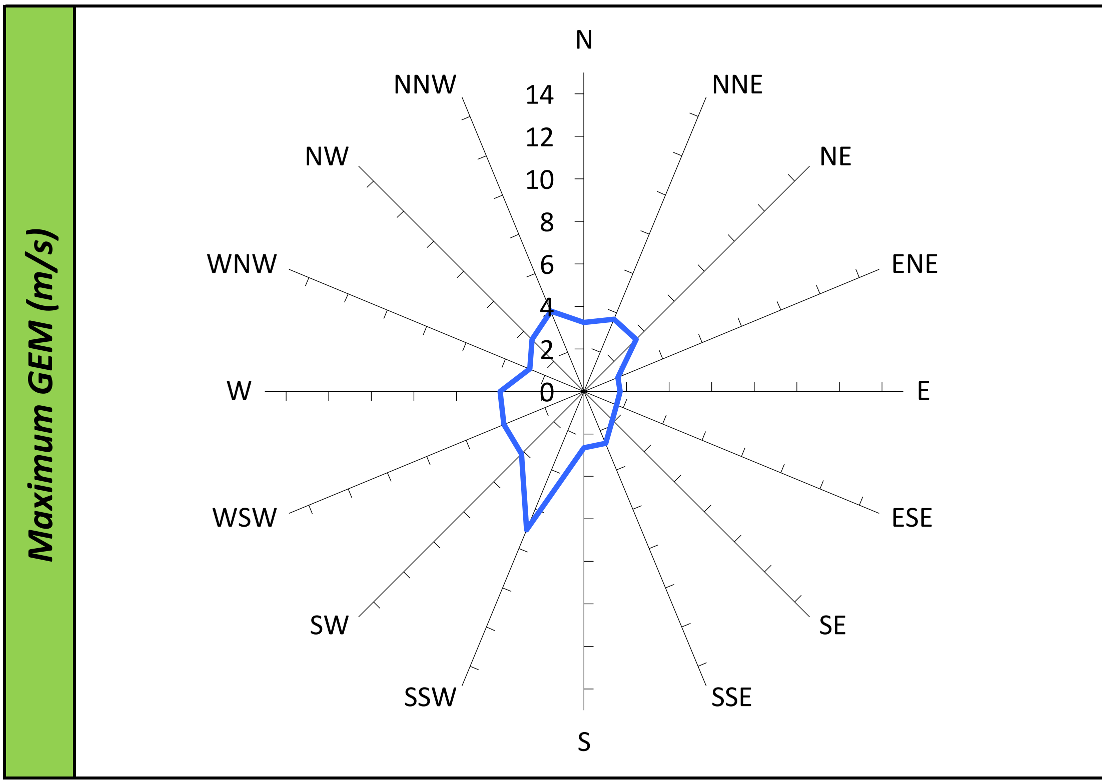
Criterion.

With development "as proposed", without proposed vegetation or other treatments.



Desired Criterion
24m/s

Measured Wind Speeds at Point 27



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

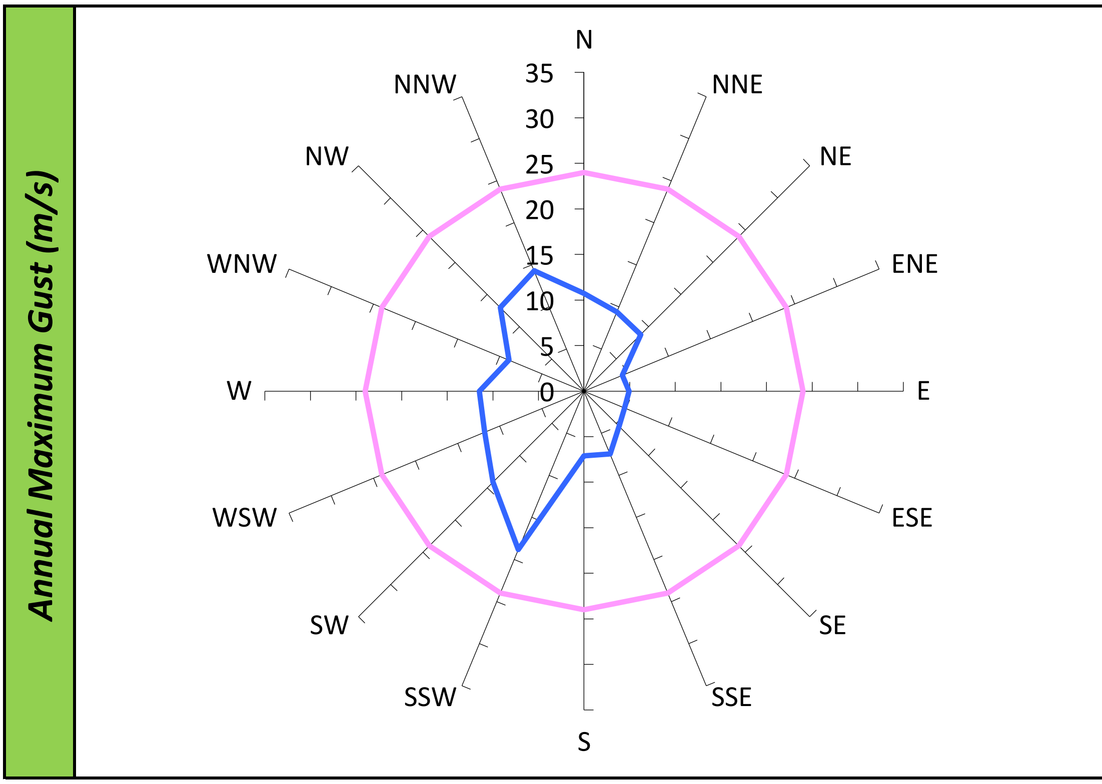
Probability of Criterion Exceedence (initial test)
4%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

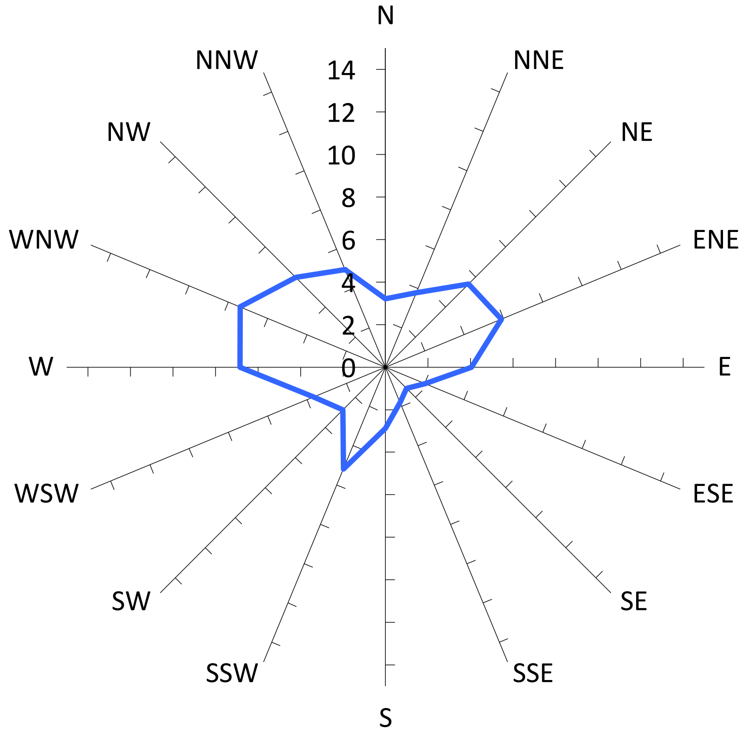
With development "as proposed", without proposed vegetation or other treatments.



Desired Criterion
24m/s

Measured Wind Speeds at Point 28

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
2%

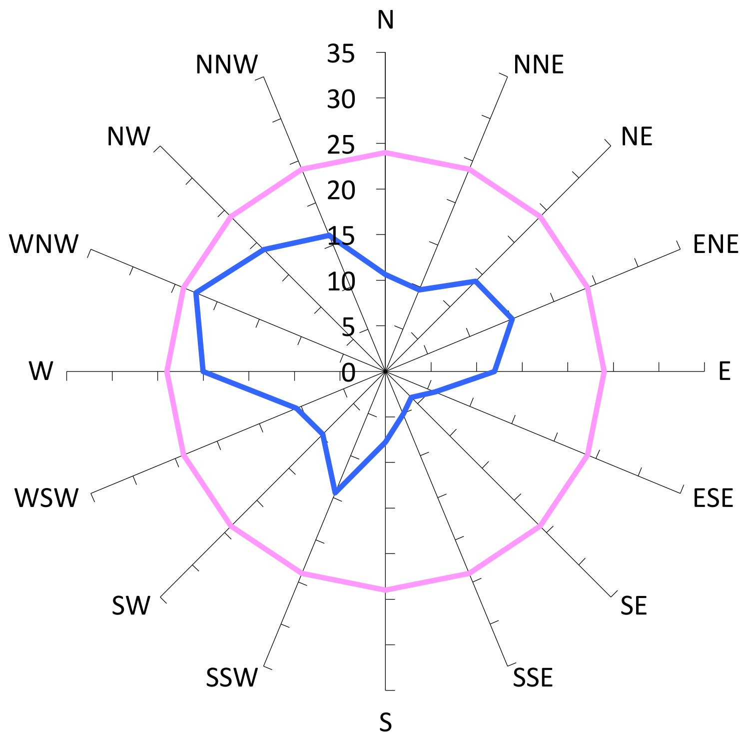
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

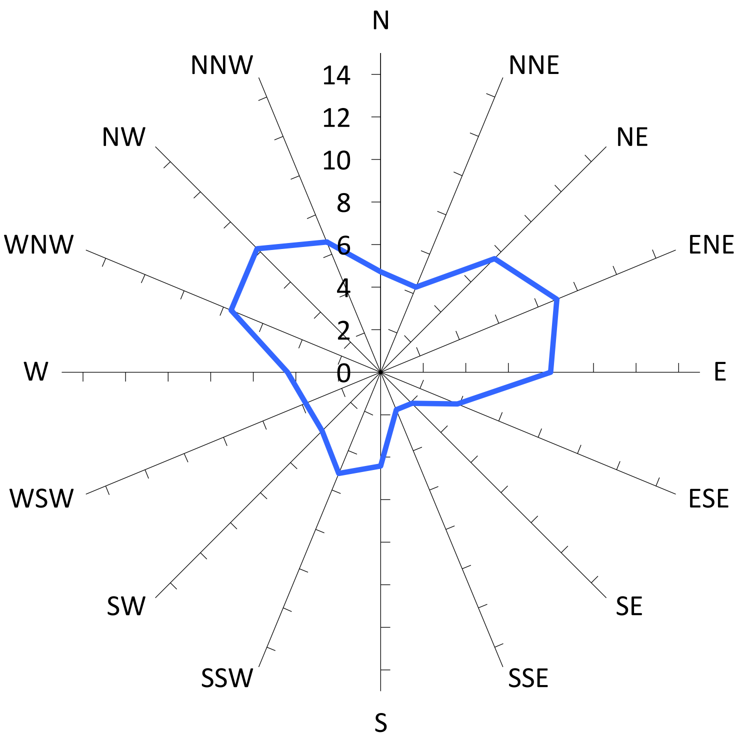
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 29

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
8%

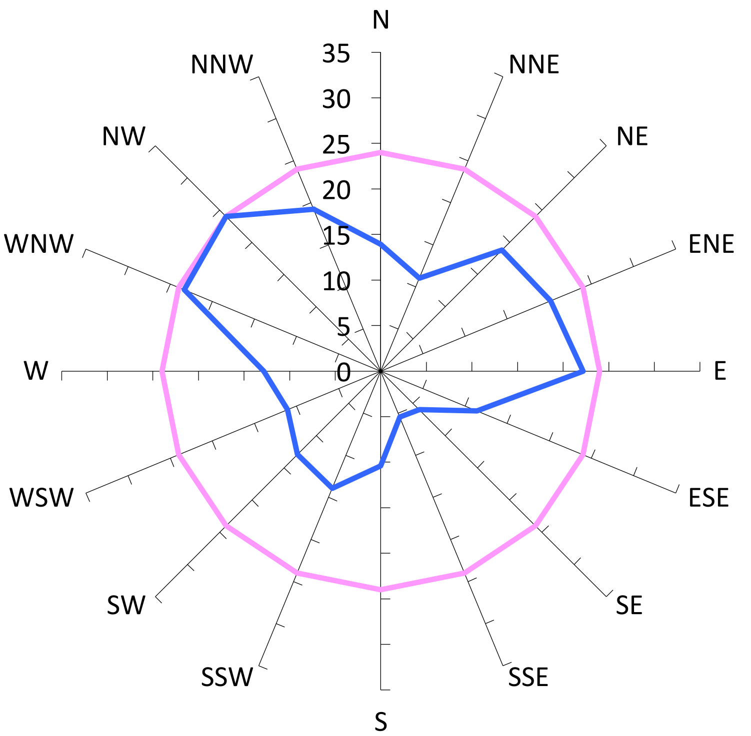
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

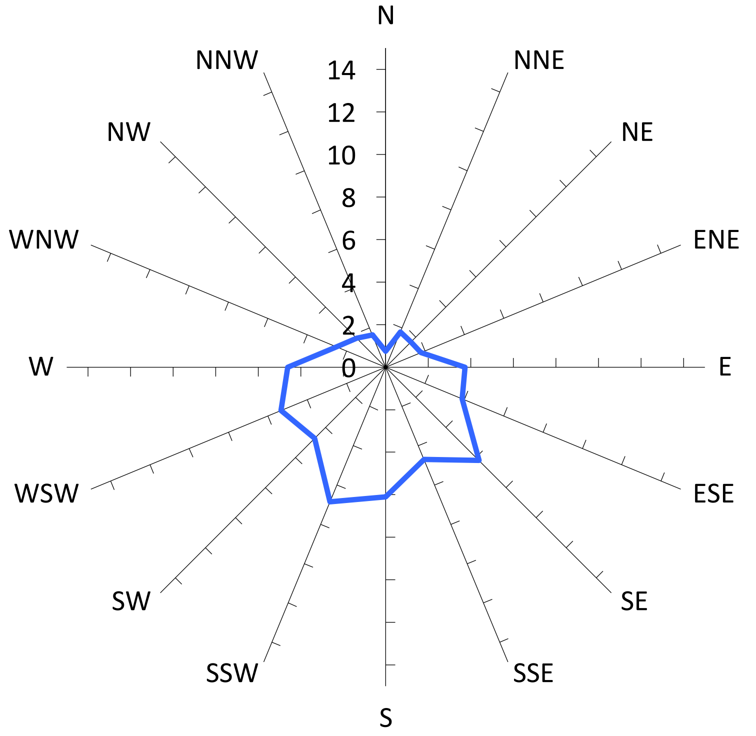
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 30

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
1%

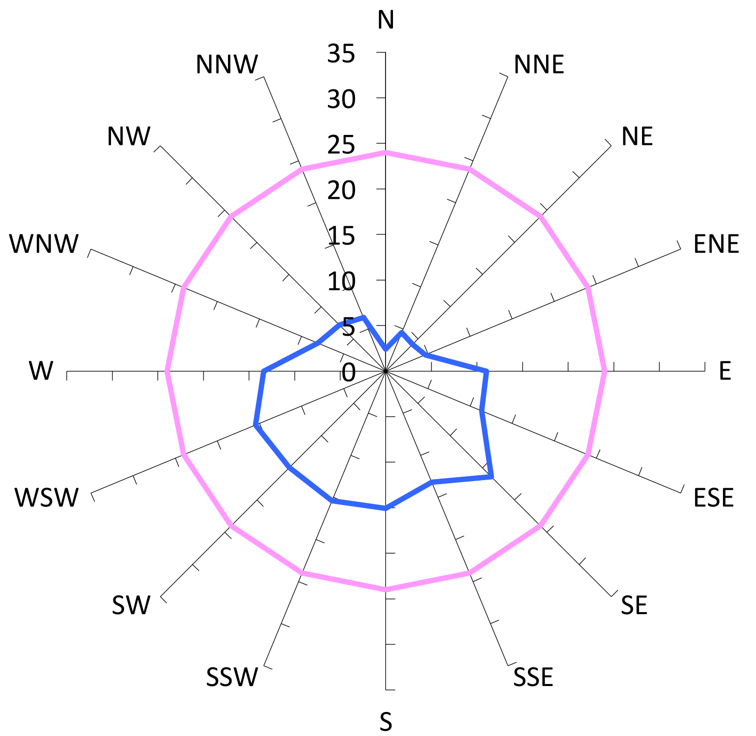
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

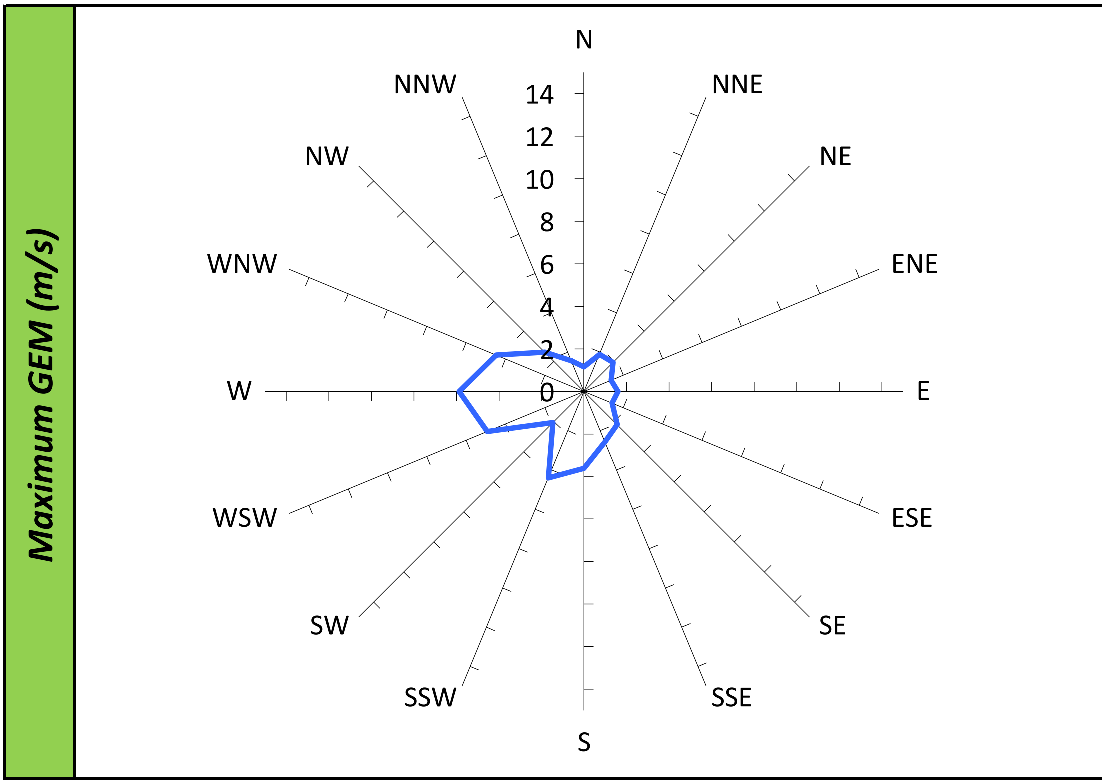
With development "as proposed", without proposed vegetation or other treatments.

Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 31



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

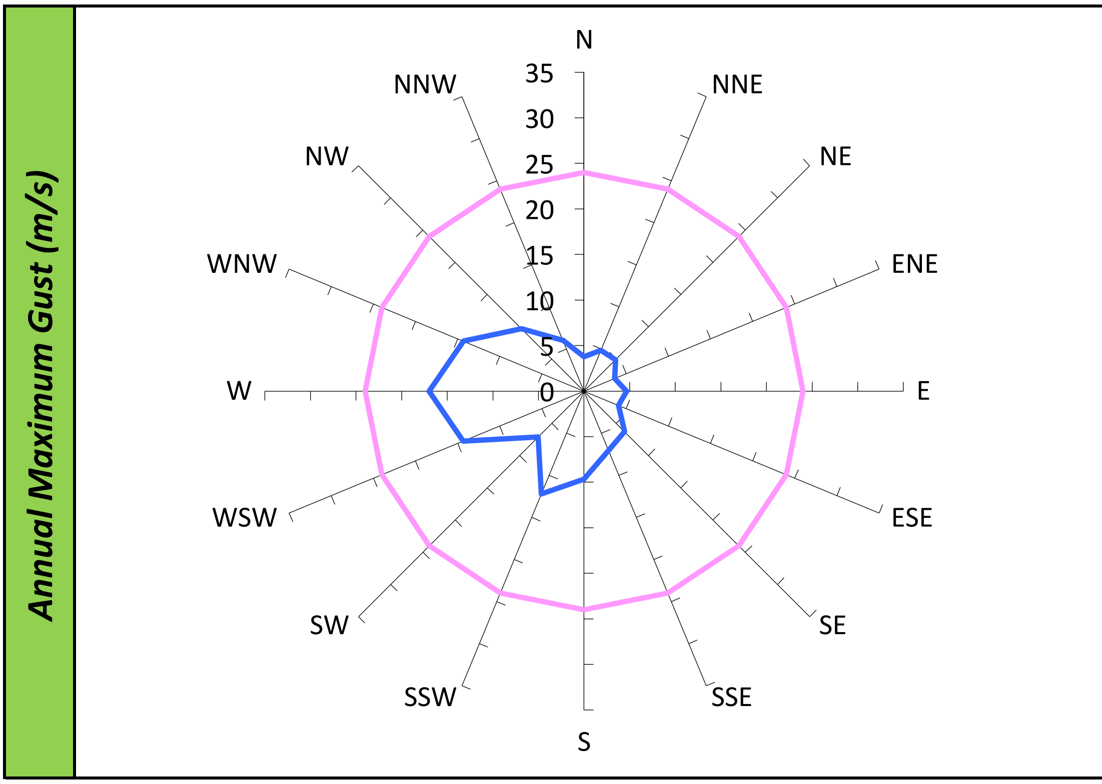
Probability of Criterion Exceedence (initial test)
2%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

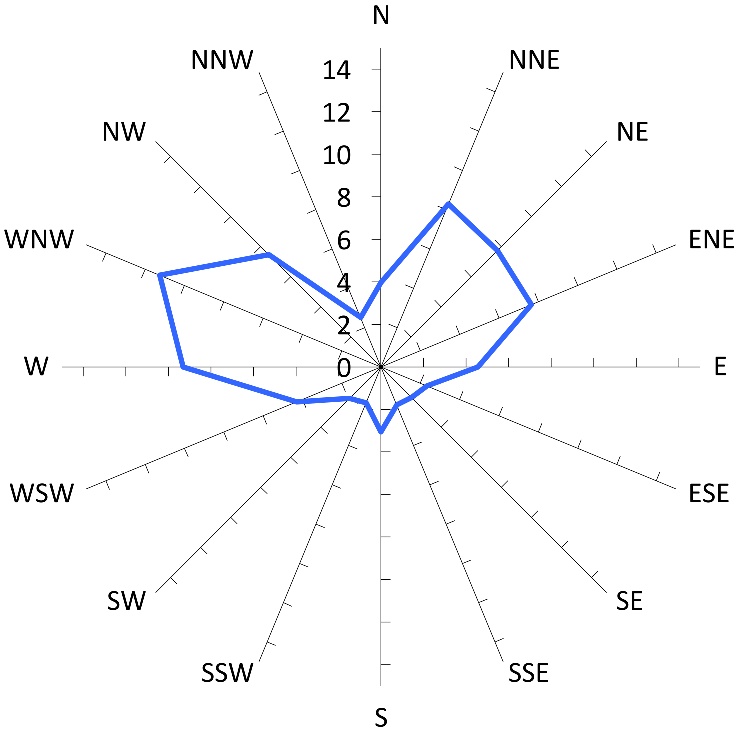
With development "as proposed", without proposed vegetation or other treatments.



Desired Criterion
24m/s

Measured Wind Speeds at Point 32

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
9%

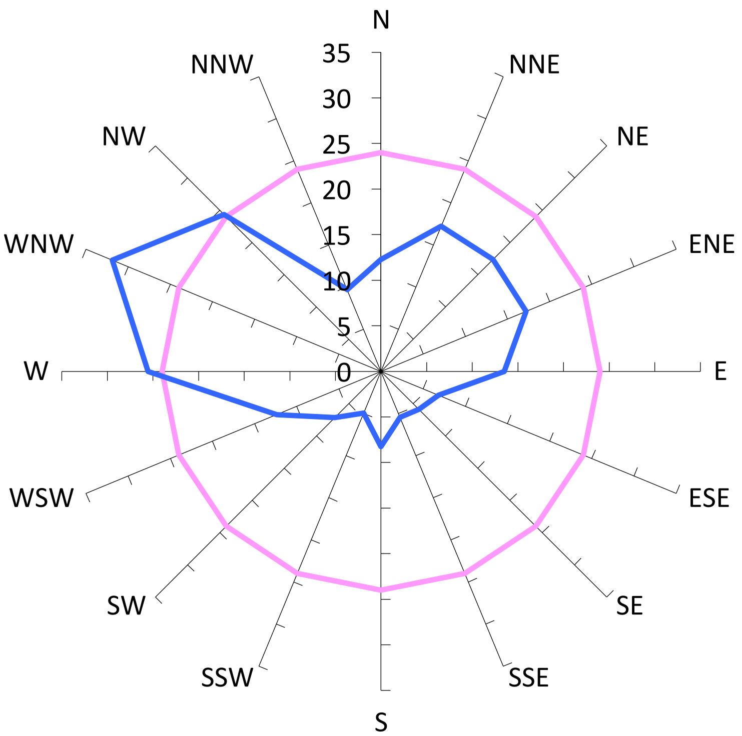
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

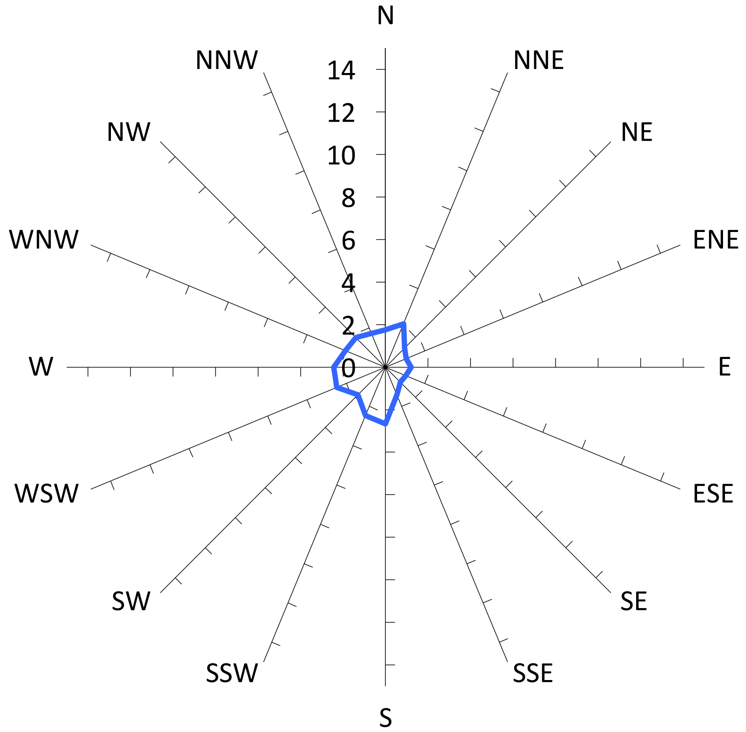
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 33

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

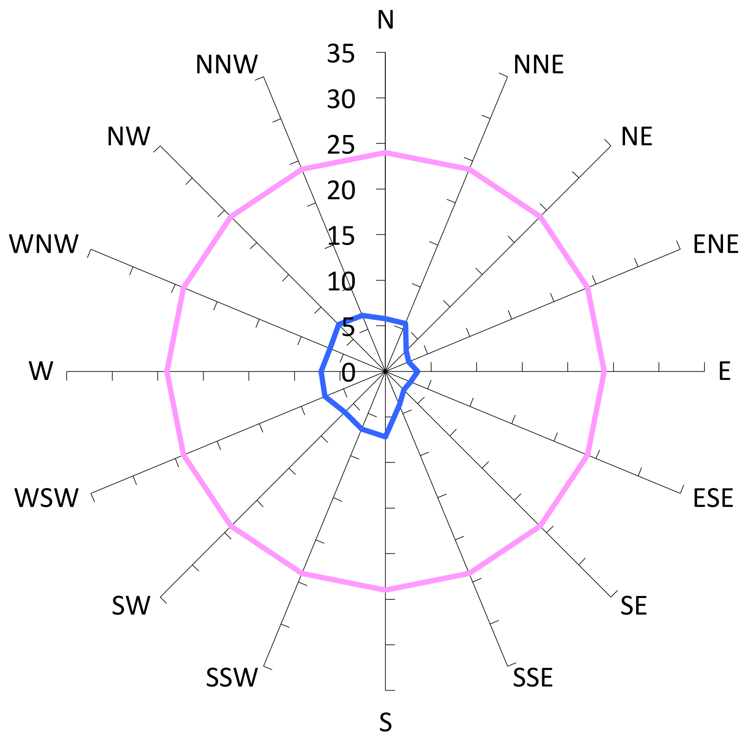
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

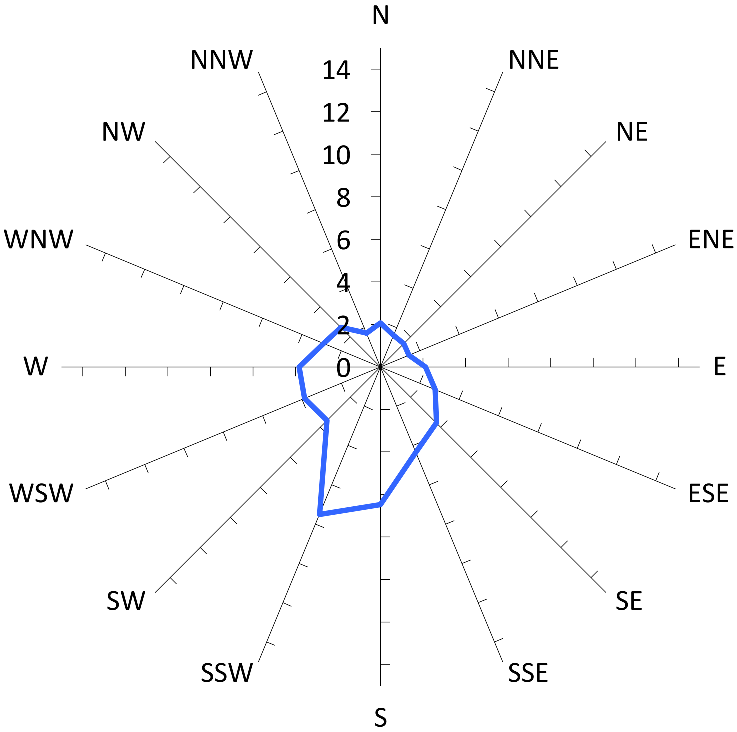
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 34

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
6%

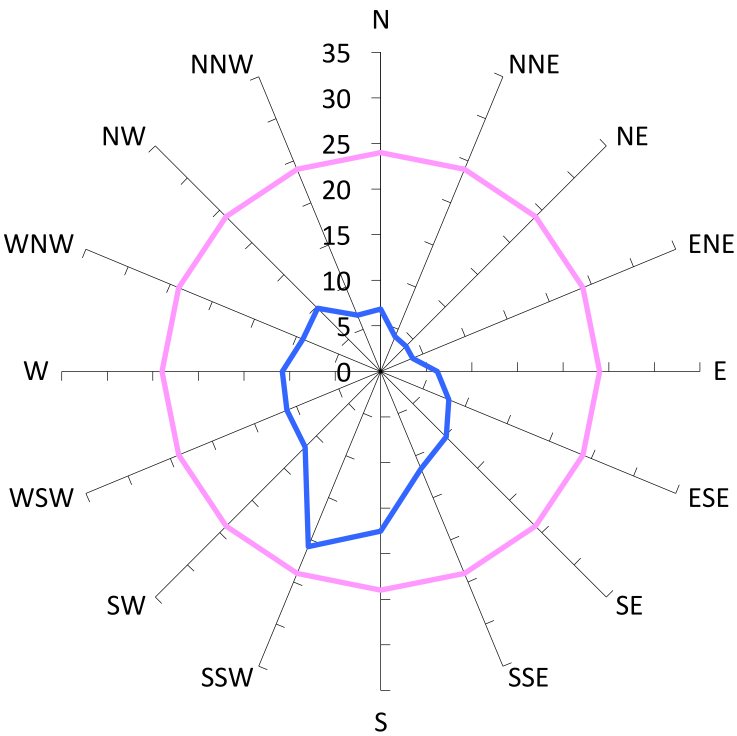
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

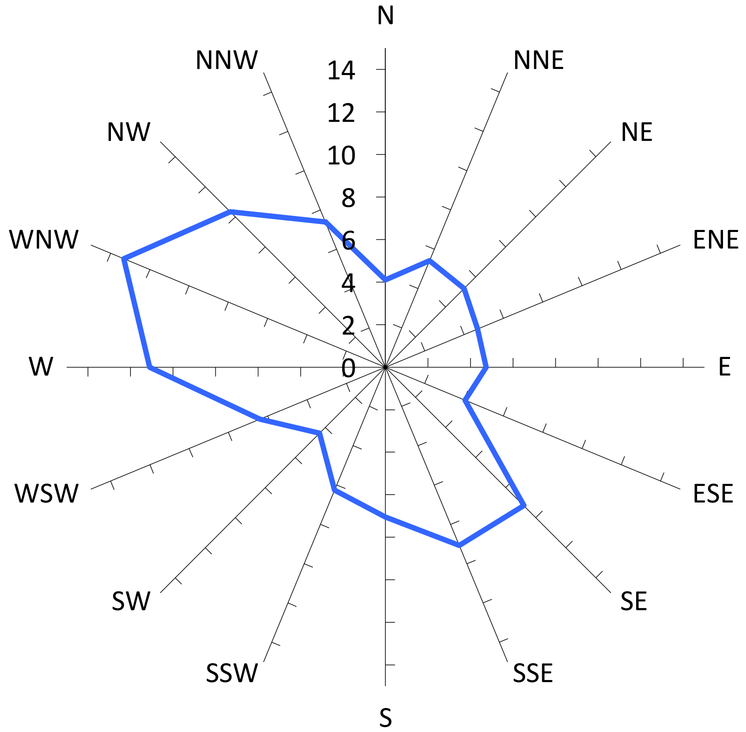
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 35

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
33%

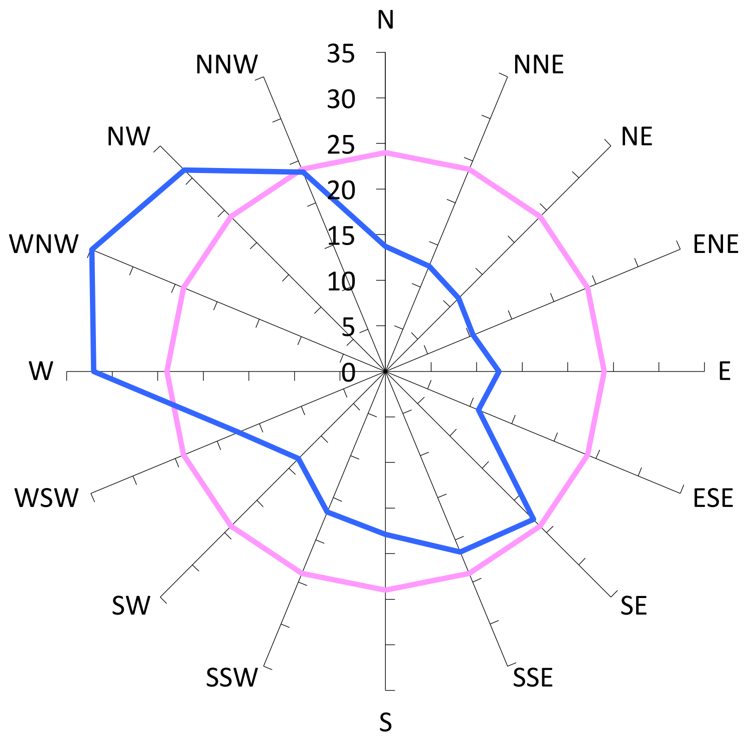
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

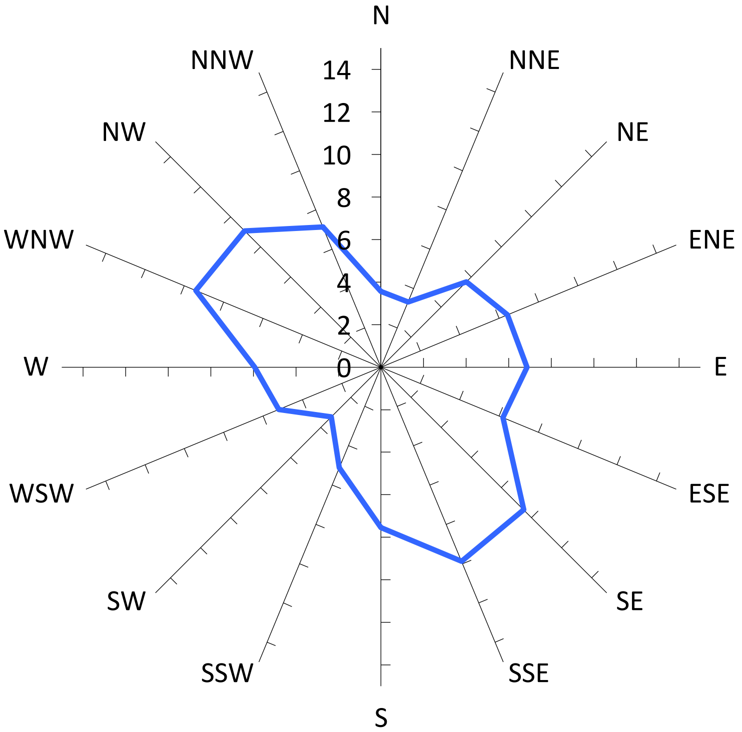
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 36

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
31%

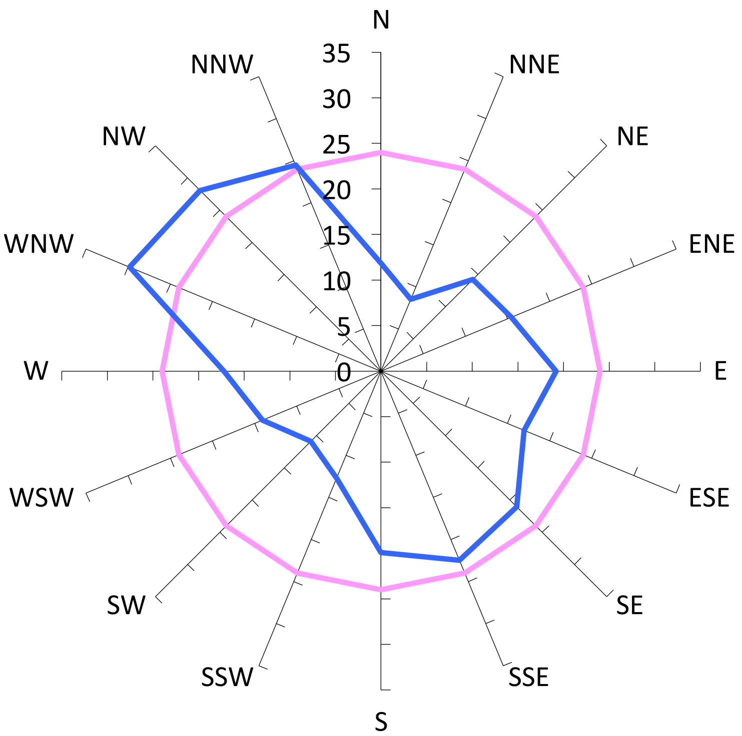
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

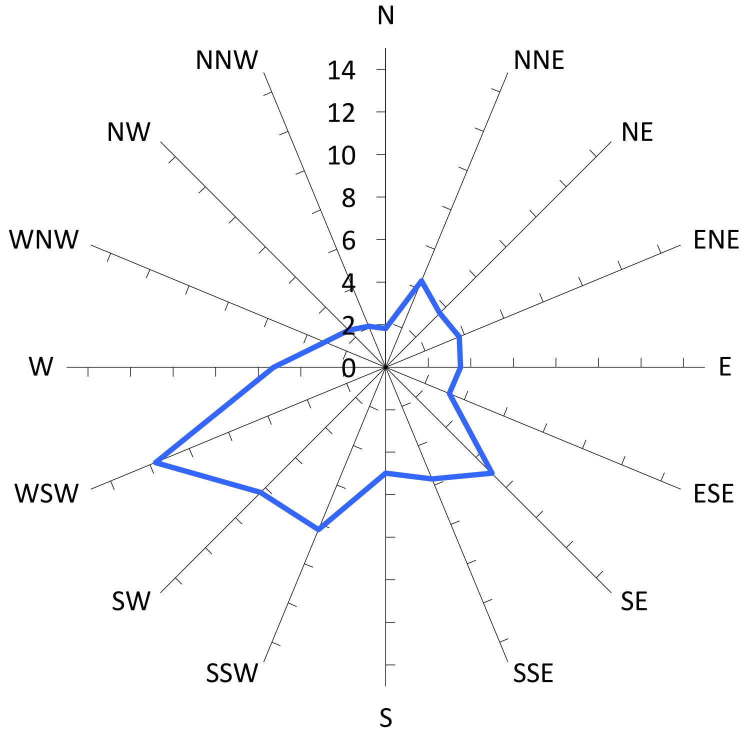
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 37

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
16%

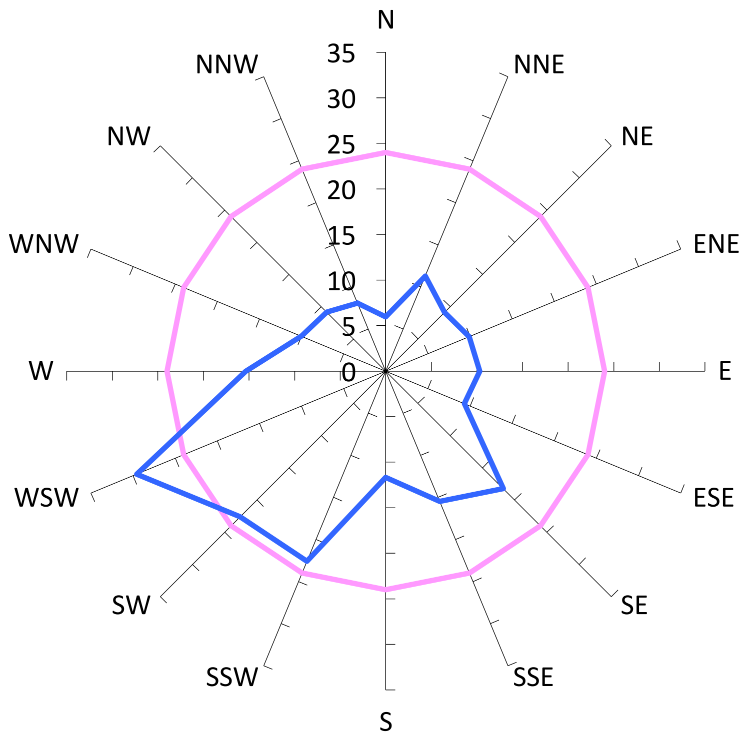
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

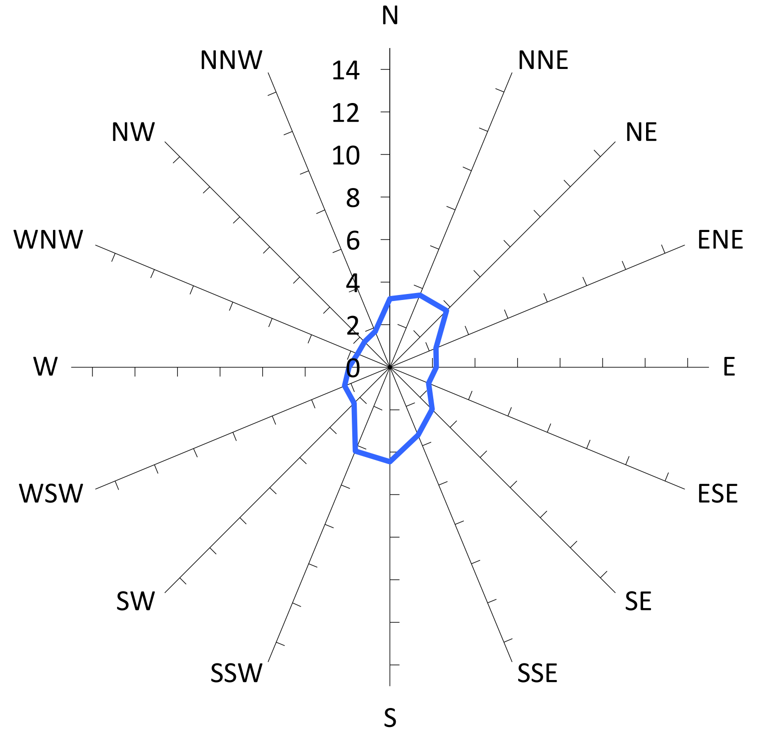
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 38

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
0%

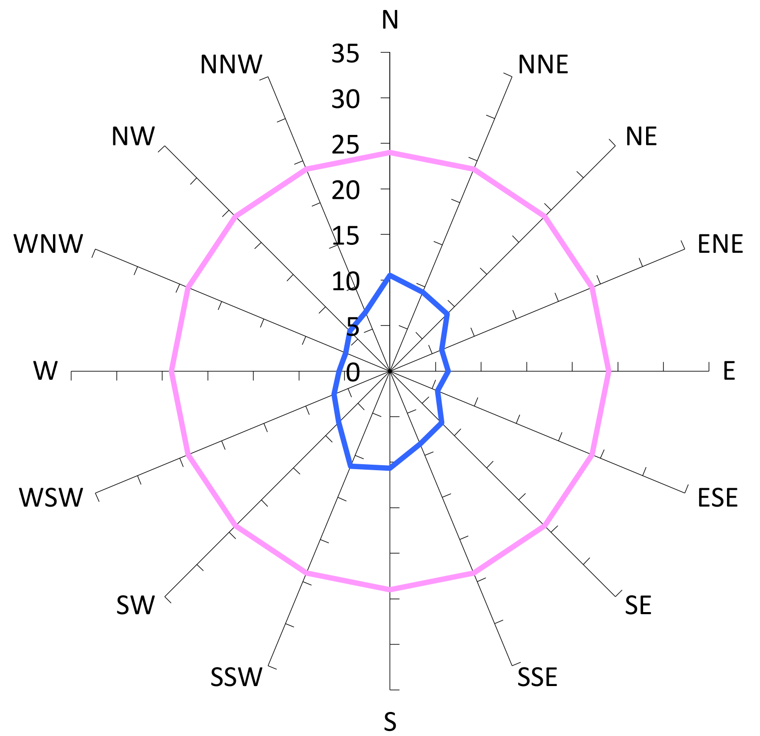
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

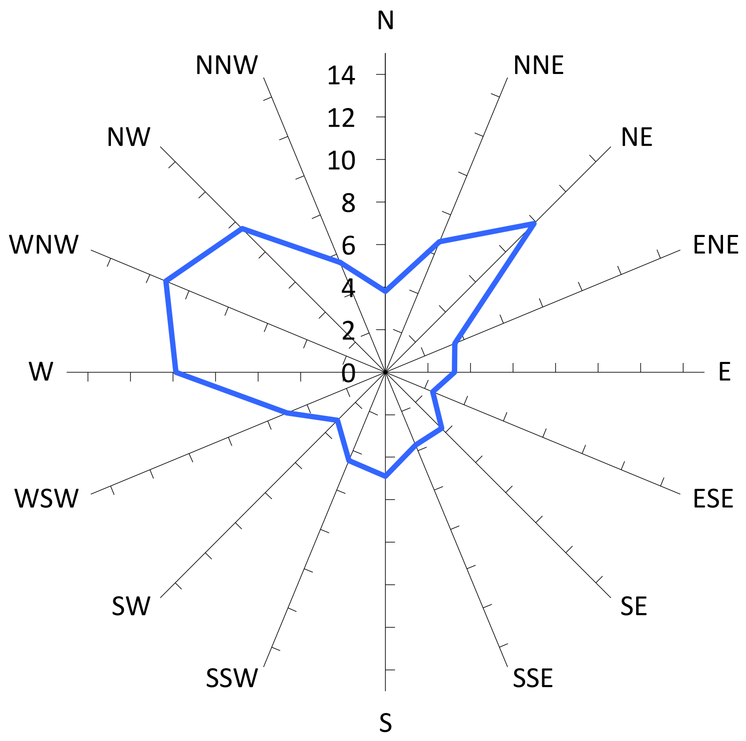
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 39

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
24%

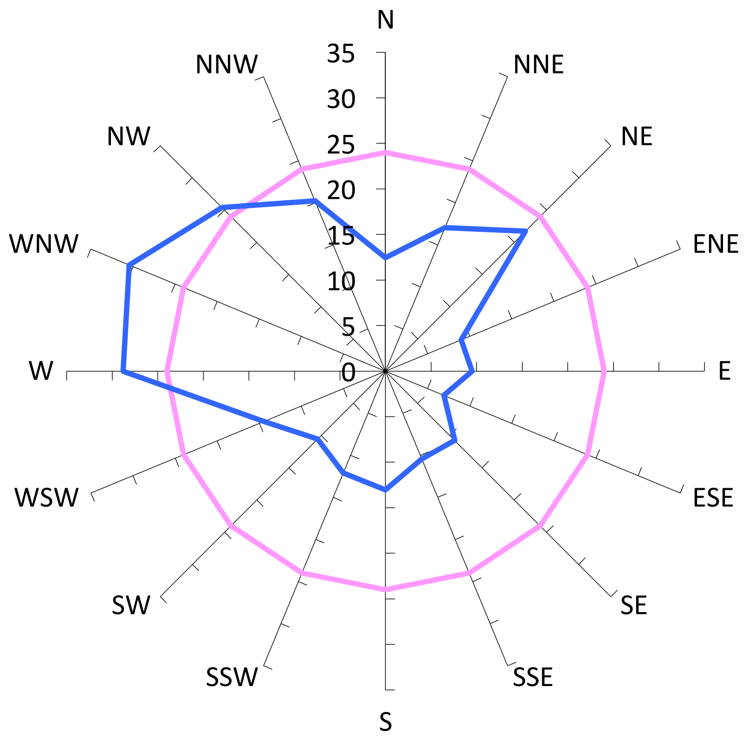
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

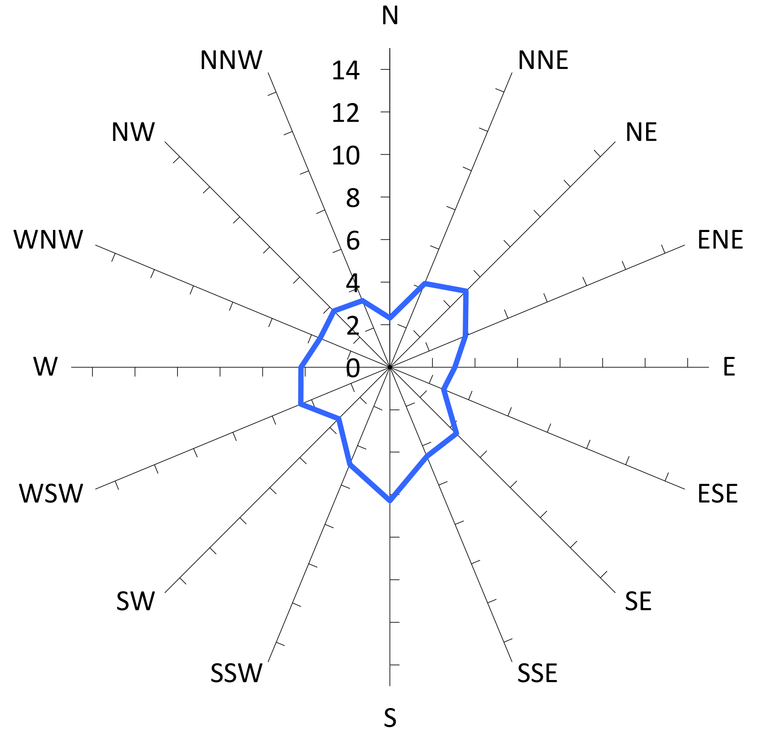
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 40

Maximum GEM (m/s)



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

Probability of Criterion Exceedence (initial test)
3%

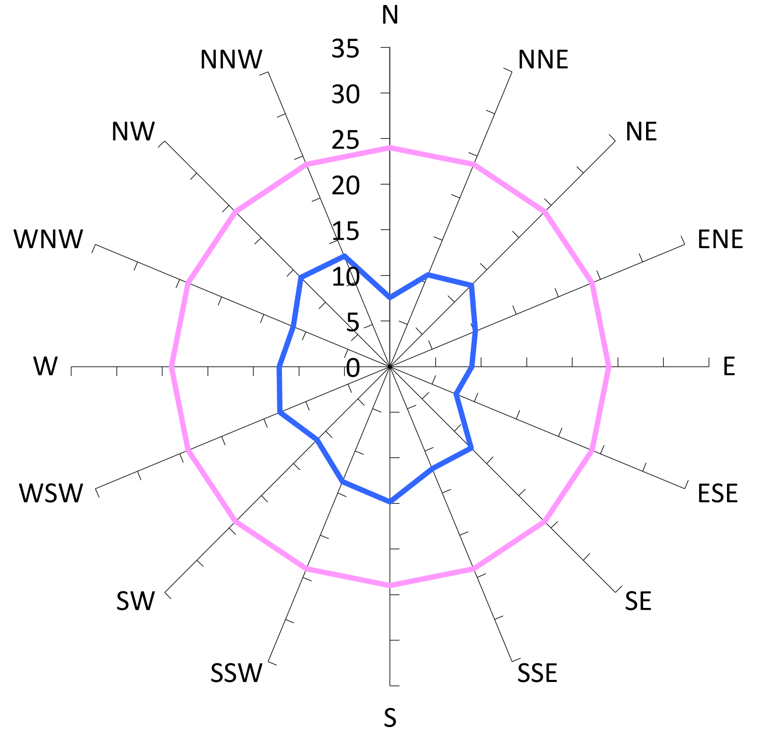
Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

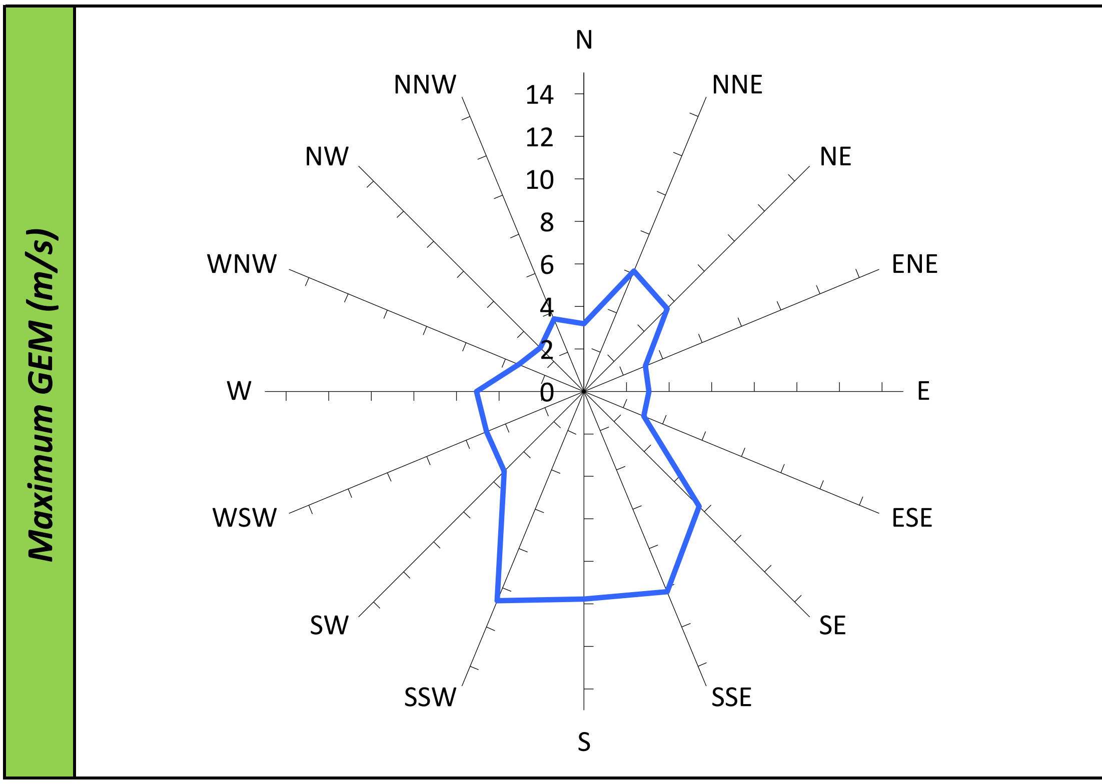
With development "as proposed", without proposed vegetation or other treatments.

Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 41



Desired Criterion
6m/s

Prob. of Criterion Exceedence (existing site conditions)
N/A

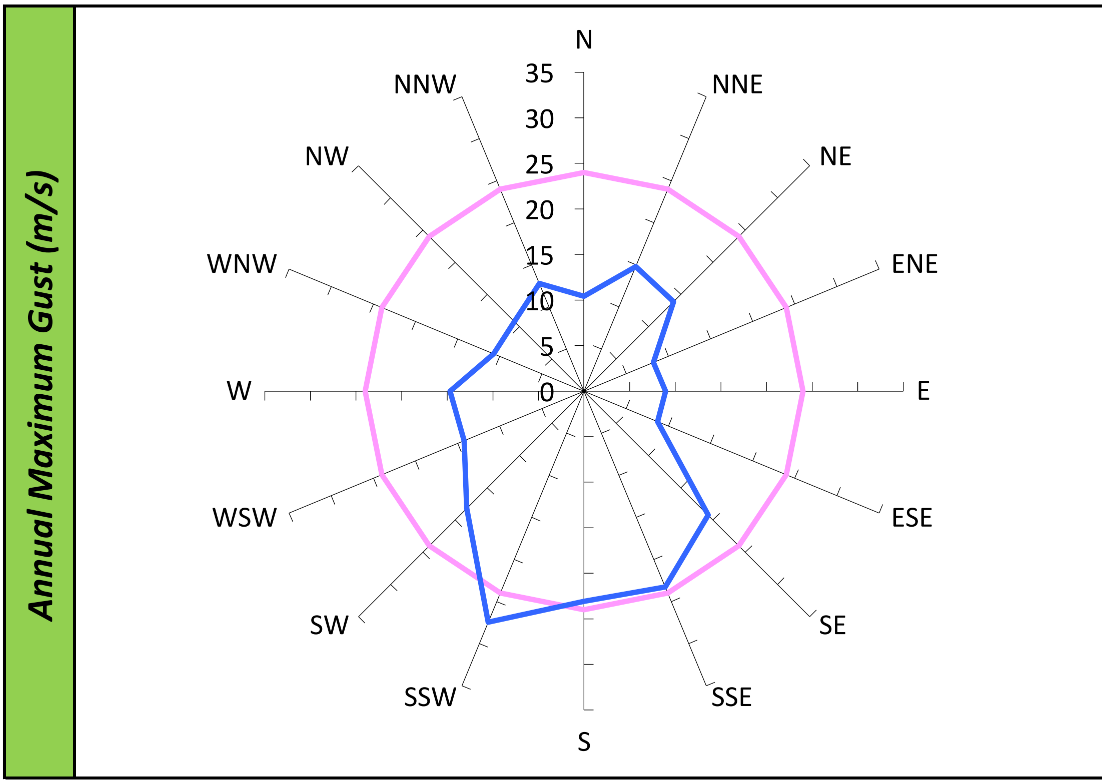
Probability of Criterion Exceedence (initial test)
25%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

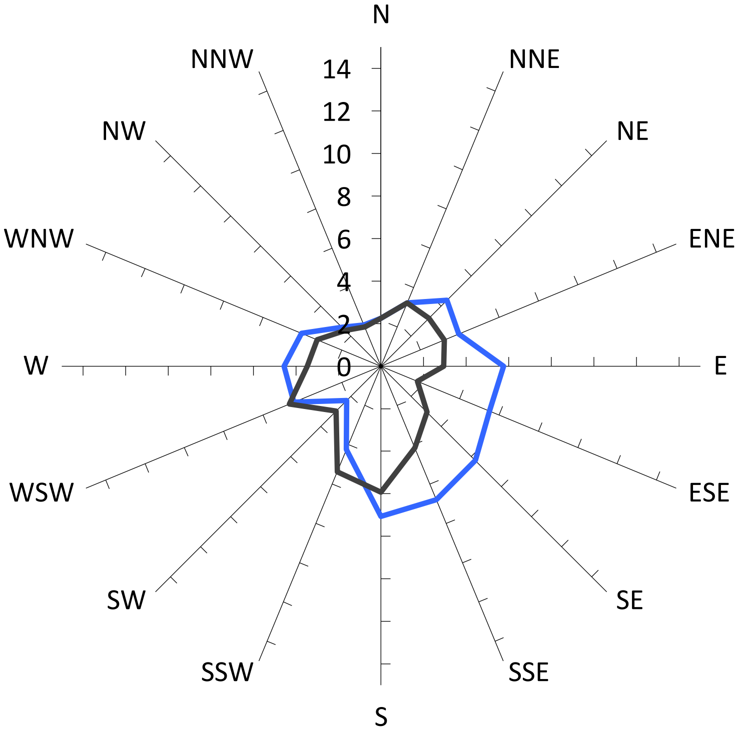
With development "as proposed", without proposed vegetation or other treatments.



Desired Criterion
24m/s

Measured Wind Speeds at Point 101

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
0%

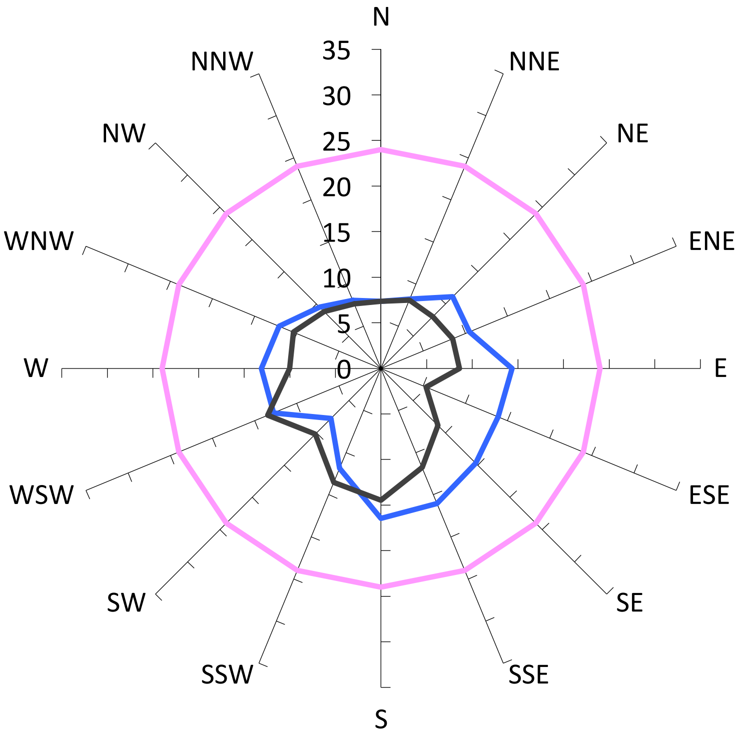
Probability of Criterion Exceedence (initial test)
2%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.
With development "as proposed", without proposed vegetation or other treatments.
With the existing site conditions

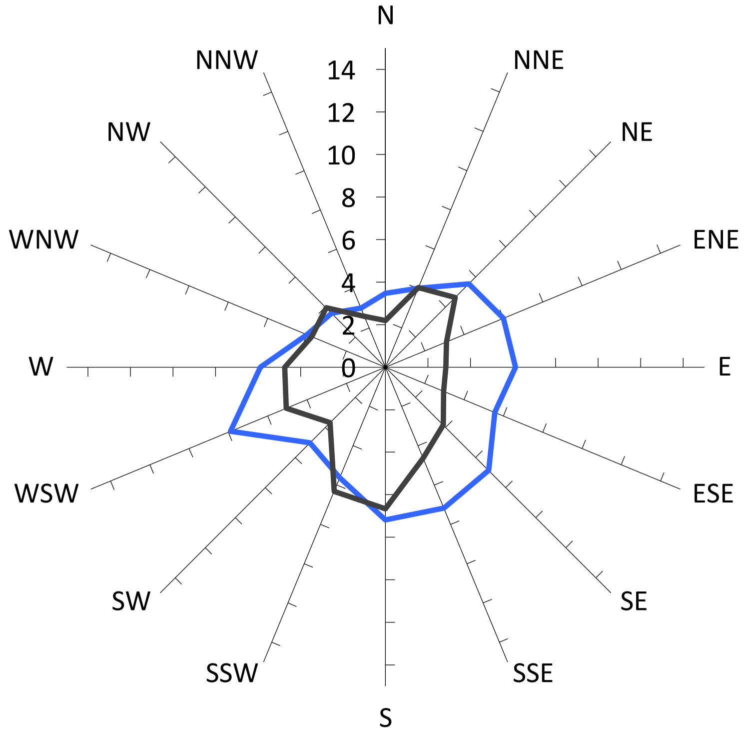
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 102

Maximum GEM (m/s)



Desired Criterion
8m/s

Prob. of Criterion Exceedence (existing site conditions)
1%

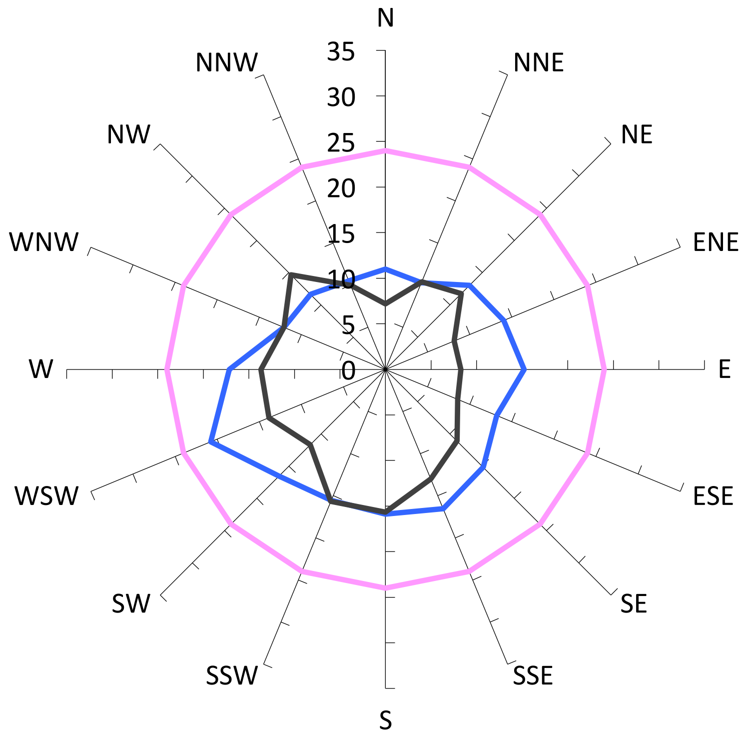
Probability of Criterion Exceedence (initial test)
4%

Probability of Criterion Exceedence (final retest)
N/A

NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.
With development "as proposed", without proposed vegetation or other treatments.
With the existing site conditions

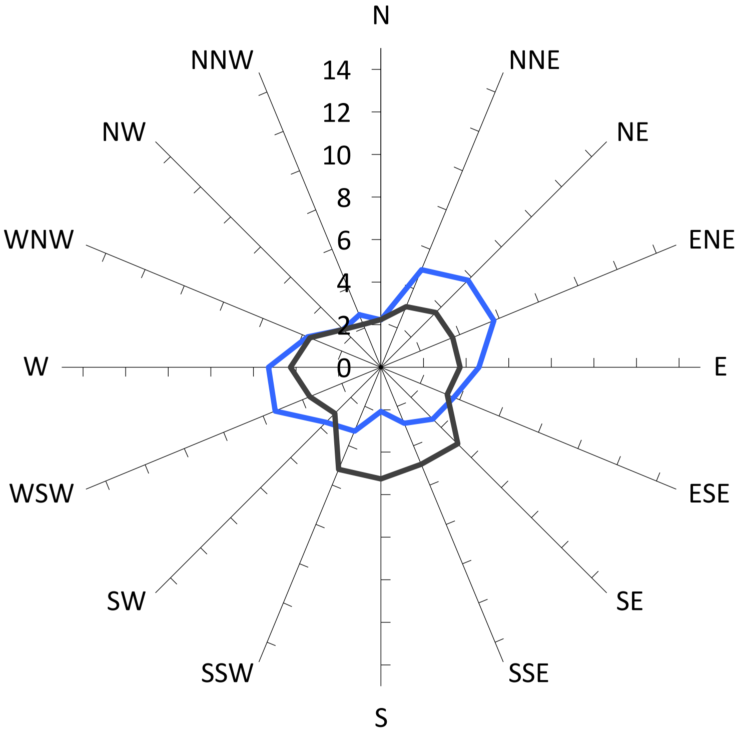
Annual Maximum Gust (m/s)



Desired Criterion
24m/s

Measured Wind Speeds at Point 103

Maximum GEM (m/s)



Desired Criterion

8m/s

Prob. of Criterion Exceedence (existing site conditions)

0%

Probability of Criterion Exceedence (initial test)

0%

Probability of Criterion Exceedence (final retest)

N/A

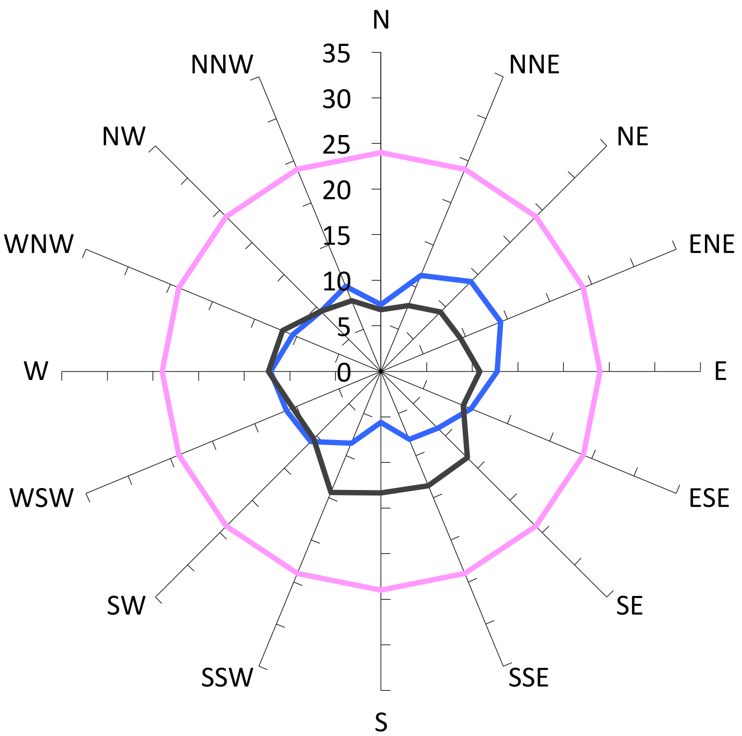
NOTE: The desired criterion is exceeded if the probability of exceedence is greater than 5%

Criterion.

With development "as proposed", without proposed vegetation or other treatments.

With the existing site conditions

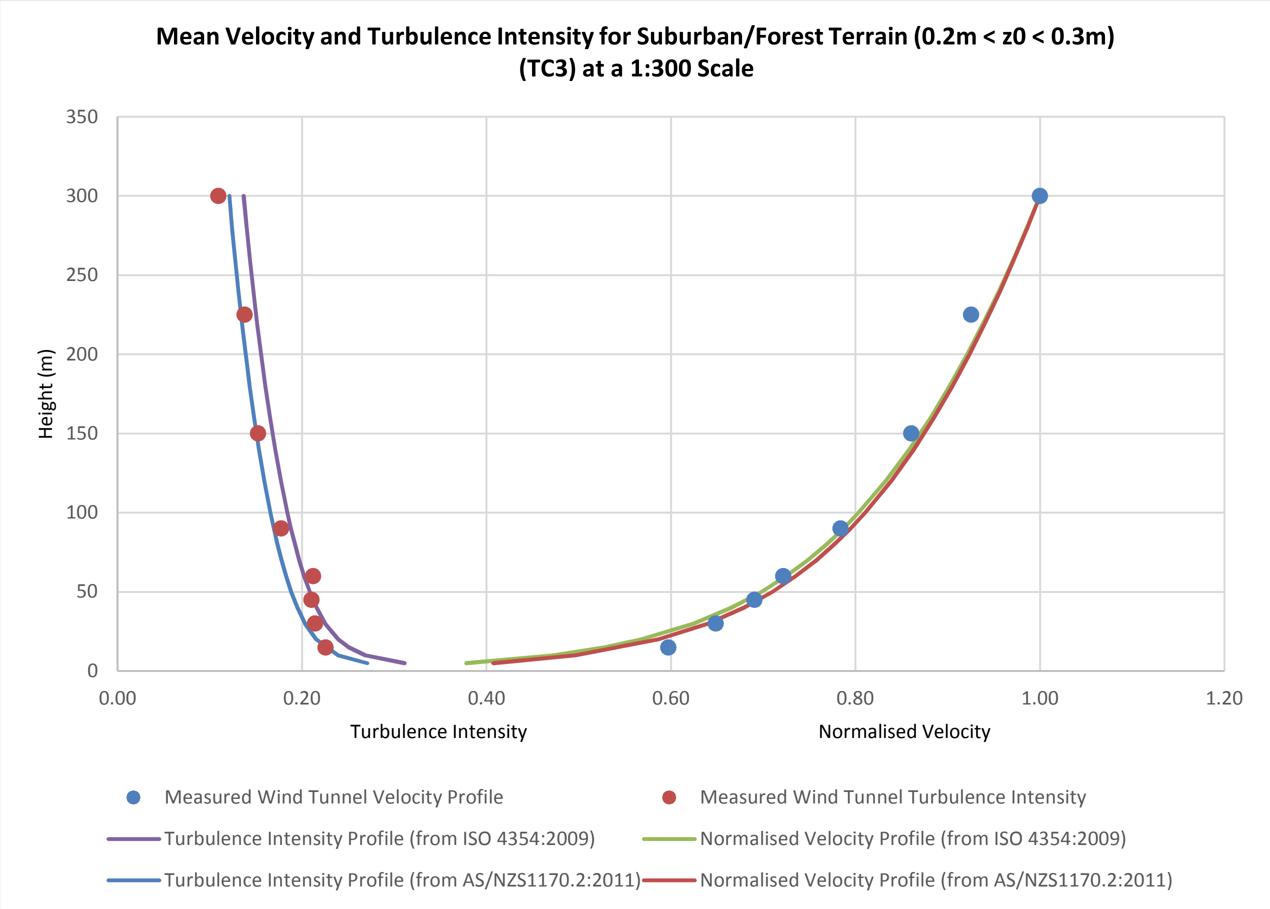
Annual Maximum Gust (m/s)

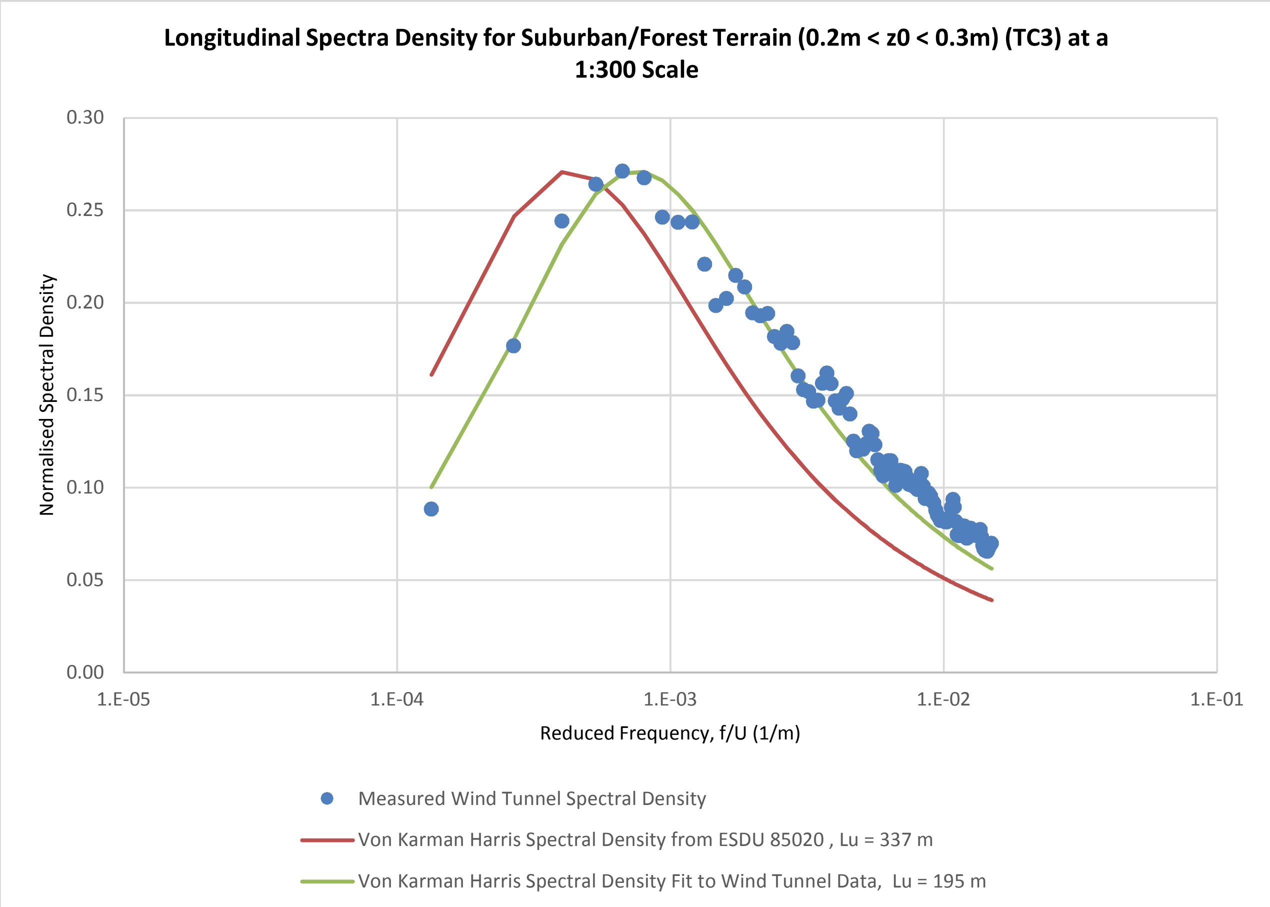


Desired Criterion

24m/s

APPENDIX B - VELOCITY AND TURBULENCE INTENSITY PROFILES


Mean Velocity and Turbulence Intensity for Suburban/Forest Terrain (0.2m < z0 < 0.3m) (TC3) at a 1:300 Scale
350
300
250
200
150
100
50
0
Height (m)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
Turbulence Intensity
Normalised Velocity
Measured Wind Tunnel Velocity Profile
Measured Wind Tunnel Turbulence Intensity
Turbulence Intensity Profile (from ISO 4354:2009)
Normalised Velocity Profile (from ISO 4354:2009)
Turbulence Intensity Profile (from AS/NZS1170.2:2011)
Normalised Velocity Profile (from AS/NZS1170.2:2011)


Longitudinal Spectra Density for Suburban/Forest Terrain (0.2m < z0 < 0.3m) (TC3) at a 1:300 Scale
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Normalised Spectral Density
1.E-05
1.E-04
1.E-03
1.E-02
1.E-01
Reduced Frequency, f/U (1/m)
Measured Wind Tunnel Spectral Density
Von Karman Harris Spectral Density from ESDU 85020 , Lu = 337 m
Von Karman Harris Spectral Density Fit to Wind Tunnel Data, Lu = 195 m