

## PEDESTRIAN WIND ENVIRONMENT STUDY 617-621 PACIFIC HIGHWAY, ST LEONARDS

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## DOCUMENT CONTROL

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## EXECUTIVE SUMMARY

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This report presents the results of a detailed investigation into the wind environment impact of the proposed development located at 617-621 Pacific Highway, St Leonards. 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 made in the wind tunnel at selected critical trafficable outdoor locations within and around the development from 16 wind directions at 22.5 degree increments 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 an area with a radius of 375m.

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 which are representative of an annual recurrence, and Gust-Equivalent Mean (GEM) wind speeds which are representative of approximately a weekly recurrence. Comparison is also made with the wind speed criteria detailed in Part B, Section 2.3.3 of the North Sydney Development Control Plan 2013. The existing wind conditions for the pedestrian footpaths around the site have also been tested to determine the impact of the proposed development.

The model of the proposed development was initially tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as screens, balustrades, awnings, etc., which are not already shown in the architectural drawings. The effect of vegetation was also excluded from the initial testing. For areas not achieving appropriate wind conditions, treatments have been formulated and tested in the wind tunnel to ensure their effectiveness.

With the inclusion of the proposed development, the results of the study indicate that some treatments are necessary to be implemented to achieve the desired wind conditions for certain outdoor trafficable locations. The suggested treatments are summarised as follows:

### Ground Level:

- Replacement of existing deciduous trees with densely foliating trees capable of growing to a height of 5m with a 5m canopy along the northern and southern aspects of the development.
- Inclusion of densely foliating evergreen shrubs capable of growing to a height of 1.5m on the south western corner of the development.
- Inclusion of full height screens with a 50% porosity on the northern and southern perimeter of the western terrace area.

Level 6 Skygarden:

- Inclusion of densely foliating trees within the proposed landscaping areas. These trees should range in size to fill the landscaping areas and should be capable of growing to a height of 3m with a 3m canopy.

Levels 7-23 Balcony Areas:

- Balconies to be fully enclosed on the south-eastern corner of the development.
- Balconies to be partially enclosed with full height impermeable sliding/folding screens on the north-western corner of the development.

Levels 25-38 Balcony Areas:

- Balconies to be fully enclosed on the south-eastern corner of the development.
- Balconies to be partially enclosed with full height impermeable sliding/folding screens on the north-western and north-eastern corners of the development.

Levels 39-48 Balcony Areas:

- Balconies to be fully enclosed on the south-eastern corner of the development.
- Balconies to be partially enclosed with full height impermeable sliding/folding screens on the north-western and north-eastern corners of the development.

With the inclusion of these recommended treatments to the final design, the results of this study indicate that wind conditions for all outdoor trafficable areas within and around the subject development will be suitable for their intended uses. Note the densely foliating trees are of an evergreen species to ensure their effectiveness in wind mitigation throughout the year. The inclusion of additional densely foliating vegetation within and around the outdoor trafficable areas of the subject development is expected to further enhance the localised wind conditions.

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APPENDIX A - Directional Plots of the Wind Tunnel Results

APPENDIX B - Velocity and Turbulence Intensity Profiles

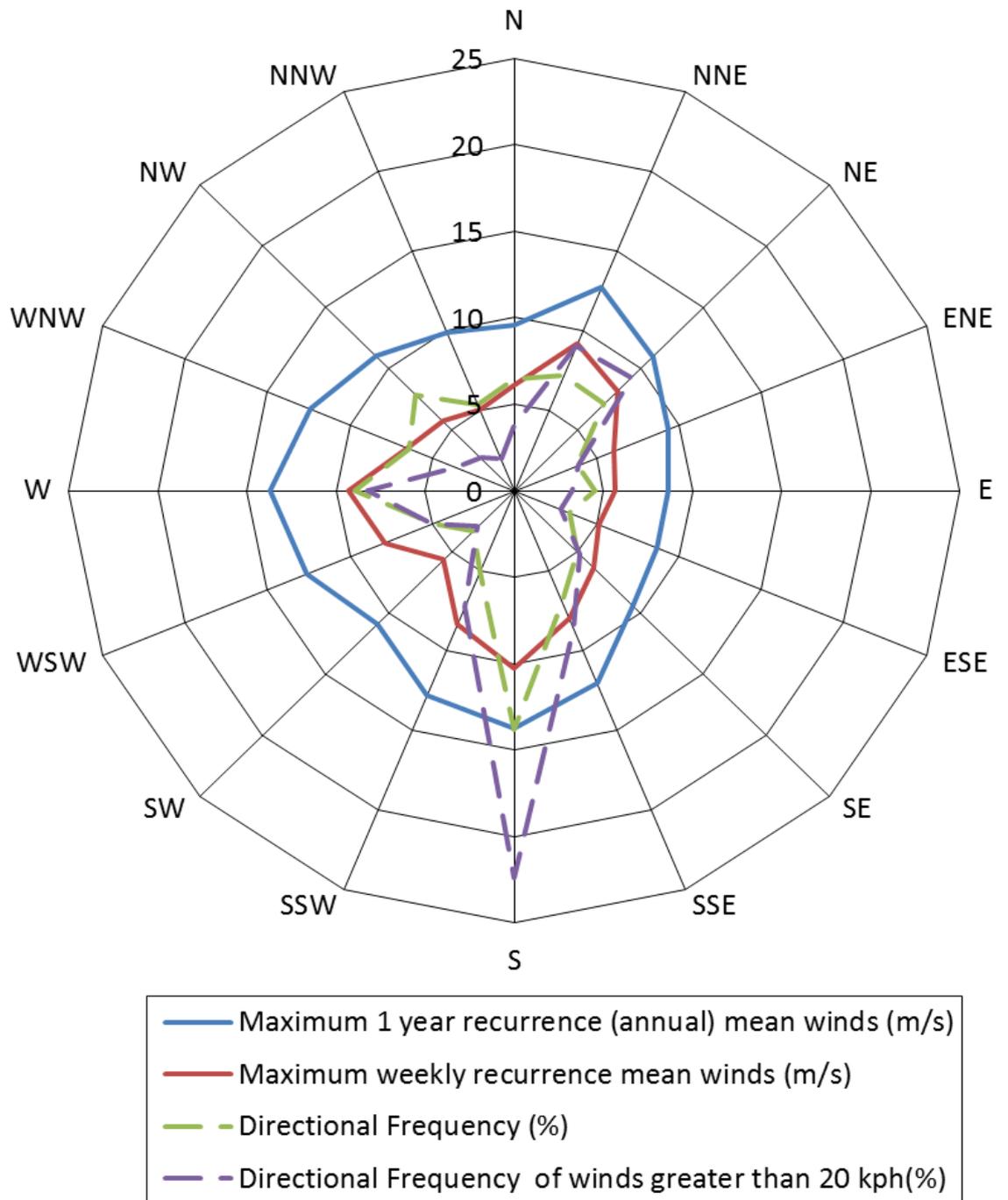
# 1 WIND CLIMATE FOR THE SYDNEY REGION

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 1939 to 2009, and corrected so that it represents winds over standard open terrain at a height of 10m above ground. The corrected data is summarised Table 1 for the weekly and annual return periods in the form of hourly means and the corresponding 3-second gust values. These directional wind speeds are also presented in Figure 1 (referenced as hourly mean wind speeds), as well as the directional frequency of occurrences for the region.

The data indicates that, for the weekly and annual return periods, the southerly winds are by far the most frequent wind 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 since they occur during the winter and hence can be a cause for discomfort for outdoor areas. North-easterly winds occur most frequently 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 Wind Speeds (m/s)			
	Weekly Recurrence		Annual Recurrence	
	Hourly Mean	3-second Gust	Hourly Mean	3-second Gust
N	6.1	9.3	9.6	14.6
NNE	9.2	14.1	12.7	19.4
NE	8.1	12.4	11.0	16.8
ENE	6.1	9.3	9.3	14.2
E	5.6	8.6	8.6	13.2
ESE	5.1	7.8	8.6	13.2
SE	6.3	9.6	9.4	14.4
SSE	8.0	12.2	12.1	18.4
S	10.3	15.7	13.7	21.0
SSW	8.4	12.8	12.8	19.5
SW	5.6	8.6	10.9	16.7
WSW	7.9	12.0	12.6	19.3
W	9.3	14.2	13.7	21.0
WNW	6.4	9.8	12.4	18.9
NW	5.7	8.7	11.0	16.8
NNW	5.0	7.7	9.9	15.1



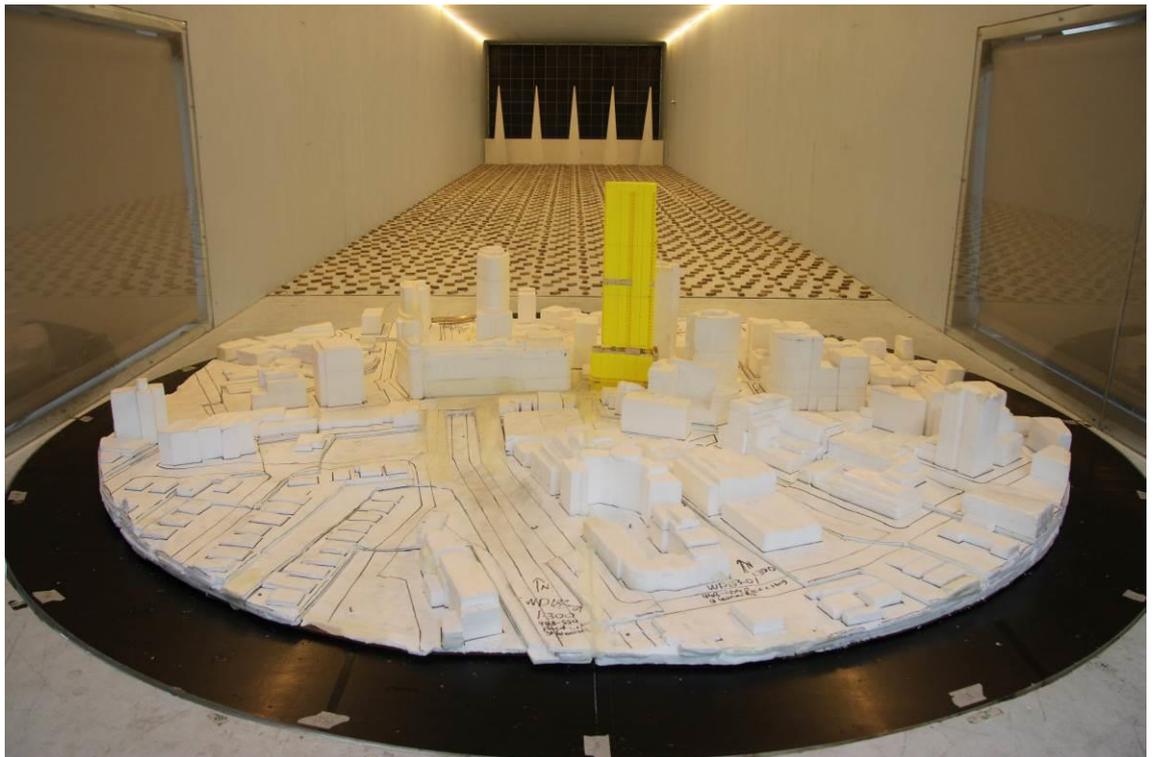
**Figure 1: Directional Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Sydney Region (for the annual and weekly return periods, referenced to standard open terrain at a height of 10m above ground)**

## 2 THE WIND TUNNEL MODEL

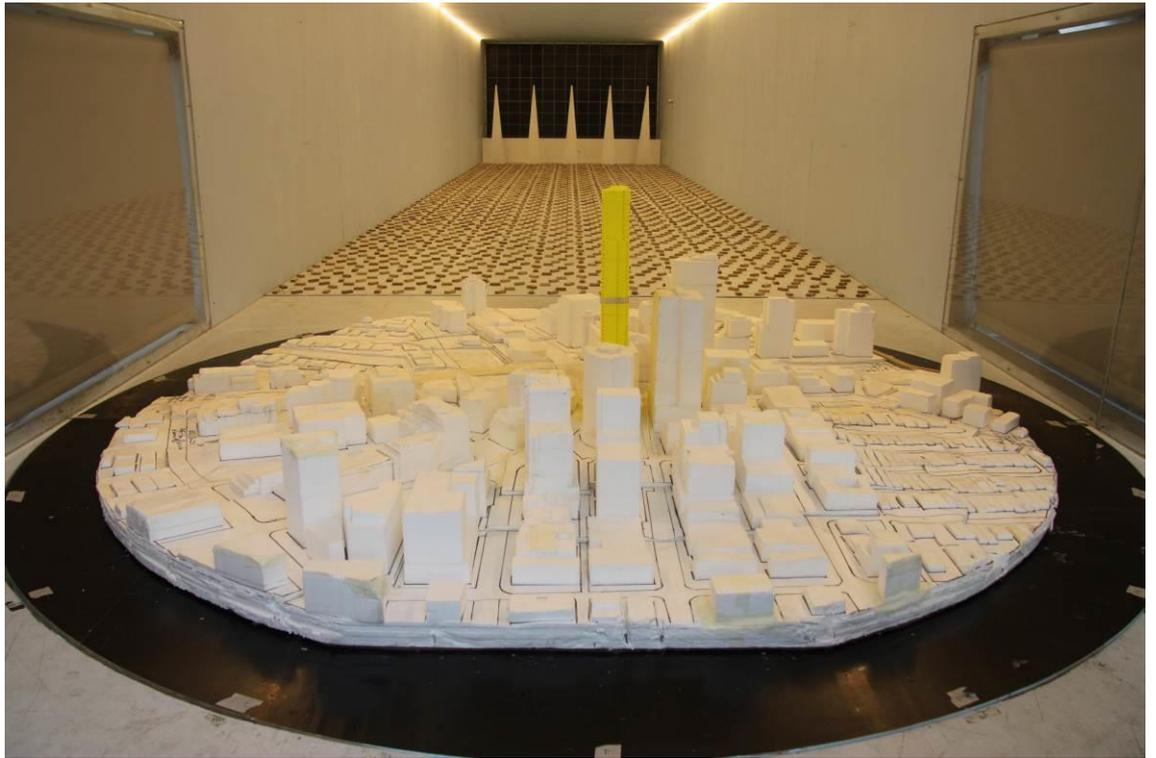
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Measurements were made in the wind tunnel at selected critical trafficable outdoor locations within and around the development from 16 wind directions at 22.5 degree increments using a 1:300 scale detailed model of the development. The study model has been constructed based on the latest available architectural drawings prepared by project architect Kannfinch, received September 2016. 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. Photographs of the wind tunnel model are presented in Figures 2a to 2e on the following pages.

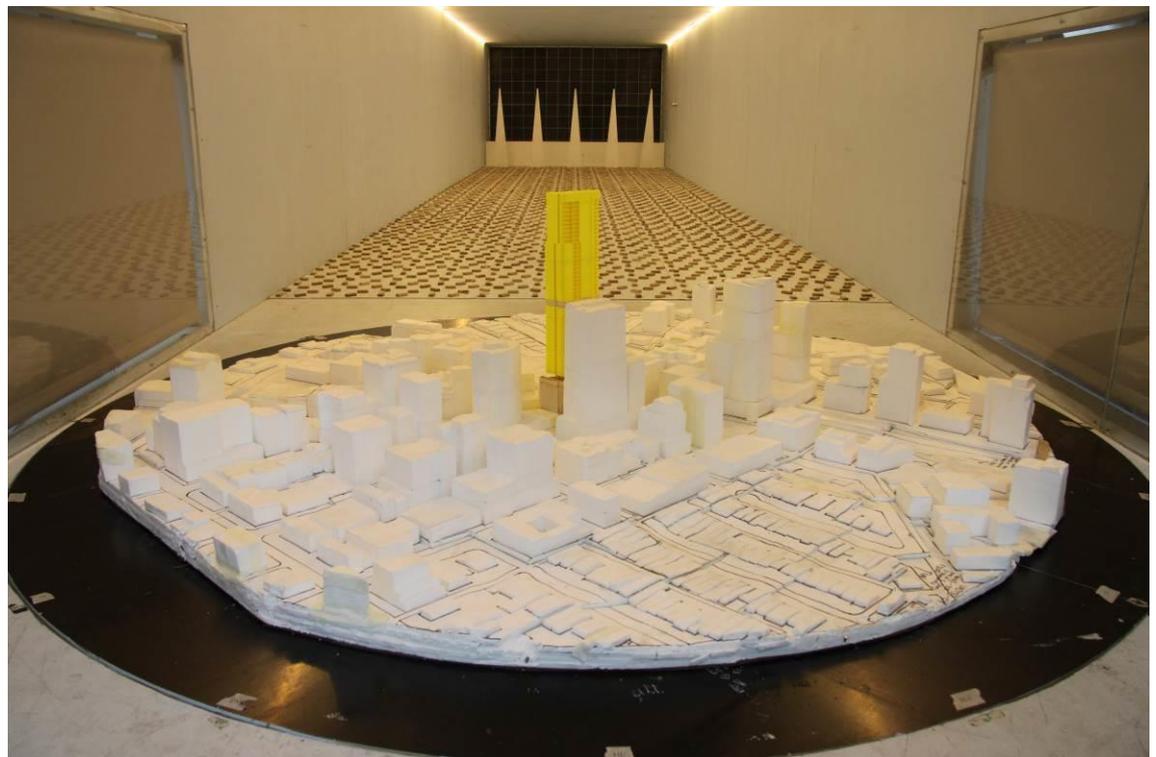
The model of the proposed development was initially tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as screens, balustrades, awnings, etc., which are not already shown in the architectural drawings. The effect of vegetation was also excluded from the initial testing. For areas not achieving appropriate wind conditions, treatments have been formulated and tested in the wind tunnel to ensure their effectiveness.



**Figure 2a: Photograph of the Wind Tunnel Model (view from the south)**



**Figure 2b: Photograph of the Wind Tunnel Model (view from the east)**



**Figure 2c: Photograph of the Wind Tunnel Model (view from the north-east)**



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



**Figure 2e: Photograph of the Wind Tunnel Model (view from the west)**

### 3 BOUNDARY LAYER WIND FLOW MODEL

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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 16 prevailing wind directions used 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 (ie: 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 (as per the definitions in 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 as per ISO4354:2009. These are summarised in Table 2, referenced to the study reference height of 80m above ground.

**Table 2: Terrain and Height Multipliers, Turbulence Intensities, and Corresponding Roughness Lengths, for the Standard ISO4354:2009 Boundary Layer Profiles (at the study reference height)**

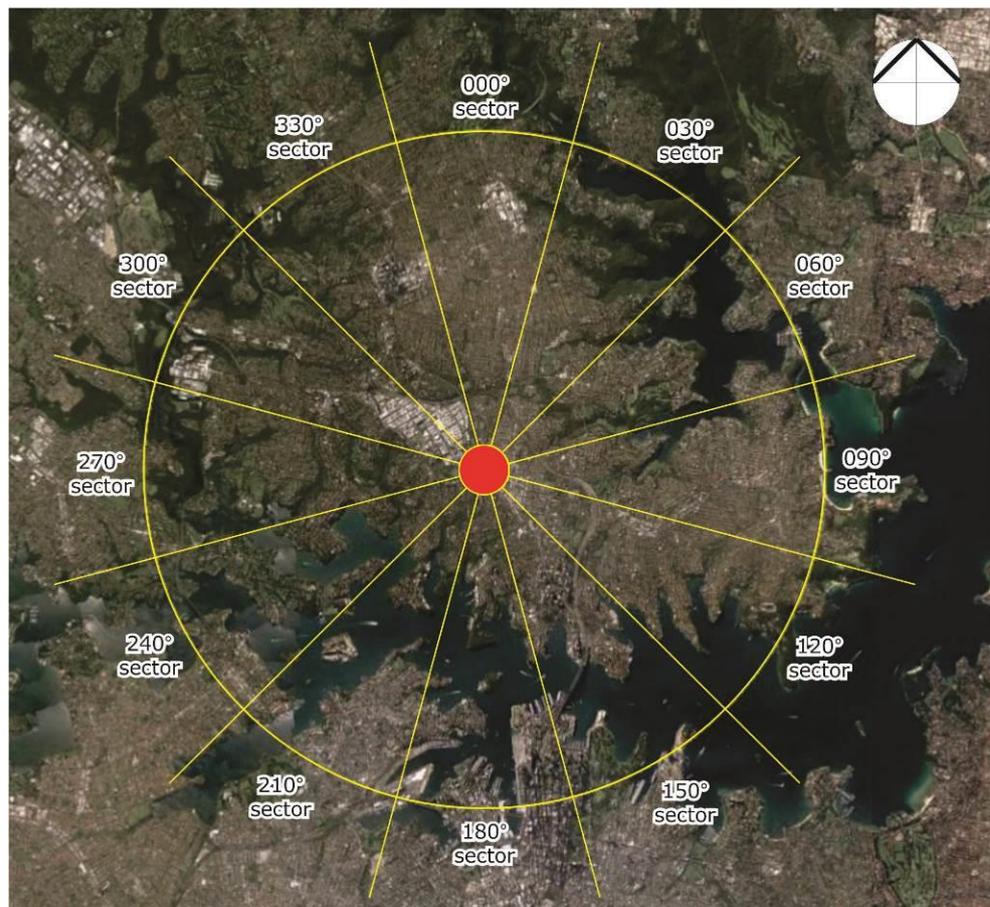
Terrain Category	Terrain and Height Multipliers			Turbulence Intensity $I_v$	Terrain Roughness Length (m) $Z_{0,r}$
	$k_{tr,T=3600s}$ (hourly)	$k_{tr,T=600s}$ (10-minute)	$k_{tr,T=3s}$ (3-second)		
1.0	1.01	1.04	1.31	0.101	0.003
1.5	0.96	0.99	1.29	0.117	0.01
2.0	0.90	0.94	1.27	0.135	0.03
2.5	0.83	0.87	1.23	0.160	0.1
3.0	0.76	0.80	1.19	0.192	0.3
3.5	0.66	0.70	1.14	0.243	1
4.0	0.55	0.59	1.06	0.318	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 4.8km 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.

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 extent of the proximity model. Plots of the wind tunnel boundary layer wind profiles are presented in Appendix B of this report.

**Table 3: Directional Mean and Gust Terrain and Height Multipliers at the Site  
(at the study reference height)**

Wind Sector (degrees)	$k_{tr,T=3600s}$ (hourly mean)	$k_{tr,T=600s}$ (10-minute mean)	$k_{tr,T=3s}$ (3-second gust)
0	0.76	0.80	1.19
30	0.80	0.84	1.22
60	0.82	0.86	1.23
90	0.76	0.80	1.19
120	0.73	0.77	1.18
150	0.84	0.87	1.23
180	0.86	0.90	1.25
210	0.86	0.89	1.24
240	0.90	0.94	1.27
270	0.76	0.80	1.19
300	0.75	0.79	1.19
330	0.74	0.78	1.18



**Figure 3: Aerial Image of the Surrounding Terrain  
(radius of 4.8km 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 (approximately once per week on average). 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	Gust 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 frequency of exceedance of approximately once per week (a probability of exceedance of 5%).

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

Classification	Activities	95 Percentile Maximum Mean (approximately once per week)
Walking Fast	Acceptable for walking, main public accessways.	$7.5 \text{ m/s} < \bar{V} < 10.0 \text{ m/s}$
Strolling, Skating	Slow walking, etc.	$5.5 \text{ m/s} < \bar{V} < 7.5 \text{ m/s}$
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	$3.5 \text{ m/s} < \bar{V} < 5.5 \text{ m/s}$
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	$\bar{V} < 3.5 \text{ m/s}$

#### 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 4) 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 (approximately once per week)
Business Walking	Objective Walking from A to B.	$8 \text{ m/s} < \bar{V} < 10 \text{ m/s}$
Pedestrian Walking	Slow walking, etc.	$6 \text{ m/s} < \bar{V} < 8 \text{ m/s}$
Short Exposure Activities	Pedestrian standing or sitting for short times.	$4 \text{ m/s} < \bar{V} < 6 \text{ m/s}$
Long Exposure Activities	Pedestrian sitting for a long duration.	$\bar{V} < 4 \text{ m/s}$

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

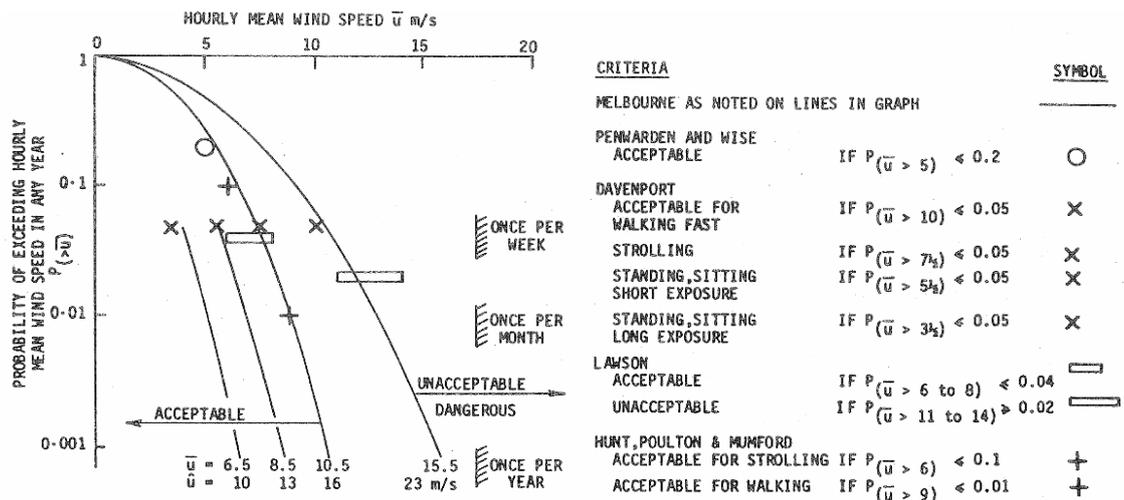
W.H. Melbourne (1978) introduced a set of criteria for the assessment of environmental wind conditions, which were developed for a temperature range of 10°C to 30°C and for people suitably dressed for outdoor conditions. These criteria are based on peak annual maximum gust wind speeds, and are outlined 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.	$\hat{V} > 23\text{m/s}$
Marginal	Unacceptable as main public accessways.	$23\text{ m/s} > \hat{V} > 16\text{ m/s}$
Comfortable Walking	Acceptable for walking, main public accessways	$16\text{ m/s} > \hat{V} > 13\text{ m/s}$
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	$13\text{ m/s} > \hat{V} > 10\text{ m/s}$
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	$10\text{ m/s} > \hat{V}$

**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 within and around the subject development are compared against two sets of criteria. For comfort, the A.G. Davenport (1972) criteria are used in conjunction with a maximum Gust-Equivalent Mean (GEM) wind speed (defined below), which are representative of approximately a weekly recurrence. The safety limit criterion by W.H. Melbourne (1978) of 23m/s for the annual maximum peak gust wind speeds is also used. Note that the A.G. Davenport (1972) criteria, used in conjunction with a GEM wind speed (defined below), has proven over time, and through field observations, to be the most reliable indicator of pedestrian comfort (A.W. Rofail, 2007). Note also that the safety limit criterion by W.H. Melbourne (1978) of 23m/s for annual maximum peak gust wind speeds is also applied to all areas.

The North Sydney DCP 2013 requires that the maximum wind speed for public outdoor spaces is 13m/s. It is assumed that this is applicable to the annual maximum gust wind speeds (in accordance with the "short exposure" criterion by W.H. Melbourne, 1978). As detailed in Section 4.2, this criterion is even more stringent than the most stringent criteria from T.V. Lawson (1975) and A.G. Davenport (1972) for pedestrian footpaths. Nonetheless, the measured wind conditions from this study for the relevant ground level areas are also compared to the 13m/s criterion from the North Sydney DCP 2013.

The existing conditions for the pedestrian footpaths around the site have also been tested as part of this study to determine the impact of the subject development. If it is found that the existing conditions exceed the 13m/s criterion from the North Sydney DCP 2013, then the target wind speed for that area with the inclusion of the proposed development is to at least match the existing site conditions.

The basic criteria which is used in this study, referenced to a range of outdoor activities, are described as follows:

- **Short Exposure:** 5.5m/s maximum GEM wind speeds (from A.G. Davenport, 1972) (representative of approximately a weekly recurrence).
- **Comfortable Walking:** 7.5m/s maximum GEM wind speeds (from A.G. Davenport, 1972) (representative of approximately a weekly recurrence).
- **Safety Limit:** 23.0m/s annual maximum gust wind speeds (from W.H. Melbourne, 1978).
- **North Sydney DCP 2013:** 13m/s annual maximum gust wind speeds (for public outdoor spaces on Ground Level).
- **Existing Site Conditions:** Where relevant, if the existing site conditions exceed the North Sydney DCP 2013 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.

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 modified version of the A.G. Davenport (1972) criteria for the maximum GEM wind speeds (which are representative of approximately a weekly recurrence), and the other comparing to the W.H. Melbourne (1978) criteria for the annual maximum peak gust wind speeds) criteria.

**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 3.5 standard deviations from the mean.
- Short Exposure applies typically to areas where short duration stationary activities are involved (less than 1 hour). This includes window shopping, waiting areas, main retail centres and retail streets, parks, communal recreational areas etc.
- Comfortable Walking applies typically to areas used mainly for pedestrian thoroughfares and other pedestrian access ways. This also includes private swimming pools and communal areas.
- In all areas, the wind conditions are also checked against the safety limit.

## 5 TEST PROCEDURE AND METHODOLOGY

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### 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-1-2001), ASCE-7-10 (Chapter C31), and CTBUH 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 1,024Hz was used, which is more than acceptable for the given frequency band. The signal was low pass filtered at 32Hz, which results in the peak gust being the equivalent of a 2 to 3 second gust (which is what the criteria for pedestrian comfort and safety are based upon).

The mean and the maximum 3-second duration peak gust velocity coefficients are derived from the wind tunnel test by the following relation:

$$\hat{C}_V = \bar{C}_V + g \cdot \sigma_V \quad (4.1)$$

where:  $\hat{C}_V$  is the 3-second gust velocity coefficient.

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

$g$  is the gust factor, which is taken to be 3.5.

$\sigma_V$  is the standard deviation of the velocity measurement.

The mean free-stream wind speed measured in the wind tunnel for this study was approximately 10.8m/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 14 seconds was used for each wind direction tested, which is equivalent to a minimum sample time of approximately 35 minutes in full-scale for the annual 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 annual maximum gust and the weekly maximum GEM wind speeds are outlined in the following sub-sections.

### 5.2.1 Annual Maximum Gust Wind Speeds

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

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

$V_{study}$  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:

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

$C_{V,study}$  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 Weekly Maximum Gust-Equivalent Mean Wind Speeds

The contribution to the probability of exceedance of a specified wind speed (ie: 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 T.V. Lawson (1980).

The criteria of A.G. Davenport (1972), which is used in this study, is referenced to a probability of exceedance of 5% of a specified wind speed and is representative of approximately a weekly recurrence interval.

### **5.3 Layout of Study Points, and Relevant Wind Speed Criteria**

For this study a total of 35 study point locations have been selected for analysis in the wind tunnel. This includes the following:

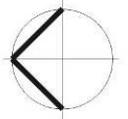
- 14 study points on the Ground Level outdoor seating areas and trafficable areas within the site.
- 8 study points on the Level 6 Skygarden.
- 9 study points on the private balconies of the development.
- 4 study points at locations within 100m of the development.

The locations of the various study points tested for this study are presented in Figures 5a to 5f in the form of a marked-up plan drawings. The target wind speed criteria for the outdoor trafficable areas within and around the development are also indicated in these figures.

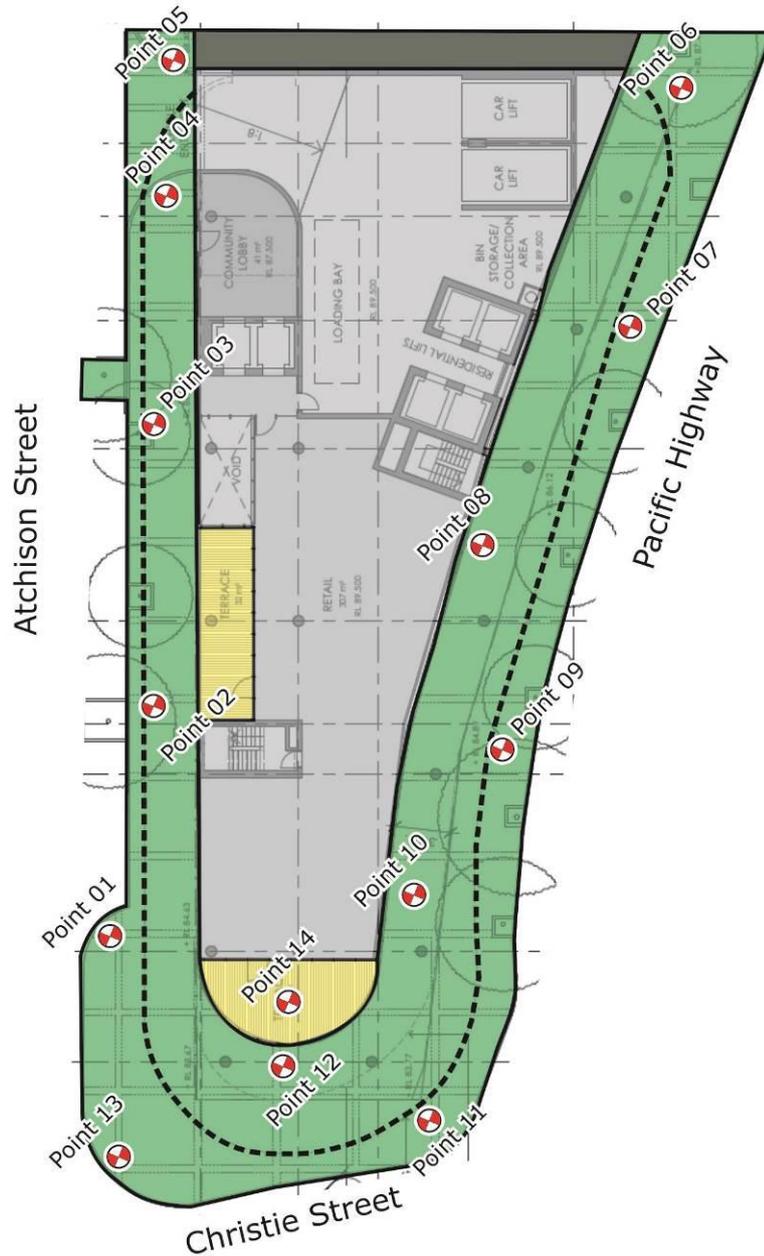
It should be noted that only the most critical outdoor locations of the development have been selected for analysis. For example, balconies located in the middle of the building face will benefit from the shielding provided by the effective use of privacy screens, and their recessed design into the overall building footprint, and wind conditions experienced on balconies such as this are expected to be suitable for the intended use.

**Target Criteria**

- A.G. Davenport (1972) criterion of 5.5m/s (weekly GEM's) for short-exposure activity.  
North Sydney DCP (2013) criterion of 13m/s (annual gusts) for safety.
- A.G. Davenport (1972) criterion of 5.5m/s (weekly GEM's) for short-exposure activity.  
W.H. Melbourne (1978) criterion of 23m/s (annual gusts) for safety.



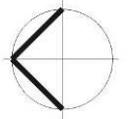
⊗ Study Points



**Figure 5a: Study Point Locations and Target Criteria – Ground Level**

**Target Criteria**

- A.G. Davenport (1972) criterion of 5.5m/s (weekly GEM's) for short-exposure activity.
- W.H. Melbourne (1978) criterion of 23m/s (annual gusts) for safety.



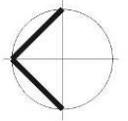
Study Points



**Figure 5b: Study Point Locations and Target Criteria – Level 6 Skygarden**

**Target Criteria**

- A.G. Davenport (1972) criterion of 7.5m/s (weekly GEM's) for pedestrian activity.
- W.H. Melbourne (1978) criterion of 23m/s (annual gusts) for safety.



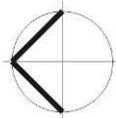
Study Points



**Figure 5c: Study Point Locations and Target Criteria – Levels 7 – 23**

**Target Criteria**

- A.G. Davenport (1972) criterion of 7.5m/s (weekly GEM's) for pedestrian activity.
- W.H. Melbourne (1978) criterion of 23m/s (annual gusts) for safety.



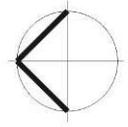
⊗ Study Points



**Figure 5d: Study Point Locations and Target Criteria – Level 25 – 38**

**Target Criteria**

- A.G. Davenport (1972) criterion of 7.5m/s (weekly GEM's) for pedestrian activity.
- W.H. Melbourne (1978) criterion of 23m/s (annual gusts) for safety.



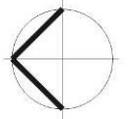
⊗ Study Points



**Figure 5e: Study Point Locations and Target Criteria – Level 39 – 48**

**Target Criteria**

□ A.G. Davenport (1972) criterion of 5.5m/s (weekly GEM's) for short-exposure activity.  
□ North Sydney DCP (2013) criterion of 13m/s (annual gusts) for safety.



⊕ Study Points



**Figure 5f: Study Point Locations – Surrounding Areas**

## 6 RESULTS AND DISCUSSION

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The model of the proposed development was initially tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as screens, balustrades, awnings, etc., which are not already shown in the architectural drawings. The effect of vegetation was also excluded from the initial testing. For areas not achieving appropriate wind conditions, treatments have been formulated and tested in the wind tunnel to ensure their effectiveness.

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

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. The suggested treatments, which are expected to achieve wind conditions that satisfy the comfort and safety criteria, are summarised as follows:

### Ground Level:

- Replacement of existing deciduous trees with densely foliageating trees capable of growing to a height of 5m with a 5m canopy along the northern and southern aspects of the development, as shown in Figure 7a.
- Inclusion of densely foliageating evergreen shrubs capable of growing to a height of 1.5m on the south western corner of the development, as shown in Figure 7a.
- Inclusion of full height screens with a 50% porosity on the northern and southern perimeter of the western terrace area, as shown in Figure 7a.

### Level 6 Skygarden:

- Inclusion of densely foliageating trees within the proposed landscaping areas, as shown in Figure 7b. These trees should range in size to fill the landscaping areas and should be capable of growing to a height of 3m with a 3m canopy.

### Levels 7-23 Balcony Areas:

- Balconies to be fully enclosed on the south-eastern corner of the development, as shown in Figure 7c.
- Balconies to be partially enclosed with full height impermeable sliding/folding screens on the north-western corner of the development, as shown in Figure 7c.

Levels 25-38 Balcony Areas:

- Balconies to be fully enclosed on the south-eastern corner of the development, as shown in Figure 7d.
- Balconies to be partially enclosed with full height impermeable sliding/folding screens on the north-western and north-eastern corners of the development, as shown in Figure 7d.

Levels 39-48 Balcony Areas:

- Balconies to be fully enclosed on the south-eastern corner of the development, as shown in Figure 7e.
- Balconies to be partially enclosed with full height impermeable sliding/folding screens on the north-western and north-eastern corners of the development, as shown in Figure 7e.

With the inclusion of these recommended treatments to the final design, the results of this study indicate that wind conditions for all outdoor trafficable areas within and around the subject development will be suitable for their intended uses. Note the densely foliating trees are of an evergreen species to ensure their effectiveness in wind mitigation throughout the year. The inclusion of additional densely foliating vegetation within and around the outdoor trafficable areas of the subject development is expected to further enhance the localised wind conditions.

**Table 9a: Wind Tunnel Results Summary – Pedestrian Footpaths**

Study Point	Desired Criterion (m/s)		Equivalent to or Better than Existing Site Wind Conditions?	Treatment Necessary to Pass?	Description of Suggested Treatment/ Notes
	Weekly GEM (Windtech Comfort Criteria)	Annual Peak (North Sydney DCP 2013 Criteria)			
Point 01	5.5	13.0	NO	YES	Densely foliating trees
Point 02	5.5	13.0	YES	NO	Similar to existing wind conditions
Point 03	5.5	13.0	YES	NO	Similar to existing wind conditions
Point 04	5.5	13.0	NO	YES	Densely foliating trees
Point 05	5.5	13.0	NO	YES	Densely foliating trees
Point 06	5.5	13.0	YES	NO	Similar to existing wind conditions
Point 07	5.5	13.0	YES	NO	Similar to existing wind conditions
Point 08	5.5	13.0	YES	NO	Similar to existing wind conditions
Point 09	5.5	13.0	NO	YES	Densely foliating trees
Point 10	5.5	13.0	NO	YES	Densely foliating trees
Point 11	5.5	13.0	NO	YES	Densely foliating shrubs
Point 12	5.5	13.0	NO	YES	Densely foliating trees
Point 13	5.5	13.0	NO	YES	Densely foliating trees
Point 101	5.5	13.0	YES	NO	Similar to existing wind conditions
Point 102	5.5	13.0	YES	NO	Similar to existing wind conditions
Point 103	5.5	13.0	YES	NO	Similar to existing wind conditions
Point 104	5.5	13.0	YES	NO	Similar to existing wind conditions

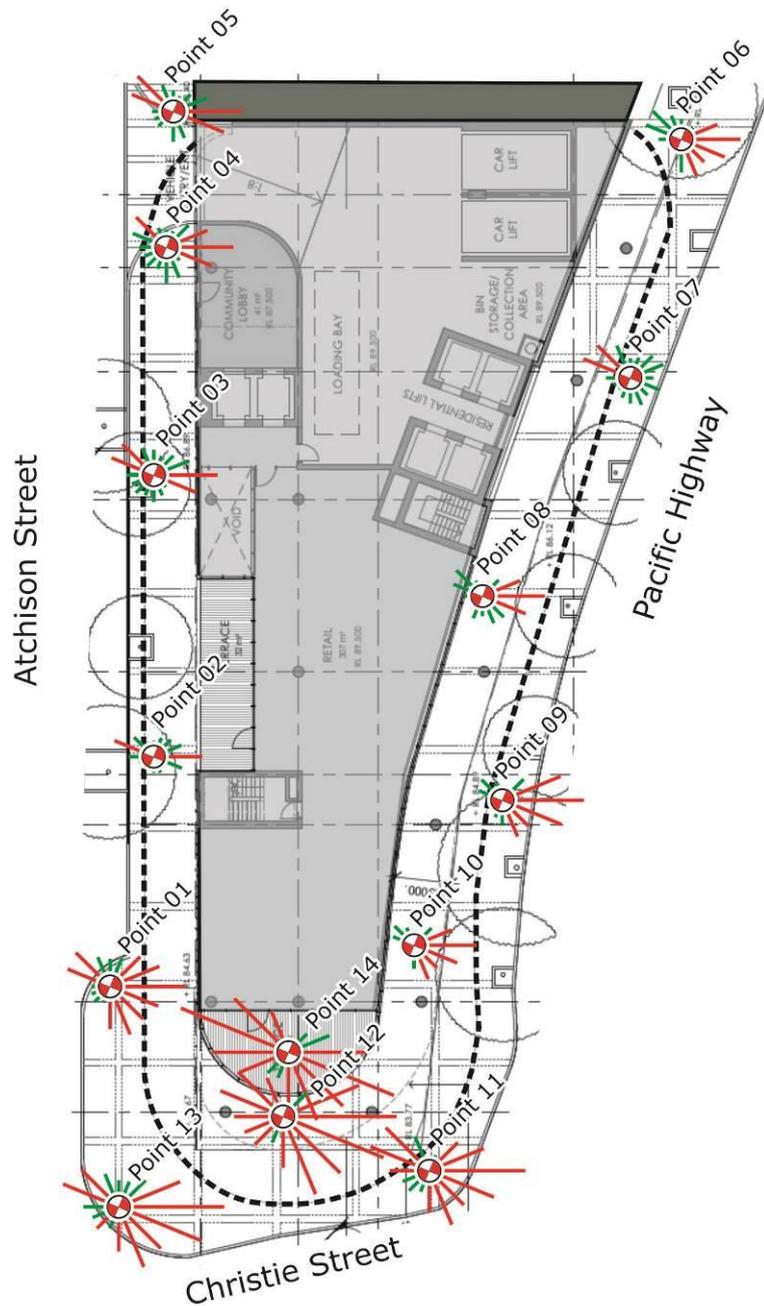
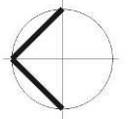
**Table 9b: Wind Tunnel Results Summary – All Remaining Areas**

Study Point	Desired Criterion (m/s)		Treatment Necessary to Pass?	Description of Treatment
	Weekly GEM (Windtech Comfort Criteria)	Annual Peak		
Point 14	5.5	23.0	YES	Full height 50% porous screen
Point 15	5.5	23.0	YES	Densely foliating trees
Point 16	5.5	23.0	YES	Extended perimeter screen
Point 17	5.5	23.0	YES	Densely foliating trees
Point 18	5.5	23.0	YES	Densely foliating trees
Point 19	5.5	23.0	NO	
Point 20	5.5	23.0	YES	Extended perimeter screen
Point 21	5.5	23.0	YES	Extended perimeter screen
Point 22	5.5	23.0	YES	Extended perimeter screen
Point 23	7.5	23.0	YES	Partially enclosed balcony
Point 24	7.5	23.0	NO	
Point 25	7.5	23.0	YES	Fully enclosed balcony
Point 27	7.5	23.0	YES	Partially enclosed balcony
Point 28	7.5	23.0	YES	Fully enclosed balcony
Point 29	7.5	23.0	YES	Partially enclosed balcony
Point 30	7.5	23.0	YES	Partially enclosed balcony
Point 31	7.5	23.0	YES	Fully enclosed balcony

**Legend**

- Wind Speed Magnitude from Directions Exceeding Criteria
- Wind Speed Magnitude from Directions Satisfying Criteria

● Study Points

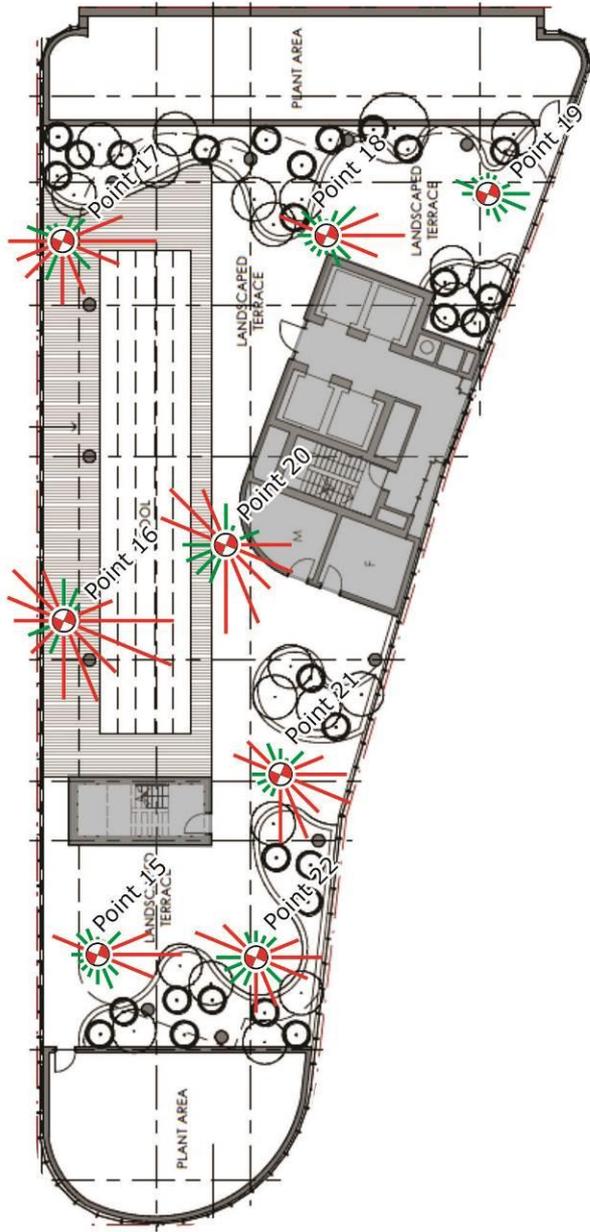
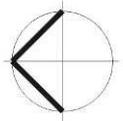


**Figure 6a: Wind Directionality Plots – Ground Floor (results shown without any treatments applied)**

**Legend**

- Wind Speed Magnitude from Directions Exceeding Criteria
- Wind Speed Magnitude from Directions Satisfying Criteria

⊗ Study Points

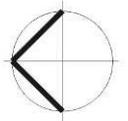


**Figure 6b: Wind Directionality Plots – Level 6 Skygarden (results shown without any treatments applied)**

**Legend**

- Wind Speed Magnitude from Directions Exceeding Criteria
- Wind Speed Magnitude from Directions Satisfying Criteria

 Study Points

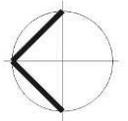


**Figure 6c: Wind Directionality Plots – Levels 7 – 23 (results shown without any treatments applied)**

**Legend**

- Wind Speed Magnitude from Directions Exceeding Criteria
- Wind Speed Magnitude from Directions Satisfying Criteria

Study Points

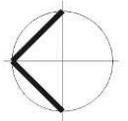


**Figure 6d: Wind Directionality Plots – Level 25 – 38 (results shown without any treatments applied)**

**Legend**

- Wind Speed Magnitude from Directions Exceeding Criteria
- Wind Speed Magnitude from Directions Satisfying Criteria

 Study Points

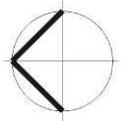


**Figure 6e: Wind Directionality Plots – Level 39 – 48 (results shown without any treatments applied)**

**Legend**

- Wind Speed Magnitude from Directions Exceeding Criteria
- Wind Speed Magnitude from Directions Satisfying Criteria

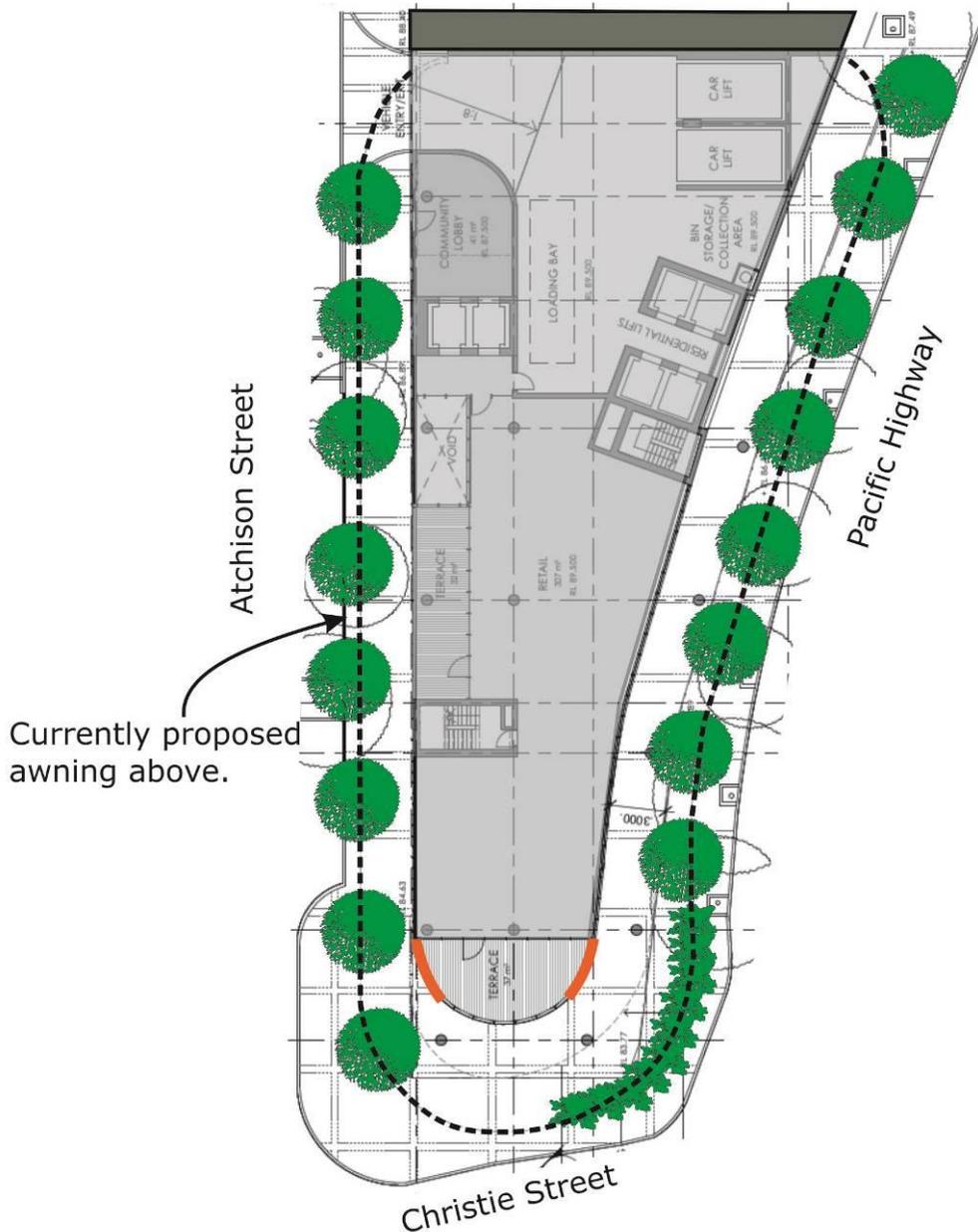
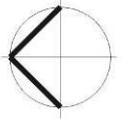
⊗ Study Points



**Figure 6f: Wind Directionality Plots – Surrounding Areas (results shown without any treatments applied)**

**Treatments Legend**

-  Recommended densely foliating evergreen trees.
-  Full height 50% porous screens.
-  1.5m high densely foliating evergreen shrubs



**Figure 7a: Recommended Treatments – Ground Floor**

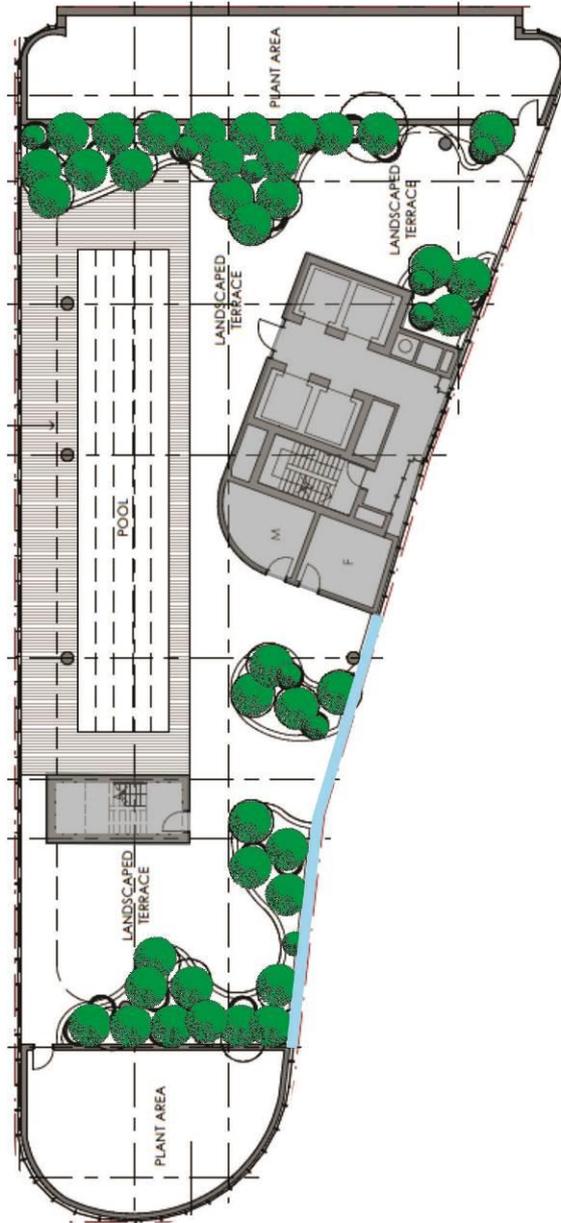
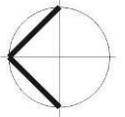
**Treatments Legend**



Densely foliating evergreen trees.



Perimeter screen extended to height of adjacent plant room enclosure.

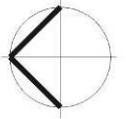


**Figure 7b: Recommended Treatments – Level 6 Skygarden**

### Treatments Legend

 Balcony to be fully enclosed as proposed.

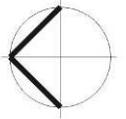
 Balcony to be partially enclosed with full height sliding/ folding screens in the areas indicated as proposed.



**Figure 7c: Recommended Treatments – Levels 7 – 23**

### Treatments Legend

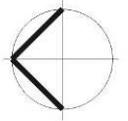
-  Balcony to be fully enclosed as proposed.
-  Balcony to be partially enclosed with full height sliding/ folding screens in the areas indicated as proposed.



**Figure 7d: Recommended Treatments – Levels 25 – 38**

**Treatments Legend**

-  Balcony to be fully enclosed as proposed.
-  Balcony to be partially enclosed with full height sliding/ folding screens in the areas indicated as proposed.



**Figure 7e: Recommended Treatments – Levels 39 – 48**

## REFERENCES

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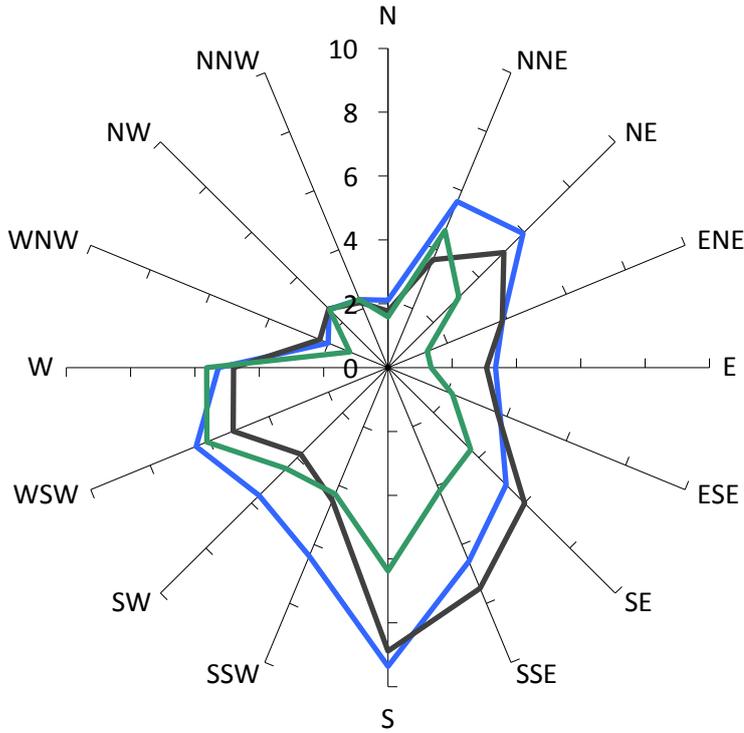
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## APPENDIX A - DIRECTIONAL PLOTS OF THE WIND TUNNEL RESULTS

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## Measured Wind Speeds at Point 01

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

14%

**Probability of Criterion Exceedence (initial test)**

18%

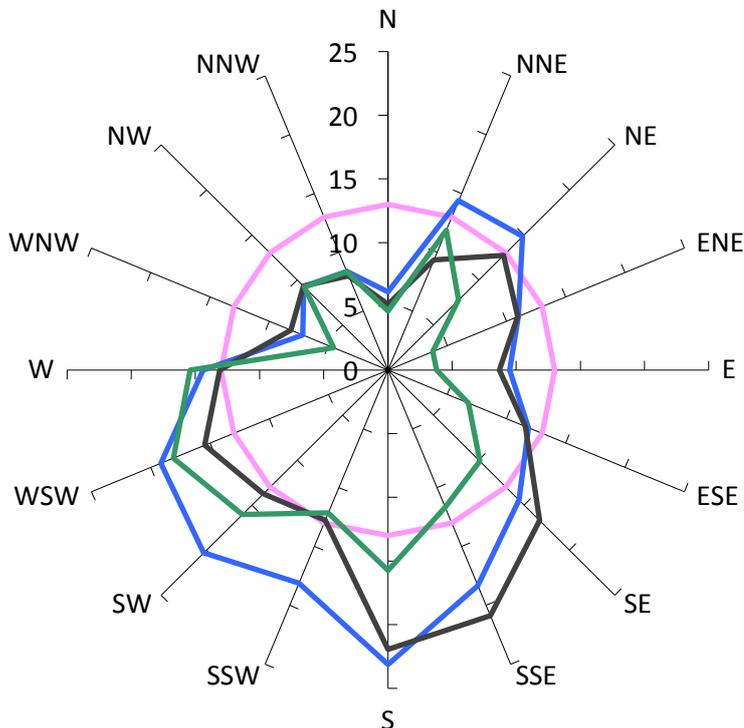
**Probability of Criterion Exceedence (final retest)**

6%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

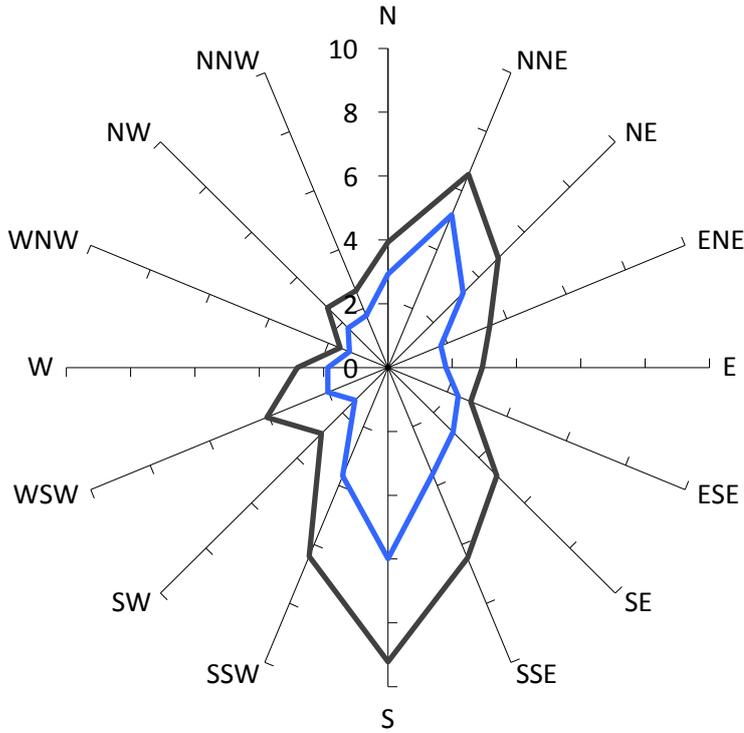


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 02

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

14%

**Probability of Criterion Exceedence (initial test)**

3%

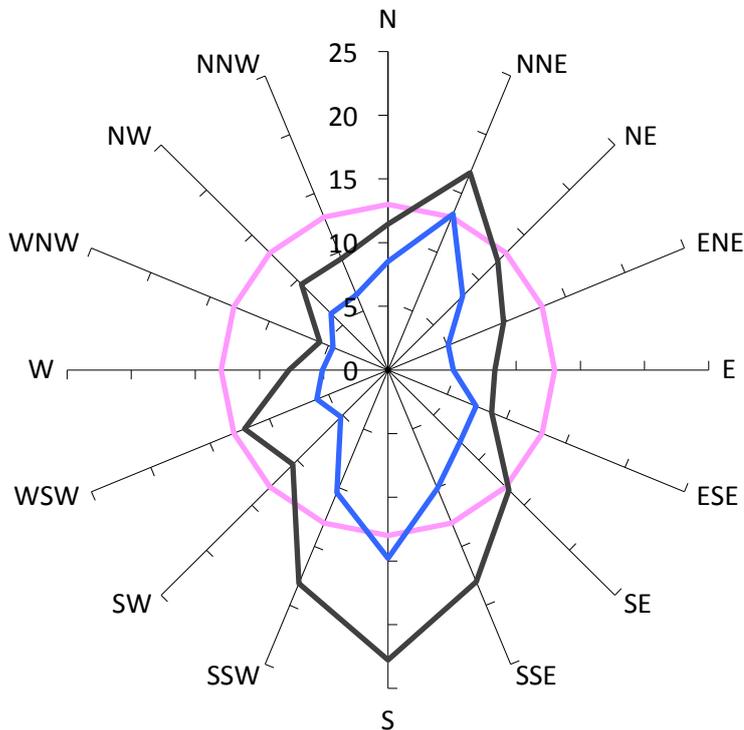
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

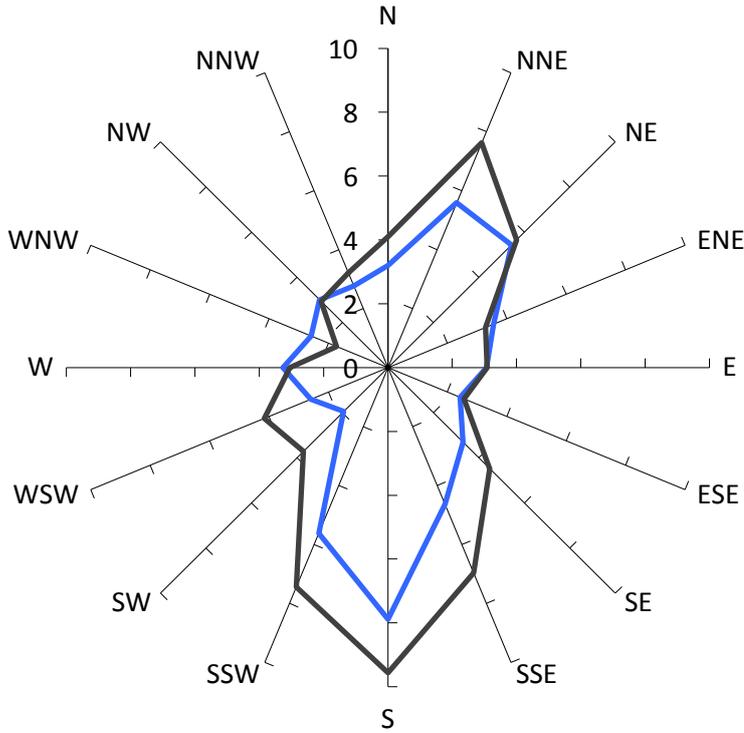


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 03

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

17%

**Probability of Criterion Exceedence (initial test)**

11%

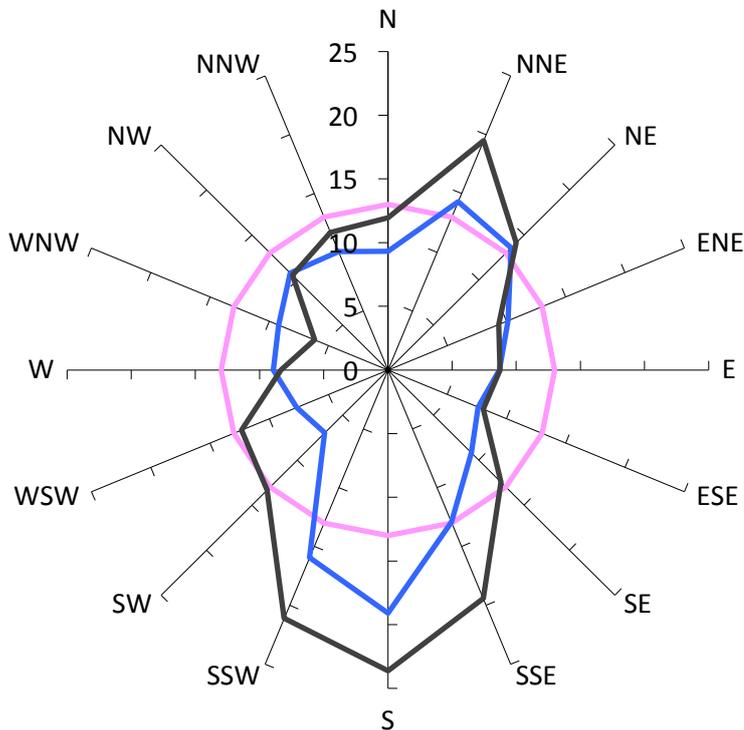
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

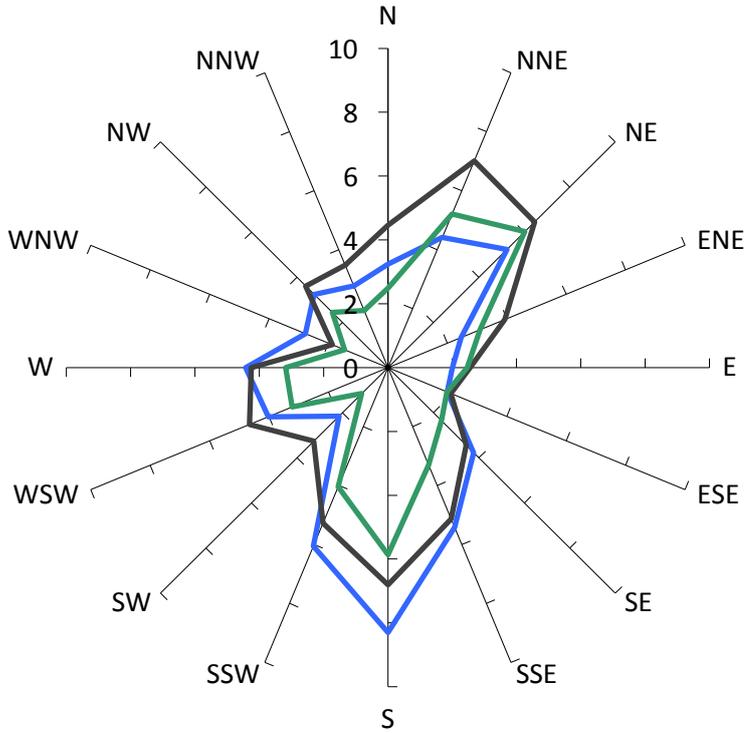


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 04

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

12%

**Probability of Criterion Exceedence (initial test)**

11%

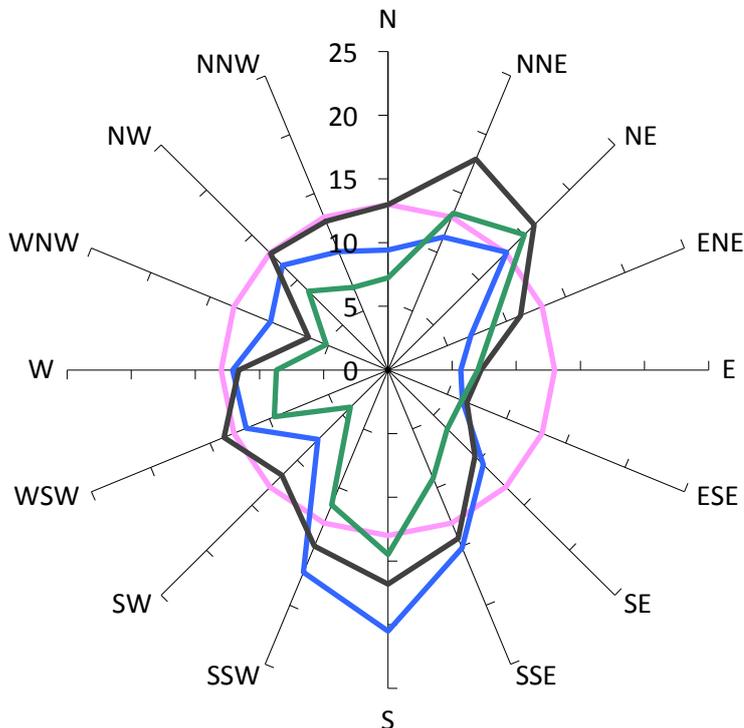
**Probability of Criterion Exceedence (final retest)**

5%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

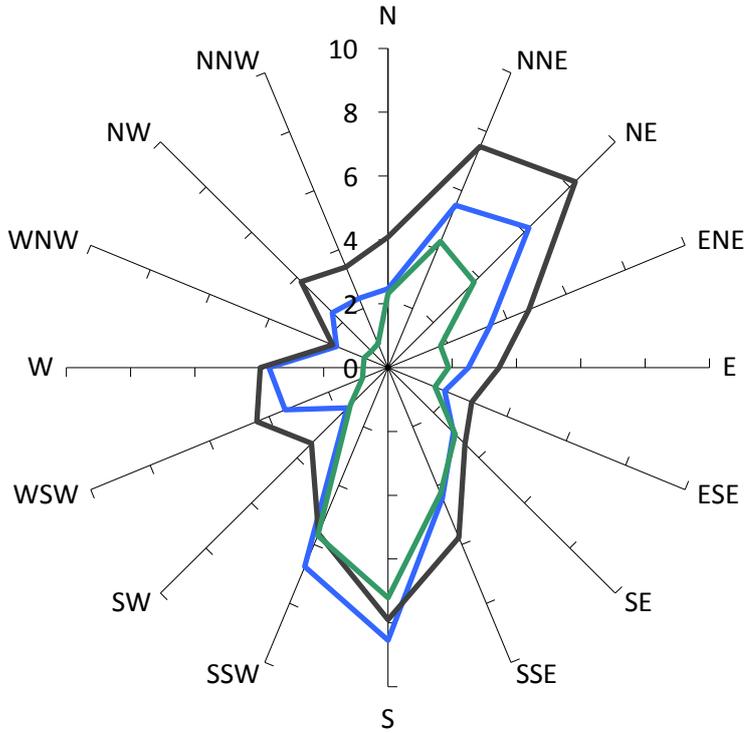


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 05

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

16%

**Probability of Criterion Exceedence (initial test)**

13%

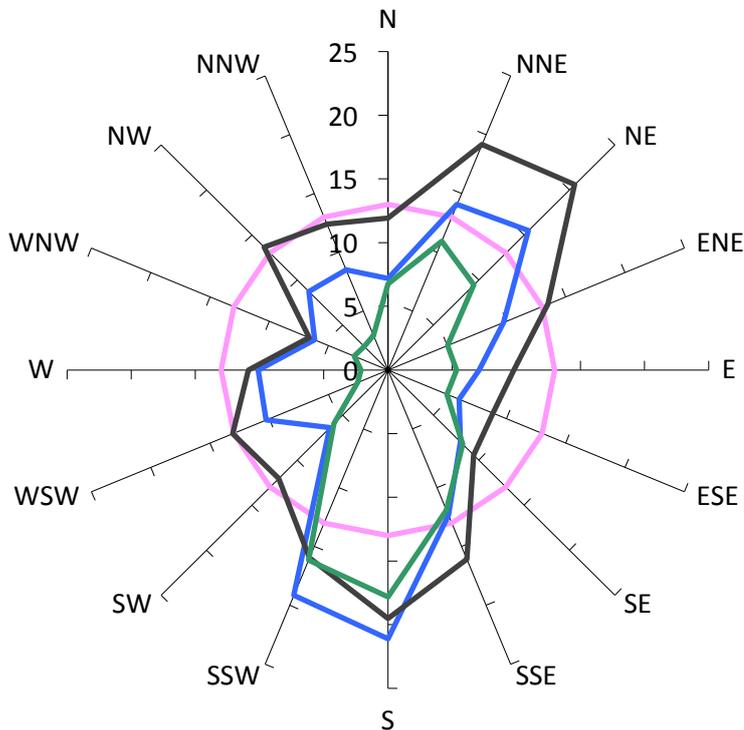
**Probability of Criterion Exceedence (final retest)**

7%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

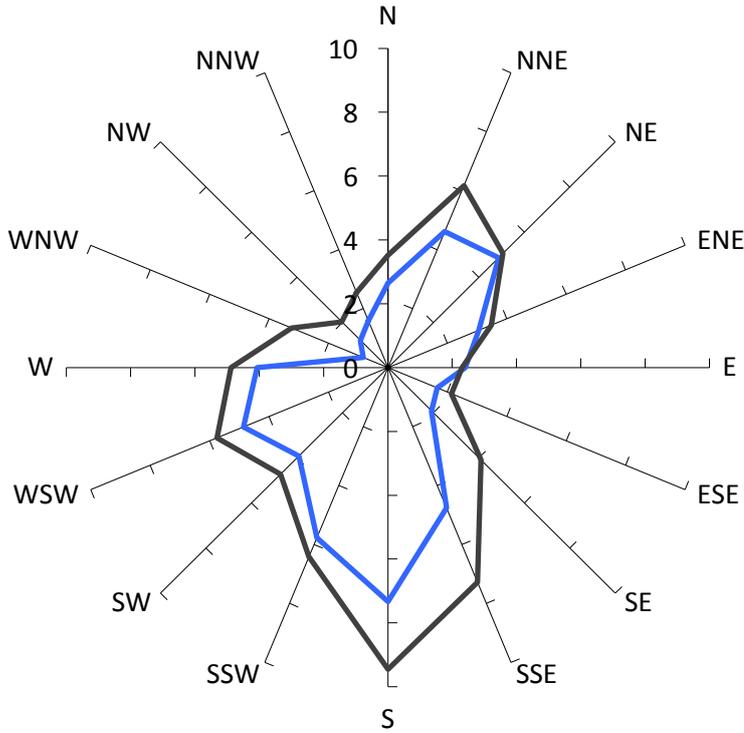


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 06

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

16%

**Probability of Criterion Exceedence (initial test)**

9%

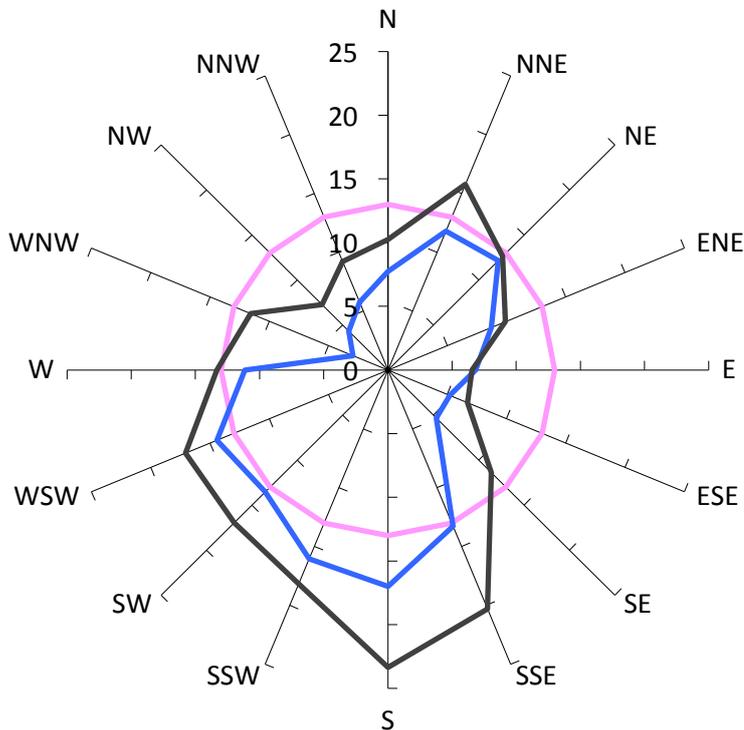
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

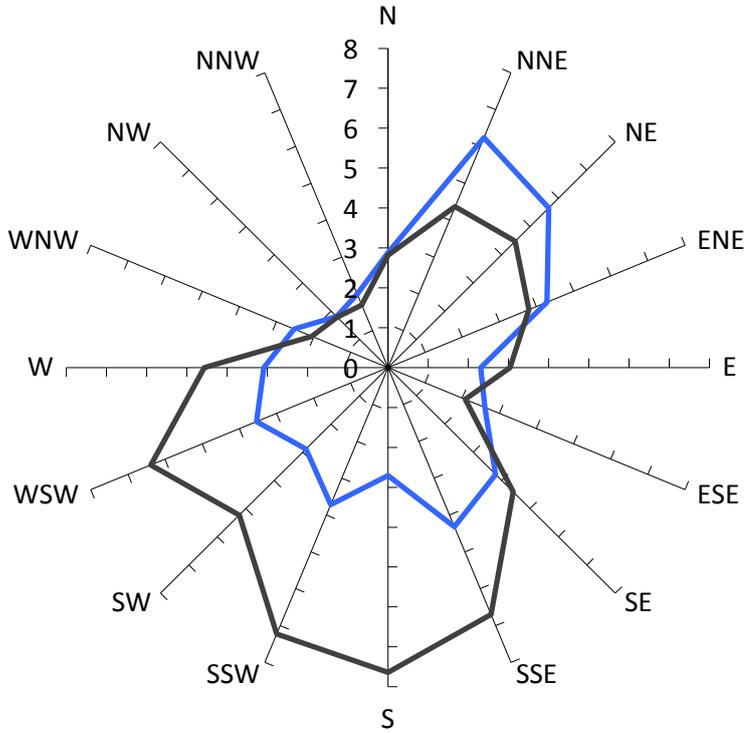


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 07

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

13%

**Probability of Criterion Exceedence (initial test)**

6%

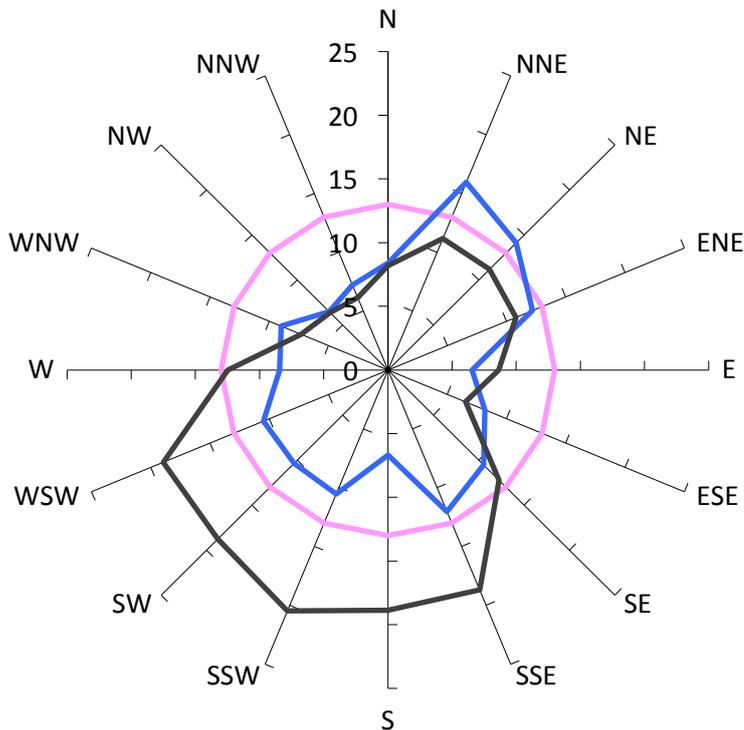
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

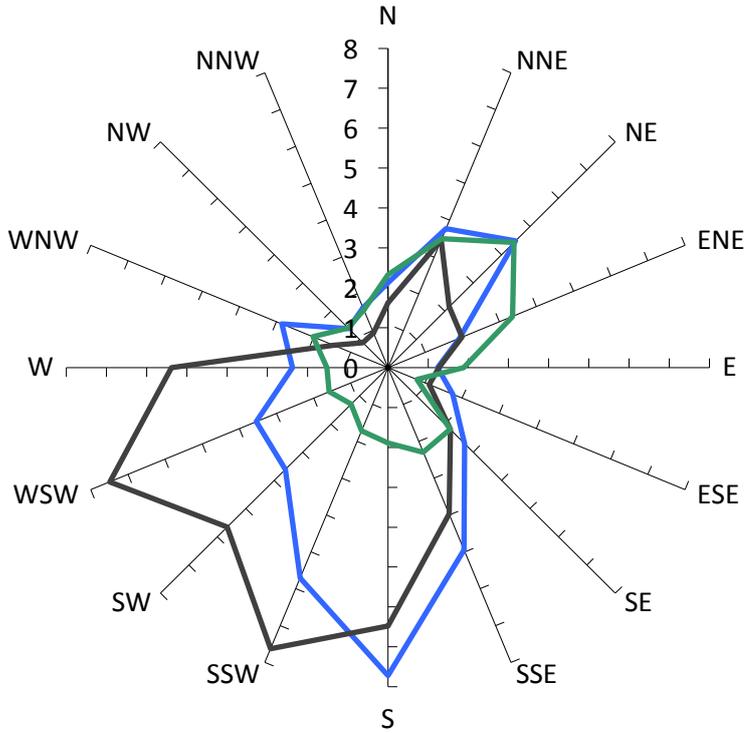


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 08

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

9%

**Probability of Criterion Exceedence (initial test)**

9%

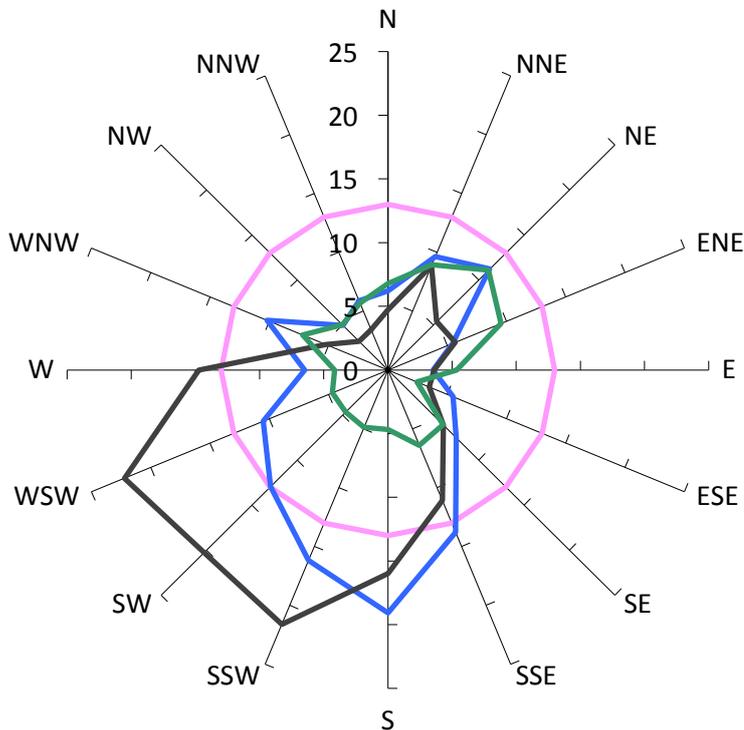
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

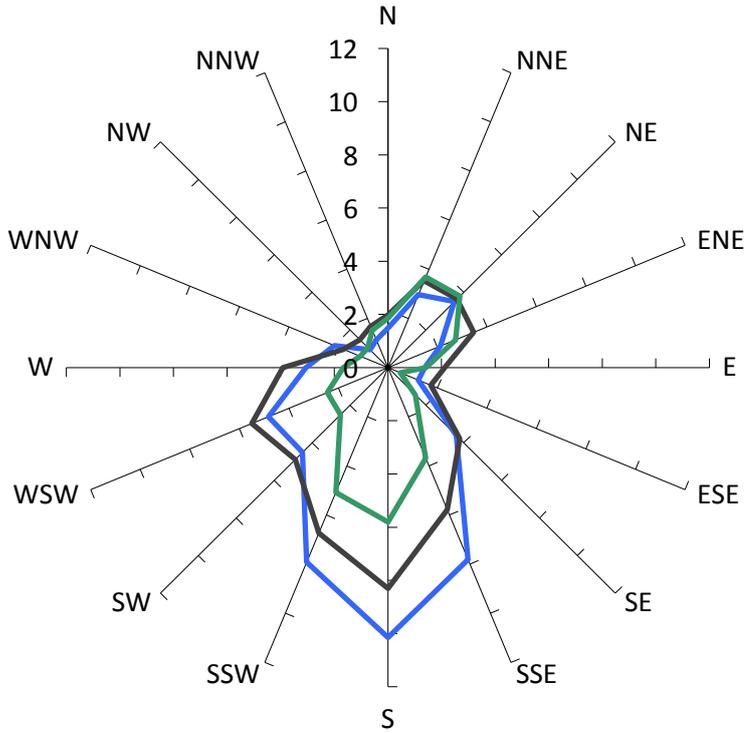


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 09

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

11%

**Probability of Criterion Exceedence (initial test)**

13%

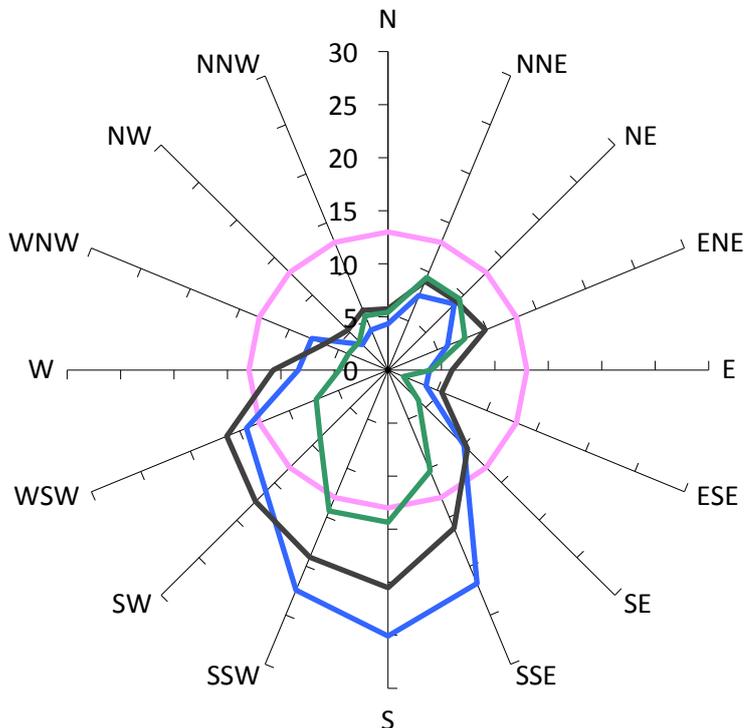
**Probability of Criterion Exceedence (final retest)**

3%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

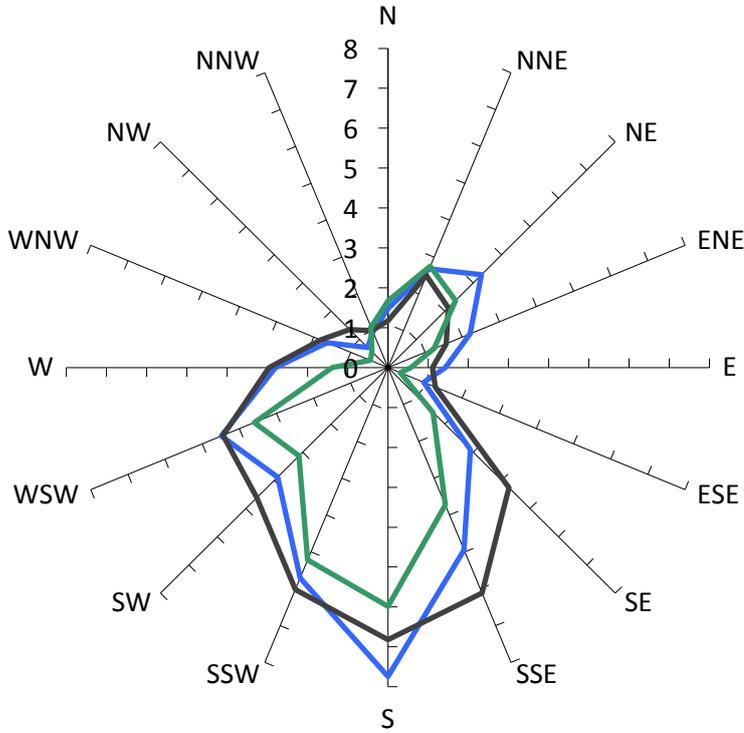


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 10

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

8%

**Probability of Criterion Exceedence (initial test)**

9%

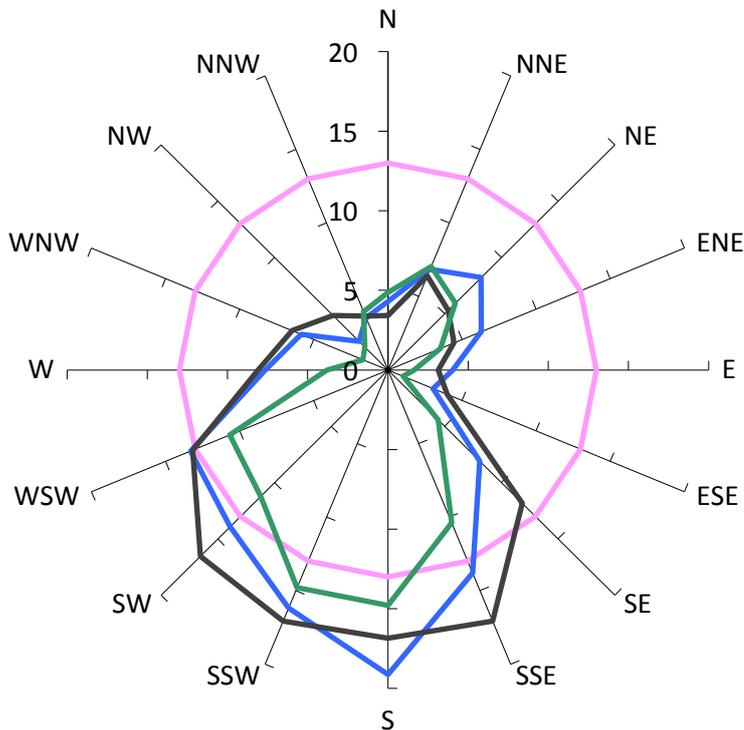
**Probability of Criterion Exceedence (final retest)**

3%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

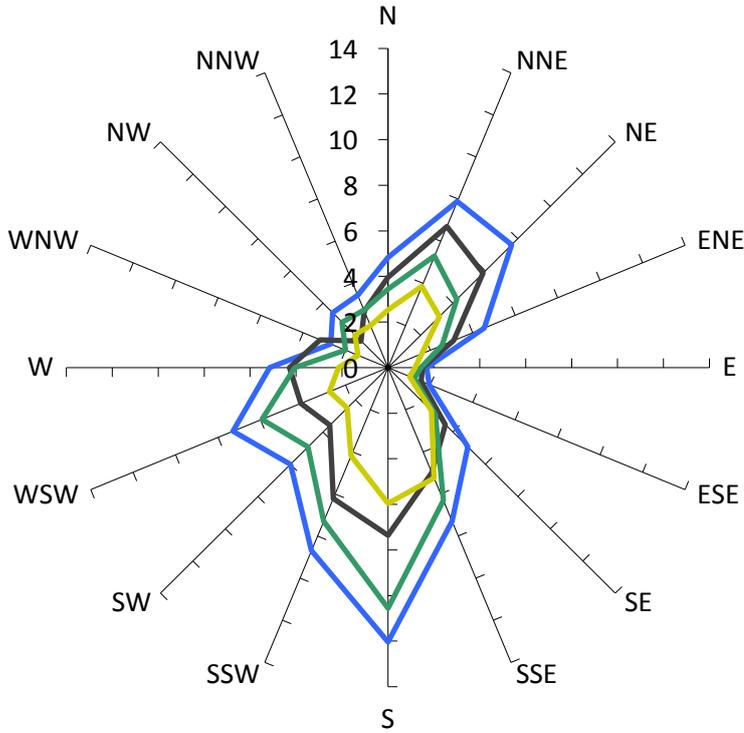


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 11

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

13%

**Probability of Criterion Exceedence (initial test)**

22%

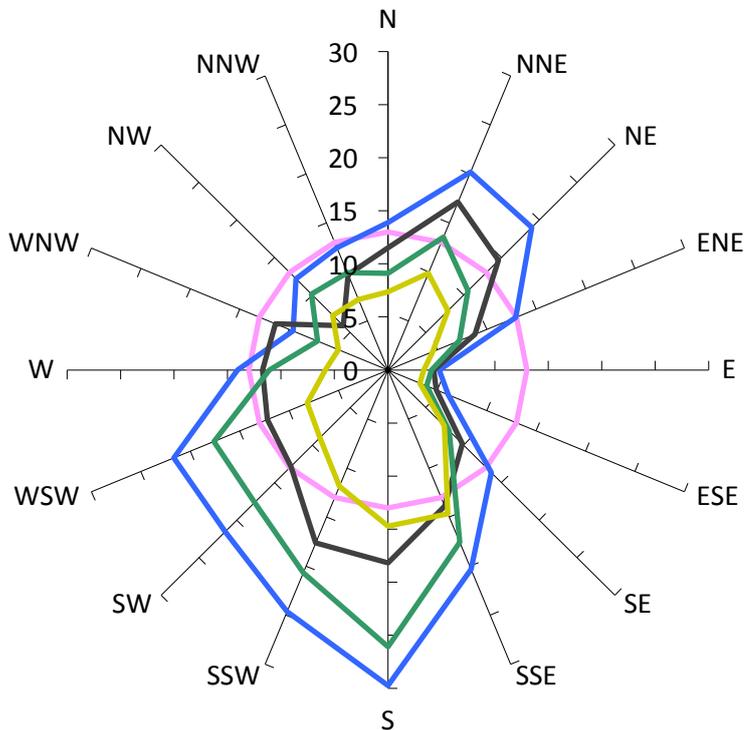
**Probability of Criterion Exceedence (final retest)**

3%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- Densely foliating trees
- Densely foliating shrubs replacing trees
- 
- 
- 

**Annual Maximum Gust (m/s)**

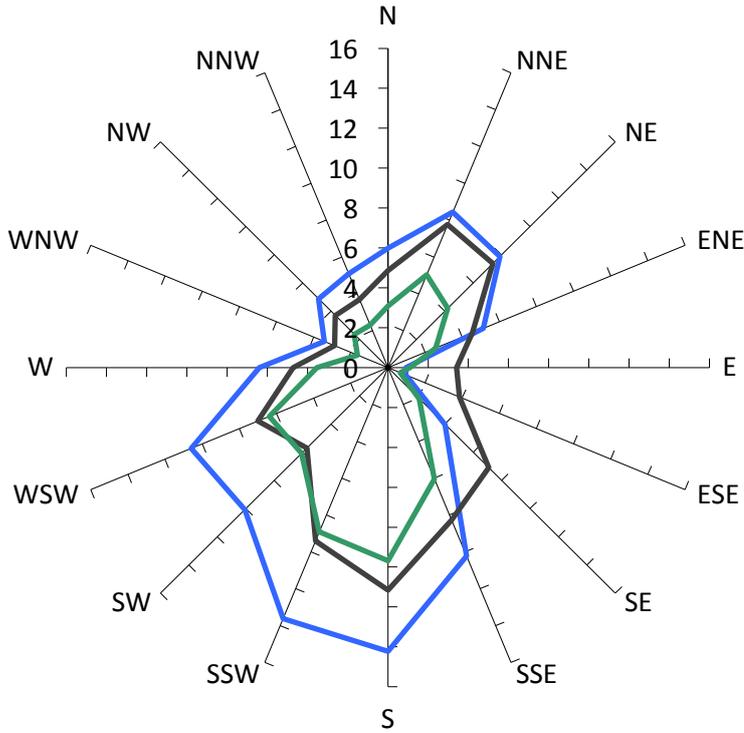


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 12

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

23%

**Probability of Criterion Exceedence (initial test)**

28%

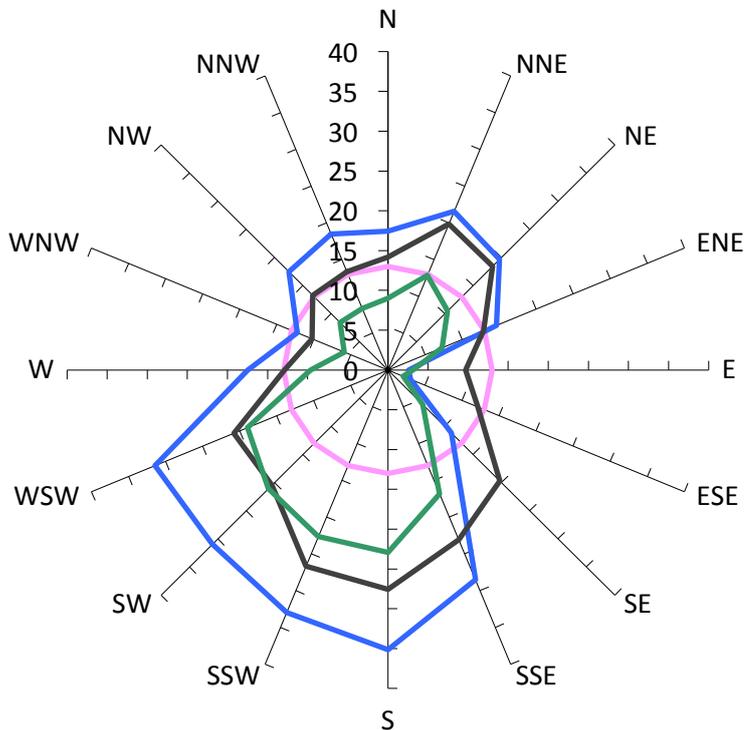
**Probability of Criterion Exceedence (final retest)**

14%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

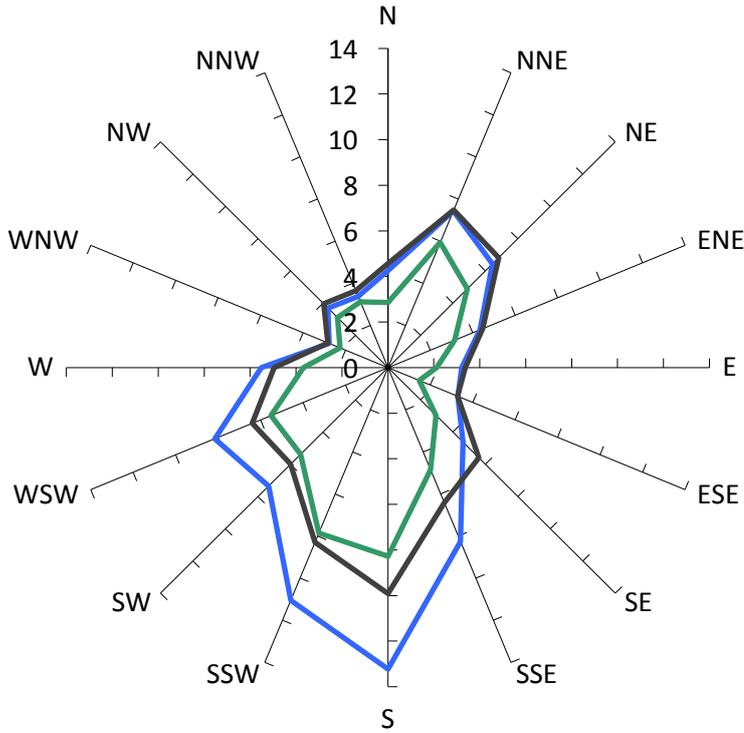


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 13

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

21%

**Probability of Criterion Exceedence (initial test)**

23%

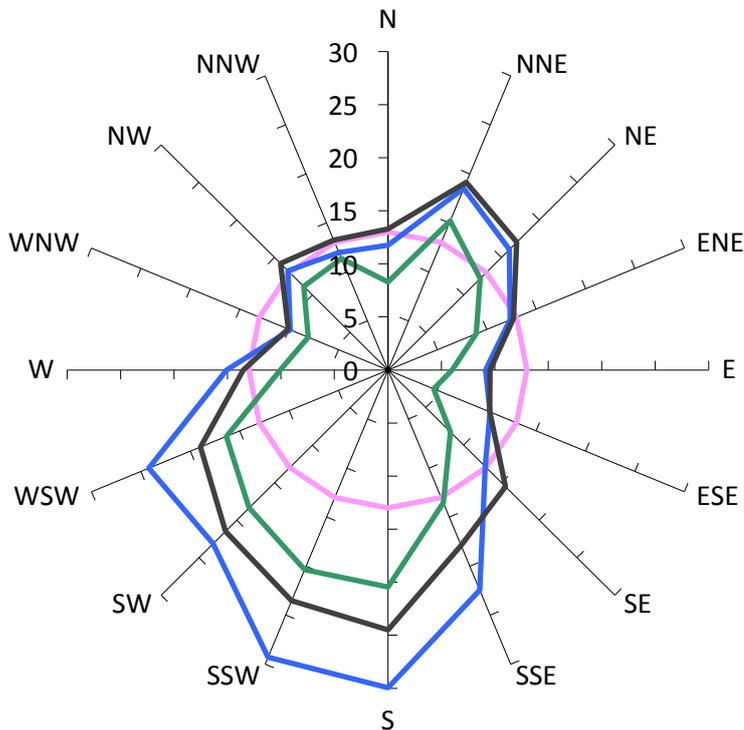
**Probability of Criterion Exceedence (final retest)**

13%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

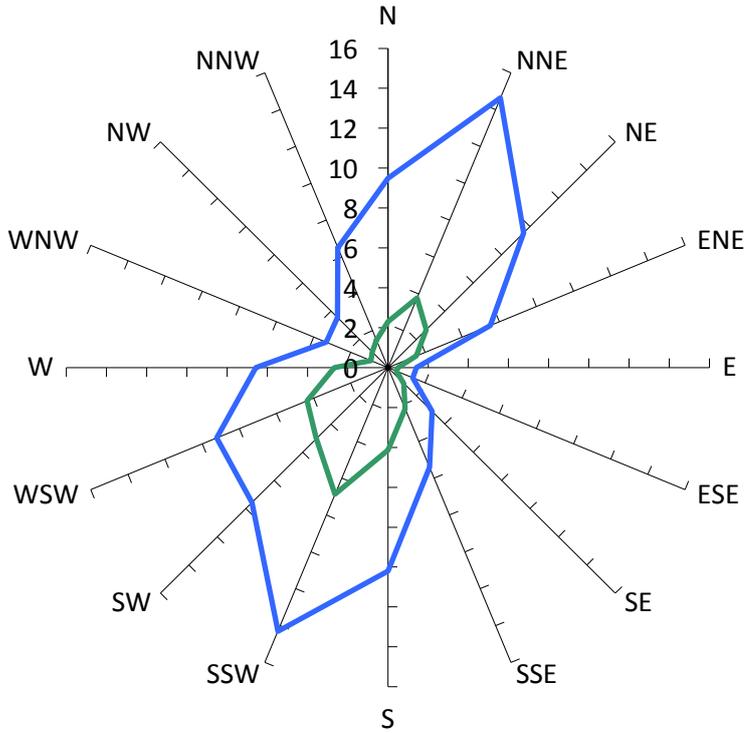


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 14

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

27%

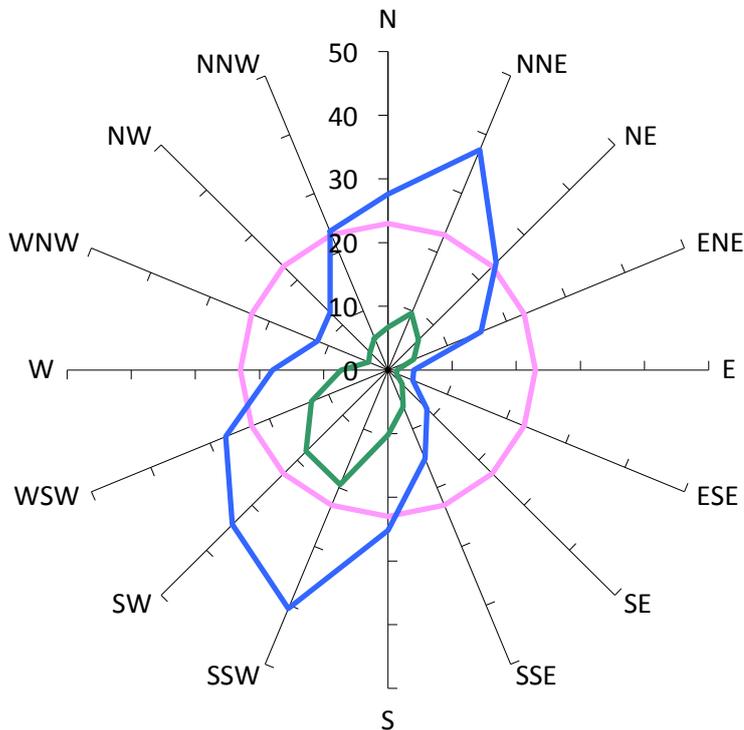
**Probability of Criterion Exceedence (final retest)**

4%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Full height 50% porous screens
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

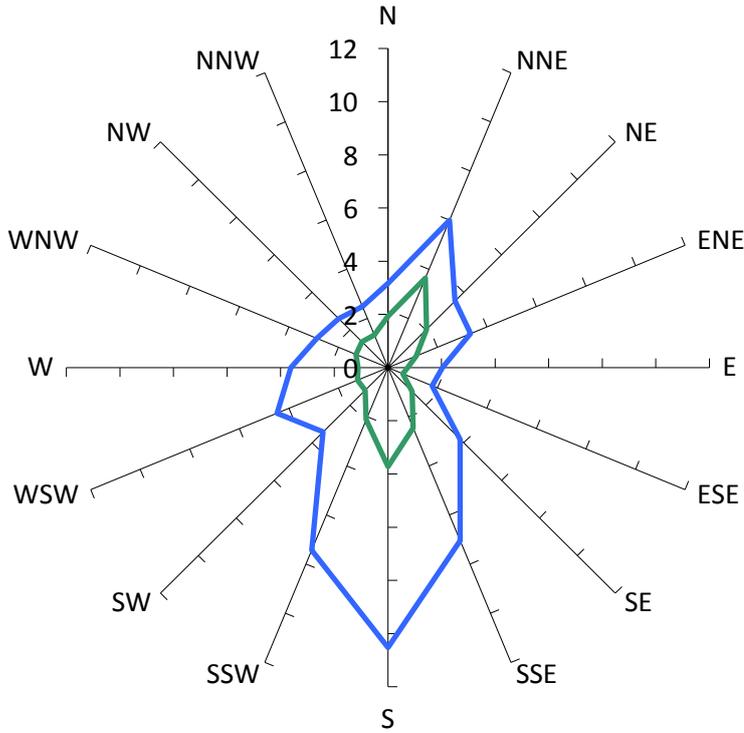


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 15

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

14%

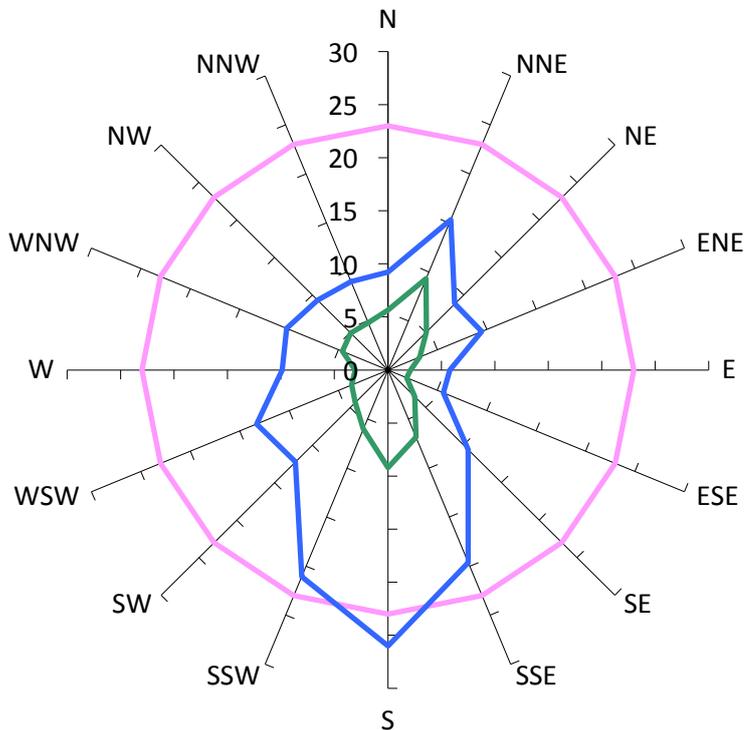
**Probability of Criterion Exceedence (final retest)**

0%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

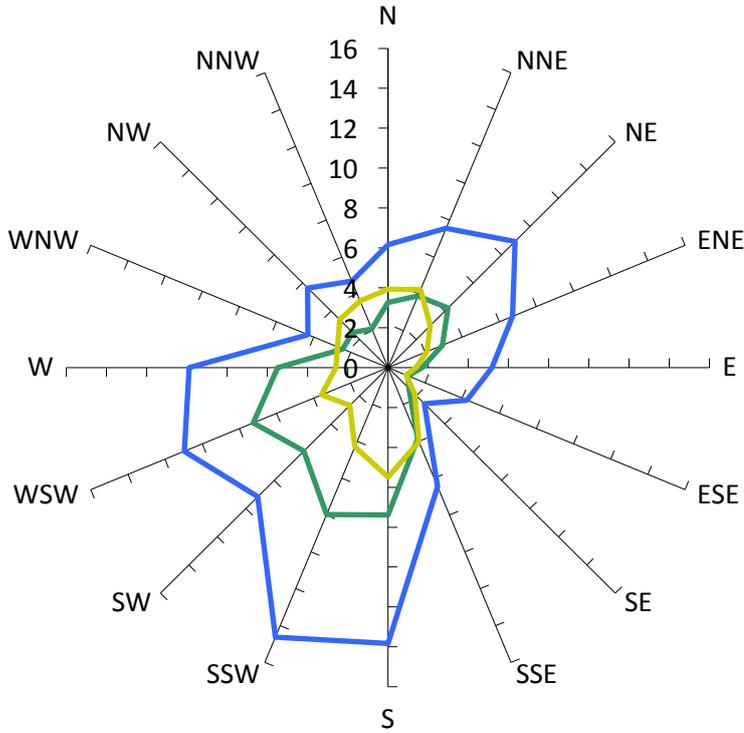


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 16

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

30%

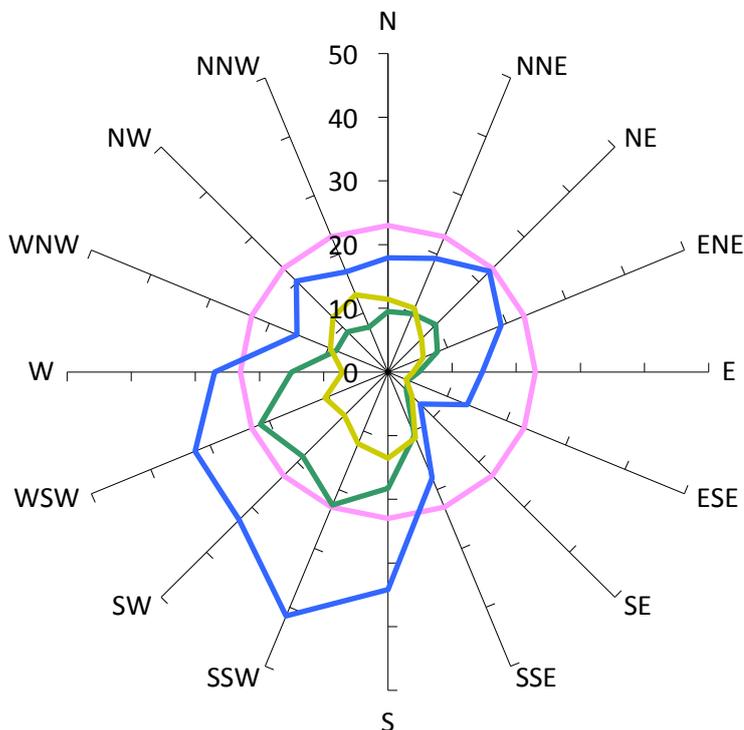
**Probability of Criterion Exceedence (final retest)**

3%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Densely foliating trees
- Densely foliating trees and perimeter screen extended.
- 
- 

**Annual Maximum Gust (m/s)**

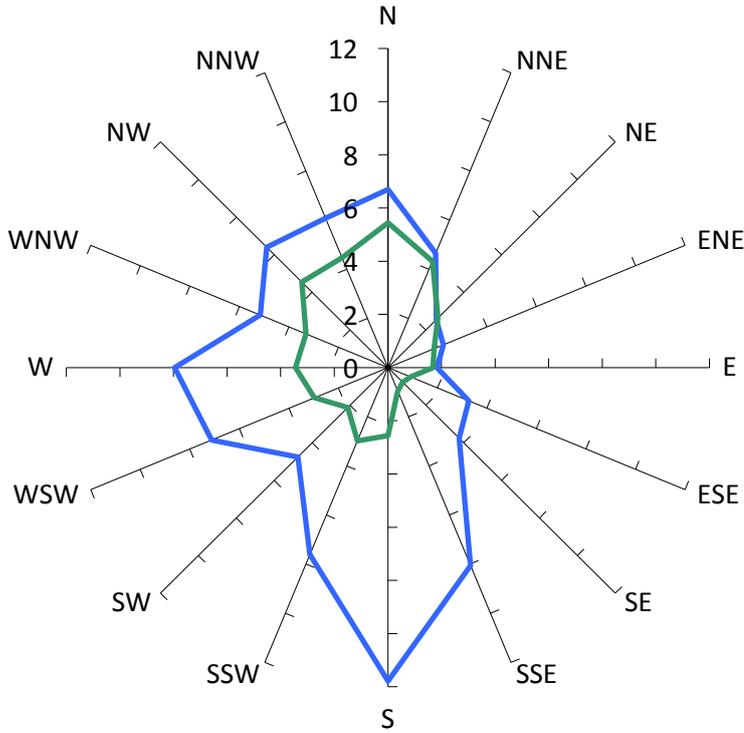


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 17

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

23%

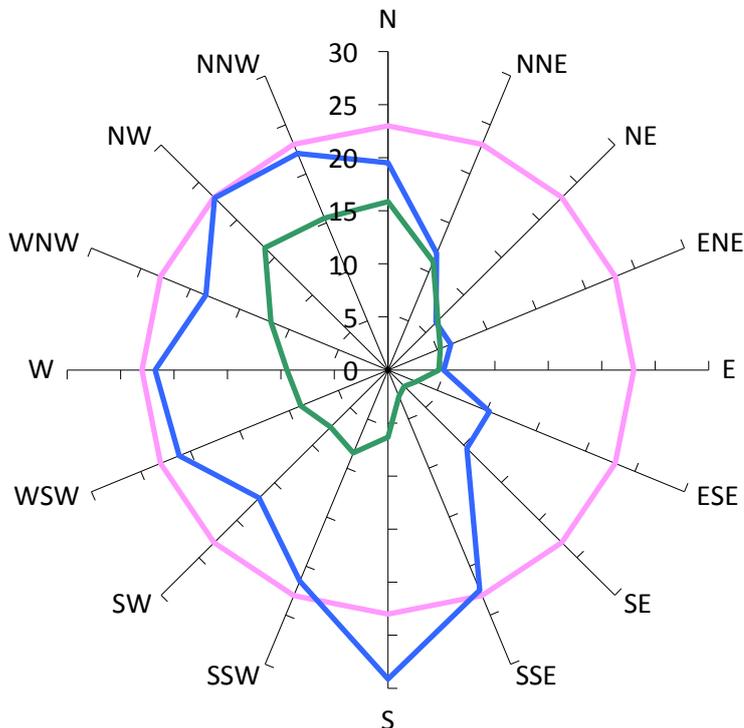
**Probability of Criterion Exceedence (final retest)**

3%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

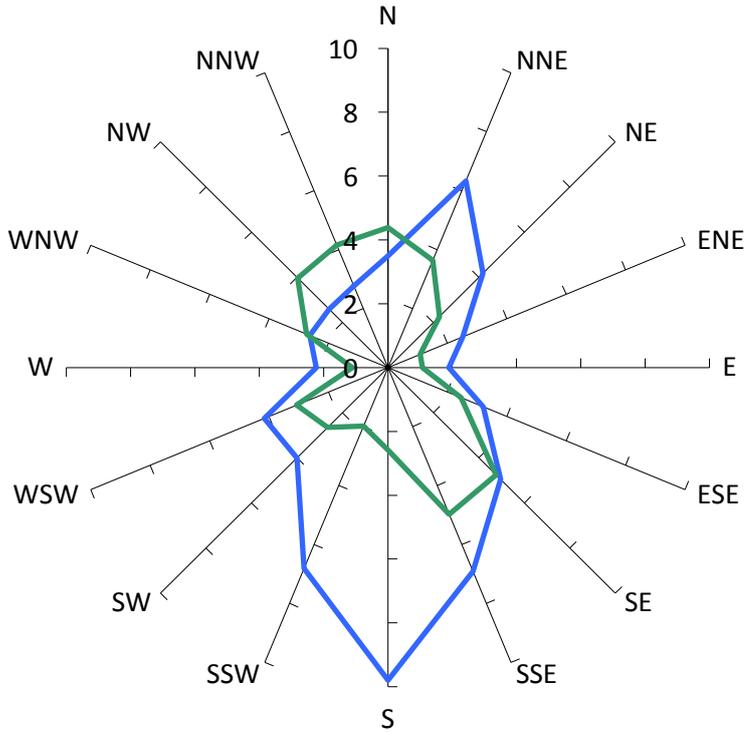


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 18

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

15%

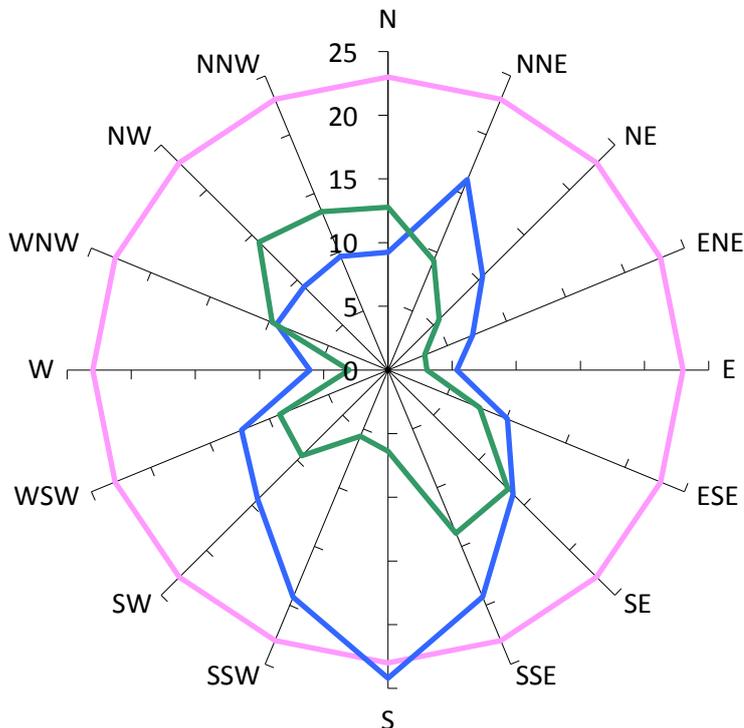
**Probability of Criterion Exceedence (final retest)**

3%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Densely foliating trees
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

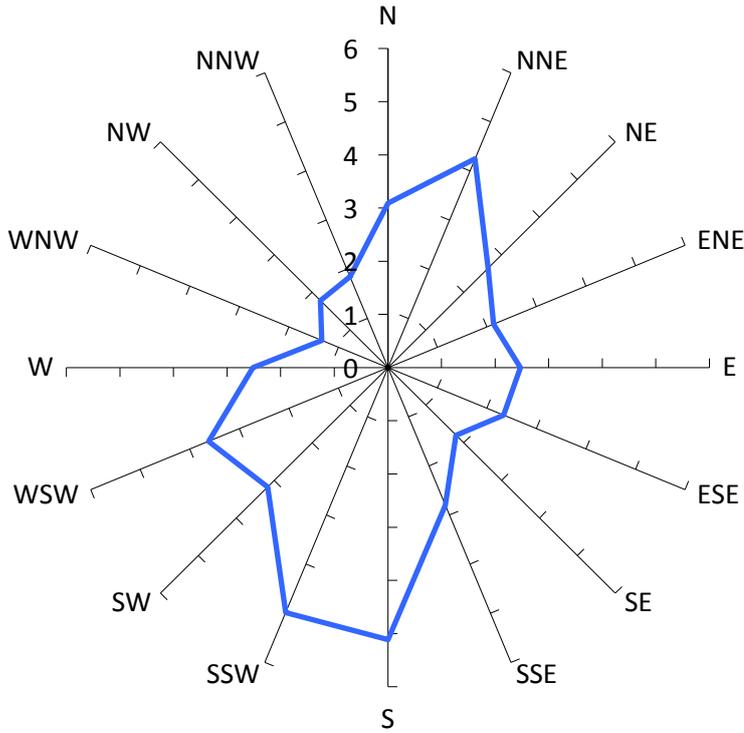


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 19

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

2%

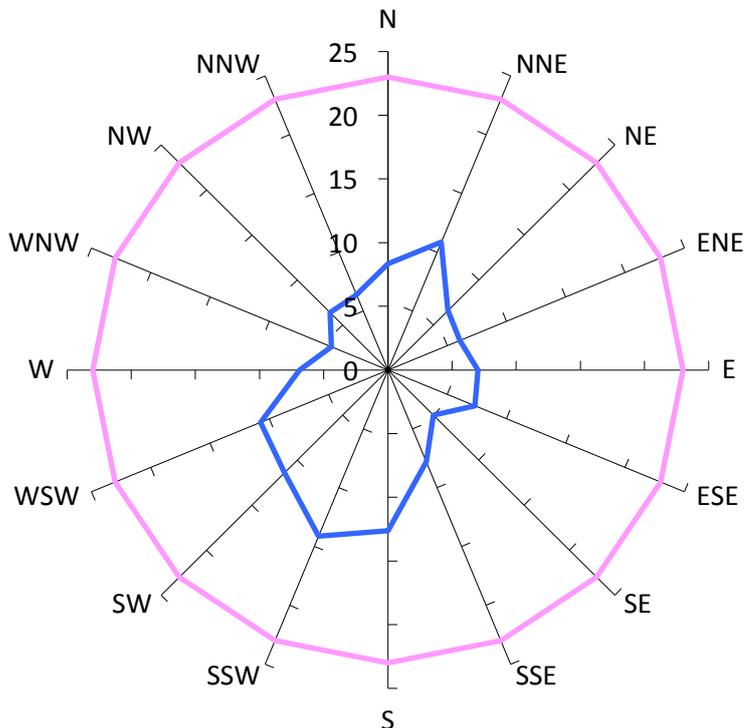
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- 
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

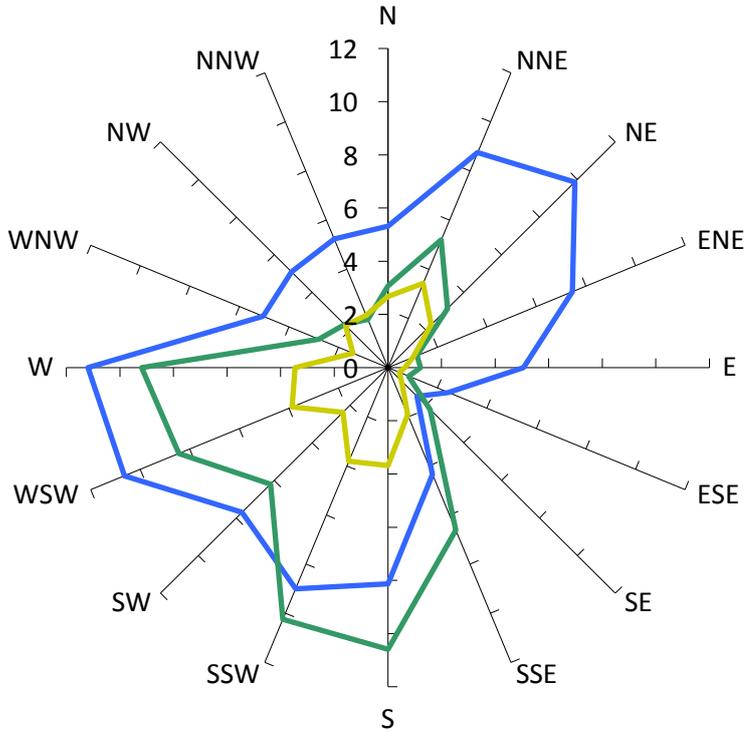


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 20

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

27%

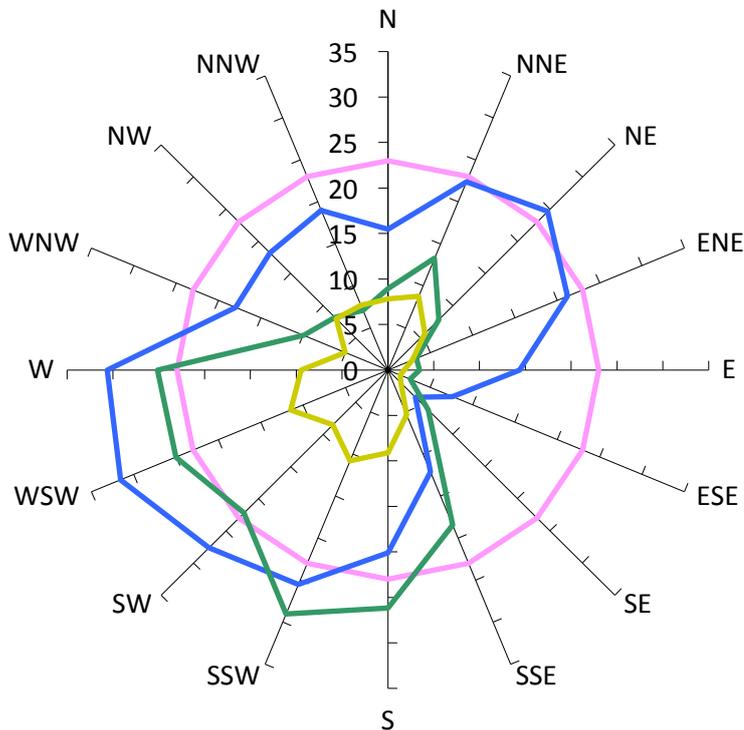
**Probability of Criterion Exceedence (final retest)**

0%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Densely foliating trees
- Densley foliating trees and perimeter screen extended.
- 
- 

**Annual Maximum Gust (m/s)**

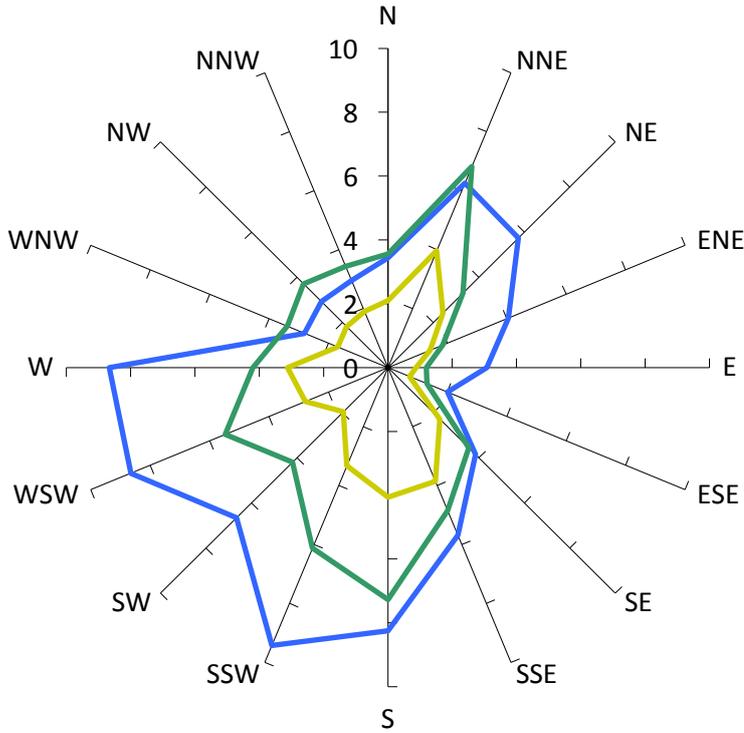


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 21

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

21%

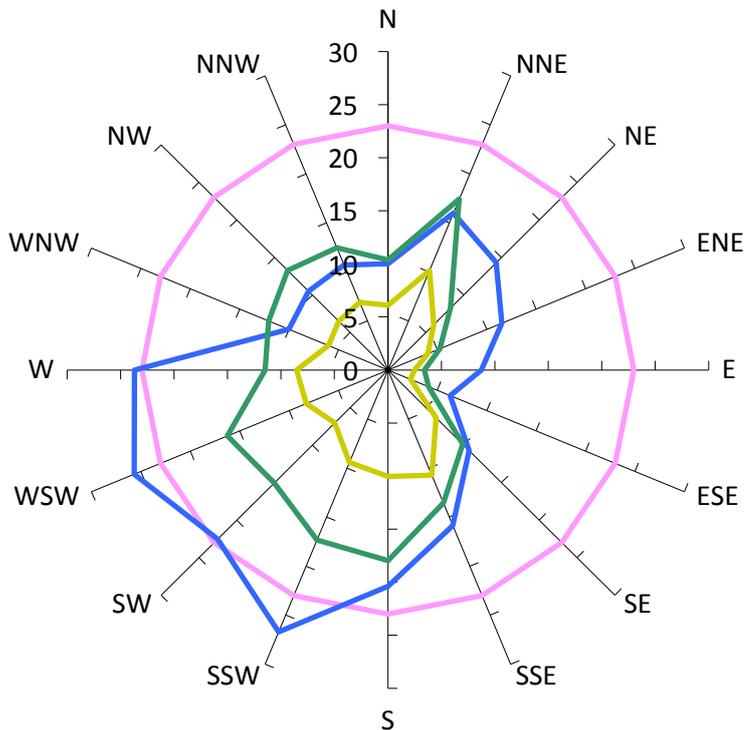
**Probability of Criterion Exceedence (final retest)**

0%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Densely foliating trees
- Densely foliating trees and perimeter screen extended.
- 
- 

**Annual Maximum Gust (m/s)**

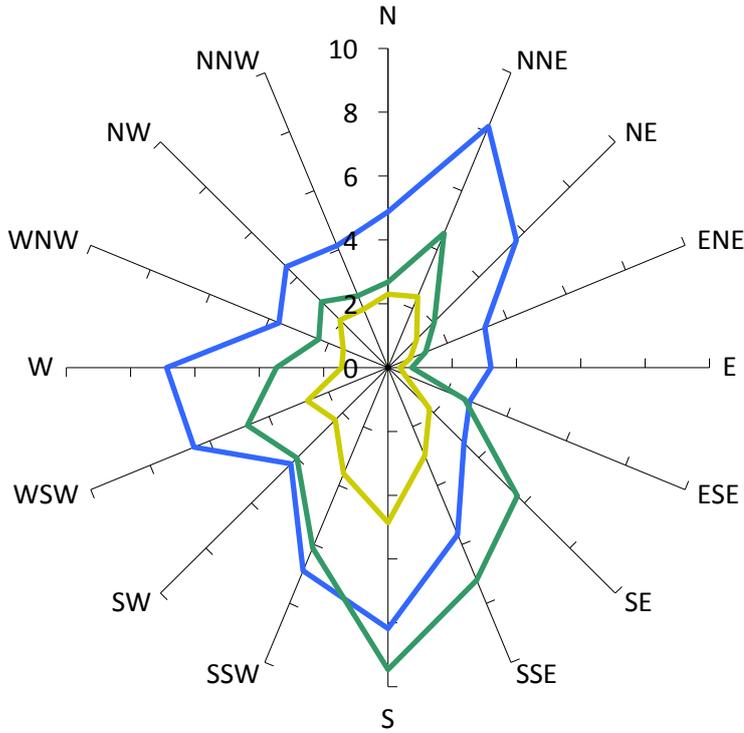


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 22

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

19%

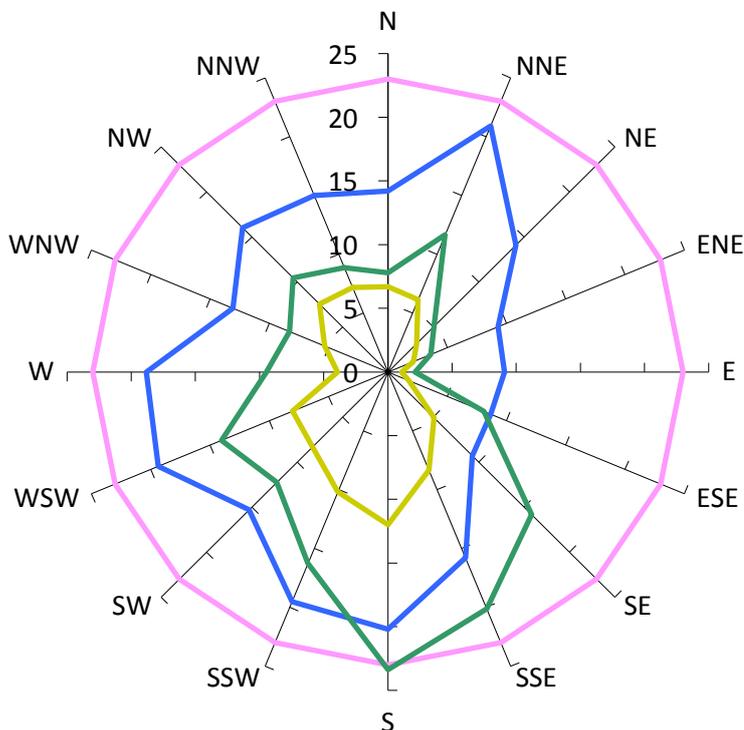
**Probability of Criterion Exceedence (final retest)**

1%

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Densely foliating trees
- Densely foliating trees and perimeter screen extended.
- 
- 

**Annual Maximum Gust (m/s)**

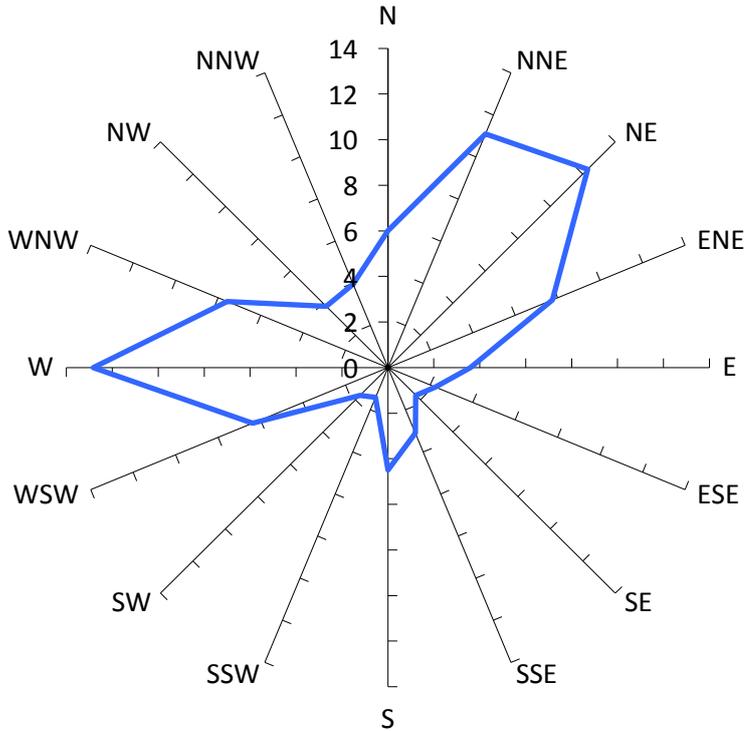


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 23

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

7.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

12%

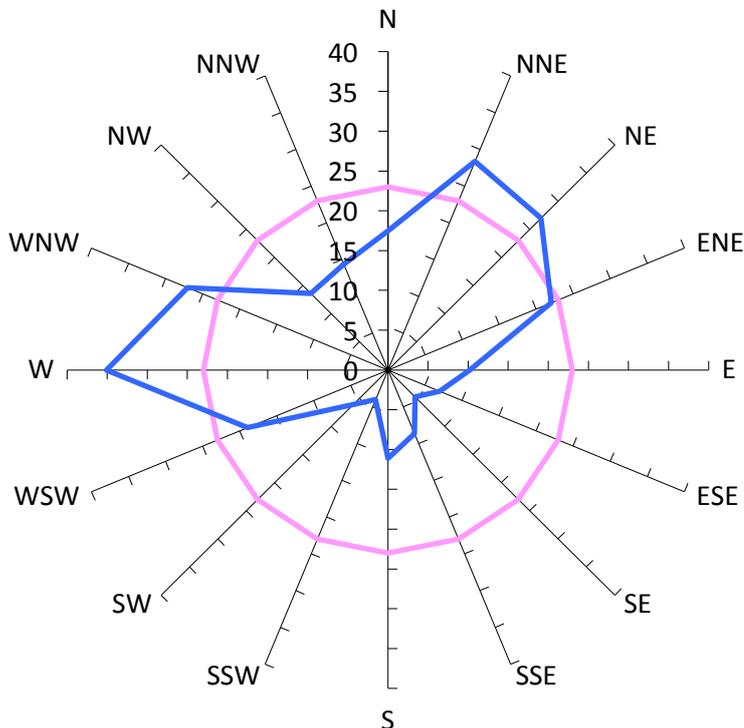
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- 
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

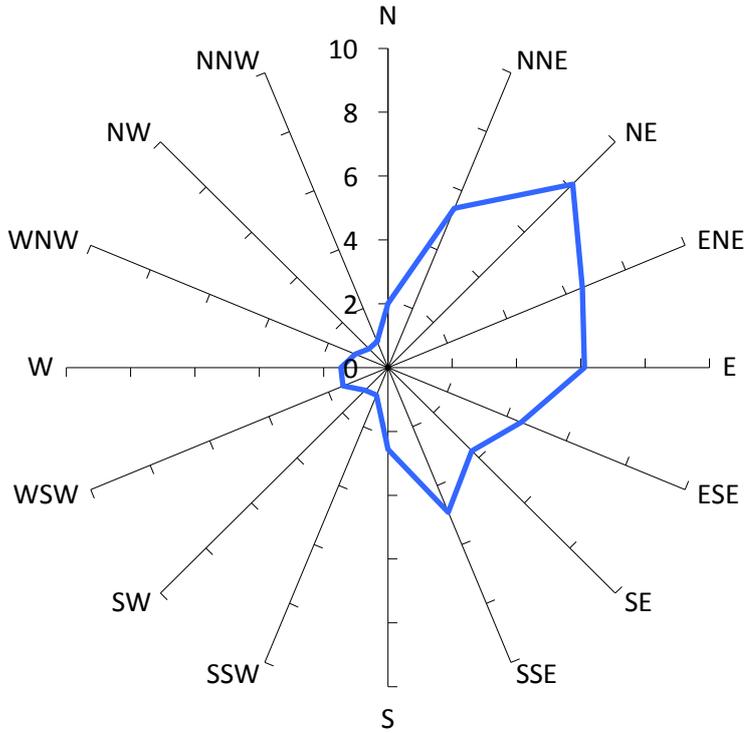


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 24

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

7.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

4%

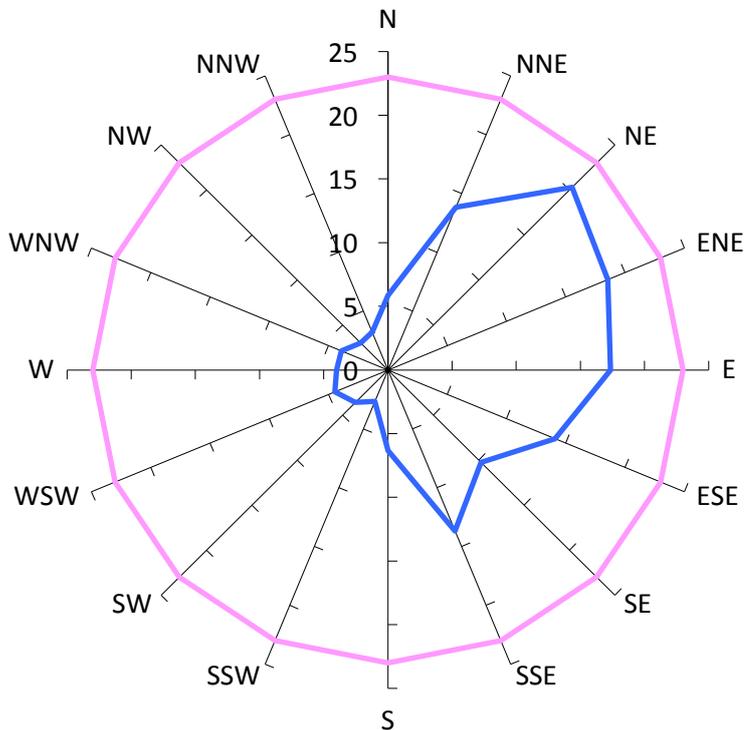
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- 
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

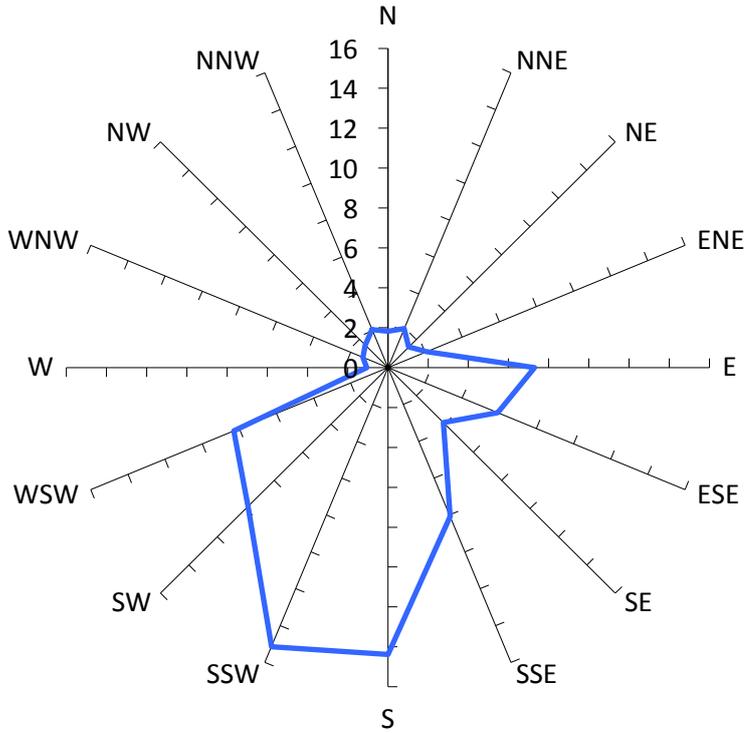


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 25

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

7.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

15%

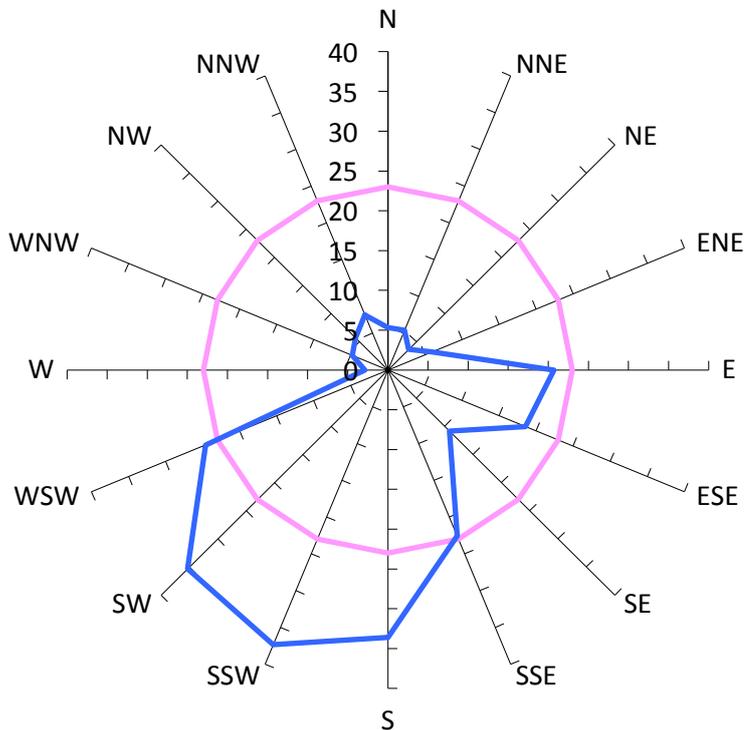
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- 
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

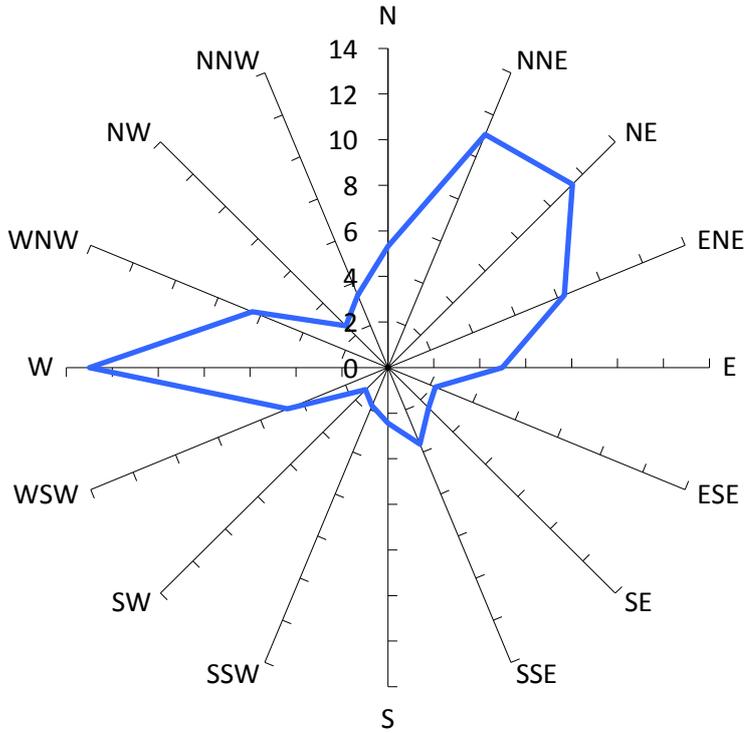


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 26

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

7.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

12%

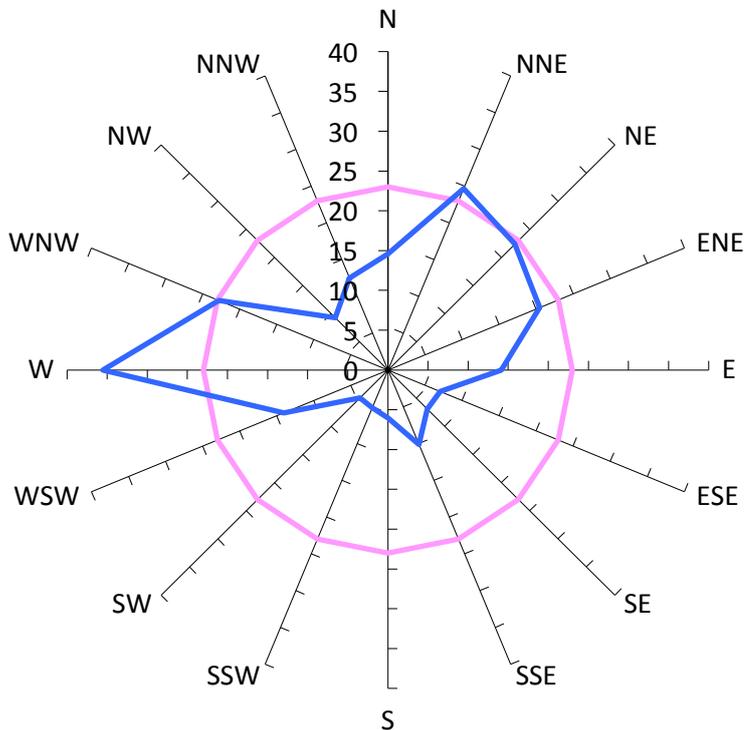
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- 
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

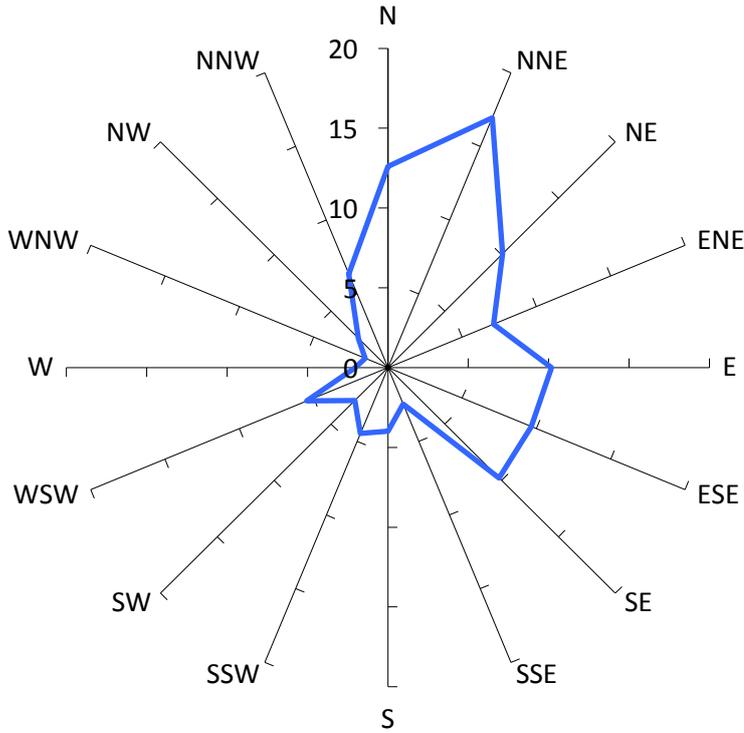


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 27

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

7.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

16%

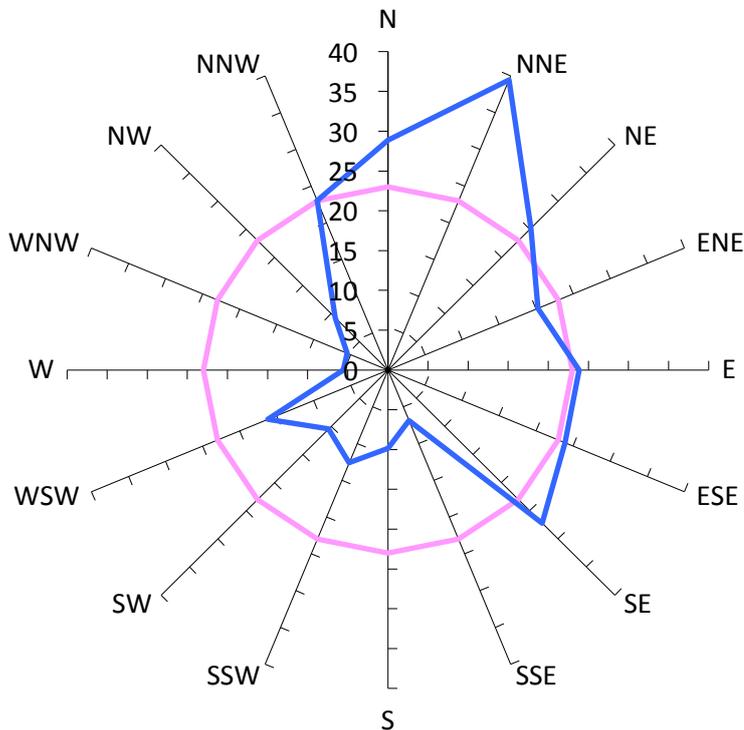
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- 
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

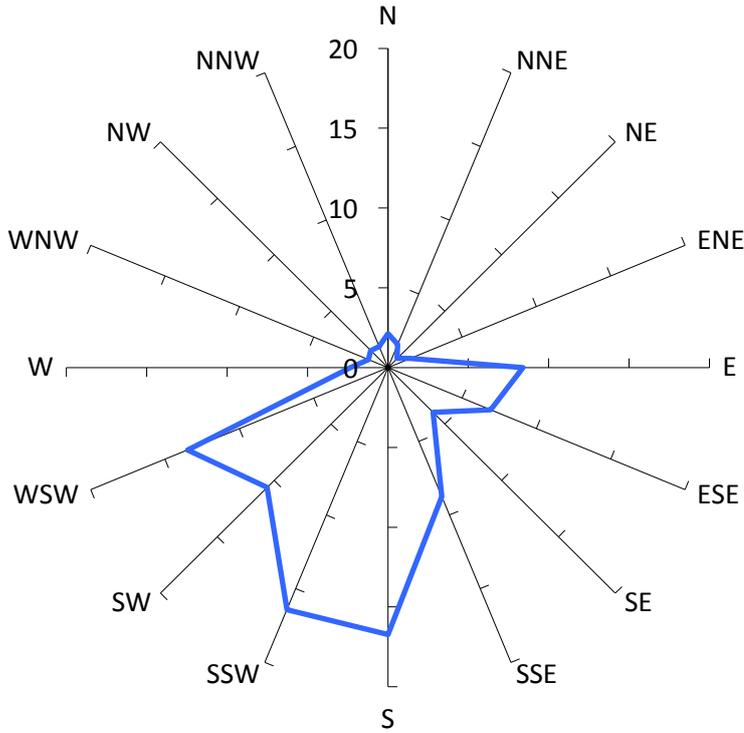


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 28

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

7.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

18%

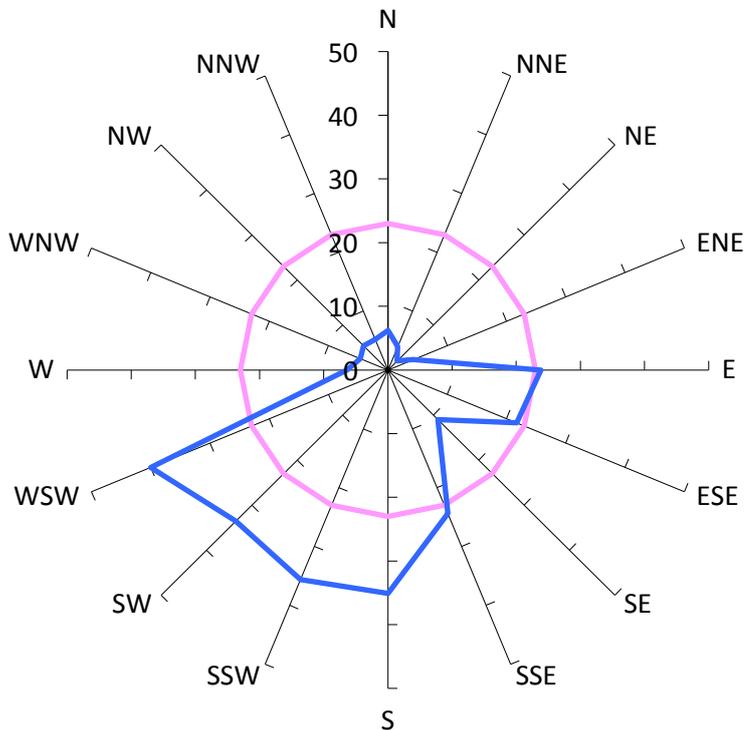
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- 
- 
- 
- 
- 
- 

**Annual Maximum Gust (m/s)**

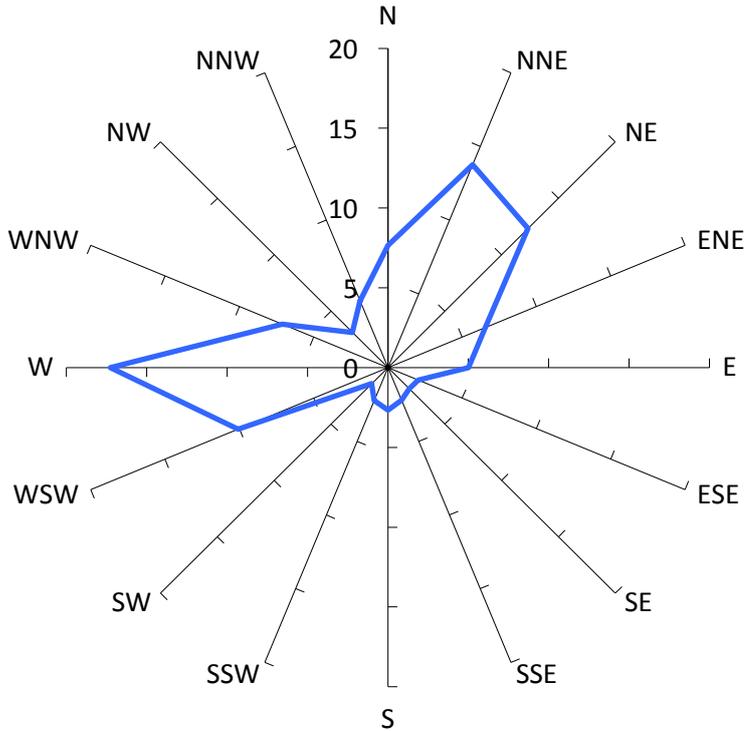


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 29

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

7.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

15%

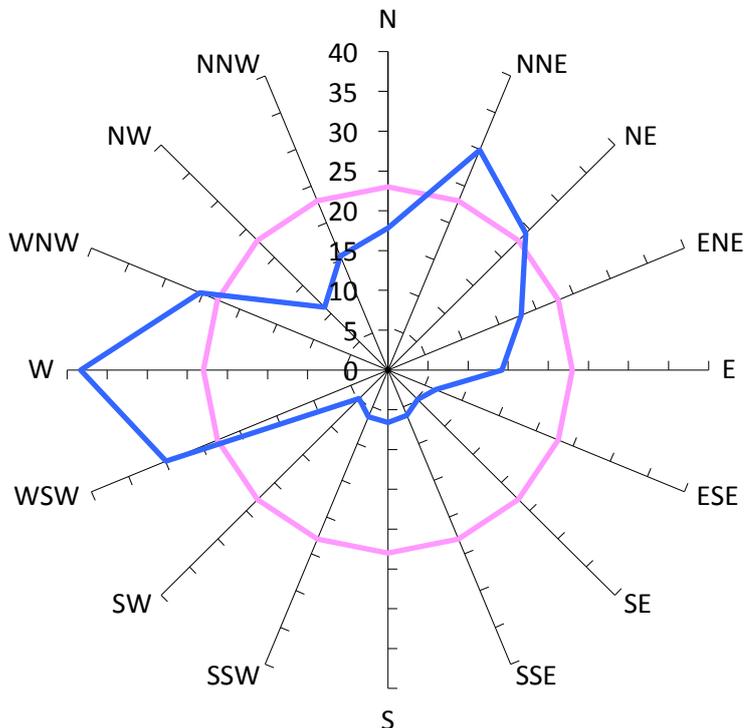
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
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**Annual Maximum Gust (m/s)**

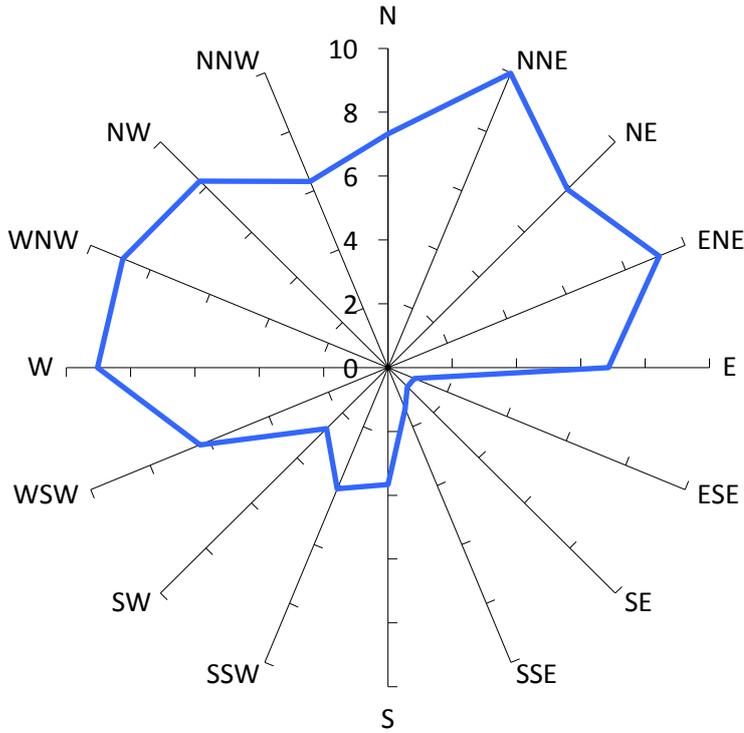


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 30

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

7.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

14%

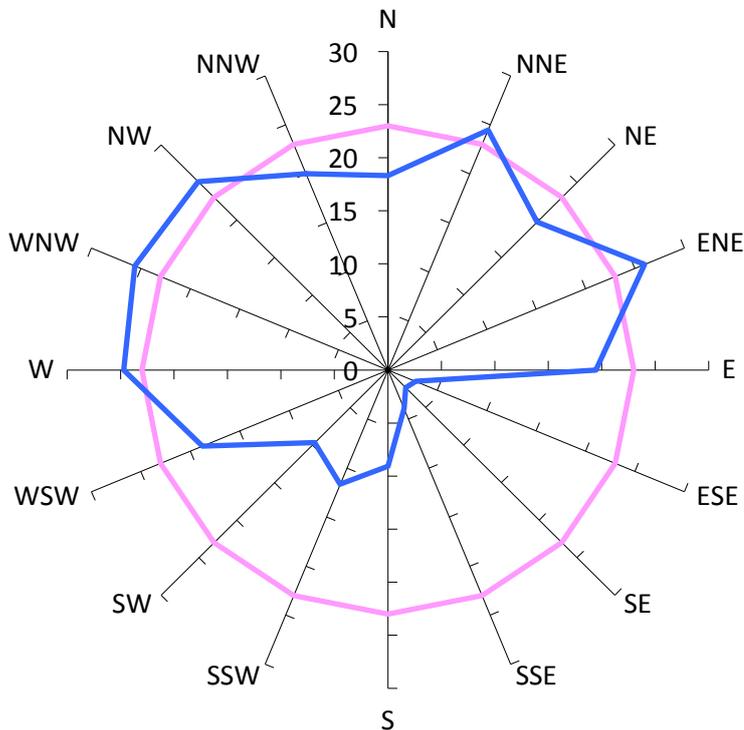
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
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**Annual Maximum Gust (m/s)**

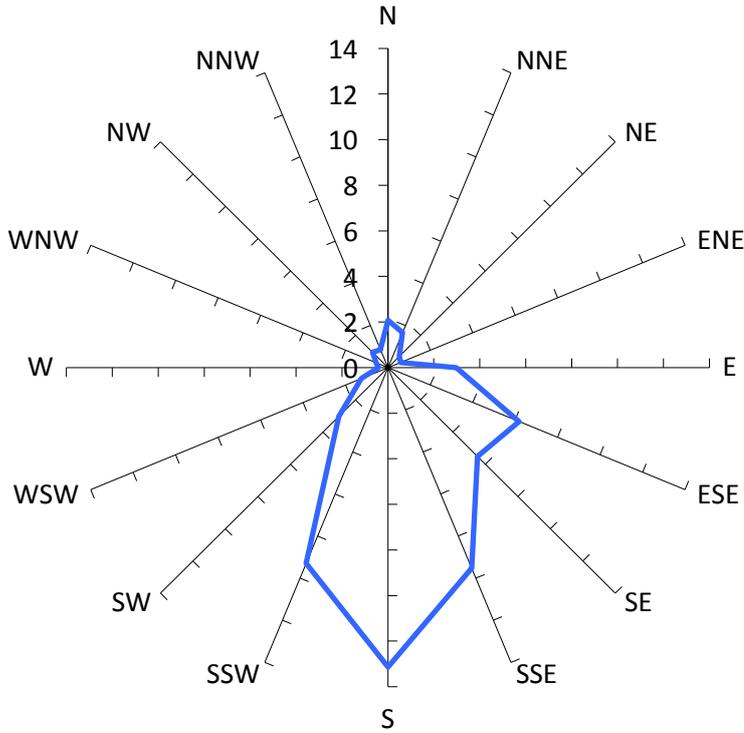


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 31

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

7.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

N/A

**Probability of Criterion Exceedence (initial test)**

12%

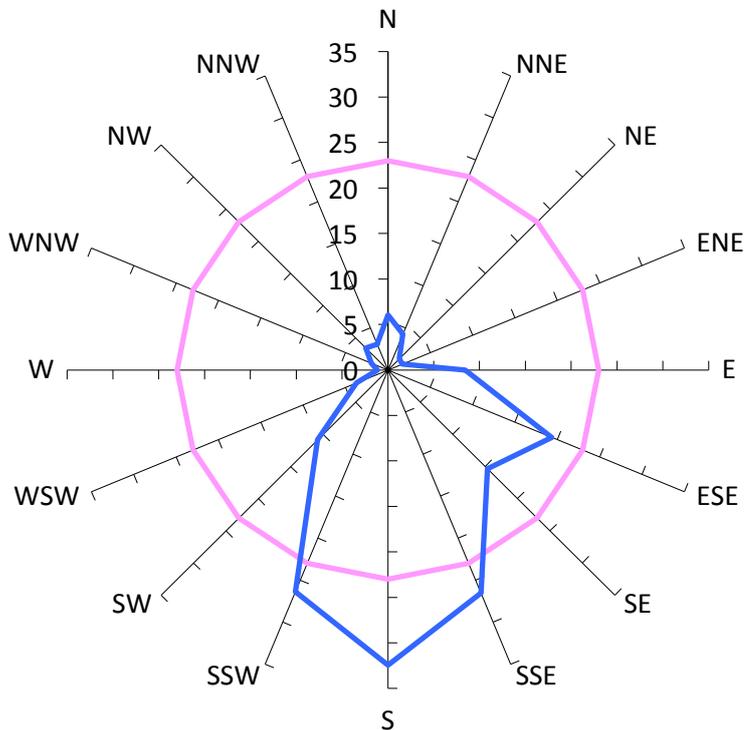
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
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**Annual Maximum Gust (m/s)**

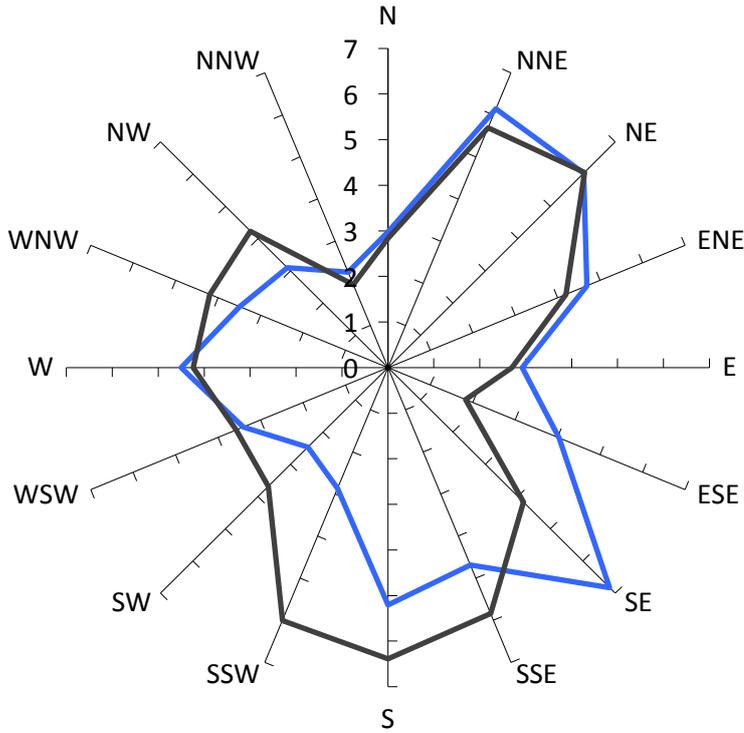


**Desired Criterion**

23m/s

## Measured Wind Speeds at Point 101

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

12%

**Probability of Criterion Exceedence (initial test)**

9%

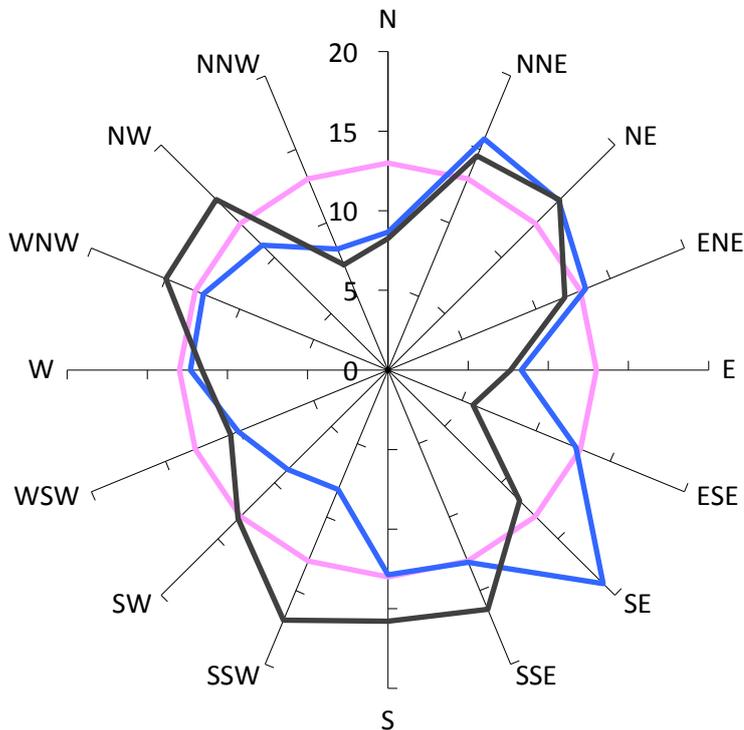
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
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**Annual Maximum Gust (m/s)**

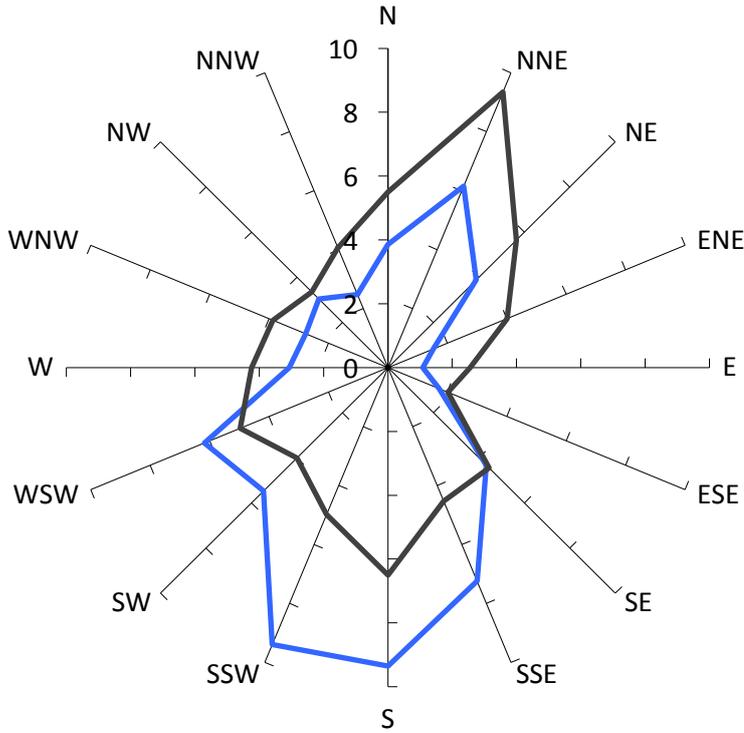


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 102

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

13%

**Probability of Criterion Exceedence (initial test)**

16%

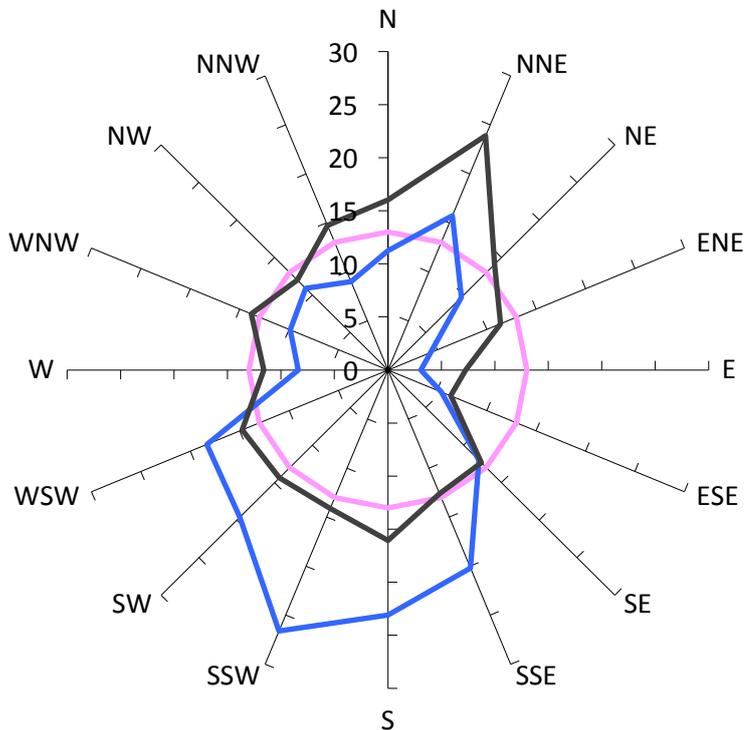
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
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**Annual Maximum Gust (m/s)**

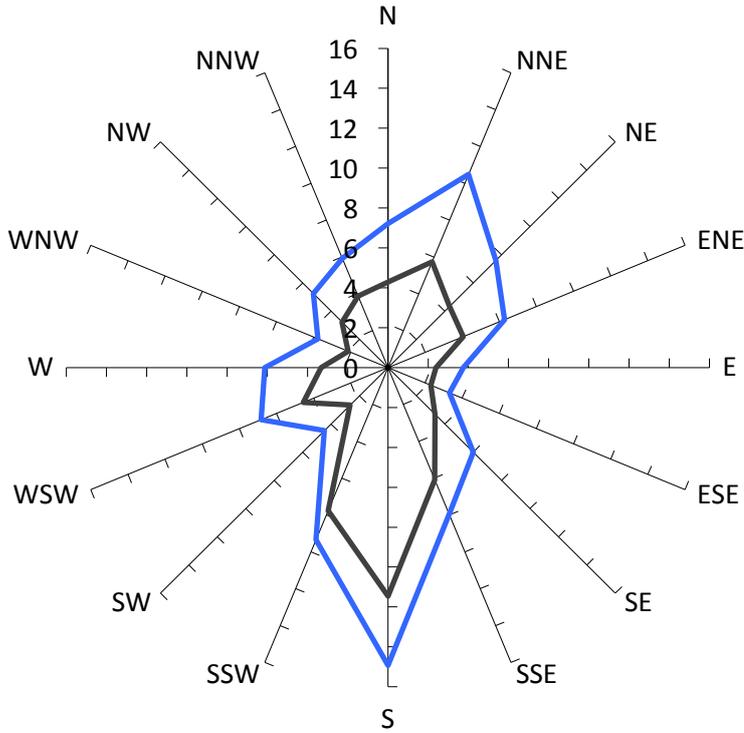


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 103

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

14%

**Probability of Criterion Exceedence (initial test)**

28%

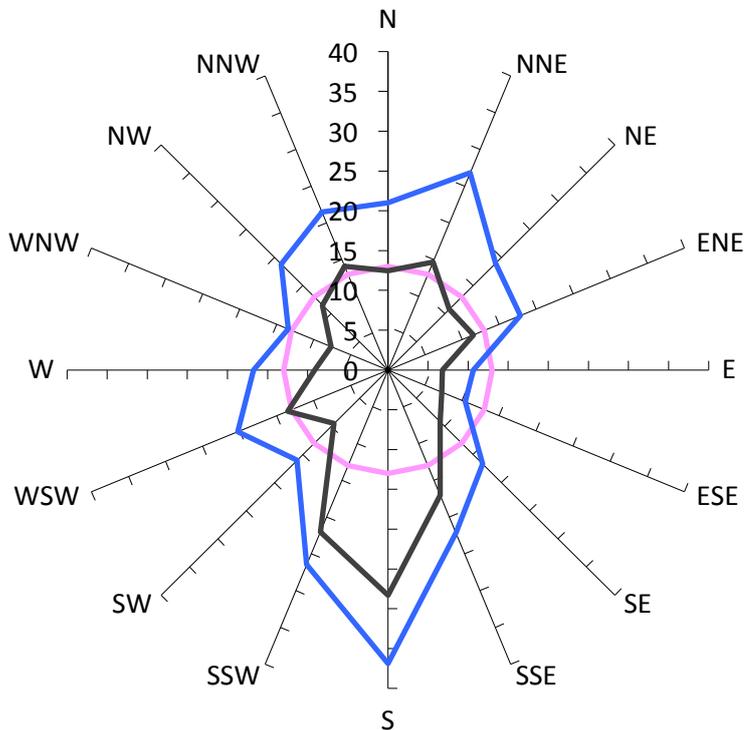
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- 
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**Annual Maximum Gust (m/s)**

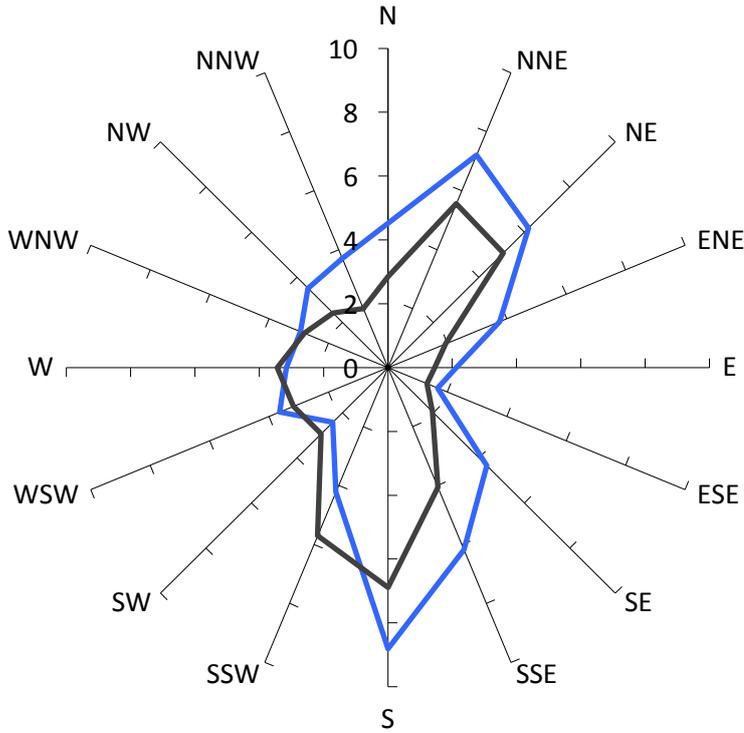


**Desired Criterion**

13m/s

## Measured Wind Speeds at Point 104

**Weekly Maximum GEM (m/s)**



**Desired Criterion**

5.5m/s

**Prob. of Criterion Exceedence (existing site conditions)**

8%

**Probability of Criterion Exceedence (initial test)**

14%

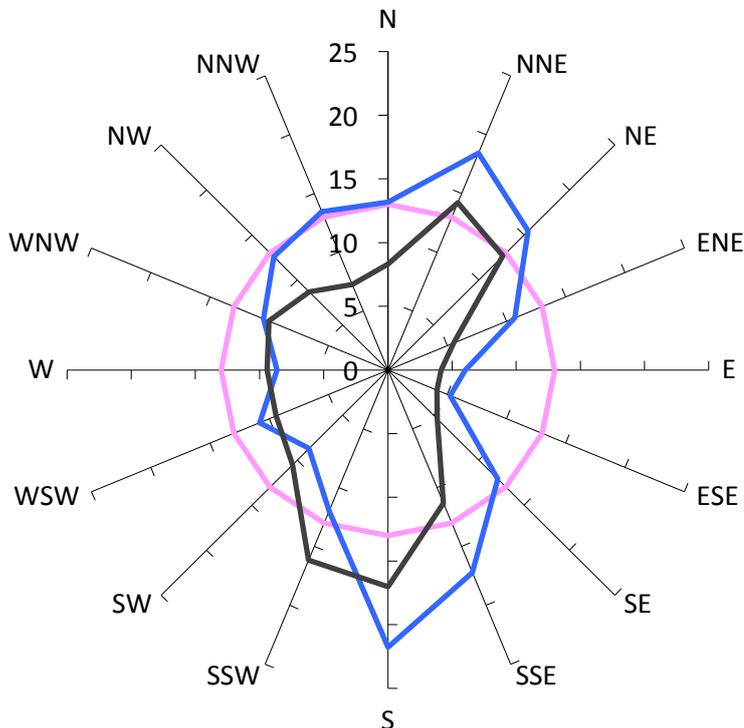
**Probability of Criterion Exceedence (final retest)**

N/A

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

- Criterion.
- With development "as proposed", no vegetation or other treatments, modified study model
- Existing Site
- 
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**Annual Maximum Gust (m/s)**



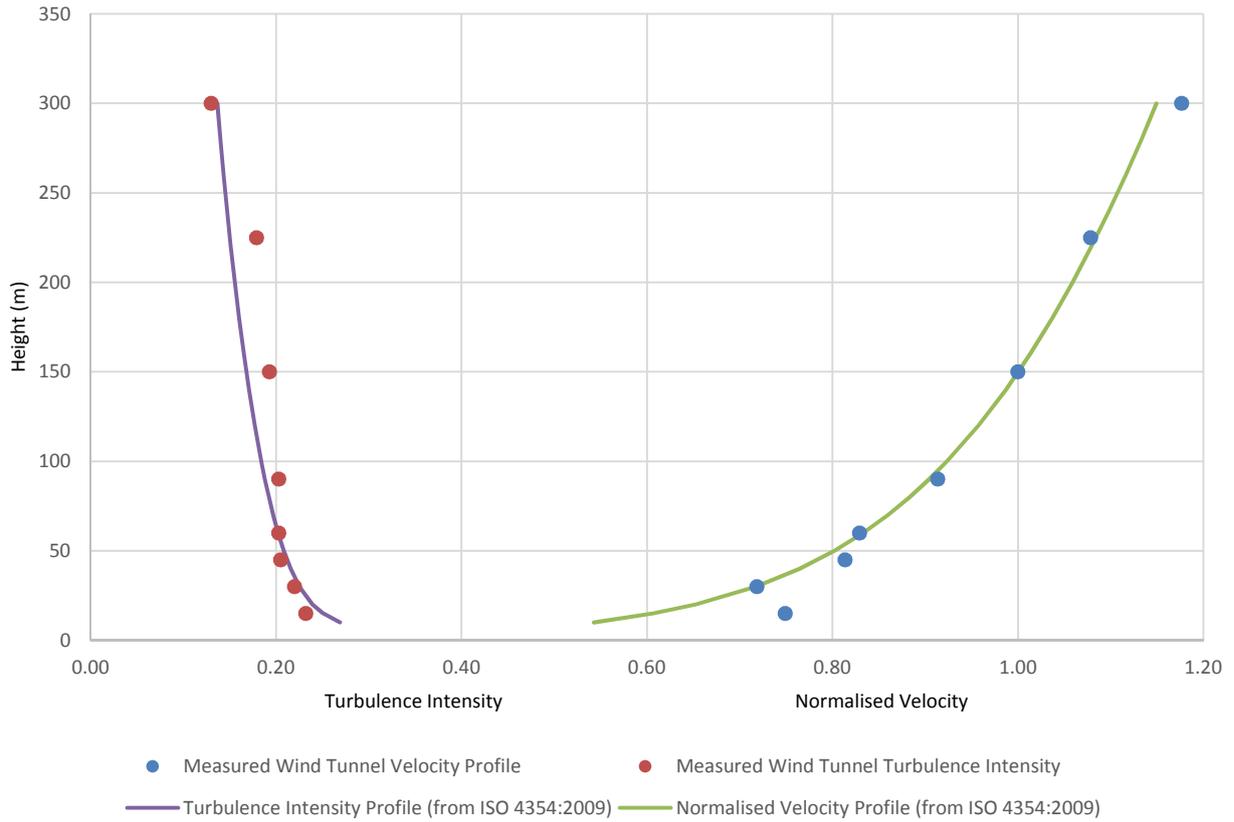
**Desired Criterion**

13m/s

## APPENDIX B - VELOCITY AND TURBULENCE INTENSITY PROFILES

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**Mean Velocity and Turbulence Intensity for Suburban Terrain (TC3) at a 1:300 Scale**



**Longitudinal Spectra Density for Suburban Terrain (TC3) at a 1:300 Scale**

