Attachment A8

Pedestrian wind environment study

WINDTECH

PEDESTRIAN WIND ENVIRONMENT STUDY

150 DAY STREET, SYDNEY

WJ067-04F02(REV1)- WE REPORT

MARCH 21, 2025

Prepared for:

Success Venture (Darling Harbour) Unit Trust

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DOCUMENT CONTROL

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EXECUTIVE SUMMARY

This report presents the results of a detailed investigation into the wind environment impact of the 150 Day Street development, located in Sydney. Testing was performed at Windtech's boundary layer wind tunnel facility. The wind tunnel has a 3.0m wide working section and a fetch length of 14m, and measurements were taken from 16 wind directions at 22.5-degree increments. Testing was carried out using a 1:300 detailed scale model of the development, which was fabricated based on the 3D massing model received on December 19, 2024. Additional modifications were made to the massing model, following design meetings with architects Hassell Studio. These modifications are detailed in the body of the report. The effects of nearby buildings and land topography have 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. The wind speed measurements are compared with criteria for pedestrian comfort and safety, based on Gust-Equivalent Mean (GEM) and annual maximum gust winds, respectively.

The model 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, although it is noted that the western edge of the site is heavily vegetated and is expected to enhance comfort levels. The existing site conditions were also tested, for comparison. In-principle treatments have been recommended for any area exposed to strong winds.

The results of the study indicate that wind conditions for all trafficable outdoor locations within and around the development will either satisfy the safety limit/relevant comfort criterion or will be equivalent to/better than the existing site conditions. Hence, it is expected that wind conditions for all outdoor trafficable areas within and around the development will be suitable for their intended uses.

CONTENTS

1 INTRODUCTION

1.1 Planning Proposal Summary

The planning proposal for the existing Park Royal Hotel at 150 Day Street, Sydney (**the site**), involves an ambitious upgrade and expansion of the existing hotel. This project aims to enhance the existing hotel offering while introducing a new, distinct hotel experience above the current structure, enabling the coexistence of the existing Park Royal and a new Pan Pacific Hotel on the same site. Strategically positioned at the edge of the City of Sydney, the development reinforces the city's entry into Darling Harbour by maintaining and emphasising the city wall characteristic of this prominent location.

The project is defined by 3 key principles – maximising adaptive reuse (setting a benchmark for future developments in Sydney), energising the Sydney visitor economy, and significantly enhancing the greening of both the public realm and the skyline, in alignment with the City of Sydney's sustainability goals. Achieving this vision involves expanding the existing core to support the new hotel above, employing a 'strip to structure' approach from ground to Level 02 to facilitate amenity upgrades, lightly refurbishing existing hotel rooms, and comprehensively upgrading all building services. This initiative aims to establish a contemporary hotel destination while setting a new standard for sustainable urban redevelopment.

To achieve the intended outcomes, this planning proposal seeks to amend the *Sydney Local Environmental Plan 2012* (the **LEP**) by inserting a new site-specific clause for the subject site under Part 6 Division 5 Site specific provisions to:

- allow a maximum building height of 85 metres,
- permit a maximum floor space ratio of 13.5:1 for hotel and associated land uses,
- restrict use to employment/hotel use and not residential accommodation or serviced apartments.

The Planning Proposal is supported by a site-specific Development Control Plan (**DCP**) and reference design scheme, prepared by Hassell. Key elements of the site specific DCP and reference design include:

- Renovation of existing 2 level basement and existing 11 storey hotel, with the addition of a new 11 storey hotel above (including a transfer floor between the two structures), and a rooftop plant floor resulting:
    - Two hotel brand offerings – Park Royal Hotel (3.5 star) and Pan Pacific Hotel (5 star)
    - 490-540 hotel keys with gross floor area of ~30,000m2
    - Upgrade existing infrastructure and services (including new lift core),
    - New and upgraded hotel facilities (including lobby, dining areas, meeting rooms, ball room, gymnasium, bar and restaurants, and pool).
    - Removal existing Porte Cochere and exit ramp resulting in single vehicle entry/exit ramp from Day Street to be used by valet only.

- Ground floor public domain, public art and landscaping design, and
- Significant greening and landscaping of western façade.

1.2 Wind Tunnel Test

A wind tunnel study has been undertaken to assess wind speeds at selected critical outdoor trafficable areas within and around the subject development. The test procedures followed for this wind tunnel study were based on the guidelines set out in the Australasian Wind Engineering Society Quality Assurance Manual (AWES-QAM-1-2019), ASCE 7-16 (Chapter C31), and CTBUH (2013).

A scale model of the development was prepared, including the surrounding buildings and land topography. Testing was performed at Windtech's boundary layer wind tunnel facility. The wind tunnel has a 3.0m wide working section and a fetch length of 14m, and measurements were taken from 16 wind directions at 22.5 degree increments. The wind tunnel was configured to the appropriate boundary layer wind profile for each wind direction. Wind speeds were measured using either Dantec hot-wire probe anemometers or pressure-based wind speed sensors, positioned to monitor wind conditions at critical outdoor trafficable areas of the development.

The model 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, although it is noted that the western edge of the site is heavily vegetated and is expected to enhance comfort levels. The wind speeds measured during testing were combined with a statistical model of the regional wind climate to provide the equivalent full-scale wind speeds at the site. The measured wind speeds were compared against appropriate criteria for pedestrian comfort and safety, and in-principle treatments in form of massing variations have been recommended for any area which was exposed to strong winds. These treatments could be in the form of retaining vegetation that is already proposed for the site, or including additional vegetation, screens, awnings, etc. Note however that, in accordance with the AWES Guidelines (2014), only architectural elements or modifications are used to treat winds which represent an exceedance of the existing wind conditions and exceed the safety limit.

2 WIND TUNNEL MODEL

Wind tunnel testing was carried out using a 1:300 scale model of the development and surroundings. The study model incorporates all necessary architectural features on the façade of the development to ensure an accurate wind flow is achieved around the model and was constructed using a Computer Aided Manufacturing (CAM) process to ensure that a high level of detail and accuracy is achieved. The study model was fabricated based on the 3D massing model received on December 19, 2024. Additional modifications were made to the massing model, following design meetings with architects Hassell Studio - These are summarised below (also refer to Figures 3):

- Inclusion of an 8m chamfer along the Ground Level southern aspect of the development.
- Inclusion of void space along the northern and southern aspect, across Levels 11 and 12.
- The Level 18 & 21 building cut-ins have been removed. These levels are now in line with the standard floor plans either above or below.

The effect of nearby buildings and land topography has been accounted for through the use of a proximity model, which represents a radius of 375m from the development site.

Photographs of the wind tunnel model are presented in Figures 1. Planview images of the various proximity model configurations are provided in Figures 2.

Figure 1a: Photograph of the Wind Tunnel Model (Proposed Scenario, view from the north-west)

Figure 1b: Photograph of the Wind Tunnel Model (Proposed Scenario, view from the south)

Figure 1c: Photograph of the Wind Tunnel Model (Proposed Scenario, view from the east)

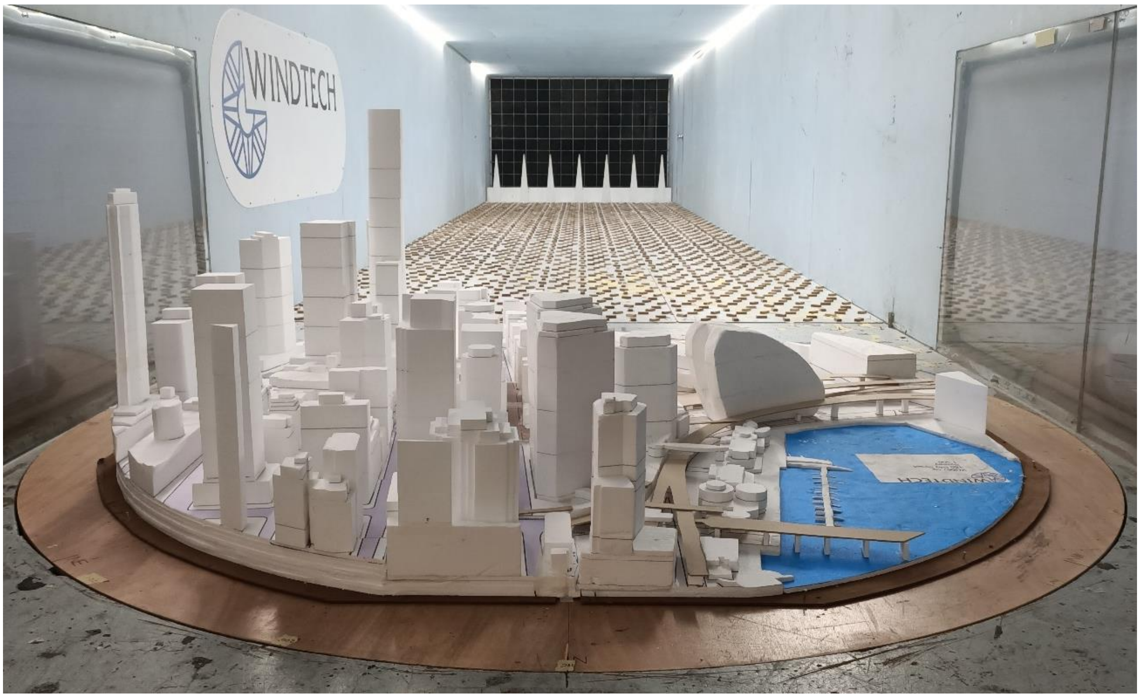

Figure 1d: Photograph of the Wind Tunnel Model (Proposed Scenario, view from the north)

Figure 1e: Photograph of the Wind Tunnel Model (Proposed Scenario, view from the south-west)

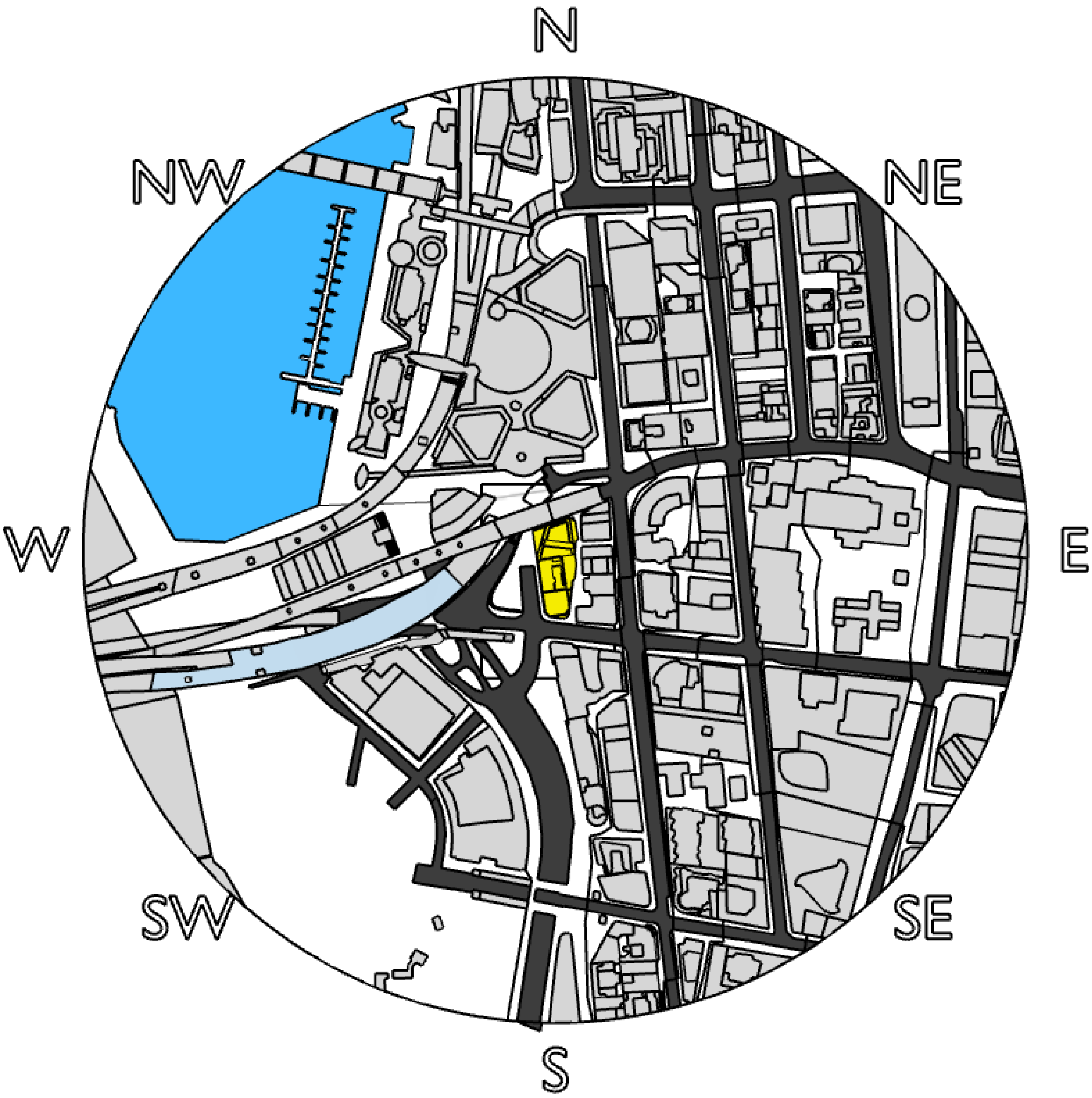

Figure 2a: Proximity Model Plan (Proposed Scenario)

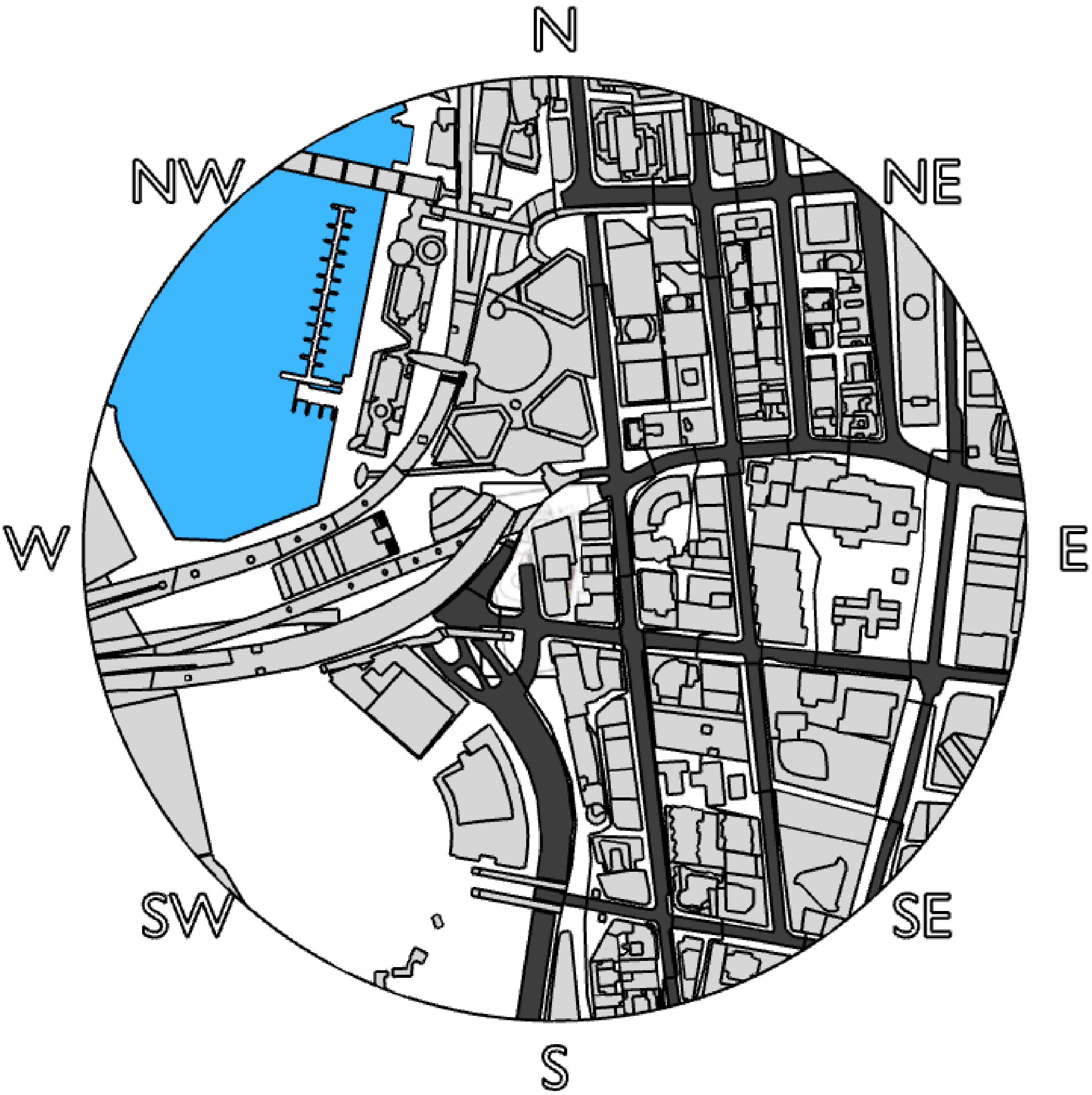

Figure 2b: Proximity Model Plan (Existing Site)

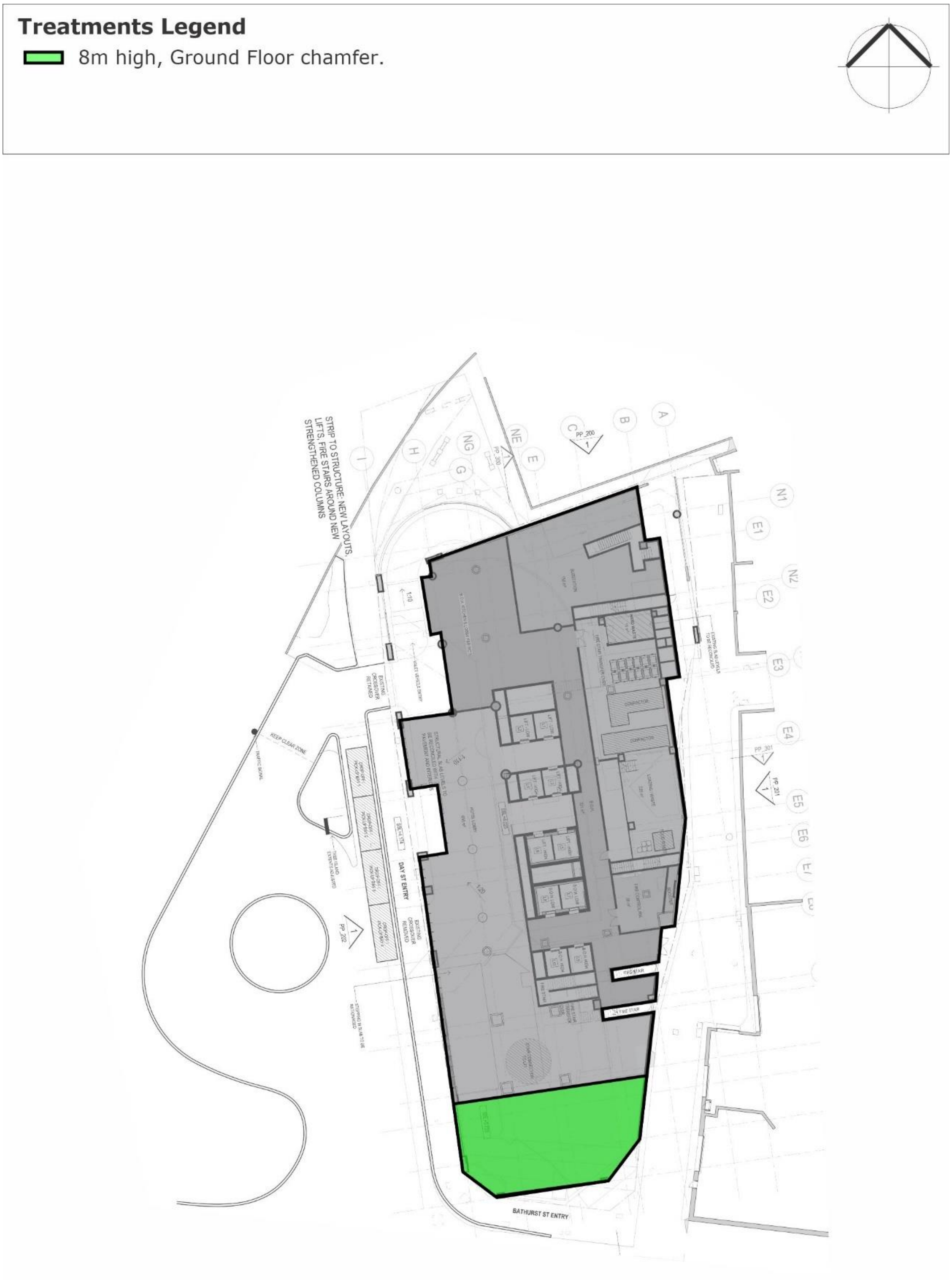

Figure 3a: Further Modifications made to the 3D Massing Model Provided (Ground Level Plan)

Treatments Legend

Inclusion of a void space across Level 11 and Level 12.

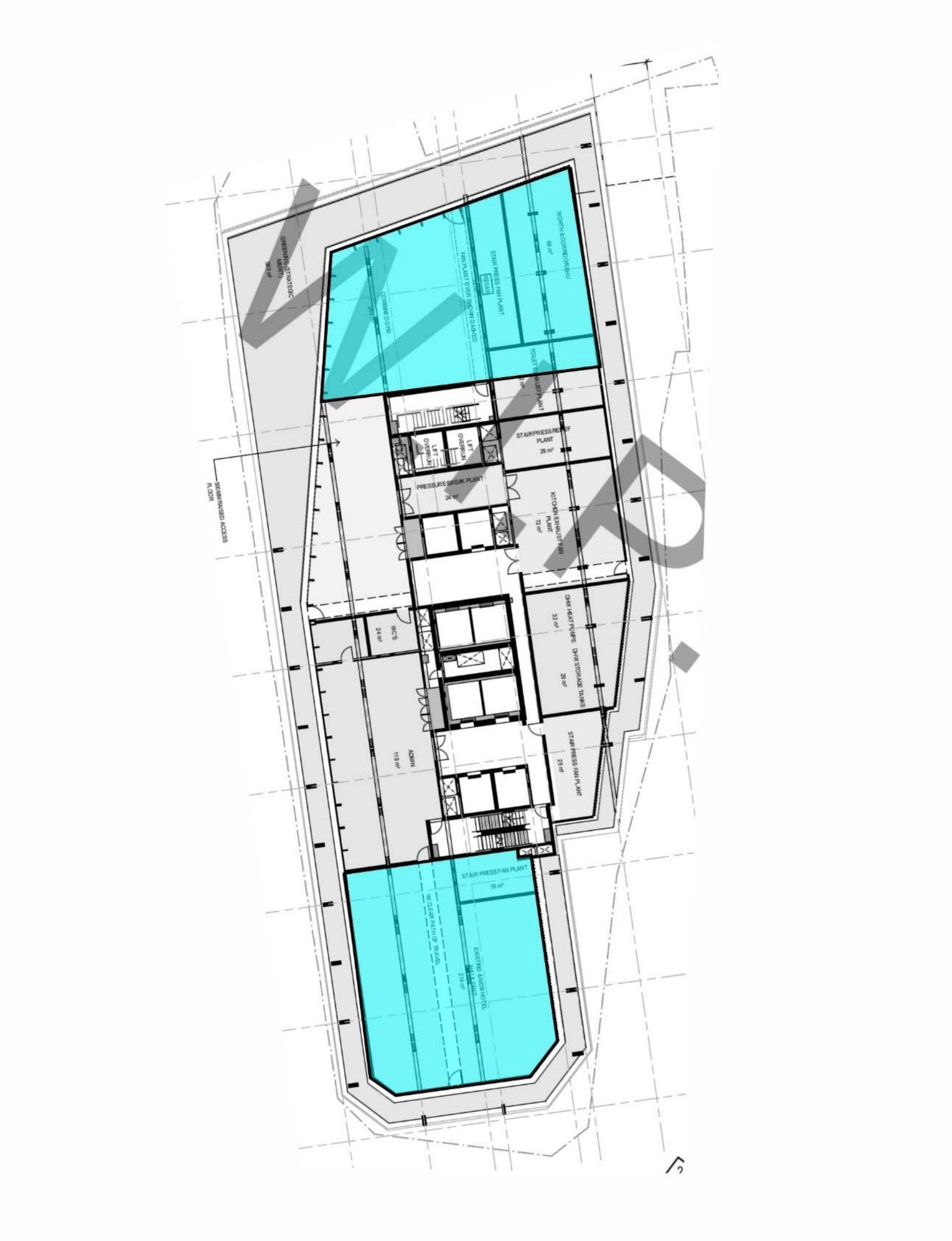

Figure 3b: Further Modifications made to the 3D Massing Model Provided (Levels 11 and 12 Plan)

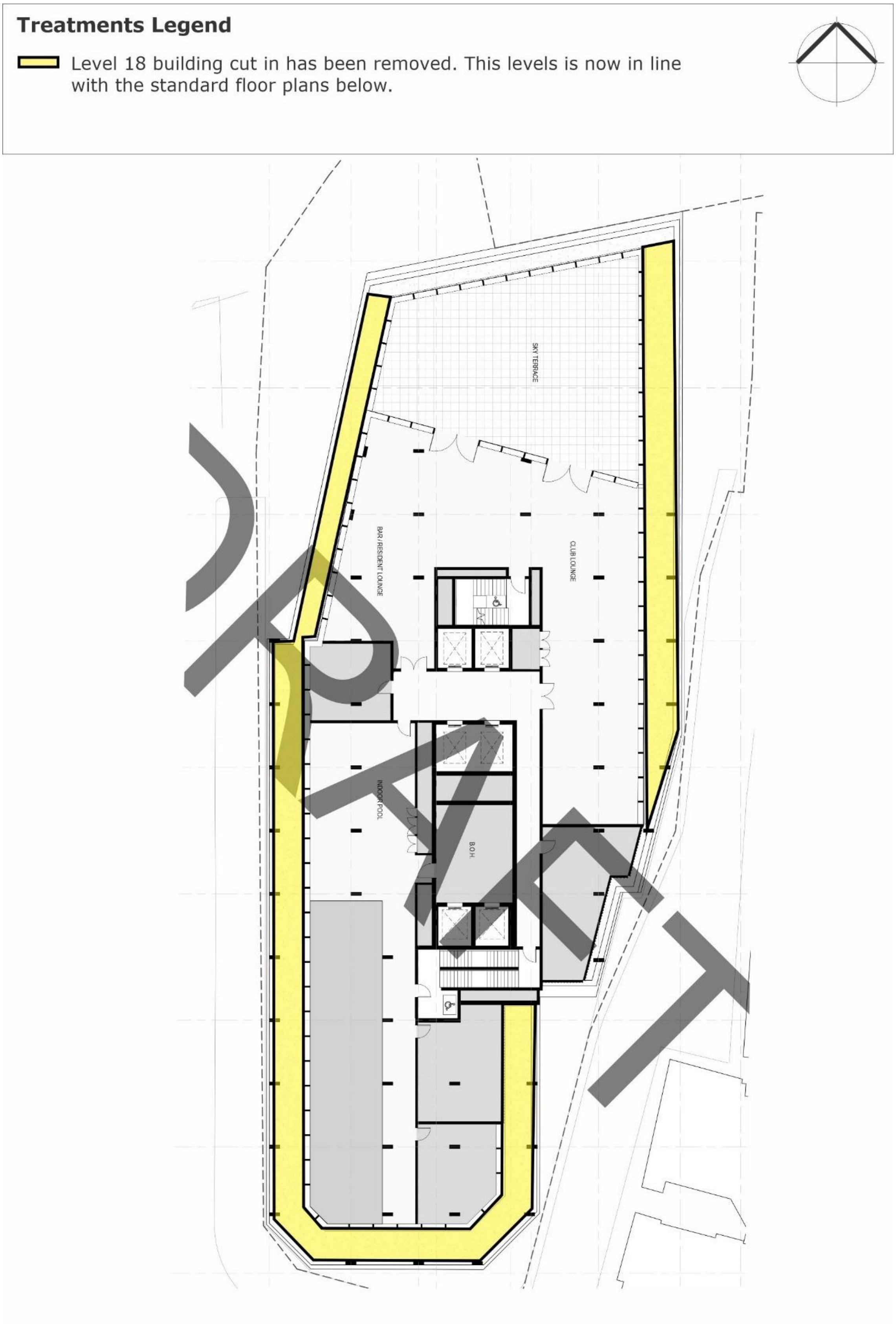

Figure 3c: Further Modifications made to the 3D Massing Model Provided (Level 18 Plan)

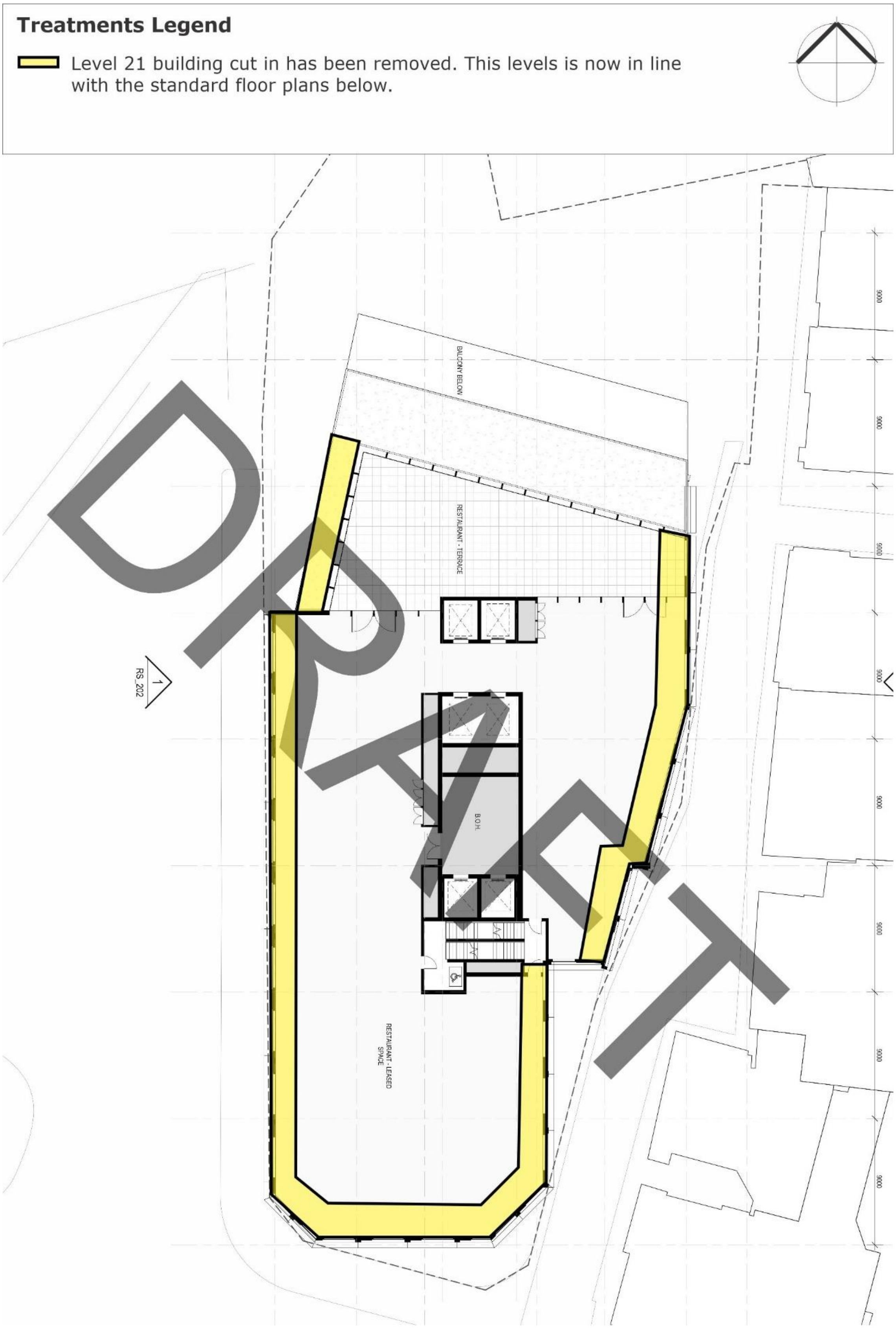

Figure 3d: Further Modifications made to the 3D Massing Model Provided (Level 21 Plan)

3 BOUNDARY LAYER WIND PROFILES AT THE SITE

The roughness of the surface of the earth has the effect of slowing down the wind near the ground. This effect is observed up to 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, etc). Within this range the prevailing wind forms a boundary layer wind profile.

Various wind codes and standards and other publications classify various types of boundary layer wind flows depending on the surface roughness z_0. Descriptions of typical boundary layer wind profiles, based on D.M. Deaves and R.I. Harris (1978), are summarised as follows:

- Flat terrain (0.002m < z_0 < 0.003m). Examples include inland water bodies such as lakes, dams, rivers, etc, and the open ocean.
- Semi-open terrain (0.006m < z_0 < 0.01m). Examples include flat deserts and plains.
- Open terrain (0.02m < z_0 < 0.03m). Examples include grassy fields, semi-flat plains, and open farmland (without buildings or trees).
- Semi-suburban/semi-forest terrain (0.06m < z_0 < 0.1m). Examples include farmland with scattered trees and buildings and very low-density suburban areas.
- Suburban/forest terrain (0.2m < z_0 < 0.3m). Examples include suburban areas of towns and areas with dense vegetation such as forests, bushland, etc.
- Semi-urban terrain (0.6m < z_0 < 1.0m). Examples include centres of small cities, industrial parks, etc.
- Urban terrain (2.0m < z_0 < 3.0m). Examples include centres of large cities with many high-rise towers, and also areas with many closely-spaced mid-rise buildings.

The boundary layer 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 wind profile to achieve a state of equilibrium. Hence an analysis of the effect of changes in the upwind terrain roughness is necessary to determine an accurate boundary layer wind profile at the development site location.

The proximity model accounts for the effect of the near field topographic effects as well as the influence of the local built forms. To account for further afield effects, an assessment of the upwind terrain roughness has been undertaken based on the method given in AS/NZS1170.2:2021, using a fetch ranging from 20 to 60 times the study reference height (as per the recommendation by AS/NZS1170.2:2021). An aerial image showing the surrounding terrain is presented in Figure 4 for a range of 2.5km from the edge of the proximity model used for the wind tunnel study. The resulting mean and gust terrain and height multipliers at the site location are presented in Table 1, referenced to the study reference height (which is approximately half the height of the subject development since typically we are most interested in the wind effects at the ground plane). Details of the boundary layer wind profiles at the site are combined with the regional wind model (see Section 4) to determine the site wind speeds.

Table 1: Approaching Boundary Layer Wind Profile Analysis Summary (at the study reference height)

Wind Sector (degrees)	Terrain and Height Multiplier			Turbulence Intensity	Equivalent Terrain Category (AS/NZS1170.2:2021 naming convention)
	$k_{tr,T=1hr}$ (hourly)	$k_{tr,T=10min}$ (10min)	$k_{tr,T=3s}$ (3sec)	I_v	
0	0.81	0.85	1.19	0.154	2.1
30	0.81	0.85	1.19	0.154	2.1
60	0.79	0.83	1.17	0.161	2.2
90	0.71	0.74	1.12	0.195	2.7
120	0.66	0.70	1.09	0.215	3.0
150	0.67	0.71	1.09	0.210	3.0
180	0.68	0.72	1.10	0.207	2.9
210	0.64	0.68	1.07	0.226	3.1
240	0.66	0.70	1.09	0.214	3.0
270	0.74	0.77	1.14	0.182	2.6
300	0.71	0.74	1.12	0.195	2.7
330	0.84	0.88	1.21	0.143	1.8

NOTE: These terrain and height multipliers are to be applied to a basic regional wind speed averaged over 3-seconds. Divide these values by 1.10 for a basic wind speed averaged over 0.2-seconds, 0.69 for a basic wind speed averaged over 10-minutes, or 0.66 for a basic wind speed averaged over 1-hour.

For each of the 16 wind directions tested in this study, the approaching boundary layer wind profiles modelled in the wind tunnel closely matched the profiles listed in Table 1. Plots of the boundary layer wind profiles used for the wind tunnel testing are presented in Appendix E of this report.

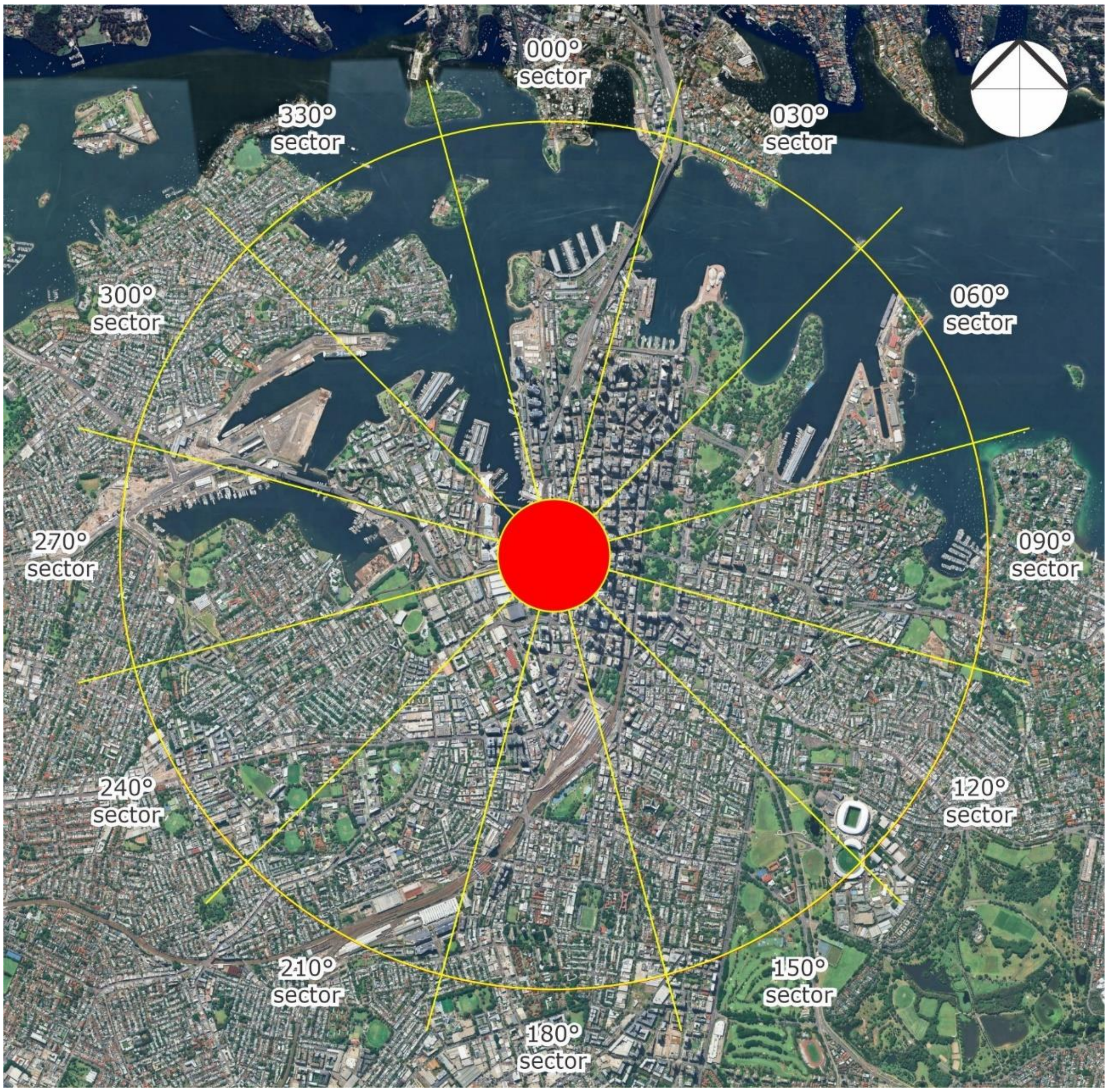

Figure 4: Aerial Image of the Surrounding Terrain (distance of 2.5km from the edge of the proximity model)

4 REGIONAL WIND MODEL

The regional wind model used in this study was determined from an analysis of measured directional mean wind speeds obtained at the meteorological recording station located at Kingsford Smith Airport (Sydney Airport). Data was collected from 1995 to 2016 and corrected so that it represents winds over standard open terrain at a height of 10m above ground for each wind direction. From this analysis, directional probabilities of exceedance and directional wind speeds for the region are determined. The directional wind speeds are summarised in Table 2. The directional wind speeds and corresponding directional frequencies of occurrence are presented in Figure 5.

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.

The recurrence intervals examined in this study are for exceedances of 5% (per 90 degree sector) of the pedestrian comfort criteria using Gust-Equivalent Mean (GEM) wind speeds, and annual maximum wind speeds (per 22.5 degree sector) for the pedestrian safety criterion. Note that the 5% probability wind speeds presented in Table 2 are only used for the directional plot presented in Figure 5 and are not used for the integration of the probabilities.

Table 2: Regional Directional Wind Speeds (hourly means, at 10m height in standard open terrain) (m/s)

Wind Direction	5% Exceedance	Annual Maximum
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

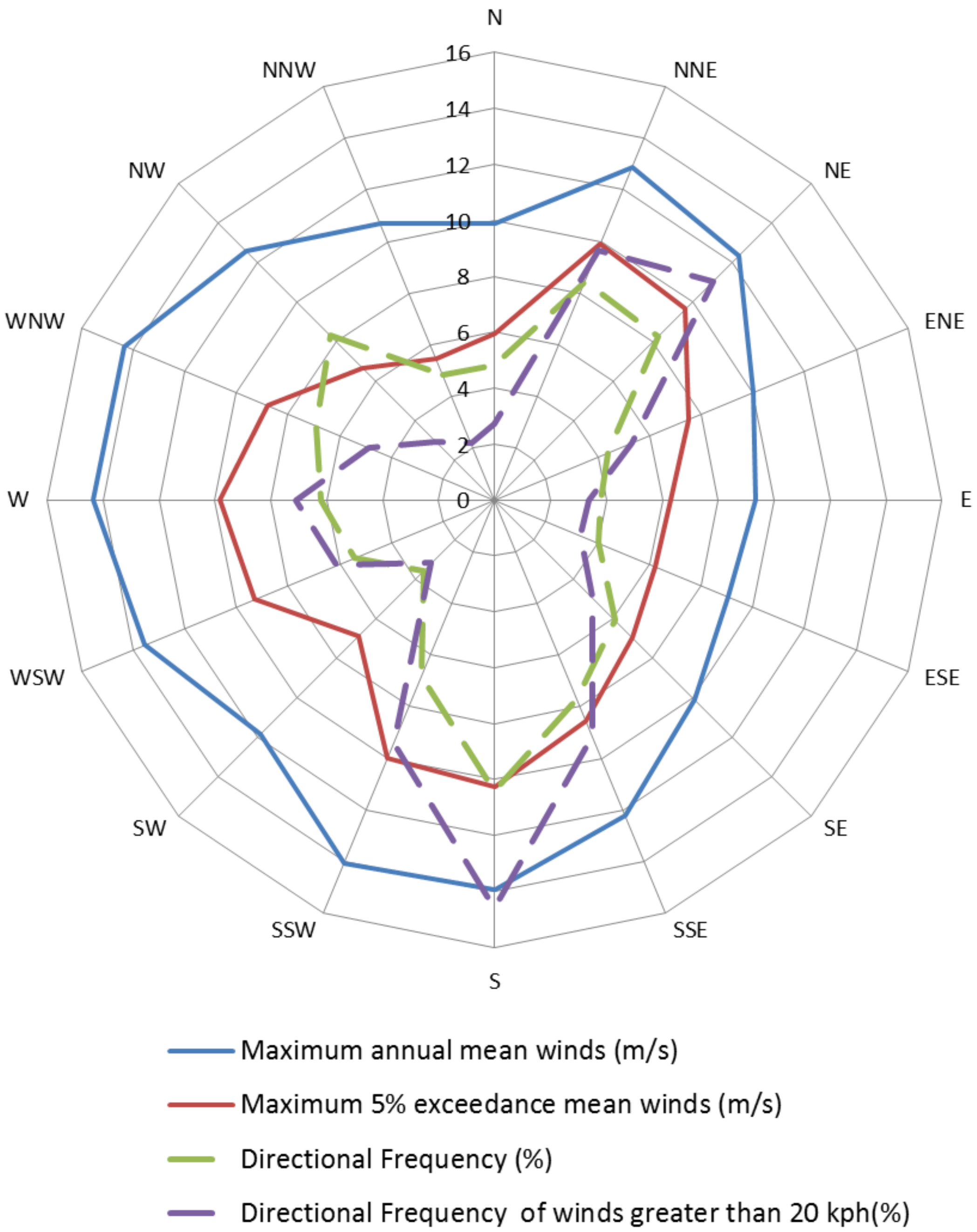

Figure 5: Annual and 5% Exceedance Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Sydney Region (at 10m height in standard open terrain)

5 PEDESTRIAN WIND COMFORT AND SAFETY

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

5.1 Measured Wind Speeds

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

Measurements were acquired for 16 wind directions at 22.5 degree increments using a sample rate of 1,024Hz. The full methodology of determining the wind speed measurements at the site from either the Dantec Hot-wire probe anemometers or pressure-based wind speed sensors is provided in Appendix B. Based on the results of the analysis of the boundary layer wind profiles at the site (see Section 3), and incorporating the regional wind model (see Section 4), the data sampling length of the wind tunnel test for each wind direction corresponds to a full-scale sample length ranging between 30 minutes and 1 hour. Research by A.W. Rofail and K.C.S. Kwok (1991) has shown that, in addition to the mean and standard deviation of the wind being stable for sample lengths of 15 minutes or more (full-scale), the peak value determined using the upcrossing method is stable for sample lengths of 30 minutes or more.

5.2 Wind Speed Criteria Used for This Study

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

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

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

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

In accordance with the provisions of the Draft Sydney DCP 2012, the wind speed assessment is undertaken for winds occurring between 6am and 10pm (AEST).

A more detailed comparison of published criteria for pedestrian wind comfort and safety is provided in Appendix A.

For this study the measured wind conditions of the selected critical outdoor trafficable areas are compared against two sets of criteria; one for pedestrian safety, and one for pedestrian comfort. The safety criterion is applied to the annual maximum gust winds, and the comfort criteria is applied to Gust Equivalent Mean (GEM) winds. In accordance with ASCE (2003), the GEM wind speed is defined as follows:

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

where:

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

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

The criteria considered in this study are summarised in Tables 3 and 4 for pedestrian comfort and safety, respectively. The results of the wind tunnel study are presented in the form of directional plots attached in Appendix C of this report. For each study point there is a plot of the annual probability of exceedance of the assigned comfort criteria, and a plot for the annual maximum gust wind speeds using the safety criterion. The velocity coefficients are also presented in the form of directional plots in Appendix D

Table 3: Pedestrian Comfort Criteria (Draft Sydney DCP 2012)

Classification	Description	Maximum 5% Exceedance GEM Wind Speed (m/s)
Standing	Short duration stationary activities (generally less than 1 hour), including window shopping, waiting areas, etc.	6.0
Walking	For pedestrian thoroughfares, private swimming pools, most communal areas, private balconies and terraces, etc.	8.0

Table 4: Pedestrian Safety Criterion (Draft Sydney DCP 2012)

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

5.3 Layout of Study Points

For this study a total of 38 study point locations were selected for analysis in the wind tunnel. This includes the following:

- 16 study points close to the site, along the main entrances, pedestrian footpaths and trafficable areas.
- 22 study points further afield, outside recreational facilities, walkways and bus stops.

The locations of the various study points tested for this study, as well as the target wind speed criteria for the various outdoor trafficable areas of the development, are presented in Figures 6 in the form of marked-up plans. It should be noted that only the most critical outdoor locations of the development have been selected for analysis.

Target Criteria

City of Sydney DCP in accordance with Draft Sydney DCP 2012 - Central Sydney Planning Review Amendment:
- Wind Comfort Standard for Standing criterion of 6m/s (5% exceedance) for standing
- Safety criterion of 24m/s (gust - 0.1% exceedance) for safety

City of Sydney DCP in accordance with Draft Sydney DCP 2012 - Central Sydney Planning Review Amendment:
- Wind Comfort Standard for Walking criterion of 8m/s (5% exceedance) for walking
- Safety criterion of 24m/s (gust - 0.1% exceedance) for safety

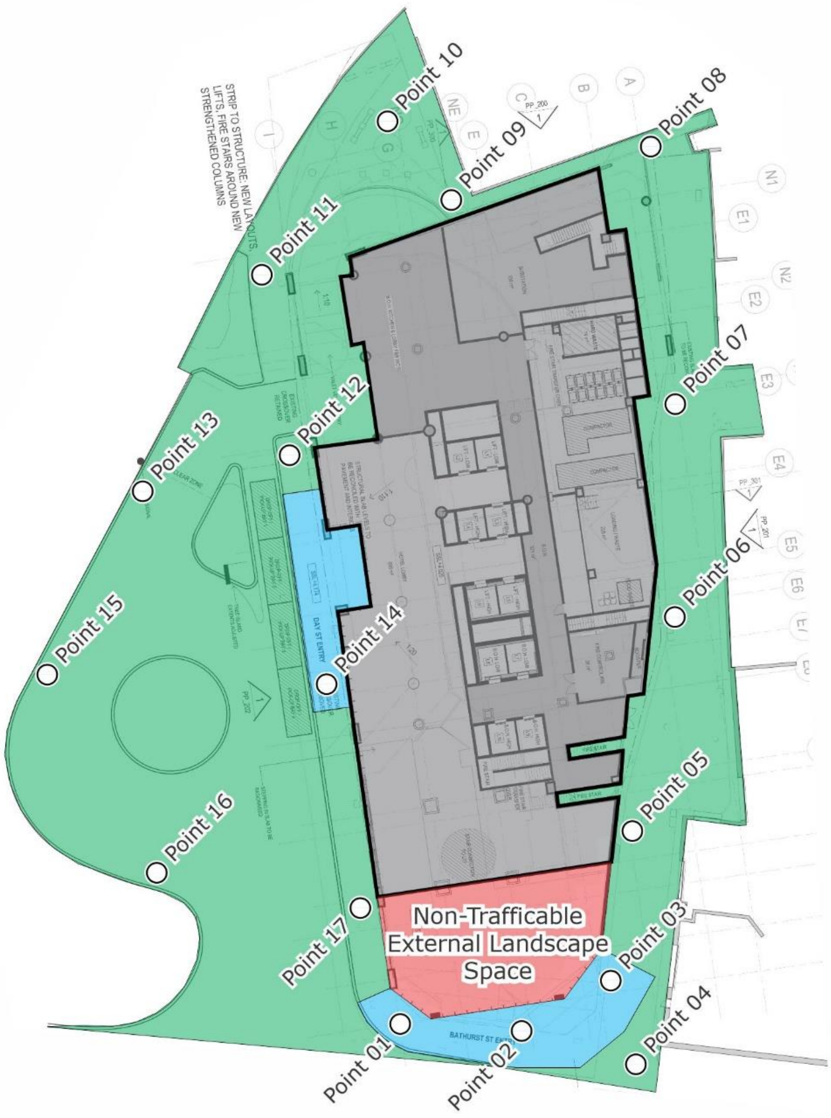

Figure 6a: Study Point Locations and Target Wind Speed Criteria – Close to Site

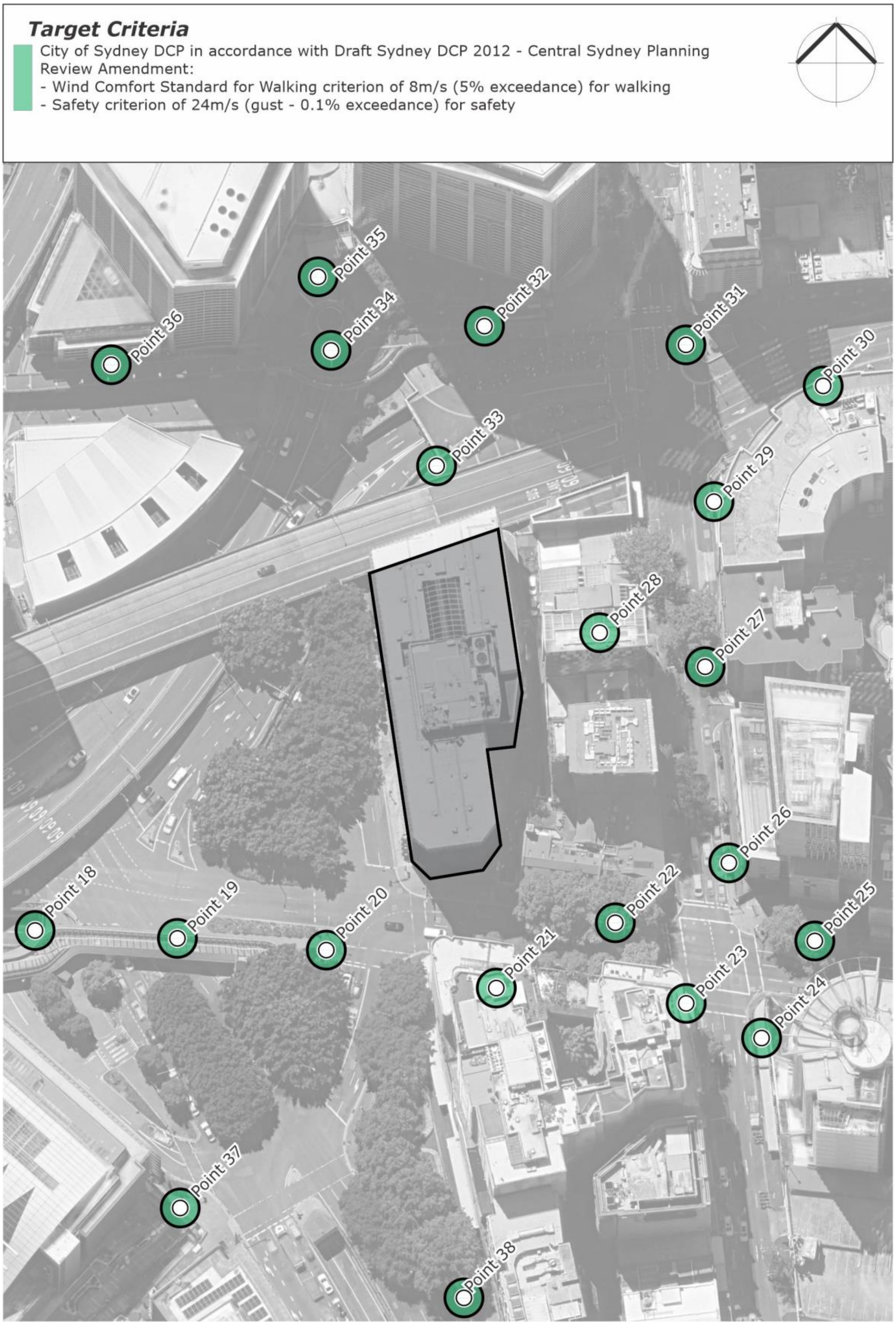

Figure 6b: Study Point Locations and Target Wind Speed Criteria – Further Afield

6 RESULTS AND DISCUSSION

The results of the wind tunnel study are presented in the form of directional plots in Appendix C for all study points locations, summarised in Table 5, and shown on marked-up plans in Figures 7. The velocity coefficients are also presented in the form of directional plots in Appendix D The wind speed criteria that the wind conditions should achieve are also listed in Table 5 for each study point location, as well as in Figures 6.

The results of the study indicate that wind conditions for all trafficable outdoor locations within and around the development will either satisfy the safety limit/relevant comfort criterion or will be equivalent to/better than the existing site conditions. It is recommended that the modifications to the massing (refer to Figures 3) be retained in the final design. Furthermore, the external space that is created by the Ground Level, southern aspect chamfer is to be made non-trafficable. It is noted that the external space is to be populated with landscape elements, which is expected to enhance pedestrian comfort locally at the Ground Level southern corner of the development.

As a general note, the use of loose glass-tops and light-weight sheets or covers (including loose BBQ lids) is not appropriate on high-rise outdoor terraces and balconies. Furthermore, lightweight furniture is not recommended unless it is securely attached to the balcony or terrace floor slab.

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 development will be suitable for their intended uses.

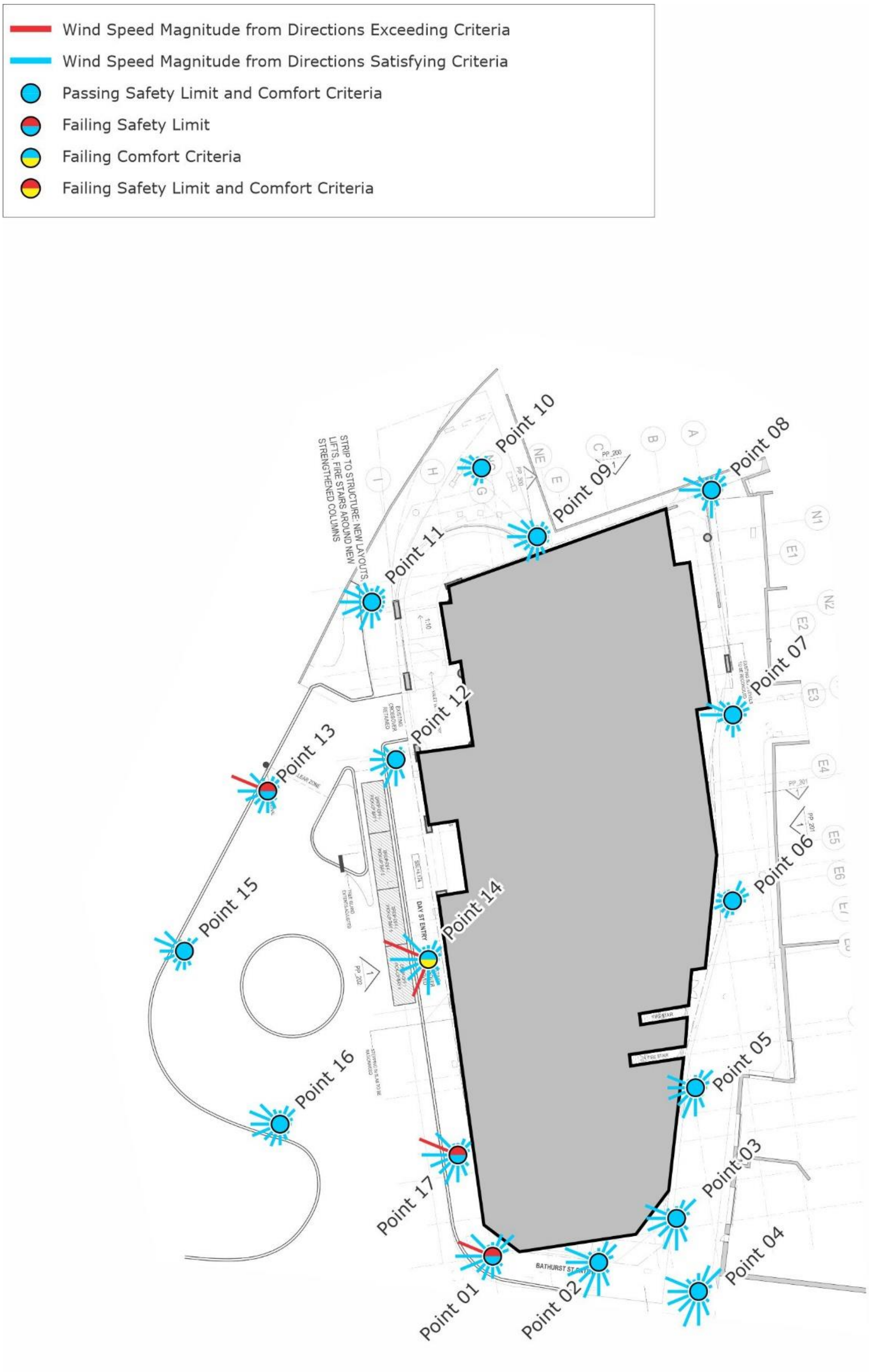

Figure 7a: Wind Tunnel Results – Close to Site
(Existing Site, results shown without treatments applied)

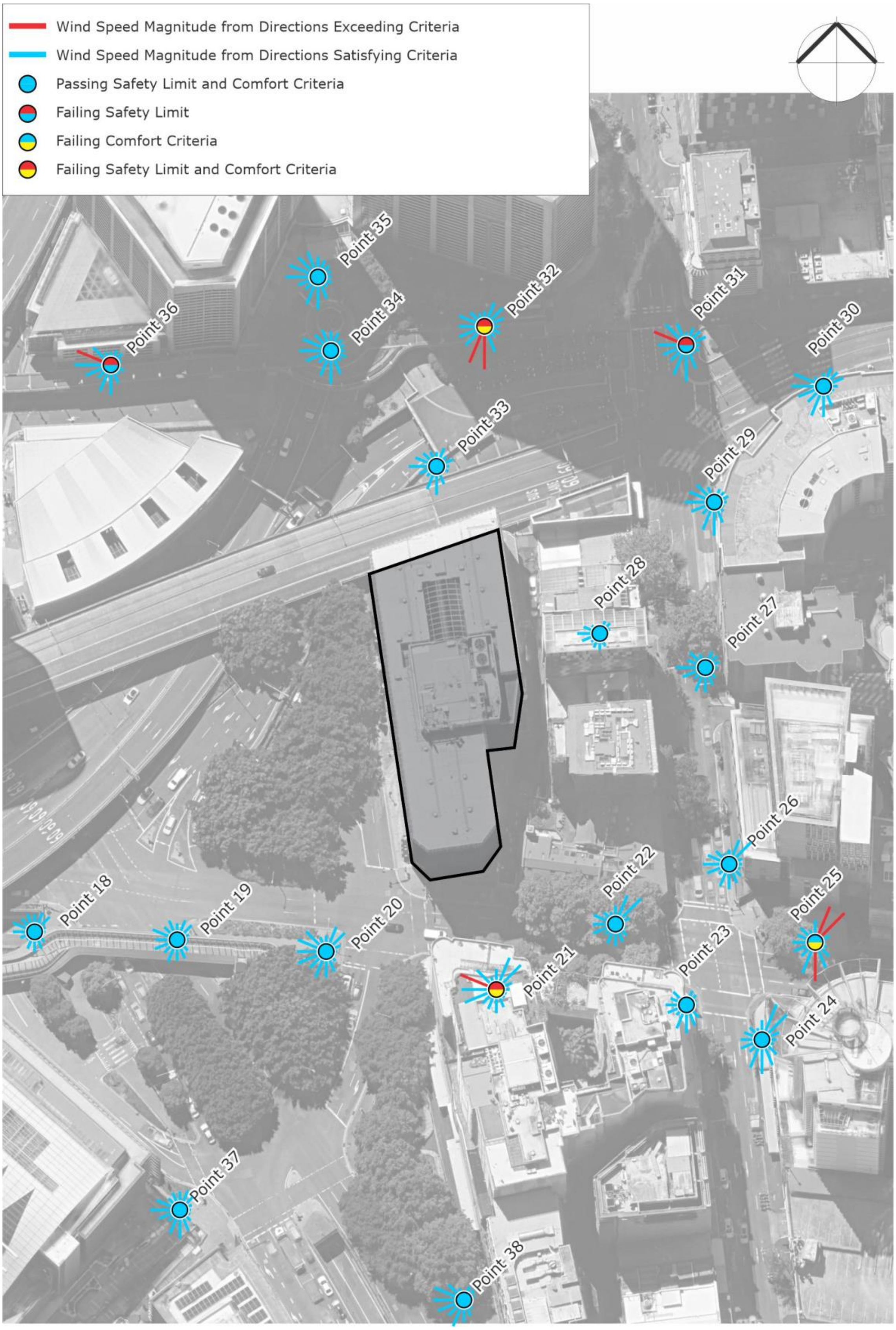

Figure 7b: Wind Tunnel Results – Further Afield
(Existing Site, results shown without treatments applied)

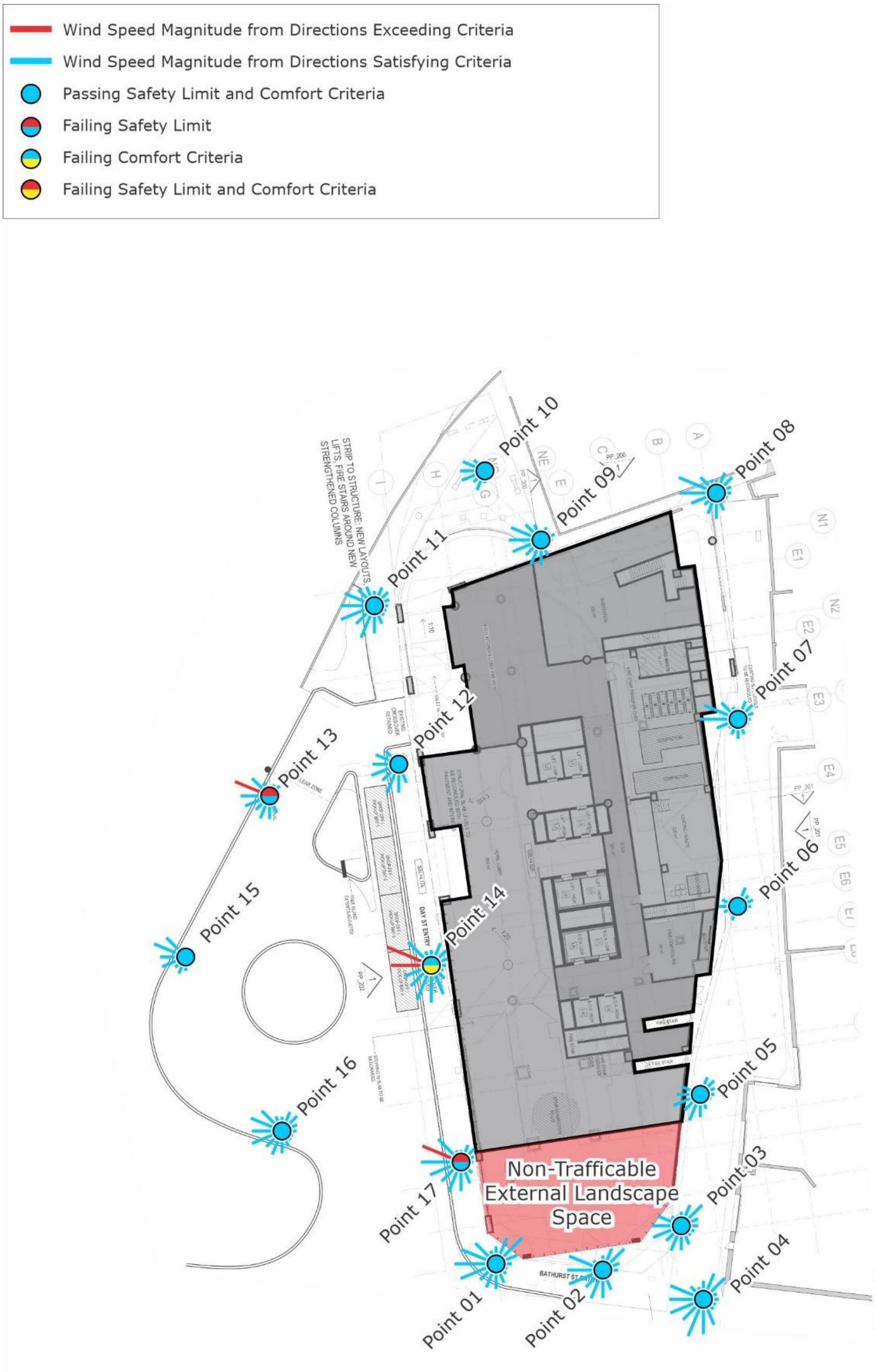

Figure 7c: Wind Tunnel Results – Close to Site
(Proposed Case, results shown without treatments applied)

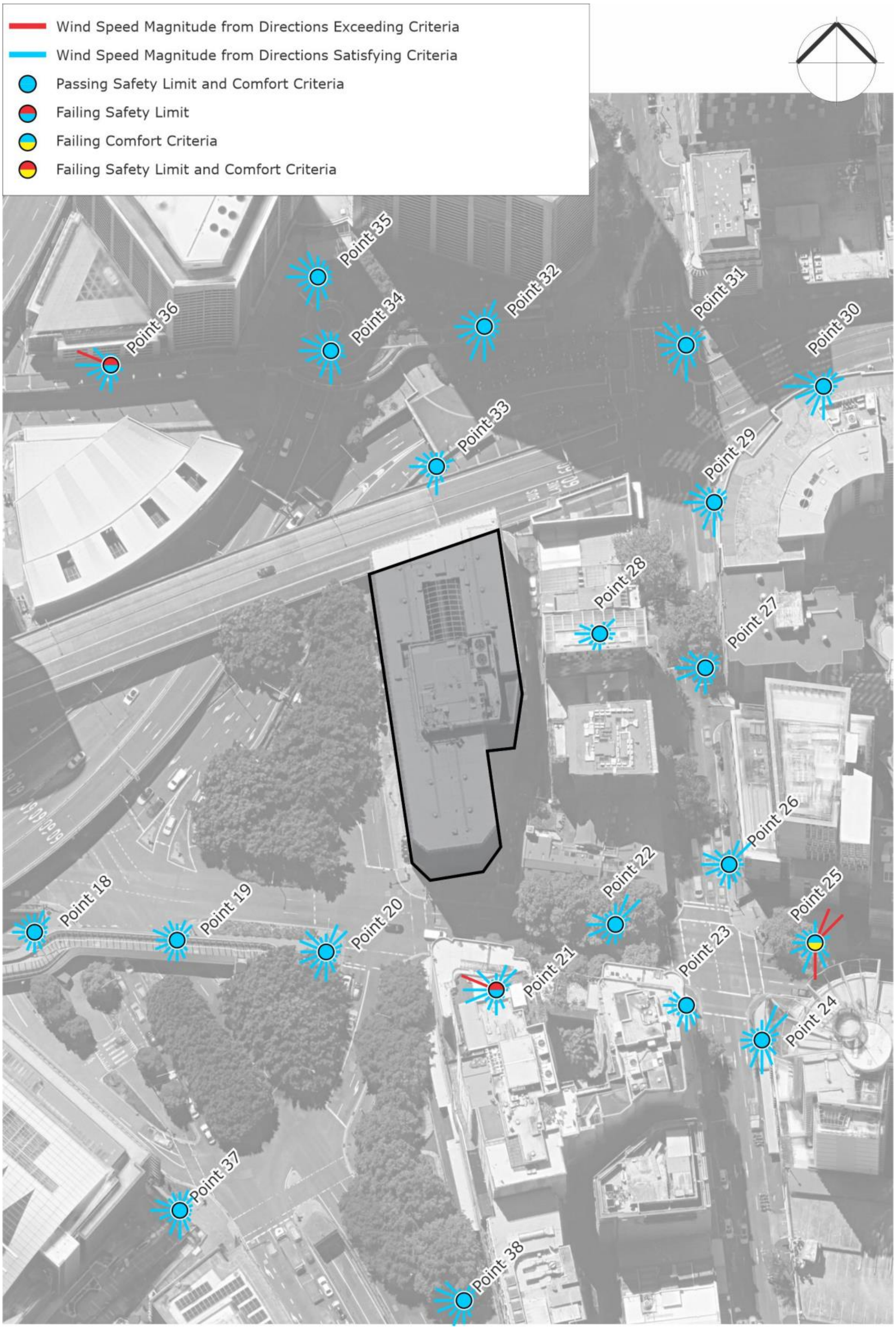

Figure 7d: Wind Tunnel Results – Further Afield
(Proposed Case, results shown without treatments applied)

Table 5: Wind Tunnel Results Summary

Study Point	GEM (5% exceedance) Criterion (m/s)	Results (%)	Results (m/s)	Grade	Annual Gust Criterion (m/s)	Results (m/s)	Grade	Final Result	Description of Treatment
Point 01	8.0	5%	7.8	Pass	24	24	Pass	Pass	
Existing		3%	7.1	Pass		25	Fail	Fail	
Point 02	8.0	3%	7.0	Pass	24	24	Pass	Pass	
Existing		3%	7.3	Pass		24	Pass	Pass	
Point 03	8.0	1%	5.9	Pass	24	18	Pass	Pass	
Existing		2%	6.7	Pass		23	Pass	Pass	
Point 04	8.0	4%	7.6	Pass	24	24	Pass	Pass	
Existing		3%	7.4	Pass		24	Pass	Pass	
Point 05	8.0	< 1%	5.3	Pass	24	17	Pass	Pass	
Existing		1%	6.3	Pass		20	Pass	Pass	
Point 06	8.0	< 1%	3.6	Pass	24	11	Pass	Pass	
Existing		< 1%	4.0	Pass		11	Pass	Pass	
Point 07	8.0	2%	6.4	Pass	24	21	Pass	Pass	
Existing		1%	5.4	Pass		20	Pass	Pass	
Point 08	8.0	2%	6.6	Pass	24	23	Pass	Pass	
Existing		1%	5.7	Pass		20	Pass	Pass	
Point 09	8.0	1%	6.1	Pass	24	21	Pass	Pass	
Existing		1%	5.8	Pass		21	Pass	Pass	
Point 10	8.0	< 1%	4.6	Pass	24	15	Pass	Pass	
Existing		< 1%	4.3	Pass		15	Pass	Pass	
Point 11	8.0	3%	7.0	Pass	24	21	Pass	Pass	
Existing		2%	6.4	Pass		20	Pass	Pass	
Point 12	8.0	1%	5.9	Pass	24	17	Pass	Pass	
Existing		1%	5.7	Pass		17	Pass	Pass	
Point 13	8.0	1%	5.9	Pass	24	25	Fail	Fail	Better than or equivalent to Existing Conditions.
Existing		2%	6.0	Pass		26	Fail	Fail	
Point 14	6.0	7%	6.2	Fail	24	24	Pass	Fail	Better than or equivalent to Existing Conditions.
Existing		7%	6.3	Fail		24	Pass	Fail	
Point 15	8.0	1%	5.4	Pass	24	22	Pass	Pass	
Existing		1%	5.3	Pass		21	Pass	Pass	
Point 16	8.0	2%	6.3	Pass	24	22	Pass	Pass	
Existing		1%	6.1	Pass		22	Pass	Pass	

Study Point	GEM (5% exceedance)				Annual Gust			Final Result	Description of Treatment
	Criterion (m/s)	Results (%)	Results (m/s)	Grade	Criterion (m/s)	Results (m/s)	Grade		
Point 17	8.0	4%	7.7	Pass	24	27	Fail	Fail	Better than or equivalent to Existing Conditions.
Existing		3%	7.3	Pass		28	Fail	Fail	
Point 18	8.0	< 1%	5.3	Pass	24	16	Pass	Pass	
Existing		< 1%	5.2	Pass		17	Pass	Pass	
Point 19	8.0	1%	5.7	Pass	24	19	Pass	Pass	
Existing		1%	5.7	Pass		19	Pass	Pass	
Point 20	8.0	3%	7.2	Pass	24	24	Pass	Pass	
Existing		3%	7.1	Pass		24	Pass	Pass	
Point 21	8.0	4%	7.5	Pass	24	28	Fail	Fail	Better than or equivalent to Existing Conditions.
Existing		6%	8.1	Fail		29	Fail	Fail	
Point 22	8.0	3%	7.2	Pass	24	19	Pass	Pass	
Existing		2%	7.0	Pass		18	Pass	Pass	
Point 23	8.0	< 1%	5.5	Pass	24	16	Pass	Pass	
Existing		< 1%	5.7	Pass		17	Pass	Pass	
Point 24	8.0	5%	7.8	Pass	24	19	Pass	Pass	
Existing		5%	7.8	Pass		19	Pass	Pass	
Point 25	8.0	7%	8.3	Fail	24	20	Pass	Fail	Better than or equivalent to Existing Conditions.
Existing		9%	8.6	Fail		20	Pass	Fail	
Point 26	8.0	1%	6.5	Pass	24	21	Pass	Pass	
Existing		1%	6.4	Pass		18	Pass	Pass	
Point 27	8.0	2%	6.6	Pass	24	20	Pass	Pass	
Existing		1%	6.0	Pass		19	Pass	Pass	
Point 28	8.0	< 1%	5.0	Pass	24	17	Pass	Pass	
Existing		< 1%	4.2	Pass		15	Pass	Pass	
Point 29	8.0	3%	7.1	Pass	24	21	Pass	Pass	
Existing		2%	7.0	Pass		21	Pass	Pass	
Point 30	8.0	5%	8.0	Pass	24	23	Pass	Pass	
Existing		3%	7.1	Pass		21	Pass	Pass	
Point 31	8.0	5%	7.9	Pass	24	24	Pass	Pass	
Existing		5%	7.8	Pass		25	Fail	Fail	
Point 32	8.0	4%	7.7	Pass	24	23	Pass	Pass	
Existing		8%	8.5	Fail		27	Fail	Fail	
Point 33	8.0	1%	5.9	Pass	24	18	Pass	Pass	
Existing		1%	6.0	Pass		18	Pass	Pass	

Study Point	GEM (5% exceedance)				Annual Gust			Final Result	Description of Treatment
	Criterion (m/s)	Results (%)	Results (m/s)	Grade	Criterion (m/s)	Results (m/s)	Grade		
Point 34	8.0	3%	7.3	Pass	24	23	Pass	Pass	
Existing		3%	7.2	Pass		22	Pass	Pass	
Point 35	8.0	4%	7.5	Pass	24	22	Pass	Pass	
Existing		4%	7.5	Pass		23	Pass	Pass	
Point 36	8.0	3%	7.2	Pass	24	26	Fail	Fail	Better than or equivalent to Existing Conditions.
Existing		4%	7.5	Pass		27	Fail	Fail	
Point 37	8.0	1%	6.4	Pass	24	19	Pass	Pass	
Existing		1%	6.3	Pass		19	Pass	Pass	
Point 38	8.0	2%	6.7	Pass	24	22	Pass	Pass	
Existing		2%	6.7	Pass		23	Pass	Pass	

Note that, for any study points listed in Table 5 with two rows of results data, the second row is for the existing site conditions. The test results shown in Table 5 are without any treatments applied.

7 REFERENCES

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APPENDIX A PUBLISHED ENVIRONMENTAL CRITERIA

A.1 Wind Effects on People

The acceptability of wind in an area is dependent upon the use of the area. For example, people walking or window-shopping will tolerate higher wind speeds than those seated at an outdoor restaurant. Quantifying wind comfort has been the subject of much research and many researchers, such as A.G. Davenport, T.V. Lawson, W.H. Melbourne, and A.D. Penwarden, have published criteria for pedestrian comfort for pedestrians in outdoor spaces for various types of activities. This section discusses and compares the various published criteria.

A.2 A.D. Penwarden (1973) Criteria for Mean Wind Speeds

A.D. Penwarden (1973) developed a modified version of the Beaufort scale which describes the effects of various wind intensities on people. Table A.1 presents the modified Beaufort scale. Note that the effects listed in this table refers to wind conditions occurring frequently over the averaging time (a probability of occurrence exceeding 5%). Higher ranges of wind speeds can be tolerated for rarer events.

Table A.1: Summary of Wind Effects on People (A.D. Penwarden, 1973)

Type of Winds	Beaufort Number	Hourly Mean Wind Speed (m/s)	Effects
Calm	0	0 - 0.3	
Calm, light air	1	0.3 - 1.6	No noticeable wind
Light breeze	2	1.6 - 3.4	Wind felt on face
Gentle breeze	3	3.4 - 5.5	Hair is disturbed, clothing flaps, newspapers difficult to read
Moderate breeze	4	5.5 – 8.0	Raises dust, dry soil and loose paper, hair disarranged
Fresh breeze	5	8.0 – 10.8	Force of wind felt on body, danger of stumbling
Strong breeze	6	10.8 – 13.9	Umbrellas used with difficulty, hair blown straight, difficult to walk steadily, wind noise on ears unpleasant
Near gale	7	13.9 – 17.2	Inconvenience felt when walking
Gale	8	17.2 - 20.8	Generally impedes progress, difficulty balancing in gusts
Strong gale	9	20.8 – 24.5	People blown over

A.3 A.G. Davenport (1972) Criteria for Mean Wind Speeds

A.G. Davenport (1972) also determined a set of criteria in terms of the Beaufort scale and for various return periods. Table A.2 presents a summary of the criteria based on a probability of exceedance of 5%.

Table A.2: Criteria by A.G. Davenport (1972)

Classification	Activities	5% exceedance Mean Wind Speed (m/s)
Walking Fast	Acceptable for walking, main public accessways.	7.5 - 10.0
Strolling, Skating	Slow walking, etc.	5.5 - 7.5
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	3.5 - 5.5
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	0 - 3.5

A.4 T.V. Lawson (1975) Criteria for Mean Wind Speeds

In 1973, T.V. Lawson, while referring to the Beaufort wind speeds of A.D. Penwarden (1973) (as listed in Table A.1), quoted that a Beaufort 4 wind speed would be acceptable if it is not exceeded for more than 4% of the time, and that a Beaufort 6 wind speed would be 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 presented in A.G. Davenport (1972) (as listed in Table A.2). These criteria are presented in Table A.3 and Table A.4 for safety and comfort respectively.

Table A.3: Safety Criteria by T.V. Lawson (1975)

Classification	Activities	Annual Mean Wind Speed (m/s)
Safety (all weather areas)	Accessible by the general public.	0 – 15
Safety (fair weather areas)	Private areas, balconies/terraces, etc.	0 – 20

Table A.4: Comfort Criteria by T.V. Lawson (1975)

Classification	Activities	5% exceedance Mean Wind Speed (m/s)
Business Walking	Objective Walking from A to B.	8 - 10
Pedestrian Walking	Slow walking, etc.	6 - 8
Short Exposure Activities	Pedestrian standing or sitting for short times.	4 – 6
Long Exposure Activities	Pedestrian sitting for a long duration.	0 - 4

A.5 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 that were developed for a temperature range of 10°C to 30°C and for people suitably dressed for outdoor conditions. These criteria are presented in Table A.5, and are based on maximum gust wind speeds with a probability of exceedance of once per year.

Table A.5: Criteria by W.H. Melbourne (1978)

Classification	Activities	Annual Gust Wind Speed (m/s)
Limit for Safety	Completely unacceptable: people likely to get blown over.	23
Marginal	Unacceptable as main public accessways.	16 - 23
Comfortable Walking	Acceptable for walking, main public accessways	13 - 16
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	10 - 13
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	0 - 10

A.6 Comparison of the Published Wind Speed Criteria

W.H. Melbourne (1978) presented a comparison of the criteria of various researchers on a probabilistic basis. Figure A.1 presents the results of this comparison, and indicates that the criteria of W.H. Melbourne (1978) are comparatively quite conservative. This conclusion was also observed by A.W. Rofail (2007) when undertaking on-site remedial studies. The results of A.W. Rofail (2007) concluded that the criteria by W.H. Melbourne (1978) generally overstates the wind effects in a typical urban setting due to the assumption of a fixed 15% turbulence intensity for all areas. It was observed in A.W. Rofail (2007) that the 15% turbulence intensity assumption is not real and that the turbulence intensities at 1.5m above ground is at least 20% and in a suburban or urban setting is generally in the range of 30% to 60%.

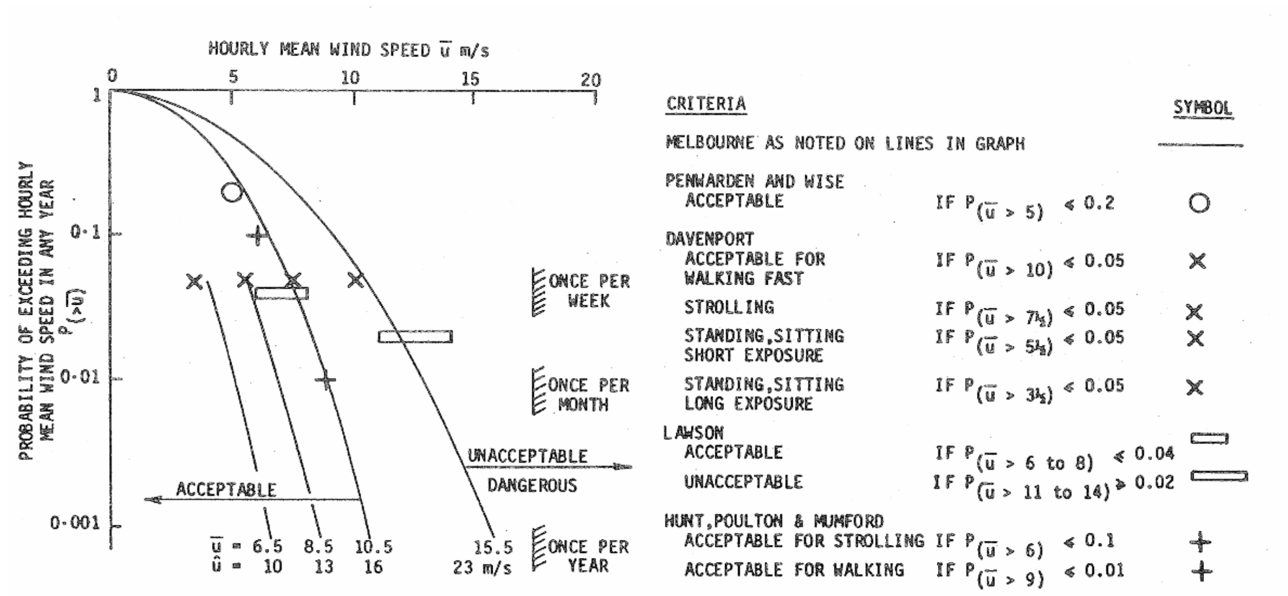

Figure A.1: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (W.H. Melbourne, 1978)

A.7 References relating to Pedestrian Comfort Criteria

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APPENDIX B DATA ACQUISITION

The wind tunnel testing procedures utilised for this study were based on the guidelines set out in the Australasian Wind Engineering Society Quality Assurance Manual (AWES-QAM-1-2019), ASCE 7-16 (Chapter C31), and CTBUH (2013). The wind speed measurements for the wind tunnel study were determined as coefficients using data acquired by either Dantec hot-wire probe anemometers or pressure-based wind speed sensors and converted to full-scale wind speeds using details of the regional wind climate obtained from an analysis of directional wind speed recordings from the local meteorological recording station(s).

B.1 Measurement of the Velocity Coefficients

The study model and proximity model were setup within the wind tunnel which was configured to the appropriate boundary layer profile, and the wind velocity measurements were monitored using either Dantec hot-wire probe anemometers or pressure-based wind speed sensors at selected critical outdoor locations. The wind velocity results presented in this study for each study point are representative of wind at a full-scale height of approximately 1.5m above ground/slab level. In the case of the Dantec hot-wire probe anemometers, the support of the probe is mounted such that the probe wire is vertical as much as possible to ensure that the measured wind speeds are independent of wind direction along the horizontal plane. In addition, care was taken in the alignment of the hot-wire probe wire and in avoiding wall-heating effects.

Wind speed measurements were made in the wind tunnel for the wind directions described within this report. Data was acquired for each wind direction using a sample rate of 1024Hz. The sample length was determined to produce a full-scale sample time that is sufficient for this type of study. In the case of the pressure-based wind speed sensors, the phase lag between the various channels where data is acquired simultaneously is within 10% of a typical pressure cycle, and the signal is low-pass filtered at 500Hz and then digital filtering is applied over this range to provide an unbiased response from the pressure measurement system (A.W. Rofail, 2004).

The mean, gust and standard deviation velocity coefficients were determined from the data acquired in the wind tunnel. The gust velocity coefficients were also derived for each wind direction from by the following relation:

$$\hat{C}_V = \bar{C}_V + g \cdot \sigma_{C_V} \qquad \text{B.1}$$

where:

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

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

g is the peak factor, taken as 3.0 for a 3-sec gust and 3.4 for a 0.5-sec gust.

σ_{C_V} is the standard deviation of the velocity coefficient measurement.

In the case of a Dantec hot-wire probe anemometer, the velocity coefficient is obtained as follows:

$$C_V = \frac{C_{V,study}}{C_{V,200m}} \qquad \text{B.2}$$

where:

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

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

However, in the case of the pressure-based wind speed sensors, these are determined from the measured differential mean, standard deviation and maximum pressure coefficients obtained from the wind speed sensor. For this analysis all calculations are performed on the square root of the differential pressure measurements. The velocity coefficient at the pressure-based wind speed sensor location is then calculated as follows:

$$C_V = \frac{\alpha + \beta\sqrt{\Delta p}}{V_{200m}} \qquad \text{B.3}$$

where:

C_V is the velocity coefficient measurement at the study point location.

α is a calibration coefficient for the pressure-based wind speed sensor.

β is a calibration coefficient for the pressure-based wind speed sensor.

Δp is the differential pressure obtained from the pressure-based wind speed sensor at the study point location.

V_{200m} is the wind speed at the free-stream reference location of 200m height (full-scale) in the wind tunnel, which is determined directly in the wind tunnel using a pitot static probe.

B.2 Calculation of the Full-Scale Results

The full-scale results determine if the wind conditions at a study location satisfy the designated criteria of that location. More specifically, the full-scale results need to determine the probability of exceedance of a given wind speed at a study location. To determine the probability of exceedance, the measured velocity coefficients were combined with a statistical model of the local wind climate that relates wind speed to a probability of exceedance. Details of the wind climate model are outlined in Section 4 of the main report.

The statistical model of the wind climate includes the impact of wind directionality as any local variations in wind speed or frequency with wind direction. This is important as the wind directions that produce the highest wind speed events for a region may not coincide 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.

B.3 Maximum Gust Wind Speeds

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

$$V_{study} = V_{ref,RH}\left(\frac{k_{200m,tr,T=1hr}}{k_{RH,tr,T=1hr}}\right)C_V \qquad \text{B.4}$$

where:

V_{study} is the full-scale wind speed at the study point location.

$V_{ref,RH}$ is the full-scale reference wind speed at the study reference height. This value is determined by combining the directional wind speed data for the region (detailed in Section 4) and the upwind terrain and height multipliers for the site (detailed in Section 3).

$k_{200m,tr,T=1hr}$ is the hourly mean terrain and height multiplier at the free-stream reference location of 200m height.

$k_{RH,tr,T=1hr}$ is the hourly mean terrain and height multiplier at the study reference height (Section 3).

C_V is the velocity coefficient, obtained from either Equation B.2 (in the case of Dantec hot-wire probe anemometers) or Equation B.3 (in the case of pressure-based wind speed sensors).

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 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/NZS1170.2:2021, which assumes that the major contributions to the combined probability of exceedance of a typical load effect comes from only two 45 degree sectors.

B.4 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) was 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 used in this study is referenced to a probability of exceedance of 5% of a specified wind speed.

B.5 References relating to Data Acquisition

American Society of Civil Engineers (ASCE), ASCE-7-16, 2016, “Minimum Design Loads for Buildings and Other Structures”.

Australasian Wind Engineering Society, QAM-1, 2019, “Quality Assurance Manual: Wind Engineering Studies of Buildings”, edited by Rofail A.W., et al.

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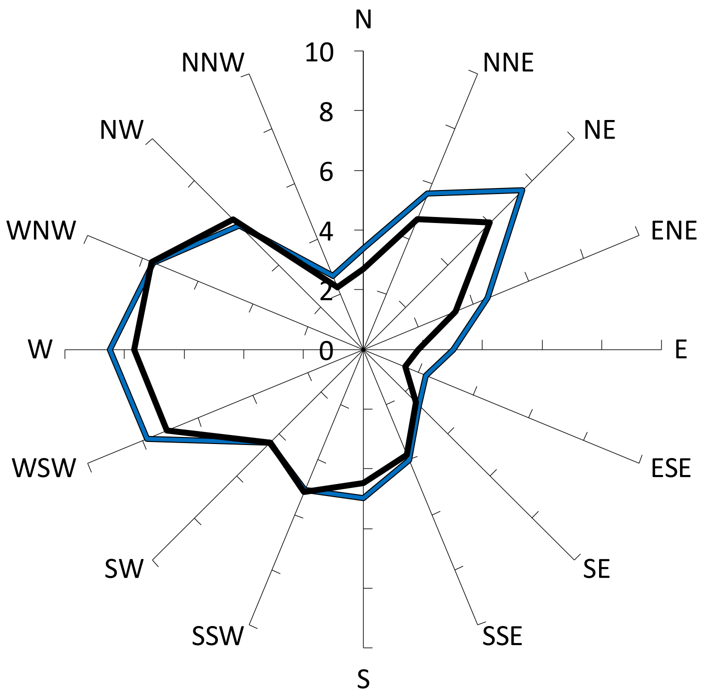
APPENDIX C DIRECTIONAL PLOTS OF WIND TUNNEL RESULTS

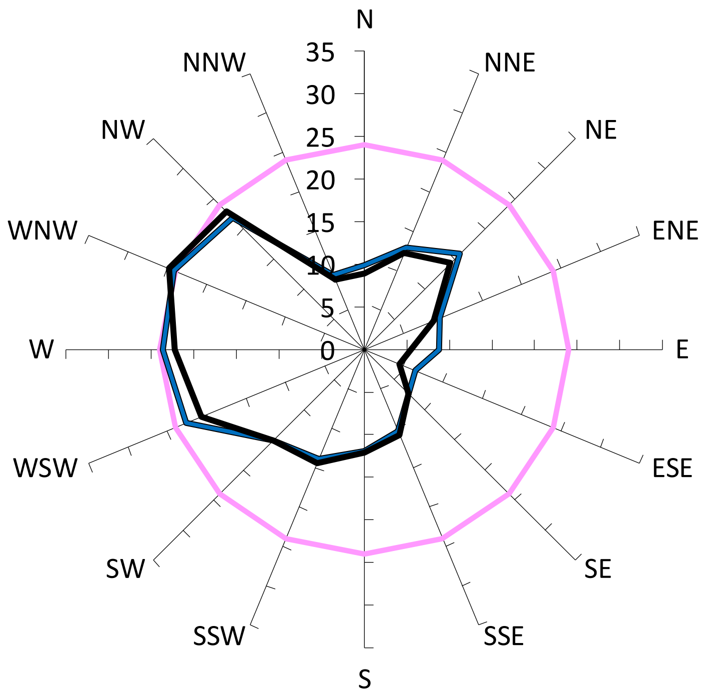
Results for Point 01

Gust Equivalent Mean (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

Annual Maximum Gust (m/s)

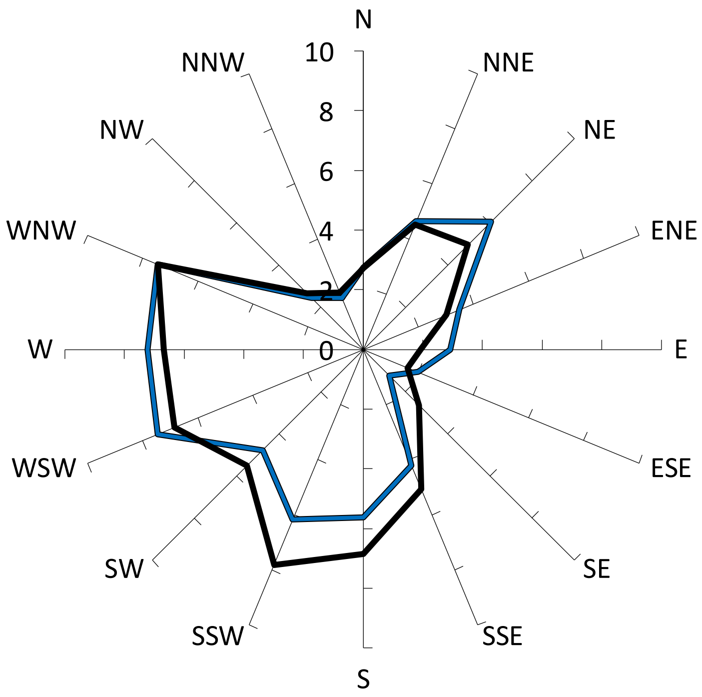


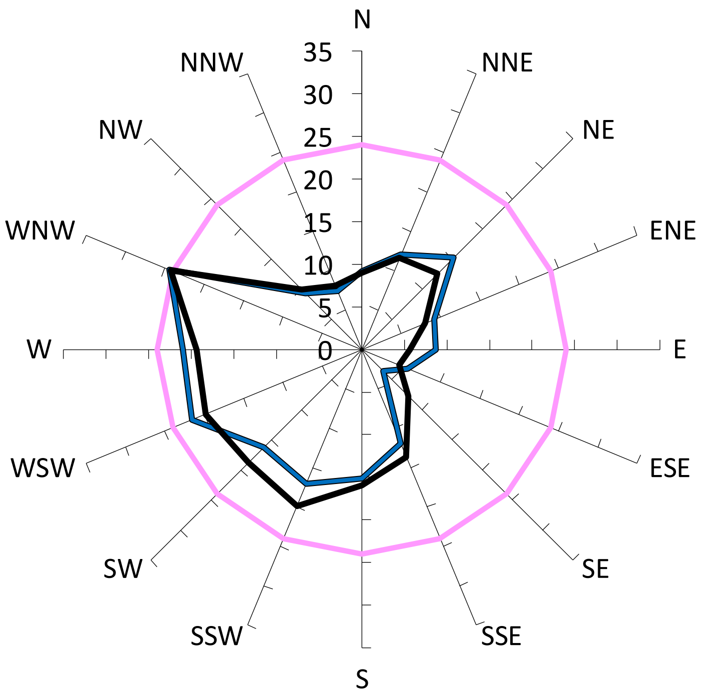
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	5%	24
Existing Site Conditions.	3%	25

Results for Point 02

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





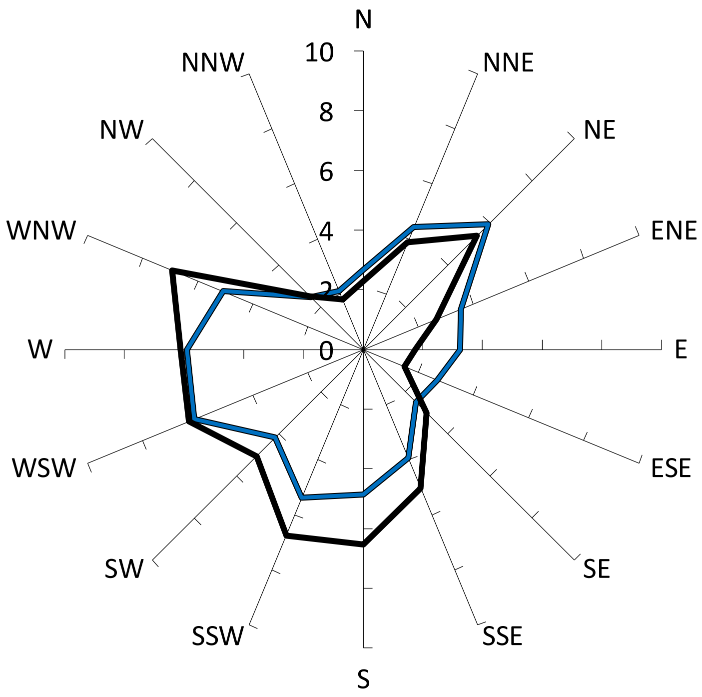
Comfort Criteria: 8m/s with 5% probability of exceedence

Safety Limit: 24m/s

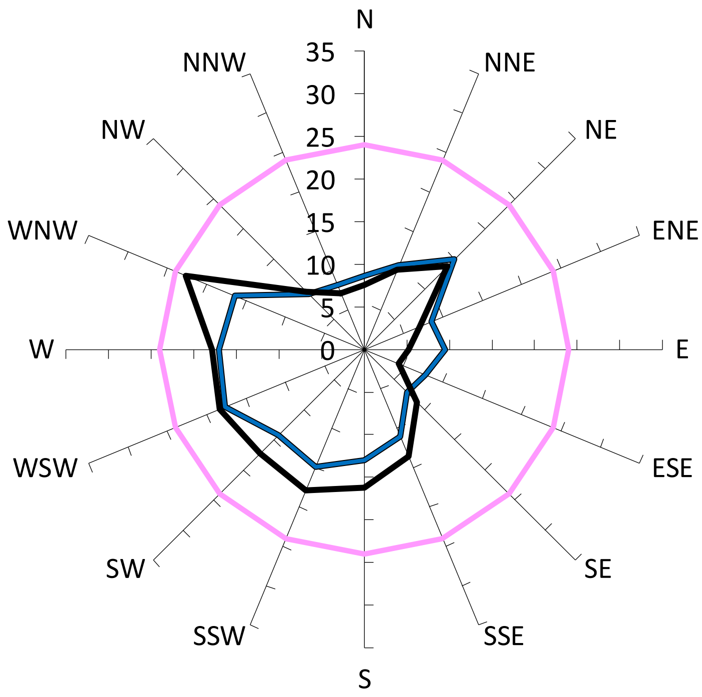
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	3%	24
Existing Site Conditions.	3%	24

Results for Point 03

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

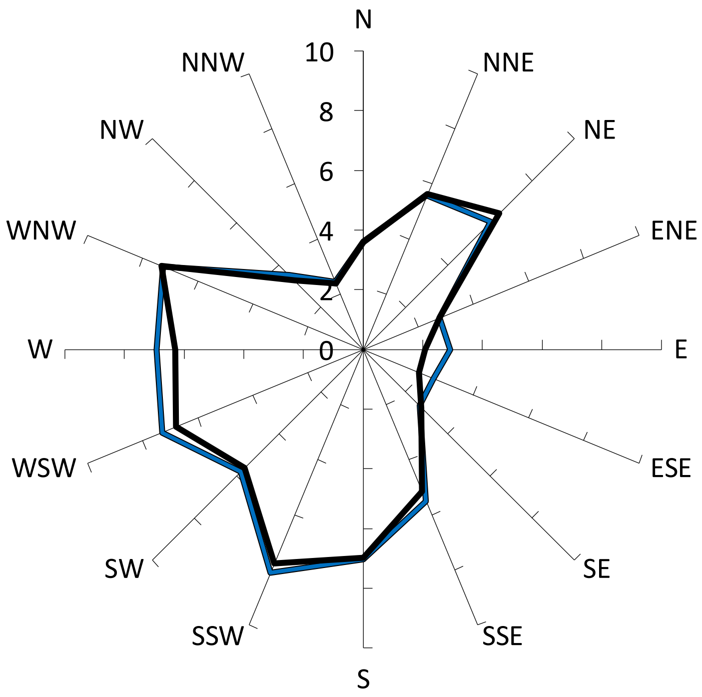


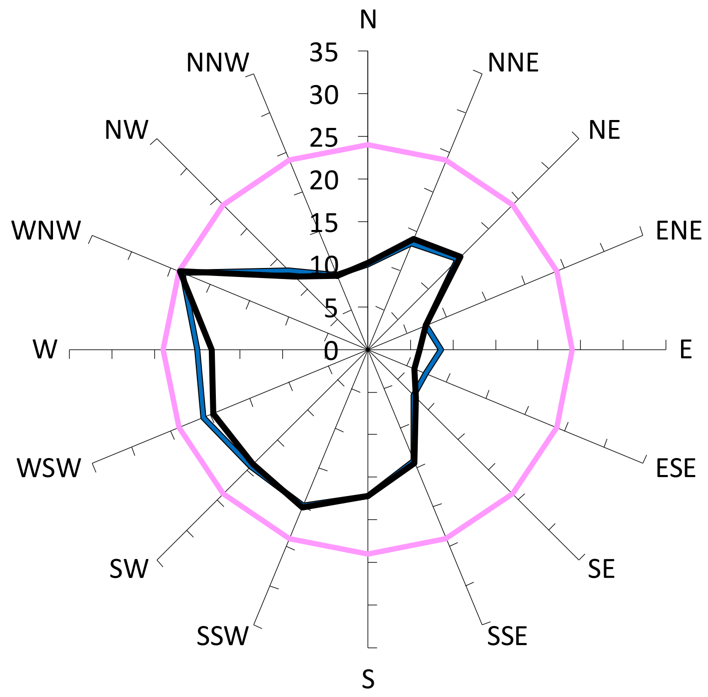
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	1%	18
Existing Site Conditions.	2%	23

Results for Point 04

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





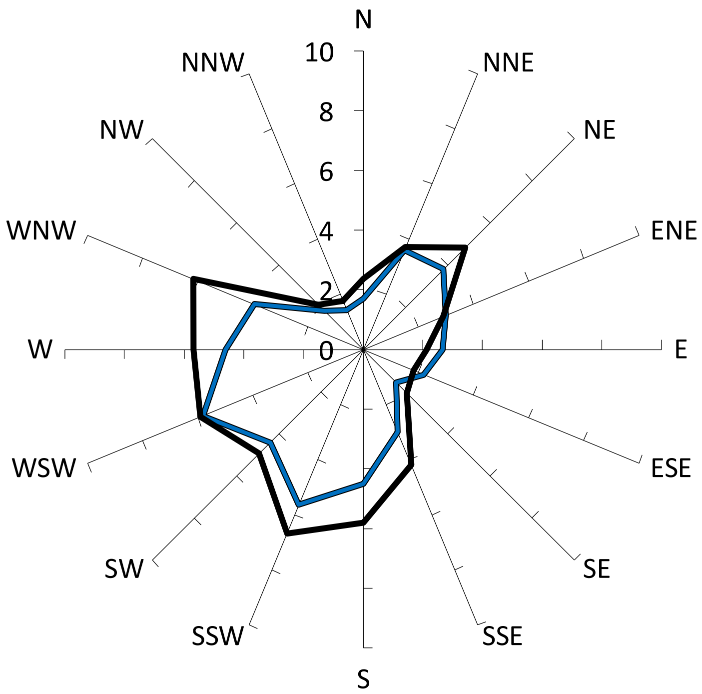
Comfort Criteria: 8m/s with 5% probability of exceedence

Safety Limit: 24m/s

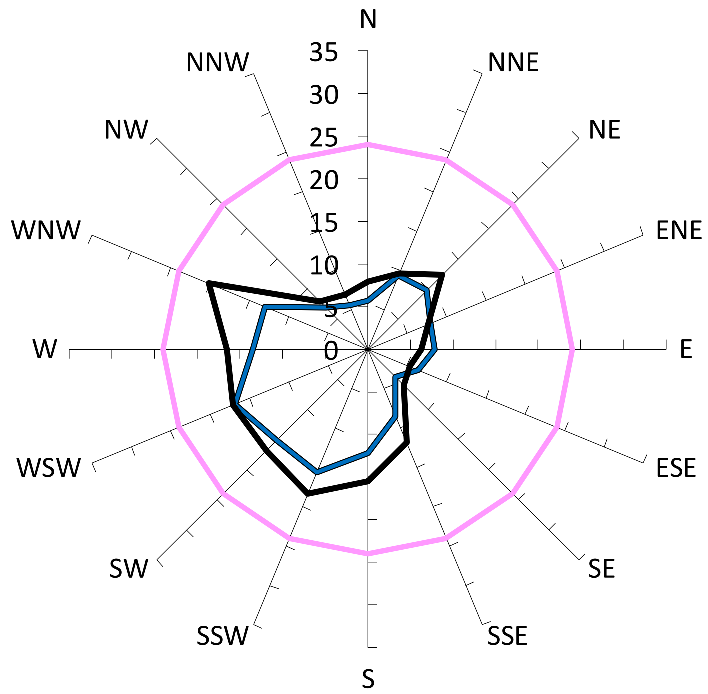
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	4%	24
Existing Site Conditions.	3%	24

Results for Point 05

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

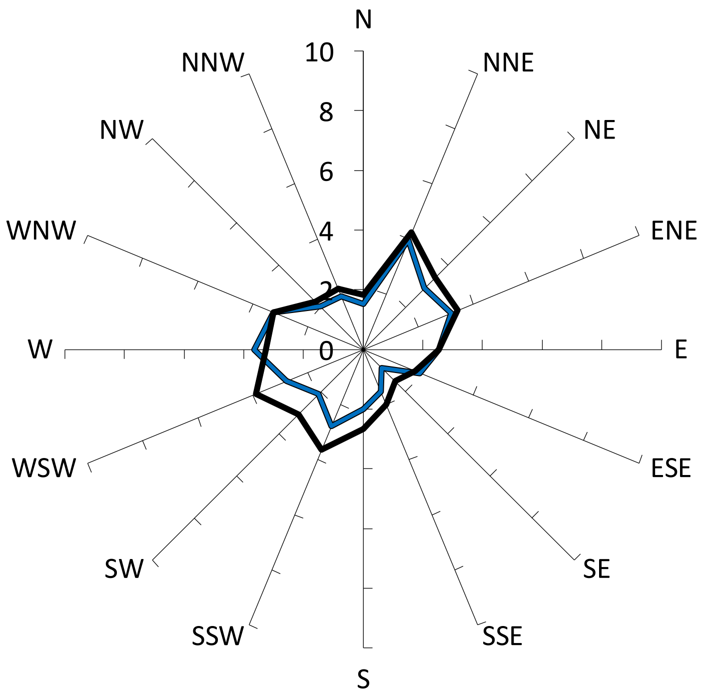


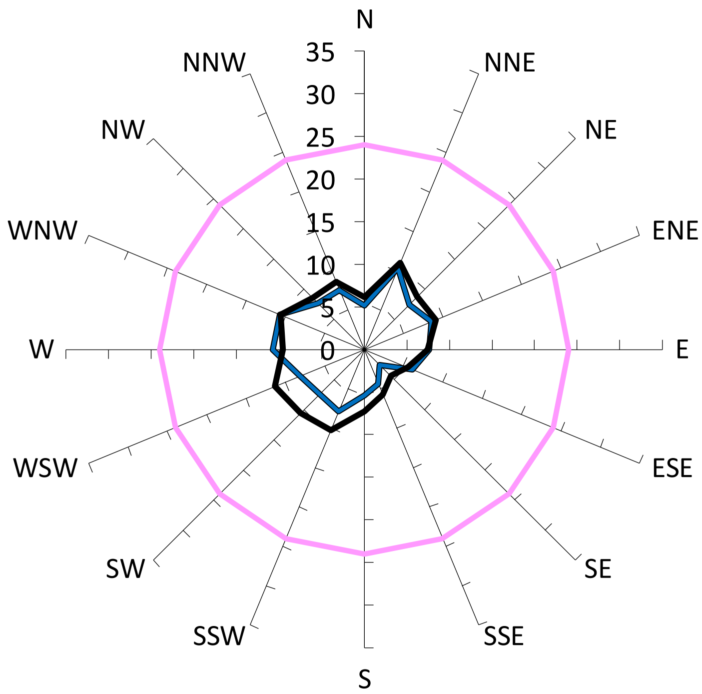
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	< 1%	17
Existing Site Conditions.	1%	20

Results for Point 06

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





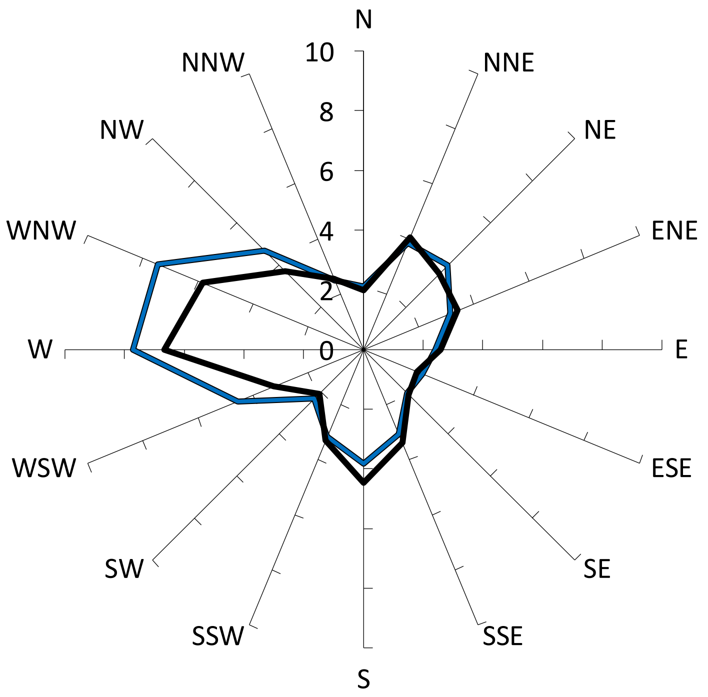
Comfort Criteria: 8m/s with 5% probability of exceedence

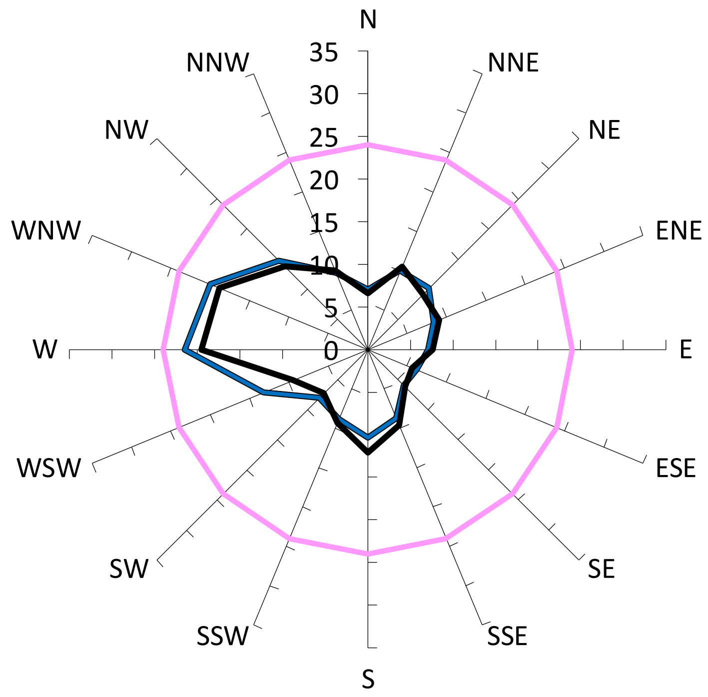
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	< 1%	11
Existing Site Conditions.	< 1%	11

Results for Point 07

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





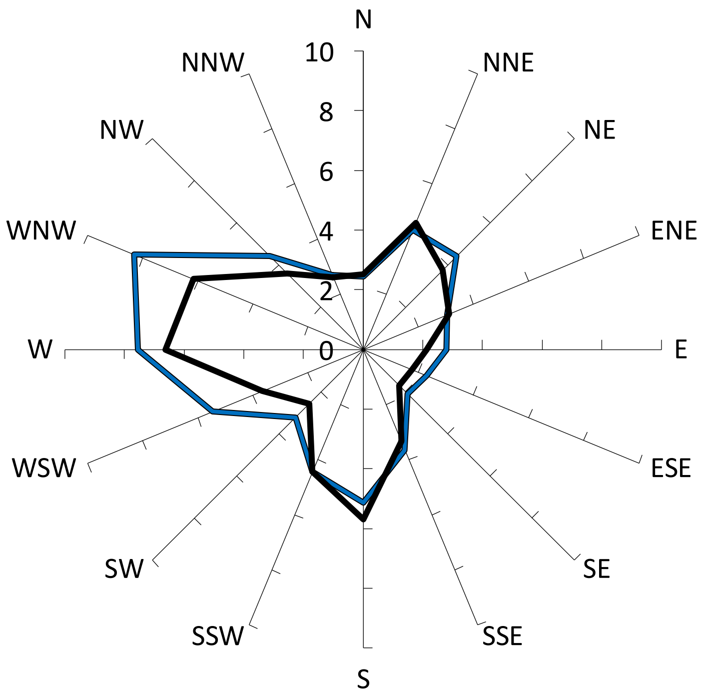
Comfort Criteria: 8m/s with 5% probability of exceedence

Safety Limit: 24m/s

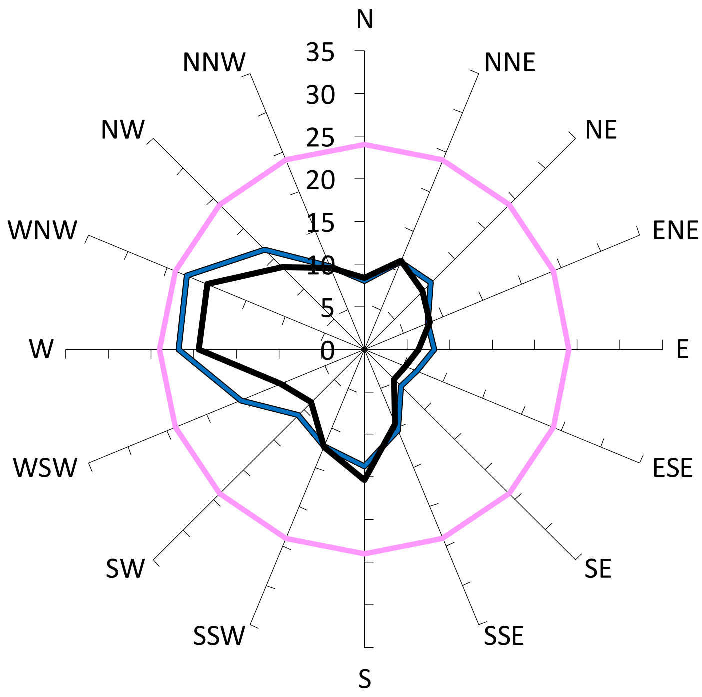
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	2%	21
Existing Site Conditions.	1%	20

Results for Point 08

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

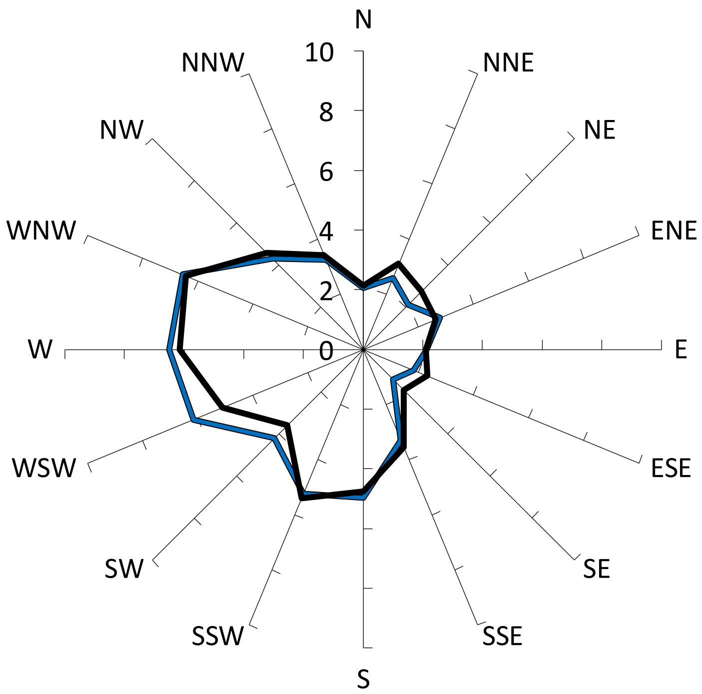


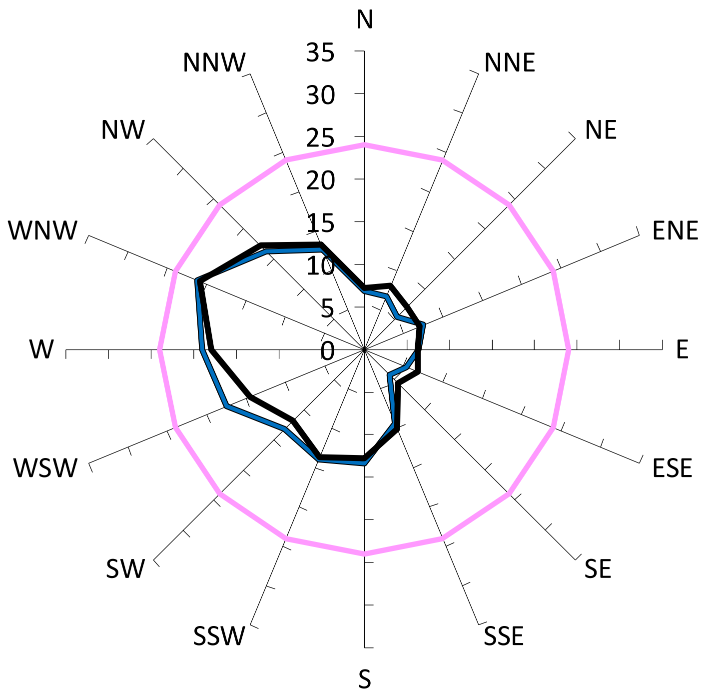
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	2%	23
Existing Site Conditions.	1%	20

Results for Point 09

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





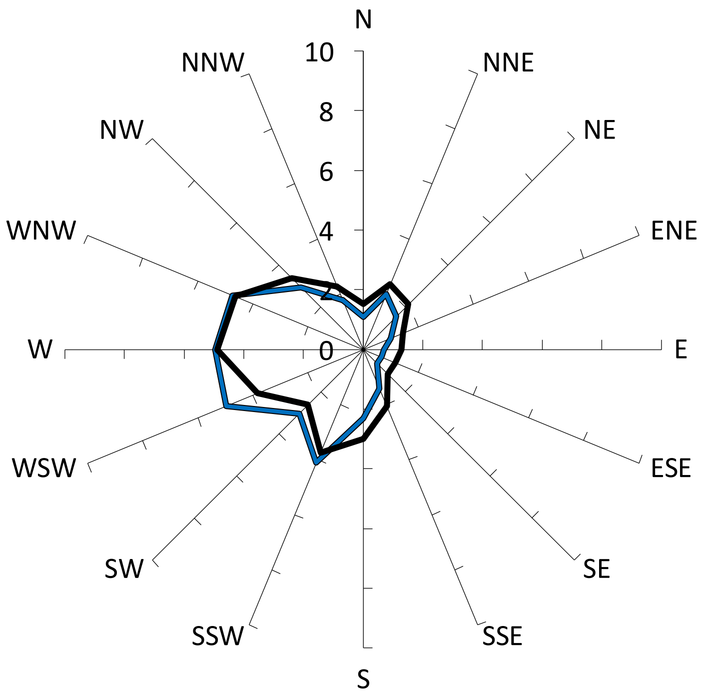
Comfort Criteria: 8m/s with 5% probability of exceedence

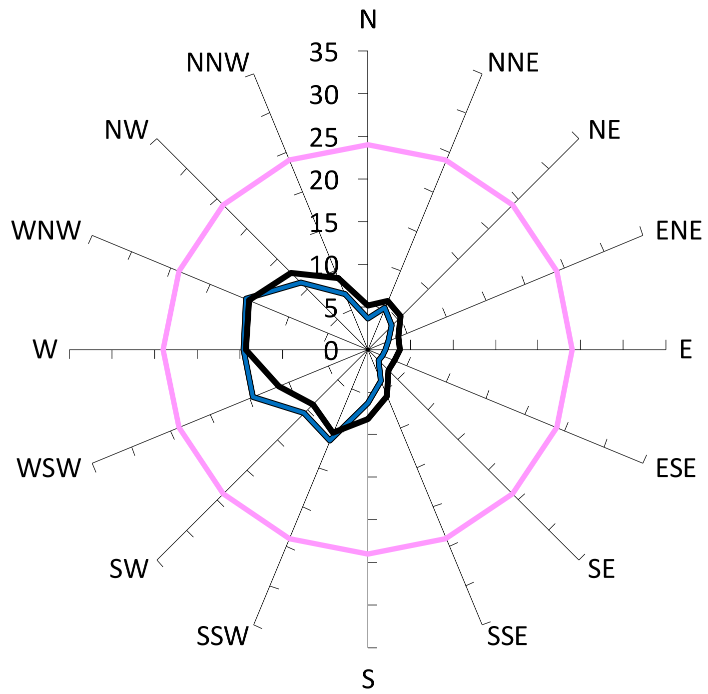
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	1%	21
Existing Site Conditions.	1%	21

Results for Point 10

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





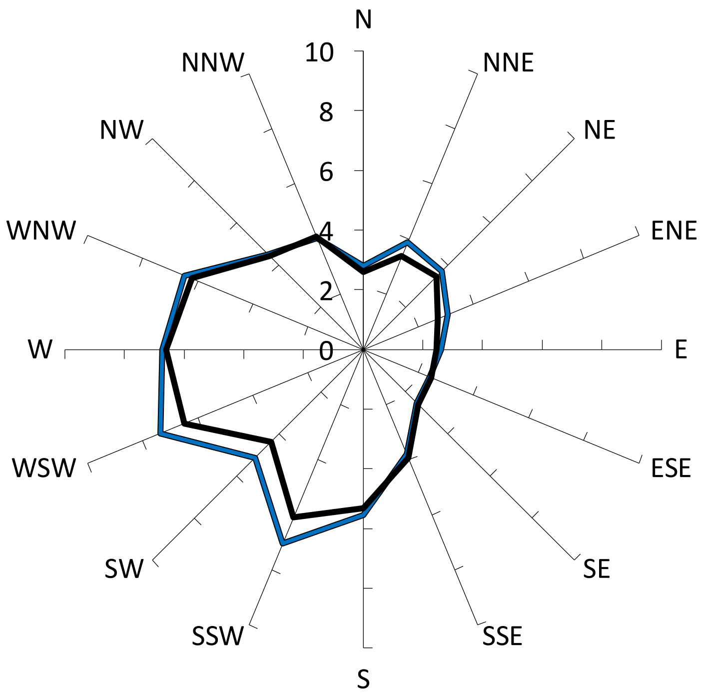
Comfort Criteria: 8m/s with 5% probability of exceedence

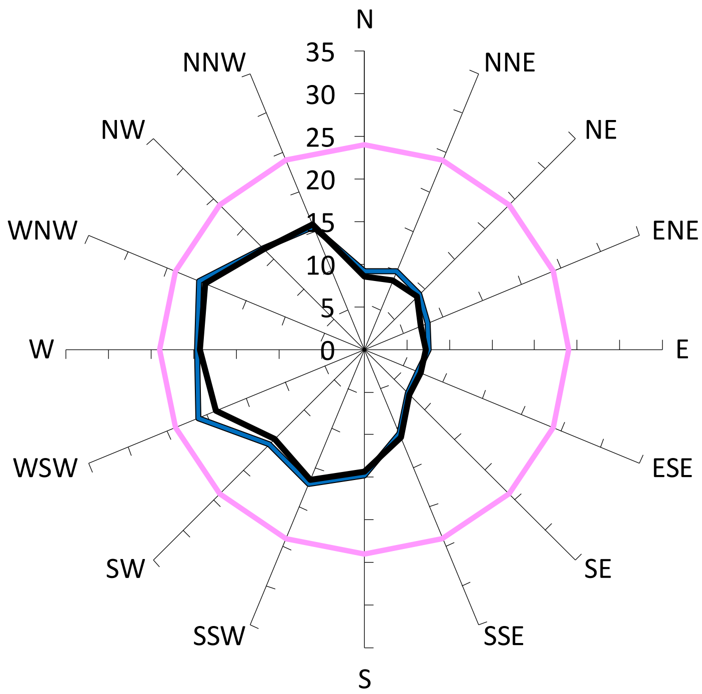
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	< 1%	15
Existing Site Conditions.	< 1%	15

Results for Point 11

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





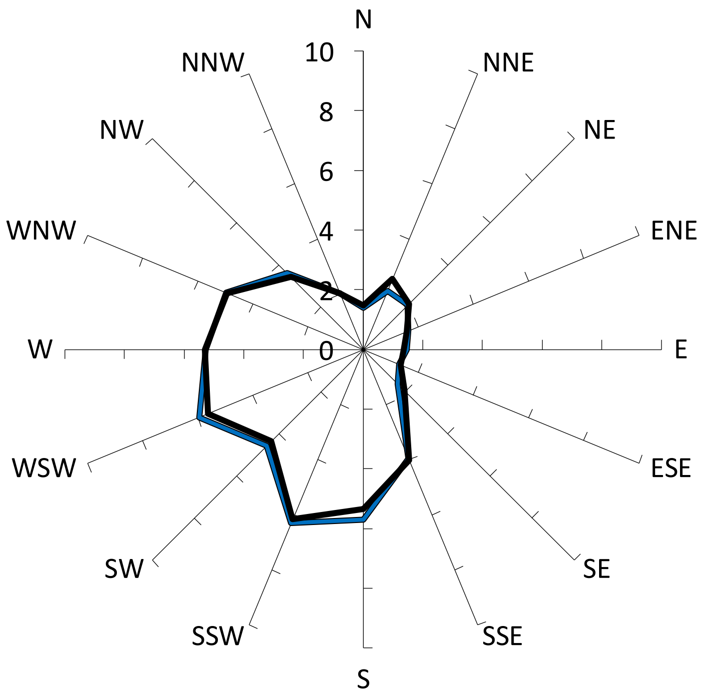
Comfort Criteria: 8m/s with 5% probability of exceedence

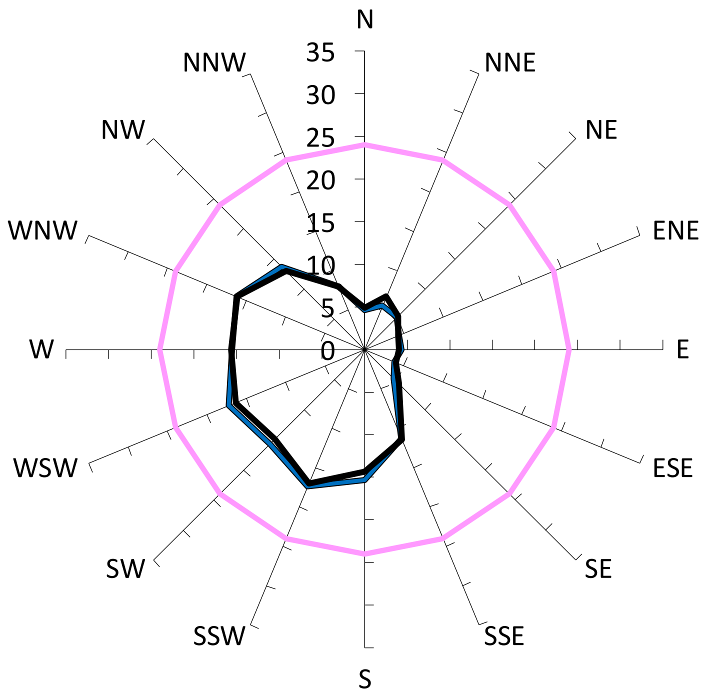
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	3%	21
Existing Site Conditions.	2%	20

Results for Point 12

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





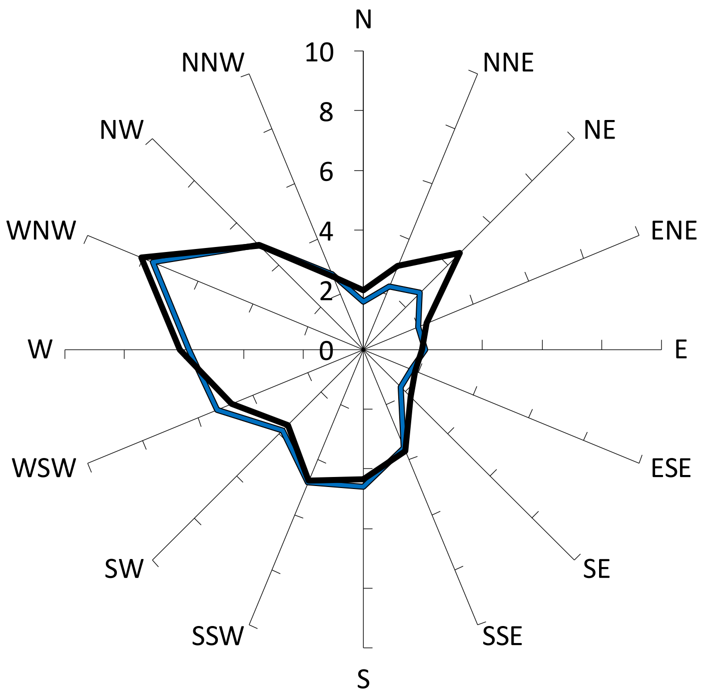
Comfort Criteria: 8m/s with 5% probability of exceedence

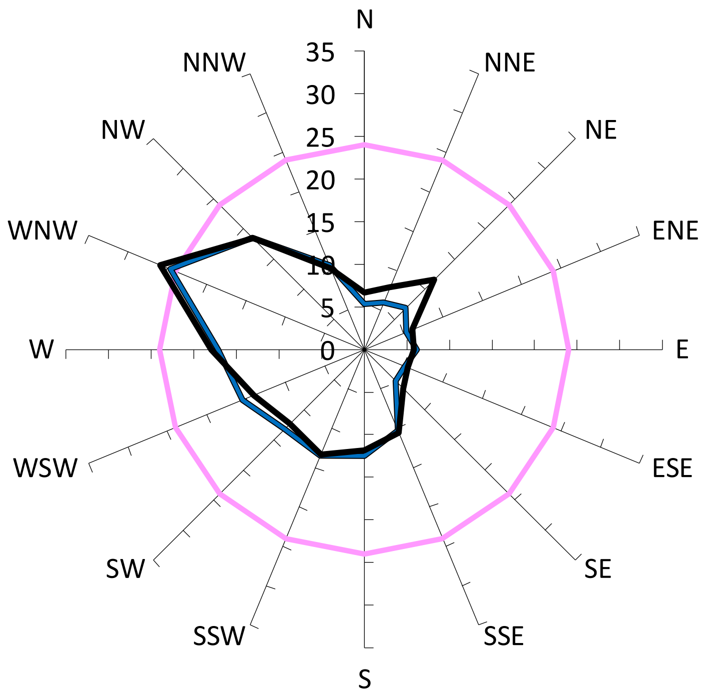
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	1%	17
Existing Site Conditions.	1%	17

Results for Point 13

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





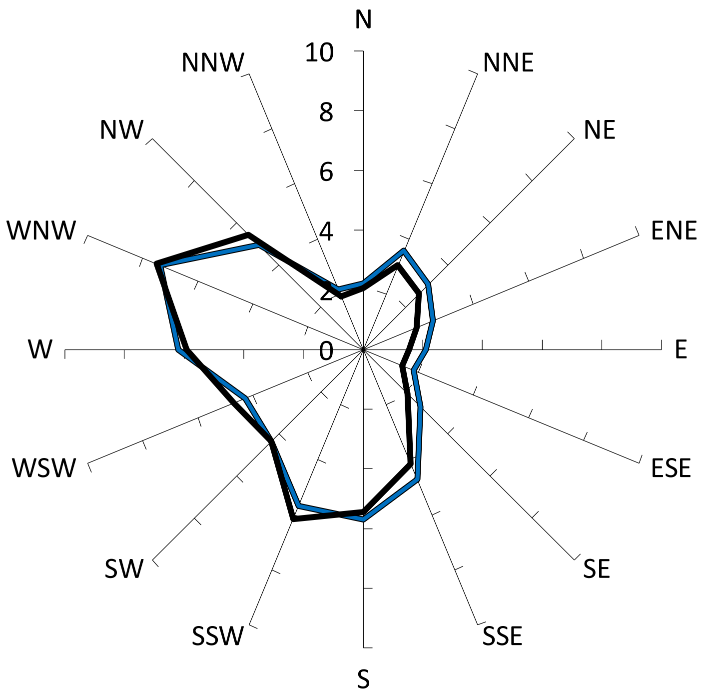
Comfort Criteria: 8m/s with 5% probability of exceedence

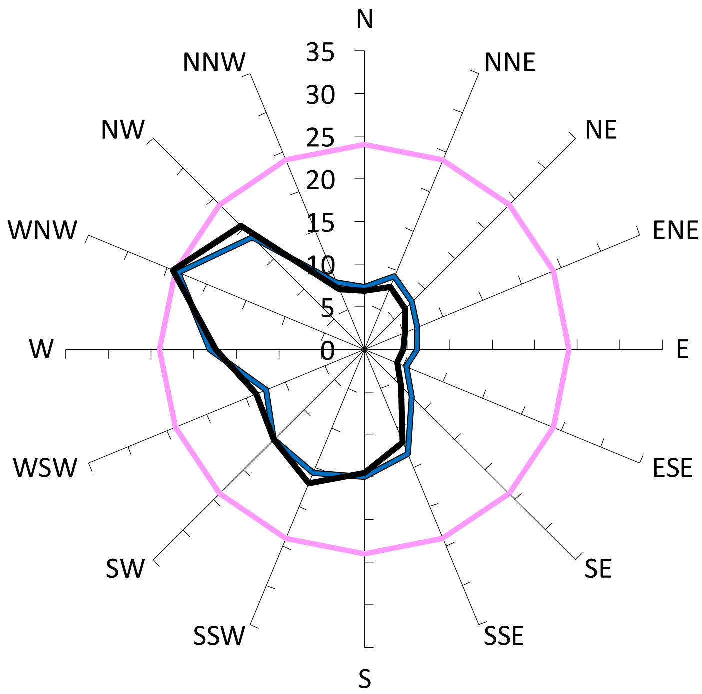
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	1%	25
Existing Site Conditions.	2%	26

Results for Point 14

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





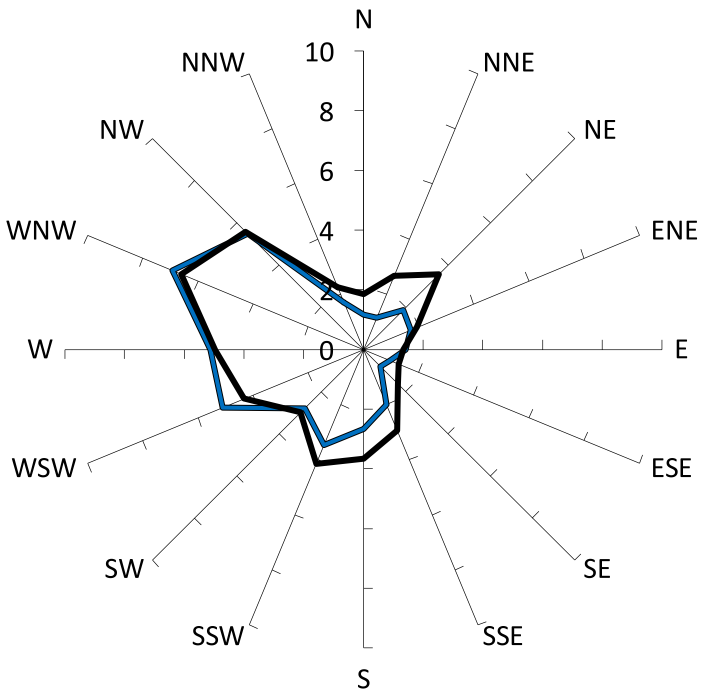
Comfort Criteria: 6m/s with 5% probability of exceedence

Safety Limit: 24m/s

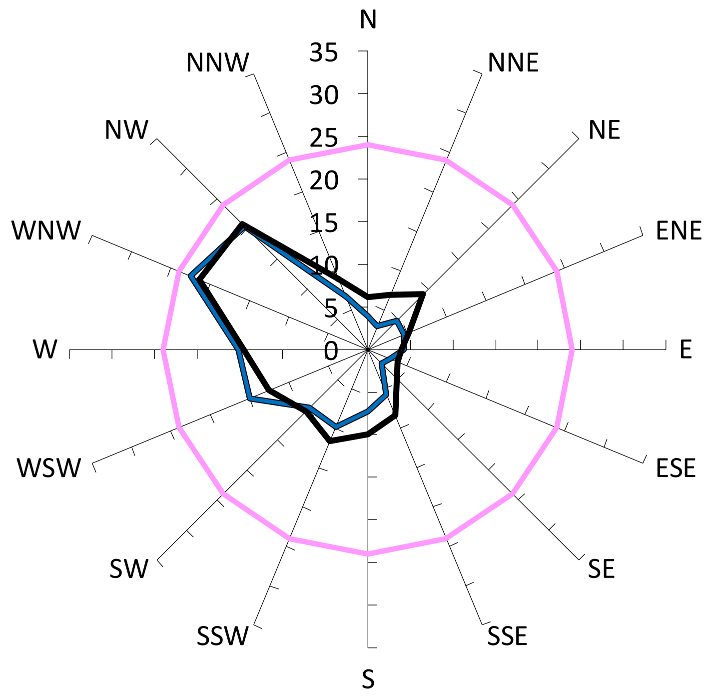
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Standing Criterion (6m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	7%	24
Existing Site Conditions.	7%	24

Results for Point 15

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

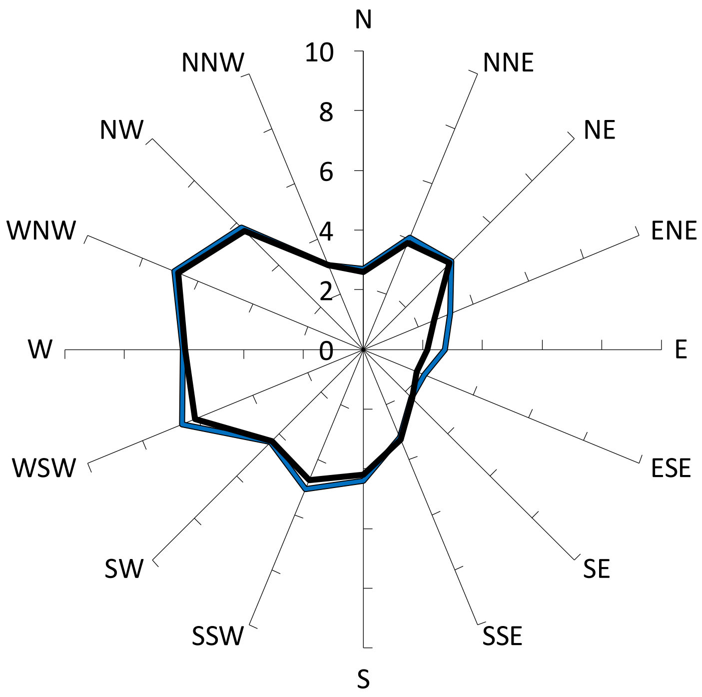


Safety Limit: 24m/s

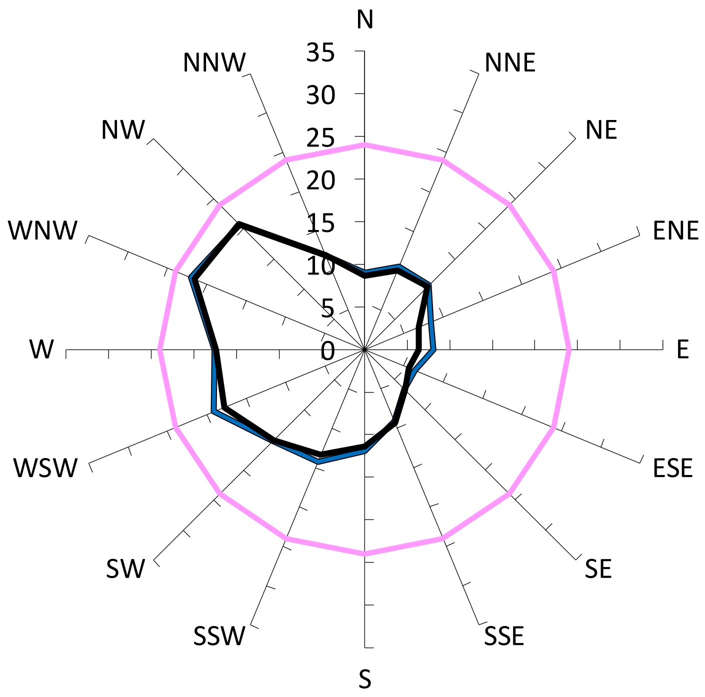
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	1%	22
Existing Site Conditions.	1%	21

Results for Point 16

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

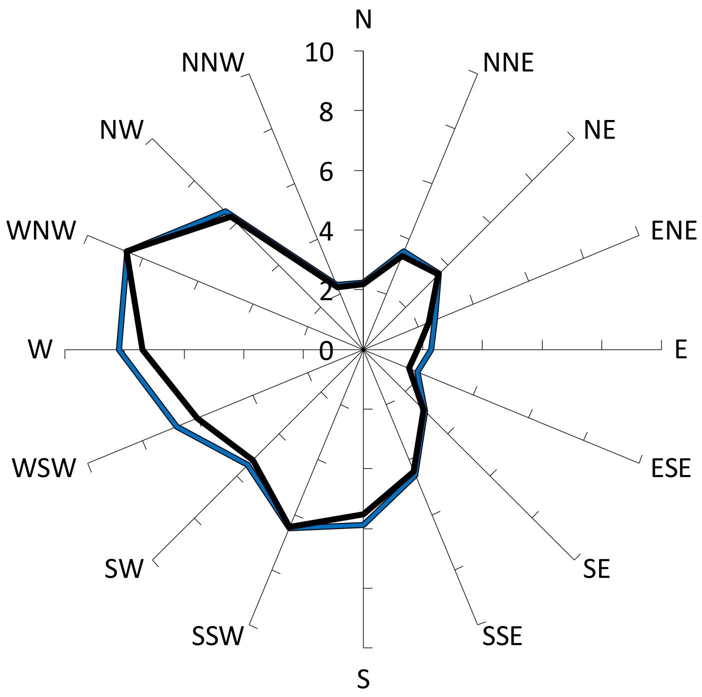


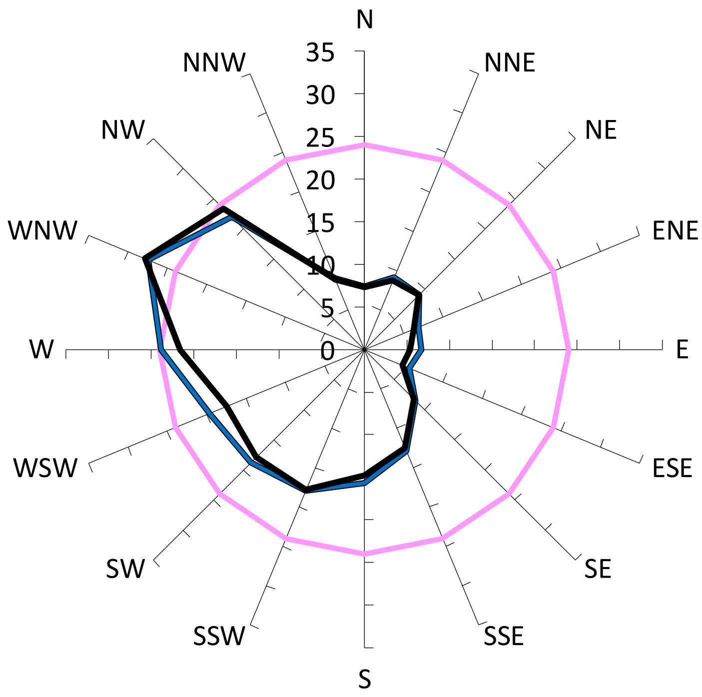
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	2%	22
Existing Site Conditions.	1%	22

Results for Point 17

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





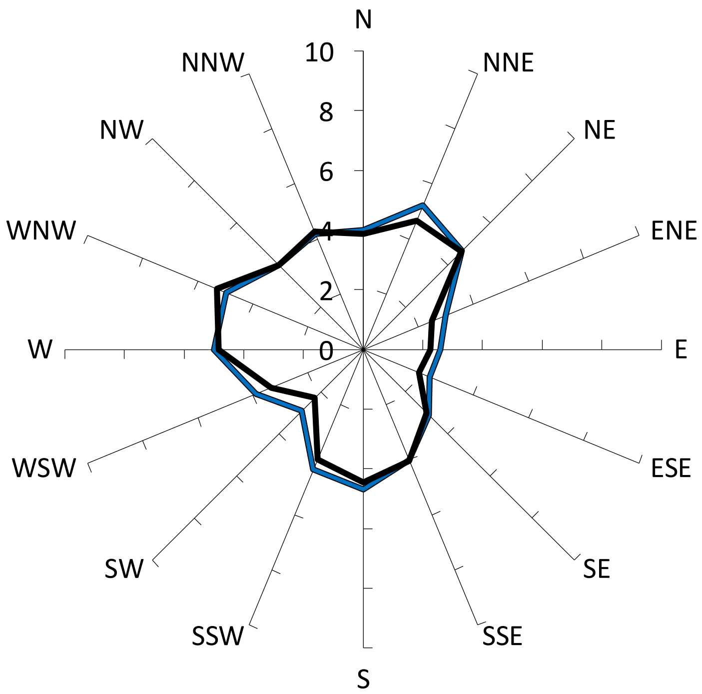
Comfort Criteria: 8m/s with 5% probability of exceedence

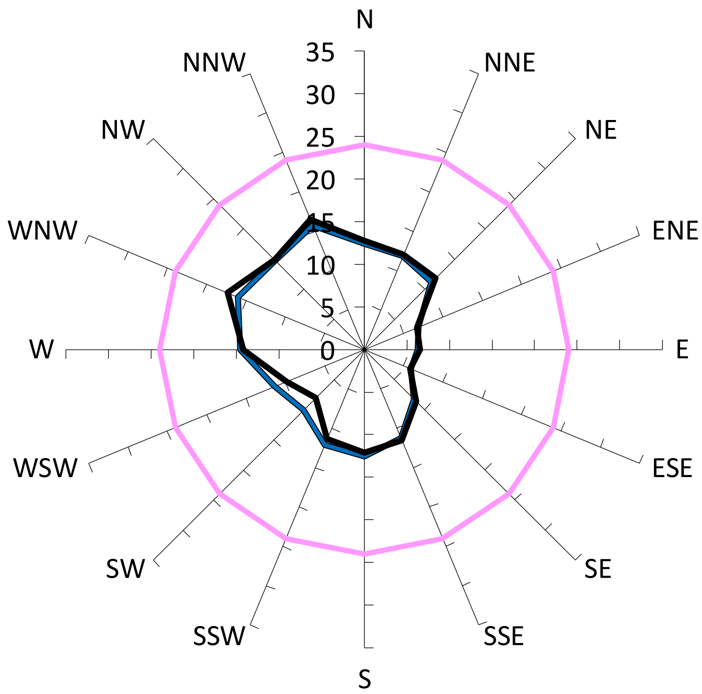
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	4%	27
Existing Site Conditions.	3%	28

Results for Point 18

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





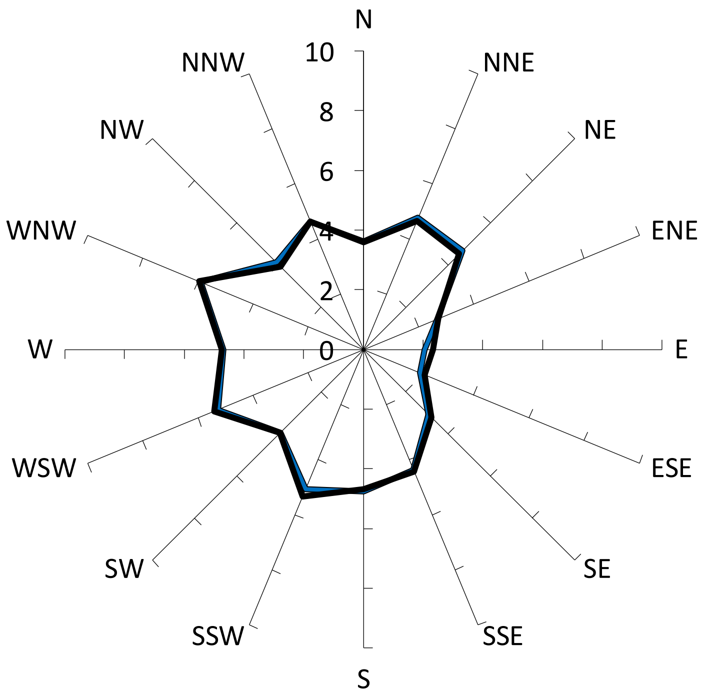
Comfort Criteria: 8m/s with 5% probability of exceedence

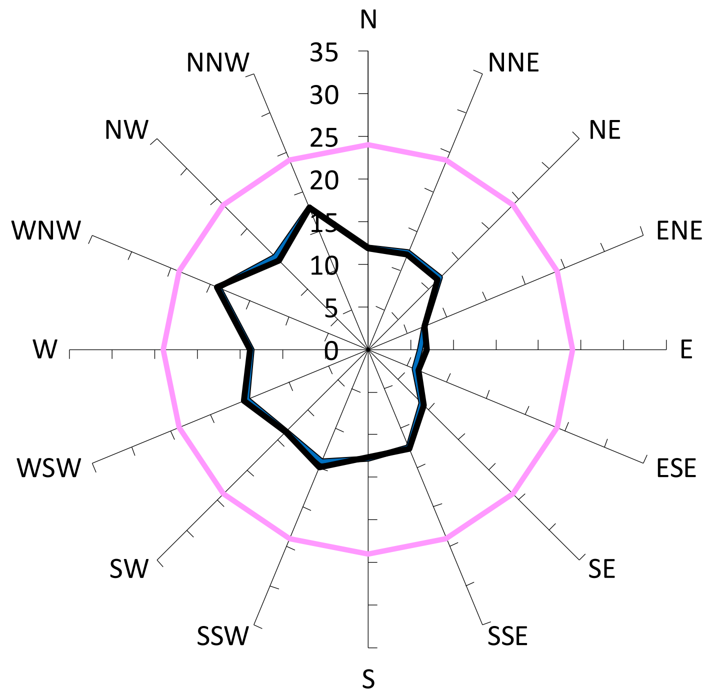
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	< 1%	16
Existing Site Conditions.	< 1%	17

Results for Point 19

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





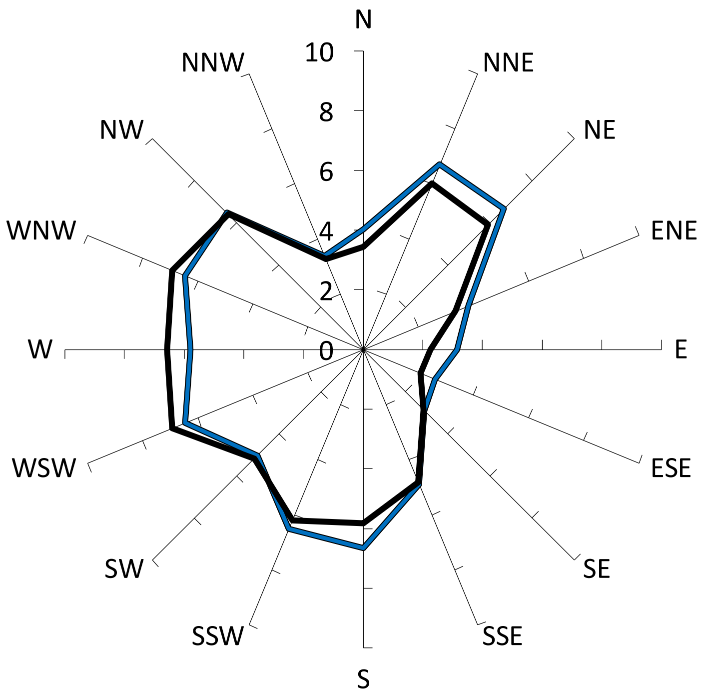
Comfort Criteria: 8m/s with 5% probability of exceedence

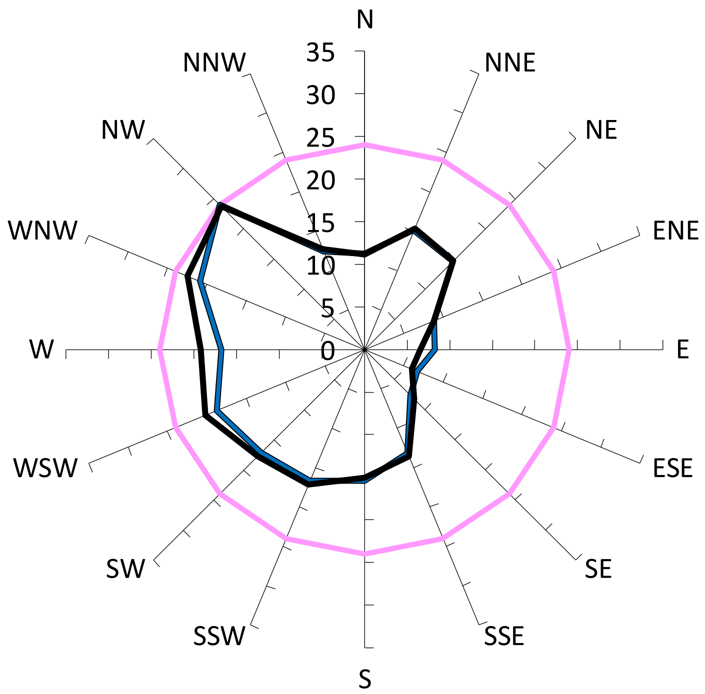
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	1%	19
Existing Site Conditions.	1%	19

Results for Point 20

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





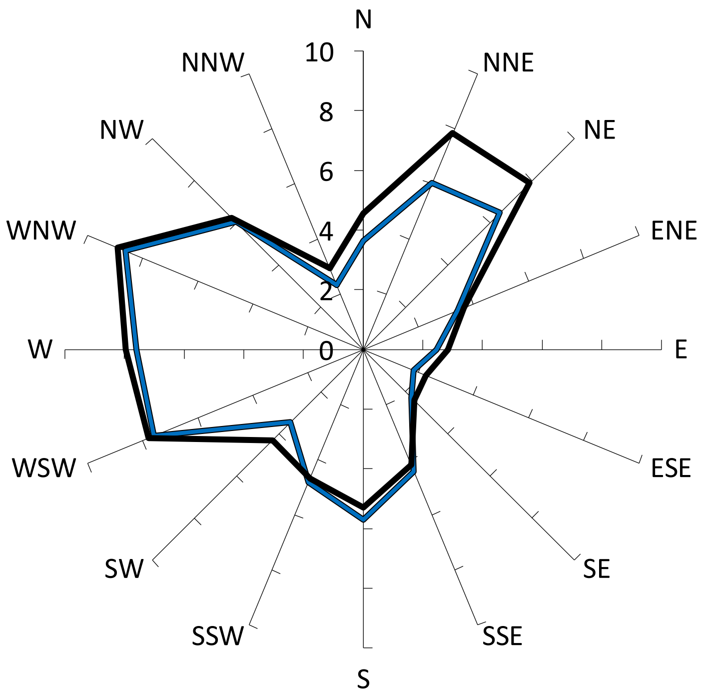
Comfort Criteria: 8m/s with 5% probability of exceedence

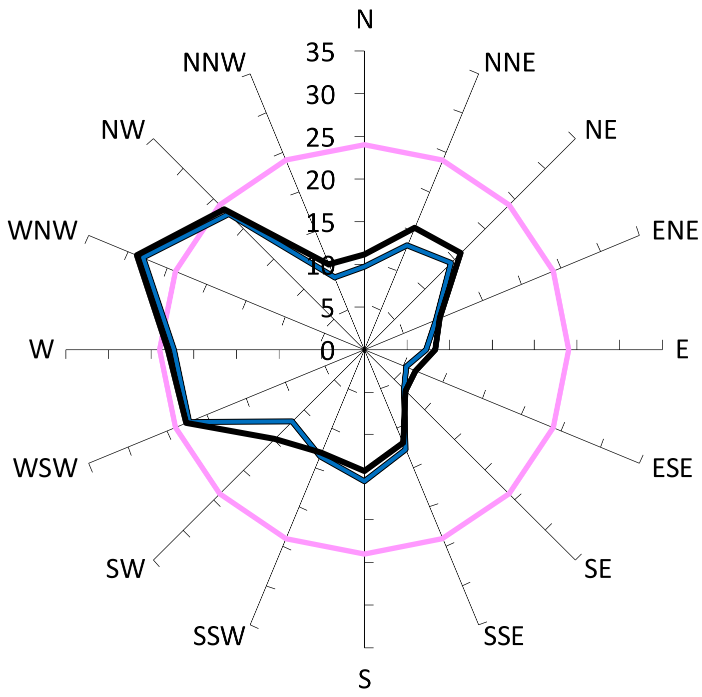
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	3%	24
Existing Site Conditions.	3%	24

Results for Point 21

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





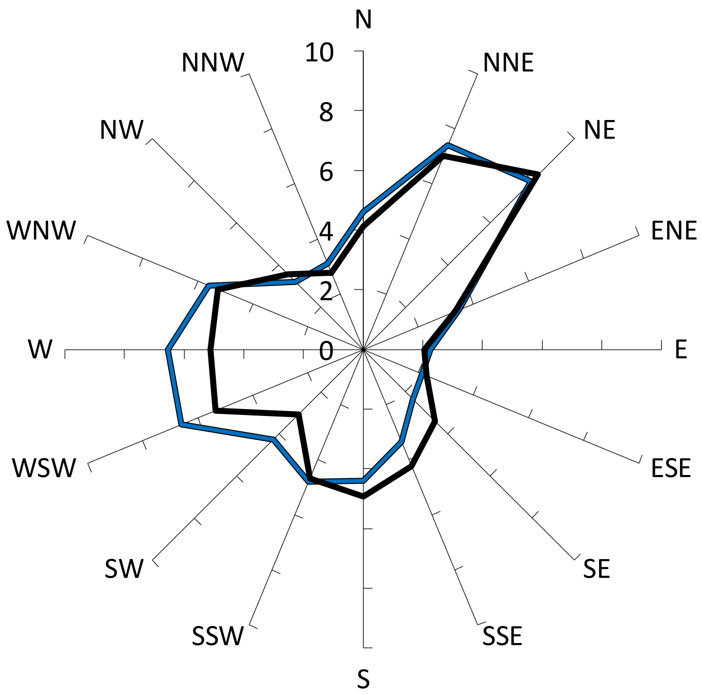
Comfort Criteria: 8m/s with 5% probability of exceedence

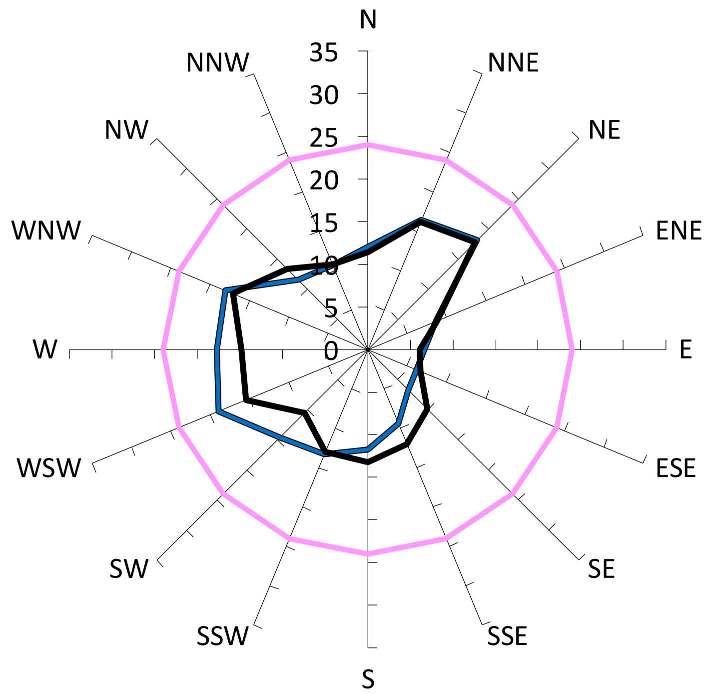
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	4%	28
Existing Site Conditions.	6%	29

Results for Point 22

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



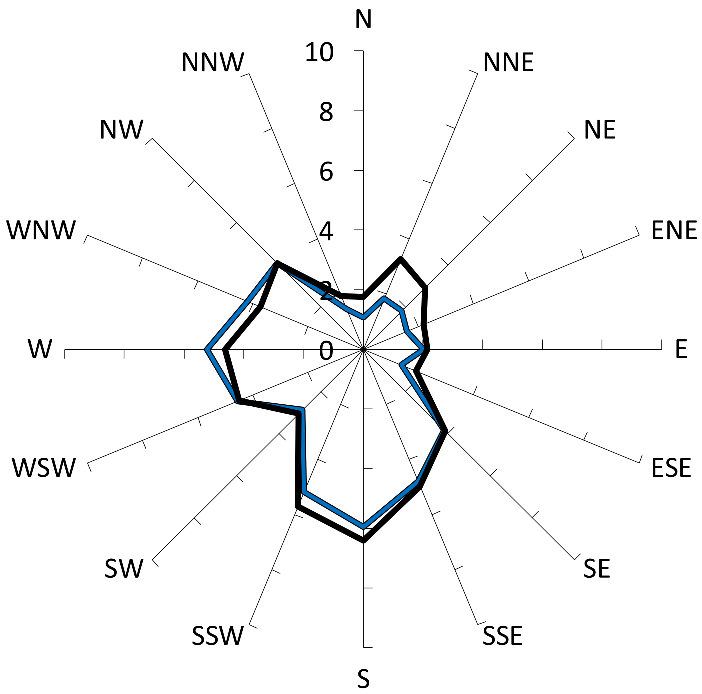


Comfort Criteria: 8m/s with 5% probability of exceedence	Safety Limit: 24m/s

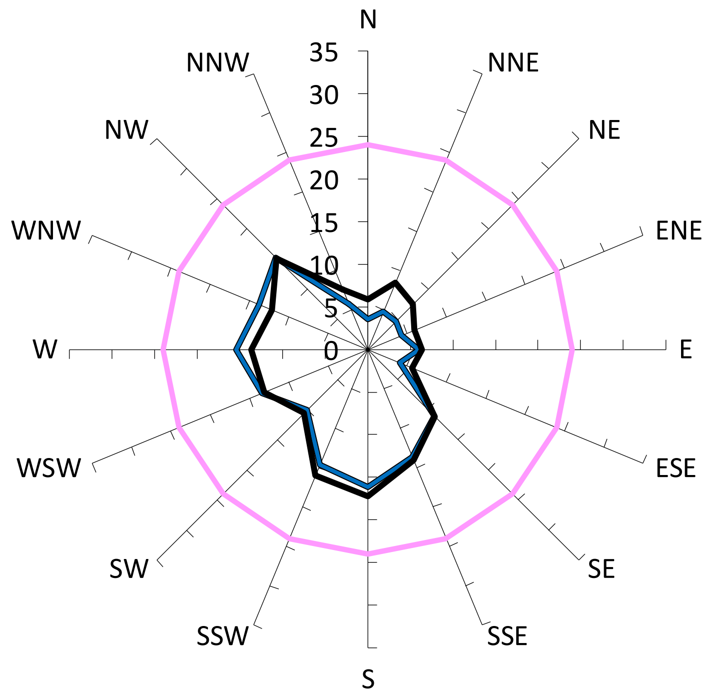
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	3%	19
Existing Site Conditions.	2%	18

Results for Point 23

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

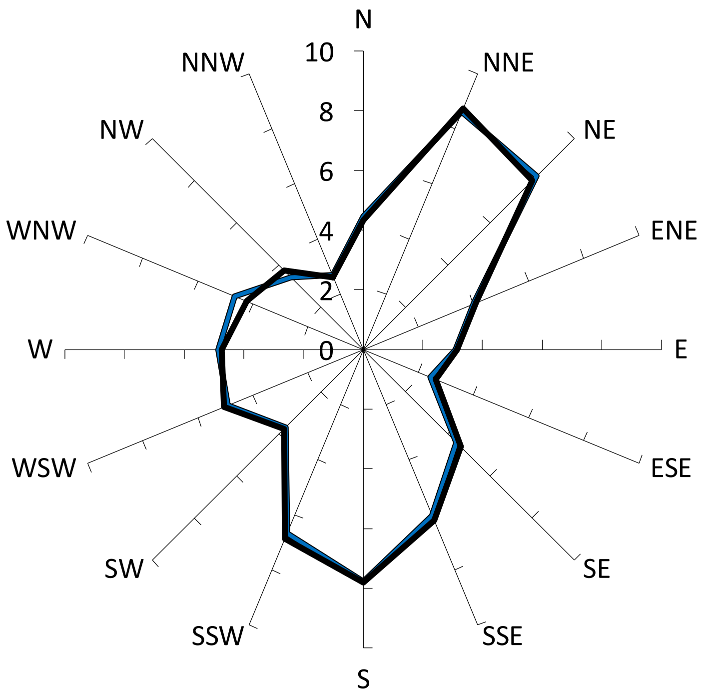


Safety Limit: 24m/s

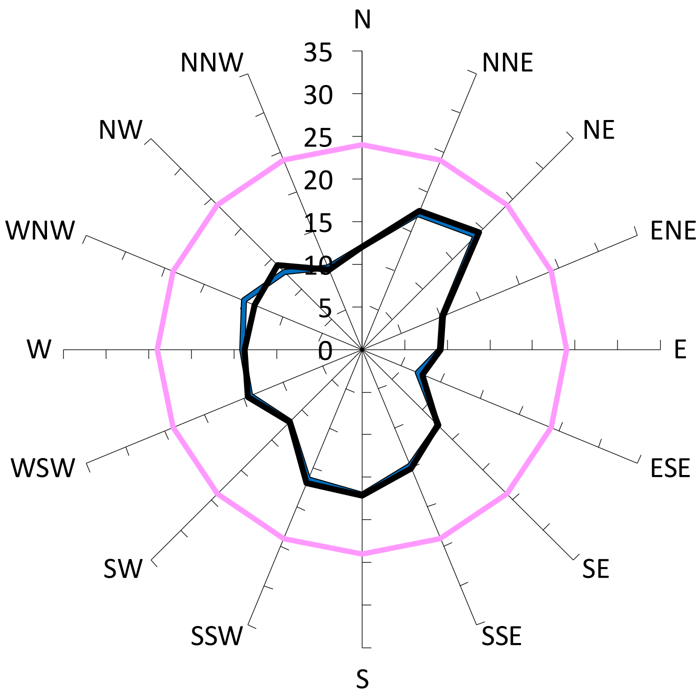
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	< 1%	16
Existing Site Conditions.	< 1%	17

Results for Point 24

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

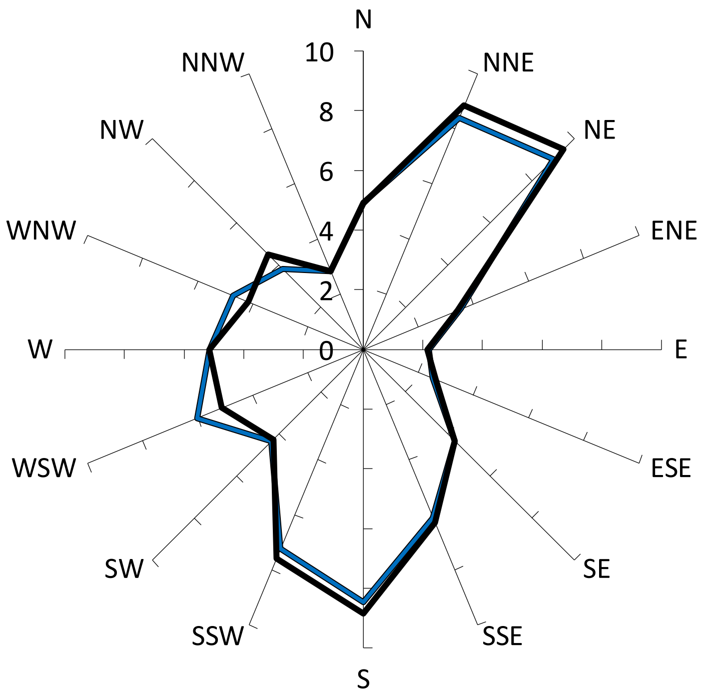


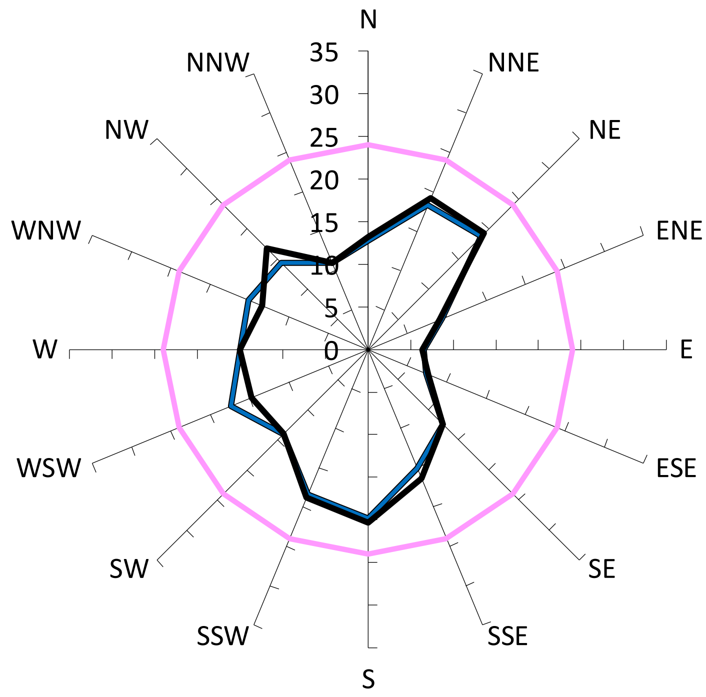
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	5%	19
Existing Site Conditions.	5%	19

Results for Point 25

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





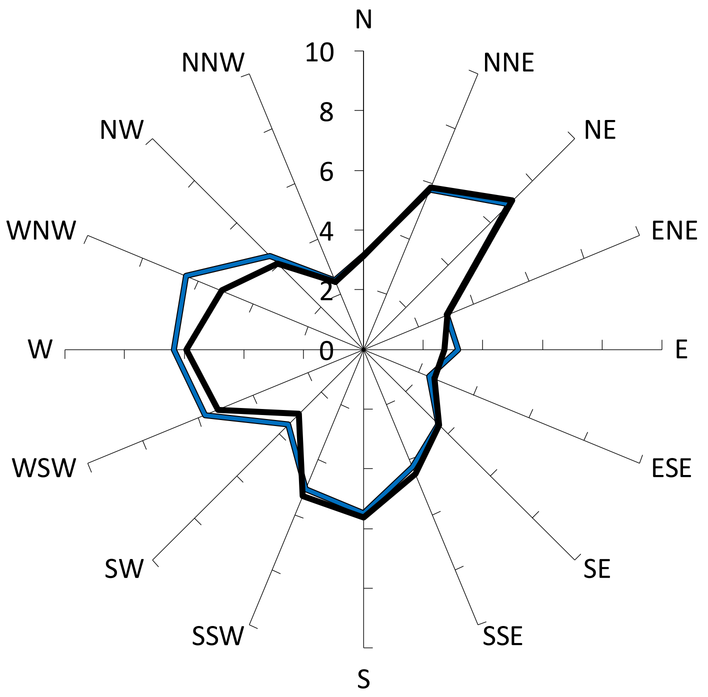
Comfort Criteria: 8m/s with 5% probability of exceedence

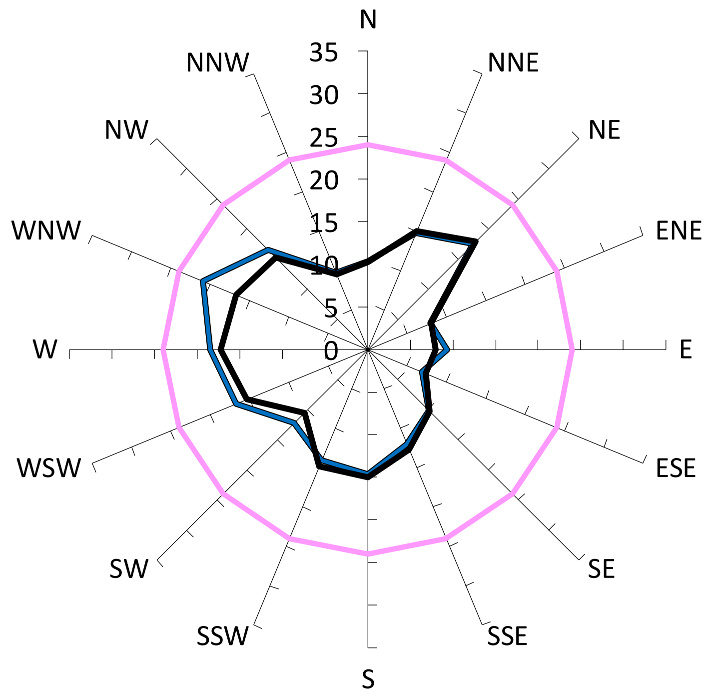
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	7%	20
Existing Site Conditions.	9%	20

Results for Point 26

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





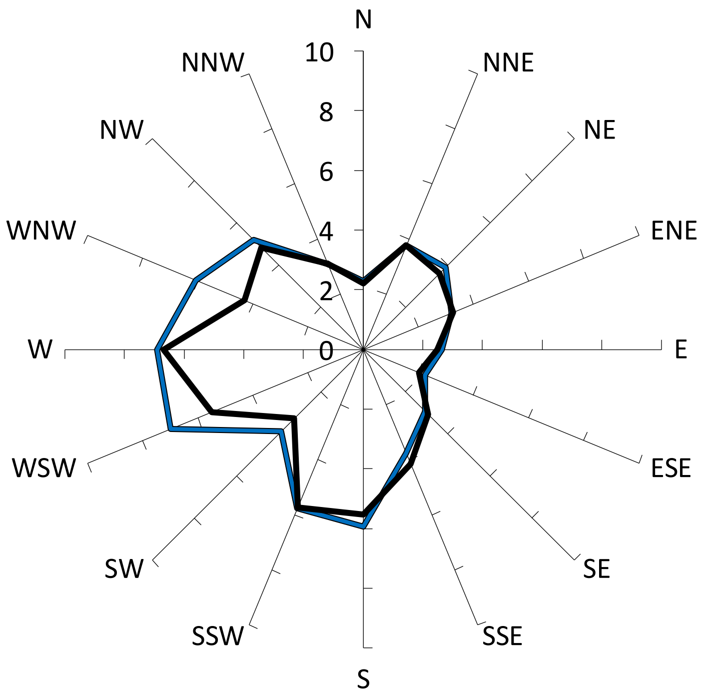
Comfort Criteria: 8m/s with 5% probability of exceedence

Safety Limit: 24m/s

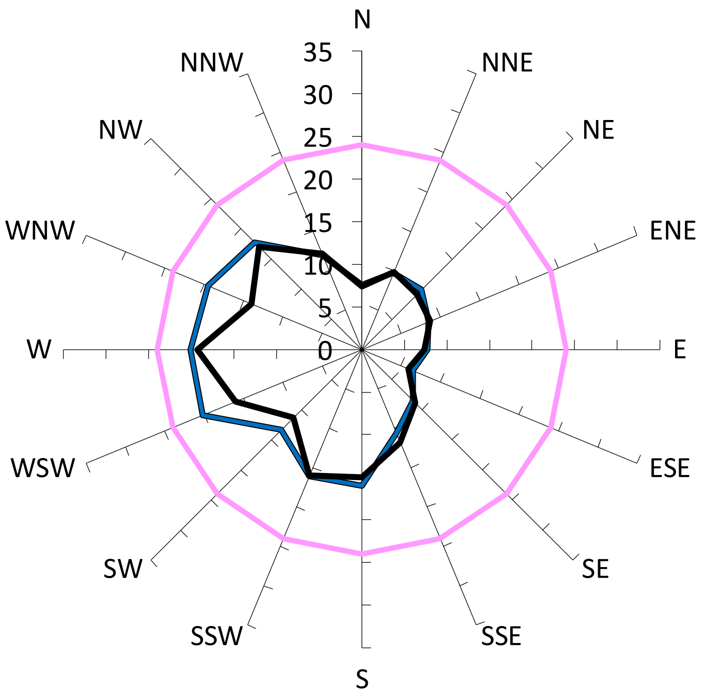
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	1%	21
Existing Site Conditions.	1%	18

Results for Point 27

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

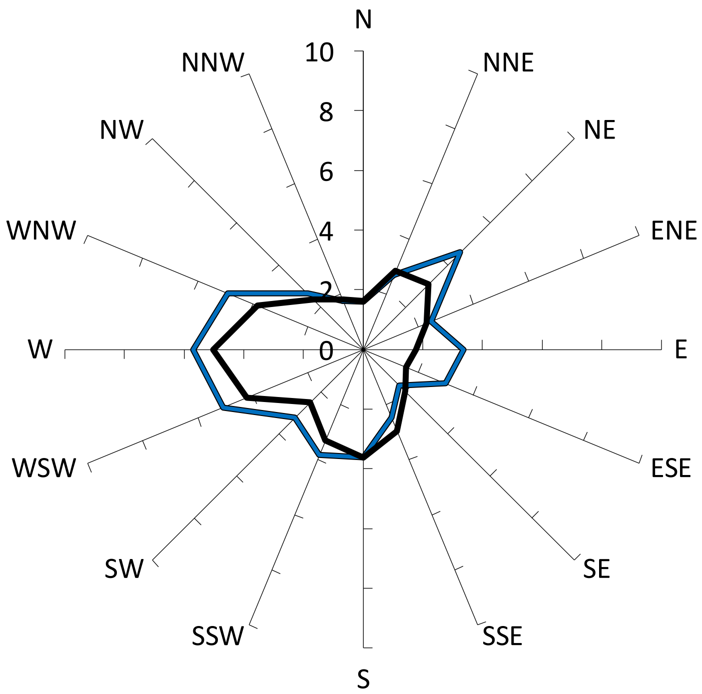


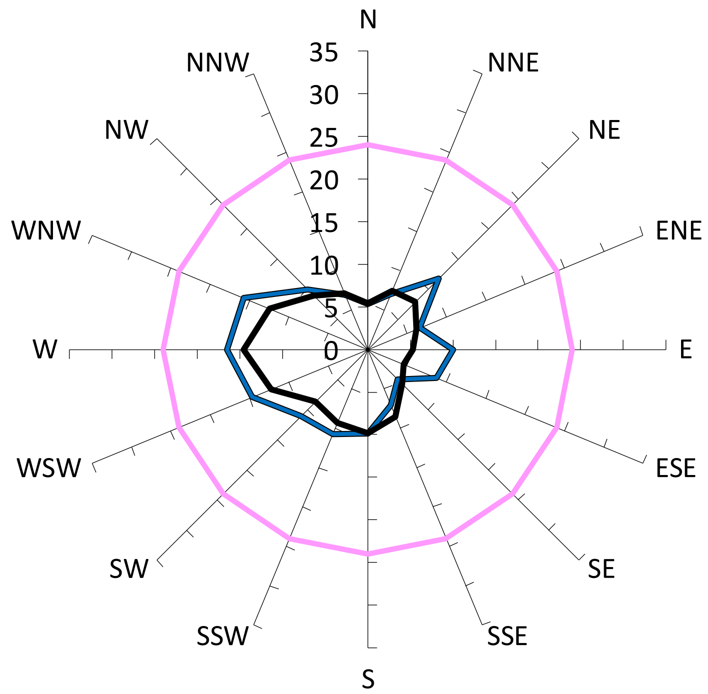
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	2%	20
Existing Site Conditions.	1%	19

Results for Point 28

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





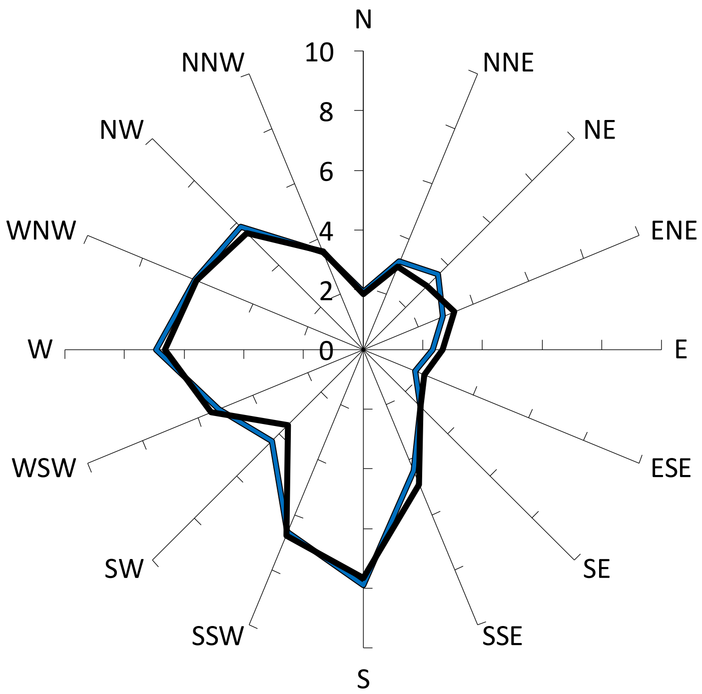
Comfort Criteria: 8m/s with 5% probability of exceedence

Safety Limit: 24m/s

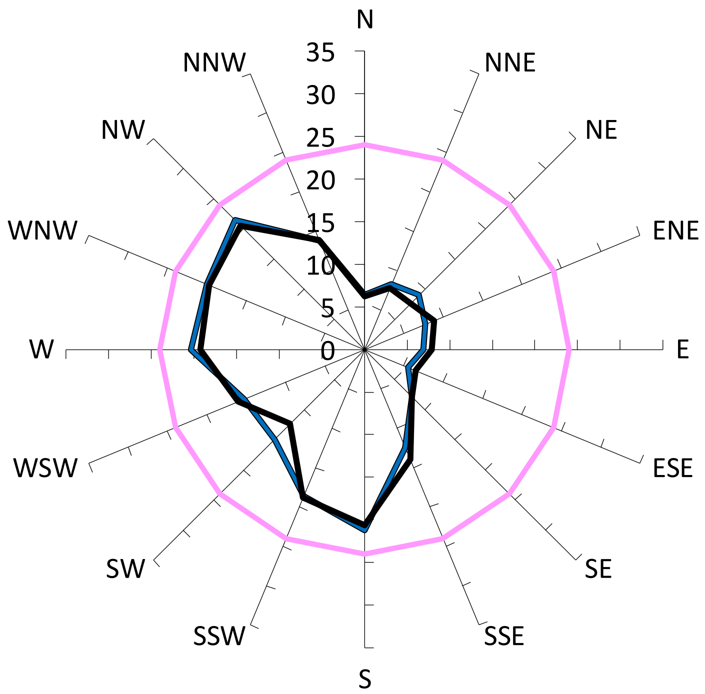
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	< 1%	17
Existing Site Conditions.	< 1%	15

Results for Point 29

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

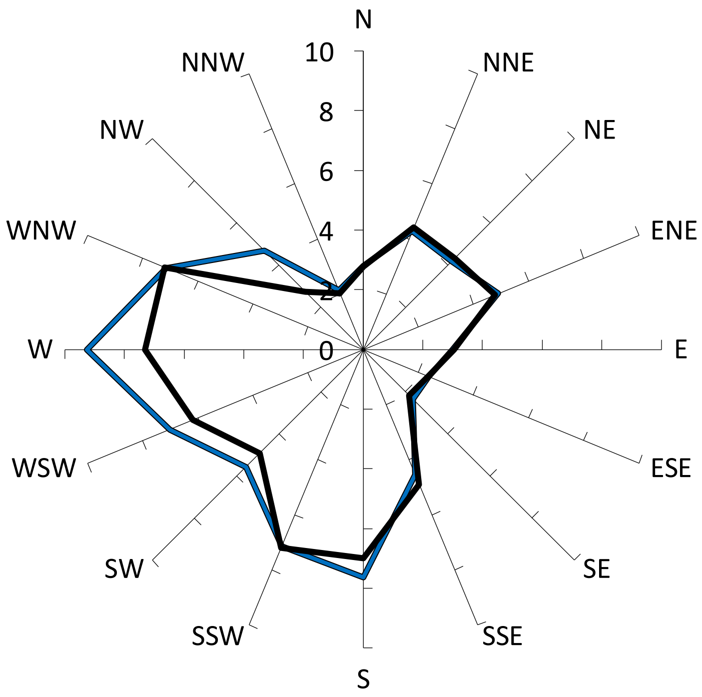


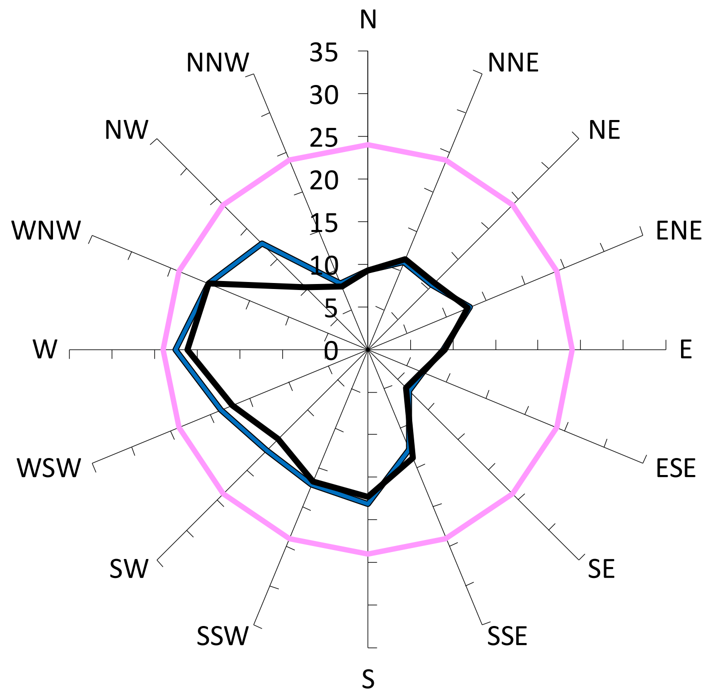
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	3%	21
Existing Site Conditions.	2%	21

Results for Point 30

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





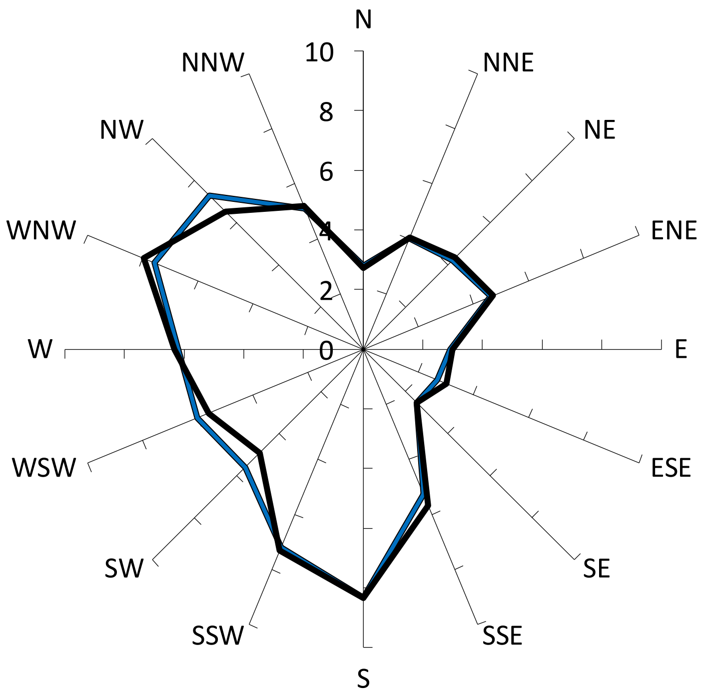
Comfort Criteria: 8m/s with 5% probability of exceedence

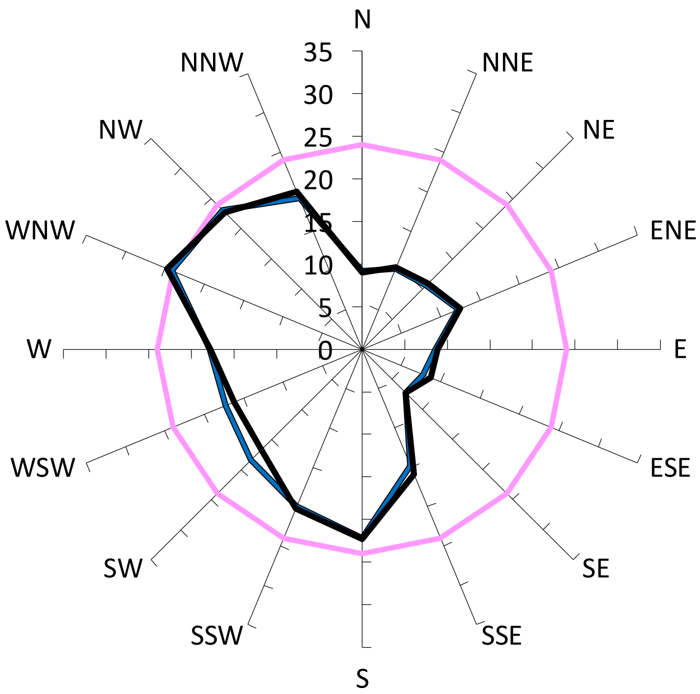
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	5%	23
Existing Site Conditions.	3%	21

Results for Point 31

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





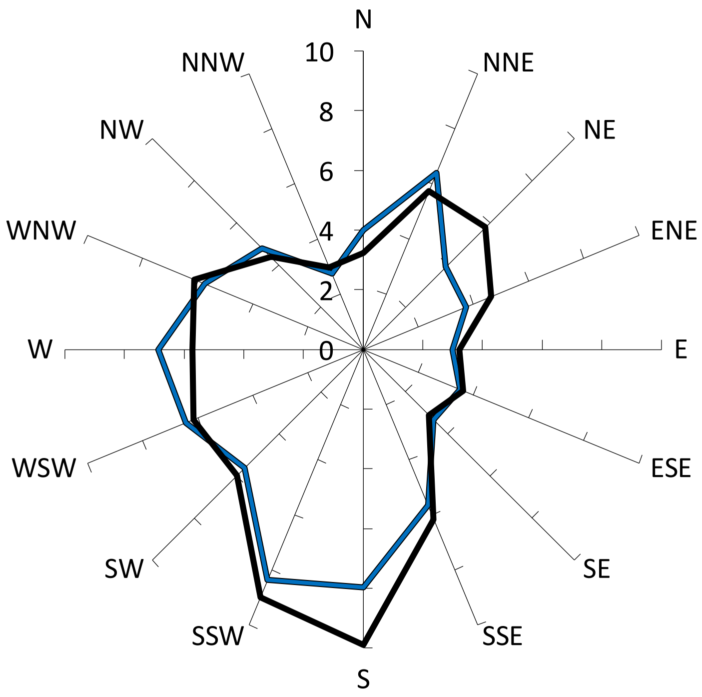
Comfort Criteria: 8m/s with 5% probability of exceedence

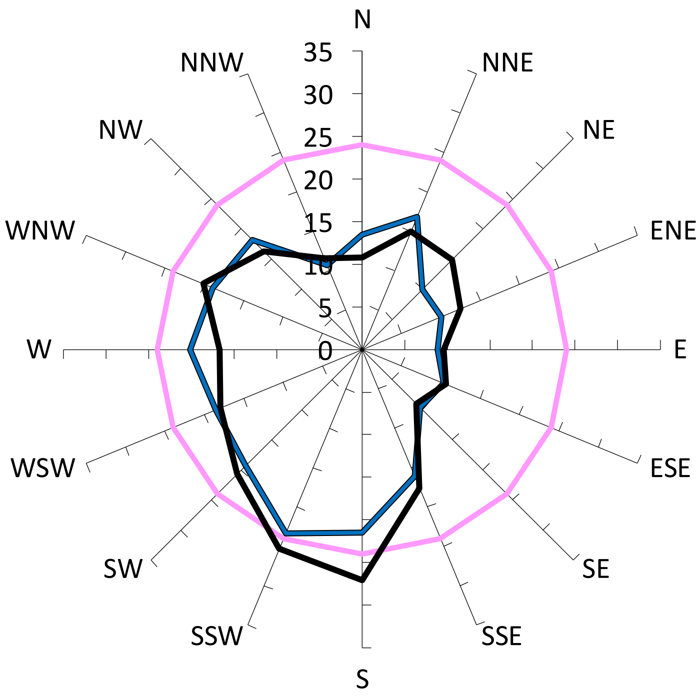
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	5%	24
Existing Site Conditions.	5%	25

Results for Point 32

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





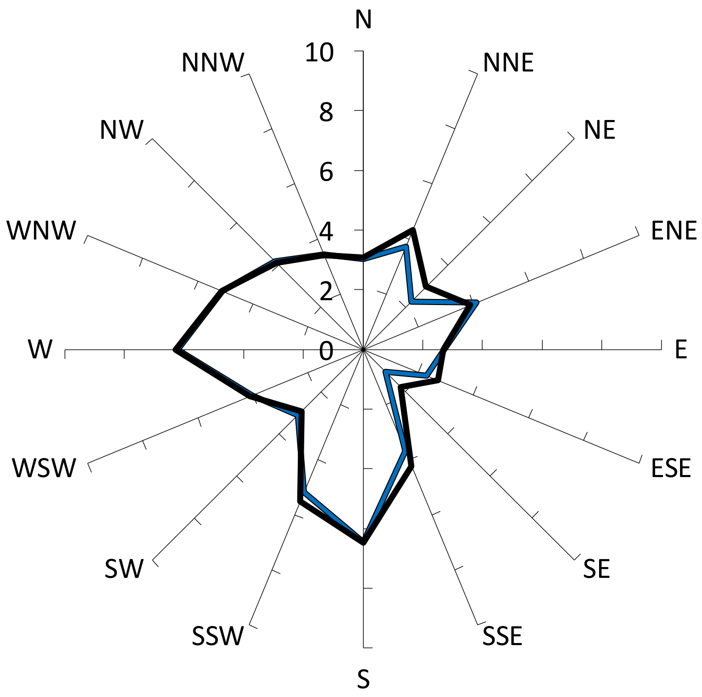
Comfort Criteria: 8m/s with 5% probability of exceedence

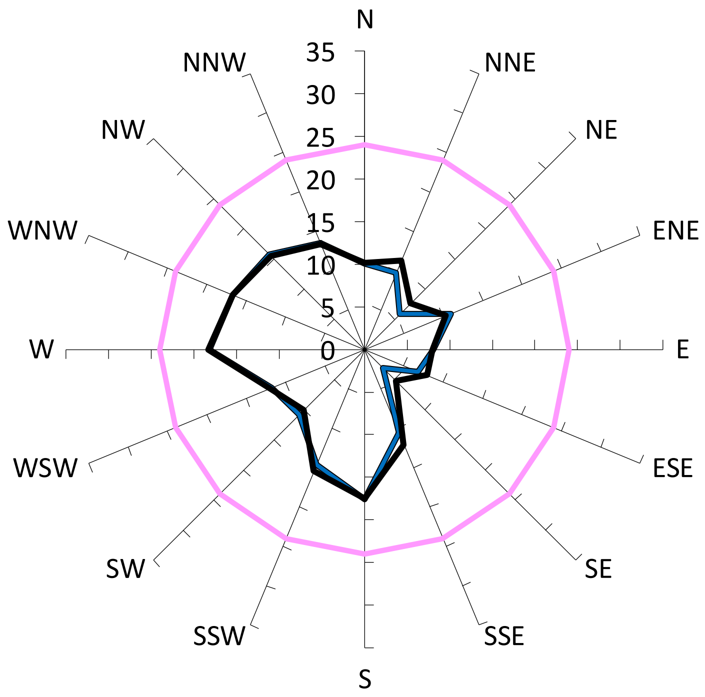
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	4%	23
Existing Site Conditions.	8%	27

Results for Point 33

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





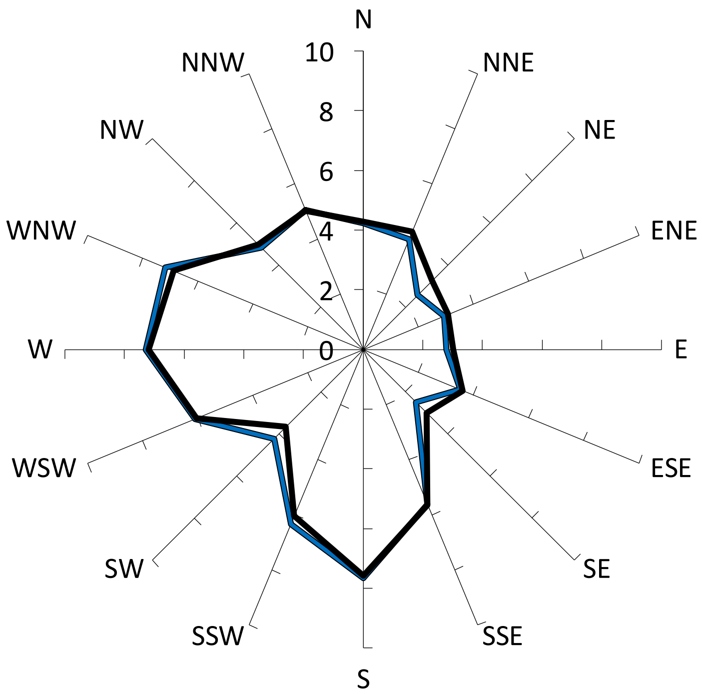
Comfort Criteria: 8m/s with 5% probability of exceedence

Safety Limit: 24m/s

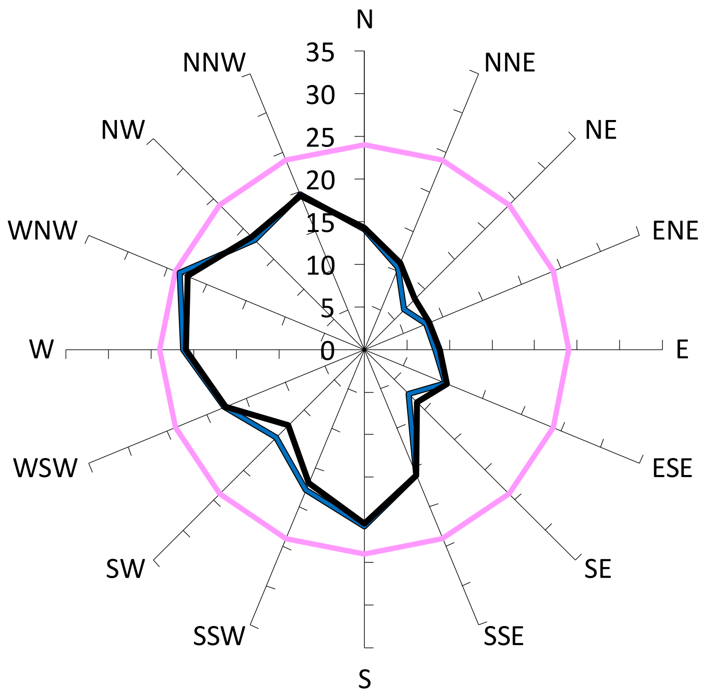
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	1%	18
Existing Site Conditions.	1%	18

Results for Point 34

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)



Comfort Criteria: 8m/s with 5% probability of exceedence

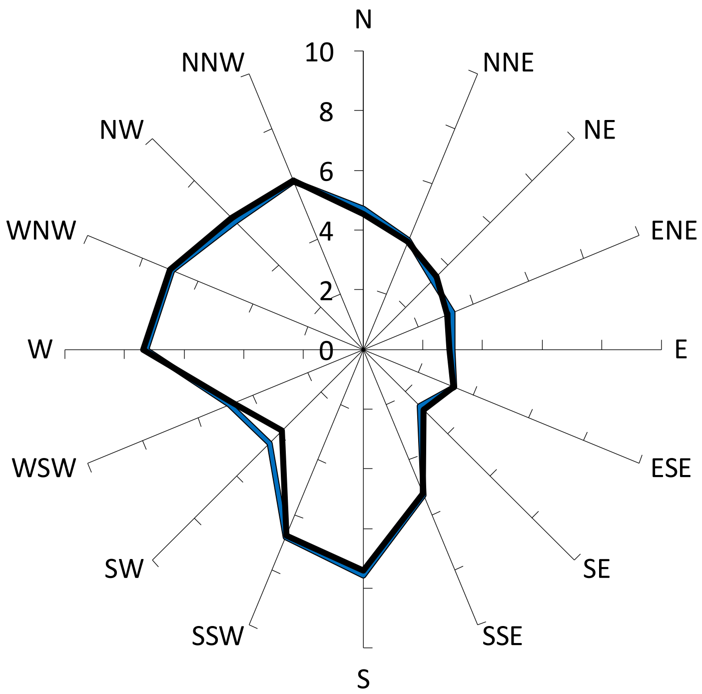


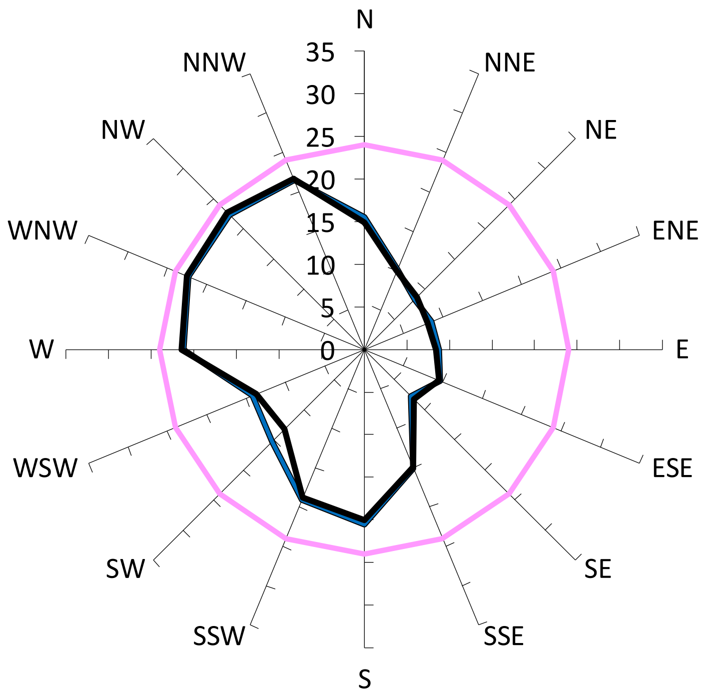
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	3%	23
Existing Site Conditions.	3%	22

Results for Point 35

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





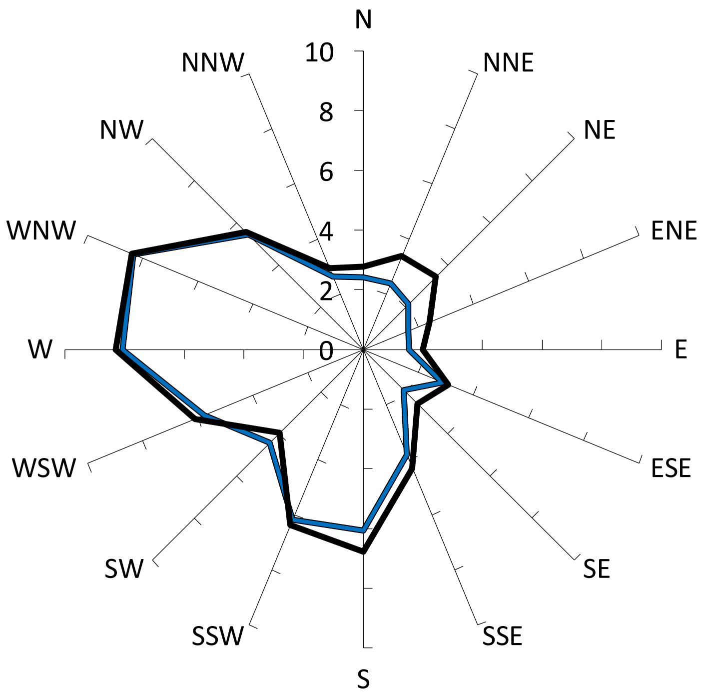
Comfort Criteria: 8m/s with 5% probability of exceedence

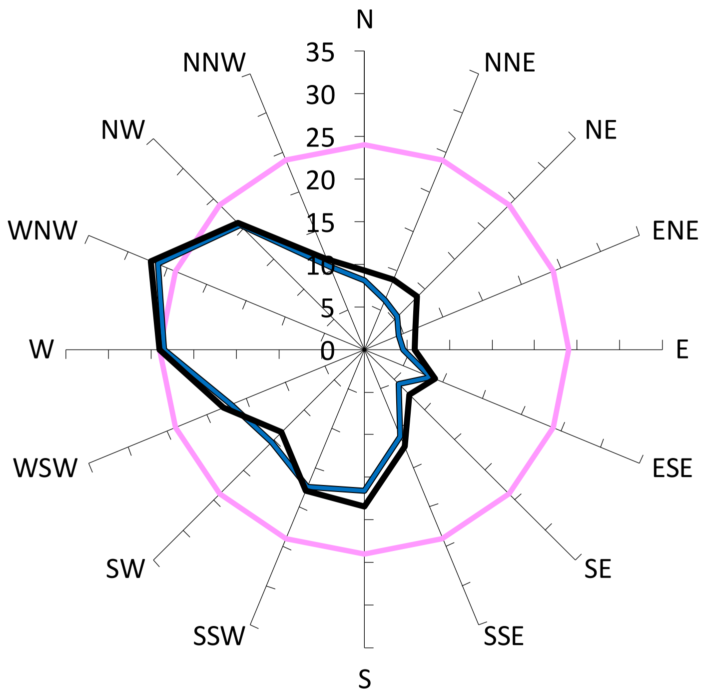
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	4%	22
Existing Site Conditions.	4%	23

Results for Point 36

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





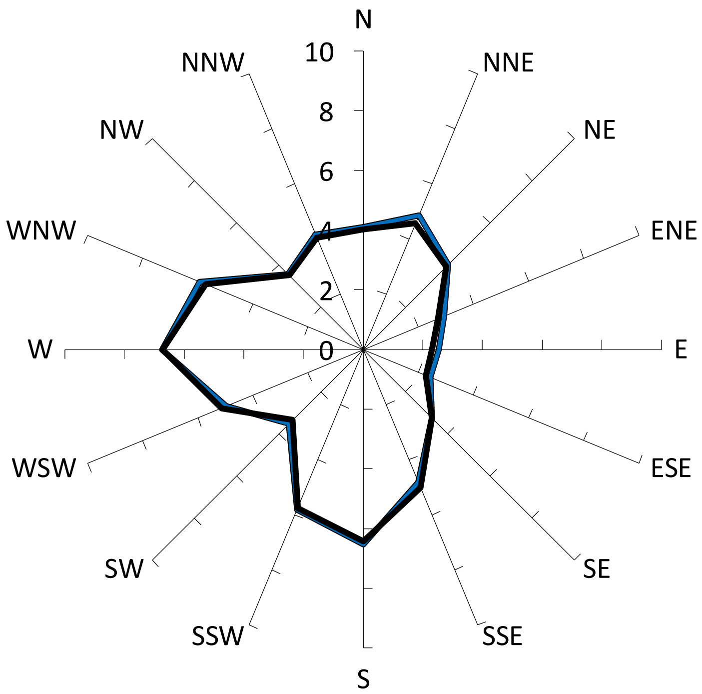
Comfort Criteria: 8m/s with 5% probability of exceedence

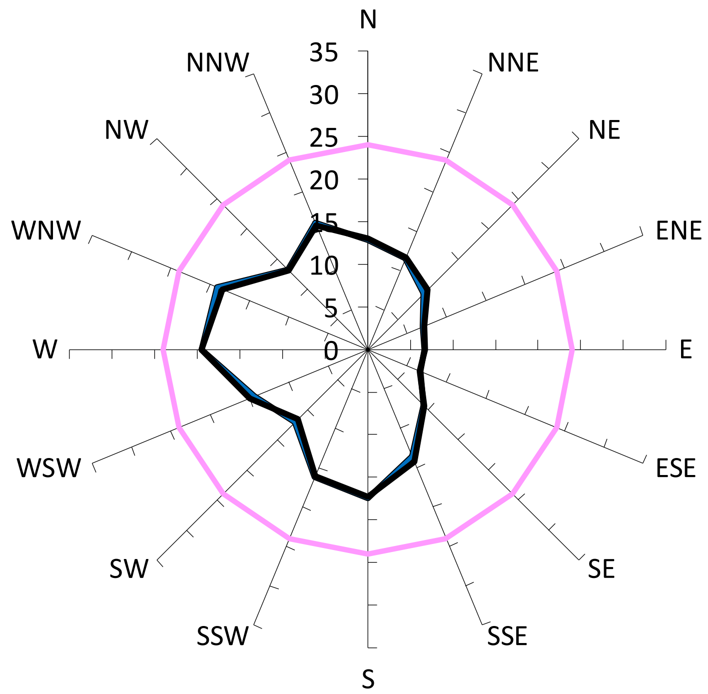
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	3%	26
Existing Site Conditions.	4%	27

Results for Point 37

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





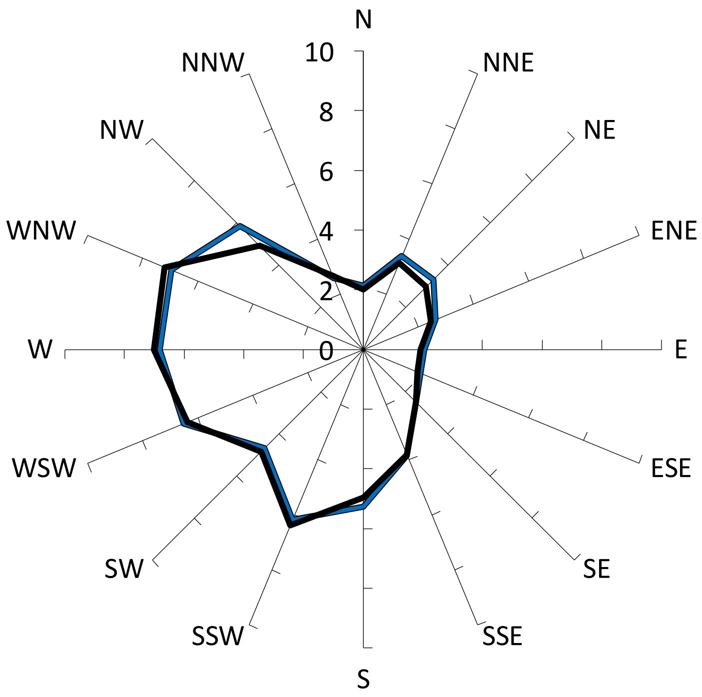
Comfort Criteria: 8m/s with 5% probability of exceedence

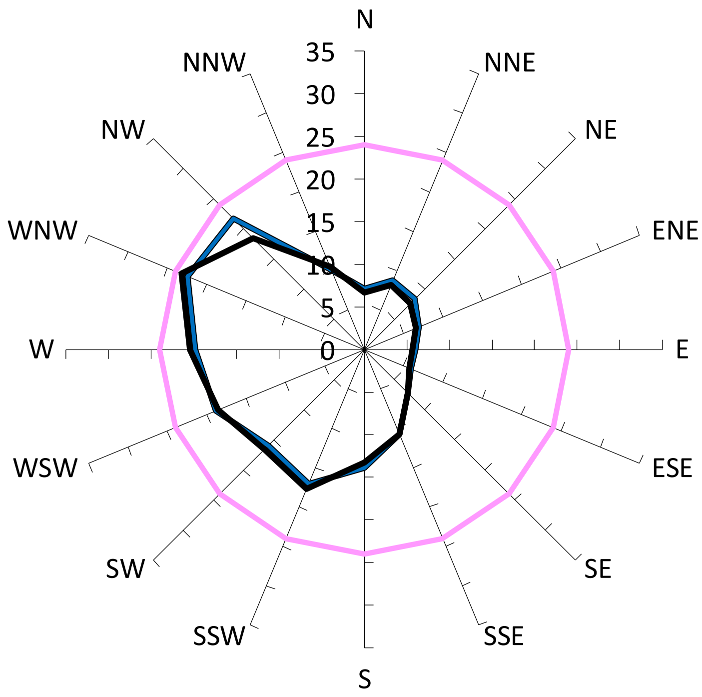
Safety Limit: 24m/s

Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	1%	19
Existing Site Conditions.	1%	19

Results for Point 38

Gust Equivalent Mean (m/s)	Annual Maximum Gust (m/s)





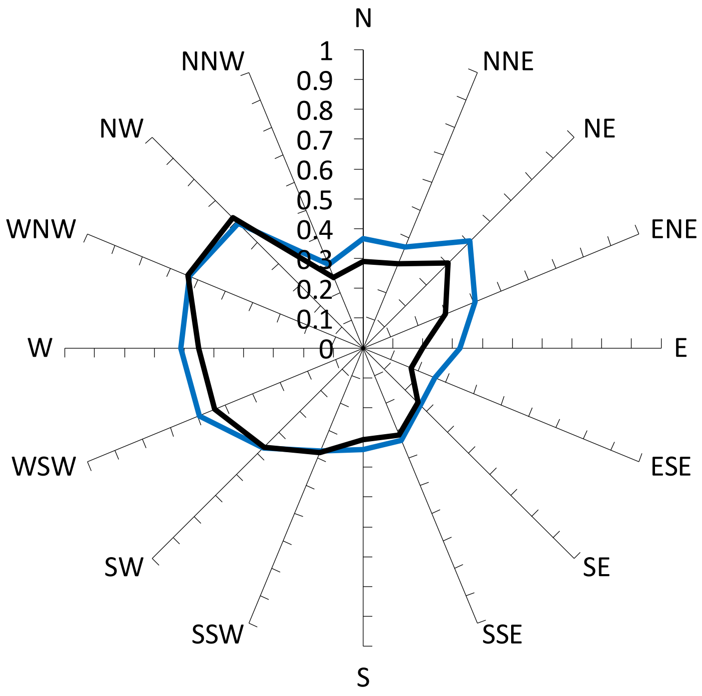
Comfort Criteria: 8m/s with 5% probability of exceedence

Safety Limit: 24m/s

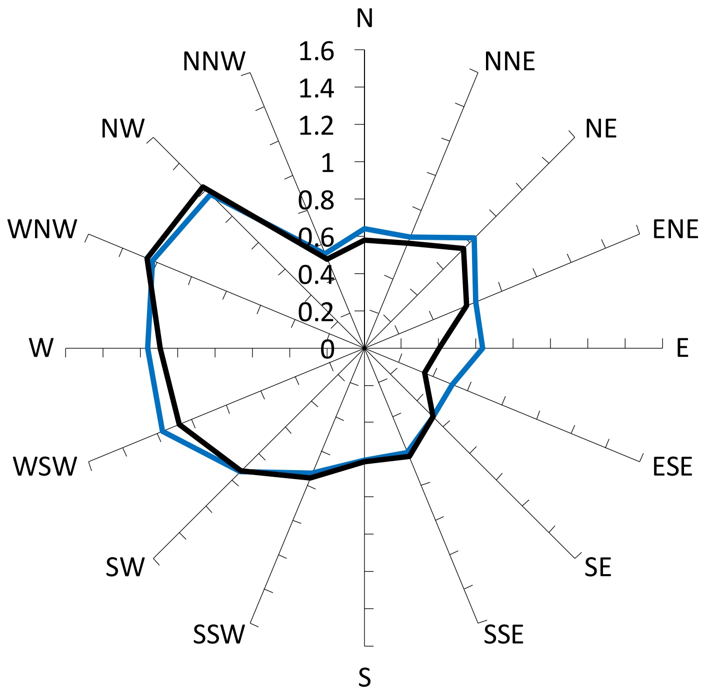
Description	GEM Prob of Exceed %	Peak Gust m/s
Criterion: Wind Comfort Standard for Walking Criterion (8m/s). Safety Limit (24m/s).	5%	24
With development "as proposed", no vegetation included.	2%	22
Existing Site Conditions.	2%	23

APPENDIX D DIRECTIONAL VELOCITY COEFFICIENT PLOTS

Results for Point 01



GEM Velocity Coefficients

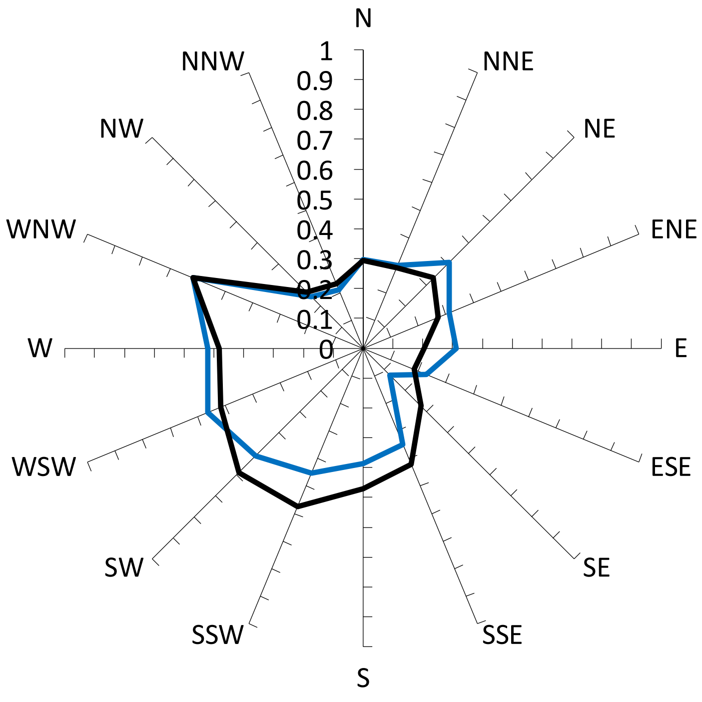


Gust Velocity Coefficients

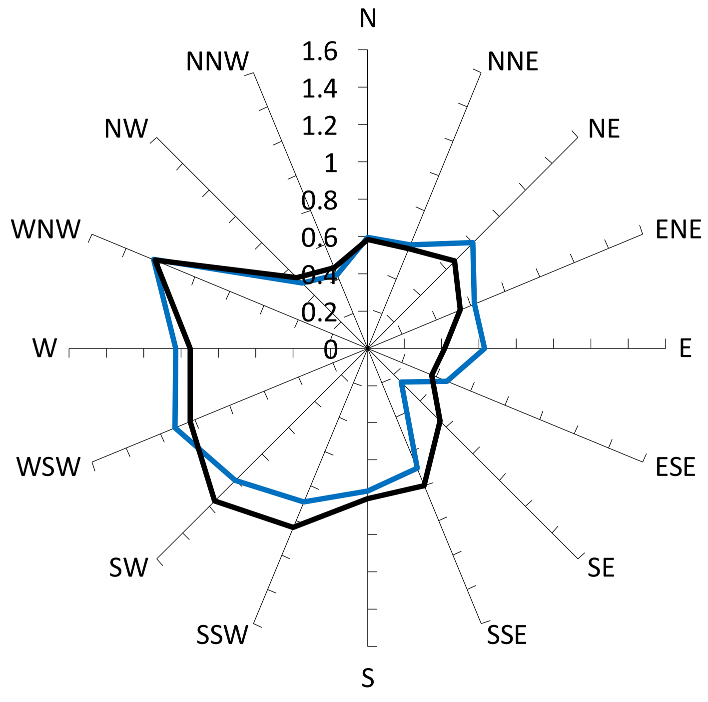
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 02



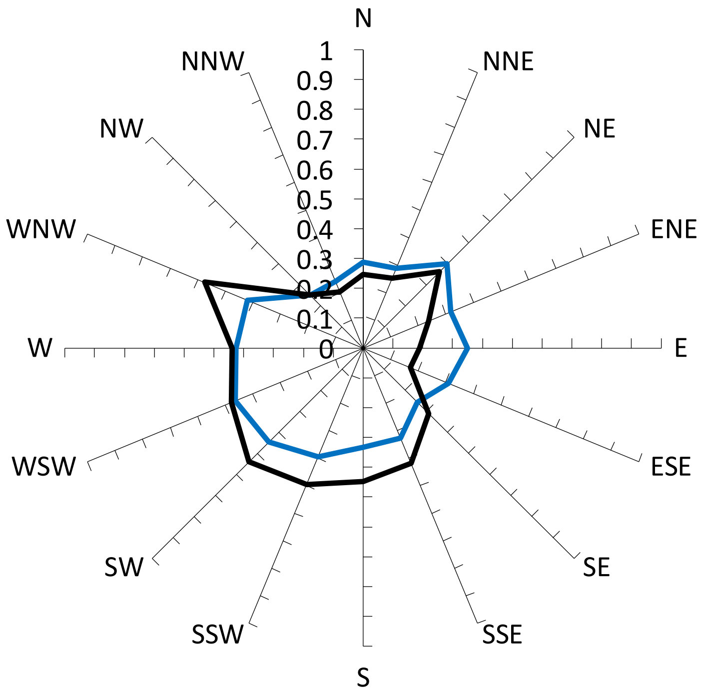
GEM Velocity Coefficients



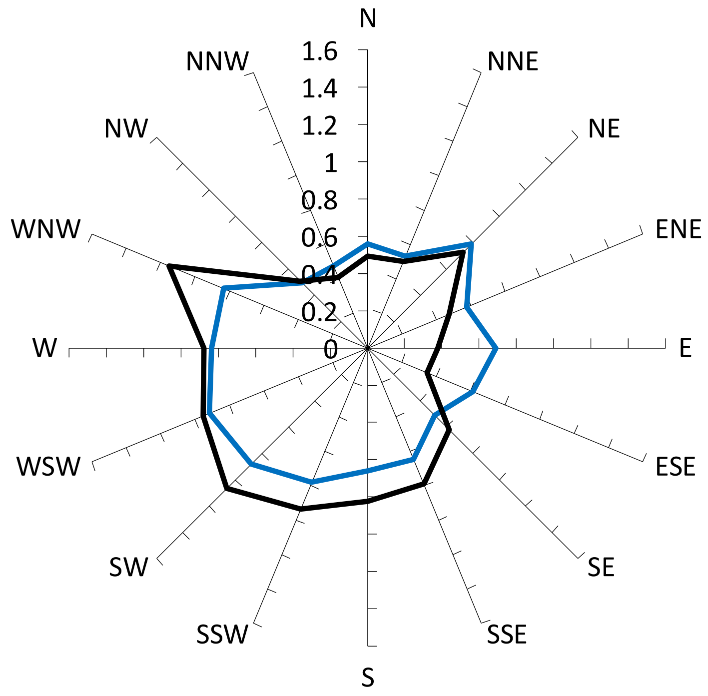
Gust Velocity Coefficients

With development "as proposed", no vegetation included.
Existing Site Conditions.

Results for Point 03



GEM Velocity Coefficients

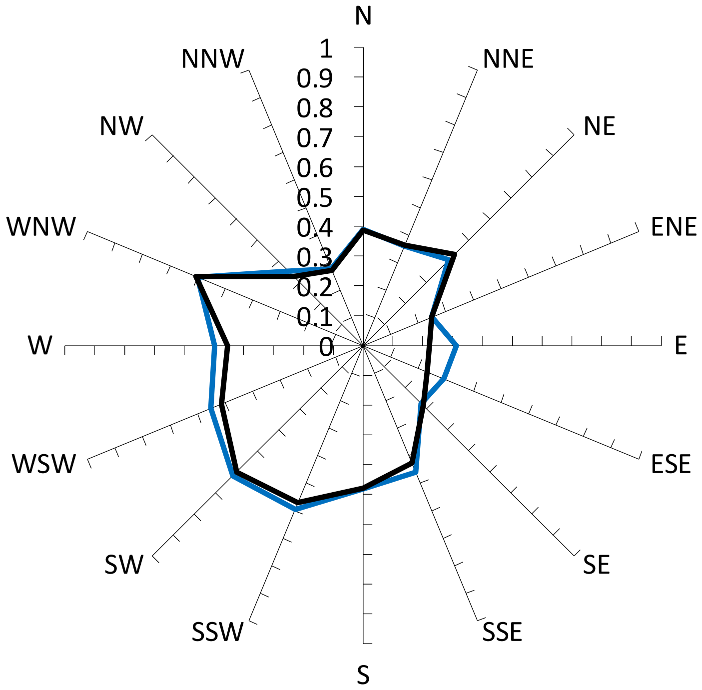


Gust Velocity Coefficients

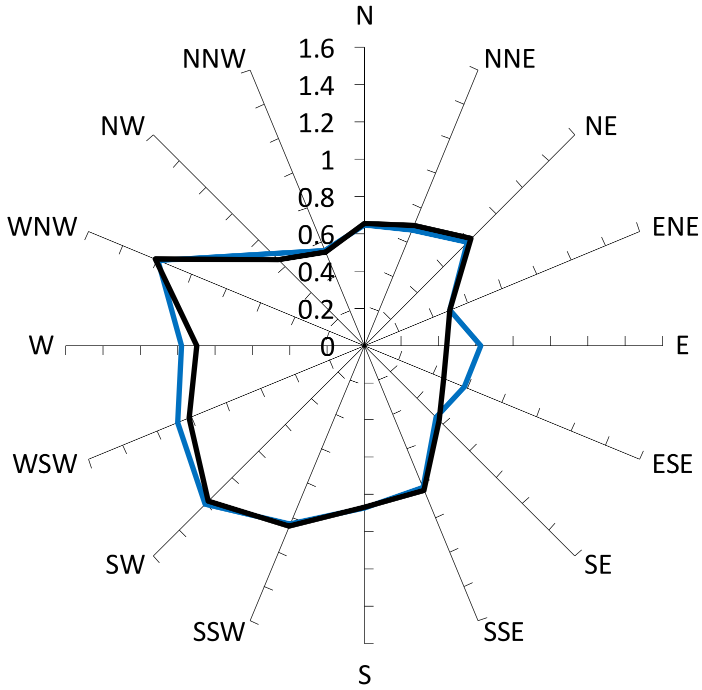
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 04



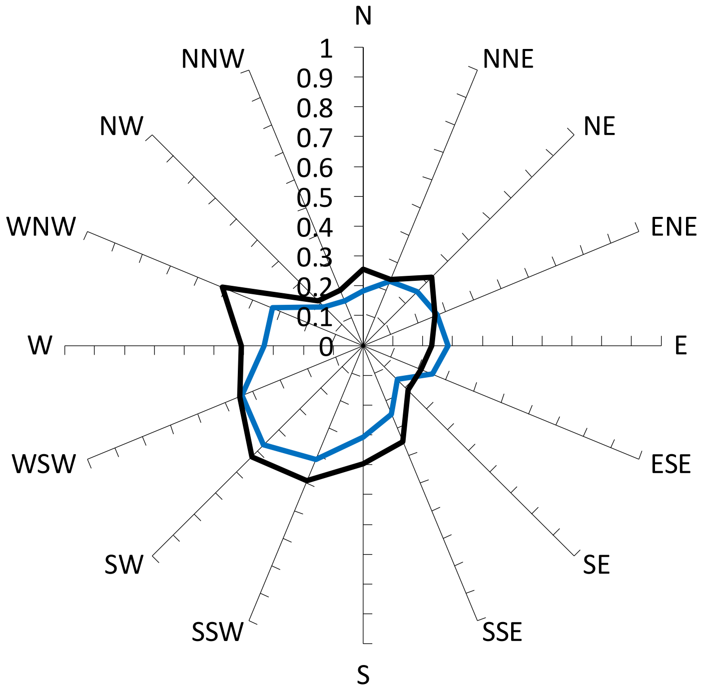
GEM Velocity Coefficients



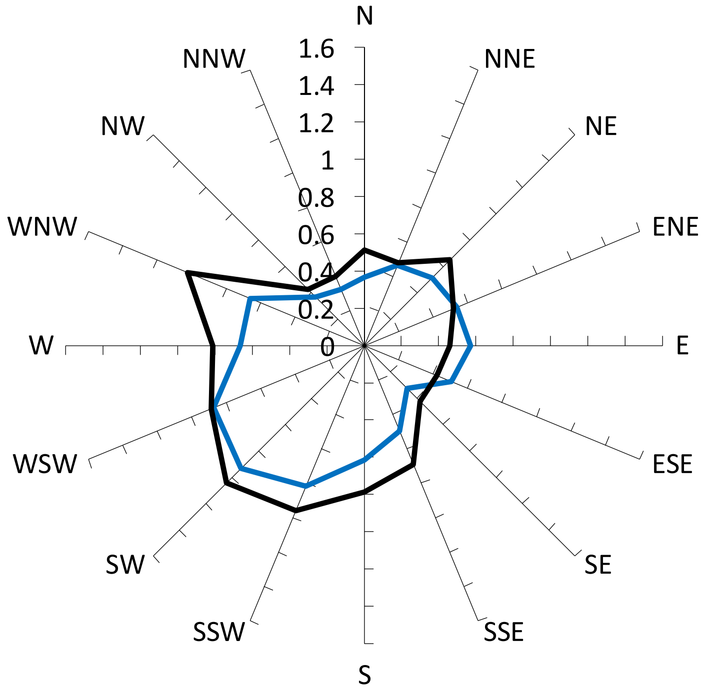
Gust Velocity Coefficients

With development "as proposed", no vegetation included.
Existing Site Conditions.

Results for Point 05



GEM Velocity Coefficients

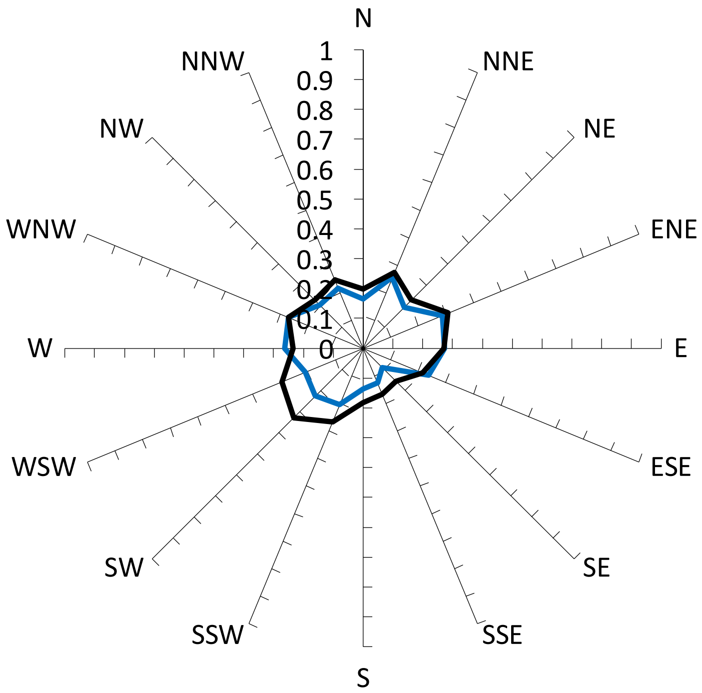


Gust Velocity Coefficients

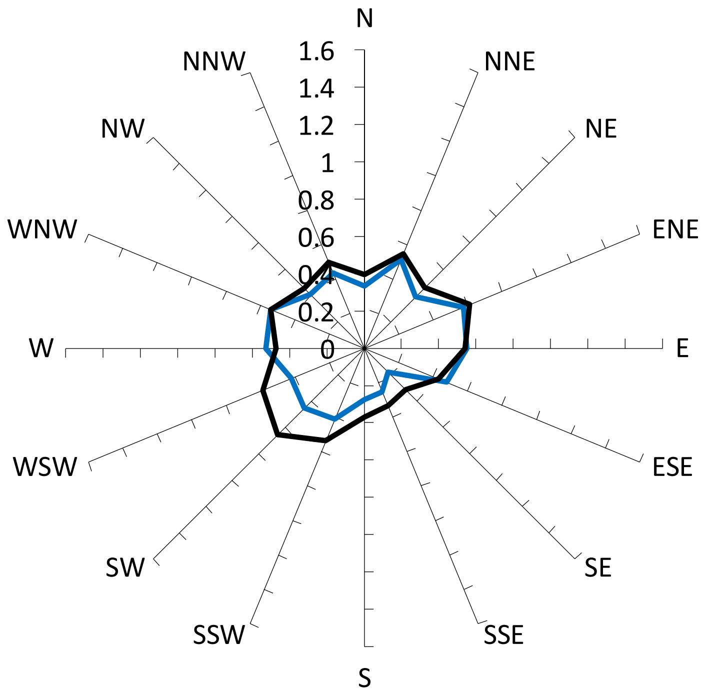
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 06



GEM Velocity Coefficients

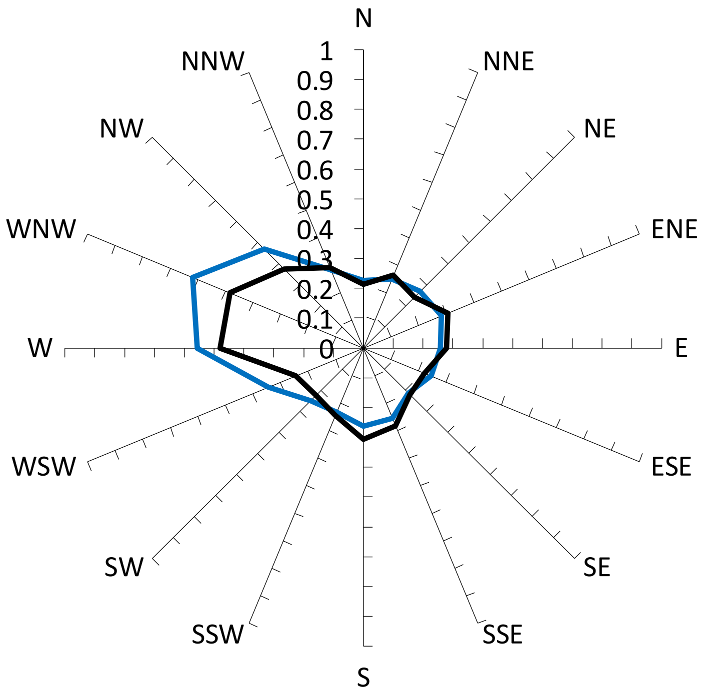


Gust Velocity Coefficients

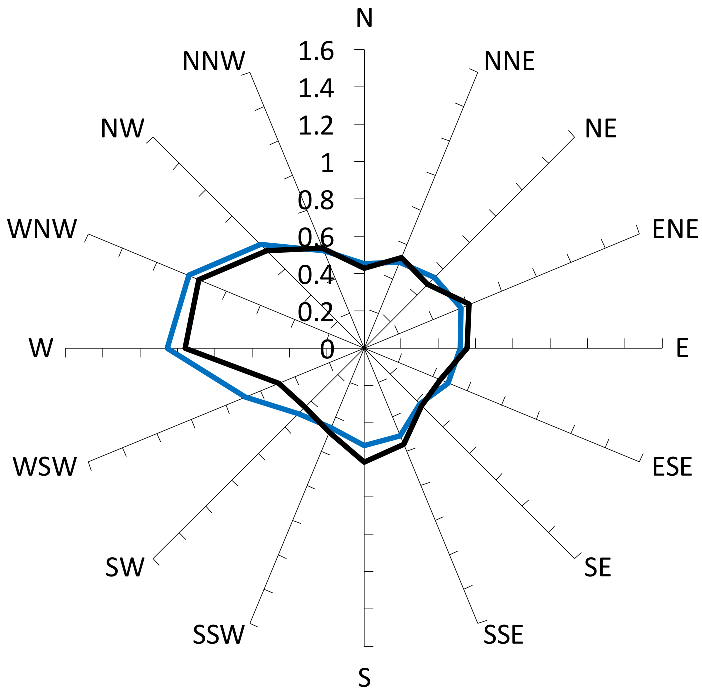
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 07



GEM Velocity Coefficients

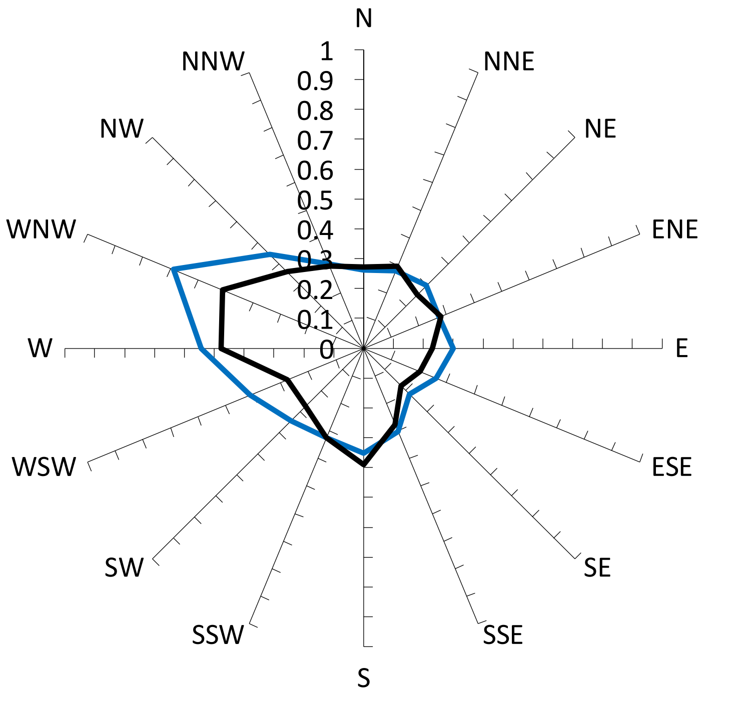


Gust Velocity Coefficients

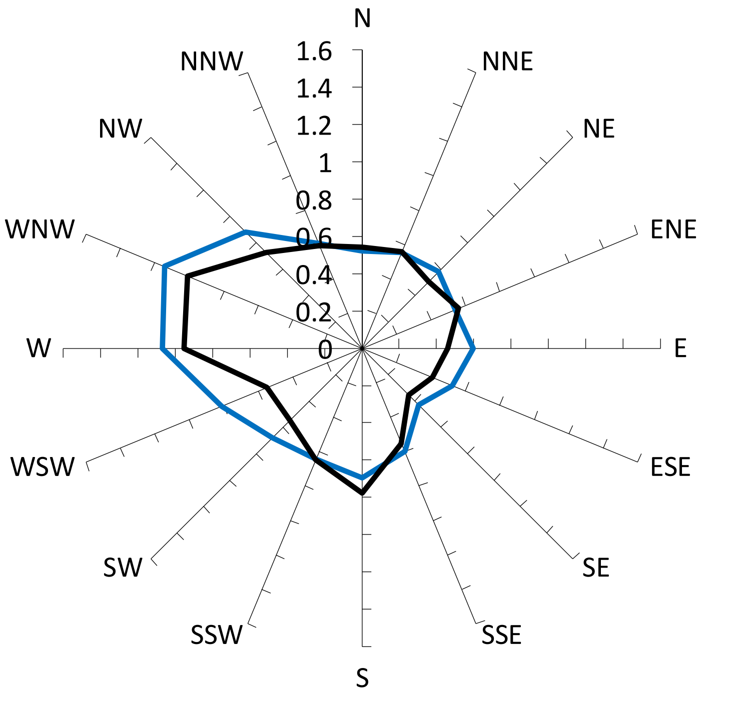
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 08



GEM Velocity Coefficients

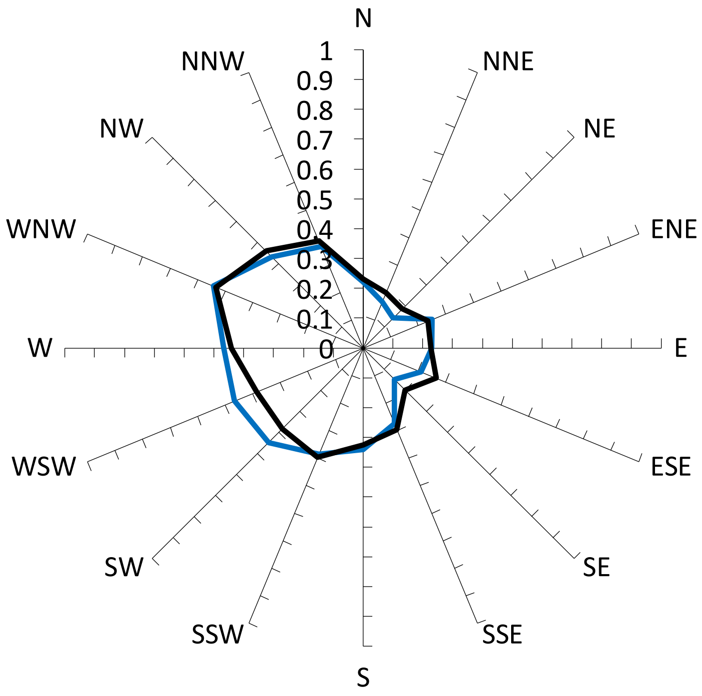


Gust Velocity Coefficients

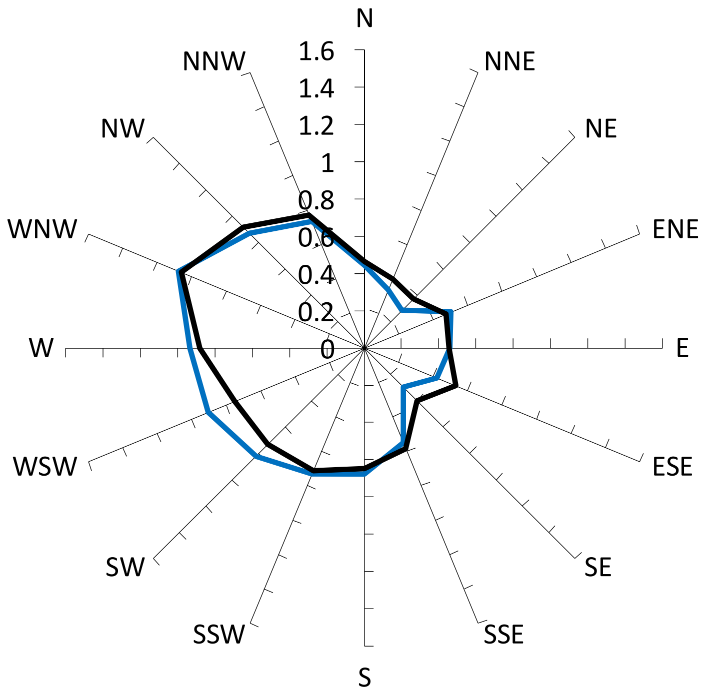
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 09



GEM Velocity Coefficients

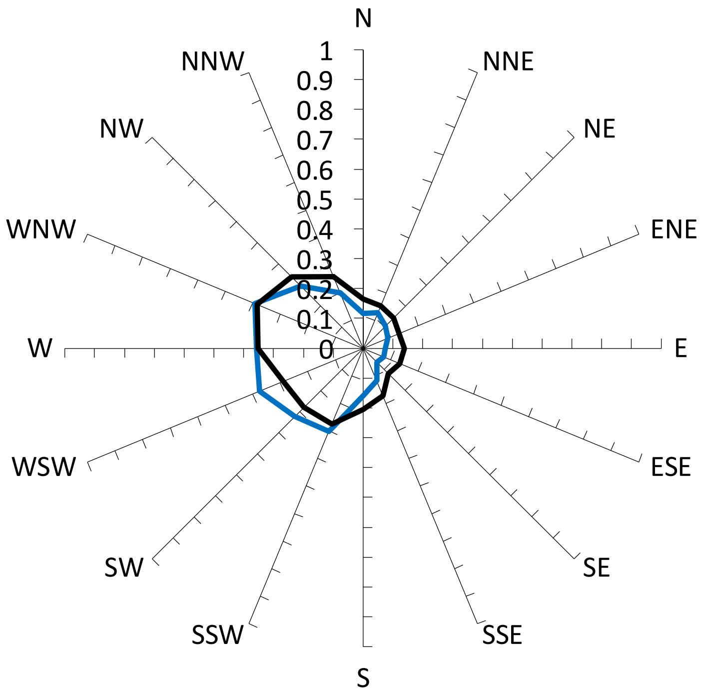


Gust Velocity Coefficients

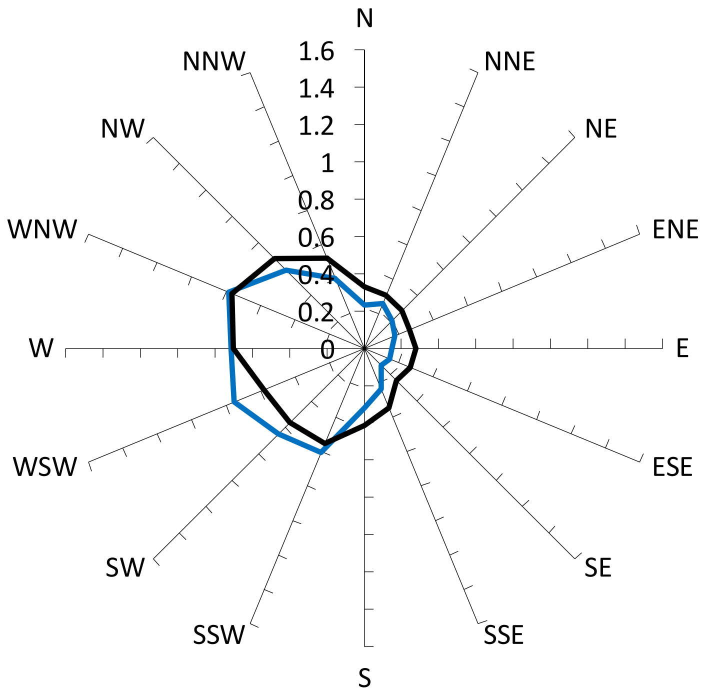
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 10



GEM Velocity Coefficients

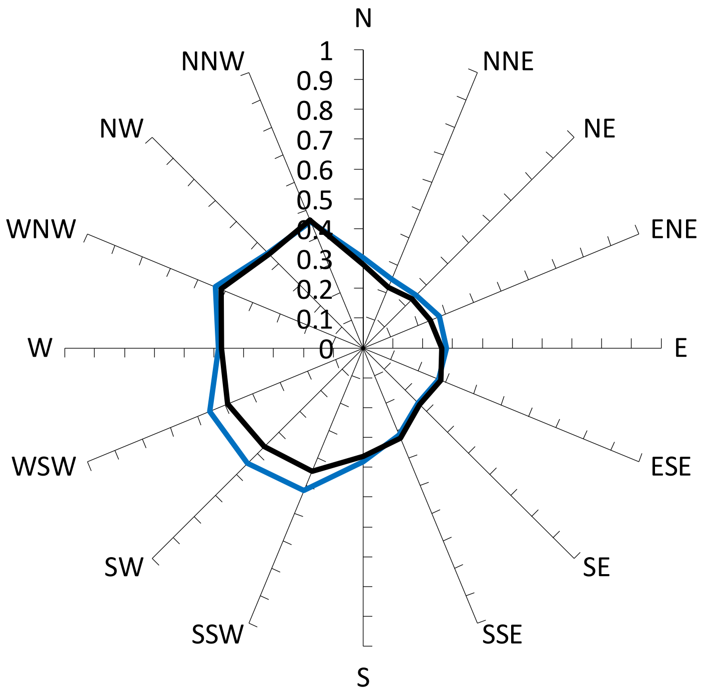


Gust Velocity Coefficients

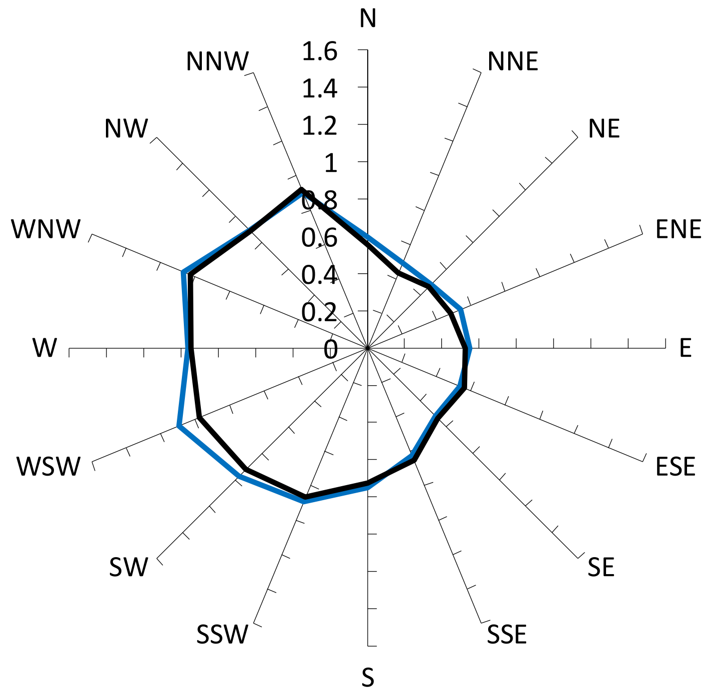
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 11



GEM Velocity Coefficients

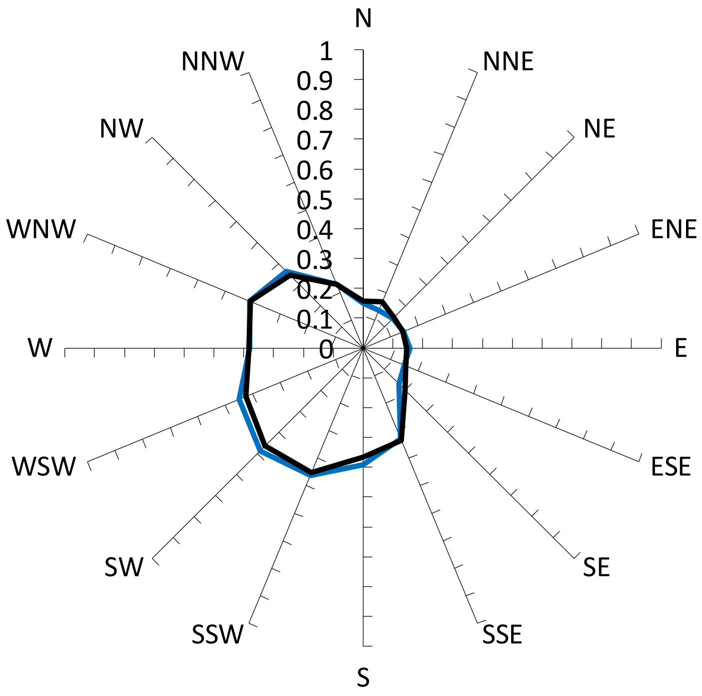


Gust Velocity Coefficients

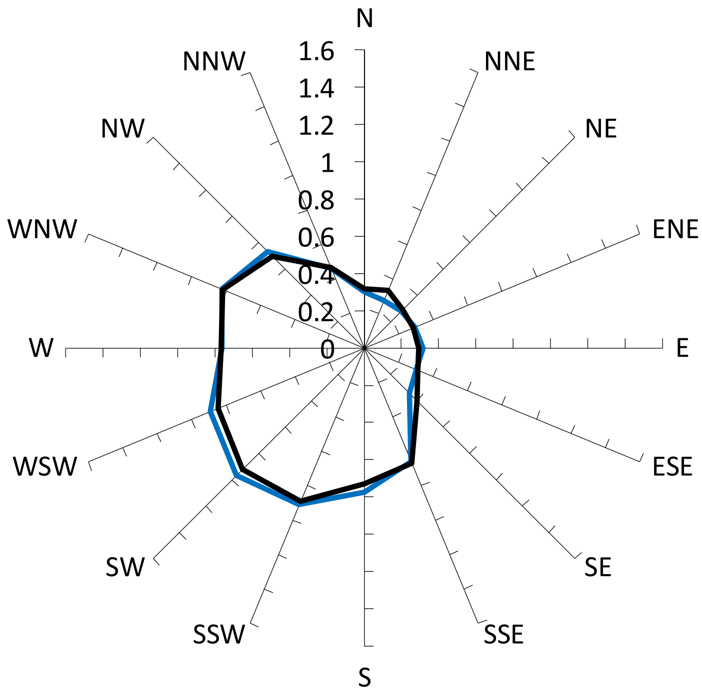
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 12



GEM Velocity Coefficients

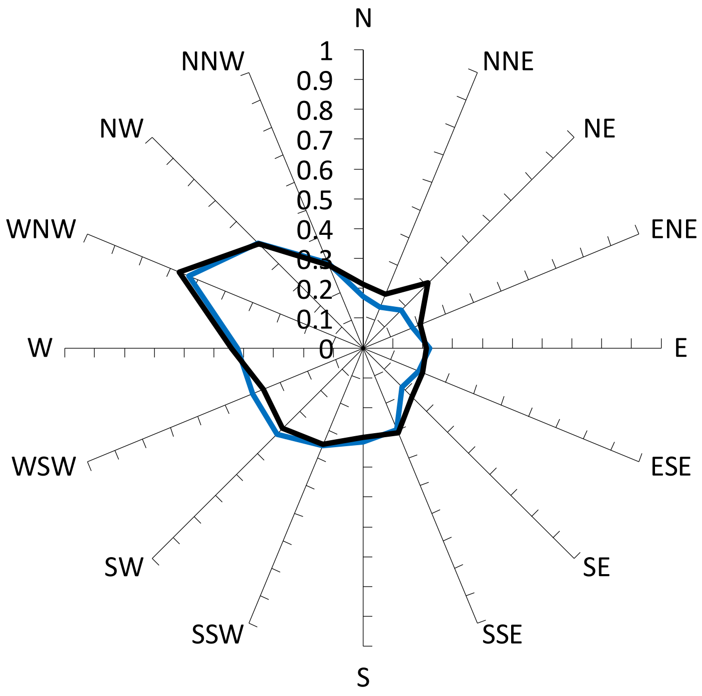


Gust Velocity Coefficients

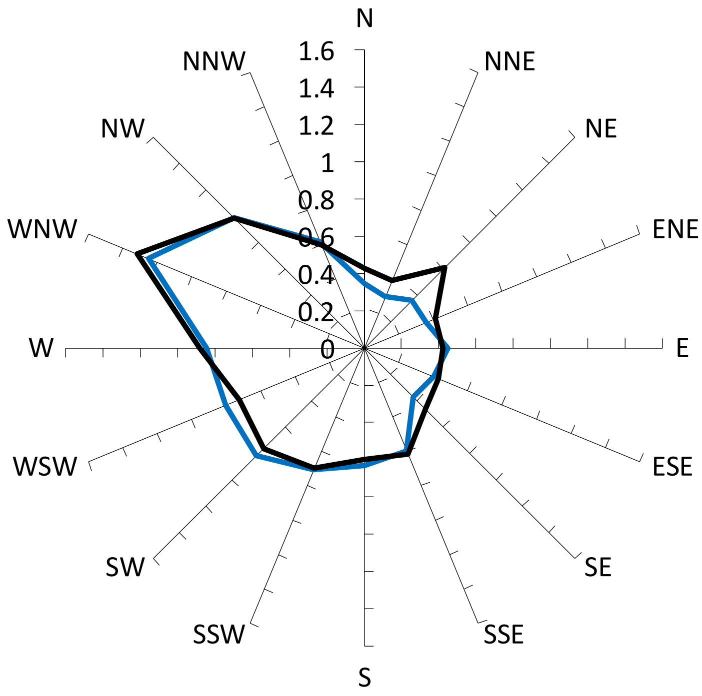
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 13



GEM Velocity Coefficients

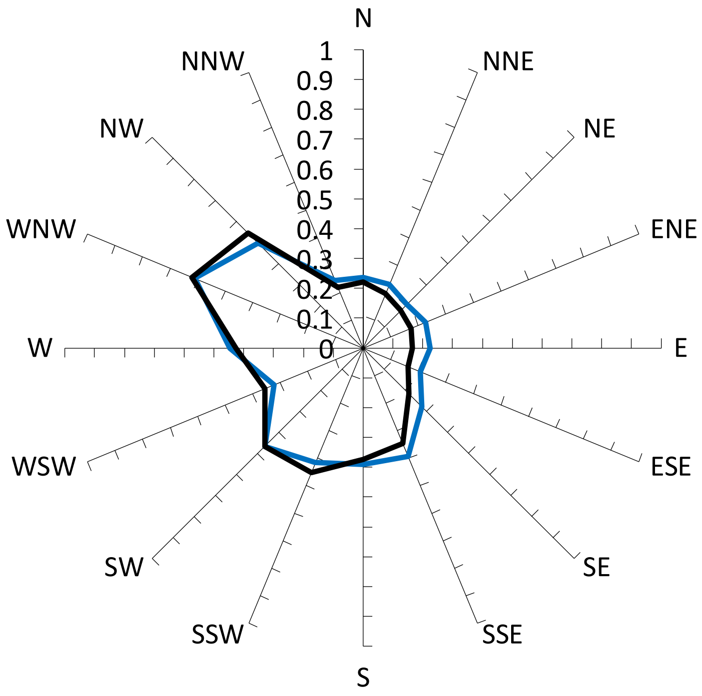


Gust Velocity Coefficients

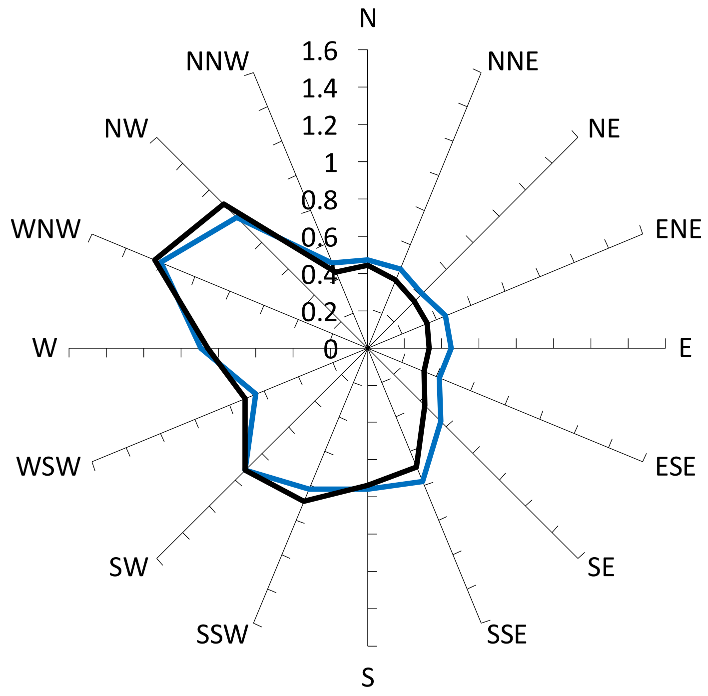
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 14



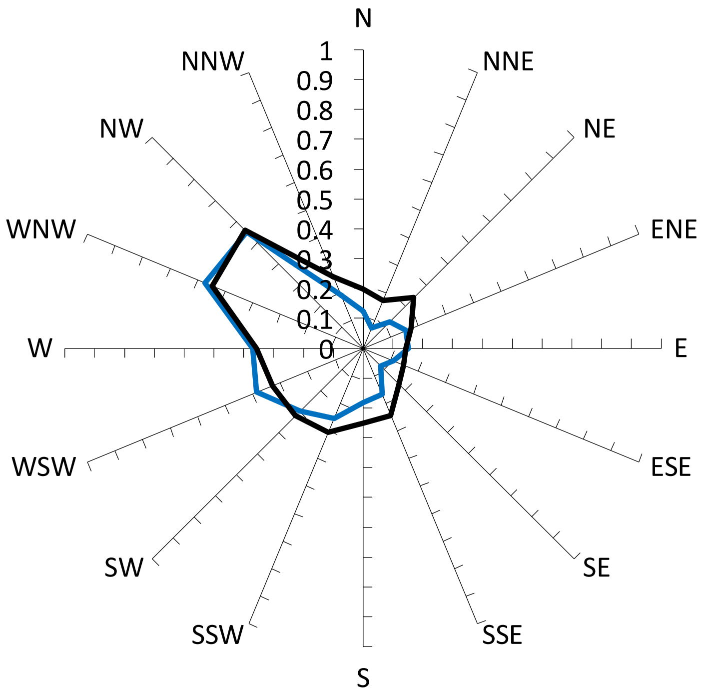
GEM Velocity Coefficients



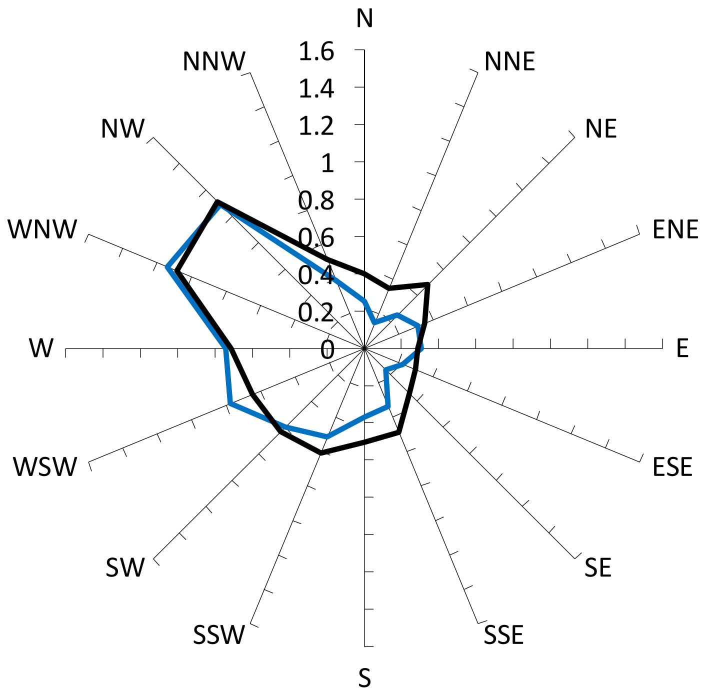
Gust Velocity Coefficients

With development "as proposed", no vegetation included.
Existing Site Conditions.

Results for Point 15



GEM Velocity Coefficients

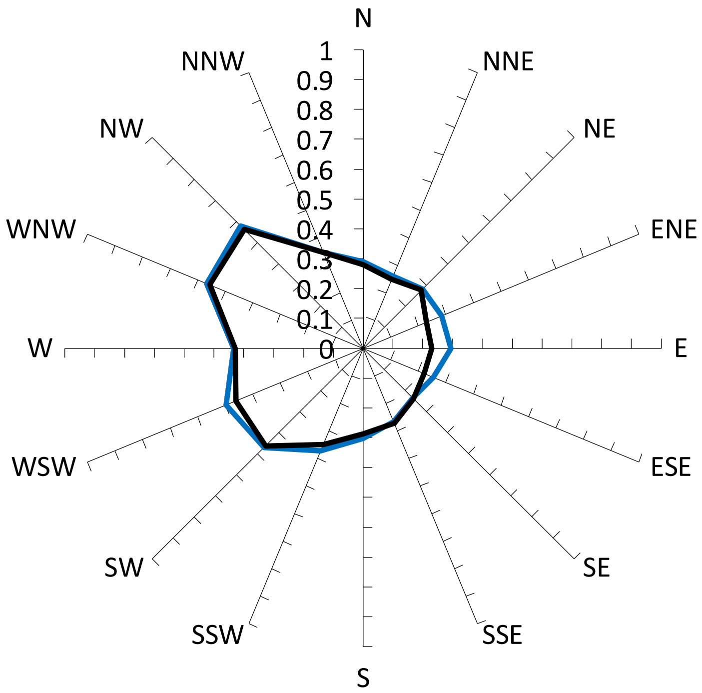


Gust Velocity Coefficients

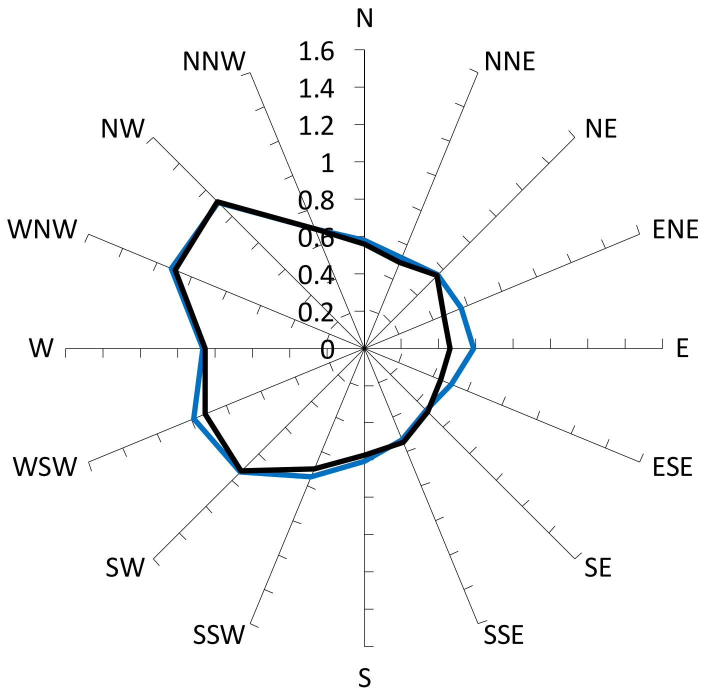
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 16



GEM Velocity Coefficients

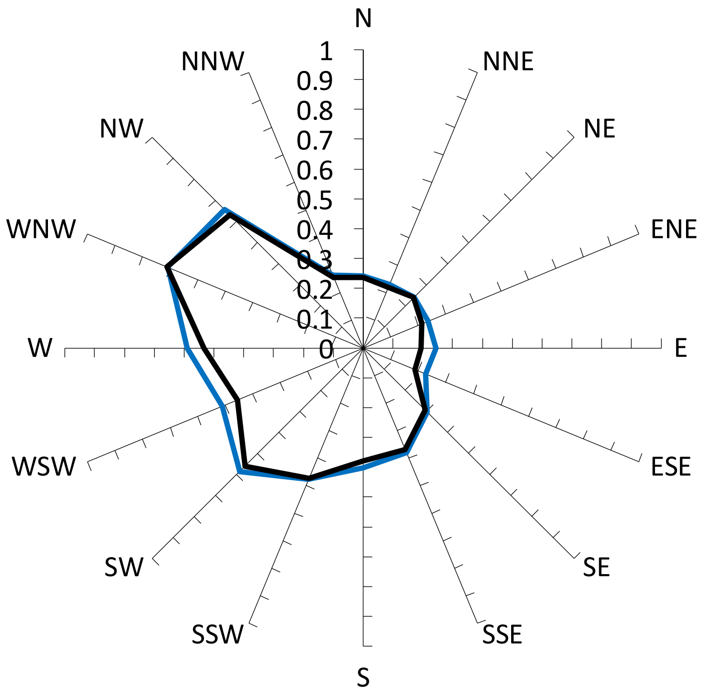


Gust Velocity Coefficients

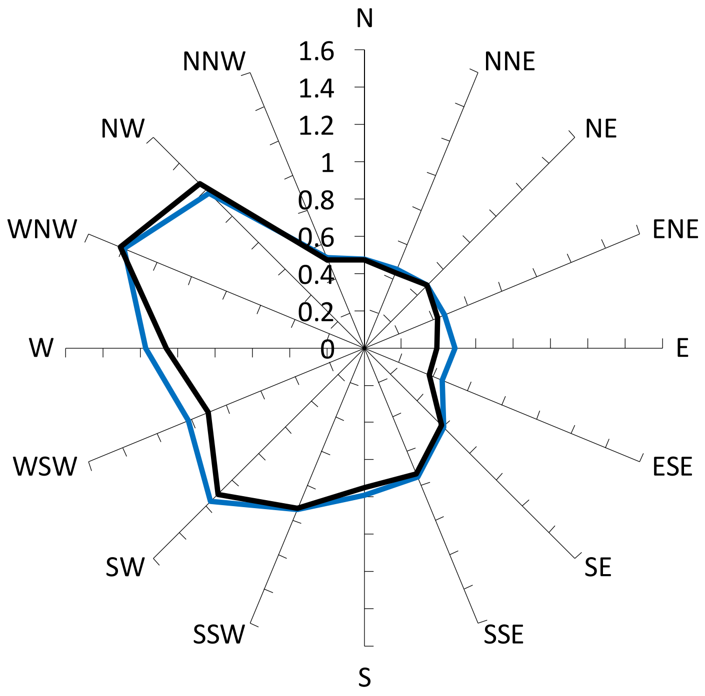
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 17



GEM Velocity Coefficients

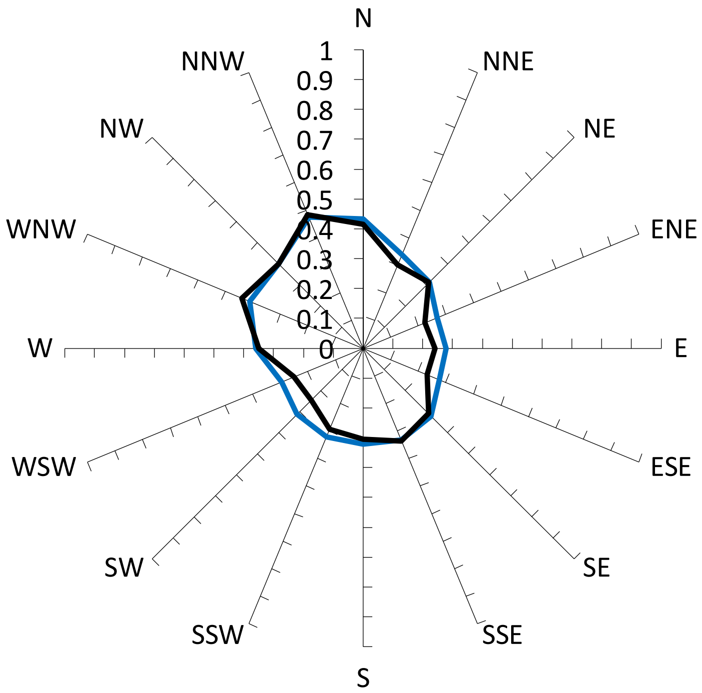


Gust Velocity Coefficients

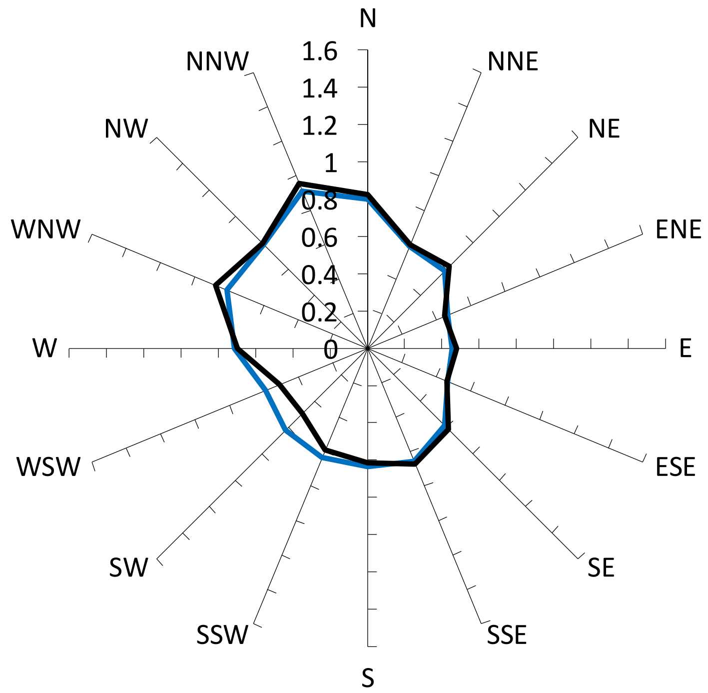
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 18



GEM Velocity Coefficients

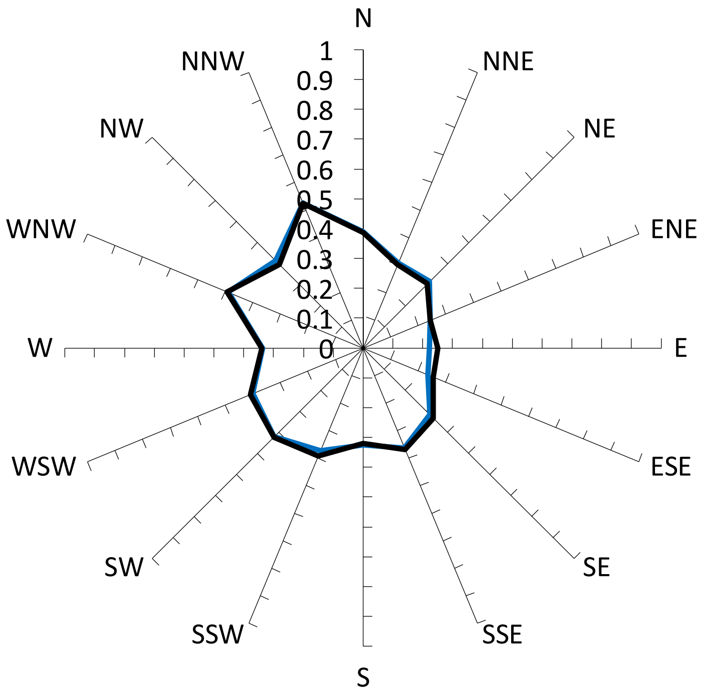


Gust Velocity Coefficients

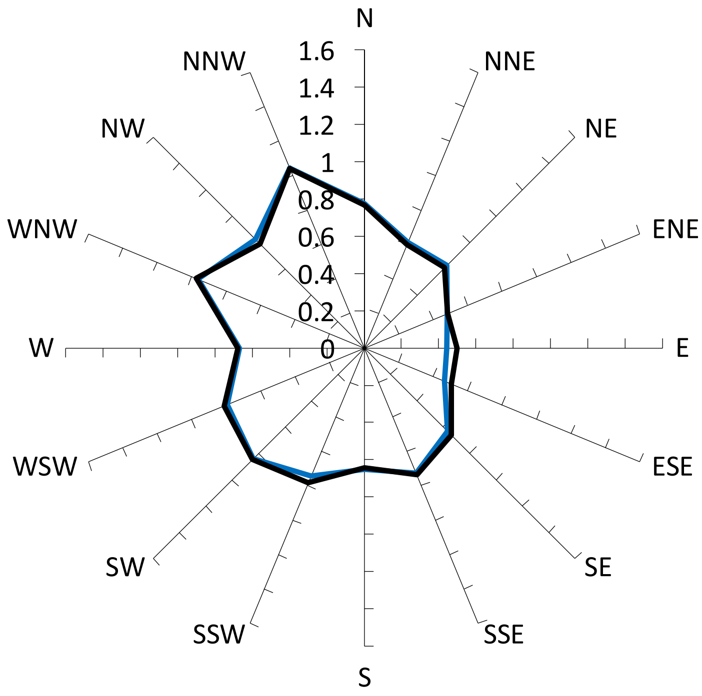
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 19



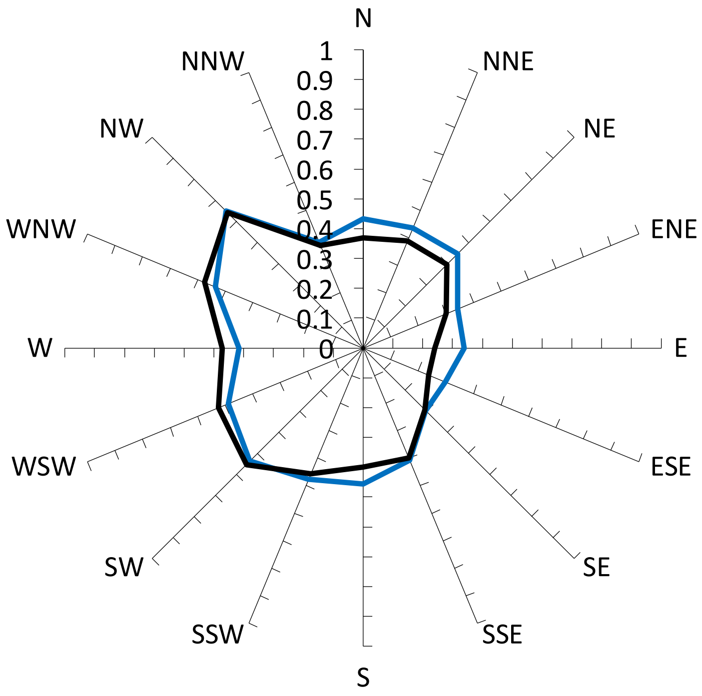
GEM Velocity Coefficients



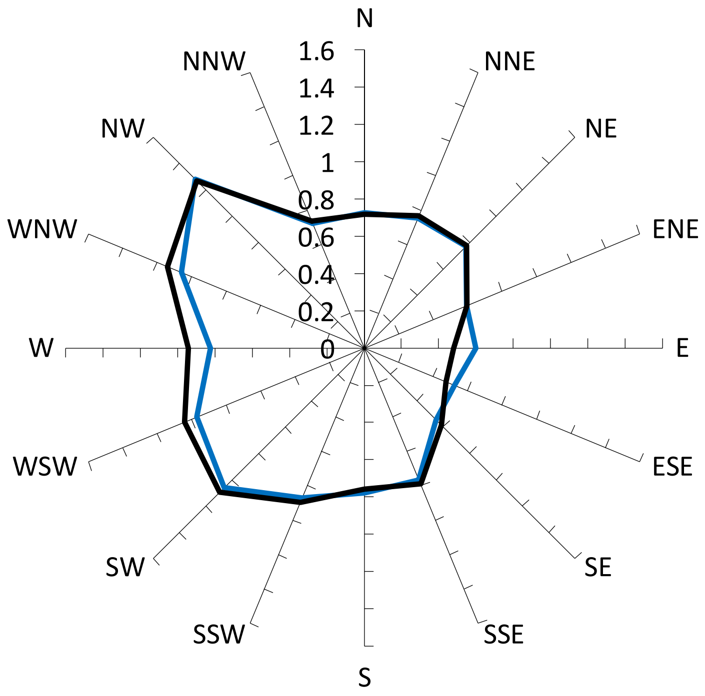
Gust Velocity Coefficients

With development "as proposed", no vegetation included.
Existing Site Conditions.

Results for Point 20



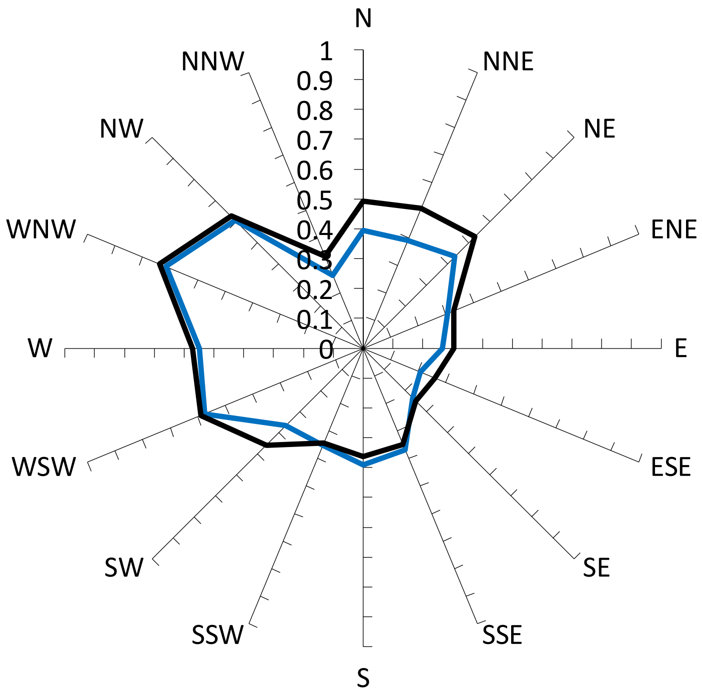
GEM Velocity Coefficients



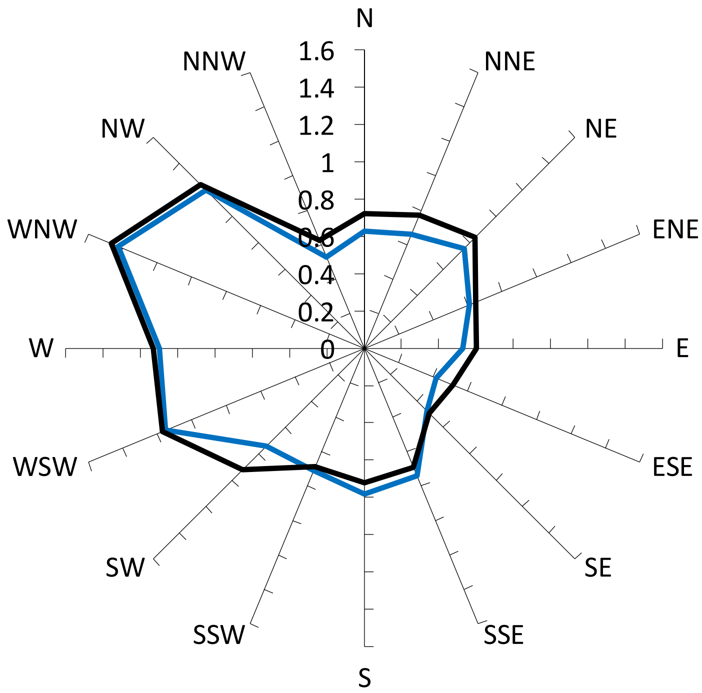
Gust Velocity Coefficients

With development "as proposed", no vegetation included.
Existing Site Conditions.

Results for Point 21



GEM Velocity Coefficients

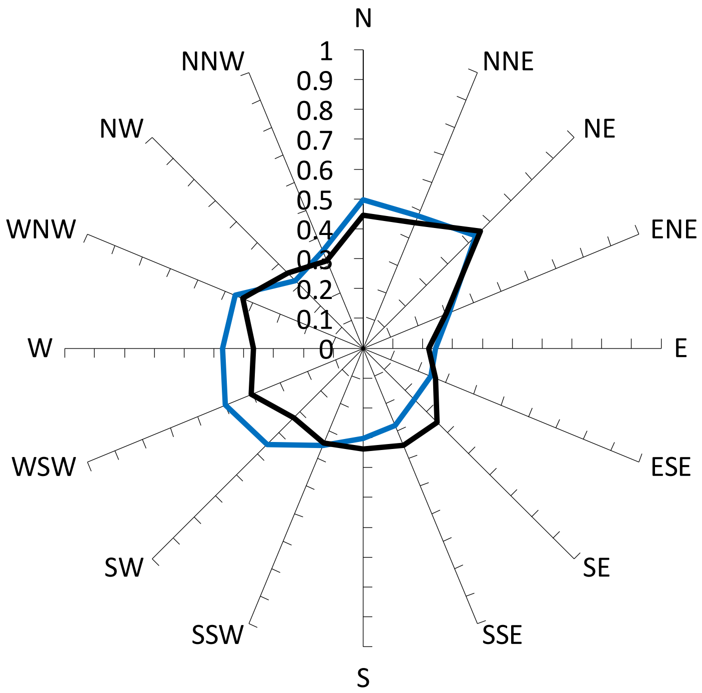


Gust Velocity Coefficients

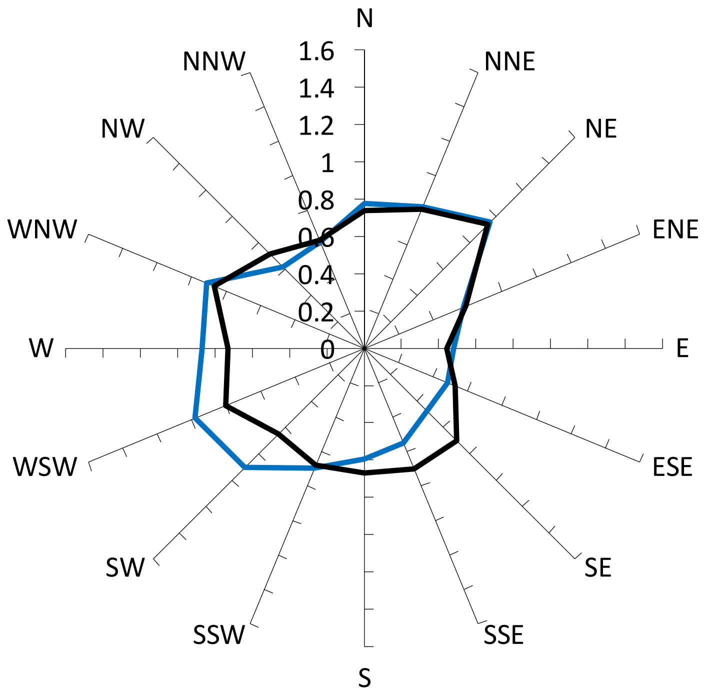
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 22



GEM Velocity Coefficients

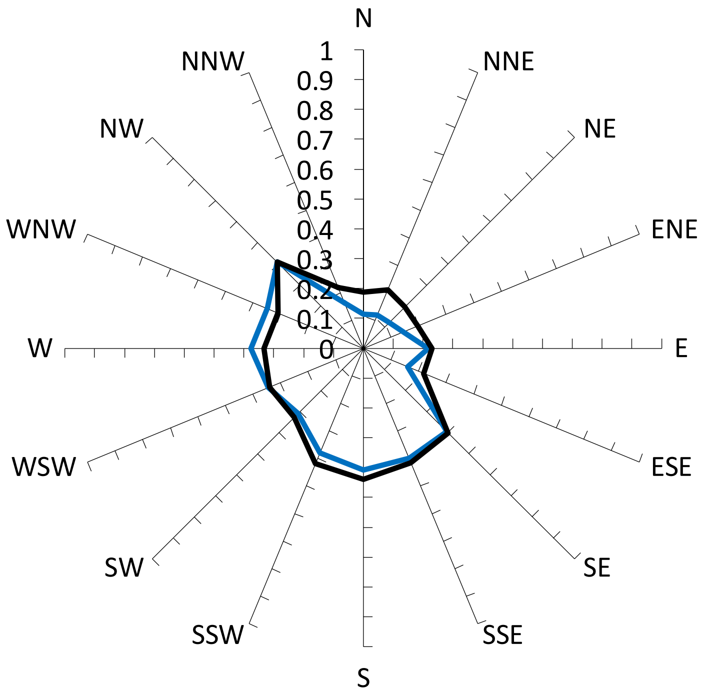


Gust Velocity Coefficients

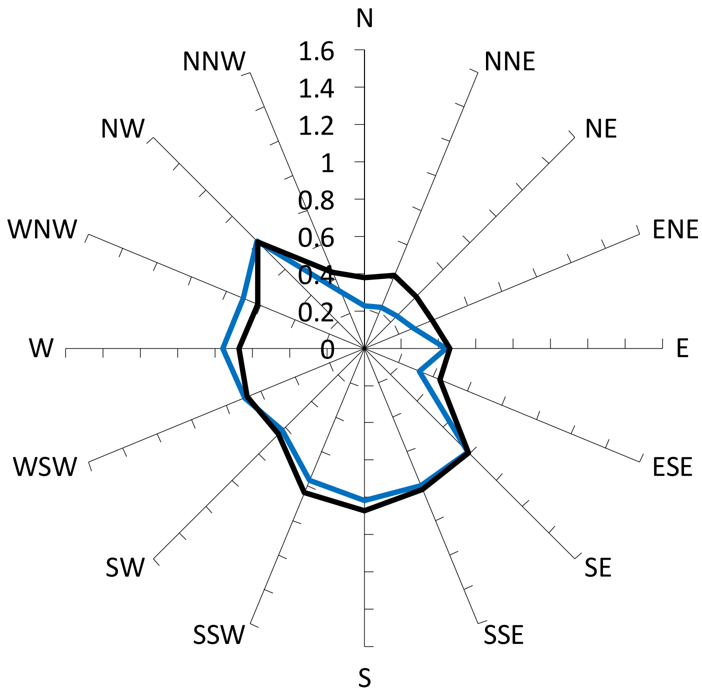
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 23



GEM Velocity Coefficients

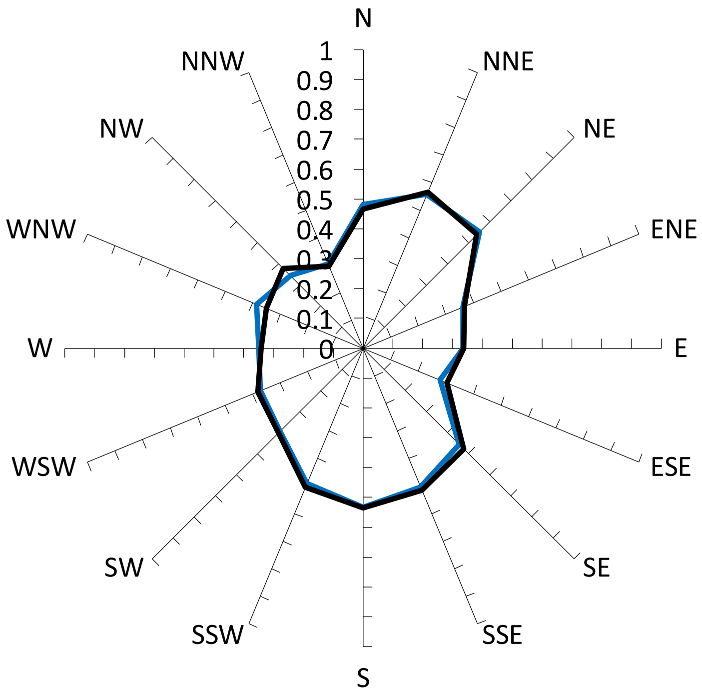


Gust Velocity Coefficients

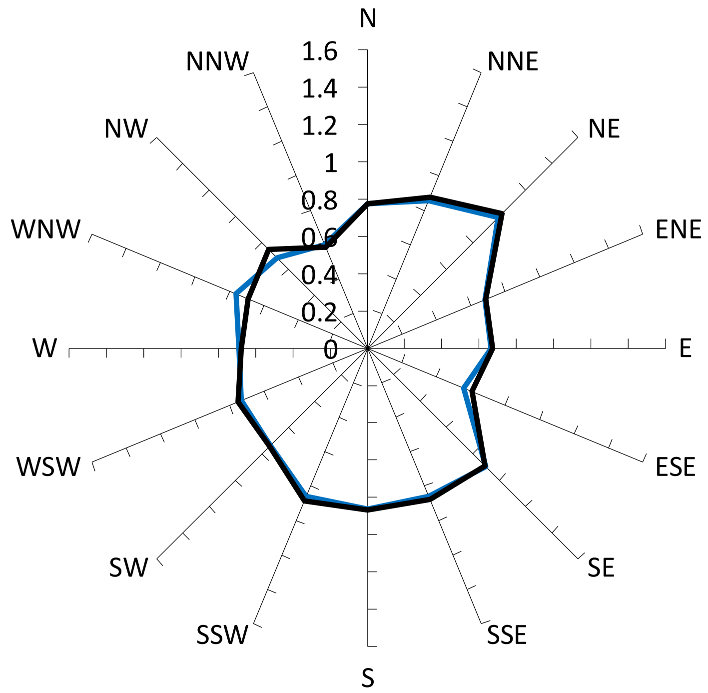
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 24



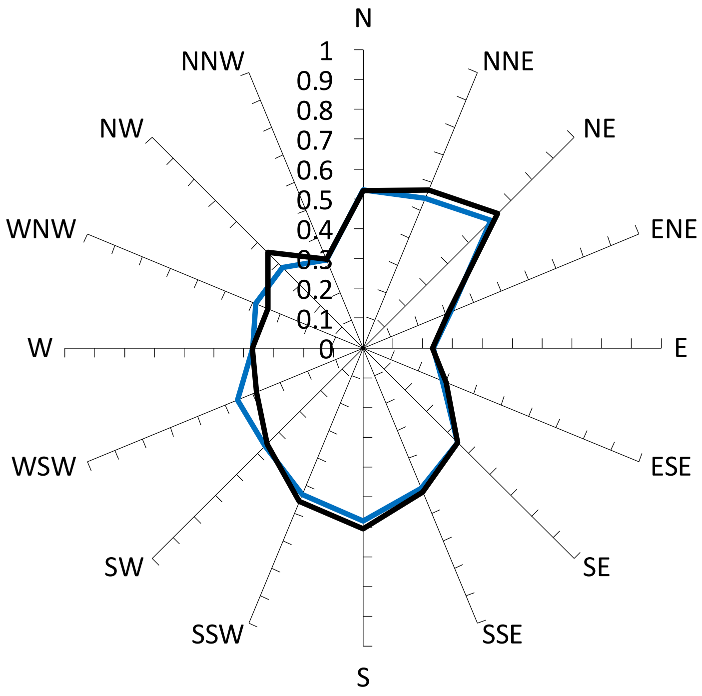
GEM Velocity Coefficients



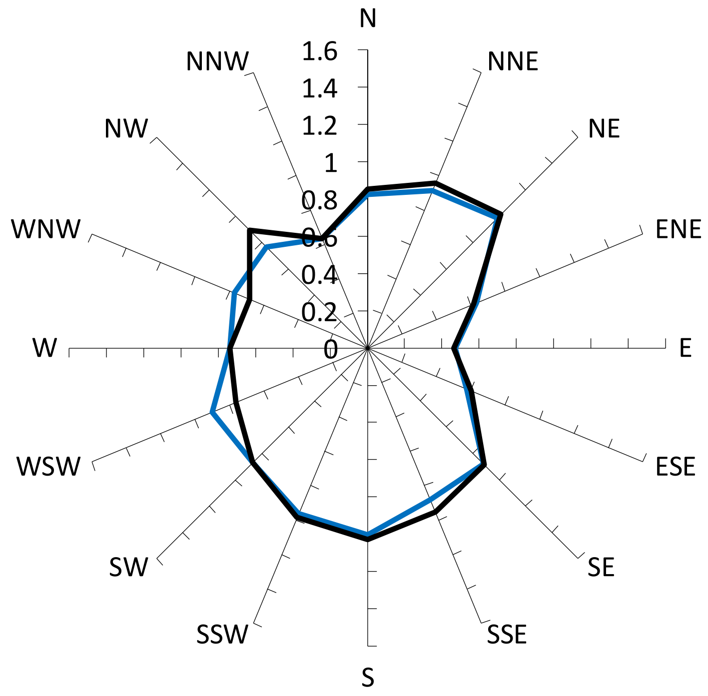
Gust Velocity Coefficients

With development "as proposed", no vegetation included.
Existing Site Conditions.

Results for Point 25



GEM Velocity Coefficients

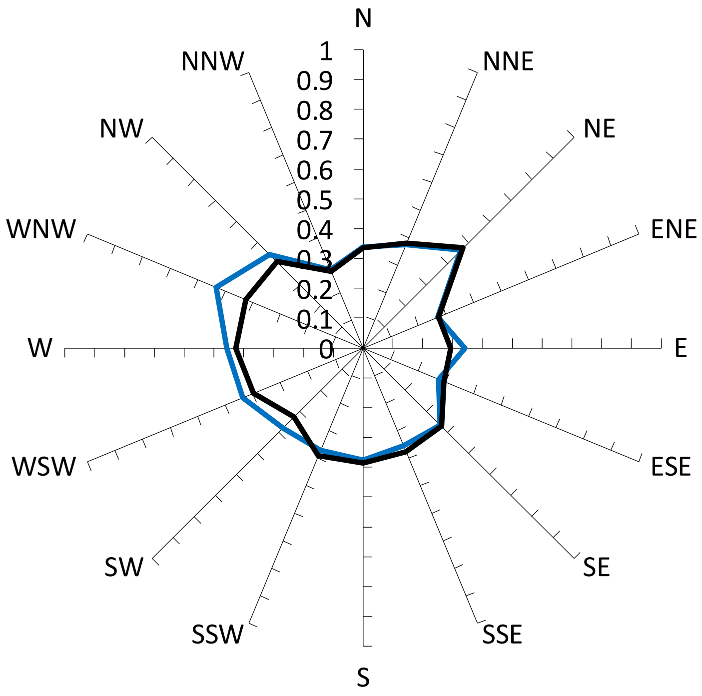


Gust Velocity Coefficients

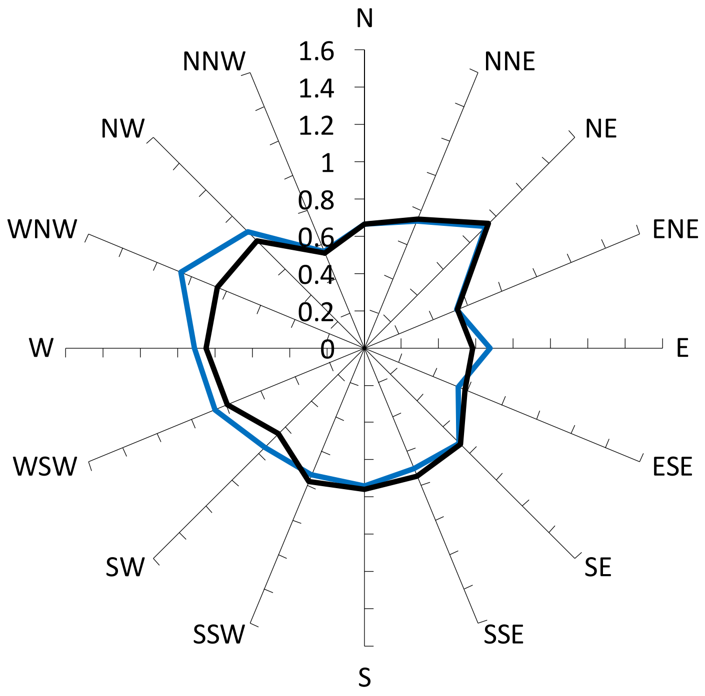
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 26



GEM Velocity Coefficients

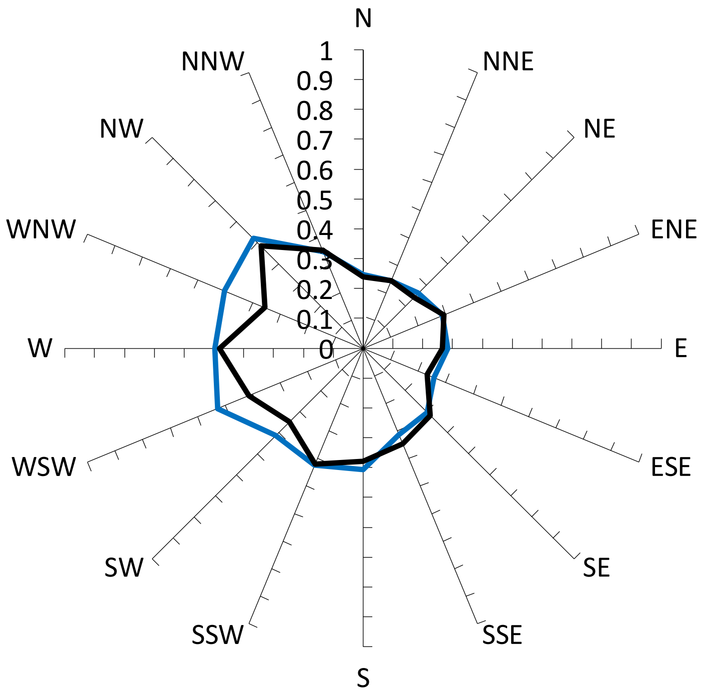


Gust Velocity Coefficients

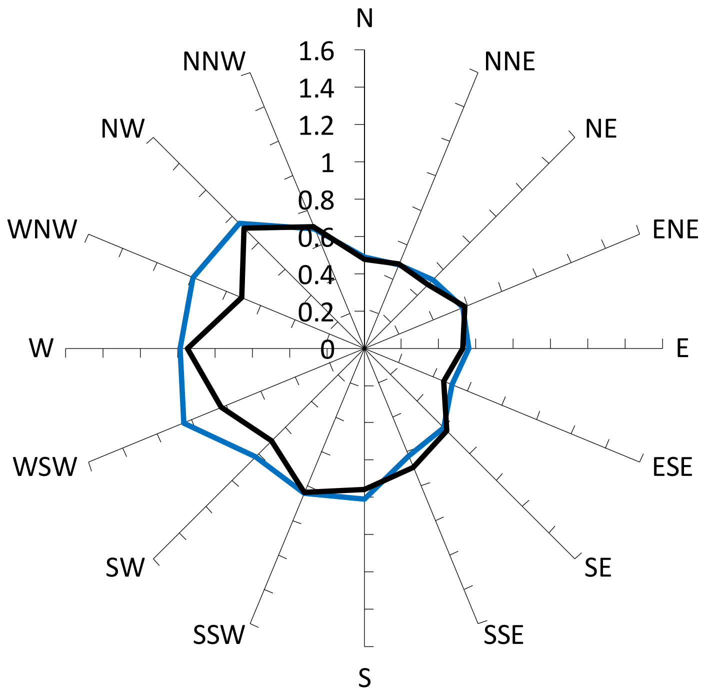
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 27



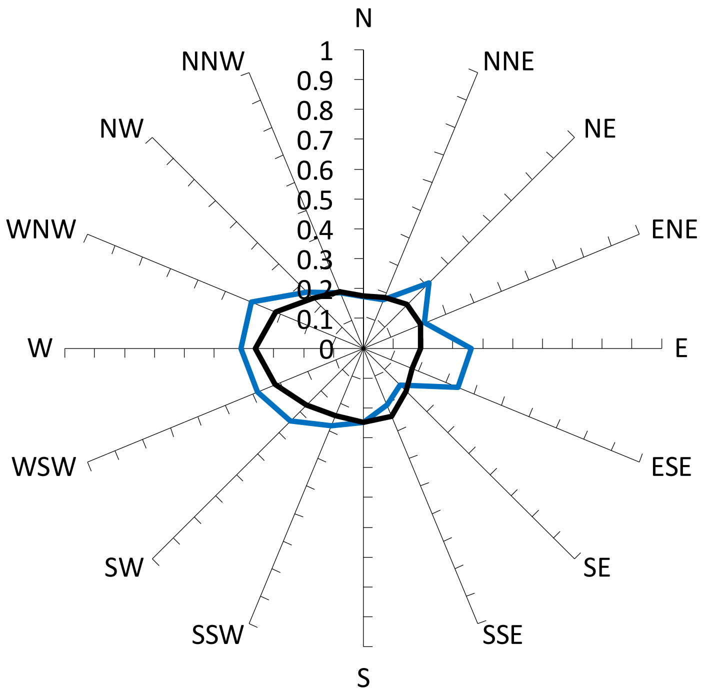
GEM Velocity Coefficients



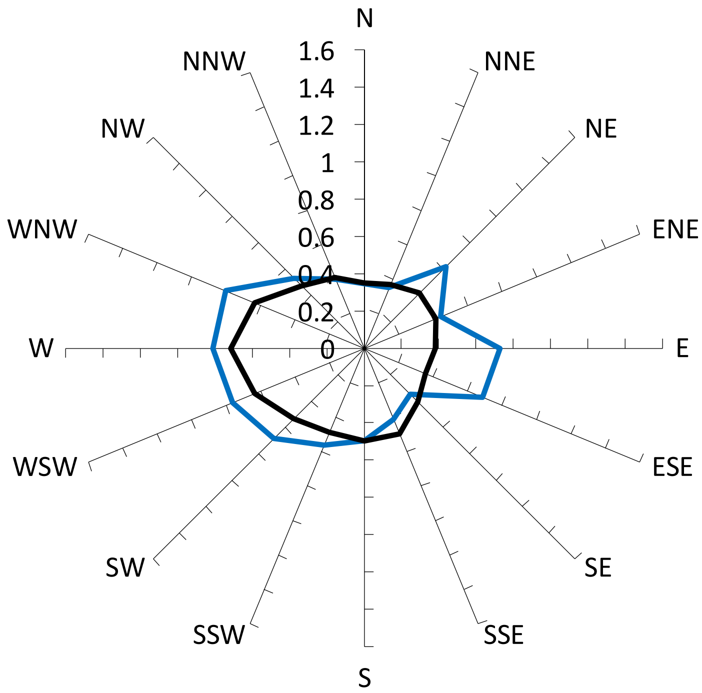
Gust Velocity Coefficients

—	With development "as proposed", no vegetation included.
—	Existing Site Conditions.
—	
—	
—	
—	
—	
—	

Results for Point 28



GEM Velocity Coefficients

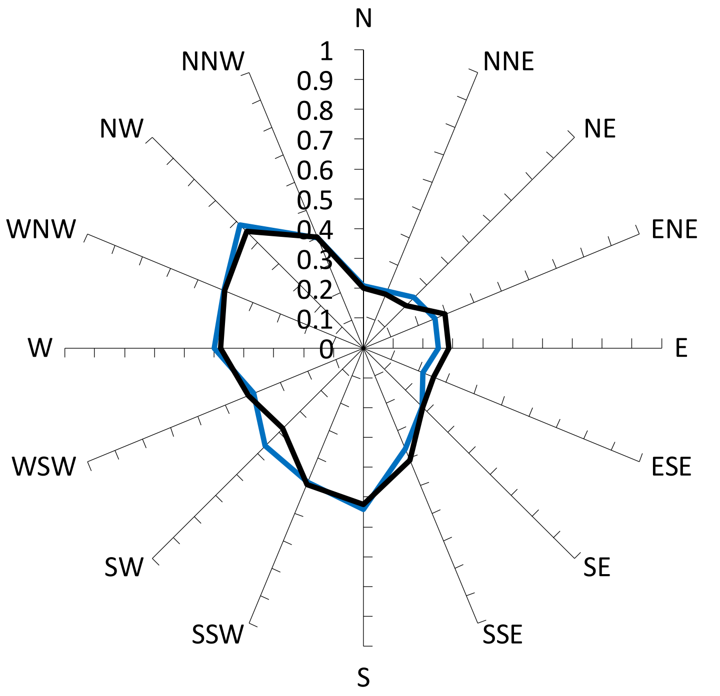


Gust Velocity Coefficients

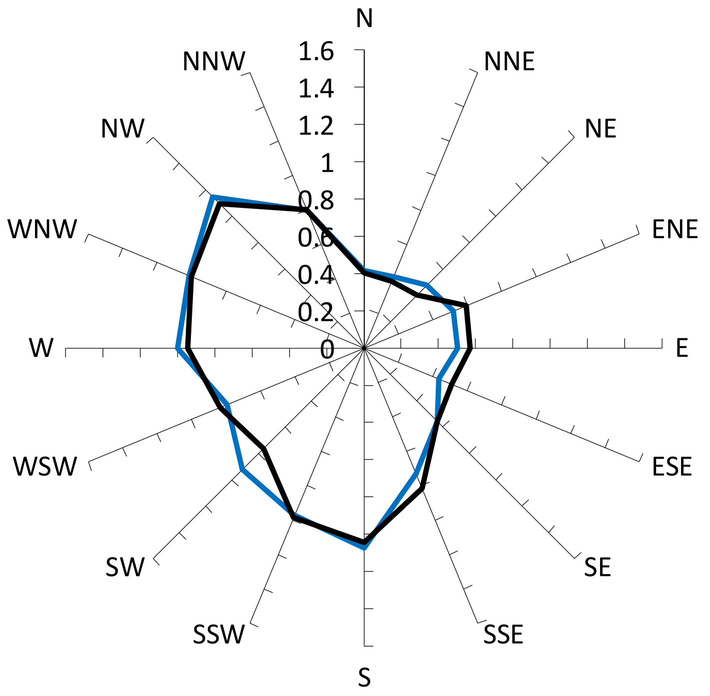
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 29



GEM Velocity Coefficients

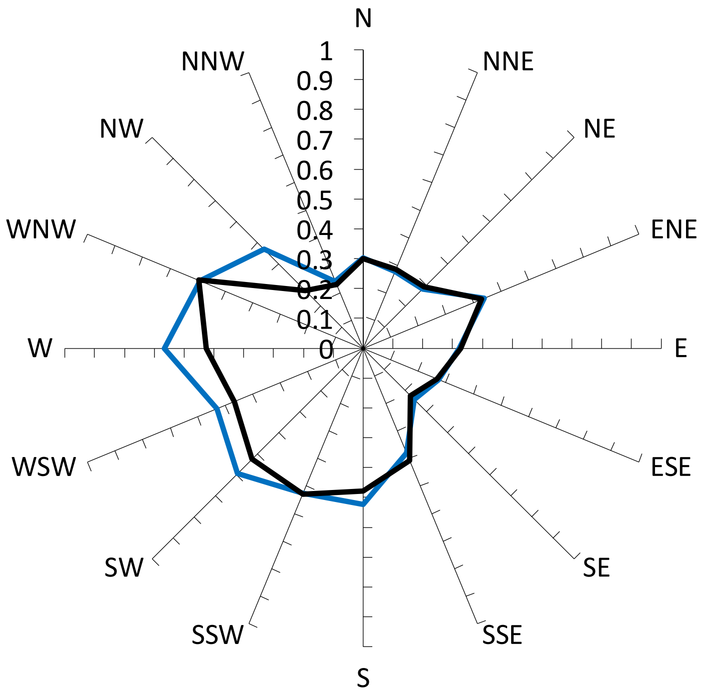


Gust Velocity Coefficients

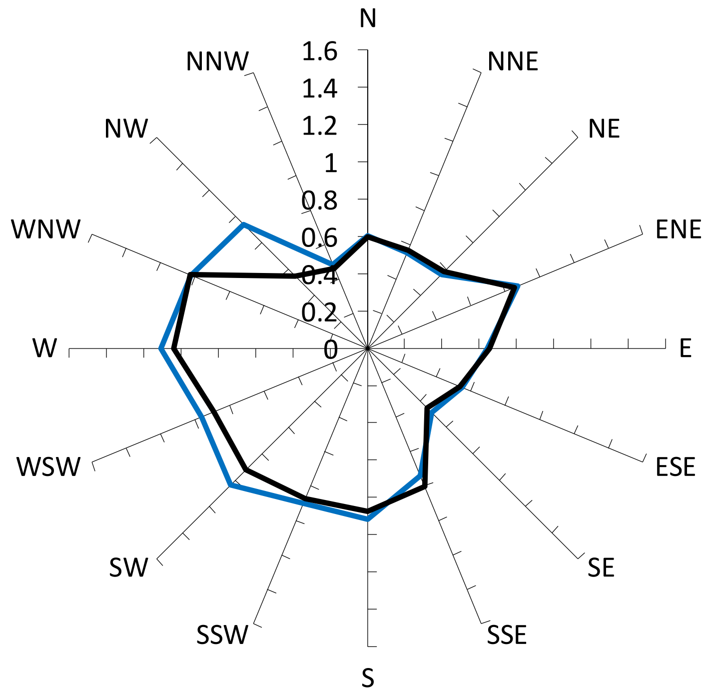
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 30



GEM Velocity Coefficients

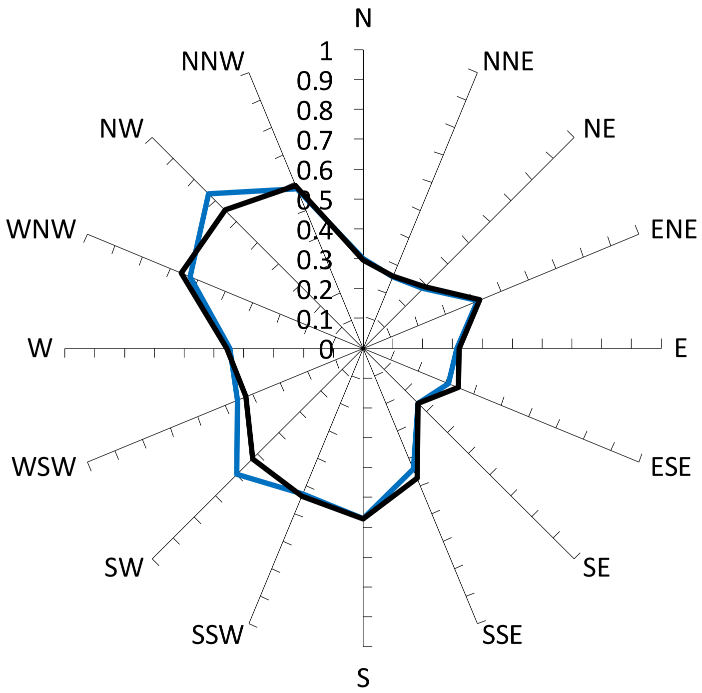


Gust Velocity Coefficients

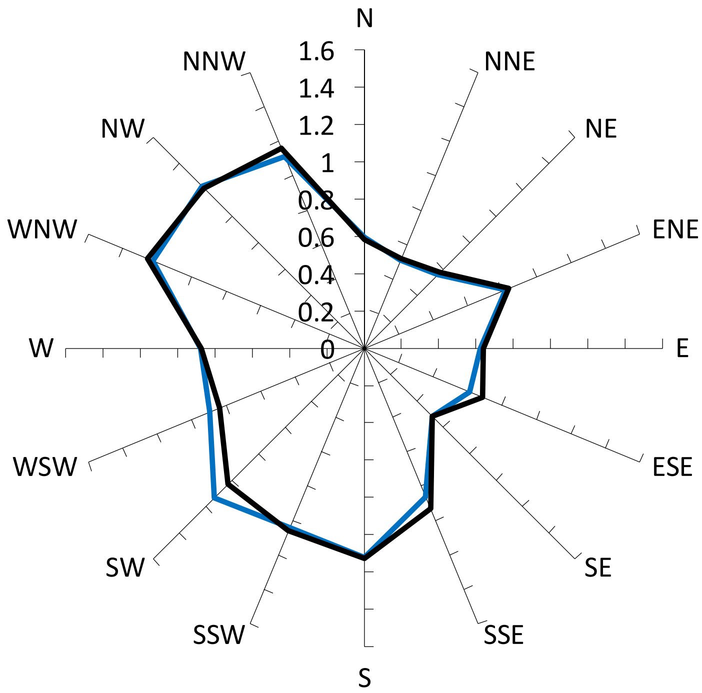
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 31



GEM Velocity Coefficients

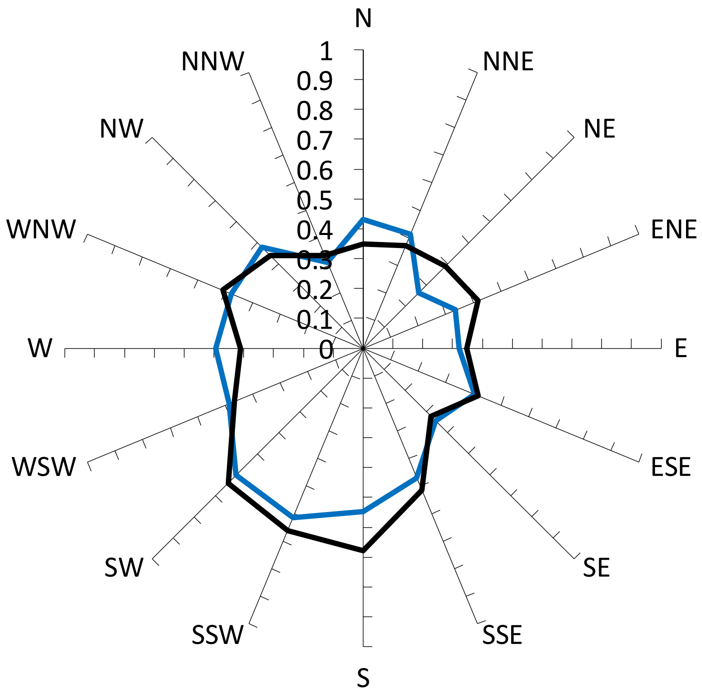


Gust Velocity Coefficients

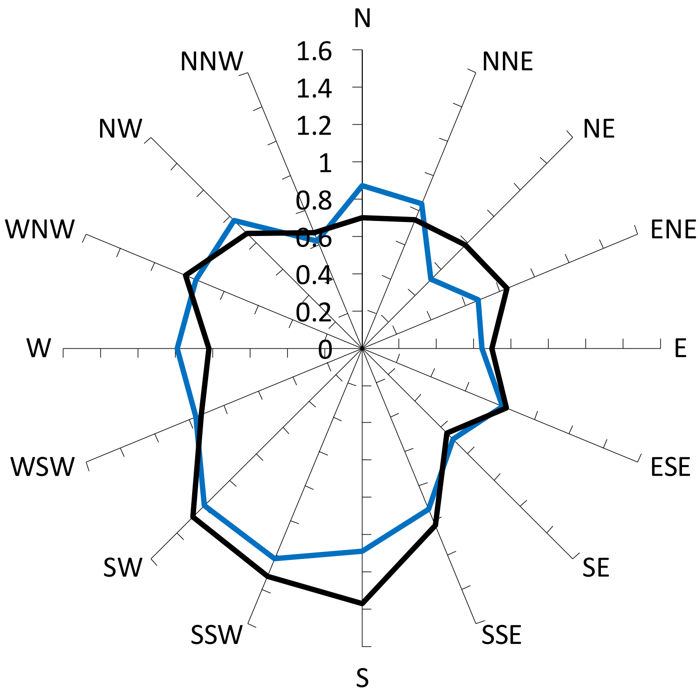
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 32



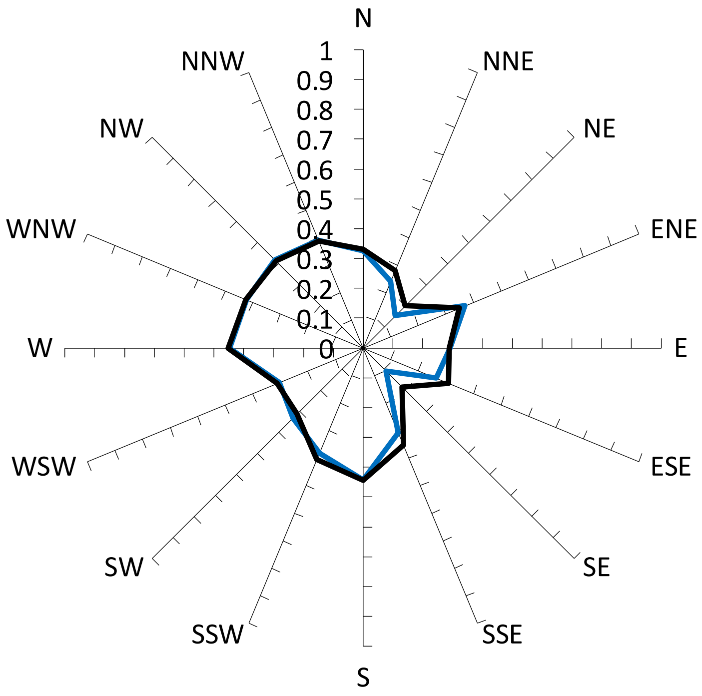
GEM Velocity Coefficients



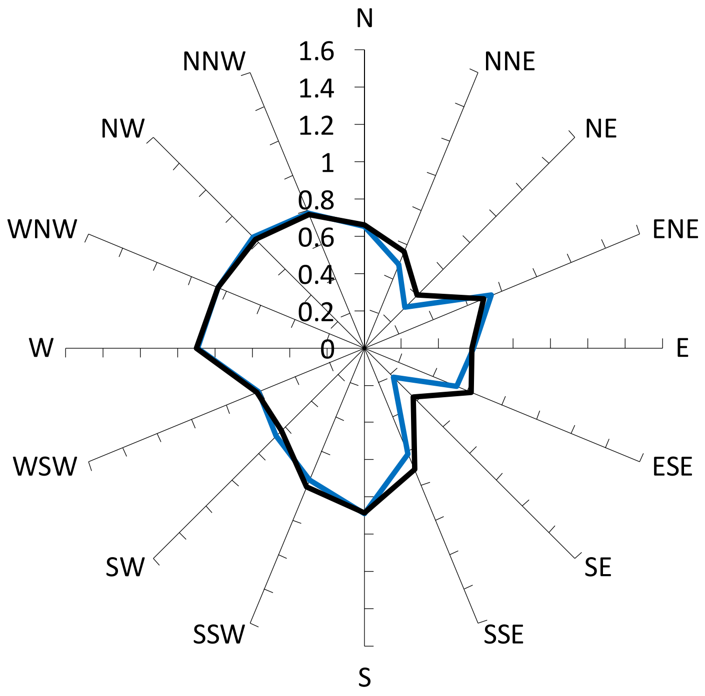
Gust Velocity Coefficients

— (blue)	With development "as proposed", no vegetation included.
— (black)	Existing Site Conditions.
— (red)	
— (orange)	
— (light green)	
— (green)	
— (light blue)	
— (purple)	

Results for Point 33



GEM Velocity Coefficients

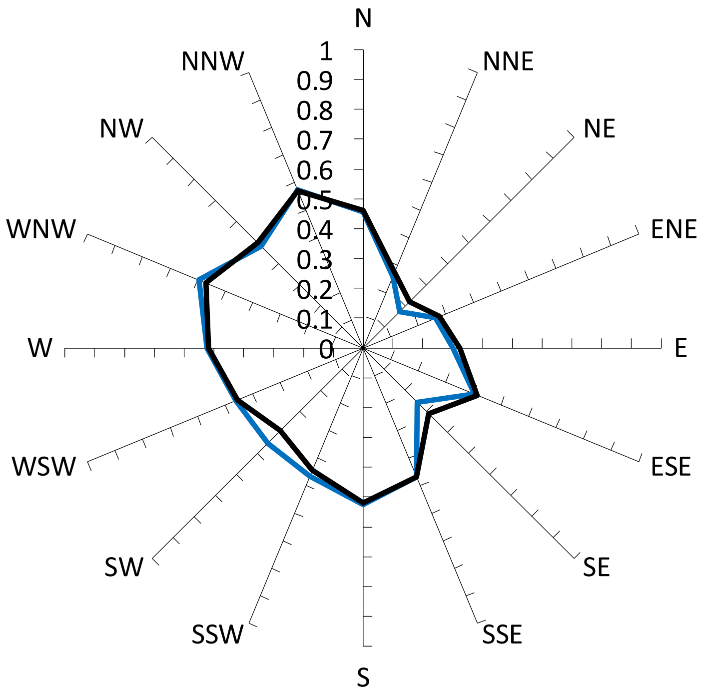


Gust Velocity Coefficients

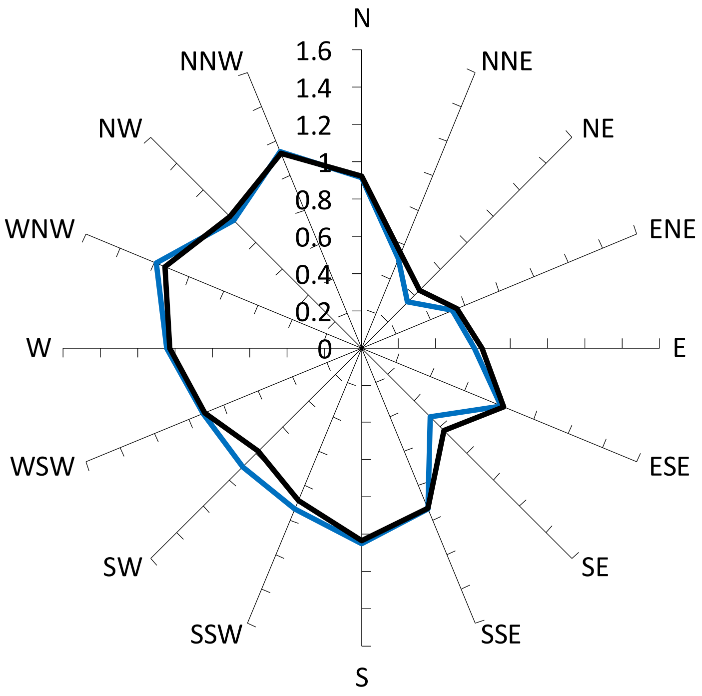
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 34



GEM Velocity Coefficients

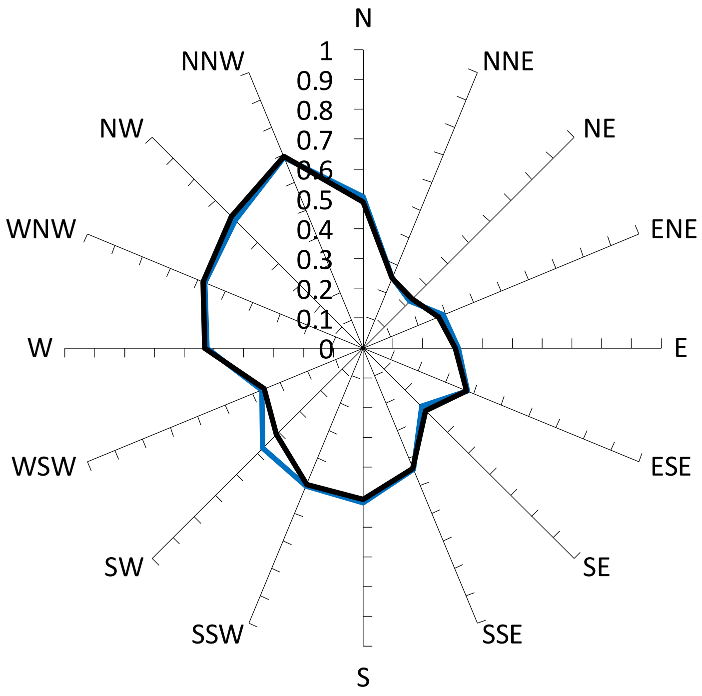


Gust Velocity Coefficients

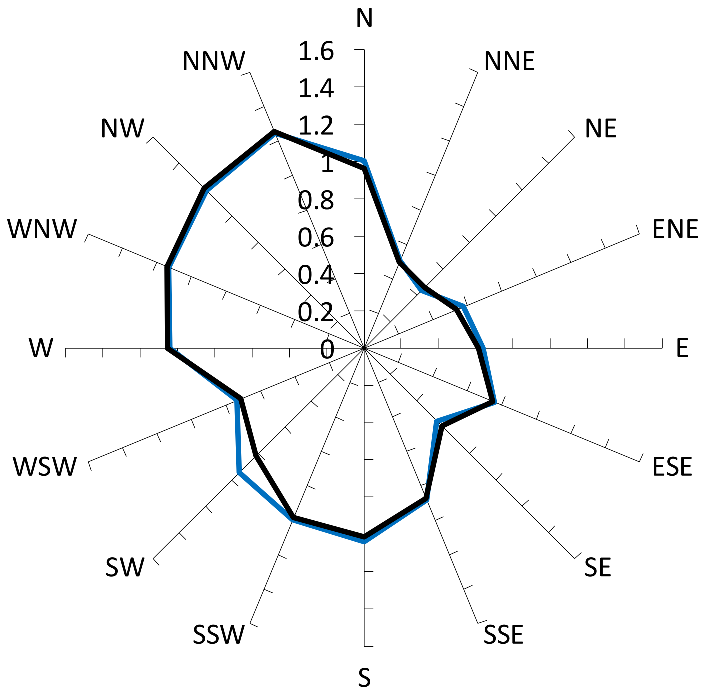
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 35



GEM Velocity Coefficients

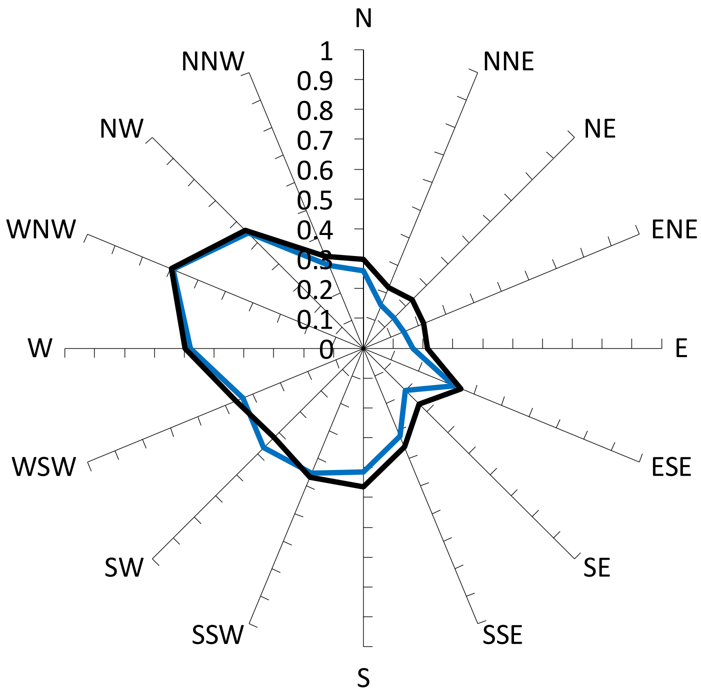


Gust Velocity Coefficients

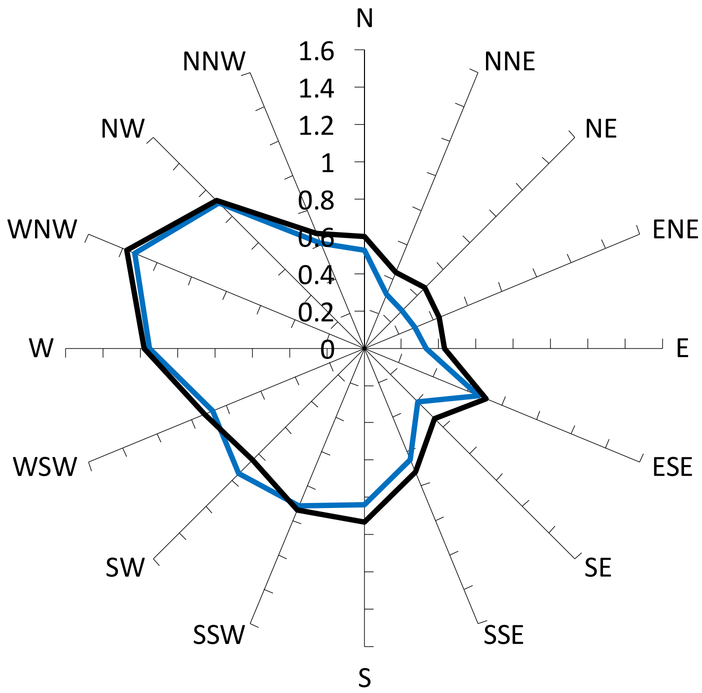
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 36



GEM Velocity Coefficients

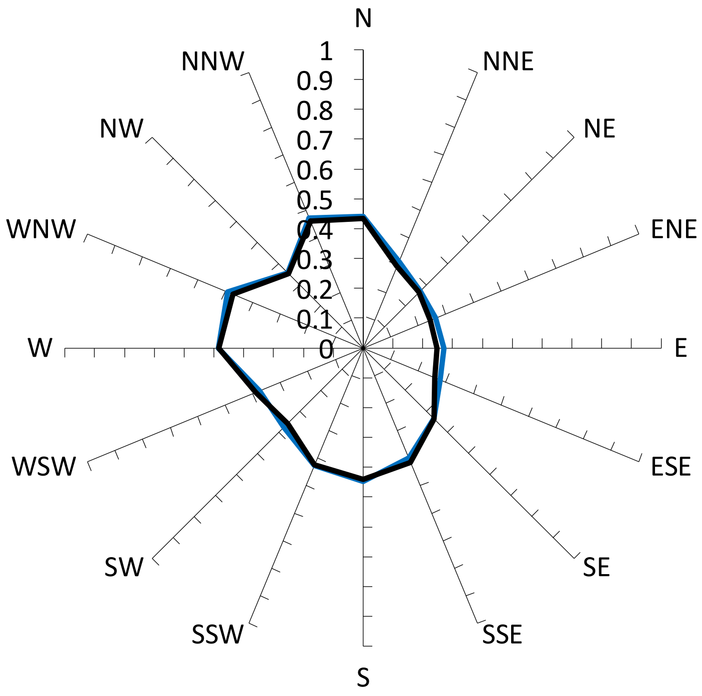


Gust Velocity Coefficients

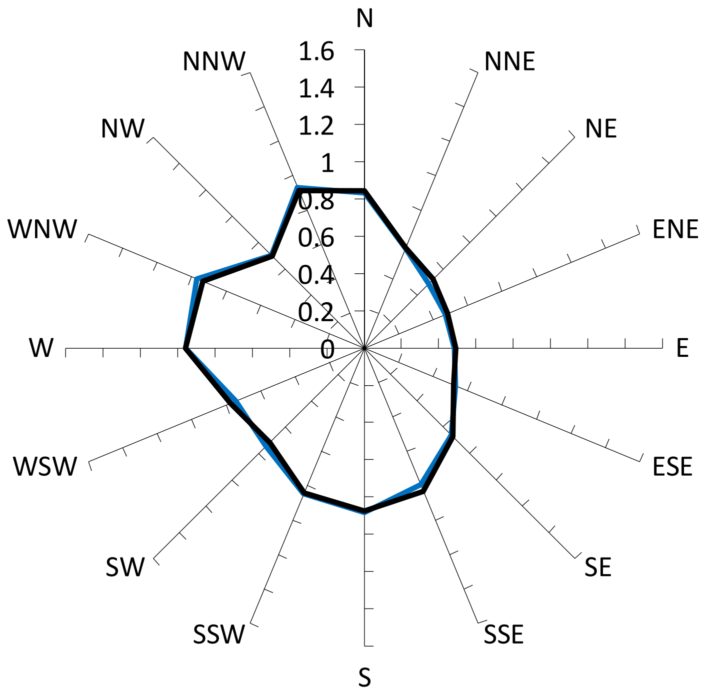
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 37



GEM Velocity Coefficients

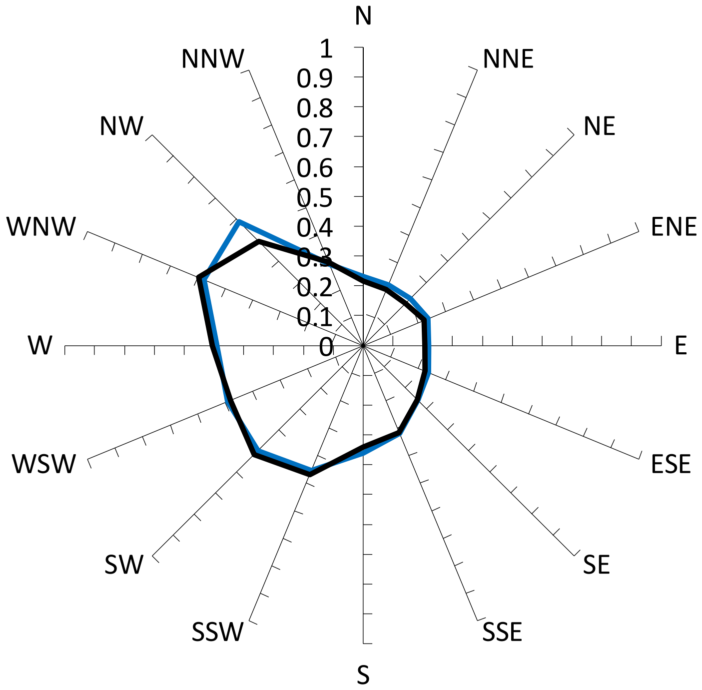


Gust Velocity Coefficients

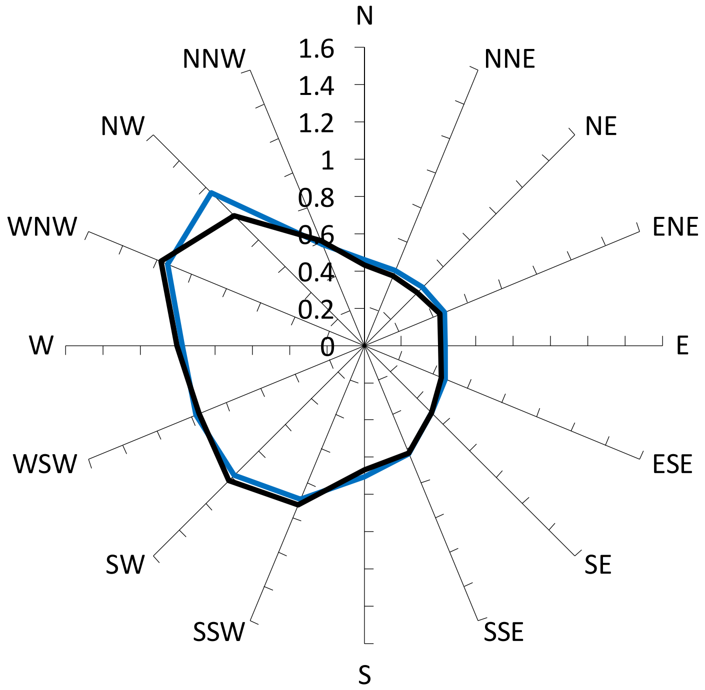
With development "as proposed", no vegetation included.

Existing Site Conditions.

Results for Point 38



GEM Velocity Coefficients

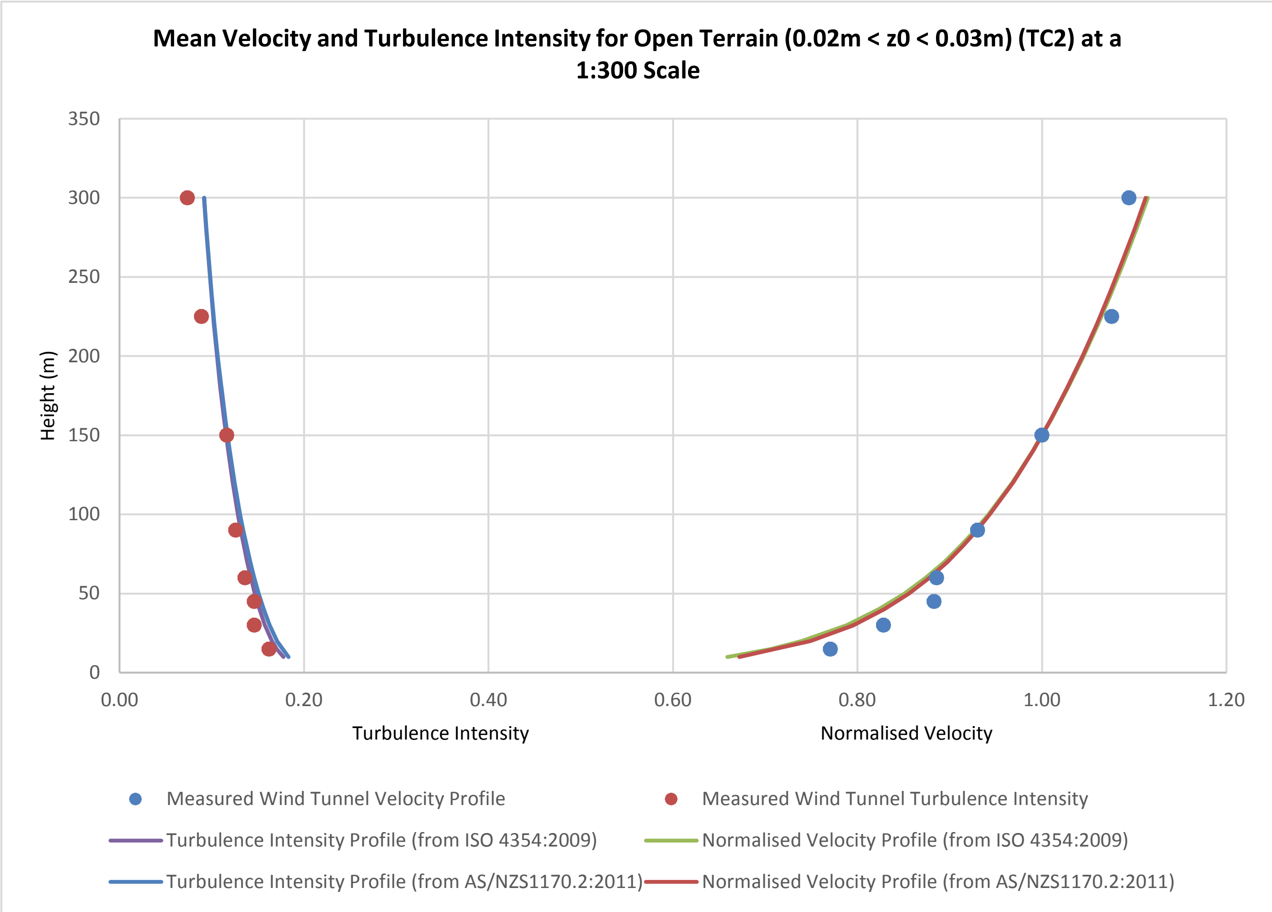


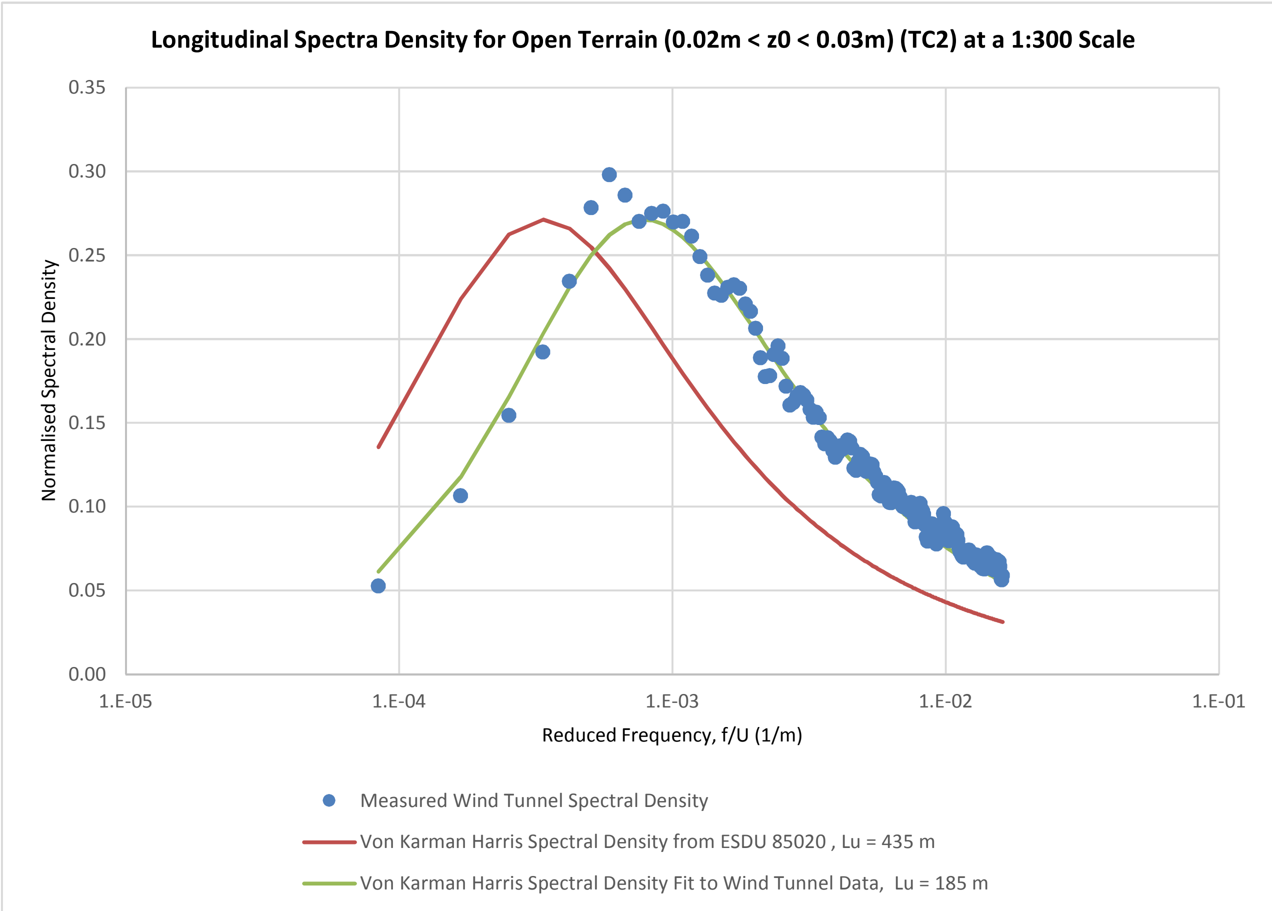
Gust Velocity Coefficients

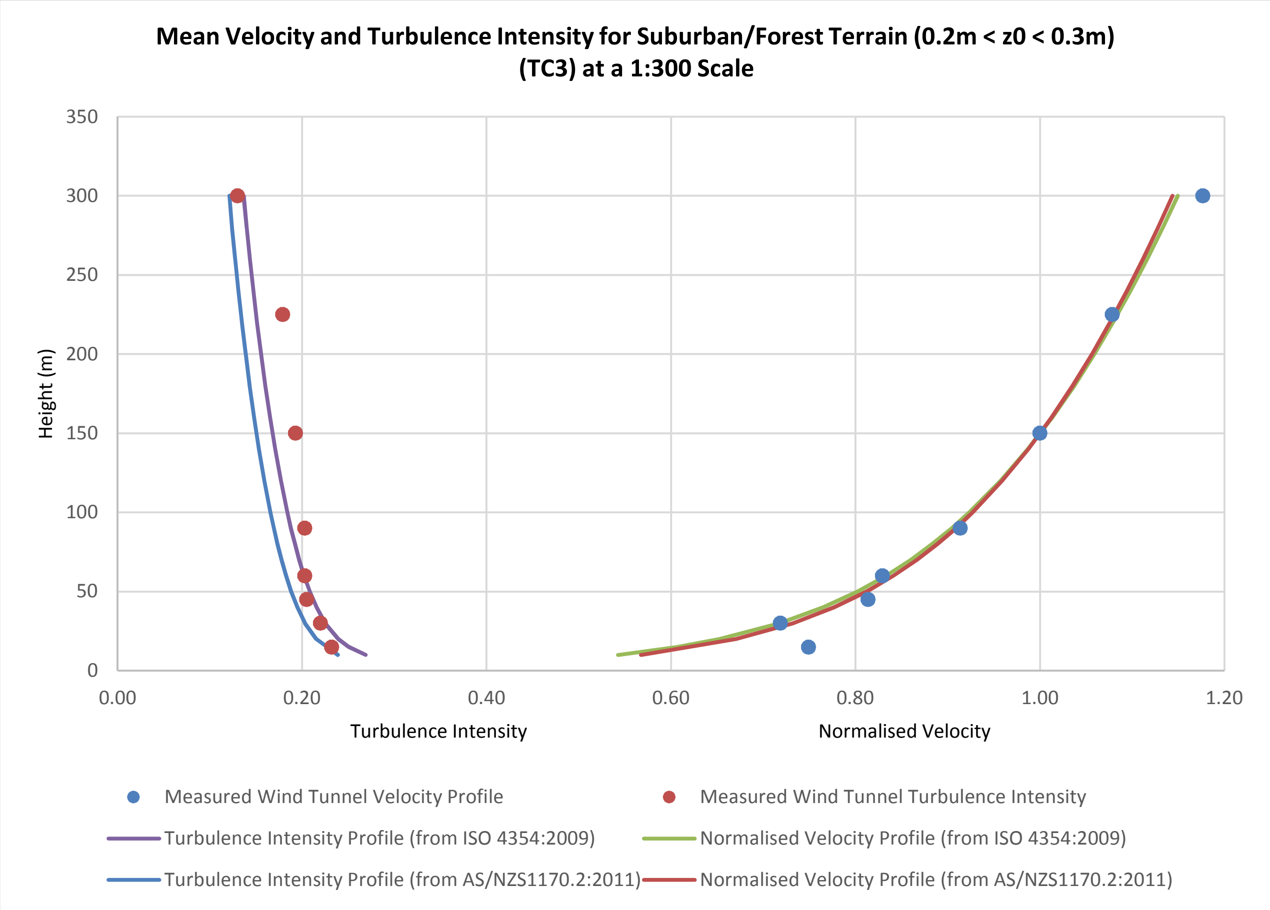
With development "as proposed", no vegetation included.

Existing Site Conditions.

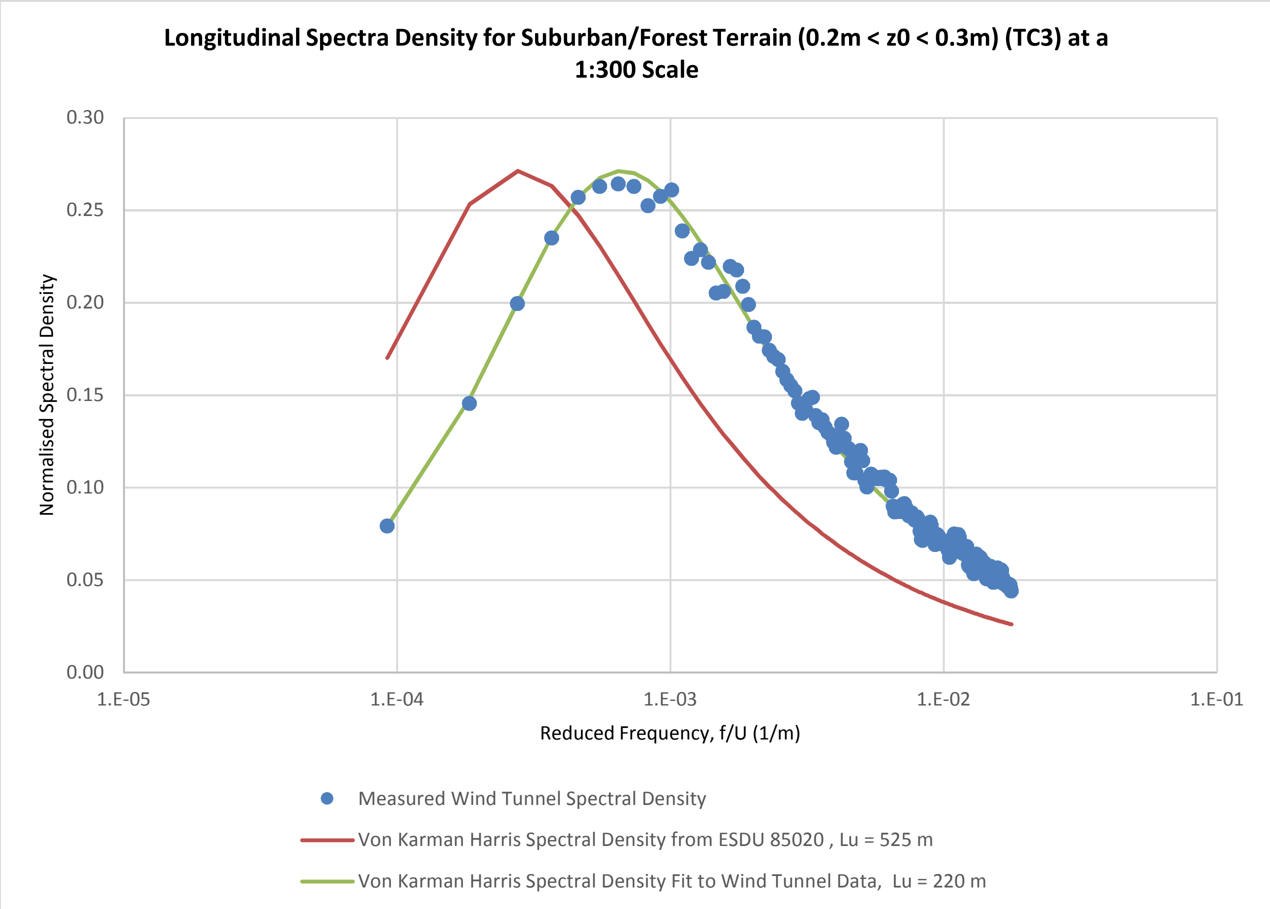
APPENDIX E VELOCITY AND TURBULENCE INTENSITY PROFILES


Mean Velocity and Turbulence Intensity for Open Terrain (0.02m < z0 < 0.03m) (TC2) at a 1:300 Scale
Height (m)
350
300
250
200
150
100
50
0
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 Open Terrain (0.02m < z0 < 0.03m) (TC2) at a 1:300 Scale
Normalised Spectral Density
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
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 = 435 m
Von Karman Harris Spectral Density Fit to Wind Tunnel Data, Lu = 185 m



Mean Velocity and Turbulence Intensity for Suburban/Forest Terrain (0.2m < z0 < 0.3m) (TC3) at a 1:300 Scale
Height (m)
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
Normalised Spectral Density
Reduced Frequency, f/U (1/m)
Measured Wind Tunnel Spectral Density
Von Karman Harris Spectral Density from ESDU 85020 , Lu = 525 m
Von Karman Harris Spectral Density Fit to Wind Tunnel Data, Lu = 220 m