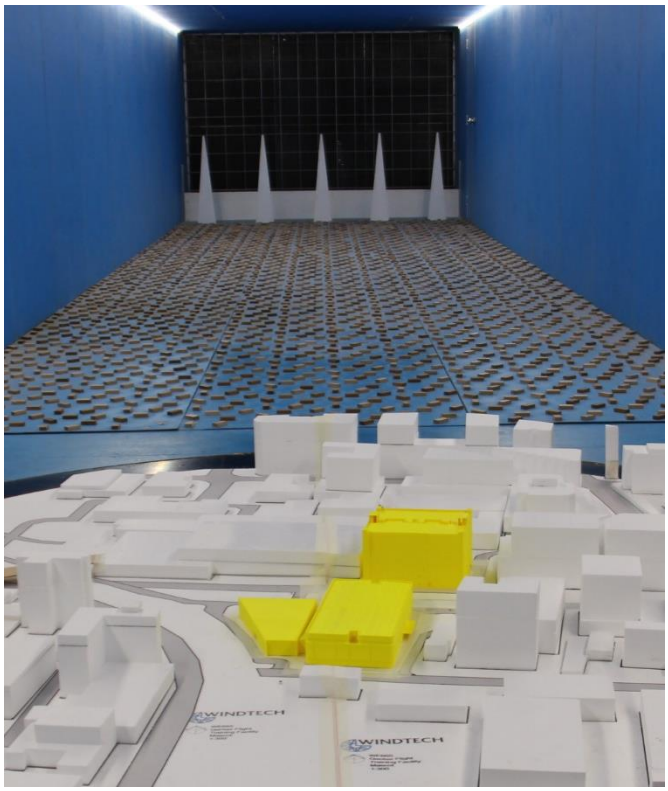


# PEDESTRIAN WIND ENVIRONMENT STUDY

# QANTAS GROUP FLIGHT TRAINING CENTRE, MASCOT

WE665-01F05(REV1)- WE REPORT

APRIL 15, 2019

Prepared for:

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# DOCUMENT CONTROL

| Date | Revision History | Issued Revision | Prepared By (initials) | Instructed By (initials) | Reviewed & Authorised by (initials) |
|---|---|---|---|---|---|
| April 12, 2019 | Initial. | 0 | KM | SR | TR/HK |
| April 15, 2019 | Revised treatment recommendation. | 1 | AB | SR | AB |
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## EXECUTIVE SUMMARY

This report presents the results of a detailed investigation into the wind environment impact of the Qantas Group Flight Training Centre, Mascot. 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. 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. In-principle treatments have been recommended for any area exposed to strong winds.

The results of the study indicate that wind conditions for the majority of trafficable outdoor locations within and around the development will be suitable for their intended uses. However, some areas will experience strong winds which will exceed the relevant criteria for comfort and/or safety Suggested treatments are described as follows:

- Retain the evergreen densely foliating tree planting to the west of the Flight Training Centre next to the rail corridor
- Install an awning at the slab of Level 1 over the southern aspect doors of the Flight Training Centre, and retain the evergreen densely foliating tree planting along that southern aspect of the Flight Training Centre.
- Retain the evergreen densely foliating tree planting running west to east along the Sydney Water drainage channel
- Maintain the open façade of the Car Park.

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.

## CONTENTS

# 1 GLOSSARY AND ABBREVIATIONS

| Term | Definition |
|---|---|
| The Site | Qantas Airways Limited owned land in Mascot to the north of Sydney Kingsford Smith Airport consisting of Lots 2-5 DP 234489, Lot 1 DP 202747, Lot B DP 164829 and Lot 133 DP 659434. Current site improvements include including at-grade car parking for Qantas staff, an industrial shed to store spare aviation parts, a substation, a disused gatehouse, a Sydney Water Asset with two driveways over it, the Qantas catering facility and Qantas tri-generation plant. |
| The Project | The construction of a new Flight Training Centre and ancillary uses to replace the existing facility on the Qantas Jetbase that will be impacted by RMS' Sydney Gateway Project. |
| Mascot Campus | Over 19ha of Qantas Airways Limited controlled land in Mascot to the north of Sydney Kingsford Smith Airport consisting of freehold and leased land.<br>The following lots are owned by Qantas: Lot 133 DP 659434; Lots 4 & 5 DP 38594 Lot 23 DP 883548; Lots 1 & 2 DP 738342; Lot 3 DP 230355; Lot 4 DP 537339; Lots 2 & 4 DP 234489; Lot 4 234489; Lot 1 DP 81210; Lot 1 DP 202093; Lot 1 DP 721562; Lot 2 DP 510447; Lot 1 DP 445957; Lot B DP 164829 and Lot 1 DP 202747 and equates to 16.5ha of land.<br>The following lots are leased by Qantas: Lot 14 DP 1199594 and Lot 2 DP 792885 and equates to 2.7ha of land. |
| Jetbase | Qantas leased land within the boundaries of Sydney Kingsford Smith Airport. |
| Sydney Gateway Project | A RMS Project including a road and rail component that is intended to increase capacity and improve connections to the ports to assist with growth in passenger, freight and commuter movements across the region, by expanding and improving the existing road and freight rail networks. |
| $z_0$ | Surface roughness |

| Abbreviation | |
|---|---|
| SEARs | Secretary's Environmental Assessment Requirements |
| AWES-QAM | Australian Wind Engineering Society Quality assurance Manual |
| ASCE | American Society of Civil Engineers |
| CTBUH | Council for Tall Buildings and Urban Habitat |
| CAM | Computer Aided Manufacture |
| GEM | Gust-Equivalent Mean |

# 2 IMAGE INDEX

# 3 INTRODUCTION

Windtech Consultants has been commissioned by Qantas Airways Ltd (Qantas) to prepare this report in accordance with the technical requirements of the Secretary's Environmental Assessment Requirements (SEARs), and in support of the SSD 10154 for the development of a new flight training centre at 297 King Street, Mascot.

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 Dantec hot-wire probe anemometers, 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. 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 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.

# 4 DESCRIPTION OF SITE AND LOCALITY

The site is located at 297 King Street, Mascot and comprises of land known as Lots 2 & 4 DP 234489, Lot 1 DP 202747, Lot B DP 164829 and Lot 133 DP 659434. The site is identified in Figure 1.

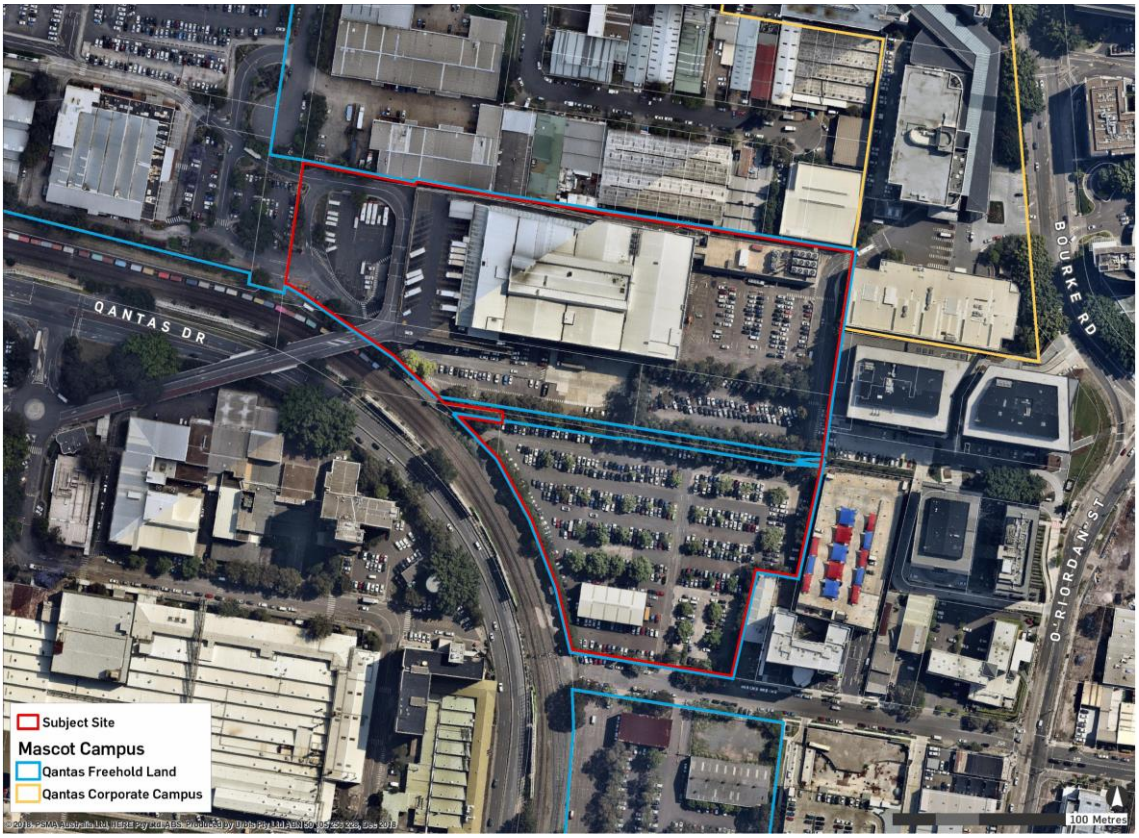


**Figure 1: The Site**

Key features of the site are as follows:

- The site is approximately 5.417ha and is an irregular shape. It is approximately 240m in length and maintains a variable width of between approximately 321m in the Northern Portion of the site and approximately 93m along the King Street frontage (refer to Figure 2)
- The site possesses a relatively level slope across the site. An open Sydney Water drainage channel bisects the northern portion of the site in an east-west direction. There are some isolated changes in level immediately adjacent to this channel. A Site Survey Plan accompanies the application which details the topographic characteristics of the site.

- Multiple mature Plane Trees are scattered throughout the site. A variety of native and exotic tress and vegetation also exist around the perimeter of the site which help screen the site from surrounding uses.
- Site improvements include at-grade car parking for Qantas staff, an industrial shed to store spare aviation parts, a substation, a disused gatehouse, a Sydney Water Asset with two driveways over it, the Qantas catering facility and Qantas tri-generation plant.
- The site forms part of a larger land holding under the ownership of Qantas that generally extends between Qantas Drive to the west, Ewan Street to the south, Coward Street to the north, with the Qantas "Corporate Campus" fronting Bourke Road.
- Vehicular access to the site from the local road network is available from King Street. The site has intra-campus connections along the northern boundary in the form of two connecting driveways in the north-eastern and north-western corner of the site along the northern boundary which link it to the broader Mascot Campus.
- The site is located within the Bayside LGA.

Key features of the locality are:

- **North:** The site is bounded to the north low scale industrial development, beyond which is Coward Street. Further north of the site is the Mascot Town Centre which is characterised by transport-oriented development including high density mixed-use development focussed around the Mascot Train Station.
- **East:** The site is bordered to the east by commercial development including a newly completed Travelodge hotel which includes a commercial car park. Additional commercial development to the east includes the Ibis Hotel and Pullman Sydney Airport fronting O'Riordan Street.
- **South:** The site is bounded to the south by King Street, beyond which is Qantas owned at-grade car parking and other industrial uses. Further south is the Botany Freight Rail Line and Qantas Drive beyond which is the Domestic Terminal at Sydney Airport.
- **West:** The site is bordered to the west by the Botany Freight Rail Line and Qantas Drive, beyond which lies Sydney Kingsford Smith Airport and the Qantas Jetbase (location of the current Flight Training Centre).

# 5 PROJECT DESCRIPTION

Safety is Qantas' first priority. The flight training centre is a key pillar of this value. The facility enables pilots and flight crews to undertake periodic testing to meet regulatory requirements by simulating both aircraft and emergency procedural environments. The Project seeks consent for the construction and operation of a new flight training centre, and associated ancillary uses including a multi-deck car park. The Project is comprised of the following uses:

**Flight Training Centre**

The proposed flight training centre will occupy the southern portion of the site. It is a building that comprises 4 core elements as follows:

- An emergency procedures hall that contains;
    - cabin evacuation emergency trainers,
    - an evacuation training pool, o door trainers,
    - door trainers,
    - fire trainers
    - slide descent towers,
    - security room,
    - aviation medicine training and equipment rooms.
- A flight training centre that contains:
    - a flight training hall with 14 bays that will house aircraft simulators,
    - integrated procedures training rooms, computer rooms, a maintenance workshop, storerooms, multiple de-briefing and briefing rooms, pilot's lounge and a shared lounge.
- Teaching Space that contains
    - training rooms,
    - classrooms and two computer based exam rooms.
- Office Space
    - Office space for staff and associated shared amenities including multiple small, medium and large meeting rooms, think tank rooms, informal meeting spaces, a video room and lunch/tea room.

- Ancillary spaces including the reception area at the ground floor, toilets, roof plant and vertical circulation. The external ground floor layout will include a loading dock, at-grade car parking for approximately 39 spaces and a bus drop-off zone at the northern site boundary.

**Car Park**

The proposed multi-deck car park will be located to the north-east of the flight training centre and adjacent the existing Qantas catering facility and tri-generation plant. The car park is 13 levels and will provide 2059 spaces for Qantas staff. Vehicle access to the car park will be provided via King Street, Kent Road and from Qantas Drive via the existing catering bridge.

# 6 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 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 2. A plan of the proximity model is provided in Figure 3.

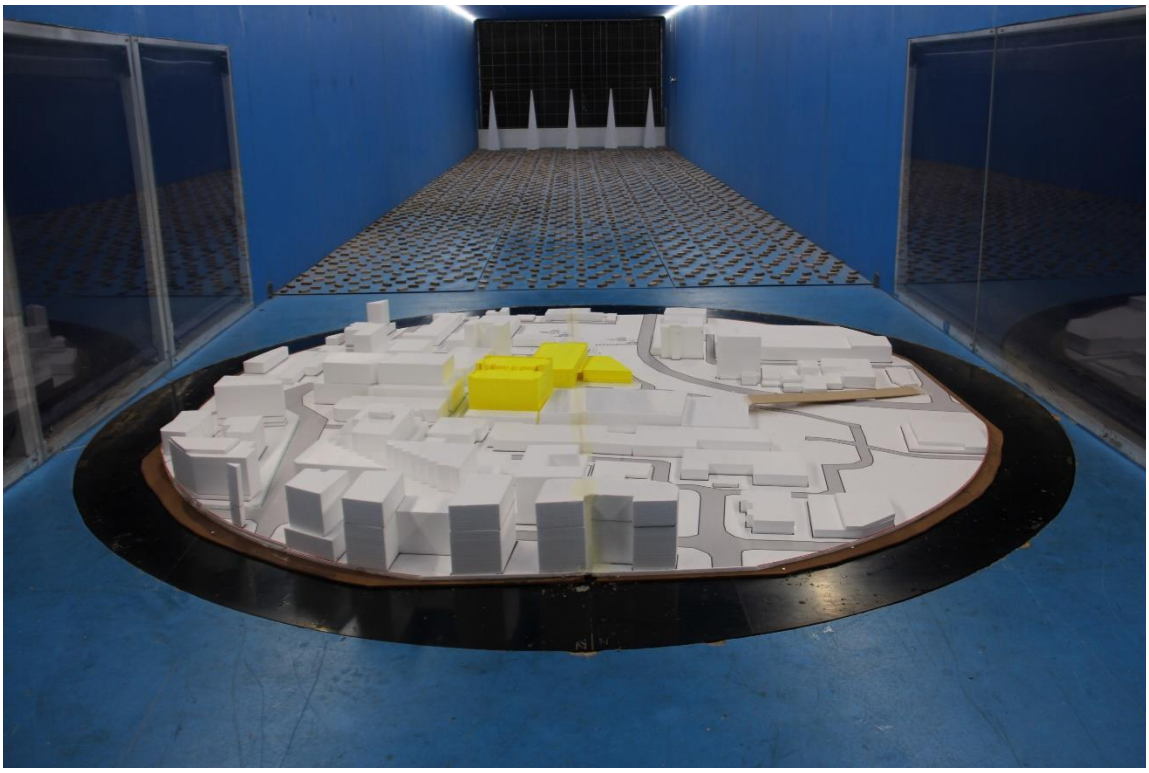

**Figure 2a: Photograph of the Wind Tunnel Model (view from the north)**

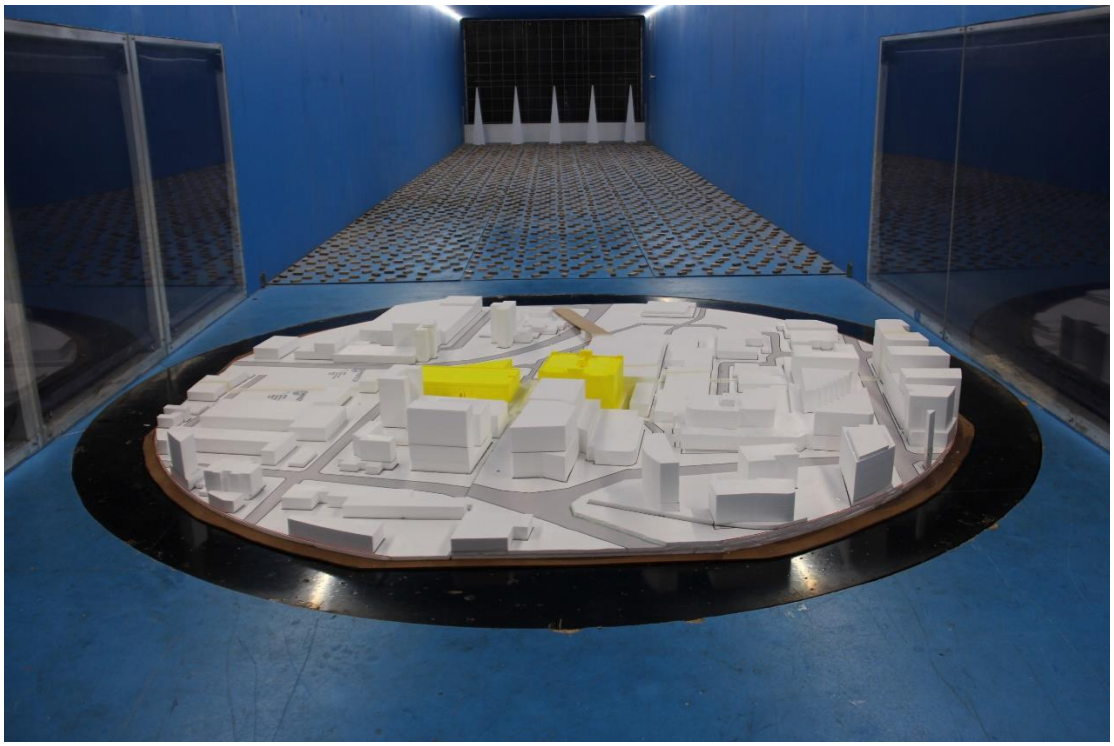

**Figure 2b: Photograph of the Wind Tunnel Model (view from the east)**

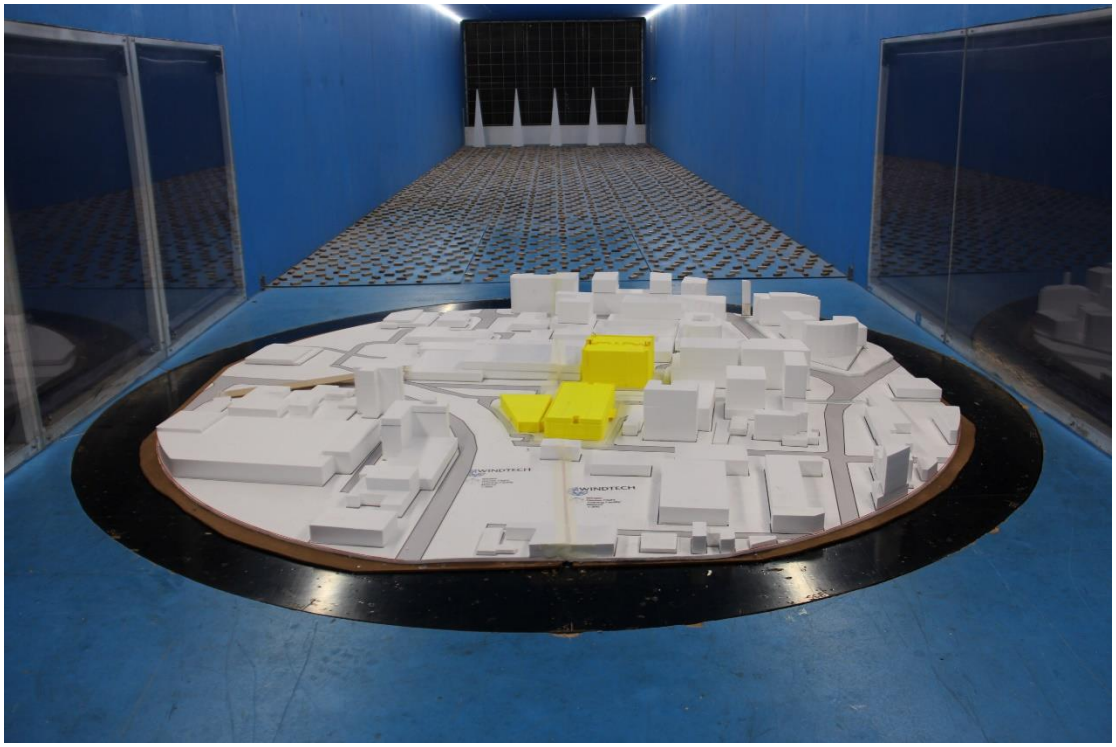

**Figure 2c: Photograph of the Wind Tunnel Model (view from the south)**

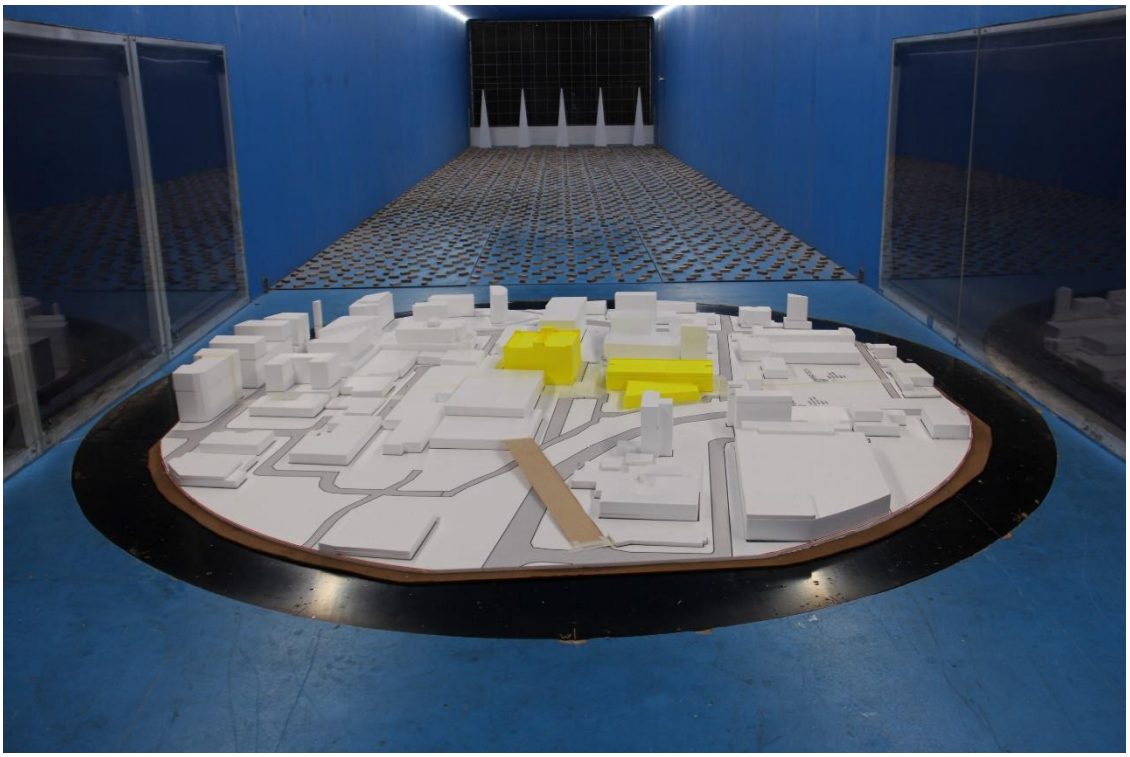

**Figure 2d: Photograph of the Wind Tunnel Model (view from the west)**

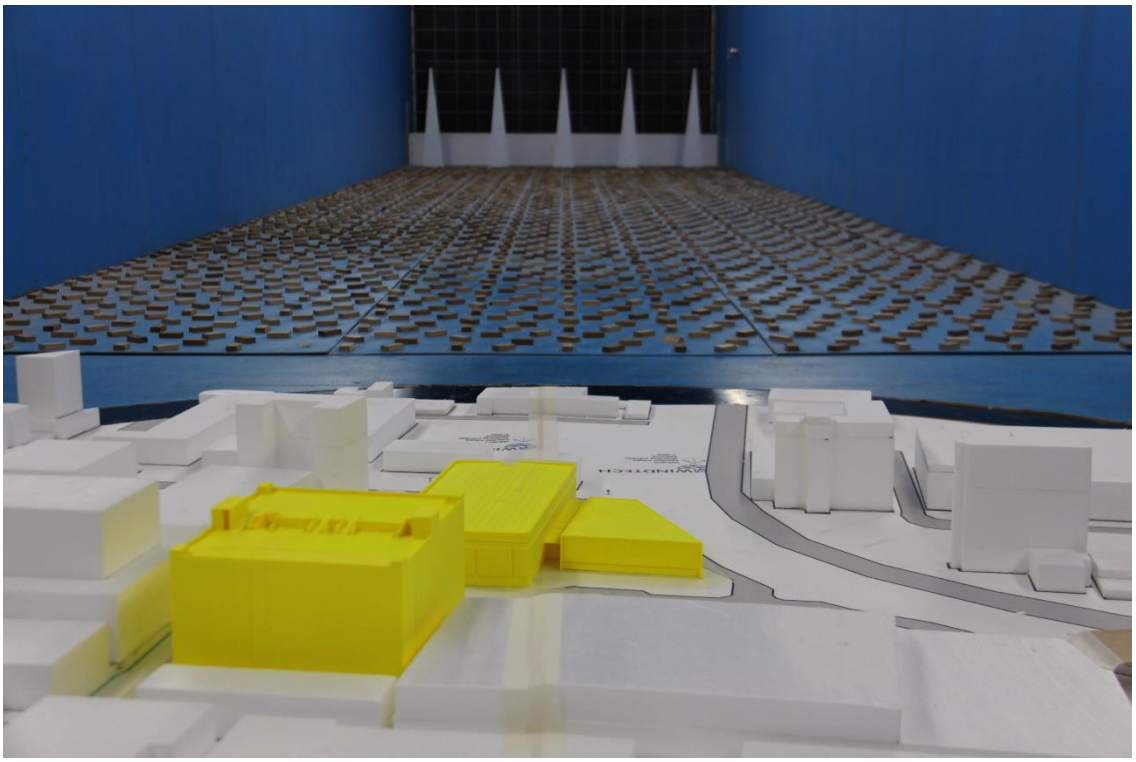

**Figure 2e: Photograph of the Wind Tunnel Model (view from the north)**


**Figure 3: Proximity Model Plan**

# 7 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 Deaves & 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.

For this study this has been undertaken based on the method given in AS/NZS1170.2:2011, using a fetch length of 20 to 40 times the study reference height (as per the recommendations of ASCE-7-16 and AS/NZS1170.2:2011). The proximity model accounts for the effect of the near field topographic effects as well as the influence of the local built forms.

An aerial image showing the surrounding terrain is presented in Figure 4 for a range of 1.2km 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 of 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 8) 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 |
|---|---|---|---|---|---|
| | $k_{tr,T=1hr}$ *(hourly)* | $k_{tr,T=10min}$ *(10min)* | $k_{tr,T=3s}$ *(3sec)* | $I_v$ | *(AS/NZS1170.2:2011 naming convention)* |
| 0 | 0.58 | 0.62 | 0.97 | 0.230 | 2.9 |
| 30 | 0.44 | 0.48 | 0.86 | 0.319 | 3.5 |
| 60 | 0.56 | 0.60 | 0.96 | 0.239 | 3.0 |
| 90 | 0.56 | 0.60 | 0.96 | 0.239 | 3.0 |
| 120 | 0.56 | 0.60 | 0.96 | 0.239 | 3.0 |
| 150 | 0.73 | 0.76 | 1.09 | 0.168 | 2.0 |
| 180 | 0.76 | 0.80 | 1.12 | 0.155 | 1.8 |
| 210 | 0.69 | 0.73 | 1.06 | 0.180 | 2.2 |
| 240 | 0.78 | 0.81 | 1.13 | 0.150 | 1.6 |
| 270 | 0.80 | 0.83 | 1.14 | 0.144 | 1.5 |
| 300 | 0.59 | 0.63 | 0.98 | 0.225 | 2.8 |
| 330 | 0.62 | 0.65 | 1.01 | 0.211 | 2.7 |

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 D of this report.

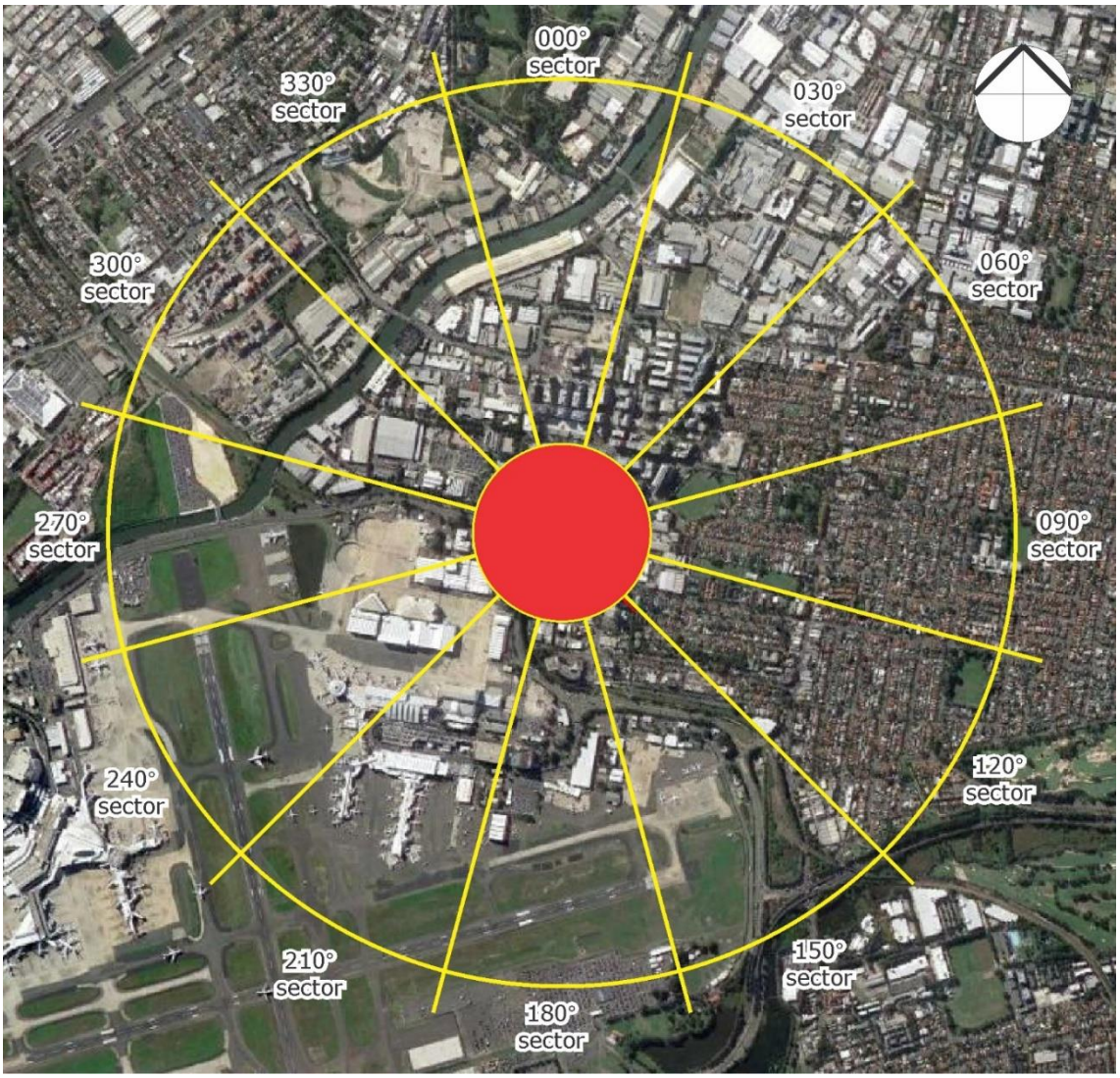


**Figure 4: Aerial Image of the Surrounding Terrain**
**(radius of 1.2km from the edge of the proximity model, which is coloured red)**

# 8 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 Sydney Airport, Mascot. Data was collected from 1995 to 2016 and corrected so that it represents wind speeds 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 analysis indicates that the southerly winds are by far the most frequent wind for the Sydney region, and are also the strongest. The westerly winds occur most frequently during the winter season for the Sydney region and are typically not as strong as the southerly winds. North-easterly winds occur most frequently during the warmer months of the year for the Sydney region and 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) for 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: Directional Wind Speeds**
**(hourly means, referenced to 10m above ground in standard open terrain)**

| Wind Direction | 5% Exceedance (m/s) | Annual Maximum (m/s) |
|---|---|---|
| N | 5.8 | 9.8 |
| NNE | 9.4 | 12.5 |
| NE | 9.1 | 11.9 |
| ENE | 7.0 | 9.8 |
| E | 5.9 | 9.2 |
| ESE | 6.0 | 9.1 |
| SE | 6.8 | 10.0 |
| SSE | 8.5 | 12.1 |
| S | 10.1 | 13.8 |
| SSW | 9.8 | 13.9 |
| SW | 7.0 | 11.8 |
| WSW | 8.9 | 13.2 |
| W | 9.3 | 14.0 |
| WNW | 7.7 | 13.7 |
| NW | 5.9 | 12.1 |
| NNW | 5.3 | 10.3 |

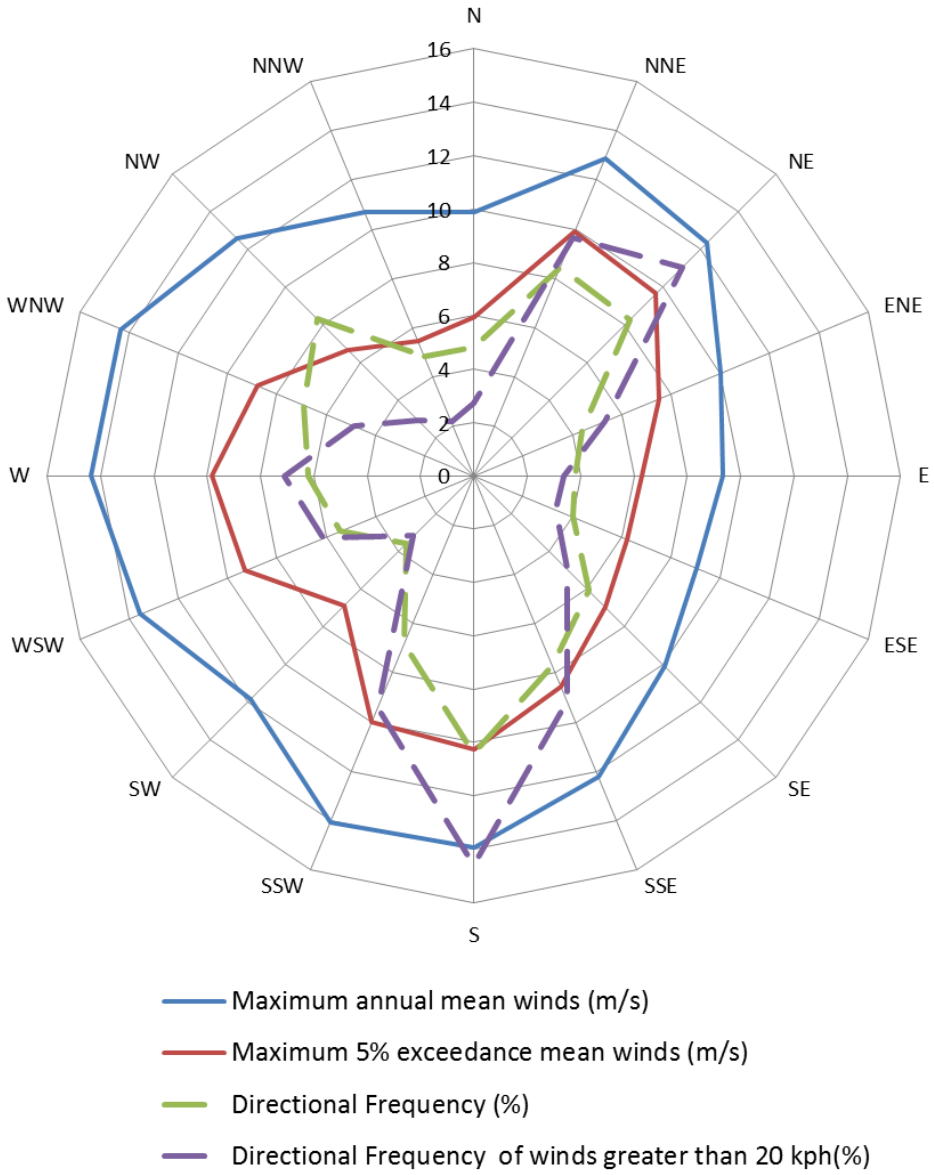


**Figure 5: Annual and 5% Exceedance Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Sydney Region (referenced to 10m above ground in standard open terrain)**

# 9 PEDESTRIAN WIND COMFORT AND SAFETY

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

## 9.1 Measured Wind Speeds

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

Measurements were acquired for 16 wind directions at 22.5 degree increments using a sample rate of 1,024Hz. The full methodology of determining the wind speed measurements at the site from the Dantec Hot-wire probe anemometers is provided in Appendix B. Based on the results of the analysis of the boundary layer wind profiles at the site (see Section 7), and incorporating the regional wind model (see Section 8), 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.

## 9.2 Wind Speed Criteria Used for This Study

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:

$$GEM = max\left(\bar{V}, \frac{\hat{V}}{1.85}\right) \tag{9.1}$$

Where:

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

$\hat{V}$ is the 3-second gust wind speed.

For pedestrian safety, the safety limit criterion of 23m/s applies to 3-second duration annual maximum gust winds for all areas, in accordance with W.H. Melbourne (1978).

For pedestrian comfort, the A.G. Davenport (1972) criteria are used in conjunction with the GEM wind speed using a 5% probability of exceedance. Research by A.W. Rofail (2007) has shown that the A.G. Davenport (1972) criteria, used in conjunction with a GEM wind speed, has proven over time and through field observations to be the most reliable indicator of pedestrian comfort. A more detailed comparison of published criteria has been provided in Appendix A.

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 GEM wind speeds using the comfort criteria, and a plot for the annual maximum gust wind speeds using the safety criterion.

**Table 3: Comfort Criteria (from A.G. Davenport, 1972)**

| Classification | Description | Maximum 5% Exceedance GEM Wind Speed (m/s) |
|---|---|---|
| Long Exposure | Long duration stationary activities such as in outdoor restaurants and theatres, etc. | 3.5 |
| Short Exposure | Short duration stationary activities (generally less than 1 hour), including window shopping, waiting areas, etc. | 5.5 |
| Comfortable Walking | For pedestrian thoroughfares, private swimming pools, most communal areas, private balconies and terraces, etc. | 7.5 |

**Table 4: Safety Criterion (from W.H. Melbourne, 1978)**

| Classification | Description | Annual Maximum Gust Wind Speed (m/s) |
|---|---|---|
| Safety | Safety criterion applies to all trafficable areas. | 23 |

## 9.3 Layout of Study Points

For this study a total of 43 study point locations were selected for analysis in the wind tunnel. This includes the following:

- 23 study points along the pedestrian footpaths and trafficable areas around the Flight Training Centre and Emergency Procedure Hall.
- 16 study points at ground level around the outside of the Car Park.
- 4 study points on the surrounding areas around the proposed development site

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 Figure 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.

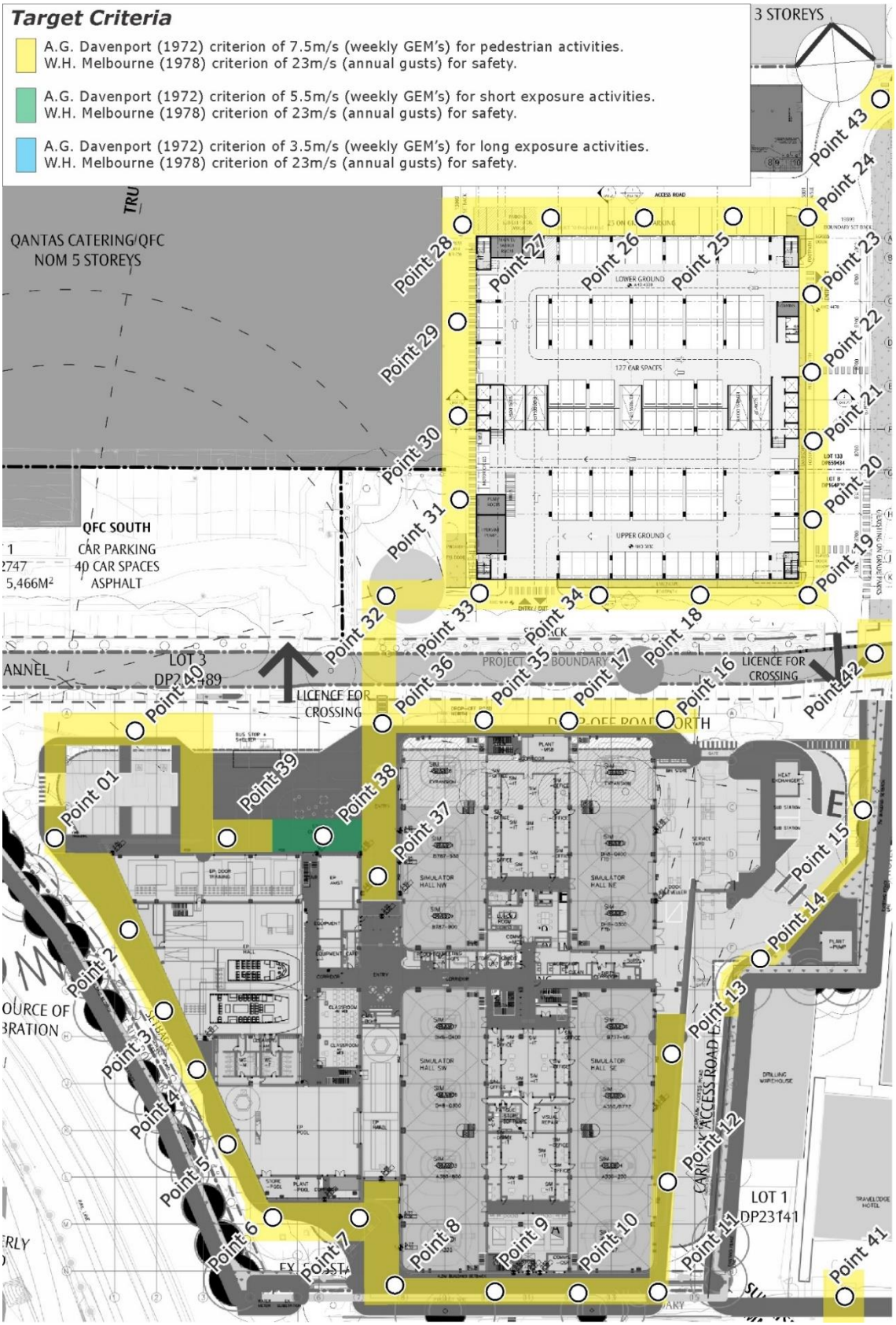


**Figure 6: Study Point Locations and Target Wind Speed Criteria**

# 10 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 Figure 6. 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 Figure 6.

The results of the study indicate that wind conditions for the majority of trafficable outdoor locations within and around the development will be suitable for their intended uses. However, some areas will experience strong winds which will exceed the relevant criteria for comfort and/or safety as shown in Figure 7. Safety is exceeded at several locations around the car park between the Qantas Catering Building to the west and the Tri-Gen building to the north (Points 26, 28, 29 and 30) as well as at the south east corner of the car park and north east corner of the Flight Training Centre (Points 15, 19 and42). These conditions are caused by the venturi effect of the wind accelerating between the various buildings. It is noted that with the open façade design of the car park the wind will not be funnelled, downwashed or side-streamed as strongly in these areas. Therefore it is recommended that the open façade design of the car park be maintained to mitigate these effects.

Suggested treatments are described as follows:

- Retain the evergreen densely foliating tree planting to the west of the Flight Training Centre next to the rail corridor
- Install an awning at the slab of Level 1 over the southern aspect doors of the Flight Training Centre, and retain the evergreen densely foliating tree planting along that southern aspect of the Flight Training Centre.
- Retain the evergreen densely foliating tree planting running west to east along the Sydney Water drainage channel
- Maintain the open façade of the Car Park.

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.

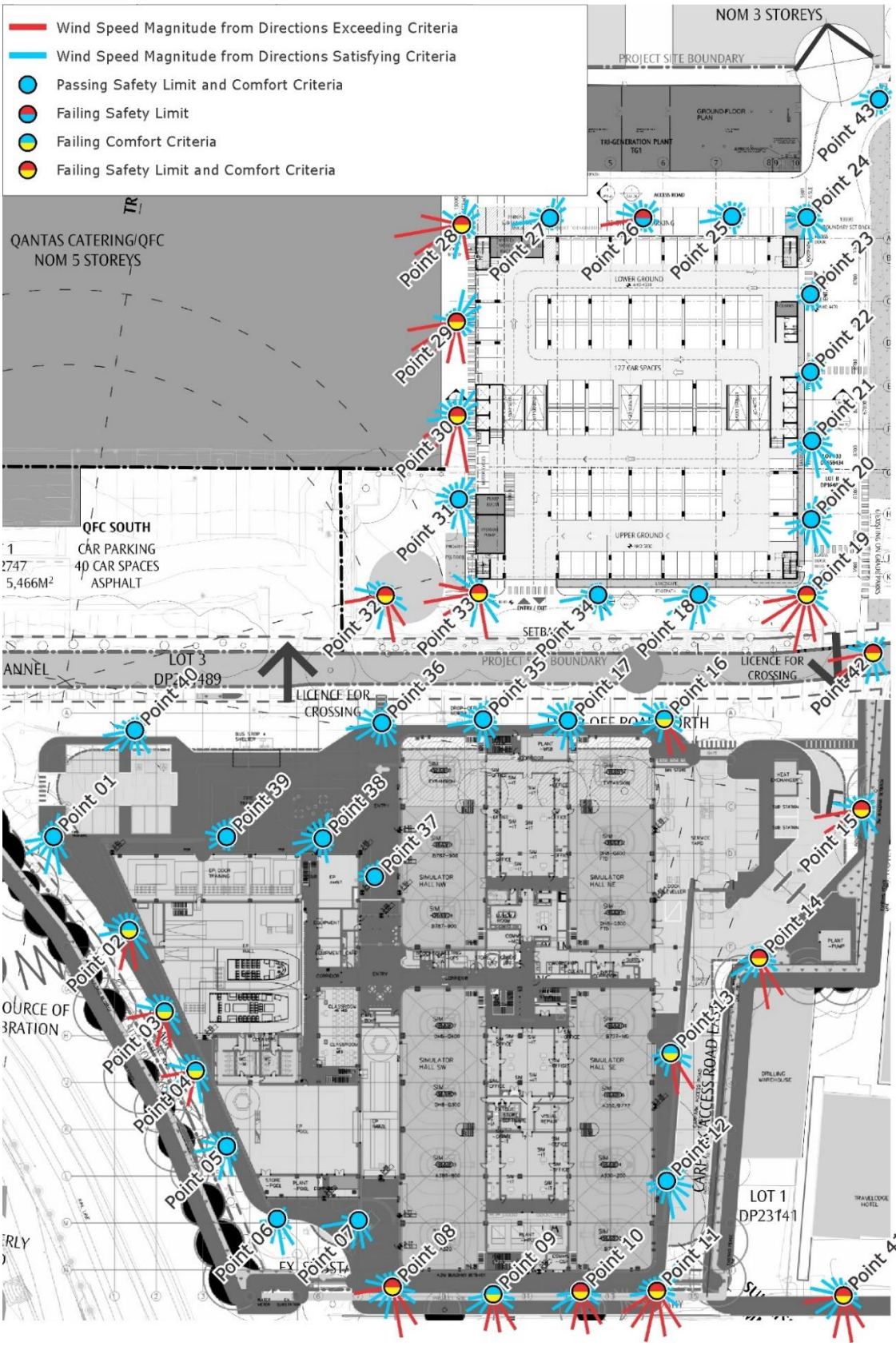


**Figure 7: Wind Tunnel Results**
**(results shown without treatments applied)**

**Table 5: Wind Tunnel Results Summary**

| Study Point | GEM (5% exceedance) | | | Annual Gust | | | Final Result | Description of Treatment |
|---|---|---|---|---|---|---|---|---|
| | Criterion (m/s) | Results (%) | Grade | Criterion (m/s) | Results (m/s) | Grade | | |
| Point 01 | 7.5 | 5% | Pass | 23 | 21 | Pass | Pass | |
| P02 | 7.5 | 9% | Fail | 23 | 23 | Pass | Fail | Retain tree planting to the west along rail corridor |
| P02 Exist | | 4% | Pass | | 20 | Pass | Pass | |
| P03 | 7.5 | 7% | Fail | 23 | 22 | Pass | Fail | Retain tree planting to the west along rail corridor |
| P03 Exist | | 8% | Fail | | 22 | Pass | Fail | |
| P04 | 7.5 | 6% | Fail | 23 | 21 | Pass | Fail | Retain tree planting to the west along rail corridor |
| P04 Exist | | 5% | Pass | | 19 | Pass | Pass | |
| Point 05 | 7.5 | 5% | Pass | 23 | 20 | Pass | Pass | |
| Point 06 | 7.5 | 2% | Pass | 23 | 20 | Pass | Pass | |
| Point 07 | 7.5 | 3% | Pass | 23 | 22 | Pass | Pass | |
| P08 | 7.5 | 18% | Fail | 23 | 27 | Fail | Fail | Install awning over southern entrances, and retain tree planning along the southern aspect. |
| P08 Exist | | 5% | Pass | | 20 | Pass | Pass | |
| P09 | 7.5 | 9% | Fail | 23 | 23 | Pass | Fail | Equivalent to existing condition |
| P09 Exist | | 8% | Fail | | 22 | Pass | Fail | |
| P10 | 7.5 | 11% | Fail | 23 | 24 | Fail | Fail | Install awning over southern entrances, and retain tree planning along the southern aspect. |
| P10 Exist | | 4% | Pass | | 19 | Pass | Pass | |
| P11 | 7.5 | 23% | Fail | 23 | 28 | Fail | Fail | Install awning over southern entrances, and retain tree planning along the southern aspect. |
| P11 Exist | | 14% | Fail | | 26 | Fail | Fail | |
| Point 12 | 7.5 | 4% | Pass | 23 | 20 | Pass | Pass | |
| P13 | 7.5 | 9% | Fail | 23 | 23 | Pass | Fail | Equivalent to existing condition |
| P13 Exist | | 9% | Fail | | 23 | Pass | Fail | |
| P14 | 7.5 | 15% | Fail | 23 | 28 | Fail | Fail | Equivalent to existing condition |
| P14 Exist | | 14% | Fail | | 27 | Fail | Fail | |
| P15 | 7.5 | 11% | Fail | 23 | 28 | Fail | Fail | Maintain open façade on car park |
| P15 Exist | | 2% | Pass | | 19 | Pass | Pass | |
| P16 | 7.5 | 6% | Fail | 23 | 22 | Pass | Fail | Retain existing tree planting between sites |
| P16 Exist | | 4% | Pass | | 21 | Pass | Pass | |
| Point 17 | 7.5 | 5% | Pass | 23 | 22 | Pass | Pass | |
| Point 18 | 7.5 | 5% | Pass | 23 | 22 | Pass | Pass | |
| P19 | 7.5 | 27% | Fail | 23 | 29 | Fail | Fail | Maintain open façade on car park |
| P19 Exist | | 9% | Fail | | 22 | Pass | Fail | |
| Point 20 | 7.5 | 4% | Pass | 23 | 18 | Pass | Pass | |
| Point 21 | 7.5 | 5% | Pass | 23 | 21 | Pass | Pass | |
| Point 22 | 7.5 | 0% | Pass | 23 | 10 | Pass | Pass | |
| Point 23 | 7.5 | 0% | Pass | 23 | 9 | Pass | Pass | |
| Point 24 | 7.5 | 1% | Pass | 23 | 14 | Pass | Pass | |

| Study Point | GEM (5% exceedance) | | | Annual Gust | | | Final Result | Description of Treatment |
|---|---|---|---|---|---|---|---|---|
| | Criterion (m/s) | Results (%) | Grade | Criterion (m/s) | Results (m/s) | Grade | | |
| Point 25 | 7.5 | 1% | Pass | 23 | 20 | Pass | Pass | |
| P26 | 7.5 | 5% | Pass | 23 | 25 | Fail | Fail | Maintain open façade on car park |
| P26 Exist | | 0% | Pass | | 14 | Pass | Pass | |
| Point 27 | 7.5 | 2% | Pass | 23 | 23 | Pass | Pass | |
| P28 | 7.5 | 17% | Fail | 23 | 31 | Fail | Fail | Maintain open façade on car park |
| P28 Exist | | 10% | Fail | | 26 | Fail | Fail | |
| P29 | 7.5 | 21% | Fail | 23 | 27 | Fail | Fail | Maintain open façade on car park |
| P29 Exist | | 4% | Pass | | 21 | Pass | Pass | |
| P30 | 7.5 | 20% | Fail | 23 | 28 | Fail | Fail | Maintain open façade on car park |
| P30 Exist | | 3% | Pass | | 21 | Pass | Pass | |
| Point 31 | 7.5 | 4% | Pass | 23 | 21 | Pass | Pass | |
| P32 | 7.5 | 14% | Fail | 23 | 25 | Fail | Fail | Maintain open façade on car park |
| P32 Exist | | 7% | Fail | | 25 | Fail | Fail | |
| P33 | 7.5 | 21% | Fail | 23 | 32 | Fail | Fail | Maintain open façade on car park |
| P33 Exist | | 10% | Fail | | 23 | Pass | Fail | |
| Point 34 | 7.5 | 3% | Pass | 23 | 22 | Pass | Pass | |
| Point 35 | 7.5 | 2% | Pass | 23 | 20 | Pass | Pass | |
| Point 36 | 7.5 | 3% | Pass | 23 | 22 | Pass | Pass | |
| Point 37 | 7.5 | 0% | Pass | 23 | 11 | Pass | Pass | |
| Point 38 | 5.5 | 2% | Pass | 23 | 14 | Pass | Pass | |
| Point 39 | 7.5 | 0% | Pass | 23 | 15 | Pass | Pass | |
| Point 40 | 7.5 | 3% | Pass | 23 | 20 | Pass | Pass | |
| P41 | 7.5 | 20% | Fail | 23 | 25 | Fail | Fail | Better than existing conditions |
| P41 Exist | | 23% | Fail | | 26 | Fail | Fail | |
| P42 | 7.5 | 10% | Fail | 23 | 28 | Fail | Fail | Maintain open façade on car park |
| P42 Exist | | 2% | Pass | | 21 | Pass | Pass | |
| Point 43 | 7.5 | 0% | Pass | 23 | 16 | 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. If treatment is required, the treatment is described in Table 5.

# 11 RISK ASSESSMENT AND MITIGATION MEASURES

| Matter | Potential Impact | Likelihood | Consequence | Risk Level | Proposed Mitigation Measure |
|---|---|---|---|---|---|
| Wind Impact | Adverse wind conditions for pedestrians generated around subject development | C | 3 | Medium | Retention of wind mitigation features in current design including the open car park façade design, an awning over the southern entrances of the Flight Training Centre and the inclusion of localised planting at the western site boundary, along the Sydney Water Drainage canal, and along the southern aspect of the Flight Training Centre. |

# 12 REFERENCES


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Rofail, A.W., and Kwok, K.C.S., 1991, "A Reliability Study of Wind Tunnel Results of Cladding Pressures". Proceedings of the 8th International Conference on Wind Engineering, Canada.

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

# 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.1.1 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 - 0.25 | |
| Calm, light air | 1 | 0 25 - 1.55 | No noticeable wind |
| Light breeze | 2 | 1.55 - 3.35 | Wind felt on face |
| Gentle breeze | 3 | 3.35 - 5.45 | Hair is disturbed, clothing flaps, newspapers difficult to read |
| Moderate breeze | 4 | 5.45 - 7.95 | Raises dust, dry soil and loose paper, hair disarranged |
| Fresh breeze | 5 | 7.95 – 10.75 | Force of wind felt on body, danger of stumbling |
| Strong breeze | 6 | 10.75 – 13.85 | Umbrellas used with difficulty, hair blown straight, difficult to walk steadily, wind noise on ears unpleasant |
| Near gale | 7 | 13.85 – 17.15 | Inconvenience felt when walking |
| Gale | 8 | 17.15 - 20.75 | Generally impedes progress, difficulty balancing in gusts |
| Strong gale | 9 | 20.75 – 24.45 | People blown over |

### A.1.2 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.1.3 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.1.4 W.H. Melbourne (1978) Criteria for Gust Wind Speeds

W.H. Melbourne (1978) introduced a set of criteria for the assessment of environmental wind conditions 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 | Human 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.2 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%.

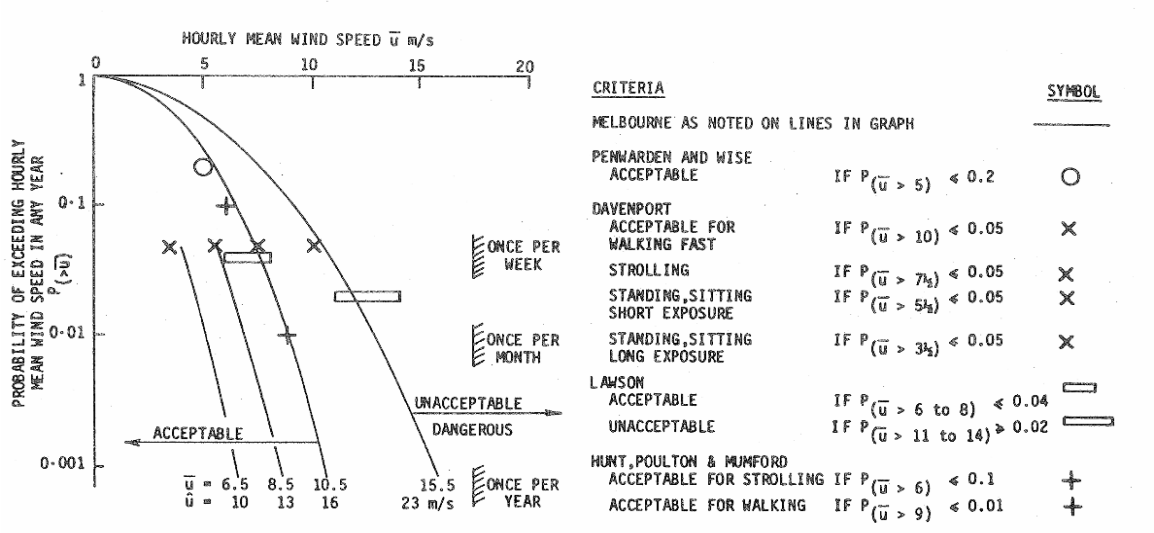


**Figure A.1: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (W.H. Melbourne, 1978)**

## A.3 References relating to Pedestrian Comfort Criteria


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

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# APPENDIX B DATA ACQUISITION

The wind tunnel testing procedures 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 acquired as coefficients by Dantec hot-wire anemometers 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 Dantec hot-wire probe anemometers at selected critical outdoor locations. The anemometers were positioned at each study location at a full-scale height of approximately 1.5m above ground/slab level. The support of the probe was mounted such that the probe wire was 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 probe wire and in avoiding wall-heating effects.

Wind speed measurements were made in the wind tunnel for 16 wind directions, at 22.5° increments. The output from the hot-wire probes was obtained using a National Instruments 12-bit data acquisition card. The 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.

The mean, gust and standard deviation velocity coefficients were measured 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 coefficient.

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

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

$\sigma_{C_V}$ is the standard deviation of coefficient measurement.

## 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 8 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.2.1 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:

$$V_{study} = V_{ref,RH}\left(\frac{k_{200m,tr,T=1hr}}{k_{RH,tr,T=1hr}}\right)C_V \qquad \text{B.2}$$

Where:

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

$V_{ref,RH}$ is the full-scale reference wind speed, measured 3m upstream at the study reference height. This value is determined by combining the directional wind speed data for the region (detailed in Section 8) and the upwind terrain and height multipliers for the site (detailed in Section 7).

$k_{200m,tr,T=1hr}$ is the standard deviation of the wind speed.

$k_{RH,tr,T=1hr}$ is the hourly mean terrain and height multiplier at the study reference height (see Section 7).

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

$$C_V = \frac{C_{V,study}}{C_{V,200m}} \qquad \text{B.3}$$

Where:

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

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

The value of $\mathrm{V_{ref,RH}}$ 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/NZS1170.2:2011, which assumes that the major contributions to the combined probability of exceedance of a typical load effect comes from only two 45 degree sectors.

### B.2.2 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.3 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*.

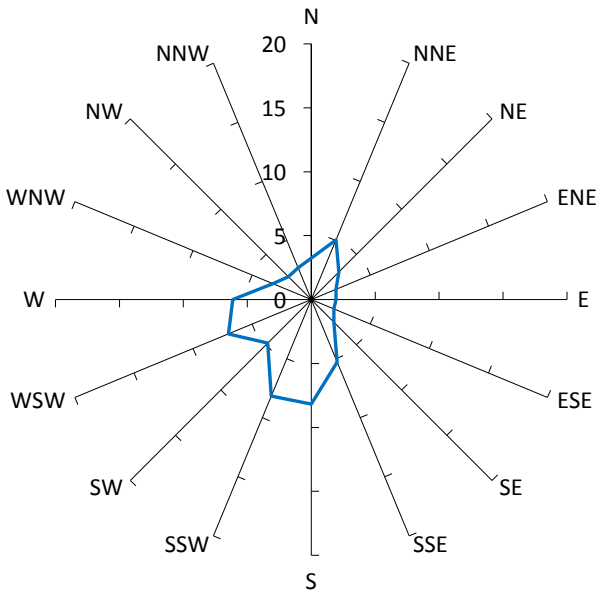
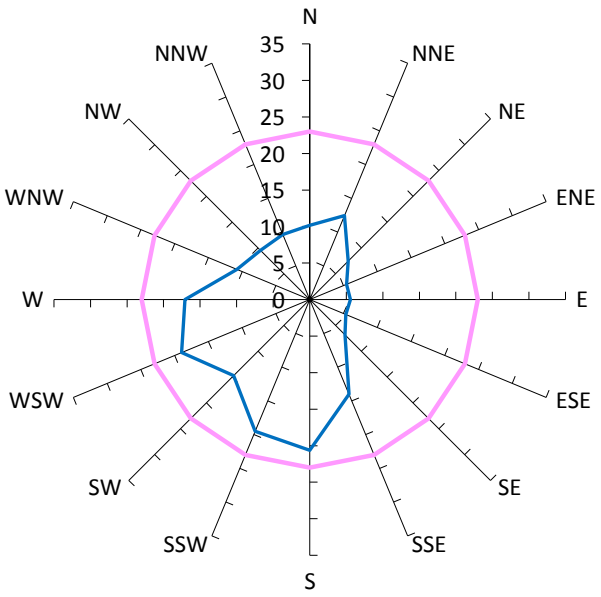
Council on Tall Buildings and Urban Habitat (CTBUH), 2013, "Wind tunnel testing of high-rise buildings", CTBUH Technical Guides.

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

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

# APPENDIX C DIRECTIONAL PLOTS OF WIND TUNNEL RESULTS

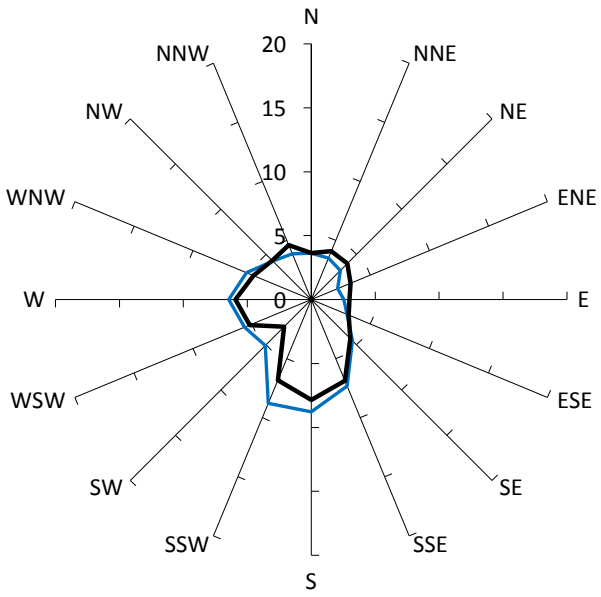
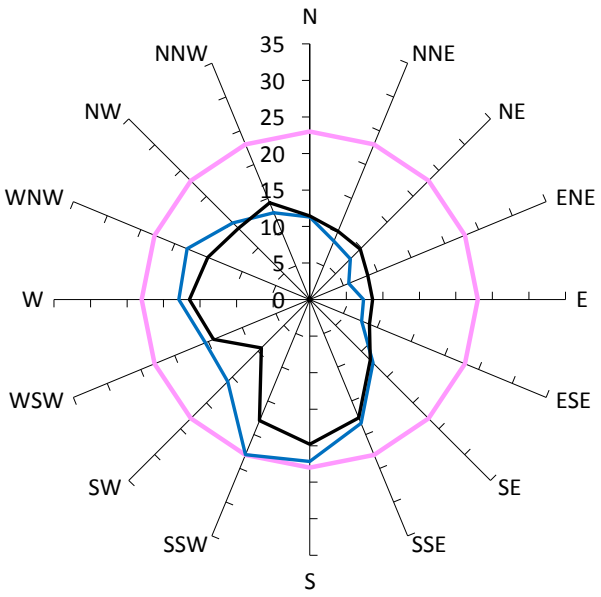
# Results for Point 01

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 5% | 21 |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

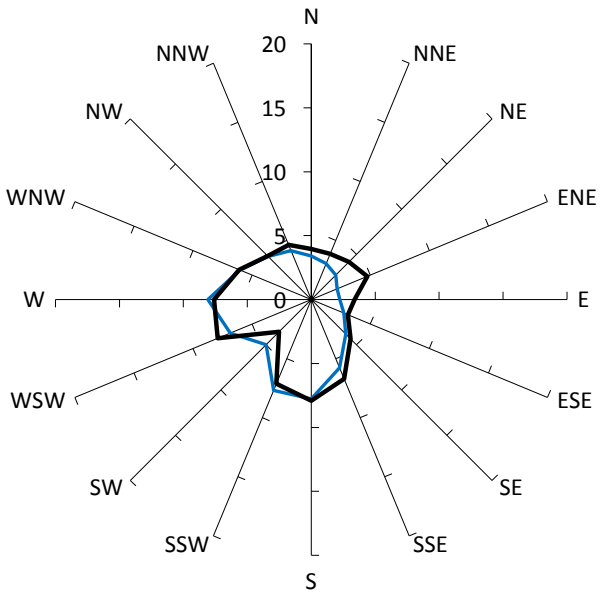
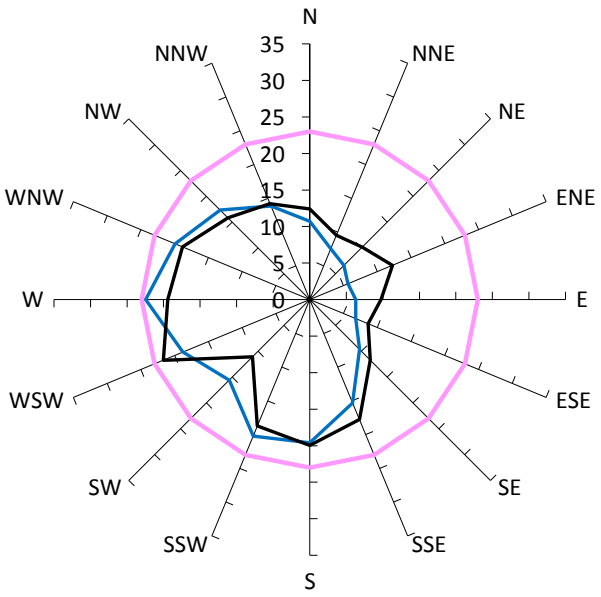
# Results for Point 02

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 9% | 23 |
| *Existing site only* | 4% | 20 |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

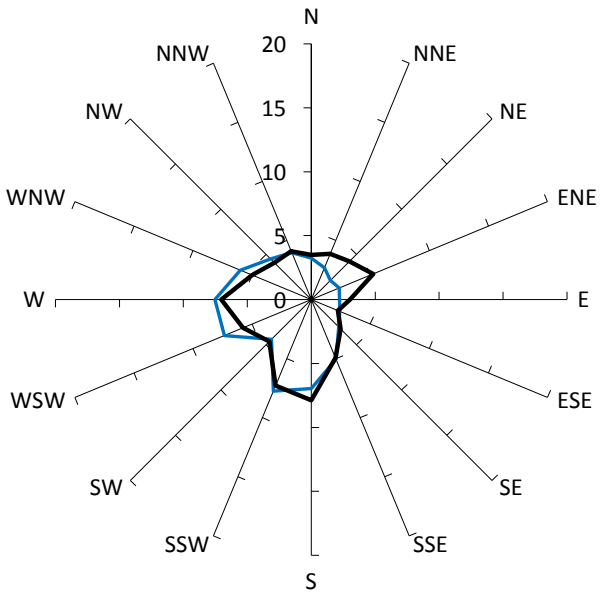
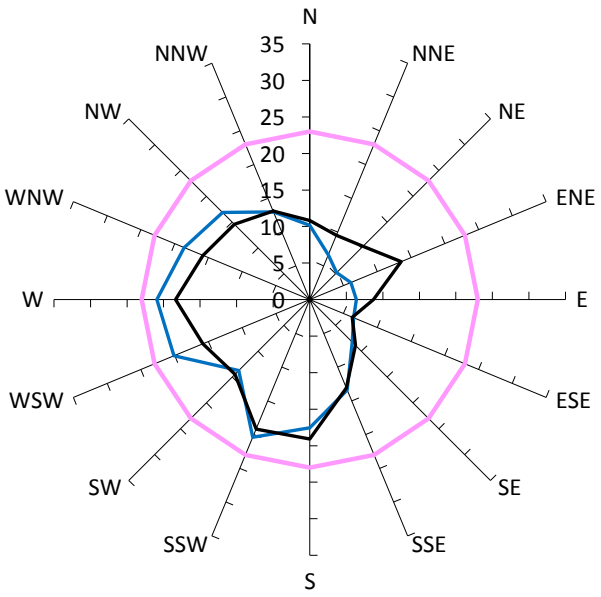
# Results for Point 03

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 7% | 22 |
| *Existing site only* | 8% | 22 |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

# Results for Point 04

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 6% | 21 |
| *Existing site only* | 5% | 19 |
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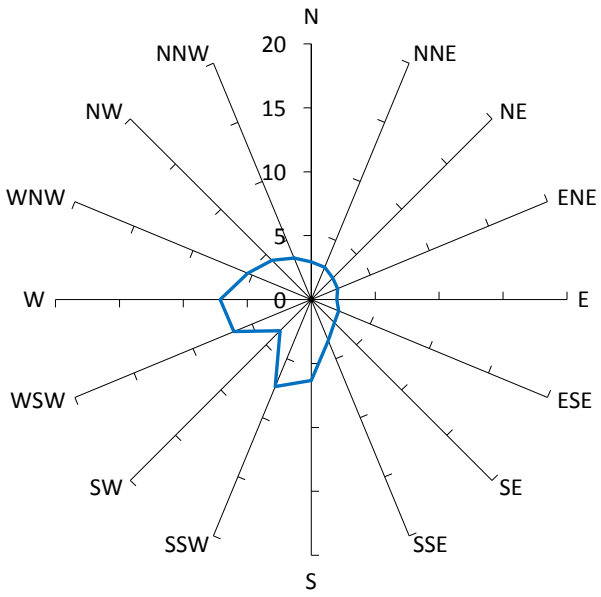
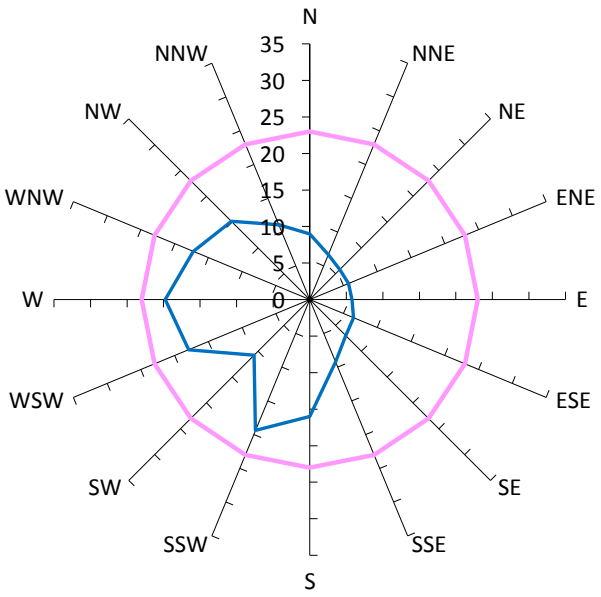
# Results for Point 05

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 4% | 20 |
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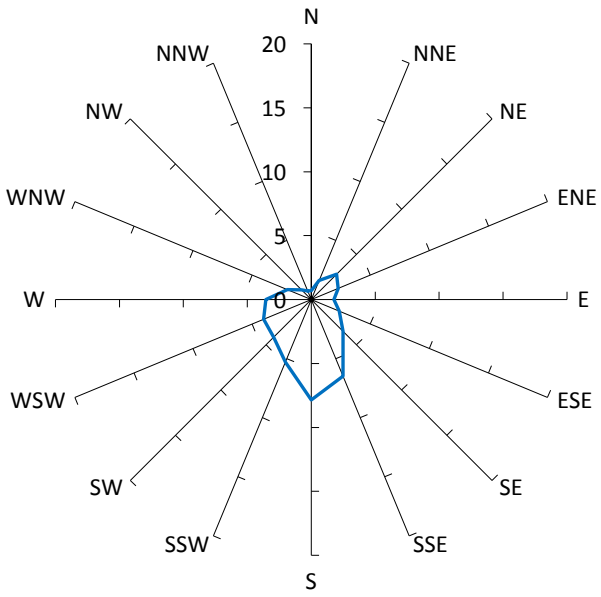
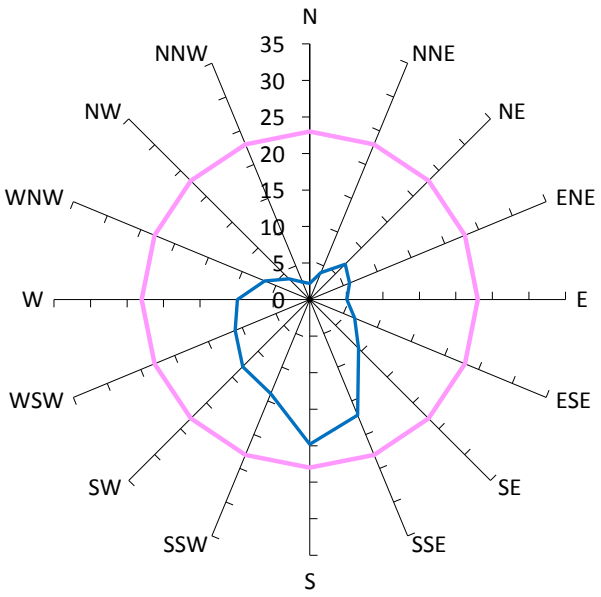
# Results for Point 06

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 2% | 20 |
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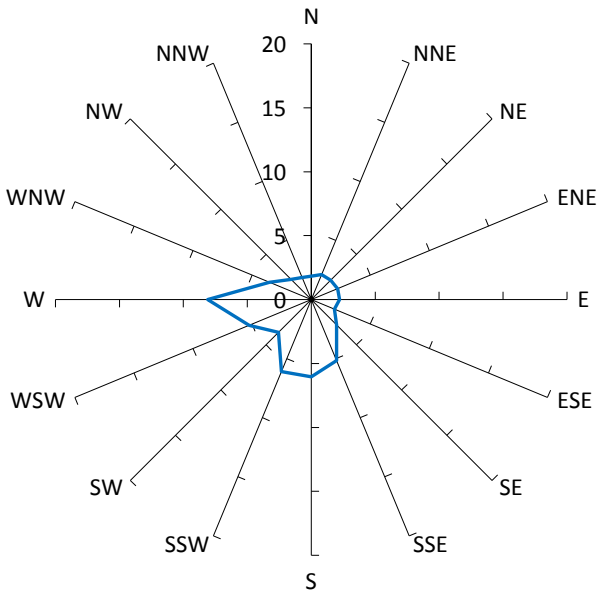
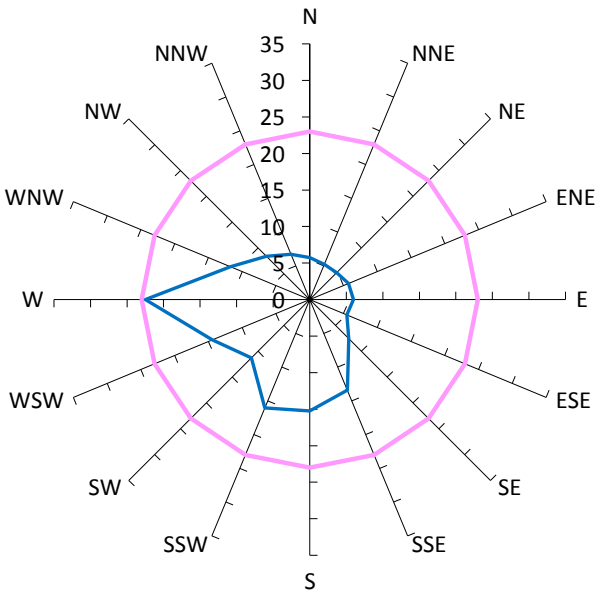
# Results for Point 07

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 3% | 22 |
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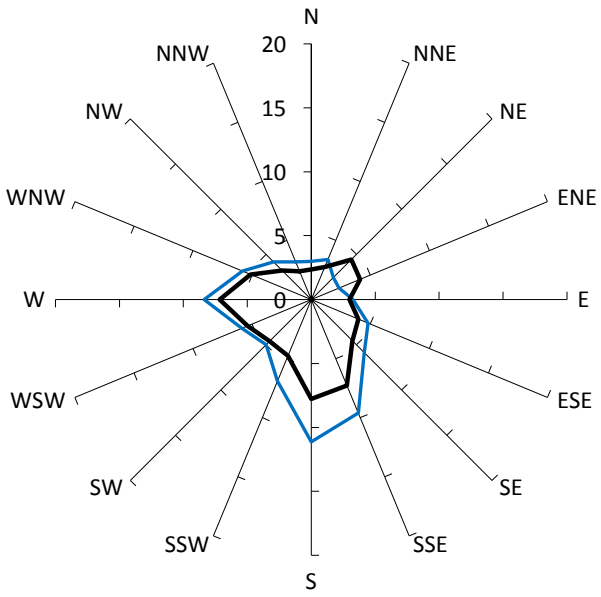
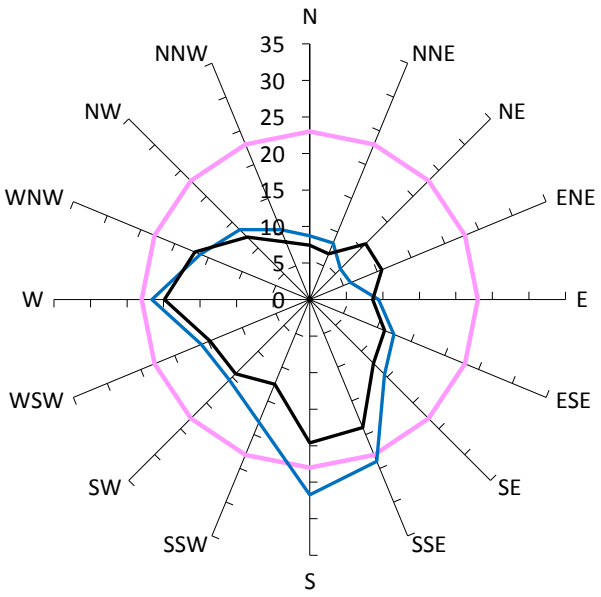
# Results for Point 08

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 18% | 27 |
| *Existing site only* | 5% | 20 |
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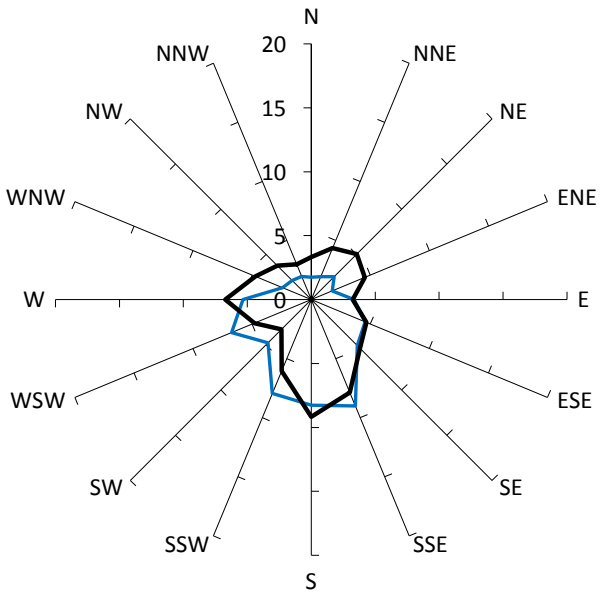
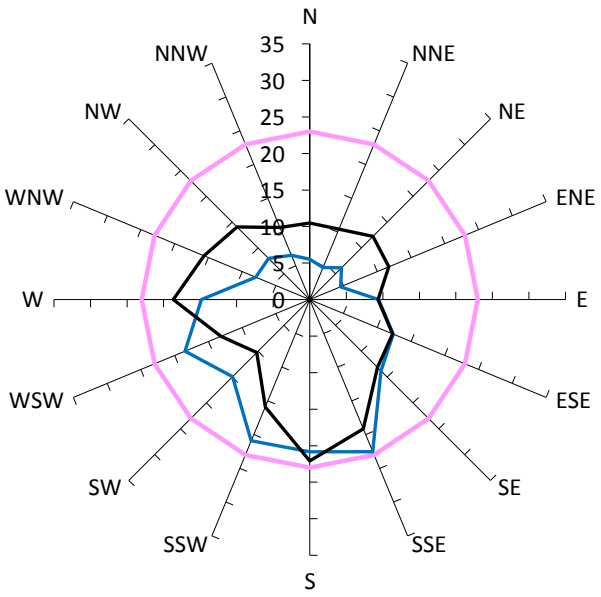
# Results for Point 09

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 9% | 23 |
| *Existing site only* | 8% | 22 |
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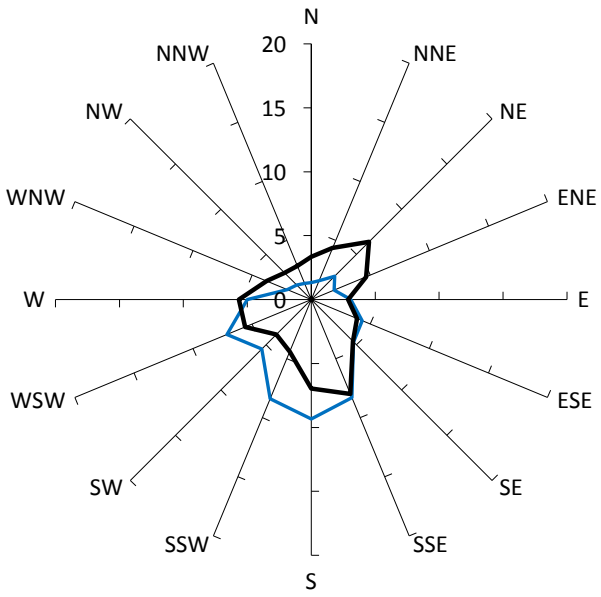
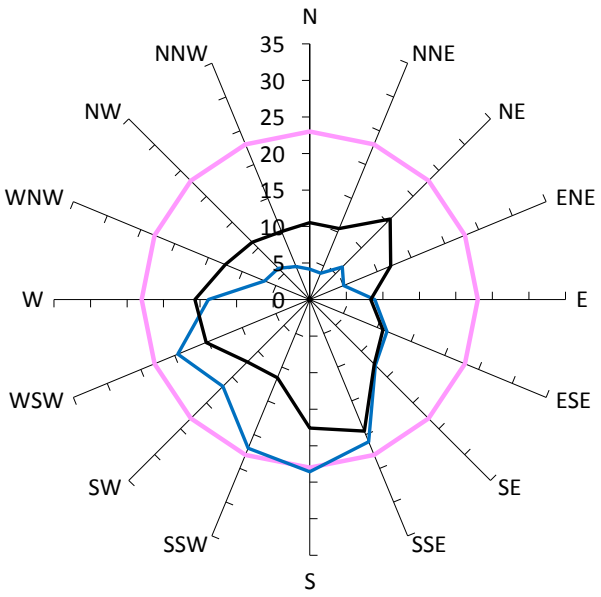
# Results for Point 10

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 11% | 24 |
| *Existing site only* | 4% | 19 |
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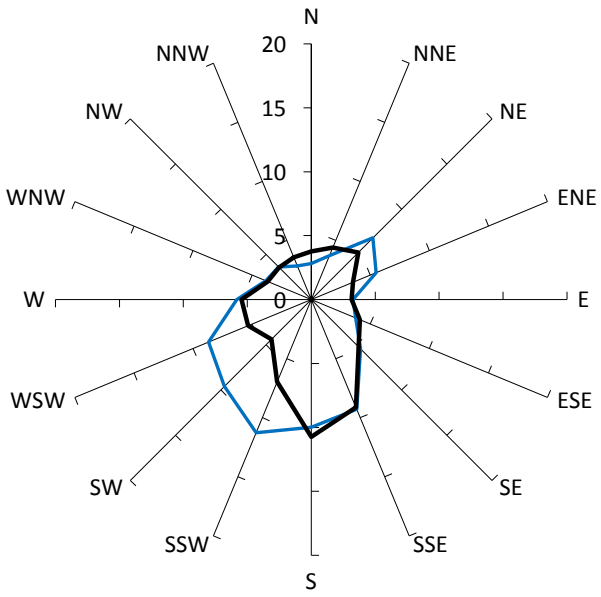
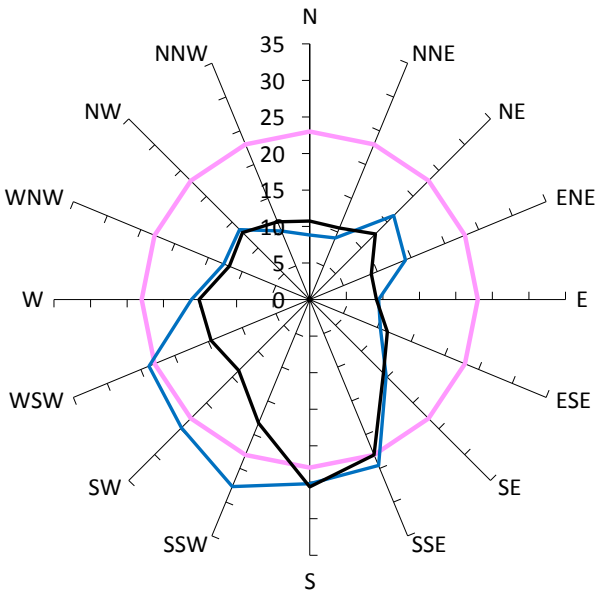
# Results for Point 11

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 23% | 28 |
| *Existing site only* | 14% | 26 |
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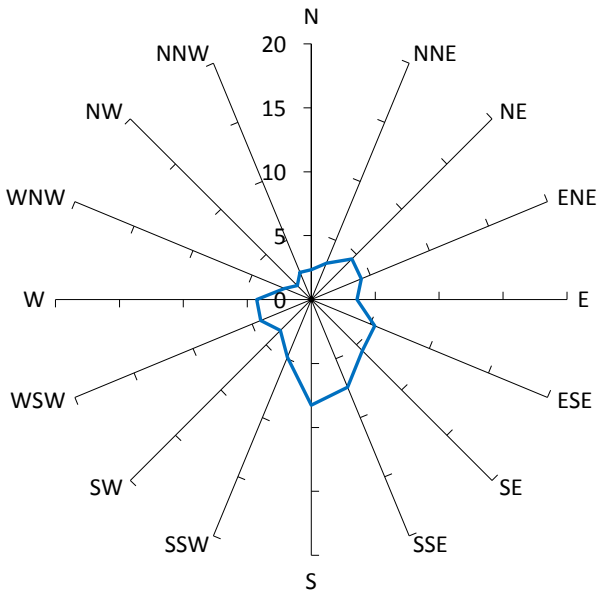
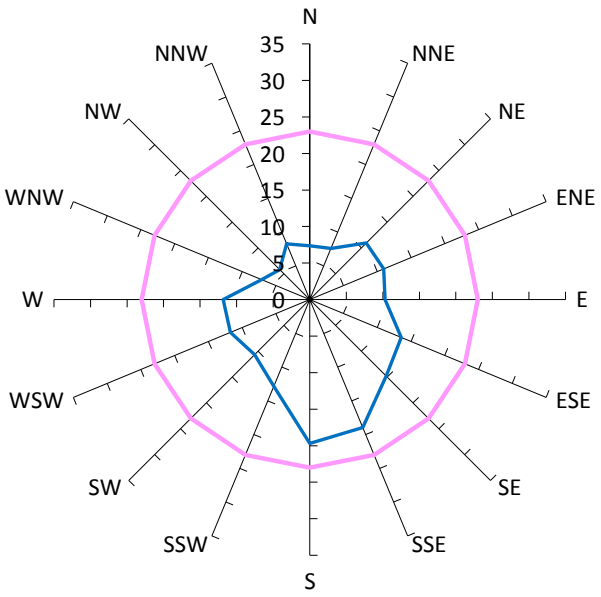
# Results for Point 12

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 4% | 20 |
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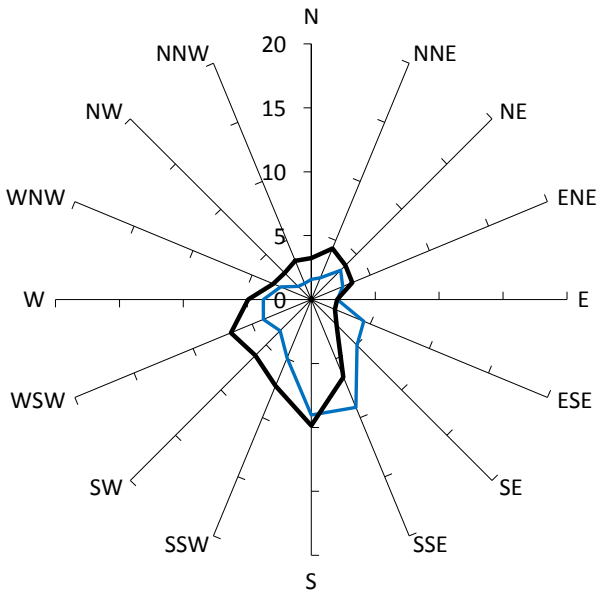
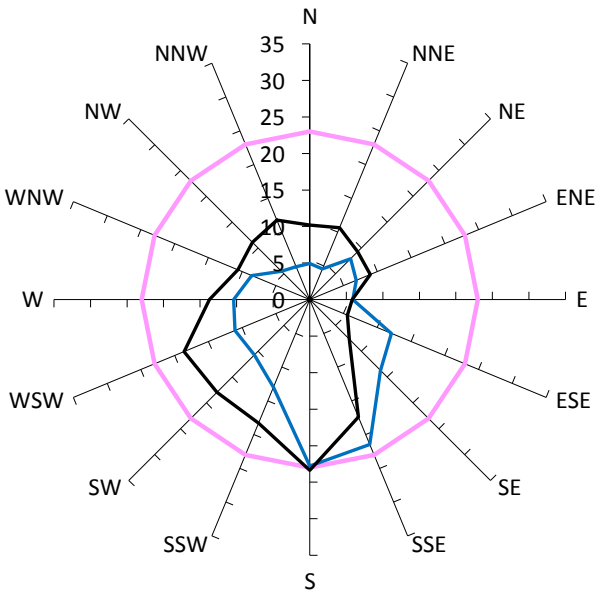
# Results for Point 13

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 9% | 23 |
| *Existing site only* | 9% | 23 |
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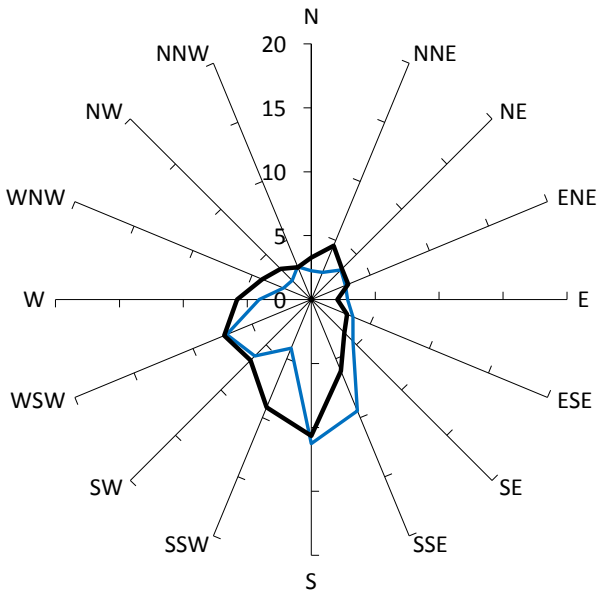
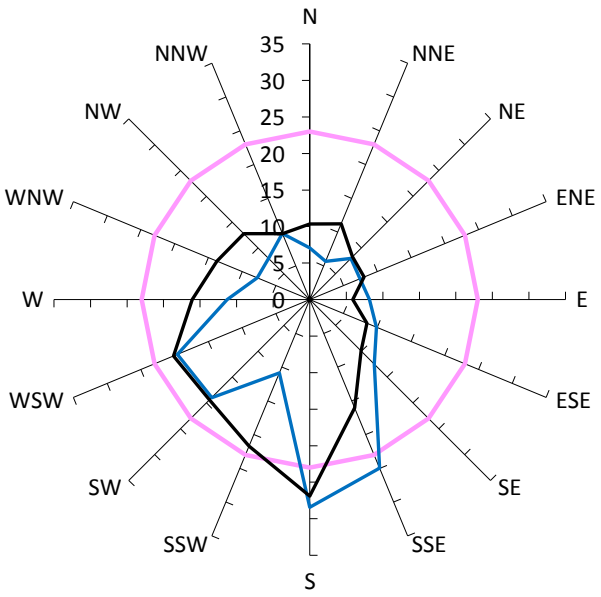
# Results for Point 14

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 15% | 28 |
| *Existing site only* | 14% | 27 |
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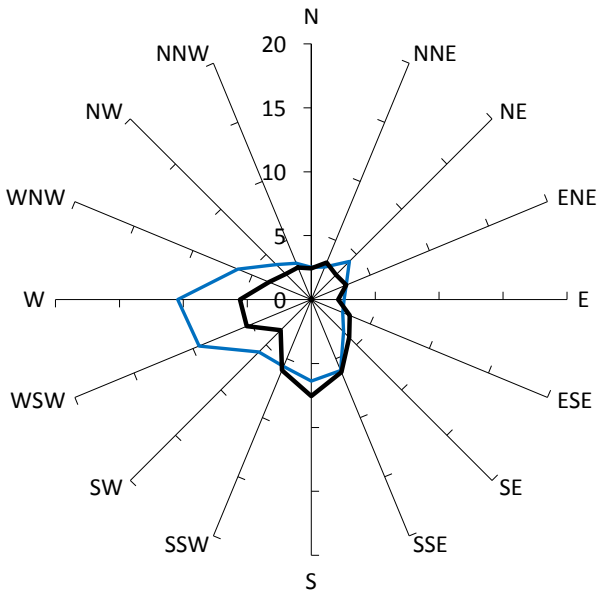
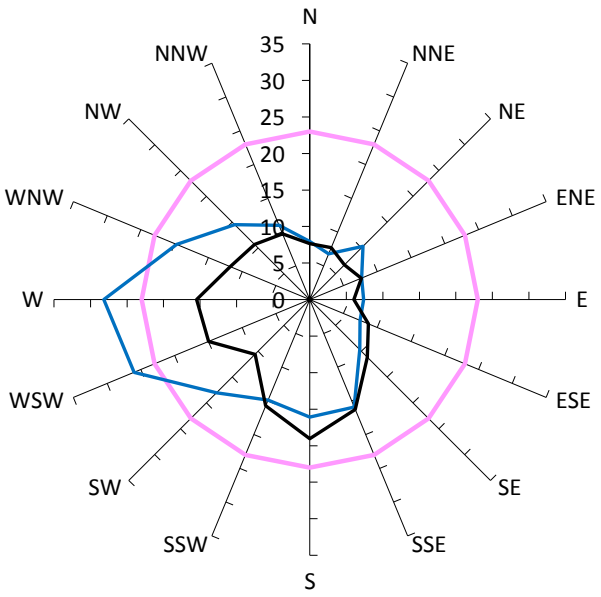
# Results for Point 15

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 11% | 28 |
| *Existing site only* | 2% | 19 |
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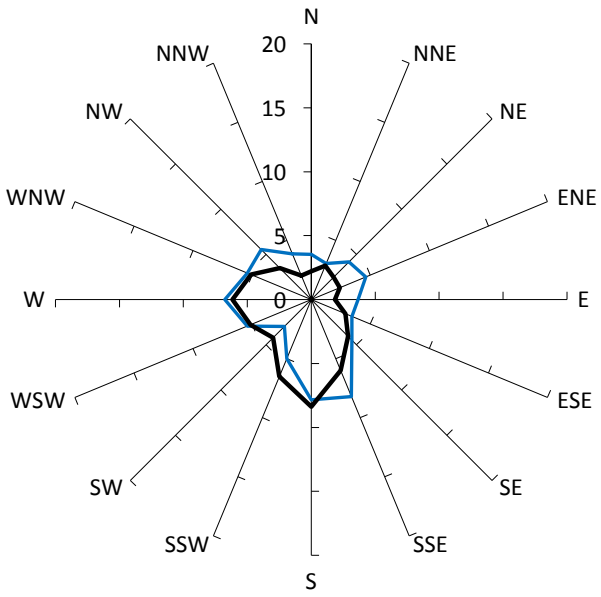
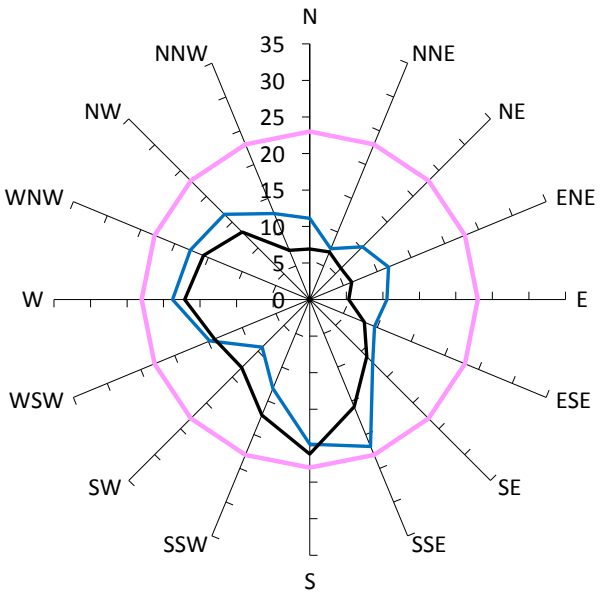
# Results for Point 16

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 6% | 22 |
| *Existing site only* | 4% | 21 |
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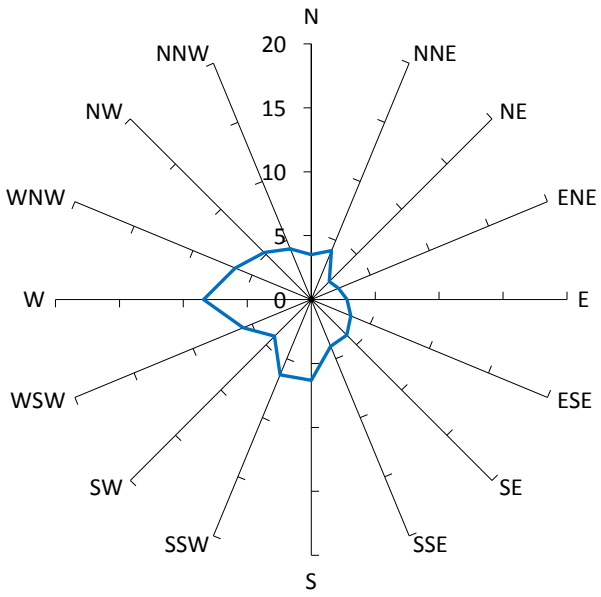
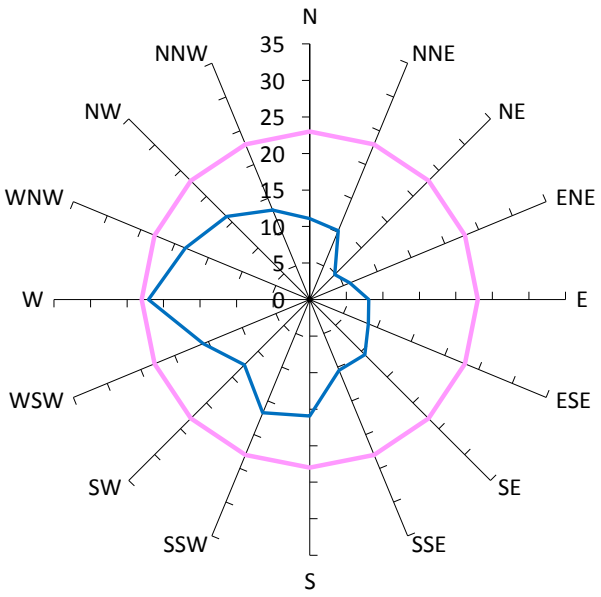
# Results for Point 17

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 5% | 22 |
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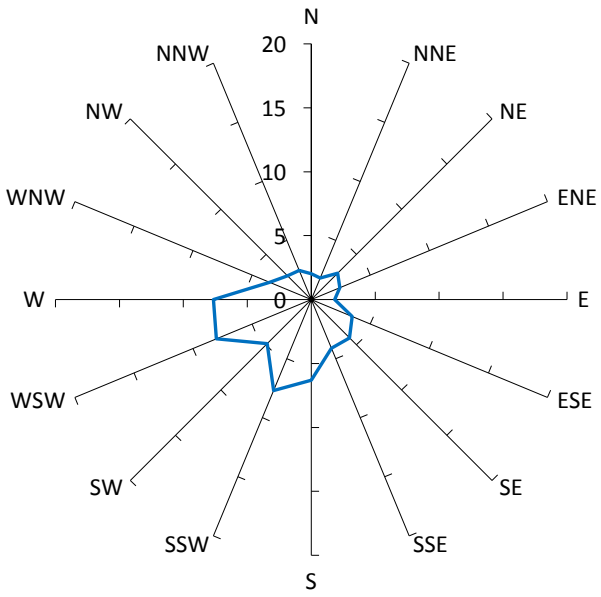
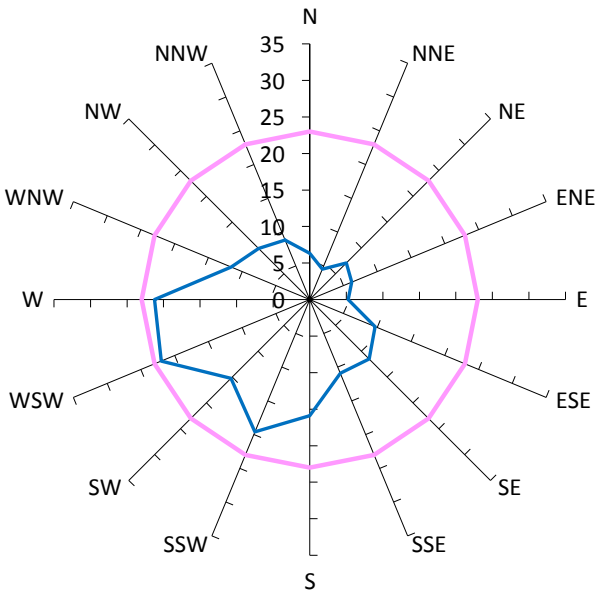
# Results for Point 18

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 5% | 22 |
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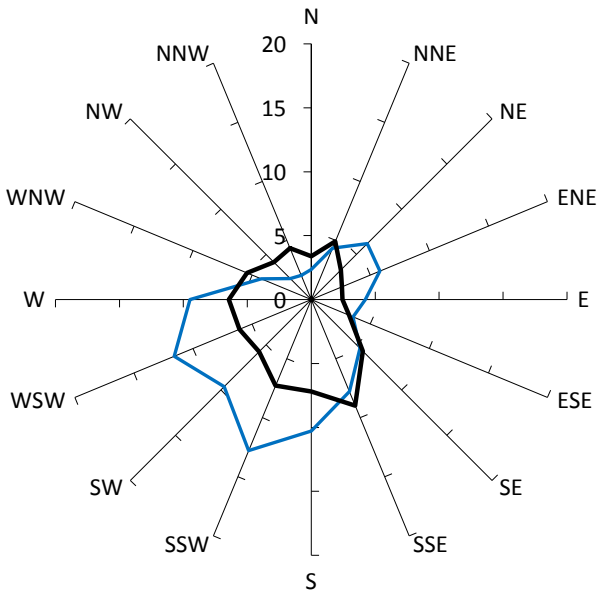
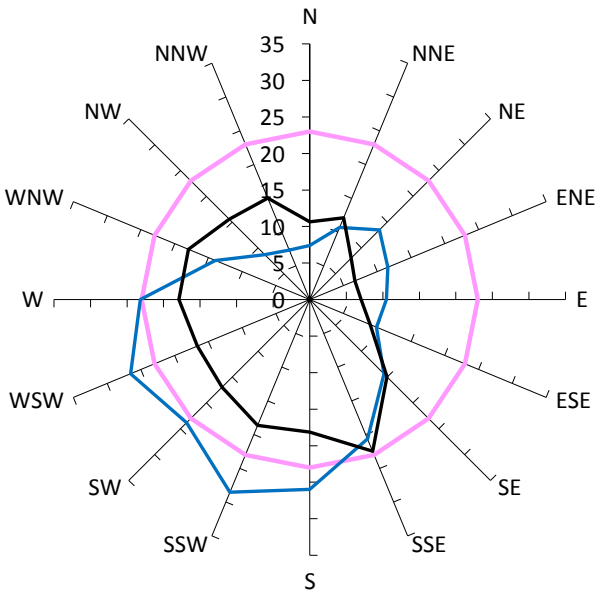
# Results for Point 19

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 27% | 29 |
| *Existing site only* | 9% | 22 |
| | | |
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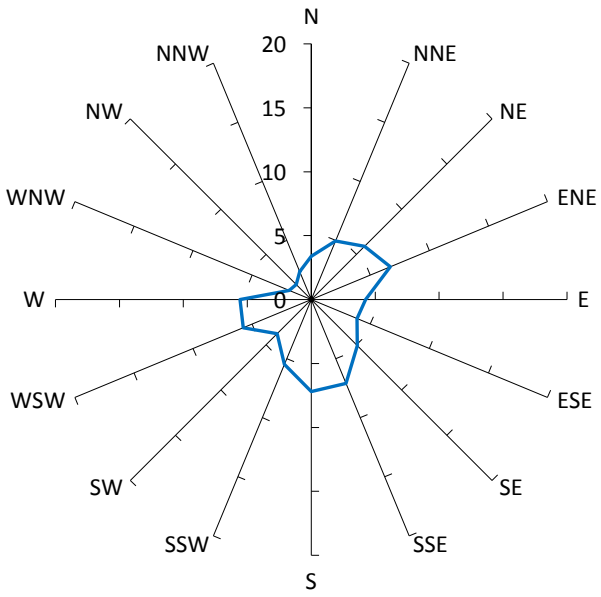
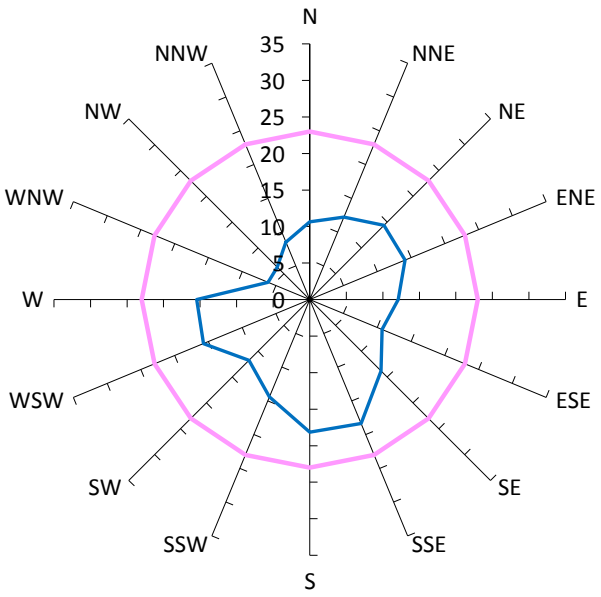
# Results for Point 20

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 4% | 18 |
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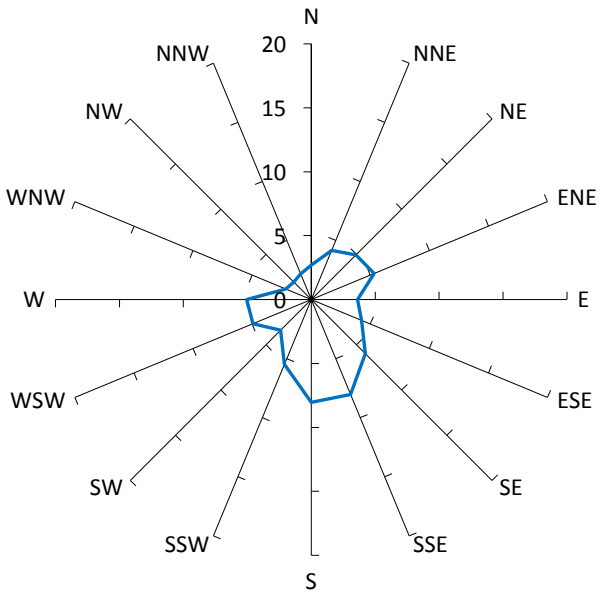
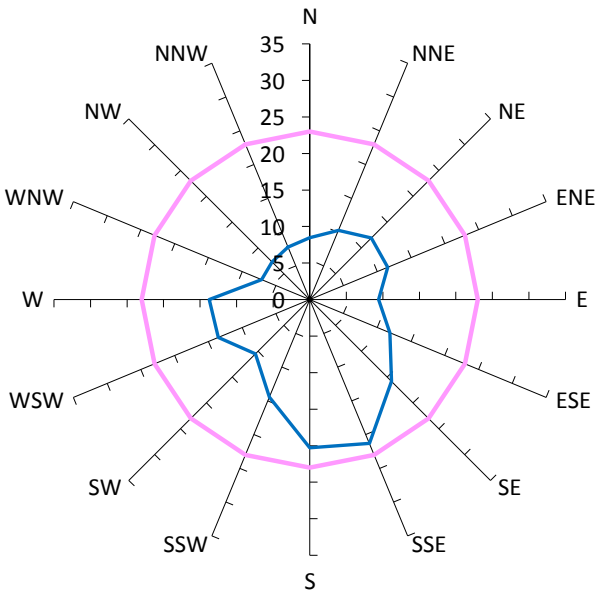
# Results for Point 21

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 5% | 21 |
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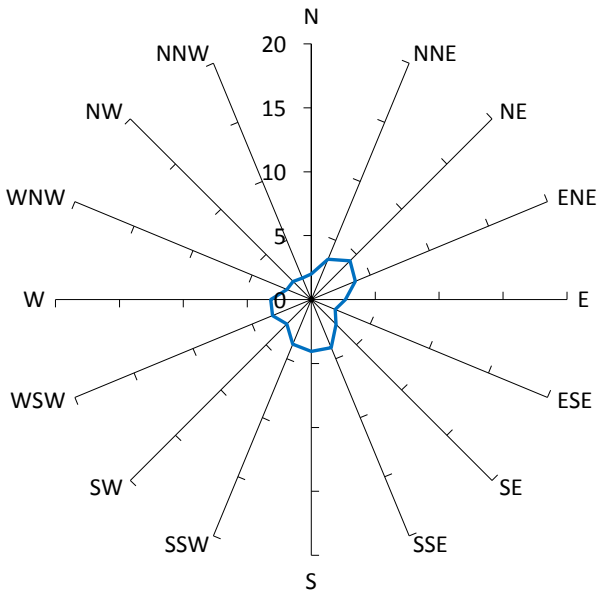
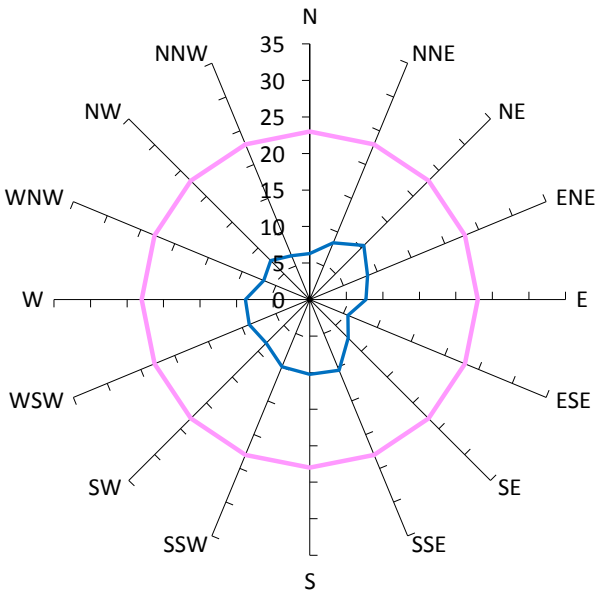
| | | |

# Results for Point 22

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 0% | 10 |
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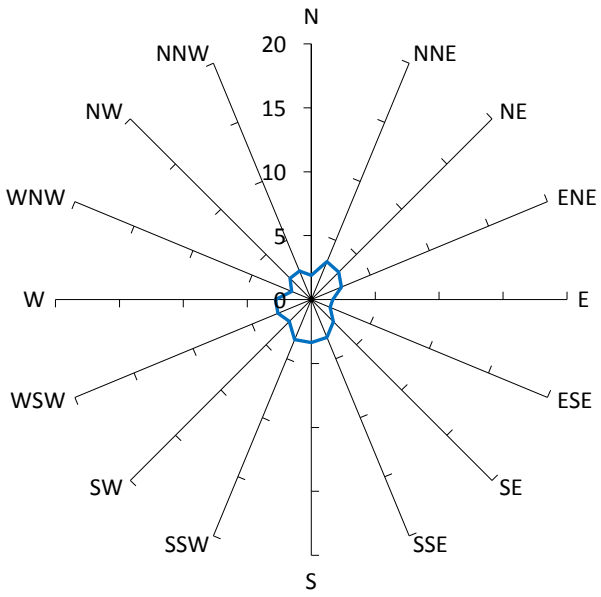
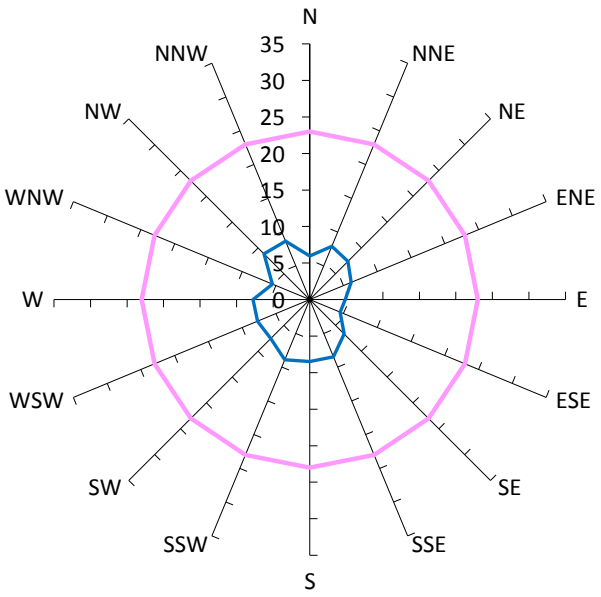
# Results for Point 23

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 0% | 9 |
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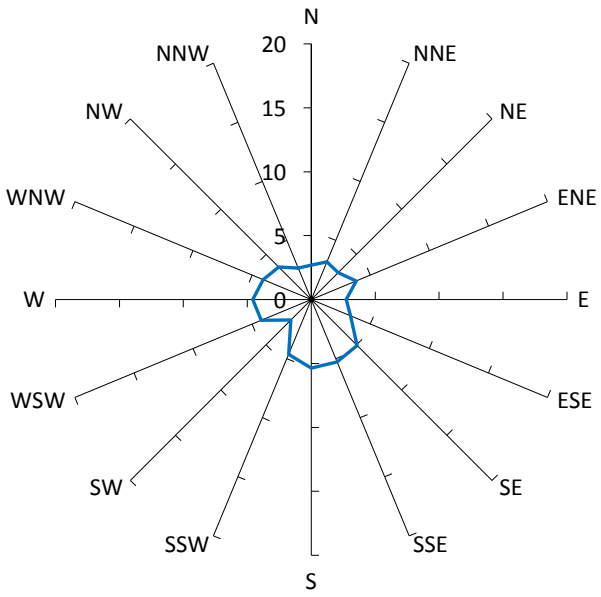
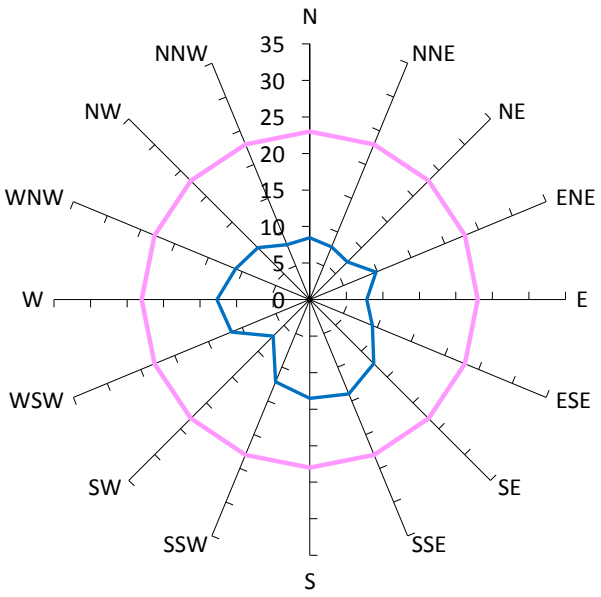
# Results for Point 24

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 1% | 14 |
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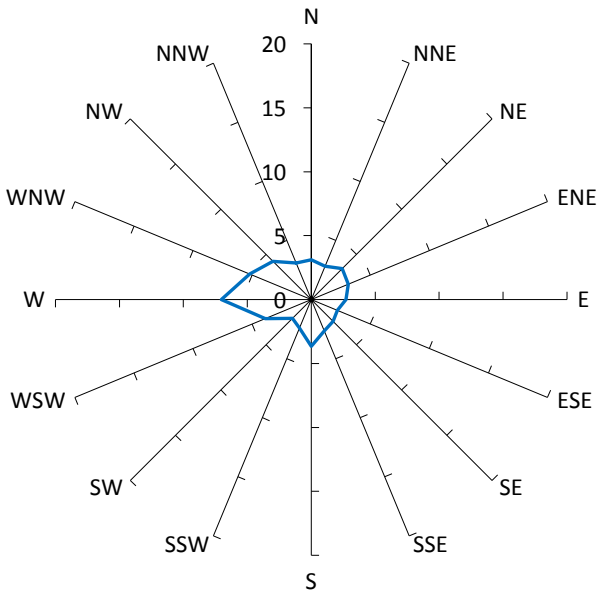
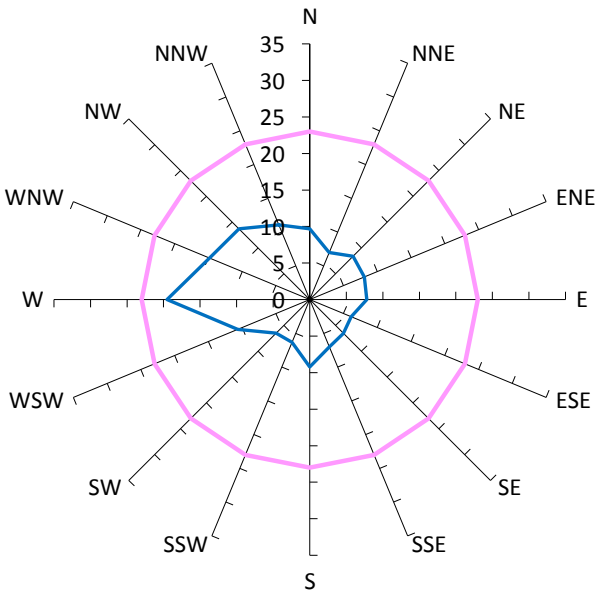
# Results for Point 25

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 1% | 20 |
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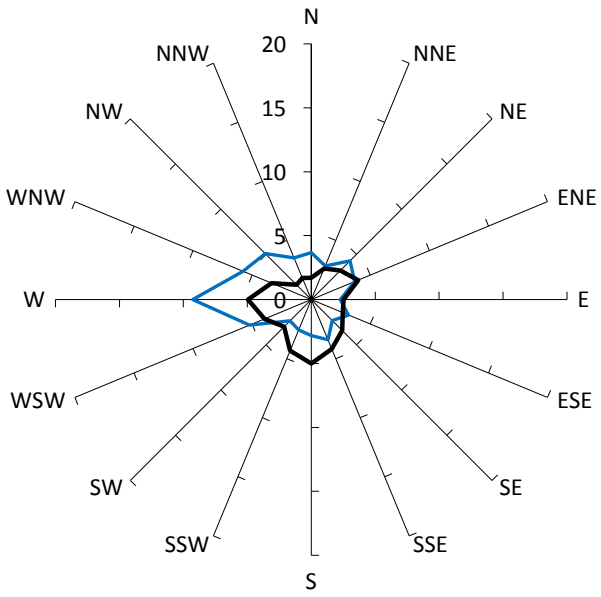
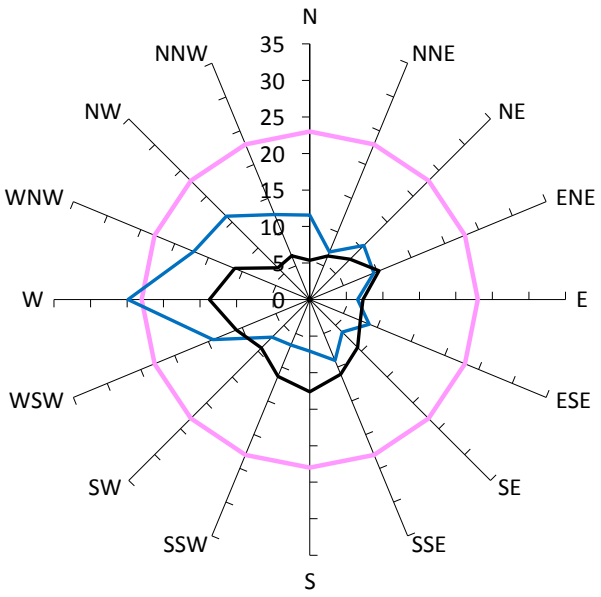
# Results for Point 26

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 5% | 25 |
| *Existing site only* | 0% | 14 |
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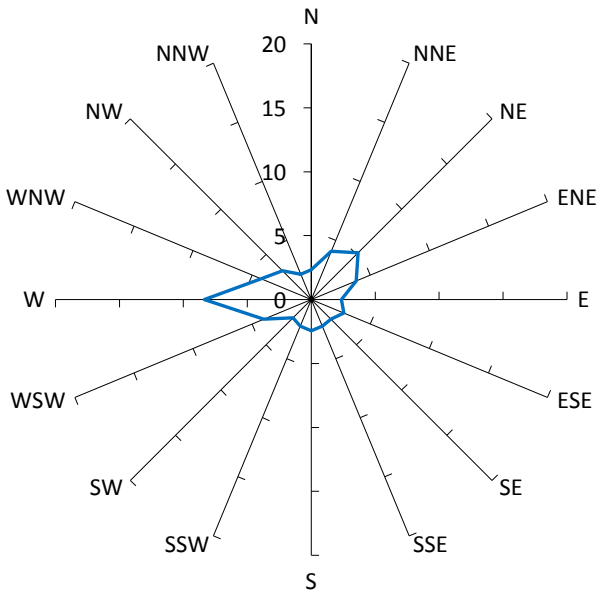
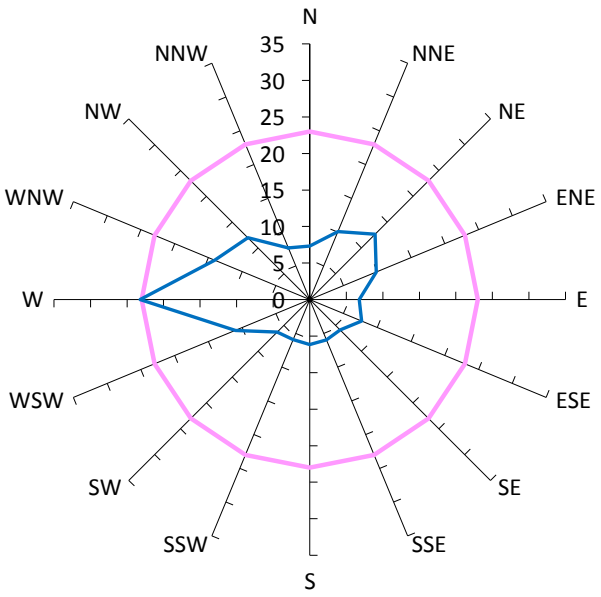
# Results for Point 27

## Gust Equivalent Mean (m/s)




Comfort Criteria: 7.5m/s with 5% probability of exceedence

## Maximum Gust (m/s)




Safety Limit: 23m/s

| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 2% | 23 |
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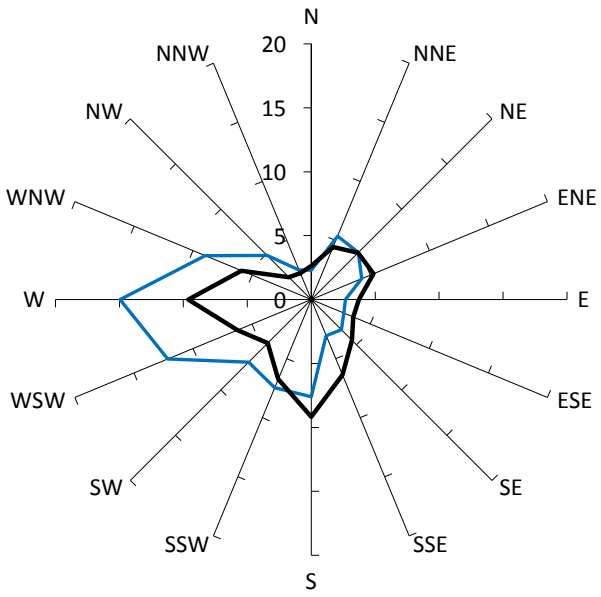
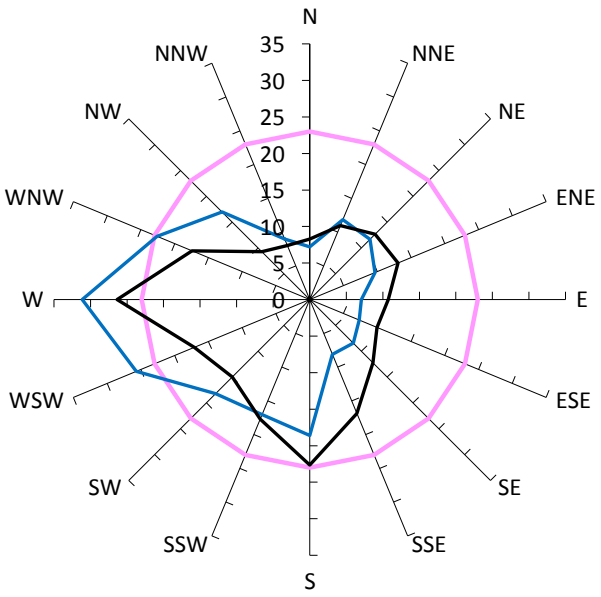
# Results for Point 28

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 17% | 31 |
| *Existing site only* | 10% | 26 |
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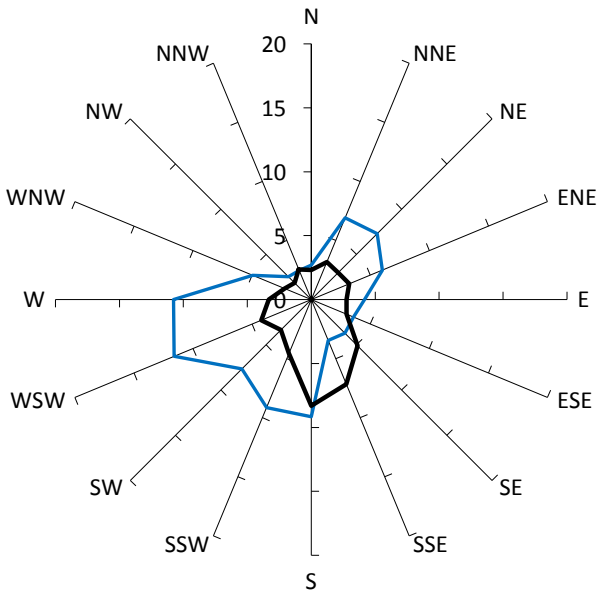
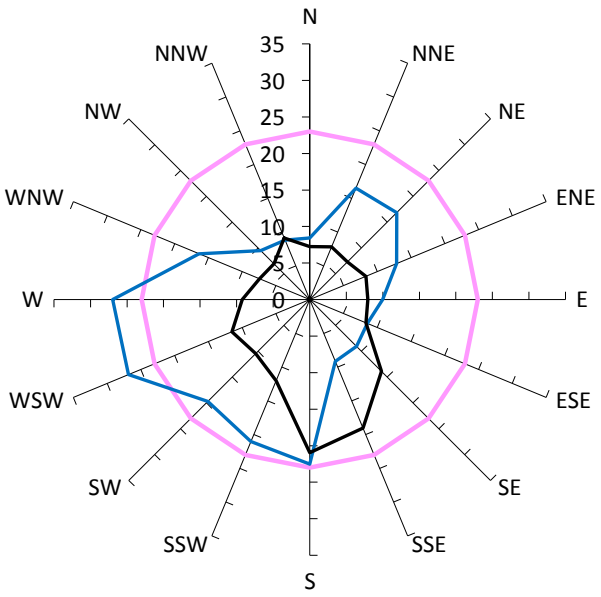
# Results for Point 29

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 21% | 27 |
| *Existing site only* | 4% | 21 |
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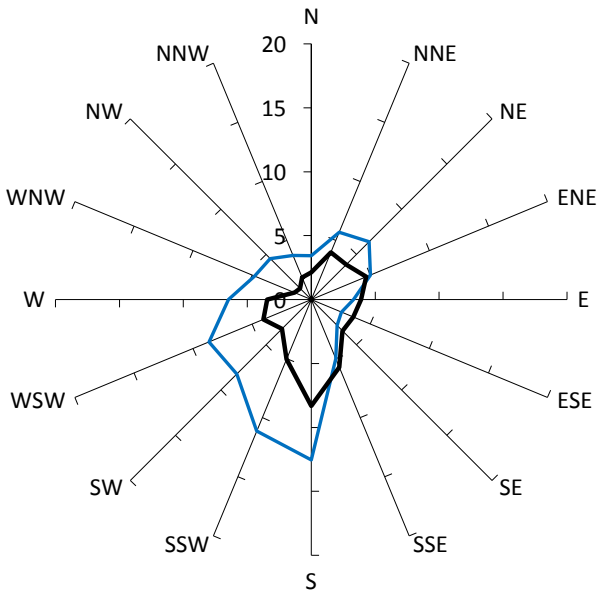
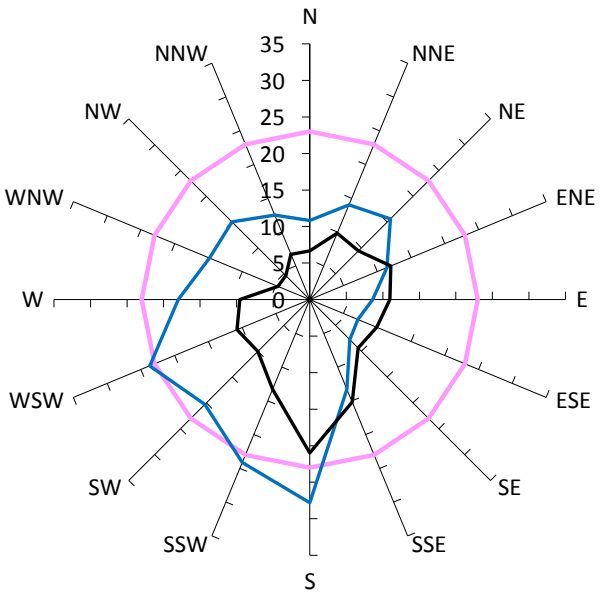
# Results for Point 30

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 20% | 28 |
| *Existing site only* | 3% | 21 |
| | | |
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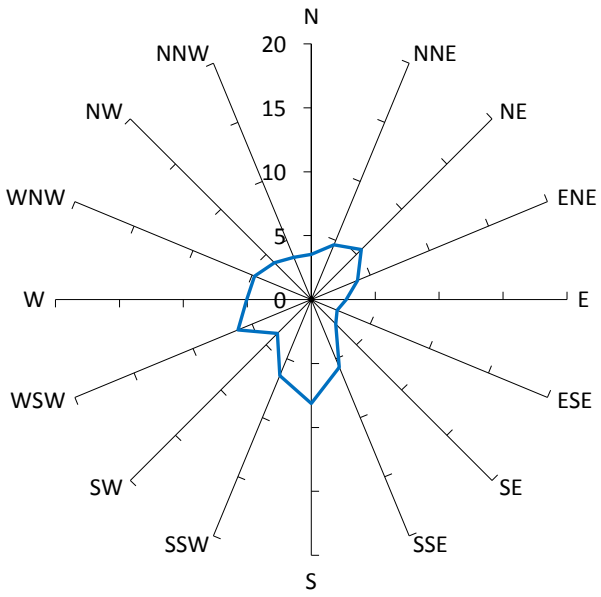
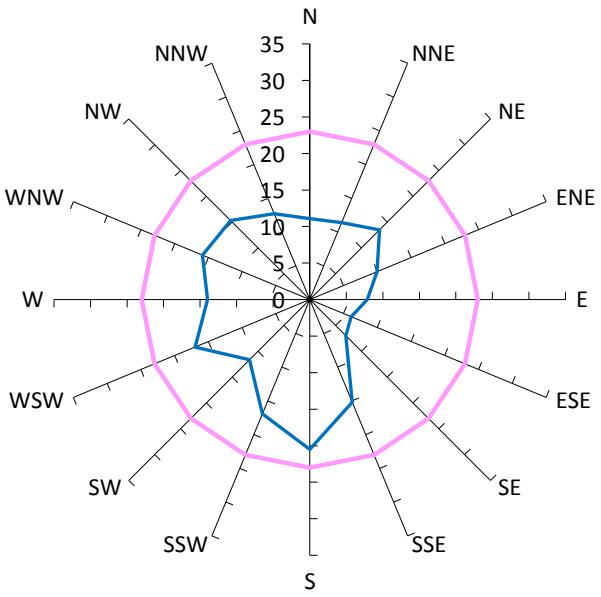
# Results for Point 31

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 4% | 21 |
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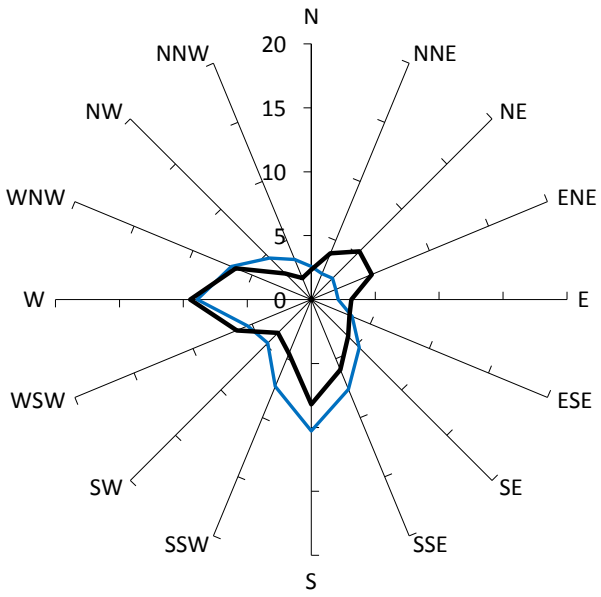
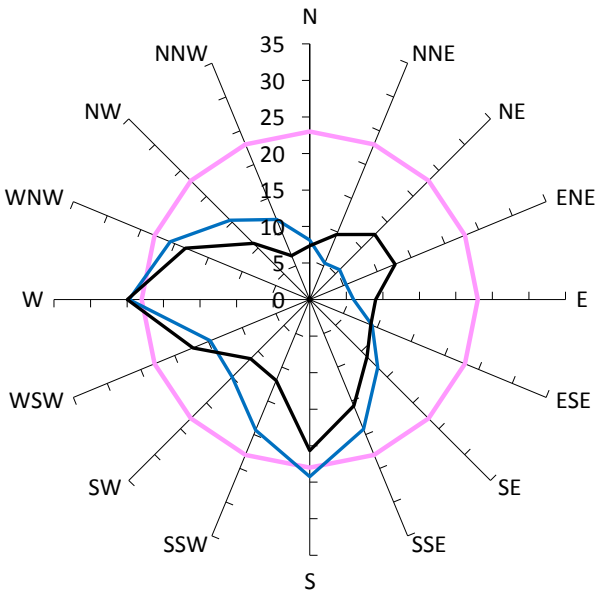
# Results for Point 32

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 14% | 25 |
| *Existing site only* | 7% | 25 |
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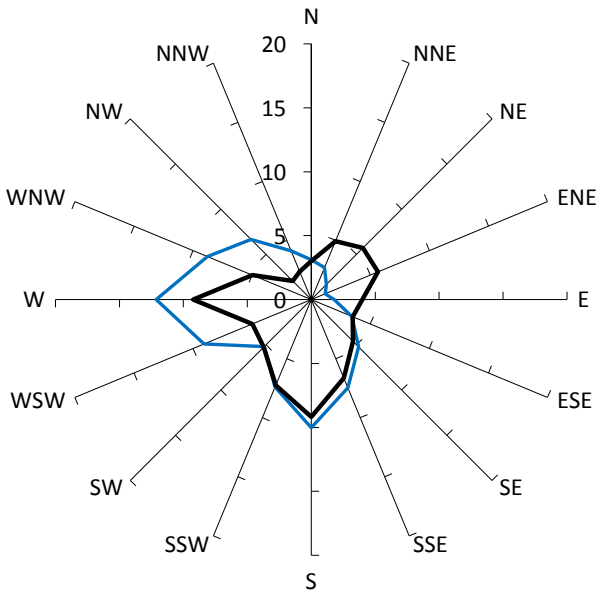
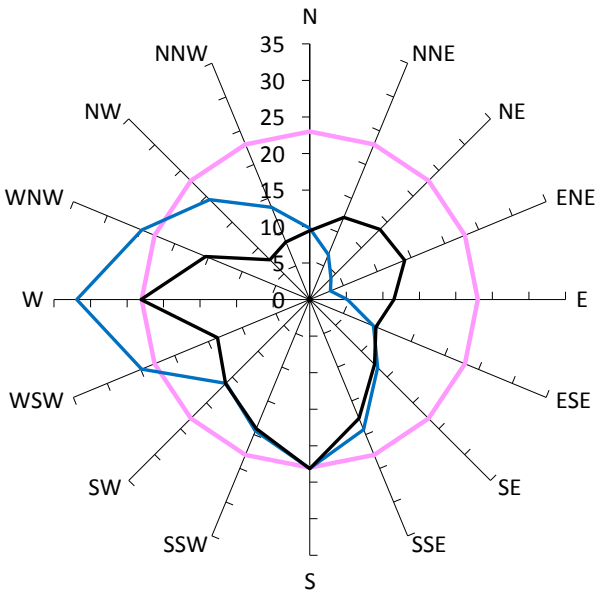
# Results for Point 33

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 21% | 32 |
| *Existing site only* | 10% | 23 |
| | | |
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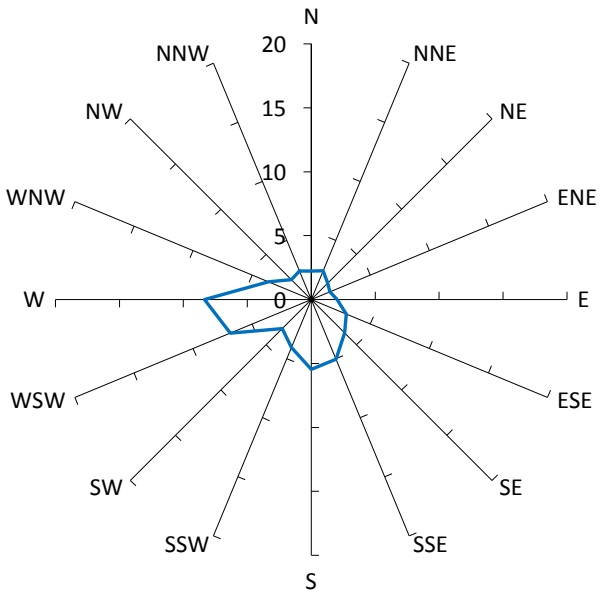
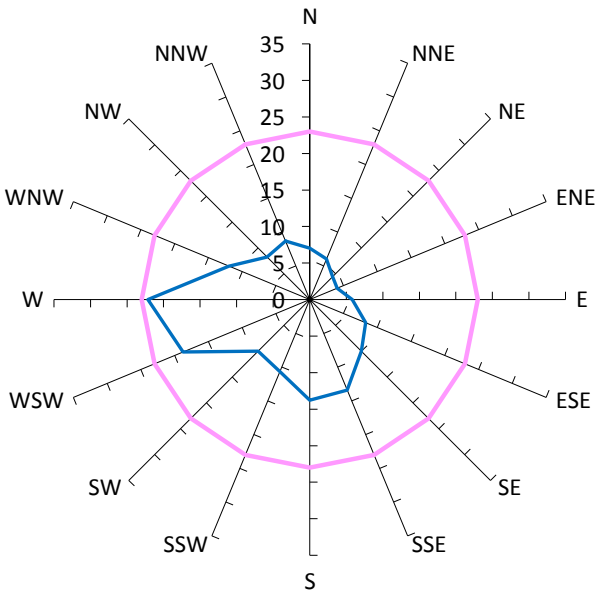
| | | |

# Results for Point 34

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 3% | 22 |
| | | |
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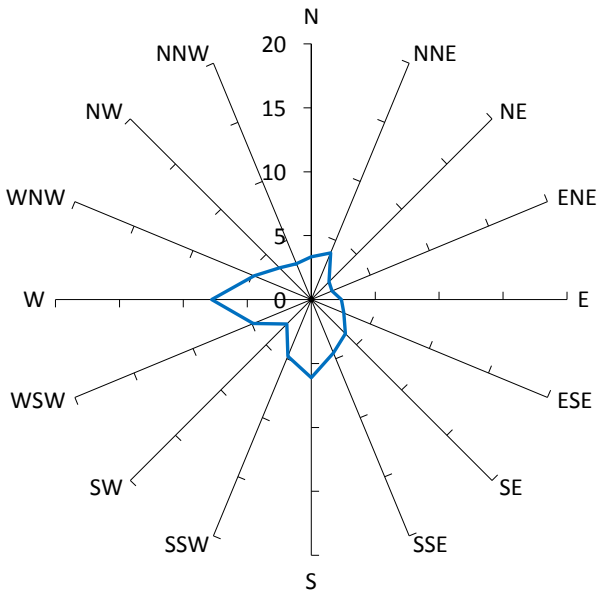
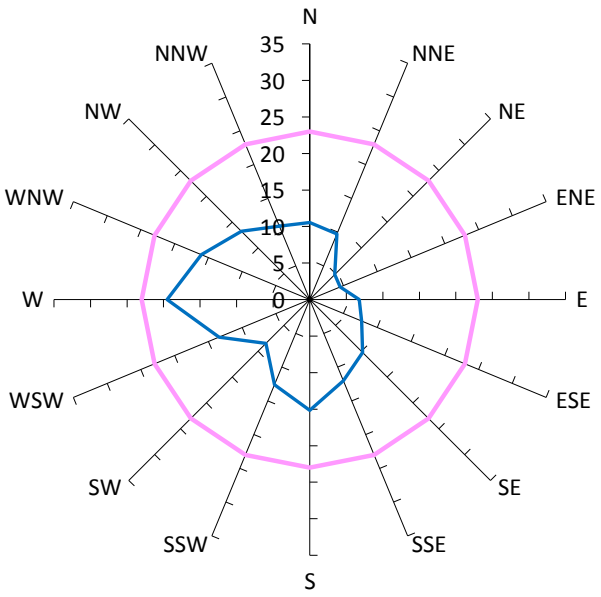
# Results for Point 35

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 2% | 20 |
| | | |
| | | |
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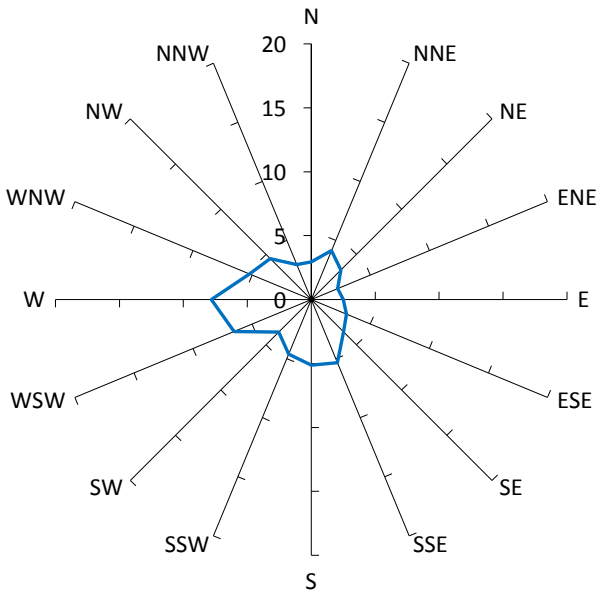
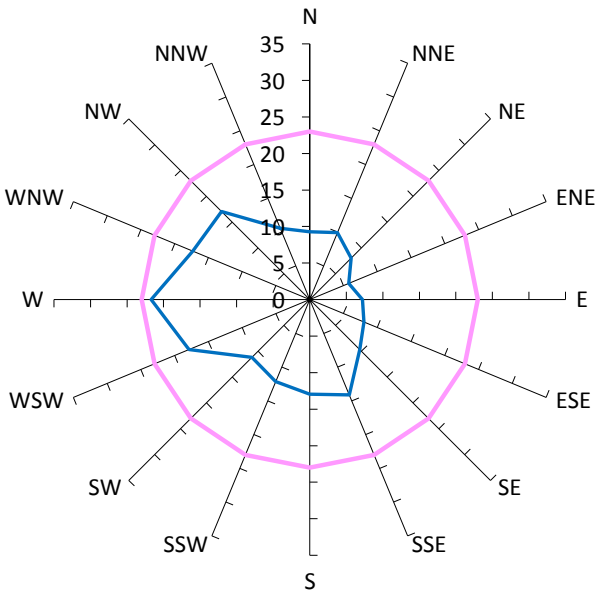
# Results for Point 36

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 3% | 22 |
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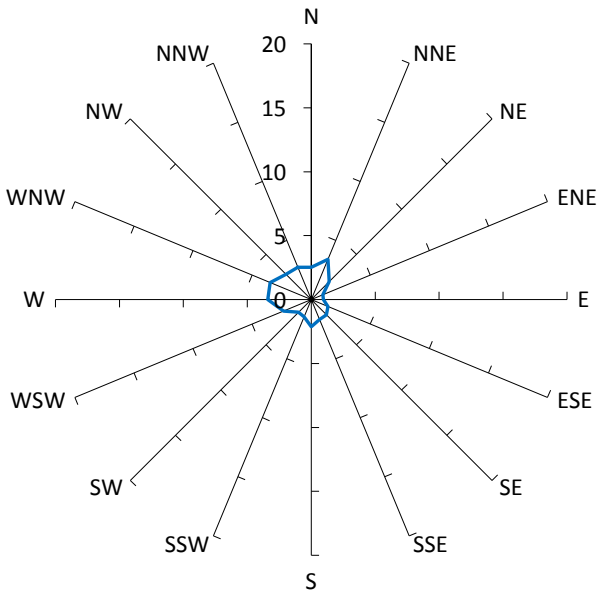
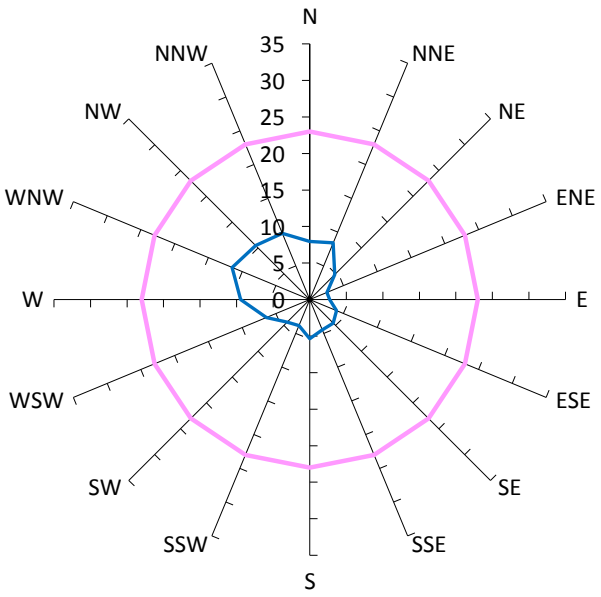
| | | |

# Results for Point 37

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 0% | 11 |
| | | |
| | | |
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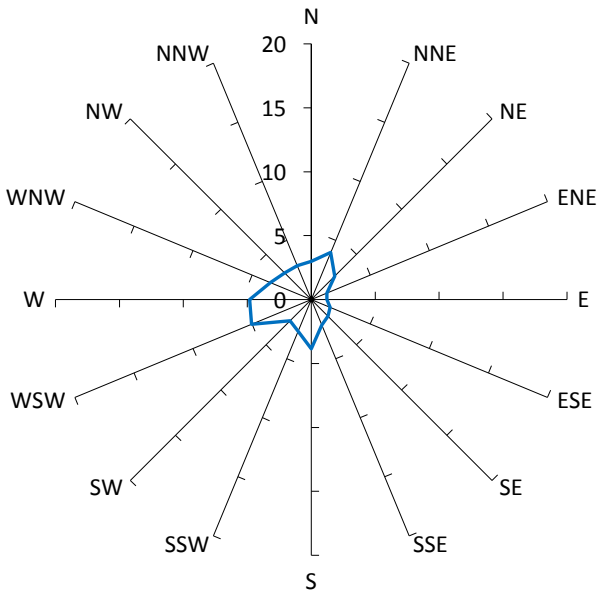
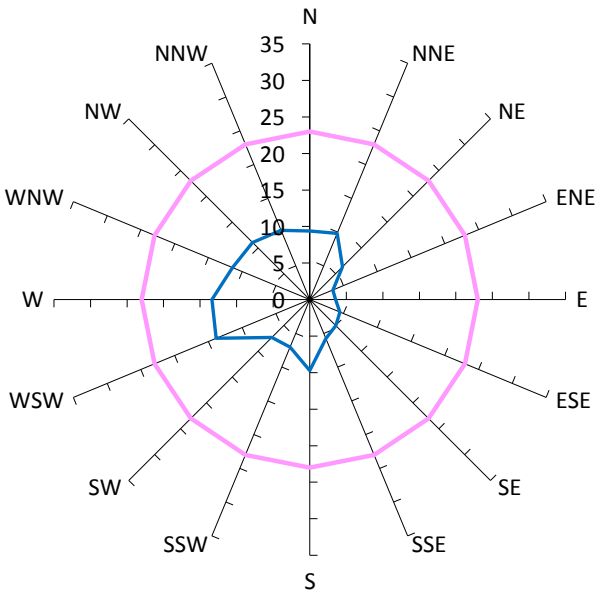
| | | |
| | | |

# Results for Point 38

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 5.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Short Exposure Activities (5.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 2% | 14 |
| | | |
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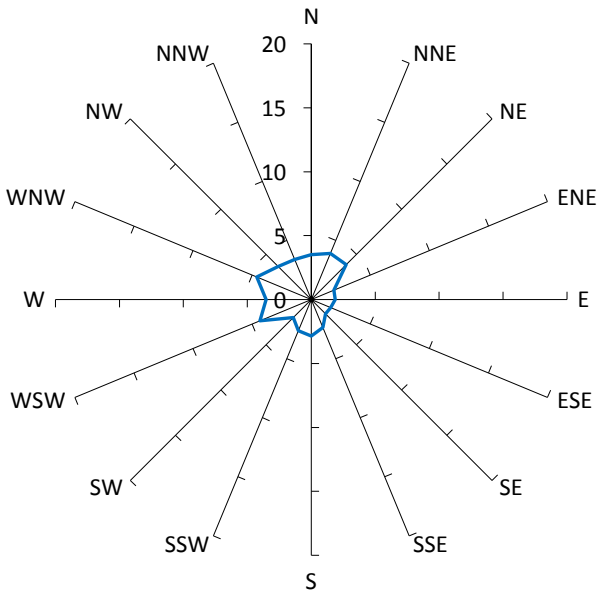
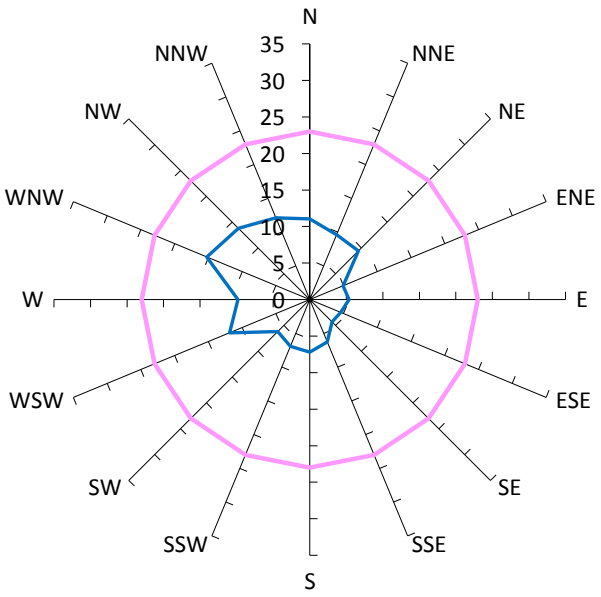
# Results for Point 39

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 0% | 15 |
| | | |
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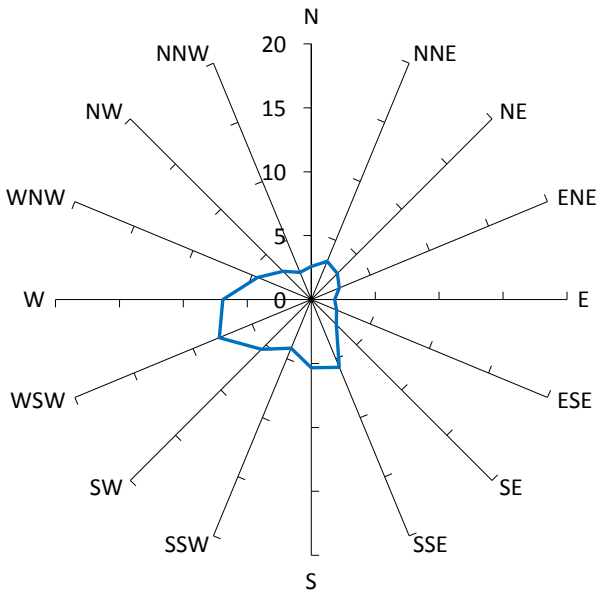
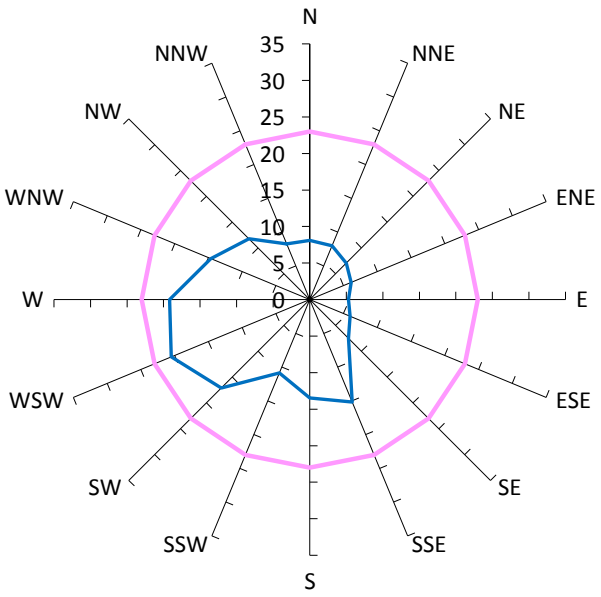
| | | |
| | | |

# Results for Point 40

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 3% | 20 |
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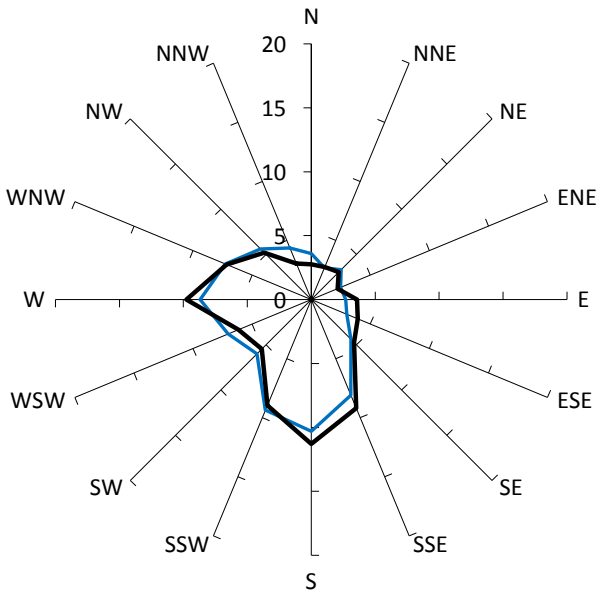
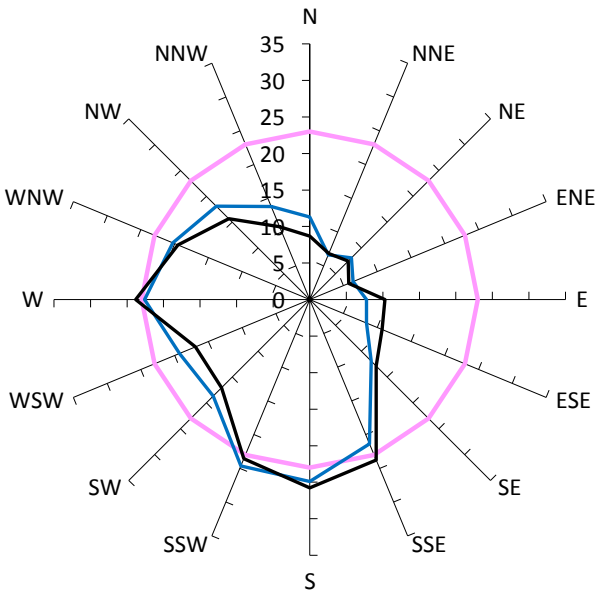
# Results for Point 41

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 20% | 25 |
| *Existing site only* | 23% | 26 |
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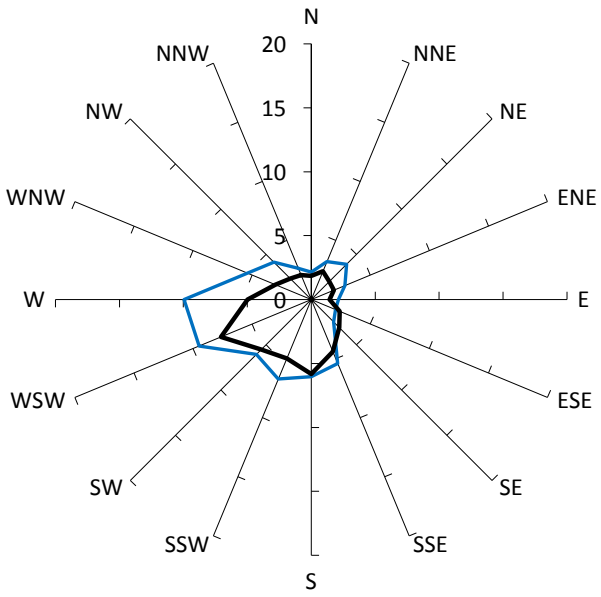
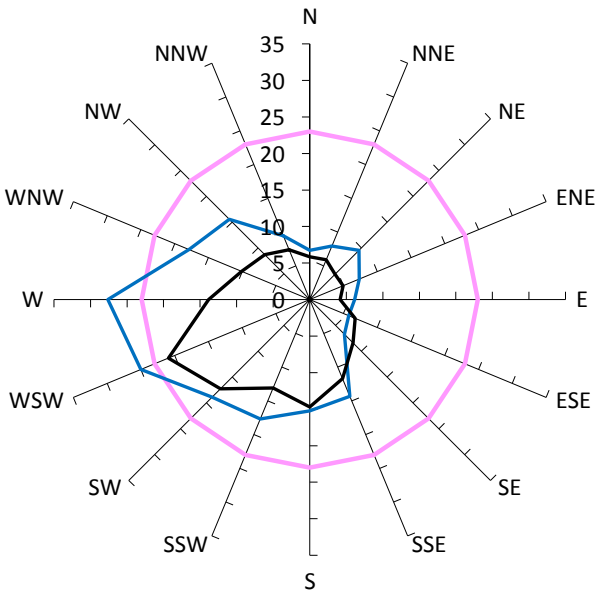
# Results for Point 42

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 10% | 28 |
| *Existing site only* | 2% | 21 |
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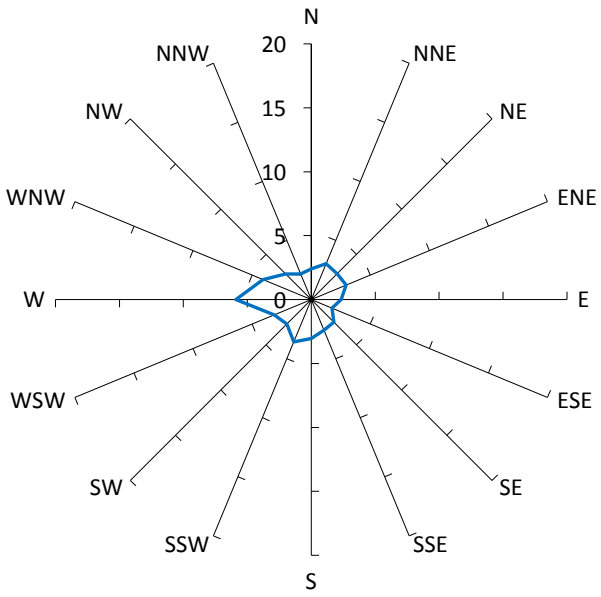
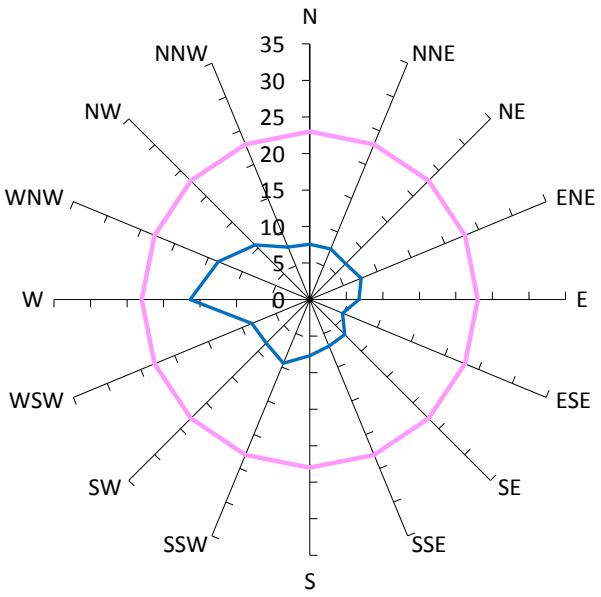
# Results for Point 43

| Gust Equivalent Mean (m/s) | Maximum Gust (m/s) |
|---|---|
|  |  |
| Comfort Criteria: 7.5m/s with 5% probability of exceedence | Safety Limit: 23m/s |



| Description | GEM Prob of Exceed % | Peak Gust m/s |
|---|---|---|
| *Criterion: Comfortable Walking Activities (7.5m/s). Safety Limit (23m/s).* | 5% | 23 |
| *With development "as proposed", no vegetation or other treatments.* | 0% | 16 |
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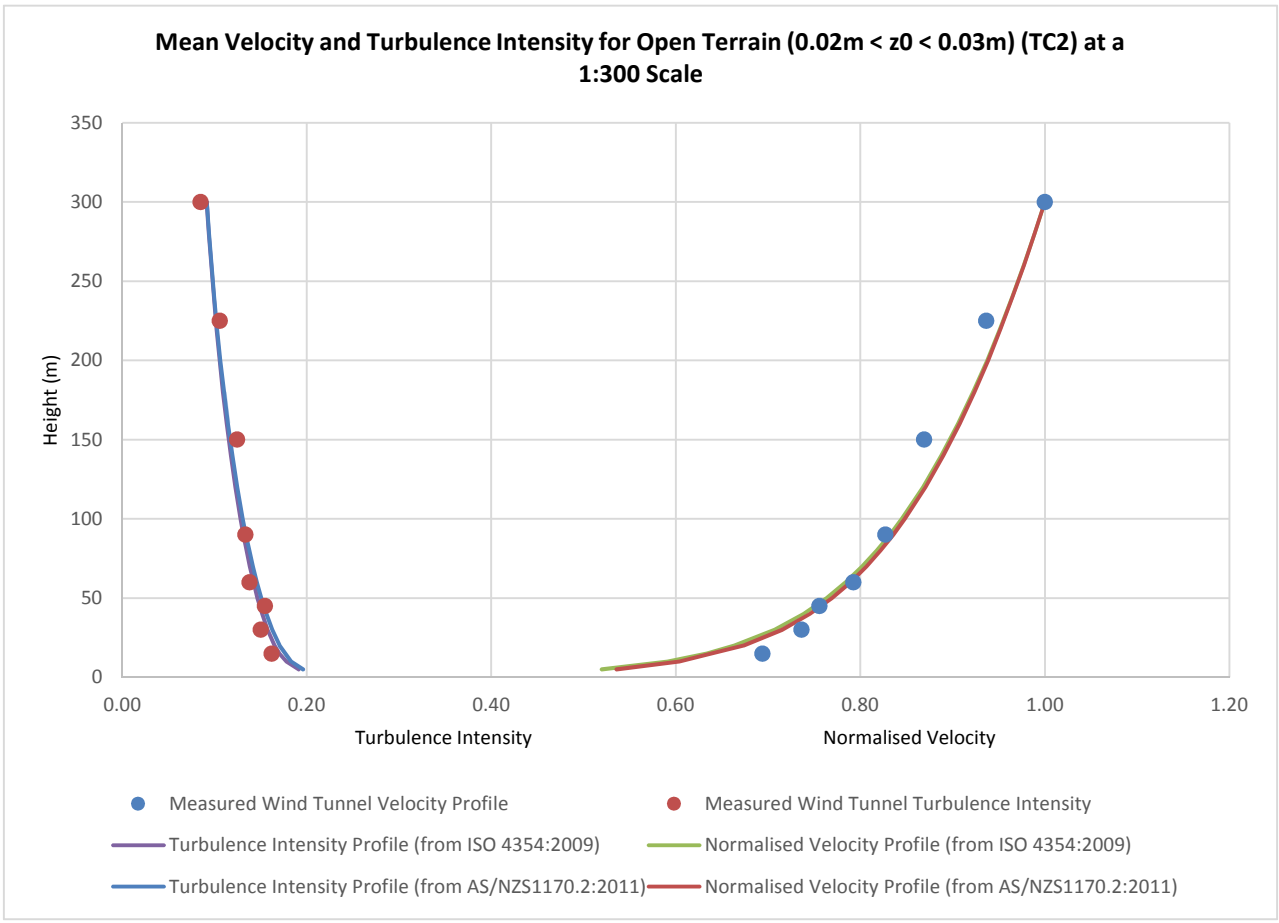
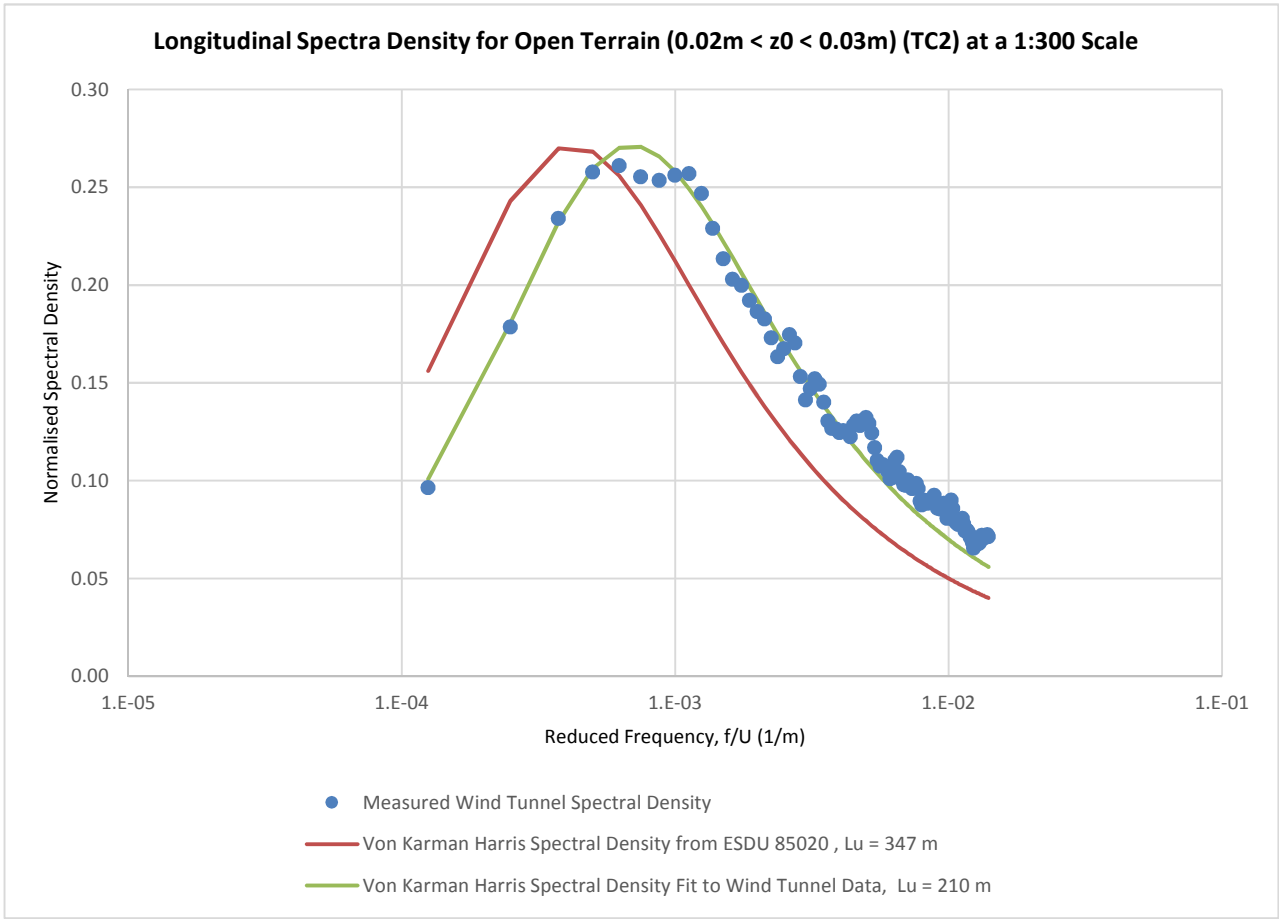
# APPENDIX D VELOCITY AND TURBULENCE INTENSITY PROFILES


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
0.30
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 = 347 m
Von Karman Harris Spectral Density Fit to Wind Tunnel Data, Lu = 210 m