WINDTECH

Pedestrian Wind Environment Study

for the proposed developments located at

100 Mount Street and 88 Walker Street & 77-81 Berry Street, North Sydney

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Document Control

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1.0 Executive Summary

This report presents the results of a detailed investigation into the wind environment impact in relation to the development applications for the sites known as:

- **100 Mount Street, North Sydney**; this development application is for a single office tower which is bounded by Mount Street to the south, Walker Street to the east, and Spring Street to the north.
- **88 Walker Street & 77-81 Berry Street, North Sydney**; this development application includes two towers. The proposed office tower is bounded by Little Spring Street to the east, Spring Street to the south, Denison Street to the west and the Beau Monde residential tower to the north. The proposed hotel tower is bounded by Walker Street to the east and Little Spring Street to the west.

Wind speed measurements at selected critical outdoor locations within and around the proposed development were carried out using a 1:400 scale model. The study model has been constructed based on architectural drawings prepared by the project architects Skidmore, Owings and Merrill LLP in conjunction with Architectus, received July, 2011. The proximity model extends to a radius of approximately 500m from the centre of the subject site and includes all of the significant surrounding buildings and topographical effects.

Testing was performed using Windtech's boundary layer wind tunnel facility, which has a 2.5m wide working section and has a fetch length of 14m. Peak gust and mean wind speeds were measured in the form of velocity coefficients, which are then related to reference wind speeds for the Sydney region to provide the equivalent full-scale wind speeds for each of the selected locations that were tested for this study. Wind speed measurements are made in the wind tunnel for sixteen wind directions, at 22.5 degree increments. The reference wind climate data used in this study is based on an analysis of 70 years of recorded 10-minute mean wind speeds obtained at the meteorological recording station located at Kingsford Smith Airport in Sydney, from 1939 to 2008

Peak gust wind speeds were measured and related to reference velocities at a height of 200m upstream of the proximity model. Wind speed velocity coefficients representing the local wind speeds are derived from the wind tunnel and are combined with the meteorological data for this region to provide the equivalent full-scale wind speeds. These wind speed measurements are compared with the wind speed criteria described in the North Sydney Development Control Plan (DCP), relevant published criteria for long and short duration stationary activities and for pedestrian comfort, as well as the existing site wind conditions. The results presented in this study are based on annual maximum peak wind speeds and weekly maximum Gust Equivalent Mean (GEM) wind speeds.

The results of the study indicate that wind conditions for the outdoor areas within and around the development site will satisfy the appropriate wind comfort and safety criteria with the inclusion of the following recommended treatments. The treatments that have been recommended for the areas exposed to adverse wind conditions include:

- Densely foliating trees along Denison and Little Spring Streets capable of growing to a height of 3 metres with a 3 metre wide canopy.

- Densely foliating evergreen trees capable of growing to a height of 3 metres with a 3 metre wide canopy within the Spring Street outdoor plaza area.
- Densely foliating evergreen trees capable of growing to a height of 3 metres with a 3 metre wide canopy at the corner of Spring Street and Little Spring Street.
- Retention of the existing trees and shrubs along Denison Street between Spring Street and Mount Street.
- Retention of the existing trees along Walker Street infront of the 88 Walker Street development site.
- Densely foliating trees capable of growing to a height of 5 metres with a 6 metre wide canopy and 9 metres with a 11 metre wide canopy along Mount Street.
- Canopy along the eastern edge of the 88 Walker Street façade.
- Canopy along the western edge of the 77-81 Berry Street façade.
- Canopy along the northern and southern aspects of the proposed new street between Denison Street and Little Spring Street.
- 1.2 metre high impermeable balustrade along the southern and eastern perimeter of the 100 Mount Street outdoor Plaza area.
- Ground Level canopy along the eastern edge of the 100 Mount Street façade.
- Canopy along the southern aspect at Level 1 of the 100 Mount Street development with an upturn at the eastern end.
- 1.2 metre high impermeable balustrade around the perimeter of the restaurant level podium area of the 77-81 Berry Street development.

With the inclusion of the abovementioned treatments to the proposed development, wind conditions for all outdoor trafficable areas within and around the development will satisfy the recommended wind comfort and safety criteria. It should be noted that it is recommended that the trees be of a densely foliating and evergreen variety to ensure there effectiveness in wind mitigation for all months of the year.

2.0 Description & Location of the Development

This study is to measure local wind speeds of the following development applications for the North Sydney CBD:

- **100 Mount Street, North Sydney**; this development application is for a single office tower which is bounded by Mount Street to the south, Walker Street to the east, and Spring Street to the north.
- **88 Walker Street & 77-81 Berry Street, North Sydney**; this development application includes two towers. The proposed office tower is bounded by Little Spring Street to the east, Spring Street to the south, Denison Street to the west and the Beau Monde residential tower to the north. The proposed hotel tower is bounded by Walker Street to the east and Little Spring Street to the west.

To the north and south of the development site are predominantly office and residential apartment buildings which make up the North Sydney CBD precinct. Further to the south of the site is Port Jackson, with the Sydney CBD further beyond this. To the east and west of the site are predominantly residential houses ranging in height between 1 and 2 storeys. Further to the north-east direction are residential houses and open parkland areas of St Leonards Park and Green Park. In the north-westerly direction are residential houses and the commercial precinct of Crows Nest.

The local land topography is relatively slope around the proposed development sites. The land slopes upwards from east to west across the 100 Mount Street site. The land also slopes upwards from east to west and south to north across the 88 Walker and 77-81 Berry Street sites. Surrounding the site the land topography generally slopes upwards from Neutral Bay to the east, Lavender Bay to the south and Berrys Bay to the south-west. The topography continues to slope upwards in the north and north-westerly directions.

An aerial image of the site locations is shown in Figure 1 below. Perspective aerial images of the site are also shown in Figures 2a and 2b

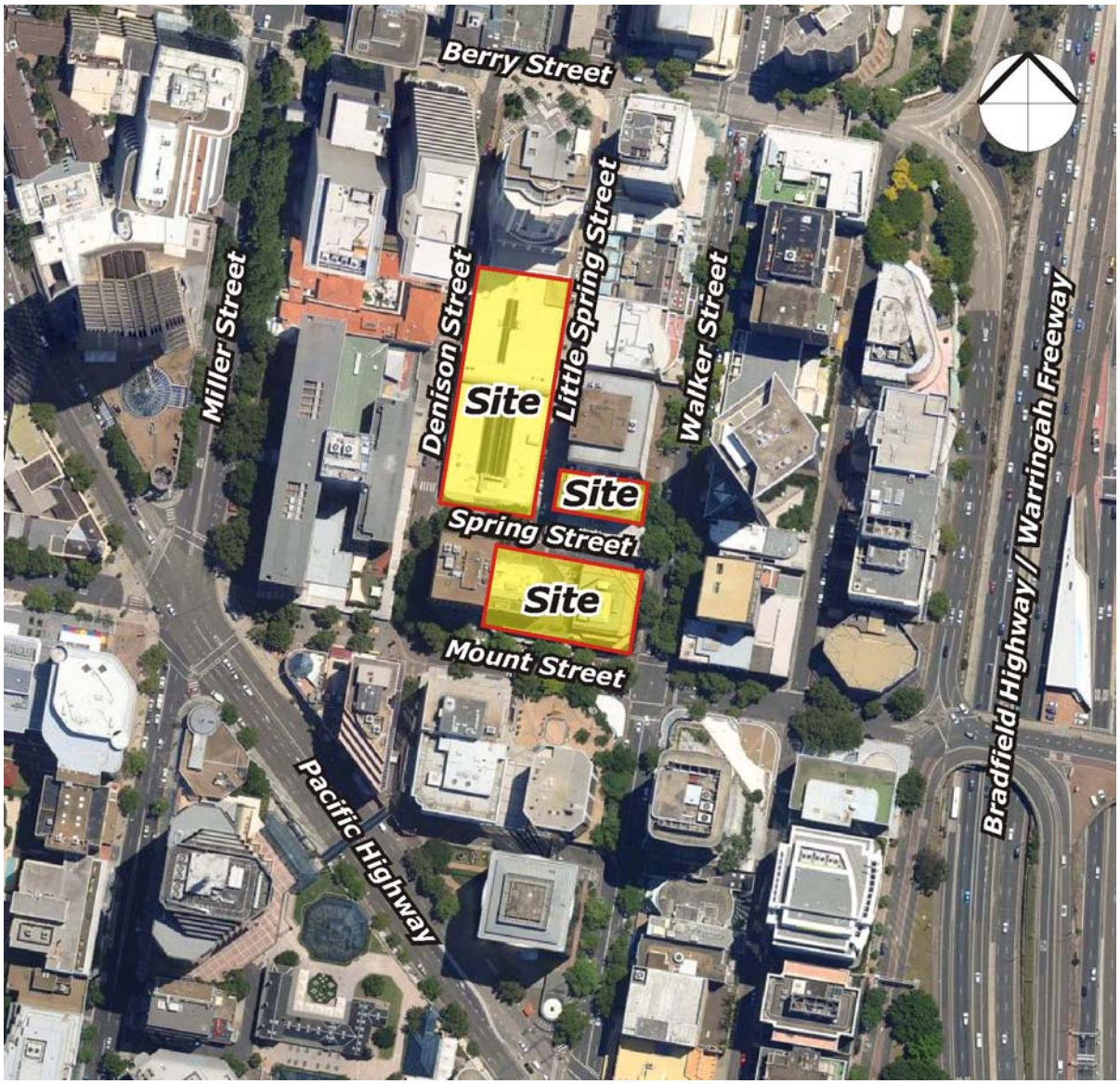

Figure 1: Aerial Image of the Site Location

The proposed 100 Mount Street development consists of a 147m high commercial office tower which covers the entirety of the site. An outdoor plaza area is proposed on ground level which is accessible from Mount Street and Spring Street. Retail areas are proposed along Walker Street.

The proposed 88 Walker Street development consists of a 117m high hotel development which covers the entirety of the site. A through site link is proposed between Walker Street and Little Spring Street, with the main entrance to the lobby of the hotel located on Walker Street.

The proposed 77-81 Berry Street development consists of a 123m high commercial office tower which is setback from the southern end of the site. An outdoor public plaza area is proposed at the southern end of the site, while a new through site road is proposed between Little Spring Street and Denison Street. An outdoor landscape area is also proposed at the northern end of the site on the podium roof.

Figure 2a: Aerial View from the South

Figure 2b: Aerial View from the East

3.0 Wind Climate of the Sydney Region

The wind climate data used in this study is based on an analysis of 70 years of recorded 10-minute mean wind speeds obtained at the meteorological recording station located at Kingsford Smith Airport in Sydney, from 1939 to 2008. A plot of the wind speed observation data is presented in Figure 3 below, referenced to a height of 10m above ground in open terrain and converted to hourly means. This data is also presented in Table 1, which also presents the corresponding daily average 60 minute mean wind speeds. The frequency of occurrence of the regional winds is also shown in Figure 3 for each wind direction. Note that the recurrence intervals examined in this study are for the daily average winds.

The data indicates that the maximum wind speeds for the region are governed by southerly, north-easterly and westerly winds. These wind directions also correspond to the directions of the most frequent winds for the region.

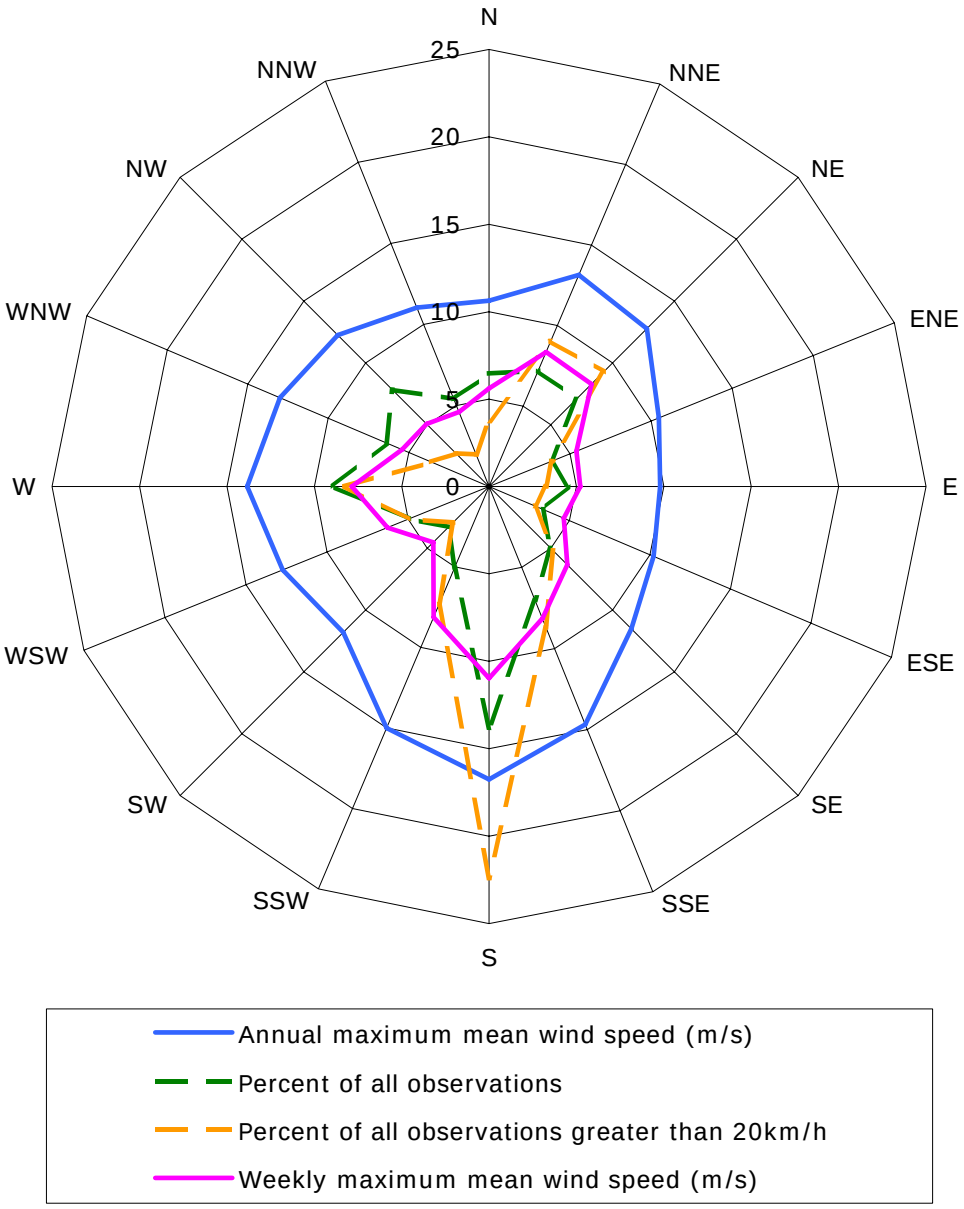

Figure 3: Annual and Weekly Maximum Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Sydney Region (referenced to open terrain at 10m)

Table 1: Regional Directional Wind Speeds for the Sydney Region (hourly means and corresponding 3-second gusts, referenced to 10m height in open terrain)

Wind Direction	Reference Wind Speeds (m/s)			
	Weekly Recurrence		Annual Recurrence	
	Hourly Mean	3-second Gust	Hourly Mean	3-second Gust
N	5.3	8.1	10.1	15.4
NNE	7.9	12.1	12.5	19.1
NE	7.9	12.0	12.1	18.5
ENE	5.1	7.8	9.9	15.2
E	5.0	7.6	9.3	14.2
ESE	4.4	6.7	9.7	14.8
SE	6.0	9.2	10.9	16.7
SSE	7.7	11.8	13.9	21.3
S	10.4	15.9	15.9	24.3
SSW	7.7	11.8	14.2	21.7
SW	4.3	6.5	11.2	17.1
WSW	6.0	9.1	12.1	18.5
W	7.5	11.4	13.1	20.1
WNW	5.1	7.8	12.3	18.8
NW	4.8	7.3	11.6	17.8
NNW	4.4	6.7	10.5	16.0

4.0 The Wind Tunnel Model

Wind speed measurements were carried out using a 1:400 scale model of the proposed development. The study model has been constructed based on architectural drawings prepared by the project architect Skidmore, Owings and Merrill LLP in conjunction with Architectus, received July, 2011. The study model incorporates all of the architectural features on the facades, except for those elements that have maximum sectional dimensions of less than approximately 1m, which is appropriate for this type of study.

The proximity model extends to a radius of approximately 500m from the centre of the subject site and includes all of the significant surrounding buildings and topographical effects.

Photographs of the wind tunnel model that has been used for this project are presented in the following figures. Figures 4a to 4b shows the existing case scenario, Figures 4c to 4d shows the proposed 100 Mount Street development with the existing sites to the north, while Figures 4e to 4f shows the proposed 100 Mount Street, 88 Walker Street and 77-81 Berry Street developments scenario.

Figure 4a: Photograph of the Model in the Wind Tunnel (Existing Buildings Scenario)

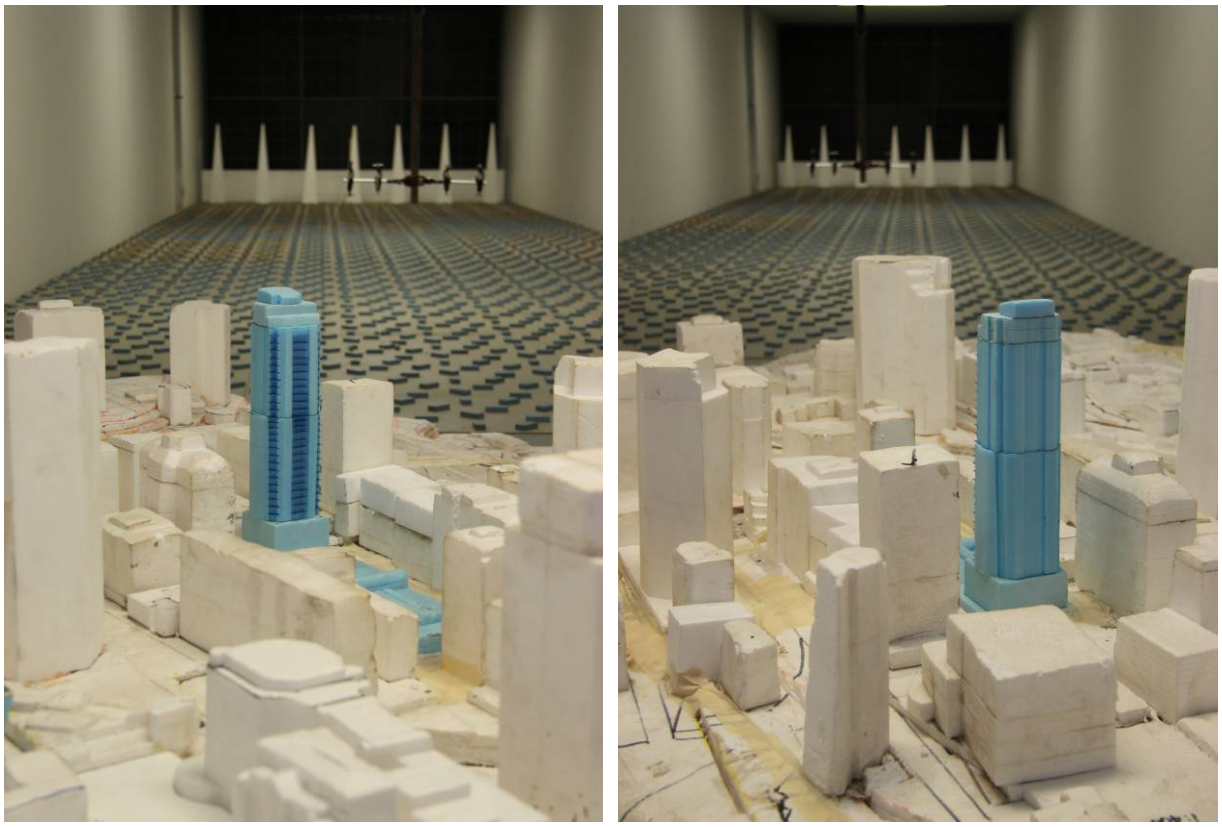

Figure 4b: Photograph of the Model in the Wind Tunnel
(Existing Buildings Scenario)

Figure 4c: Photograph of the Model in the Wind Tunnel
(Proposed 100 Mount Street, Existing Northern Buildings)

Figure 4d: Photograph of the Model in the Wind Tunnel
(Proposed 100 Mount Street, Existing Northern Buildings)

Figure 4e: Photograph of the Model in the Wind Tunnel
(All Proposed Developments)

Figure 4f: Photograph of the Model in the Wind Tunnel
(All Proposed Developments)

Figure 4g: Photograph of the Model in the Wind Tunnel
(All Proposed Developments)

5.0 Boundary Layer Wind Flow Model

The approaching boundary layer wind flow modelled in the wind tunnel matched the model scale and the overall surrounding terrain characteristics beyond the 500m radius of the proximity model for each of the sixteen wind directions tested. For the fetch beyond the extent of the model the boundary layer wind profiles used in the wind tunnel are simulated based on the standard Deaves and Harris model (1978). The wind profile shape is calculated based on an analysis of the surrounding terrain for each wind direction tested. The roughness of the upwind terrain from the site determines the shape of the boundary layer wind profile for each wind direction tested.

The reference height used for the terrain analysis study is 147m above ground, and the fetch length used to determine the approaching wind profile is 5.9km. Note that the fetch length is calculated as being a distance of 40*h* from the edge of the proximity model, where *h* is the reference height used for the terrain analysis. The site location and the surrounding fetch area for the calculation of the approaching boundary layer wind flow is shown in Figure 5. This figure also shows whether the surrounding terrain within the fetch length is classified as open, suburban or urban.

The length of each terrain type, and the distance each terrain type is from the site, is analysed for each wind direction tested. When the wind travels from one terrain type to another, the mean velocity profile does not change instantly. A lag occurs, and is measured as a distance by the following equation:

$$x_i = z_{0,r}\left[\frac{z}{0.3z_{0,r}}\right]^{1.25} \qquad (5.1)$$

where x_i is the lag length caused by the change in terrain type.

z is the height above ground.

$z_{0,r}$ is the larger of the two roughness lengths of the two terrain types (see Table 2).

The wind profile for each wind direction is calculated using the lag distance equation above, and the site terrain analysis data measured from the image shown in Figure 5.

For example, for wind coming from the east-north-easterly direction (67.5 degrees), it is assumed that the approaching wind profile at the outer edge of the fetch length (5.9km from the edge of the surrounds model) is the standard Deaves and Harris (1978) open terrain profile, since this is coming from over Port Jackson. As the wind approaches the site it continues over Port Jackson before travelling over the residential housing area of Mosman where the suburban terrain is most appropriate. The final wind profile for this wind direction, shown in Appendix B of this report, indicates that it is somewhere between the open and suburban terrain profile.

The hourly mean, 10-minute mean, and 3-second gust terrain and height multipliers, and the corresponding roughness lengths, are summarised in Table 2 for the various standard Deaves and Harris model (1978) profiles, referenced to 147m above ground.

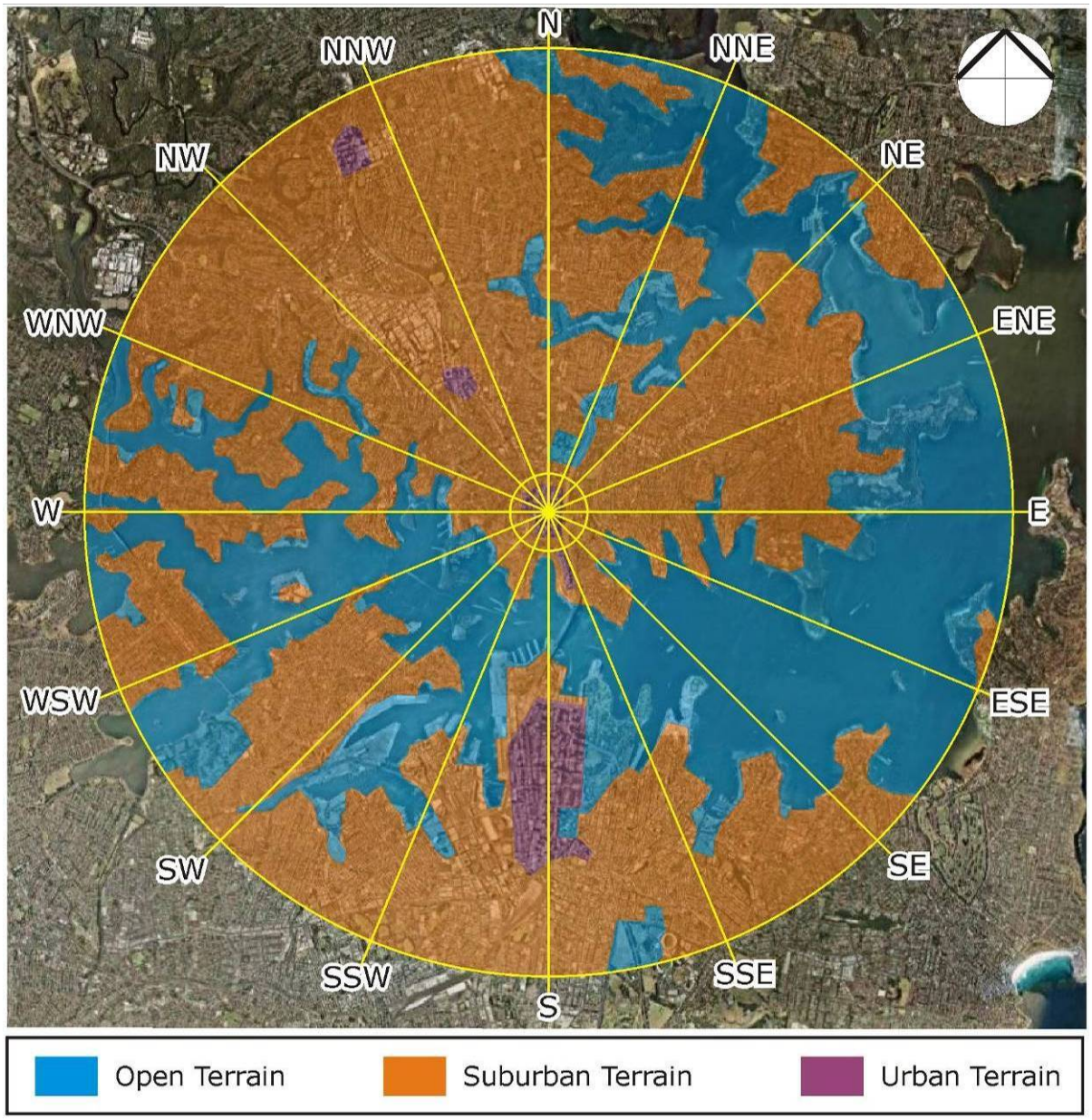

Figure 5: Surrounding Terrain Types (5.9km fetch length)

Table 2: Terrain & Height Multipliers and Turbulence Intensities, and the Corresponding Roughness Lengths (standard Deaves and Harris (1978) profiles, at 147m above ground)

Terrain Description	Terrain & Height Multipliers (for 147m above ground)			Turbulence Intensity	Roughness Length
	$k_{tr,T=3600s}$	$k_{tr,T=600s}$	$k_{tr,T=3s}$	$I_{v,147m}$	(m) $z_{0,r}$
Open	0.99	1.02	1.33	0.116	0.03
Suburban	0.85	0.89	1.29	0.169	0.3
Dense Urban	0.66	0.71	1.20	0.275	3

6.0 Reference Wind Speeds for the Study

The reference hourly mean wind speeds that are used for this study are calculated for each wind direction at the reference height of 147m above ground, at the upwind edge of the proximity model (500m upwind of the site). These values are presented in Table 3, and are derived from the 3-second gust wind speed data obtained at the meteorological station at Kingsford Smith Airport (see Table 1 of this report), which is referenced to a height of 10m in open terrain, by applying the hourly mean terrain and height multiplier that were calculated from the analysis of the surrounding terrain types (shown in Table 3 below).

Table 3: Reference Wind Speeds Upwind of the Development Site (referenced to a height of 147m above ground)

Wind Direction	Hourly Mean Terrain & Height Multiplier $k_{tr,T=3600s}$	Hourly Mean Wind Speed (m/s)	
		Weekly Recurrence	Annual Recurrence
N	0.87	6.5	13.8
NNE	0.96	11.0	18.2
NE	0.88	13.0	19.0
ENE	0.89	8.1	14.2
E	0.90	7.3	14.2
ESE	0.91	6.1	14.6
SE	0.89	10.0	18.3
SSE	0.85	12.2	22.0
S	0.79	14.6	22.5
SSW	0.86	12.2	22.1
SW	0.86	8.6	18.5
WSW	0.87	9.3	19.3
W	0.87	11.8	21.1
WNW	0.86	8.7	19.2
NW	0.85	8.2	17.1
NNW	0.85	5.8	14.9

7.0 Test Procedure

Testing was performed using Windtech's boundary layer wind tunnel facility, which has a 2.5m wide working section and has a fetch length of 14m. Due to the effective blockage-tolerant design of Windtech's wind tunnel, no correction was required for blockage effects.

The model of the subject development was setup within the wind tunnel, and peak gust and mean wind speeds were measured in the form of velocity coefficients which are then related to reference wind speeds for the Perth region to provide the equivalent full-scale wind speeds for each of the selected locations that were tested for this study. Wind speed measurements were made in the wind tunnel for sixteen wind directions, at 22.5 degree increments.

The free-stream and test-location air currents were monitored using a set of two Dantec hot-wire probe anemometers. The probe support for each study location was mounted such that the probe wire was vertical as much as possible, which ensures that the measured wind speeds are independent of wind direction along the horizontal plane. In addition, care was taken in the alignment of the probe wire and in avoiding wall-heating effects. This procedure provides comprehensive information about the wind environment to be expected at each of the study locations for the various wind directions.

The output from the hot-wire probes was obtained using a National Instruments 12-bit data acquisition card. The signal was low-pass filtered at 32 Hz and results in peak gust being the equivalent of the 2 to 3 second gust on which the criteria are based. A sample rate of 1000 samples per second was used, which is more than adequate for the given frequency band.

The mean and the maximum 3-second duration peak gust coefficients were derived from the following relation:

$$\hat{V} = \overline{V} + g.\sigma_V \qquad (7.1)$$

where: $\hat{V}$ is the 3-second gust velocity.

$\overline{V}$ is the mean velocity.

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

σ_V is the standard deviation of the velocity measurement.

The mean free-stream wind speed measured in the wind tunnel for this study was approximately 10.7m/s. Note that the measurement location for the mean free-stream wind speed is at a height of 200m at the upwind edge of the proximity model. The resulting velocity scale range was of approximately 1:1.3 to 1:2.1 for the annual maximum peak wind speeds. Hence the sample length in the model scale of 12 seconds is equivalent to a range of approximately 38 to 63 minutes in full-scale for the annual maximum peak wind speeds, which is suitable for this type of study.

For each of the sixteen wind directions, peak gust and mean wind speed coefficients were measured using the hot-wire anemometers at selected study point locations at a full-scale height of approximately 1.5m. The full-scale wind speed at these study locations are then obtained from the measured coefficients for each wind direction using the relationship as described in Equation 7.2.

$$V_{study} = V_{ref,147m}\left(\frac{k_{200m,tr,T=3600s}}{k_{147m,tr,T=3600s}}\right)\left(\frac{HW_{study}}{HW_{200m}}\right) \qquad (7.2)$$

where:

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

$V_{ref,147m}$ is the full-scale reference wind speed at the upwind edge of the proximity model, referenced to 147m above ground (see Table 3).

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

$k_{147m,tr,T=3600s}$ is the hourly mean terrain and height multiplier at 147m height (see Table 3).

HW_{study} is the measurement obtained from the hot-wire anemometer at the study point location.

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

A total of 82 study locations were chosen for detailed analysis as shown in Figures 6a and 6d. These include 51 ground level test point locations, 10 test point locations on various terrace areas on the Restaurant Level of the 88 Walker Street & 77-81 Berry Street development and 7 test points on the outdoor Plaza area of the 100 Mount Street development. 15 test points were used to monitor wind conditions on the existing Tower Square, Beau Monde residential tower and Fire Station Hotel outdoor areas. Note that Study Points 54, 55 and 73 to 76 have been omitted from this study.

Note that testing was initially undertaken without the inclusion of any wind ameliorating devices such as screens, awnings, etc, that are not already shown in the architectural drawings. Furthermore, the effect of vegetation was also not initially included in this study. The results from the initial tests assist in developing an understanding of the mechanisms of the winds affecting the site.

From the initial results, for areas where wind conditions exceed the relevant criteria for pedestrian comfort and/or safety, retests were undertaken with the inclusion of various treatments to the model. Treatments are usually in the form of trees, screens awnings, etc. These are discussed in detail in the following section of this report.

Note that the wind conditions for the existing site were also measured at the relevant locations. This allows for a direct comparison to see the impact that the development has on the local wind environment.

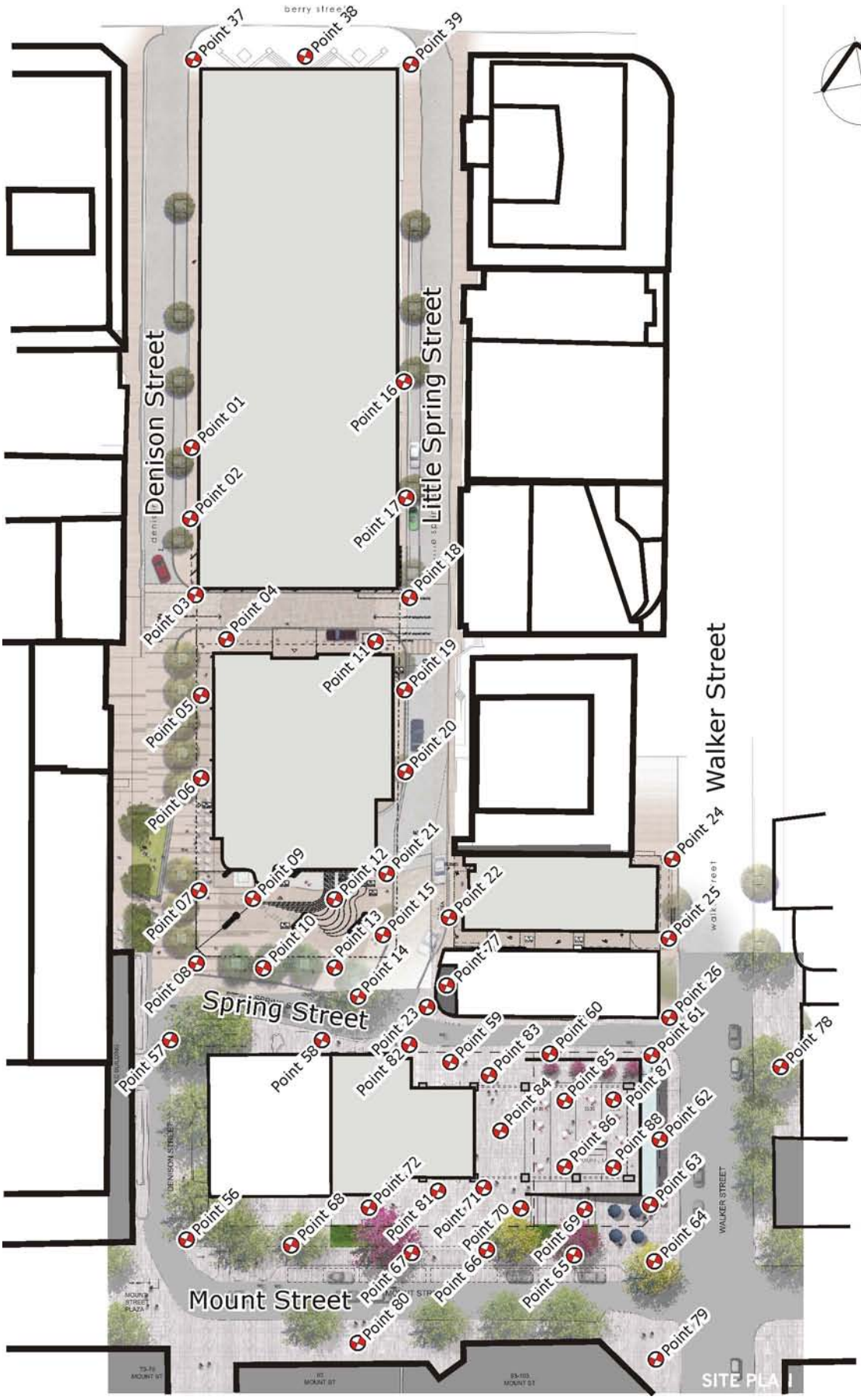

Figure 6a: Study Point Locations (Ground Level Areas)

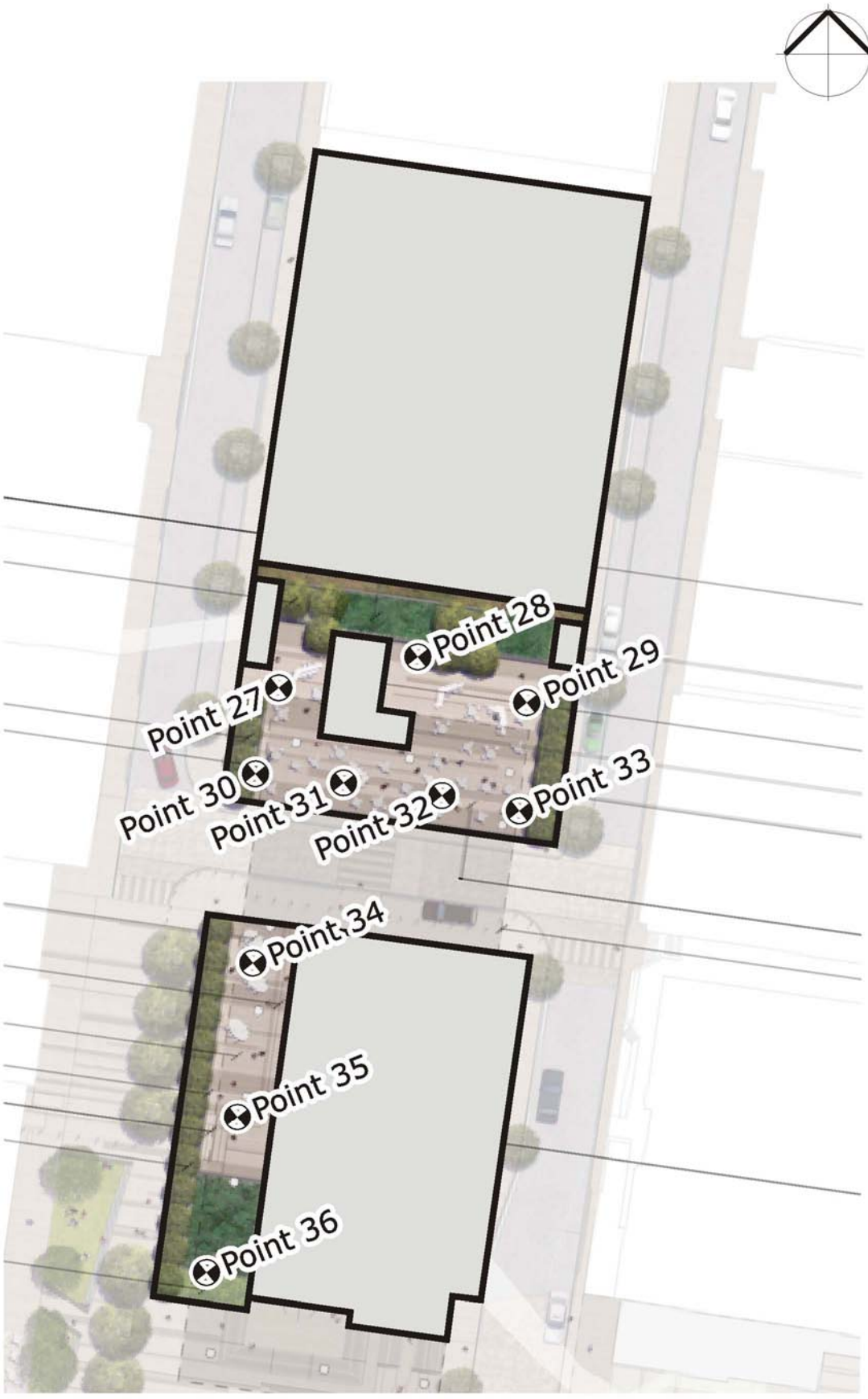

Figure 6b: Study Point Locations
(Restaurant Level - 88 Walker Street & 77-81 Berry Street)

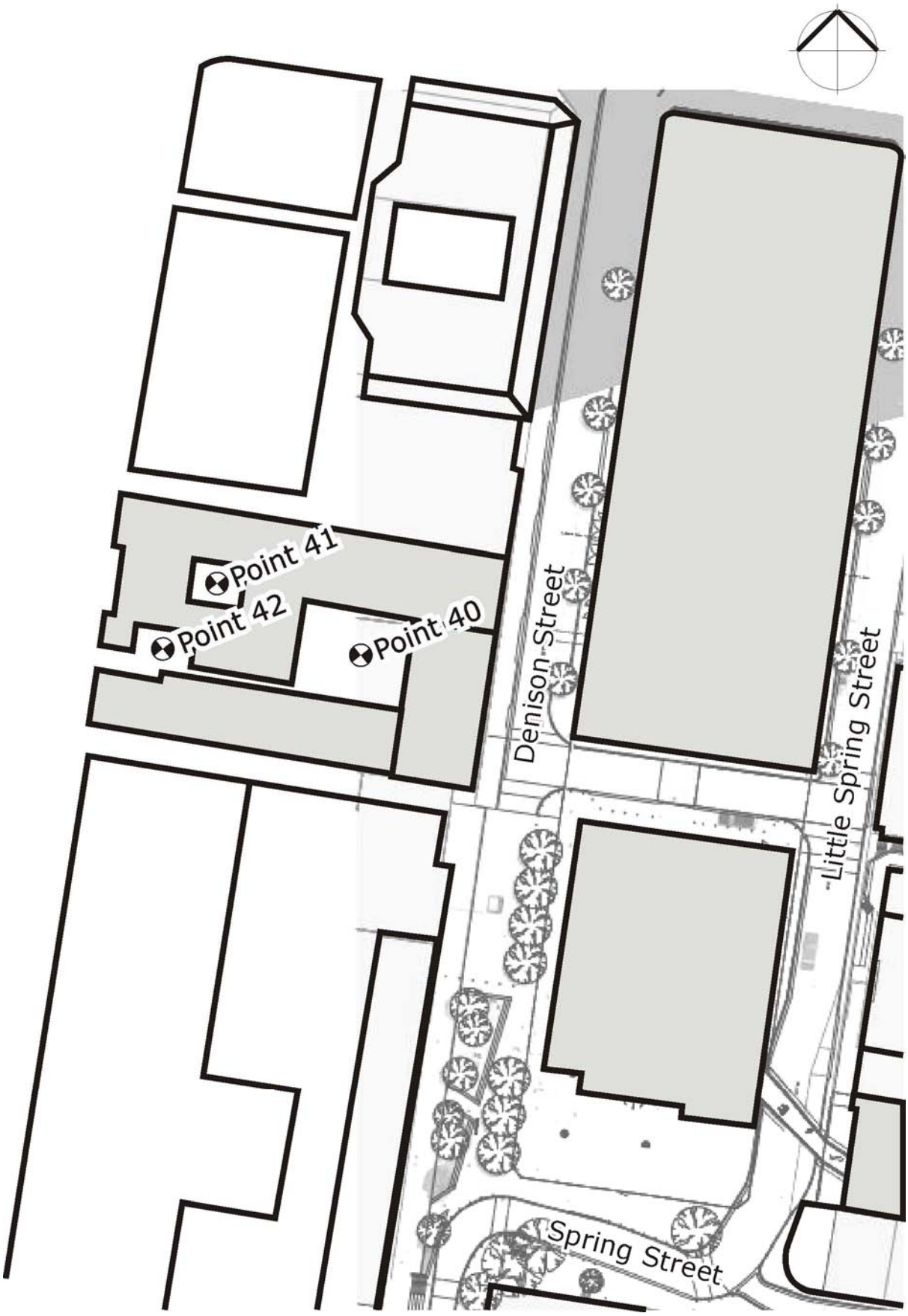

Figure 6c: Study Point Locations (Tower Square)

Figure 6d: Study Point Locations
(Beau Monde Residential Tower)

8.0 Environmental Wind Speed Criteria

The acceptability of wind in any area is dependent upon its use. For example, people walking or window-shopping will tolerate higher wind speeds than those seated at an outdoor restaurant. The following table developed by Penwarden (1975) is a modified version of the Beaufort Scale, and describes the effects of various wind intensities on people. Note that the applicability column related to wind conditions occurring frequently (approximately once per week on average). Higher ranges of wind speeds can be tolerated for rarer events.

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

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

Lawson (1973) quotes that Beaufort 4 wind speeds (6 to 8m/s means) would be acceptable if it is not exceeded for more than 4% of the time; and a Beaufort 6 (11 to 14m/s means) as being unacceptable if it is exceeded more than 2% of the time.

8.1 Davenport's Criteria for Mean Wind Speeds

Davenport (1972) had also come up with a set of criteria in terms of the Beaufort Scale and for various return periods. The values presented in Table 5 below are based on a frequency of exceedance of once per week (a probability of exceedance of 5%).

Table 5: Criteria by Davenport (1972)

Classification	Human Activities	95 Percentile Maximum Mean (once per week)
Walking Fast	Acceptable for walking, main public accessways	10 m/s > *u* > 7.5 m/s
Strolling, Skating	Slow walking, etc.	7.5 m/s > *u* > 5.5 m/s
Short Exposure Activities	Generally acceptable for walking & short duration stationary activities such as window-shopping, standing or sitting in plazas.	5.5 m/s > *u* > 3.5 m/s
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	3.5 m/s > *u*

8.2 Lawson's Criteria for Mean Wind Speeds

Later, Lawson (1975) came up with a set of criteria very similar to those of Davenport's. These are presented in Tables 6a and 6b, below.

Table 6a: Safety Criteria by Lawson (1975)

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

Table 6b: Comfort Criteria by Lawson (1975)

Classification	Human Activities	95 Percentile Maximum Mean (once per week)
Business Walking	Objective Walking from A to B	10 m/s > *u* > 8m/s
Pedestrian Walking	Slow walking, etc.	8 m/s > *u* > 6 m/s
Short Exposure Activities	Pedestrian Standing or sitting for a short time	6 m/s > *u* > 4 m/s
Long Exposure Activities	Pedestrian sitting for a long duration	4 m/s > *u*

8.3 Melbourne's Criteria for Peak Wind Speeds

Melbourne (1978) introduced a set of criteria for the assessment of environmental wind conditions. These criteria were developed for temperatures in the range from 10^{o}C to 30^{o}C and for people suitably dressed for outside temperature conditions. These criteria are based on peak gust wind speeds. Melbourne's criteria are outlined in Table 7 below. This set of criteria tends to be more conservative than criteria suggested by other researchers such as those indicated in Figure 7.

Table 7: Criteria by Melbourne (1978)

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

8.4 Comparison of the Various Wind Speed Criteria

The criteria mentioned in Table 7, as well as other criteria, are compared on a probabilistic basis in Figure 7, below.

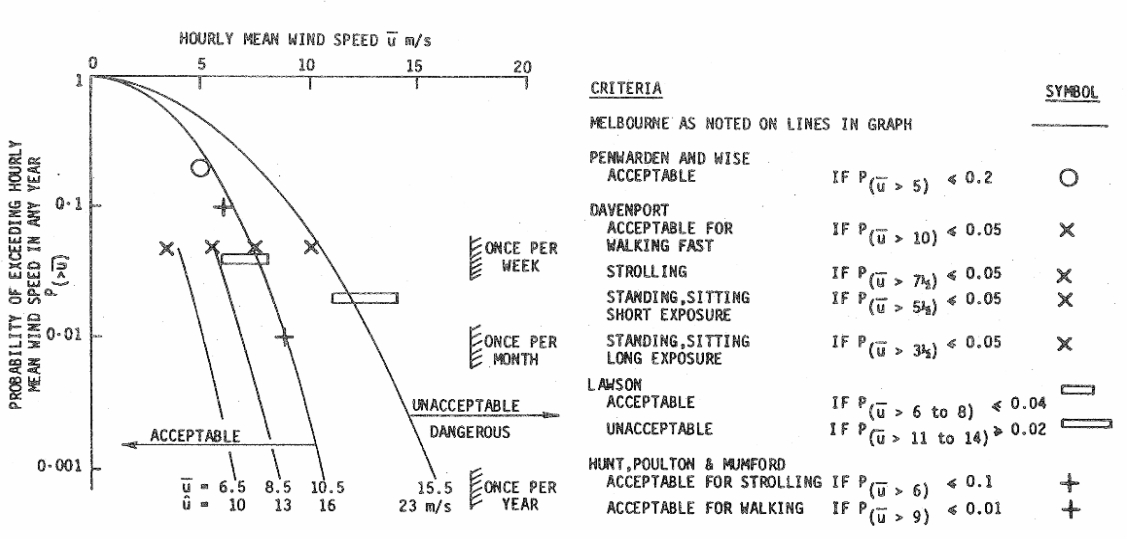

Figure 7: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (after Melbourne, 1978)

However, a comparative study presented by Ratcliff and Peterka (1990) based on measurements taken from a total of 246 locations in various urban situations tends to indicate that the criteria suggested by Melbourne (1978) can be considerably more conservative than the other criteria set out above. The results are in indicated in Figure 8. This agrees with our own observations (Rofail, 2007). This discrepancy in the criteria by Melbourne is due to the assumption of a fixed 15% turbulence intensity for all areas, which in our experience tends to be at the lower end of the range of turbulence intensities.

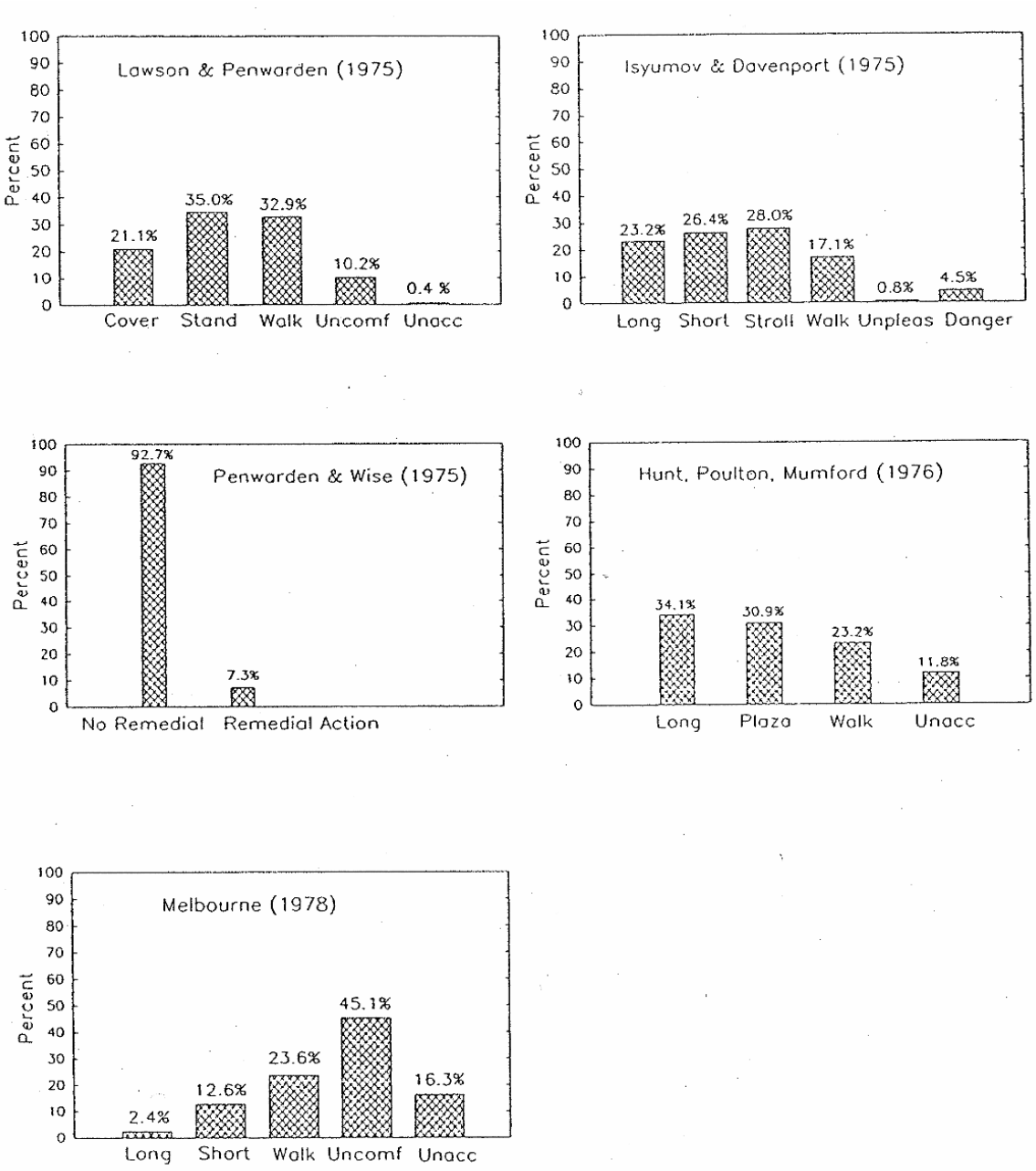

Figure 8: Distribution of Pedestrian Wind Comfort over Five Criteria for 246 locations examined in the Wind Tunnel (after Ratcliff & Peterka, 1990)

8.5 Wind Speed Criteria Used for This Study

For this study, the local wind climate has been compared against the North Sydney Development Control Plan (DCP) wind speed criteria, which is for the annual maximum peak wind speeds and is partly based on criteria by Melbourne (1978). The measured wind speeds are also compared to the corresponding existing site wind conditions. For terrace level areas the wind speeds are related to the comfort criteria by Davenport (1972), modified to correspond to a Gust Equivalent Mean (GEM) wind speed (described below), and also to the peak safety criterion.

To summarise, the wind comfort criteria used for this study are as follows;

- Wind conditions for all pedestrian accessible ground level areas within and around the proposed development sites should not exceed the existing wind conditions, or if they do they should not exceed 13m/s for the annual maximum peak wind speeds (as specified in the North Sydney DCP).
- Wind conditions for private balconies and terraces of the proposed developments should satisfy the safety limit of 23m/s for the annual maximum peak wind speeds. However, if a terrace is used frequently as a communal area (accessible by all occupants of the development), the short exposure criterion of 5.5m/s for the weekly maximum Gust Equivalent Mean (GEM) wind speeds should also be satisfied.

Note that the abovementioned Gust Equivalent Mean (GEM) wind speed (defined below), in conjunction with the Davenport criteria (see Section 4 of this report), has proven over time and through field observations to be the most reliable indicator of pedestrian comfort. The most reliable source of data for field observation results are obtained when undertaking remedial wind environment studies. Note that the Safety Limit criterion by Melbourne (1978) of 23m/s for annual maximum peak wind speeds is also applied to all areas. This criterion is used for most areas of Australia and around the world, unless stipulated otherwise by the local government authority.

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

- **Long Exposure:** 3.5m/s weekly maximum GEM wind speeds
- **Short Exposure:** 5.5m/s weekly maximum GEM wind speeds
- **Comfortable Walking:** 7.5m/s weekly maximum GEM wind speeds
- **Fast Walking:** 10.0m/s weekly maximum GEM wind speeds
- **Safety Limit:** 23.0m/s annual maximum gust wind speeds

Note that the criteria above for the weekly maximum GEM wind speeds are based on the Devenport (1972) criteria, but converted for weekly wind speeds.

Notes:

- The GEM is defined as the maximum of the following:
  - Mean wind speed
  - Gust wind speed divided by a gust factor of 1.85

- The gust wind speed is defined as 3.5 standard deviations from the mean.
- Long Exposure applies typically to outdoor dining areas in restaurants, amphitheatres, etc.
- Short Exposure applies typically to areas where short duration stationary activities are involved (less than 1 hour). This includes window shopping, waiting and drop-off areas.
- Comfortable Walking applies typically to areas used mainly for pedestrian thoroughfares. This also includes private swimming pools and communal areas.
- Fast walking applies typically to car parks, laneways, infrequently used public pedestrian thoroughfares and parks, balconies, private terraces etc.
- In all areas, the wind conditions are also checked against the safety limit.

9.0 Results of Study

A detailed study of wind activity around and within the various outdoor areas of the proposed development sites and the existing neighbouring Beau Monde residential tower, Fire Station Hotel and Tower Square was carried out. A total of 82 study locations were chosen for detailed analysis as shown in Figures 6a and 6d. These include 51 ground level test point locations, 10 test point locations on various terrace areas on the Restaurant Level of the 88 Walker Street & 77-81 Berry Street development and 7 test points on the outdoor Plaza area of the 100 Mount Street development. 15 test points were used to monitor wind conditions on the existing Tower Square, Beau Monde residential tower and Fire Station Hotel outdoor areas. Note that Study Points 54, 55 and 73 to 76 have been omitted from this study.

Initially the existing wind conditions were measured around the subject development sites. These tests included the effect of the existing vegetation. The wind conditions within and around the proposed development sites were then measured and, where applicable, compared with the existing results. It should be noted that the initial tests of the proposed tower developments were undertaken without the effect of any form of wind ameliorating devices such as balustrades or screens not shown in the architectural design. The initial tests with the proposed developments also ignored the effect of existing and/or proposed vegetation. For areas not achieving appropriate wind conditions retesting was undertaken with various forms of ameliorative treatments until an effective outcome was reached. The third case tested was to include the effect of the latest design for the proposed 88 Walker Street & 77-81 Berry Street development to determine the wind effects associated with the two proposed development sites.

Plots of results of the local directional wind speeds for the various test locations, as derived from the wind tunnel tests, are presented in the attached Appendix A. These results were assessed using the annual maximum peak wind speed criteria as required by the North Sydney Development Control Plan (DCP), as outlined in Section 4.5 of this report, for the public areas of the development. The weekly maximum GEM wind speeds are also presented and are used for the private terraces and balcony areas of the various tower developments. For the street level area, if existing conditions already exceed the criteria of the North Sydney DCP of 13m/s for the annual maximum peak wind speeds, then wind conditions for the subject proposed developments are not to result in an exceedence of the existing wind speeds.

9.1 Pedestrian Areas along Denison Street

The Study Points

Test Points 1 to 3, 5 to 8, 56 and 57 are used to monitor the ground level wind conditions of the pedestrian footpath areas along Denison Street on the western perimeter of the proposed development. The location of each Test Point is shown in Figure 6a.

Applicable Criteria

Test Points 1 to 3, 5 to 8, 57 and 58 represent the ground level pedestrian areas along Denison Street that are accessible by pedestrians. These areas are primarily used as pedestrian thoroughfares. If existing wind conditions for these areas already exceed the criteria of the North

Sydney DCP of 13m/s for the annual maximum peak wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedence of the existing wind speeds.

Results and Recommendations

The initial test results with the inclusion of the proposed developments indicate that wind conditions at all of the study point locations along Denison Street will exceed the 13m/s requirement of the North Sydney DCP for the annual maximum peak wind speeds. Retests were undertaken with the addition of the vegetation scheme indicated in the architectural drawings. The results of the retest indicate that the vegetation scheme was effective in mitigating the adverse wind conditions for most of these study point locations.

Additional tests were performed for Test Points 7 and 8, which are still exposed to adverse westerly to southerly winds, with additional densely foliating trees. Test Points 56 and 57, which are still exposed to adverse southerly and north-easterly winds, were also retested with the inclusion of an impermeable balustrade at the corner of Denison and Spring Street similar to what is currently in place and a 1.2m high shrub at the corner of Denison and Mount Streets. These treatments are shown in Figure 7a. The results of these retests indicates that these additional treatments will be effective in mitigating the adverse winds affecting these locations, and the wind speeds will be better than the corresponding existing wind conditions.

Due to the westerly winds, the trees along Denison Street should be of a densely foliating evergreen variety to be effective in mitigating the westerly winds which are predominant during the winter months for Sydney. Alternatively, a 2 metre deep awning along the western aspect of the development at Level 1 from the Street between Denison Street and Little Spring Street to the north of the site with densely foliating trees would be required.

9.2 Pedestrian Areas along the Street between Denison Street and Little Spring Street

The Study Points

Test Points 4 and 11 are used to monitor the ground level wind conditions of the pedestrian footpath areas along the street linking Denison Street with Little Spring Street, which cuts through the podium of the 88 Walker & 77-81 Berry Street proposed development. The location of each Test Point is shown in Figure 6a.

Applicable Criteria

Test Points 4 and 11 represent the ground level pedestrian areas along the street across the proposed development site from Denison Street to Little Spring Street. These areas are primarily used as pedestrian thoroughfares. If existing wind conditions for these areas already exceed the criteria of the North Sydney DCP of 13m/s for the annual maximum peak wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedence of the existing wind speeds.

Results and Recommendations

The street through the site connecting Little Spring and Denison Street does not currently exist as this is a proposed street to be added as part of the development.

The initial test results for Test Points 4 and 11 indicate this area of the site is exposed to strong westerly and north-easterly winds being downwashed and funnelled through the street which cuts through the podium and under the main tower across the site. Test Point 4 and 11 were retested with the addition of an awning on the northern and southern aspects of the street at Level 1. The result of these retests indicates that this wind deflector/awning will be effective in mitigating the adverse north-easterly and south-easterly winds from being downwashed to this location, however the results also indicated that there will be no improvement to the adverse westerly winds in these locations. An additional tree was modelled at the south-western corner of the street, as indicated in Figure 7a. Points 4 and 11 were retested, and the results indicated that with an awning on the southern and northern aspects of the street, and with an additional densely foliating evergreen tree at the south-western corner of the street, wind conditions at these locations will be equivalent to the existing conditions, and are acceptable.

9.3 Pedestrian Areas along Spring Street

The Study Points

Test Points 9 to 10, 12 to 15, 58 to 60 and 82 are used to monitor the ground level wind conditions of the pedestrian footpath areas along Spring Street between the proposed two developments. The location of each Test Point is shown in Figure 6a.

Applicable Criteria

Test Points 9 to 10, 12 to 15, 58 to 60 and 82 represent the ground level pedestrian areas along Spring Street that are accessible by pedestrians. These areas are primarily used as pedestrian thoroughfares. If existing wind conditions for these areas already exceed the criteria of the North Sydney DCP of 13m/s for the annual maximum peak wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedence of the existing wind speeds.

Results and Recommendations

The initial test results with the inclusion of the proposed developments indicate that wind conditions at Study Points 9, 10, 12 to 15 and 58 to 60 will exceed the 13m/s requirement of the North Sydney DCP for the annual maximum peak wind speeds. Retests were undertaken with the addition of the trees indicated in the architectural drawings. The results of the retest indicate that the trees are effective in improving wind conditions. The results for Test Point 9 indicate that wind conditions will be within 13m/s for the annual maximum gust wind speeds. The retest results for Point 59 and 60 indicated that wind conditions will be better than the corresponding existing wind conditions at that location. Hence, with the addition of the trees in the locations as indicated in the

architectural drawings, wind conditions at Test Points 9, 10, 58 and 60 will be acceptable.

The results of the retest indicated that the vegetation scheme was not effective in ameliorating the adverse westerly to southerly and north-easterly winds at Test Points 12 to 15 and 58. These locations were again retested, this time with the addition of a row of densely foliating trees along the northern boundary of Spring Street and western boundary of Little Spring Street, and a single densely foliating tree on the southern side of Spring Street (opposite Little Spring Street), as indicated in Figure 7a. The results of these retests indicate that the additional densely foliating trees were effective in mitigating the wind conditions affecting Test Points 12 to 15 and 58 so that the 13m/s criterion is satisfied for the annual maximum peak wind speeds.

9.4 Pedestrian Areas along Little Spring Street

The Study Points

Test Points 16 to 23 are used to monitor the ground level wind conditions of the pedestrian footpath areas along Little Spring Street between the 88 Walker and 77-81 Berry Street development. The location of each Test Point is shown in Figure 6a.

Applicable Criteria

Test Points 16 to 23 represent the ground level pedestrian areas along Little Spring Street that are accessible by pedestrians. These areas are primarily used as pedestrian thoroughfares. If existing wind conditions for these areas already exceed the criteria of the North Sydney DCP of 13m/s for the annual maximum peak wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedence of the existing wind speeds.

Results and Recommendations

The initial test results with the inclusion of the proposed developments indicate that wind conditions for all of the test points along Little Spring Street will exceed the 13m/s requirement of the North Sydney DCP for the annual maximum peak wind speeds. The test points located along Little Spring Street are exposed to adverse north-easterly and westerly to southerly winds. These study locations were retested with the addition of a row of densely foliating trees along Little Spring Street as indicated in Figure 7a. The results of this retest indicate that these densely foliating trees are effective in mitigating the adverse wind conditions observed at Test Points 16 to 21, although the measured wind conditions at Test Points 17 and 19 still exceed the 13m/s criterion. However, with the addition of the trees the wind conditions at Test Points 17 and 19 were ameliorated such that the wind speeds are better than the corresponding existing wind conditions. Hence, with the recommended treatments as indicated in Figure 7a, wind conditions along the pedestrian footpaths of Little Spring Street will be acceptable.

9.5 Pedestrian Areas along Walker Street

The Study Points

Test Points 24 to 26 and 61 to 63 are used to monitor the ground level wind conditions of the pedestrian footpath areas along Walker Street on the eastern side of the proposed developments. The location of each Test Point is shown in Figure 6a.

Applicable Criteria

Test Points 24 to 26 and 61 to 63 represent the ground level pedestrian areas along Walker Street that are accessible by pedestrians. These areas are primarily used as pedestrian thoroughfares. If existing wind conditions for these areas already exceed the criteria of the North Sydney DCP of 13m/s for the annual maximum peak wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedence of the existing wind speeds.

Results and Recommendations

The initial test results with the inclusion of the proposed developments indicate that wind conditions at all of these study point locations will exceed the 13m/s requirement of the North Sydney DCP for the annual maximum peak wind speeds. Retests were undertaken with the addition of the existing trees at the corner of Walker and Spring Streets. The results of the retest indicate that the trees are effective in mitigating the adverse westerly to southerly winds at Test Points 24 and 25, and that the measured wind speeds will be better than the corresponding existing wind conditions at these locations.

The results of the retest for Test Point 26 indicate that this location was still exposed to adverse westerly to southerly winds. This location was again retested with the addition of another densely foliating tree north of the point. The result of this retest indicates that the additional densely foliating tree will be effective in mitigating the adverse winds affecting Point 26, and will result in wind conditions which will be better than the existing wind conditions for that location.

Since the existing trees along Walker Street are of a deciduous species, an alternative treatment options were sought to ameliorate the adverse westerly winds which tend to occur during the winter months (westerly winds occur predominantly during the winter months for the Sydney region, as indicated in Table 2). The inclusion of the existing 1.2m high impermeable parapet on the neighbouring building to the south and an awning on Level 1 of the 88 Walker Street hotel tower proposed development were tested. With these treatments, wind conditions along Walker Street during the winter months, even when the deciduous streets are not effective in wind mitigation, will be better than the measured existing wind conditions.

The initial test results indicate that Test Points 61 to 63 will all exceed their applicable wind comfort criterions due to strong north-westerly and south-westerly winds. Retests were undertaken with the inclusion of an awning along the southern aspect of 100 Mount Street at Level 1. With the inclusion of this awning it was observed that the captured south-westerly winds would downwash off the eastern edge of the awning. Retests were then undertaken with the inclusion of an upturn at the

eastern edge and return of the ground level awning along the southern aspect, as indicated in Figure 9b.

The results of the retests indicate that the awnings would be effective in reducing wind conditions to be within existing conditions. If this area is proposed as a café area, the use of portable 1.2m high impermeable screens is advisable during events of strong southerly winds.

9.6 Pedestrian Areas along Mount Street

The Study Points

Test Points 64 to 70, 72 and 81 are used to monitor the ground level wind conditions of the pedestrian footpath areas along Mount Street at the southern aspect of the proposed 100 Mount Street development. The location of each Test Point is shown in Figure 6a.

Applicable Criteria

Test Points 64 to 70, 72 and 81 represent the ground level pedestrian areas along Mount Street that are accessible by pedestrians. These areas are primarily used as pedestrian thoroughfares. If existing wind conditions for these areas already exceed the criteria of the North Sydney DCP of 13m/s for the annual maximum peak wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedence of the existing wind speeds.

Results and Recommendations

The initial test results indicate that the wind conditions at Test Points 64, 69, 70, 72 and 81 will exceed the recommended wind conditions as well as the existing wind conditions for the respective areas. This is primarily due to the southerly winds being downwashed off the southern façade of the development. Testing was also undertaken with the inclusion of the Plaza being enclosed which would occur during a strong wind event or when the Plaza area is closed. With the screens around the Plaza area lowered, the wind conditions along Mount Street are further increased due to the downwashed southerly winds.

Retests were undertaken with the inclusion of the awning along the southern aspect at Level 1, which was found to slightly improve wind conditions. With the inclusion of the southern awning, as well as the proposed densely foliating trees along Mount Street as indicated in the landscape drawings, wind conditions will be suitable for their intended uses, with the Plaza area open or closed.

9.7 Pedestrian Areas along Berry Street

The Study Points

Test Points 37 to 39 are used to monitor the ground level wind conditions of the pedestrian footpath areas along Berry Street located to the north of the entry to the existing Beau Monde residential tower. The location of each Test Point location is shown in Figure 6a.

Applicable Criteria

Test Points 37 to 39 represent the ground level pedestrian areas along Berry Street that are accessible by pedestrians. These areas are

primarily used as pedestrian thoroughfares. If existing wind conditions for these areas already exceed the criteria of the North Sydney DCP of 13m/s for the annual maximum peak wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedence of the existing wind speeds.

Results and Recommendations

The initial test results for Test Points 37 and 39 indicate this area of Berry Street, without the inclusion of any trees, is exposed to strong north-easterly, westerly and southerly winds. With the inclusion of the proposed developments, westerly winds are funnelled along Denison Street while south-easterly winds are funnelled along Little Spring Street, causing wind conditions on Berry Street to exceed the current wind conditions. With the inclusion of the recommended tree planting scheme along Little Spring Street and Denison Street as indicated in Figure 7a, wind conditions along Berry Street will be similar to or better then the existing wind conditions.

9.8 Restaurant Level Outdoor Terrace Areas of the 88 Walker & 77-81 Berry Streets Development

The Study Points

Test Points 27 to 36 are used to monitor the wind conditions on the various outdoor terrace areas on the Restaurant Level of the proposed development. Note that this area was tested for two cases; with the proposed 88 Walker & 77-81 Berry Streets design, and with the design based on the council massing model limitations for the site. The locations of the Test Point are shown in Figure 6b.

Applicable Criteria

Test Points 27 to 36 represent the communal garden terrace areas on the Restaurant Level. These areas are accessible by tenants of the development and are used primarily as an outdoor dining area. Hence the appropriate wind comfort criterion to be satisfied for this area is the short exposure criterion of 5.5m/s for weekly maximum GEM wind speeds.

The appropriate wind comfort criteria for these areas are also indicated in Figure 6b. Note that the safety limit of 23m/s for annual maximum peak wind speeds should also be satisfied for all study points.

Results and Recommendations

The initial test results with the inclusion of the proposed 88 Walker & 77-81 Berry Streets design indicate that only Test Point 35 will satisfy the recommended short exposure wind comfort criterion for the weekly maximum GEM wind speeds. The results indicate that the outdoor dining area is exposed to strong north-easterly and westerly winds. This area was retested with the addition of a 1.2m high impermeable balustrade along the perimeter of the terrace as well as the trees and shrubs in the landscaping plan, as indicated in Figure 7b. A 1.2m high impermeable balustrade was also added to the perimeter of the proposed terrace along the western side of the development to assist in mitigating the adverse winds affecting that area.

The results of the retests indicate that the 1.2m high impermeable balustrade and landscaping plan were effective in ameliorating the

adverse wind conditions to these areas. Hence it is recommended that the impermeable balustrades and landscaping plan be included into the final design of the proposed development, and that with this recommendation these areas will be suitable for their intended uses.

Additional tests were undertaken for the design based on the council massing model limitations for the site. The results indicate that wind conditions for the Restaurant Level terrace area will be similar to or worse than the measured wind conditions with the current proposed design. The adverse wind effects are due to the increased aspect of the building producing a larger surface area to downwash and funnel the westerly and easterly winds building and the podium beneath. Ameliorative treatments for this alternate site design were not examined in this scope of work.

9.9 Ground Level Plaza Area of the 100 Mount Street Development

The Study Points

Test Points 71 and 83 to 87 are used to monitor the wind conditions on the ground level plaza area of the proposed 100 Mount Street development. The Plaza area was tested with the perimeter screens in the raised open position which would provide the worse-case scenario, with the screens able to be closed during strong adverse wind events. The locations of the Test Point are shown in Figure 6a.

Applicable Criteria

Test Points 71 and 83 to 87 represent the outdoor plaza area above the Retail Level of the proposed 100 Mount Street development. These areas are accessible by customers and occupants of the development and are used primarily for pedestrian activities. Hence the appropriate wind comfort criterion to be satisfied for this area is the short exposure criterion of 5.5m/s for weekly maximum GEM wind speeds.

The appropriate wind comfort criteria for these areas are also indicated in Figure 6e. Note that the safety limit of 23m/s for annual maximum peak wind speeds should also be satisfied for all study points.

Results and Recommendations

The initial results of the study indicated that the Plaza area is exposed to southerly winds which are downwashed off the southern façade of the development. Further more, the results indicated that wind conditions will generally be increased with the inclusion of the proposed 88 Walker Street development to the north.

Retests were undertaken with the inclusion of the proposed densely foliating trees along Mount Street, a 1.2 metre high impermeable balustrade along the southern and eastern aspects, as well as an awning at Level 1 along the southern aspect. With the inclusion of the abovementioned treatments, wind conditions of the for all Test Points except 86 will generally satisfy the recommended short exposure criterion of 5.5m/s for weekly maximum GEM wind speeds. Test Point 86 is still exposed to the strong southerly winds. During strong southerly wind events, the southern aspect of the perimeter Plaza screens may be lowered to mitigate this adverse effect for the outdoor Plaza area. This

would also further enhance wind conditions for the other test points located within the outdoor area.

9.10 Tower Square Outdoor Areas

The Study Points

Test Points 40 to 42 were used to monitor the wind conditions for existing outdoor areas located in the Tower Square building located on Denison Street to the west of the proposed development sites. The locations of these Test Points are shown in Figure 6c.

Applicable Criteria

Test Points 40 to 42 represent the nearby outdoor areas located in the Tower Square building. These areas are expected to be used for short duration activities. If existing wind conditions for these areas already exceed the criteria of the North Sydney DCP of 13m/s for the annual maximum peak wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedence of the existing wind speeds.

Results and Recommendations

The results indicate that, with the addition of the proposed developments, wind conditions at Test Points 40 to 42 will satisfy the 13m/s wind speed criterion of the North Sydney DCP. The results also indicate that wind conditions will be similar to or better than the current existing conditions for these outdoor areas. Hence these areas will continue to be suitable for their intended uses with the addition of the proposed developments.

9.11 Beau Monde Residential Tower Balcony and Podium Areas

The Study Points

Test Points 43 to 53 were used to monitor the wind conditions at existing outdoor balcony and podium areas located on the southern aspect of the existing Beau Monde residential tower located to the north of the development sites. The locations of the Test Point are shown in Figure 6d.

Applicable Criteria

Private balconies are generally used infrequently, and the wind criterion typically applied to these is the safety limit of 23m/s for the annual maximum gust wind speeds. Note that the use of light-weight furniture or other light-weight items is not recommended for high-rise balcony areas where there is a risk of these types of items being carried by the wind.

Results and Recommendations

Testing of the current wind conditions on the podium and in the various critical balcony areas located on the southern aspect of the Beau Monde building, indicate that the existing conditions are within the safety limit with the exception of the mid to upper level corner balconies.

With the inclusion of the two proposed developments, wind conditions on the podium and the various critical balcony locations of the Beau Monde

tower are generally equivalent to or better than the current wind conditions.

Additional testing was performed to investigate the effect of a hypothetical case where the massing for the 88 Walker Street & 77-81 Berry Street development is altered such that the height is reduced to be within the North Sydney Council DLEP controls and with the consequent extension of the tower plan towards the north (also to the 18m limit to the Beau Monde residential tower of the draft planning controls). The hypothetical model results in a slight overall improvement of the wind conditions in the southern corner balconies of the Beau Monde tower. However the Beau Monde balconies located in the middle of the southern aspect (for the various levels of the tower) experienced increased wind speeds due to the narrower gap between the two buildings.

9.12 Nearby Outdoor Ground Level Eateries

The Study Points

Test Points 77 to 80 were used to monitor the wind conditions at existing outdoor ground level eateries linked to adjacent buildings around the development sites as indicated by the client. The locations of the Test Point are shown in Figure 6a.

Applicable Criteria

Test Points 77 to 80 represent the nearby outdoor eateries. These areas are used for short duration activities. If existing wind conditions for these areas already exceed the criteria of the North Sydney DCP of 13m/s for the annual maximum peak wind speeds, then wind conditions for these areas with the proposed development are not to result in an exceedence of the existing wind speeds.

Results and Recommendations

The initial test results with the inclusion of the proposed developments indicate that wind conditions at Test Points 77 and 80 will generally satisfy the 13m/s wind speed requirement by the North Sydney DCP. Although the wind conditions at Test Points 78 and 79 exceeded 13m/s, they were generally either equivalent to or better than the maximum values recorded for the existing wind conditions. Hence with the addition of the proposed developments these areas will continue to be suitable for their intended uses.

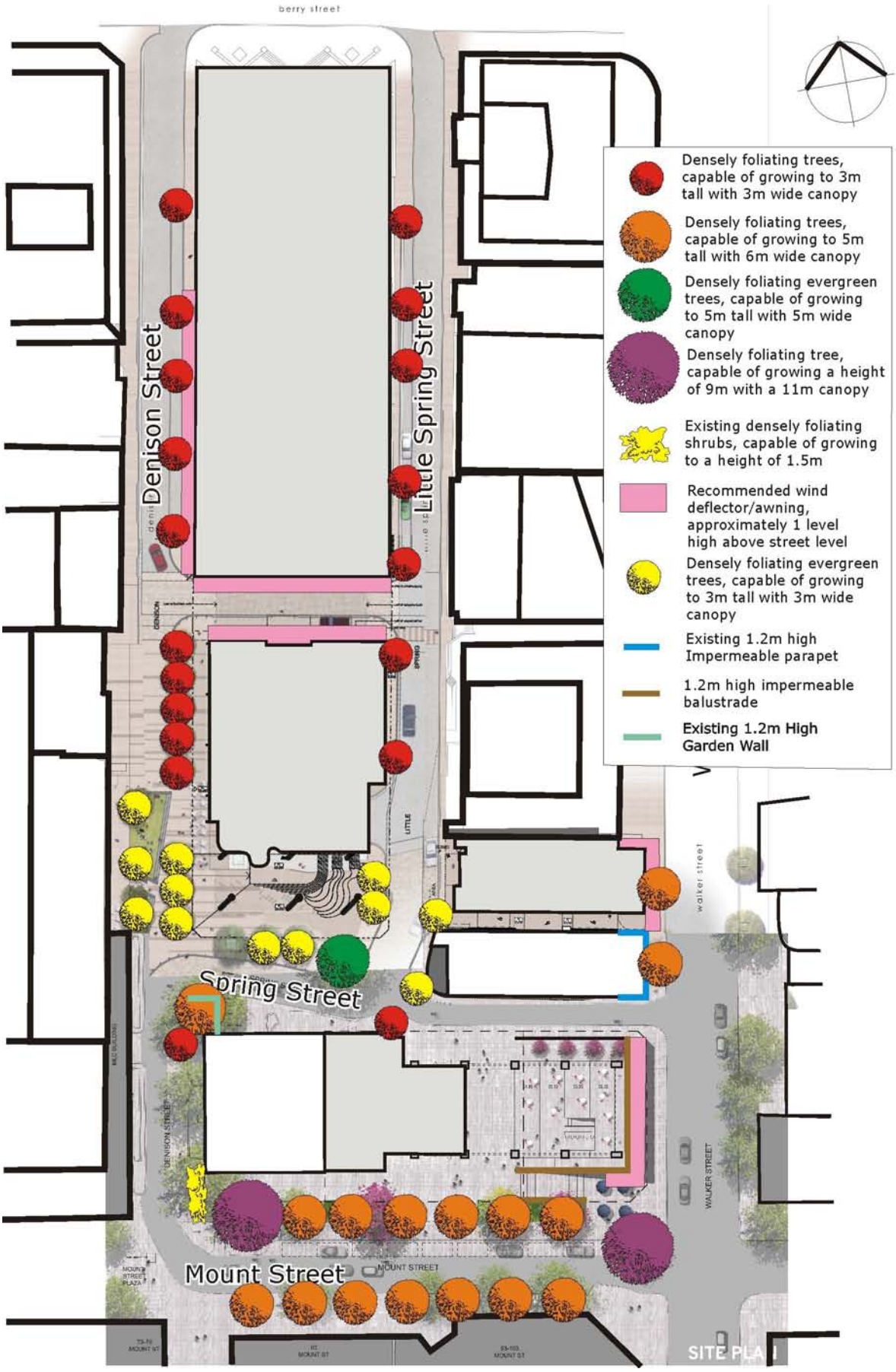

Figure 9a: Recommended Ground Level Treatments

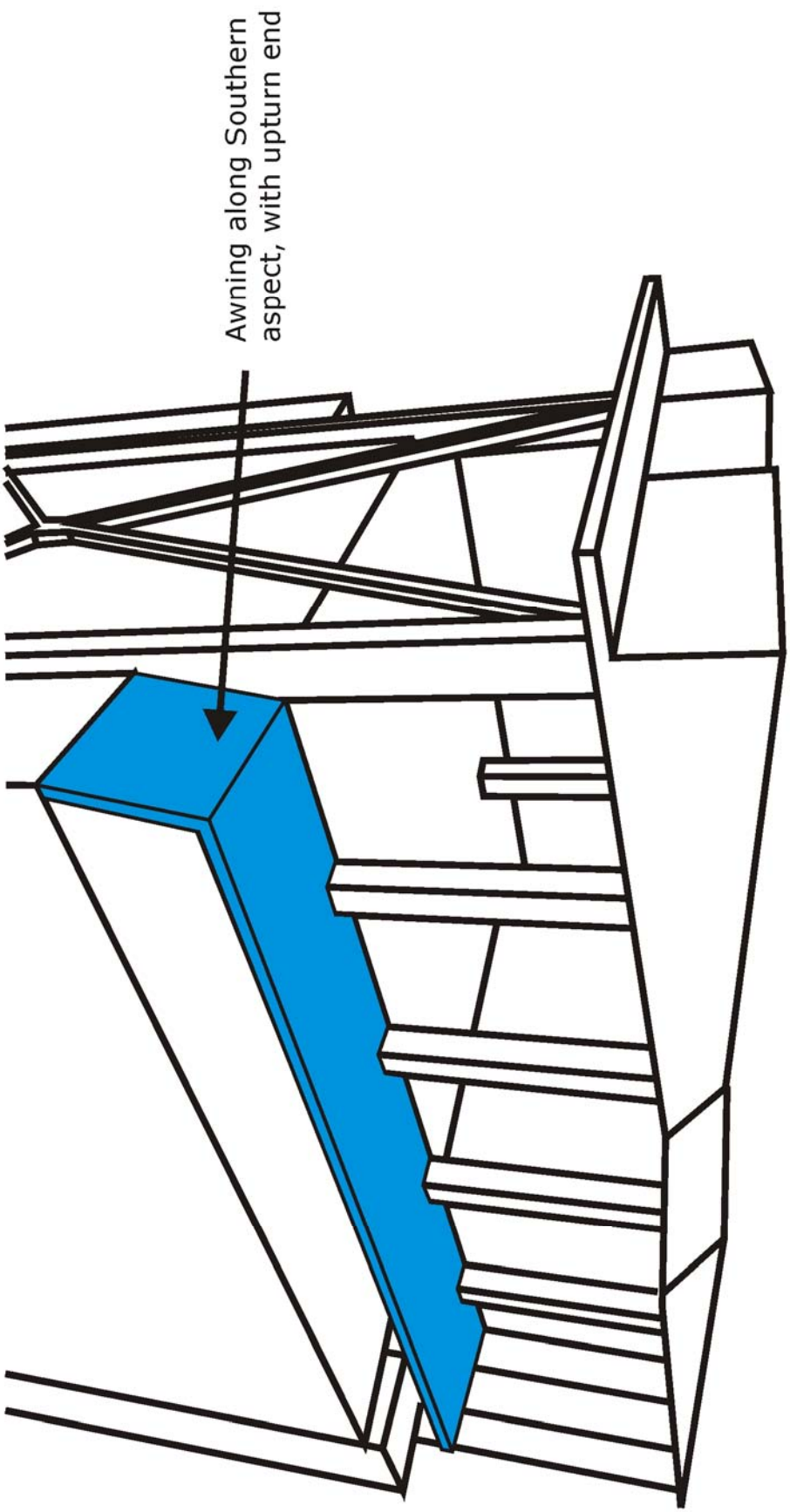

Figure 9b: Recommended Plaza Treatments (100 Mount Street)

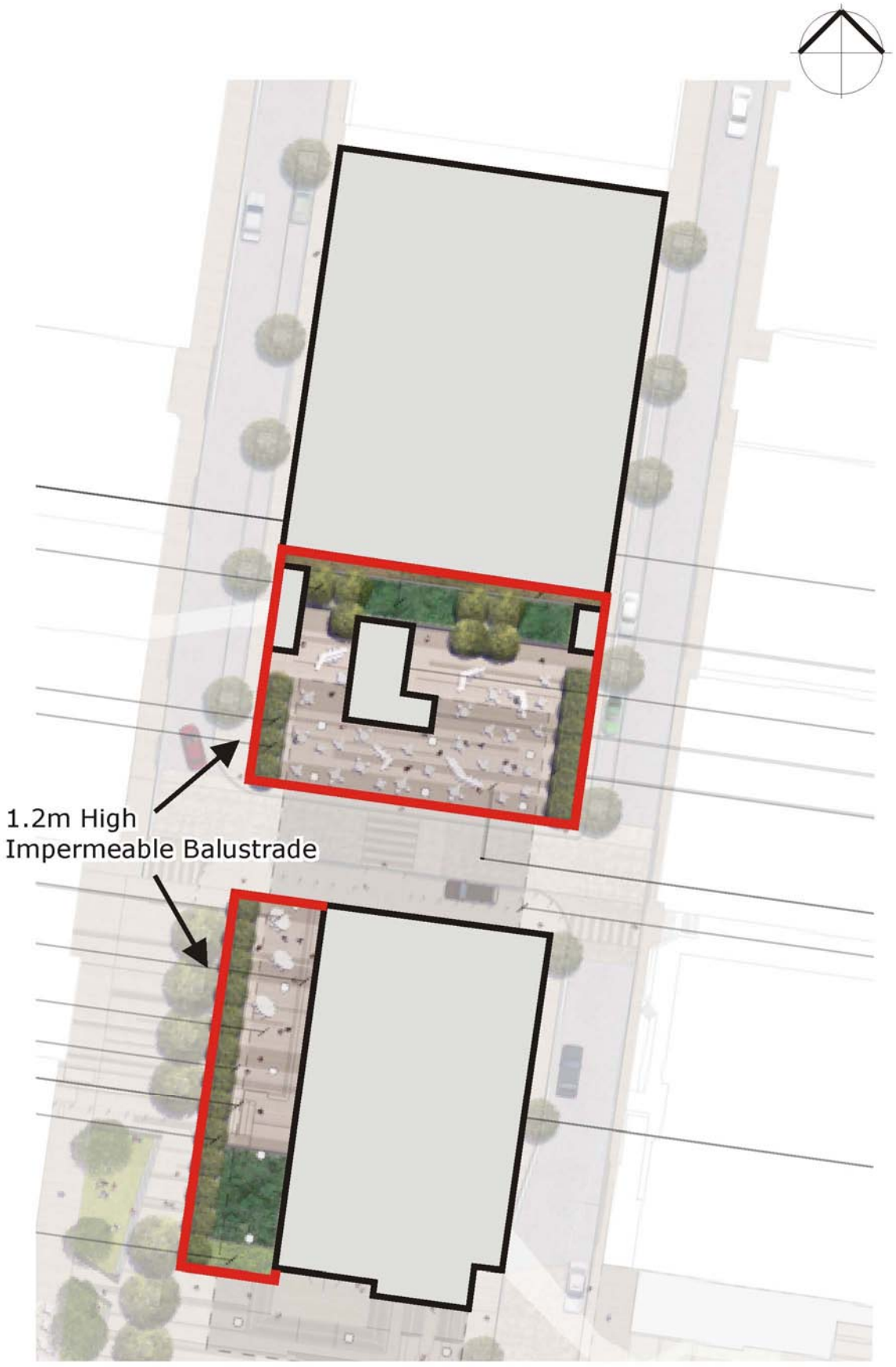

Figure 9c: Recommended Restaurant Podium Treatments (77-81 Berry Street)

10.0 Conclusion

This report presents the results of a detailed investigation into the wind environment impact in relation to the development applications for the sites known as:

- **100 Mount Street, North Sydney**; this development application is for a single office tower which is bounded by Mount Street to the south, Walker Street to the east, and Spring Street to the north.
- **88 Walker Street & 77-81 Berry Street, North Sydney**; this development application includes two towers. The proposed office tower is bounded by Little Spring Street to the east, Spring Street to the south, Denison Street to the west and the Beau Monde residential tower to the north. The proposed hotel tower is bounded by Walker Street to the east and Little Spring Street to the west.

The results of the study indicate that wind conditions for the outdoor areas within and around the development site will satisfy the appropriate wind comfort and safety criteria with the inclusion of the following recommended treatments. The treatments that have been recommended for the areas exposed to adverse wind conditions include:

- Densely foliating trees along Dension and Little Spring Streets capable of growing to a height of 3 metres with a 3 metre wide canopy.
- Densely foliating evergreen trees capable of growing to a height of 3 metres with a 3 metre wide canopy within the Spring Street outdoor plaza area.
- Densely foliating evergreen trees capable of growing to a height of 3 metres with a 3 metre wide canopy at the corner of Spring Street and Little Spring Street.
- Retention of the existing trees and shrubs along Denison Street between Spring Street and Mount Street.
- Retention of the existing trees along Walker Street infront of the 88 Walker Street development site.
- Densely foliating trees capable of growing to a height of 5 metres with a 6 metre wide canopy and 9 metres with a 11 metre wide canopy along Mount Street.
- Canopy along the eastern edge of the 88 Walker Street façade.
- Canopy along the western edge of the 77-81 Berry Street façade.
- Canopy along the northern and southern aspects of the proposed new street between Denison Street and Little Spring Street.
- 1.2 metre high impermeable balustrade along the southern and eastern perimeter of the 100 Mount Street outdoor Plaza area.
- Ground Level canopy along the eastern edge of the 100 Mount Street façade.
- Canopy along the southern aspect at Level 1 of the 100 Mount Street development with an upturn at the eastern end.
- 1.2 metre high impermeable balustrade around the perimeter of the restaurant level podium area of the 77-81 Berry Street development.

With the inclusion of the abovementioned treatments to the proposed development, wind conditions for all outdoor trafficable areas within and around the development will satisfy the recommended wind comfort and safety criteria. It should be noted that it is recommended that the trees be of a densely foliating and evergreen variety to ensure there effectiveness in wind mitigation for all months of the year.

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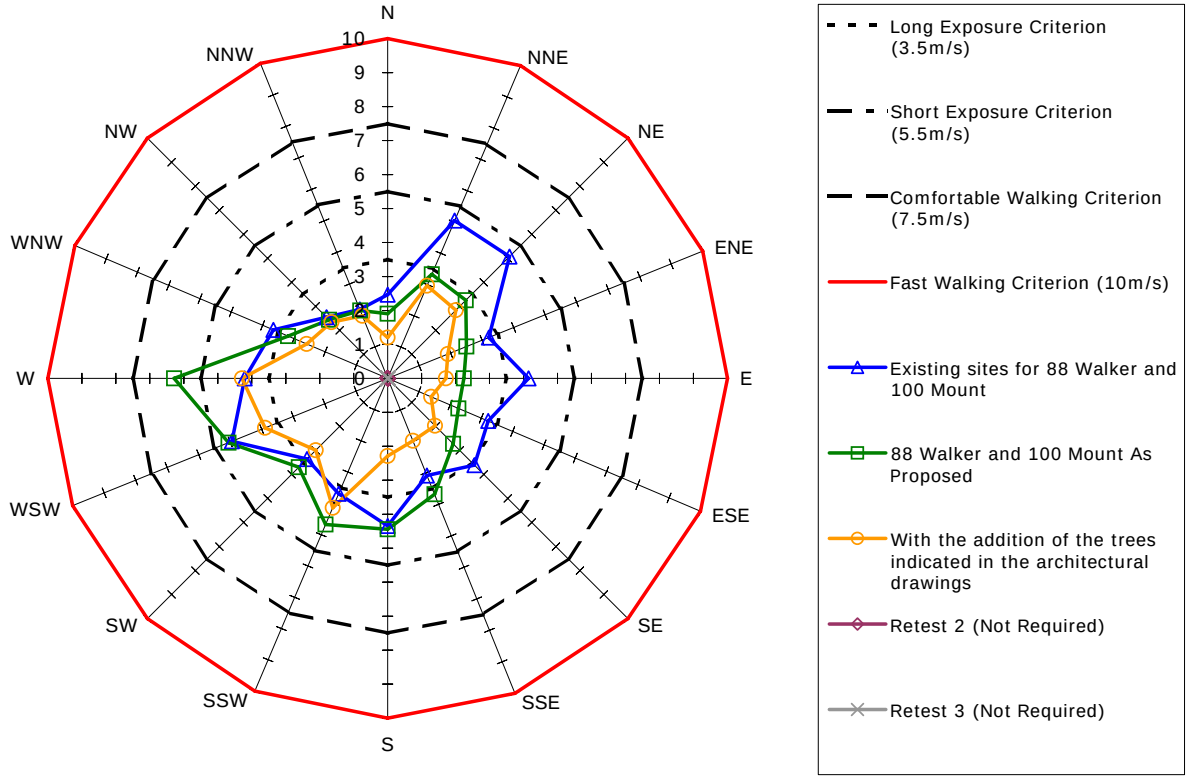
Appendix A

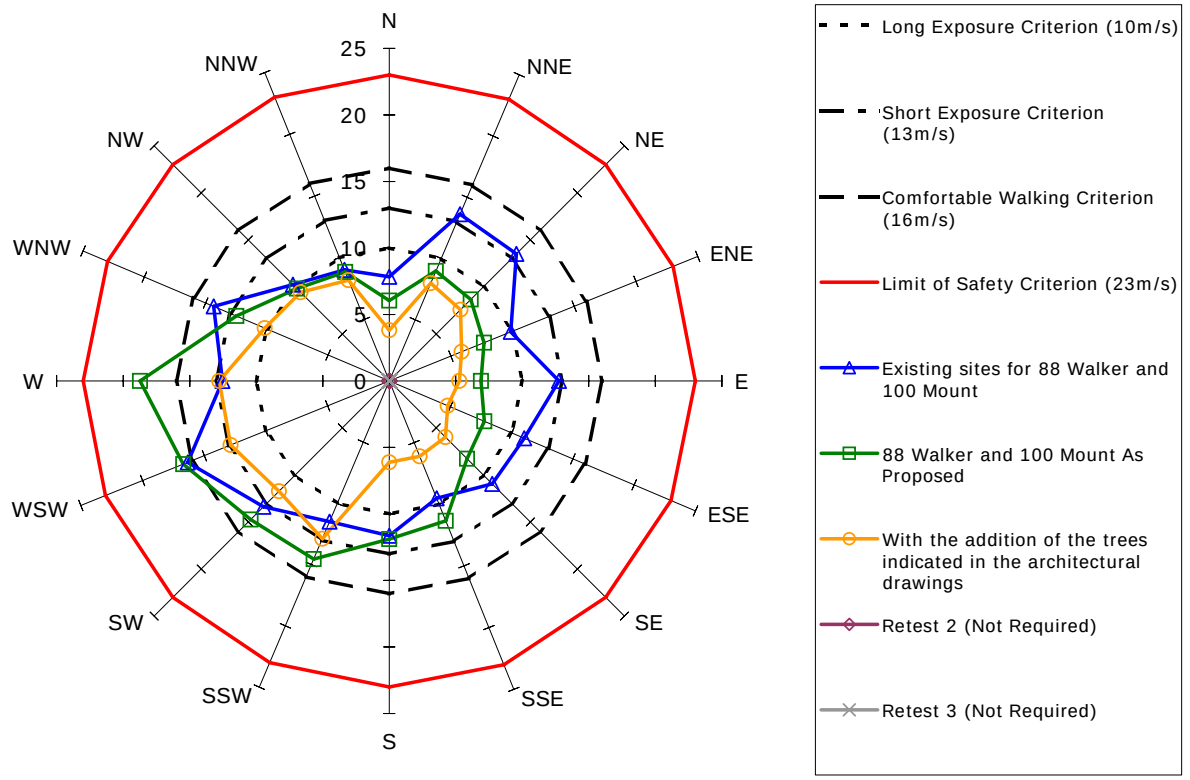
Plots of Wind Tunnel Results

Measured Wind Speeds at Point 01

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

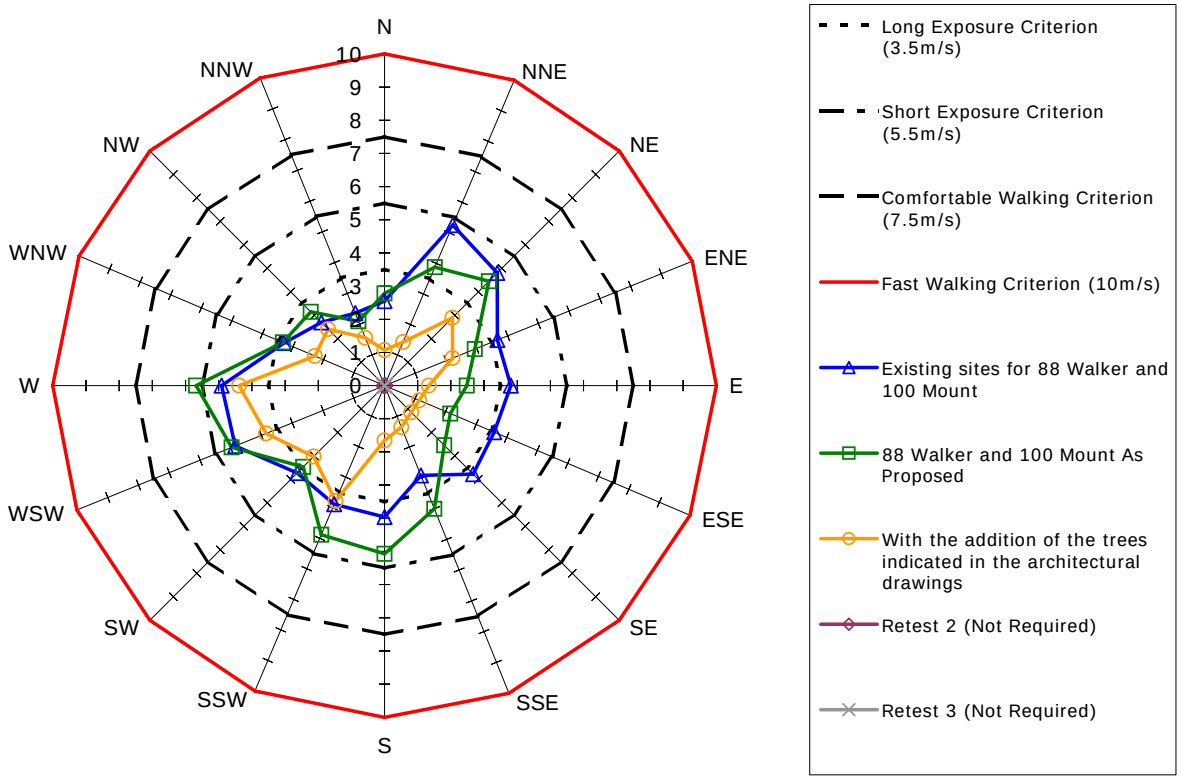


Annual Maximum Gust Wind Speeds (m/s)

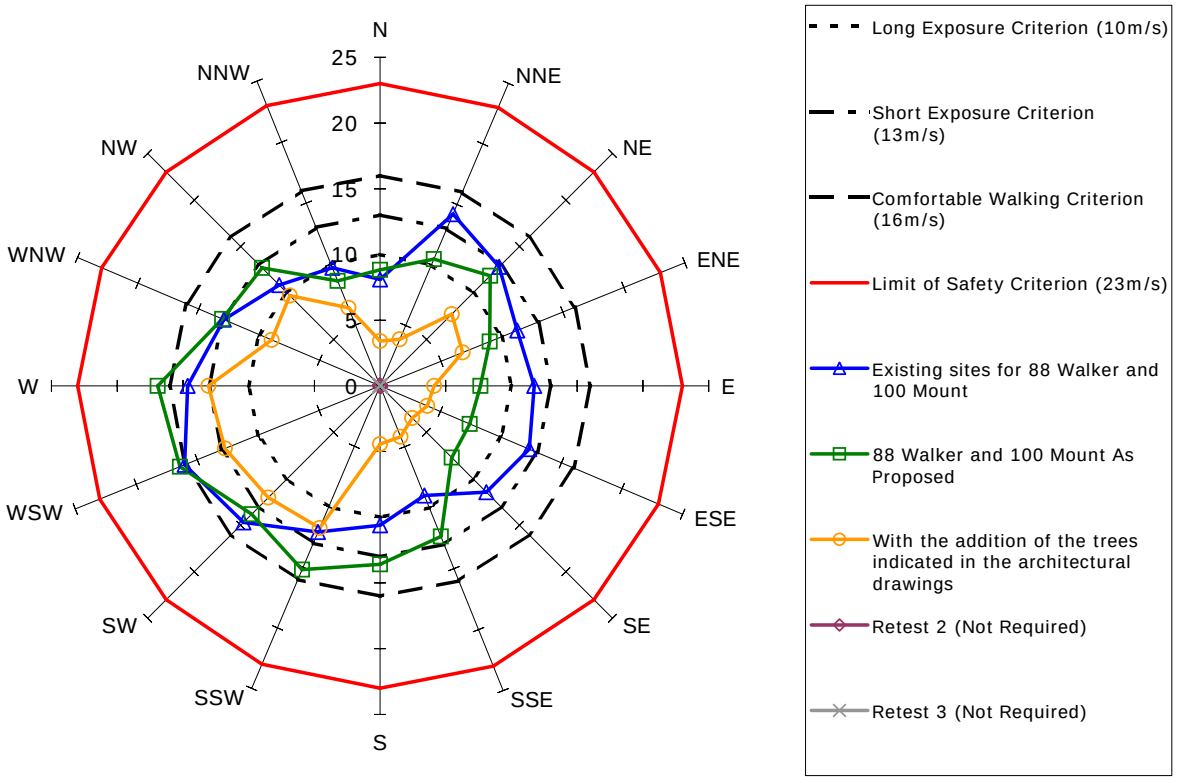


Measured Wind Speeds at Point 02

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

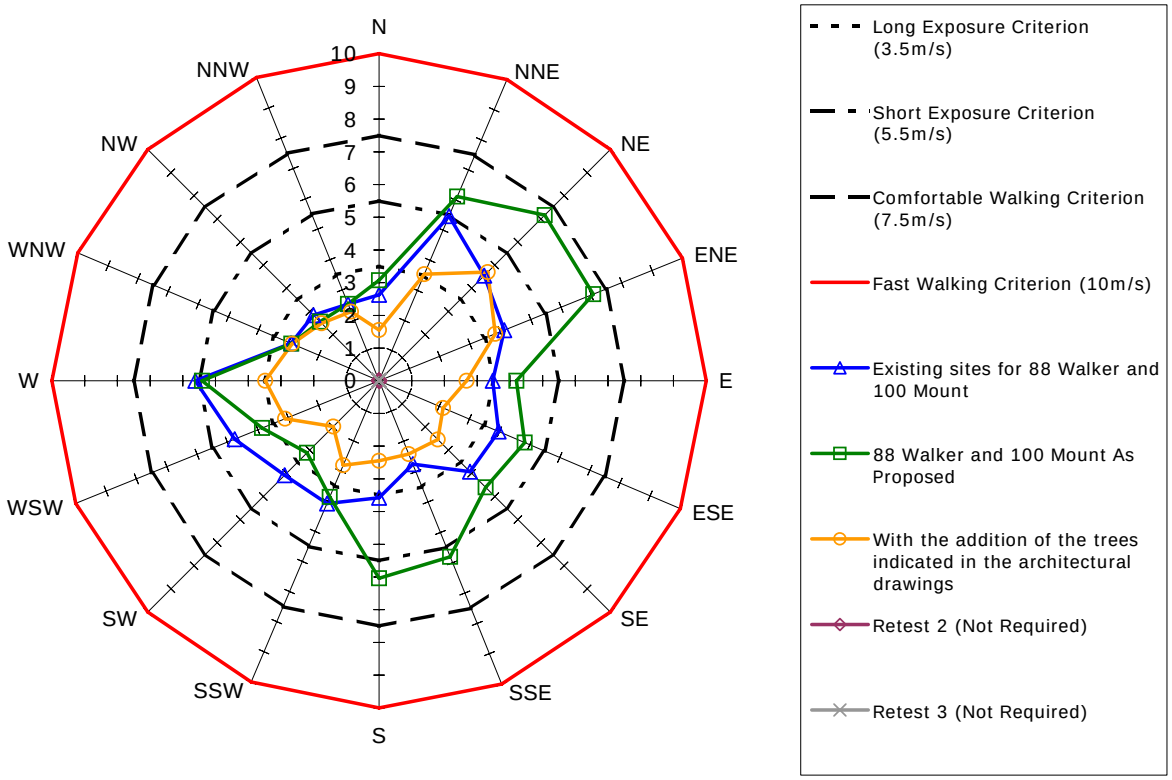


Annual Maximum Gust Wind Speeds (m/s)

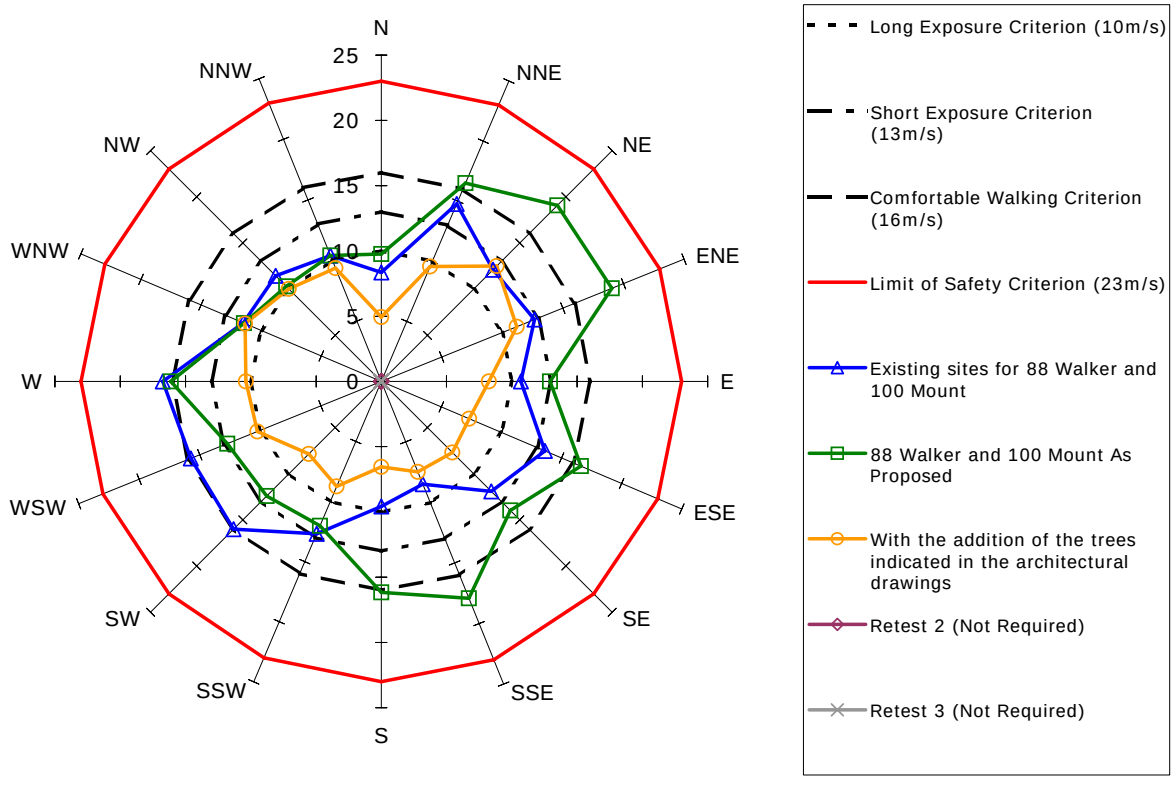


Measured Wind Speeds at Point 03

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

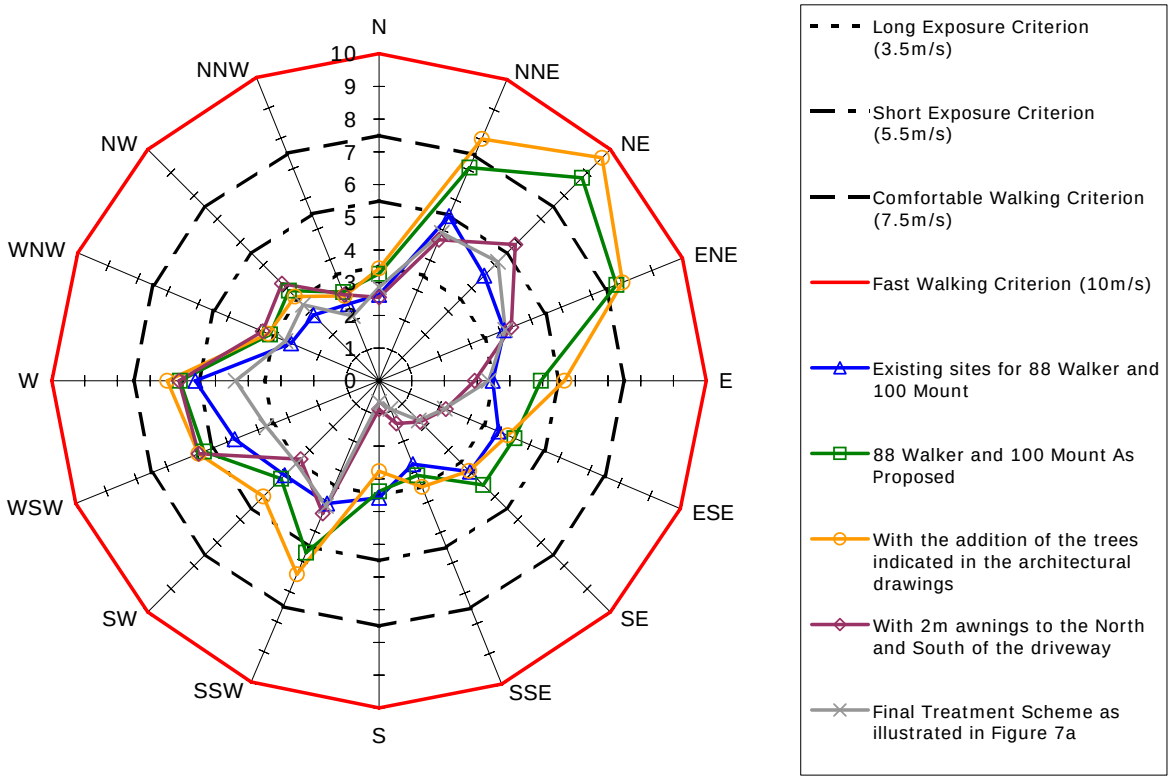


Annual Maximum Gust Wind Speeds (m/s)

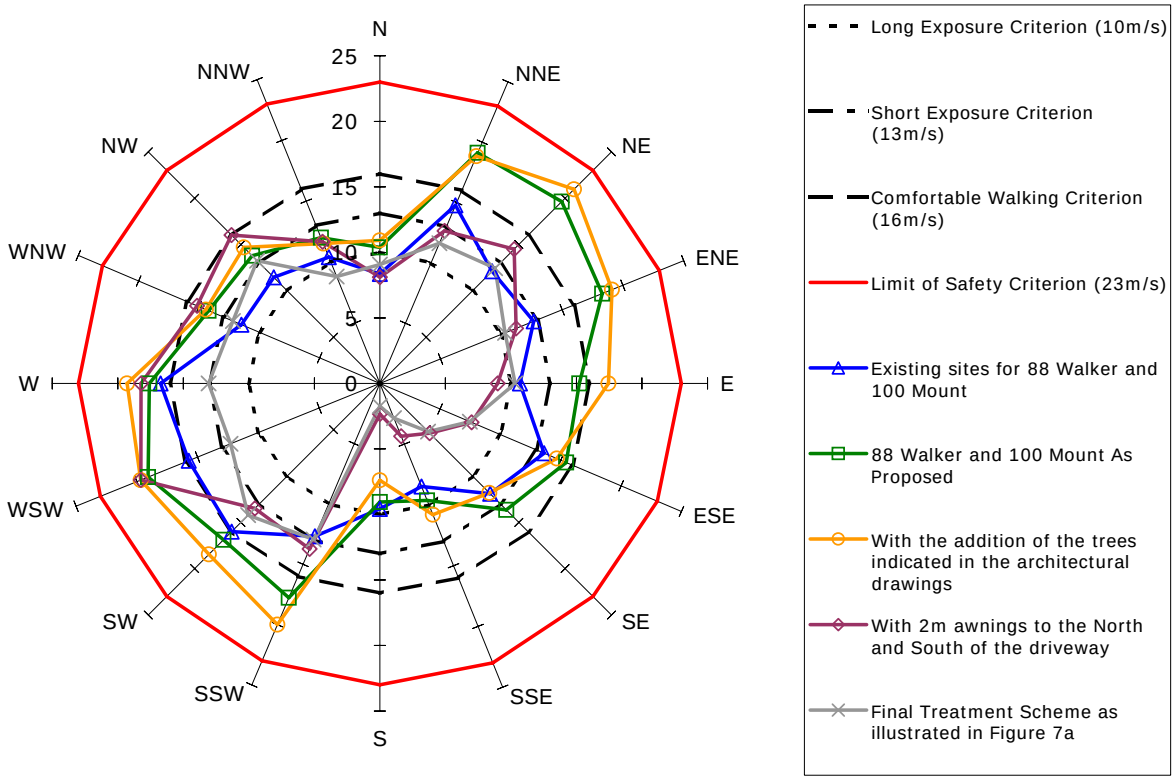


Measured Wind Speeds at Point 04

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

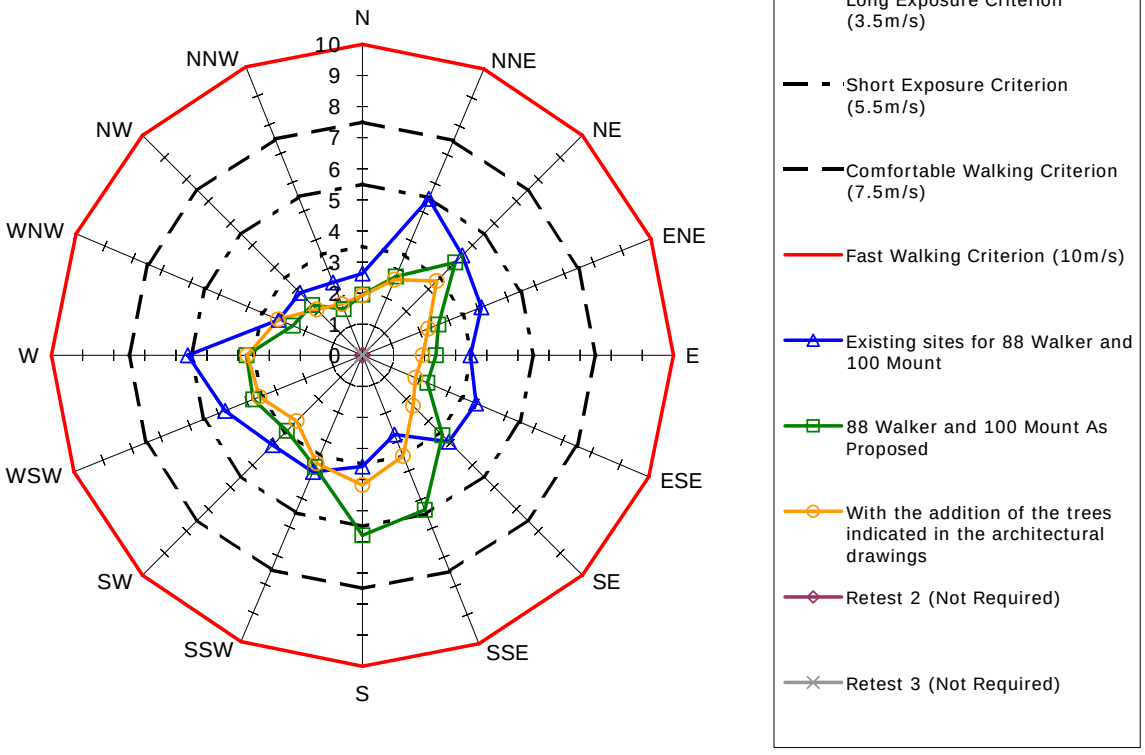


Annual Maximum Gust Wind Speeds (m/s)

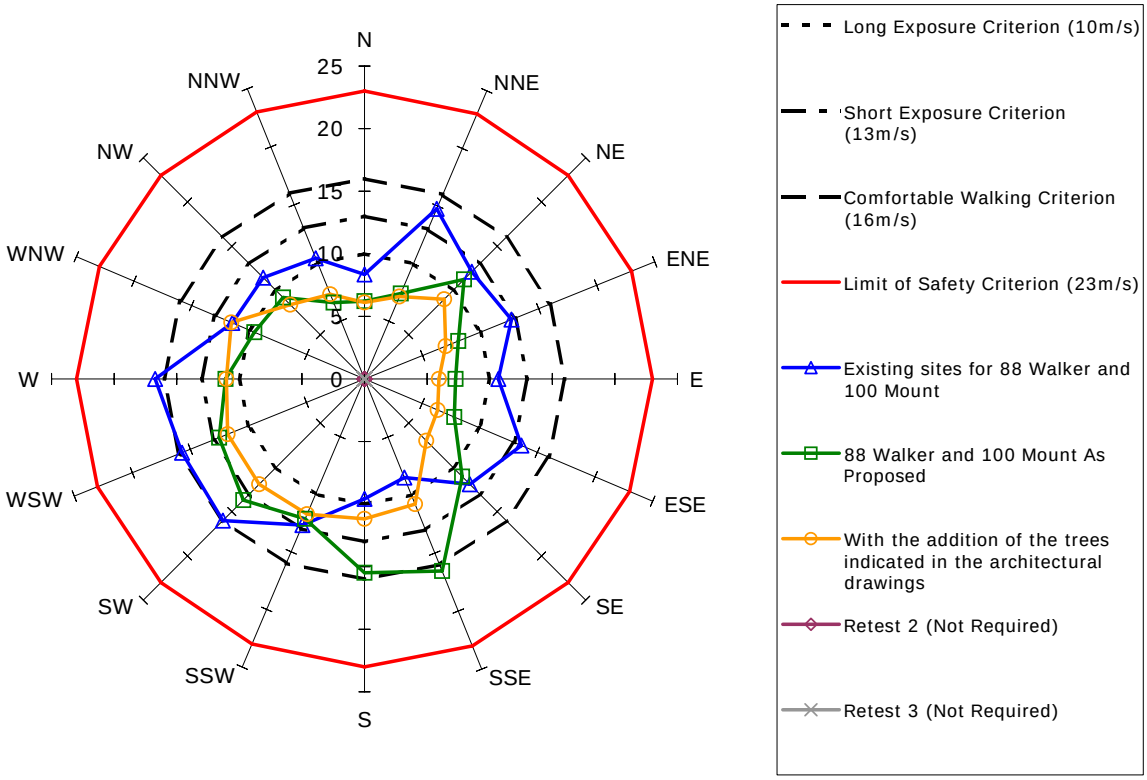


Measured Wind Speeds at Point 05

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

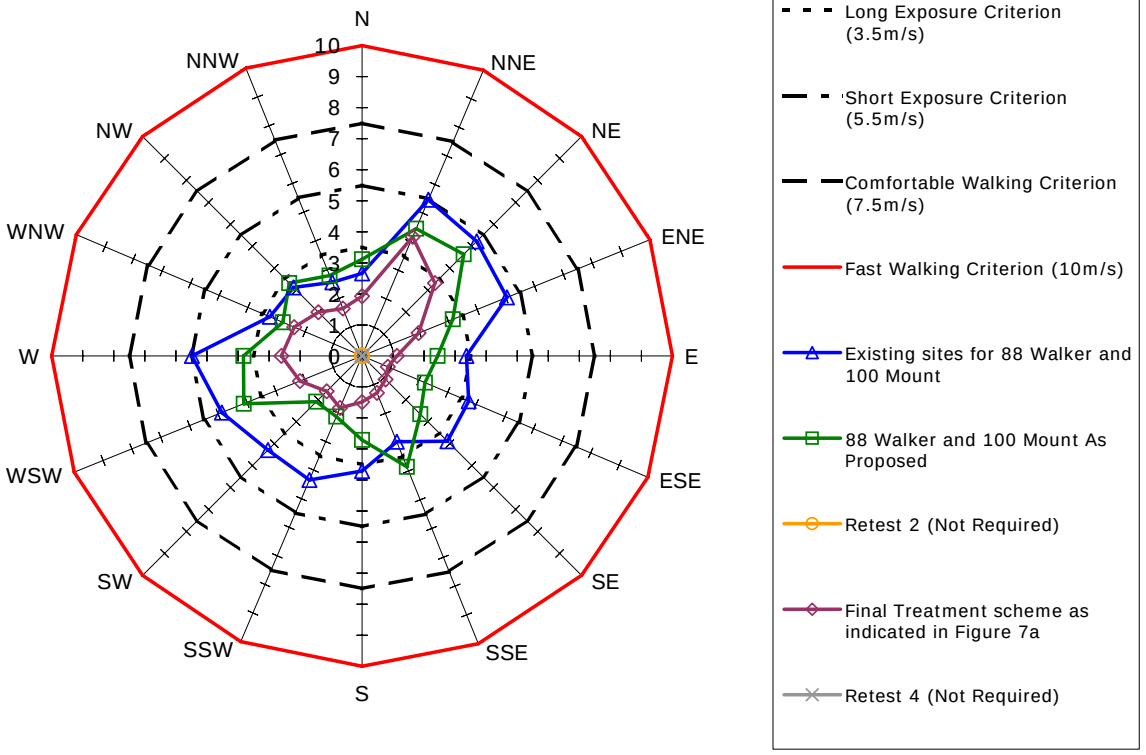


Annual Maximum Gust Wind Speeds (m/s)

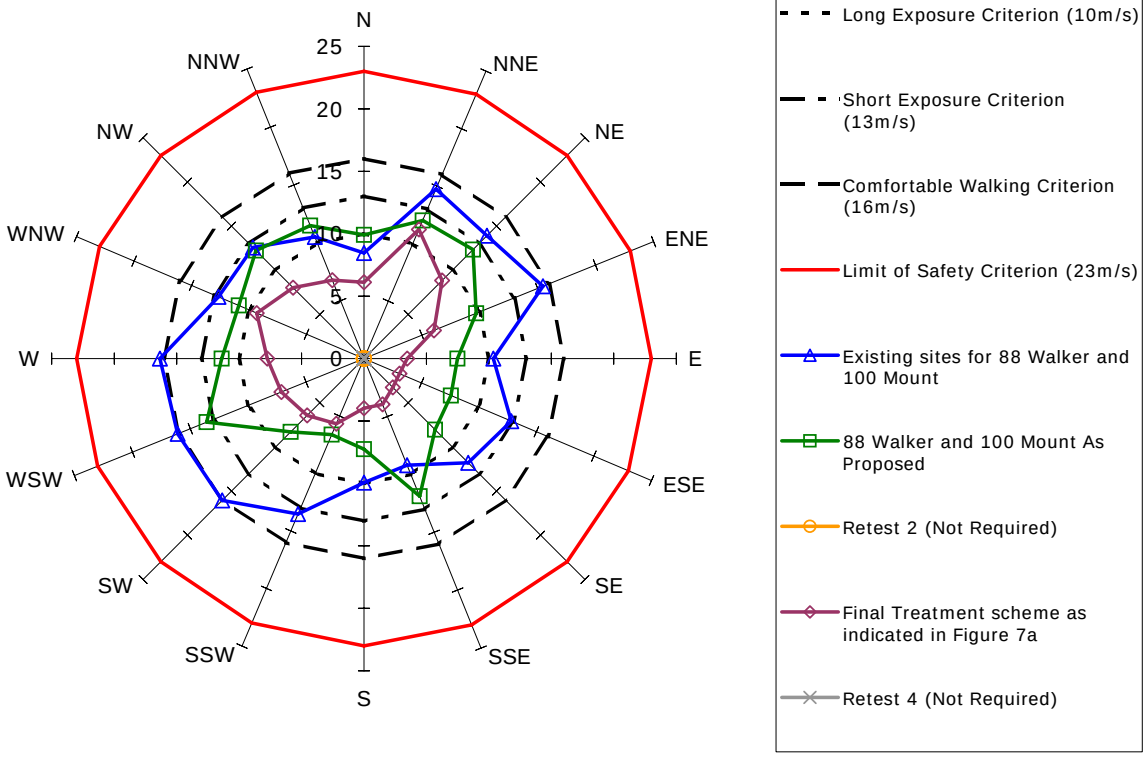


Measured Wind Speeds at Point 06

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

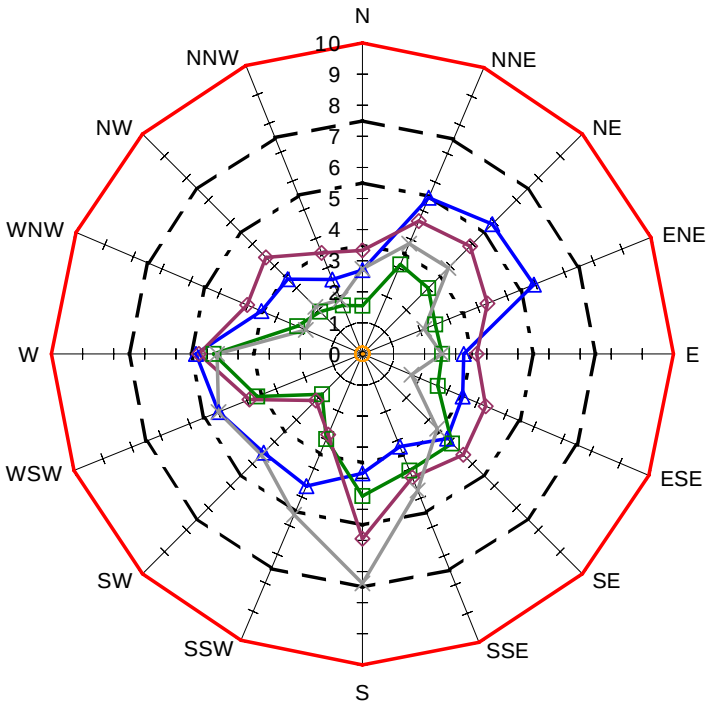


Annual Maximum Gust Wind Speeds (m/s)



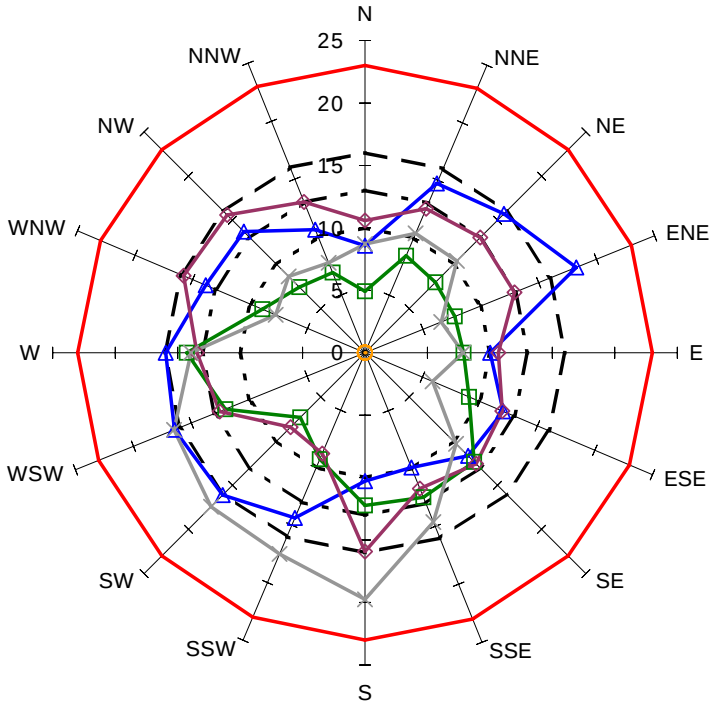
Measured Wind Speeds at Point 07

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)



- Long Exposure Criterion (3.5m/s)
- Short Exposure Criterion (5.5m/s)
- Comfortable Walking Criterion (7.5m/s)
- Fast Walking Criterion (10m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- Final Treatment Scheme as illustrated in Figure 7a
- With Existing 88 Walker and 100 Mount As Proposed

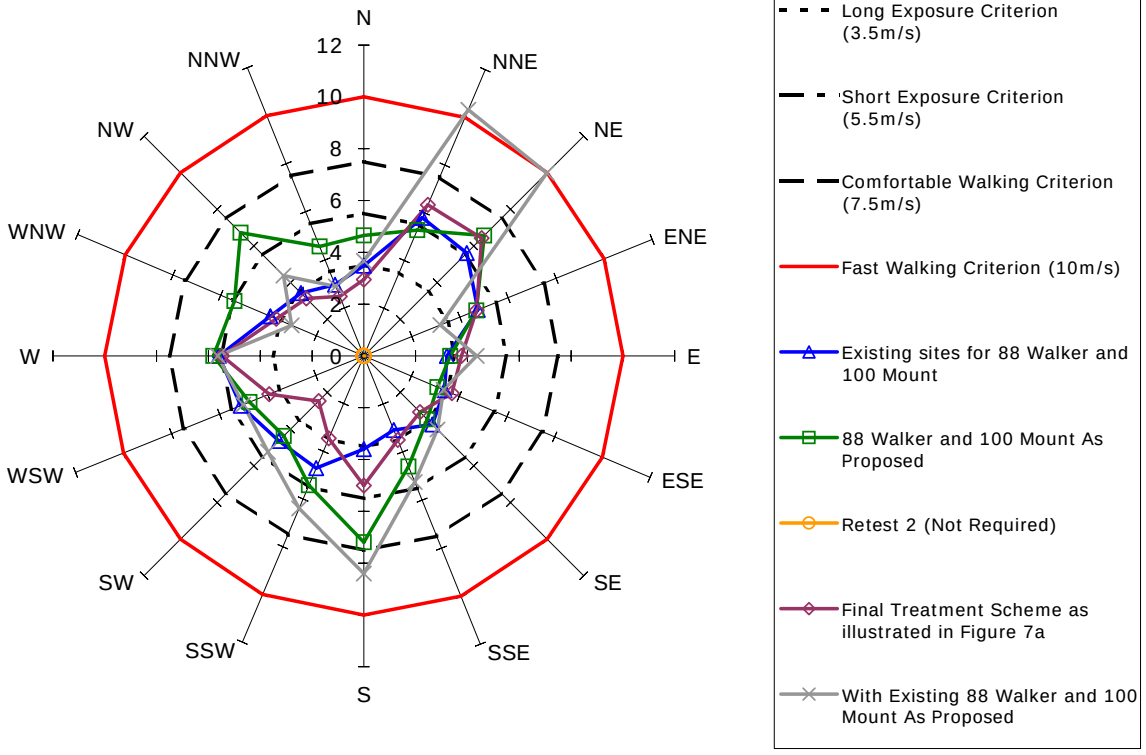
Annual Maximum Gust Wind Speeds (m/s)



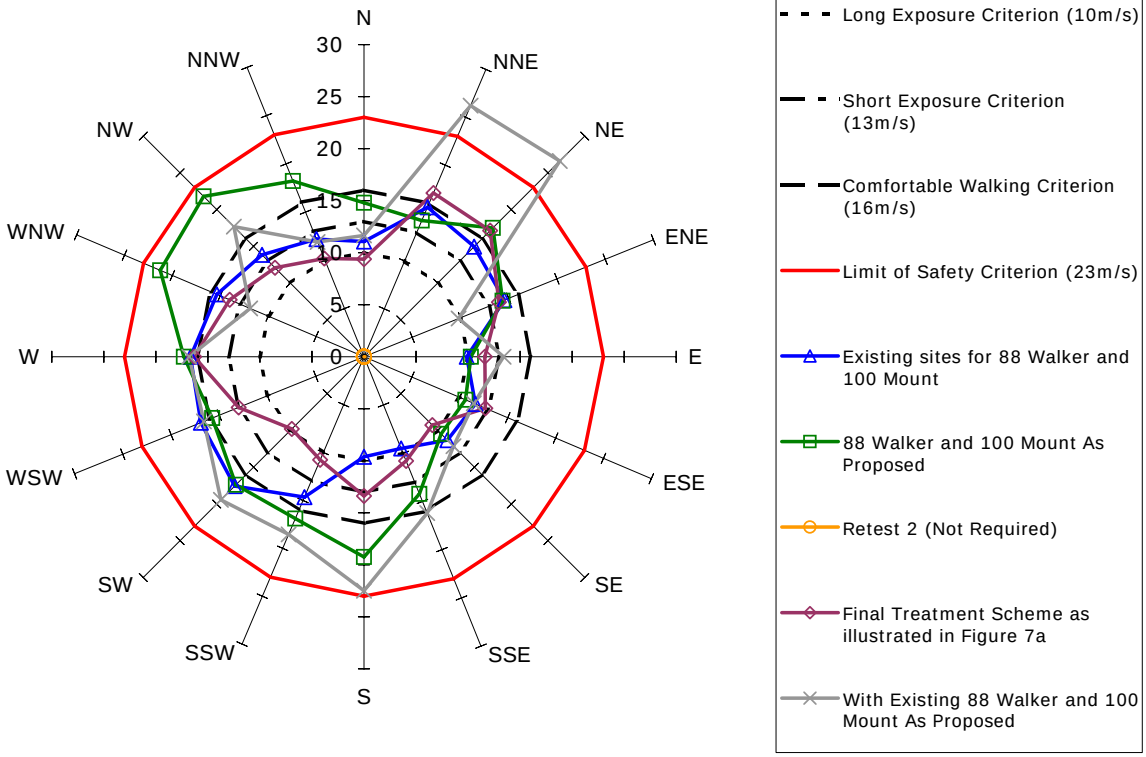
- Long Exposure Criterion (10m/s)
- Short Exposure Criterion (13m/s)
- Comfortable Walking Criterion (16m/s)
- Limit of Safety Criterion (23m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- Final Treatment Scheme as illustrated in Figure 7a
- With Existing 88 Walker and 100 Mount As Proposed

Measured Wind Speeds at Point 08

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

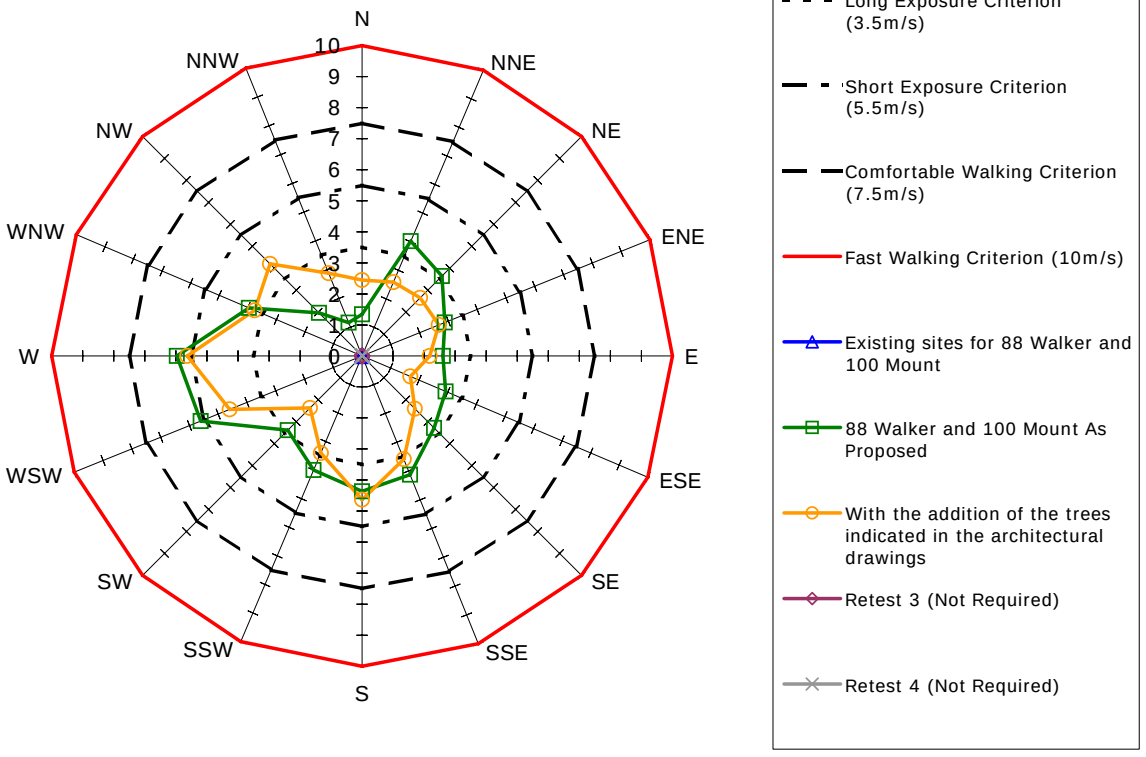


Annual Maximum Gust Wind Speeds (m/s)

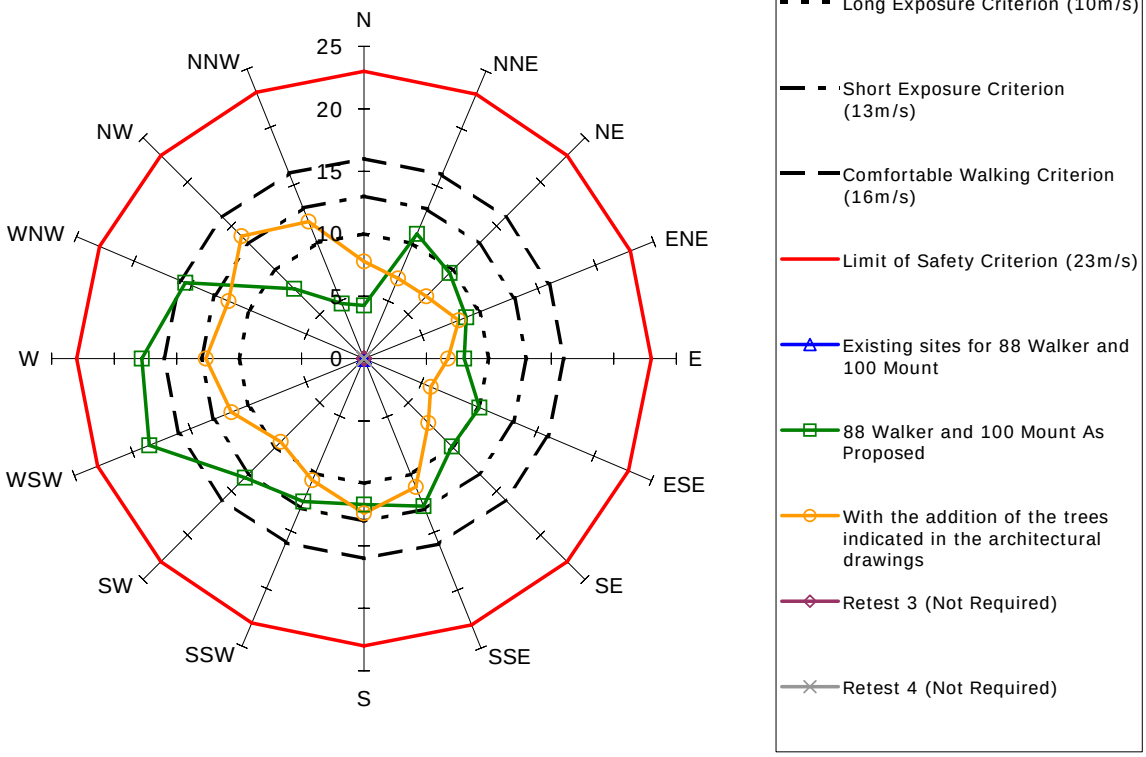


Measured Wind Speeds at Point 09

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

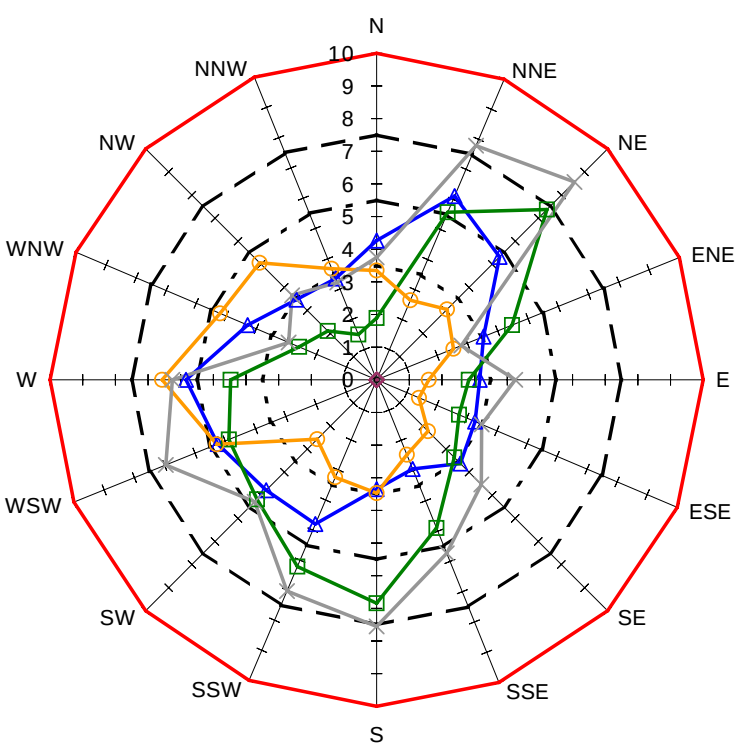


Annual Maximum Gust Wind Speeds (m/s)



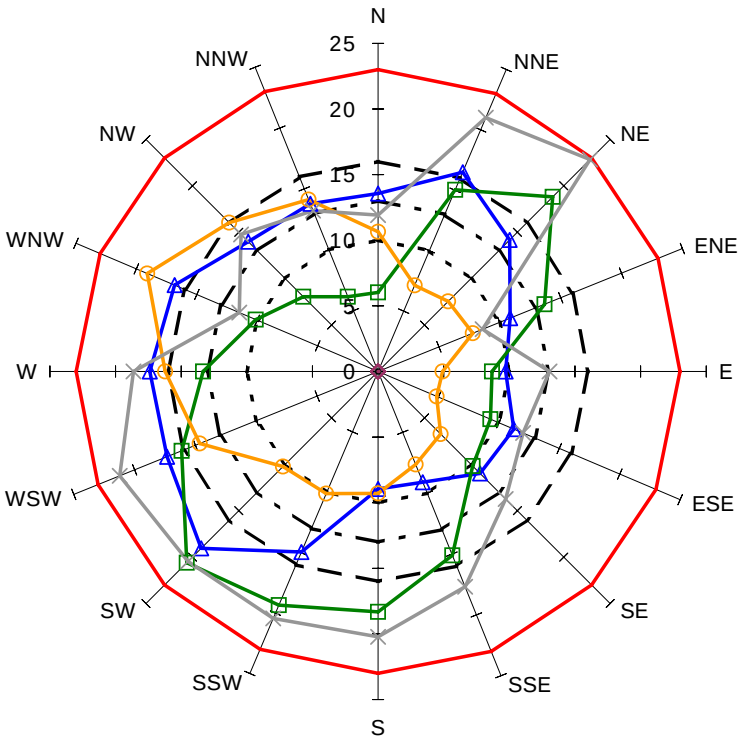
Measured Wind Speeds at Point 10

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)



- Long Exposure Criterion (3.5m/s)
- Short Exposure Criterion (5.5m/s)
- Comfortable Walking Criterion (7.5m/s)
- Fast Walking Criterion (10m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- With the addition of the trees indicated in the architectural drawings
- Retest 3 (Not Required)
- With Existing 88 Walker and 100 Mount As Proposed

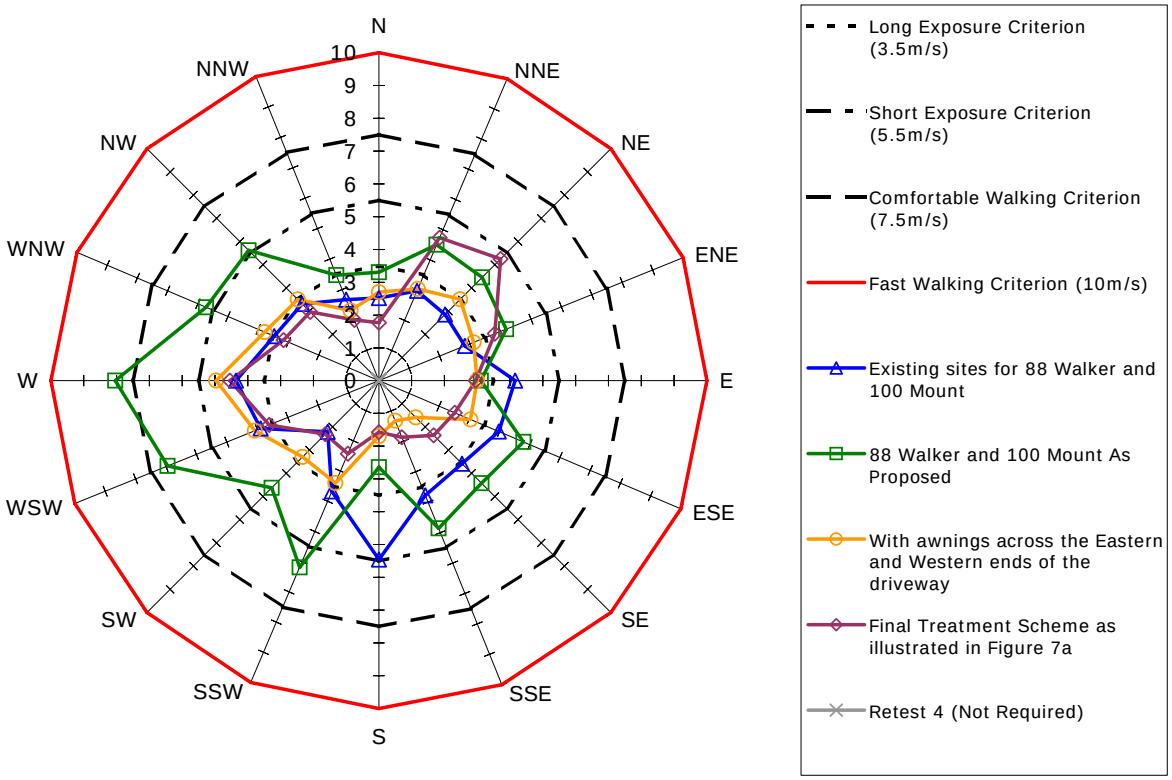
Annual Maximum Gust Wind Speeds (m/s)



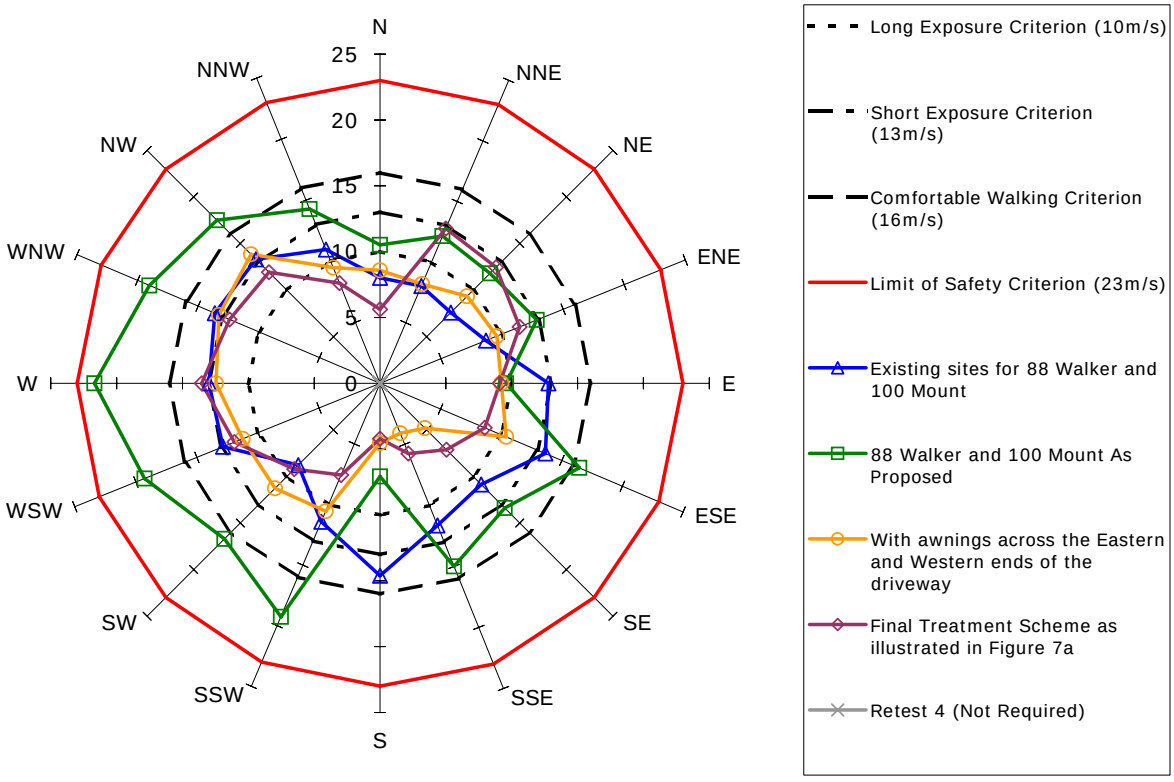
- Long Exposure Criterion (10m/s)
- Short Exposure Criterion (13m/s)
- Comfortable Walking Criterion (16m/s)
- Limit of Safety Criterion (23m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- With the addition of the trees indicated in the architectural drawings
- Retest 3 (Not Required)
- With Existing 88 Walker and 100 Mount As Proposed

Measured Wind Speeds at Point 11

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

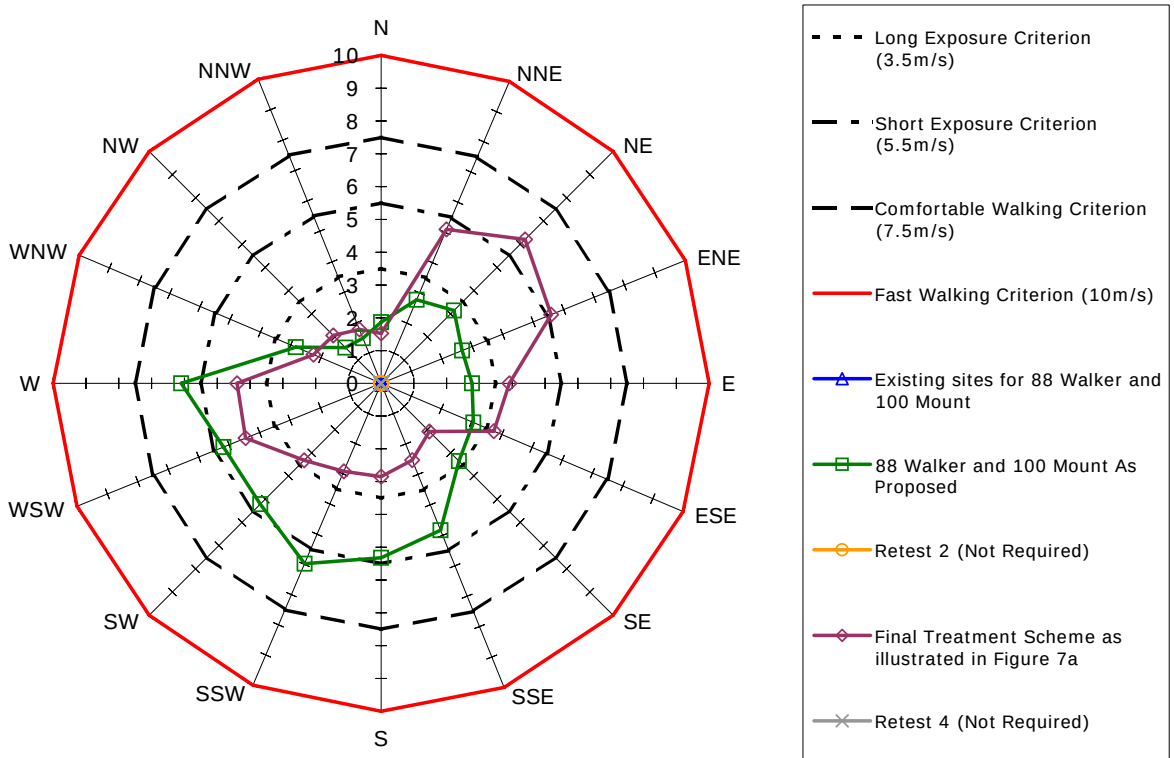


Annual Maximum Gust Wind Speeds (m/s)

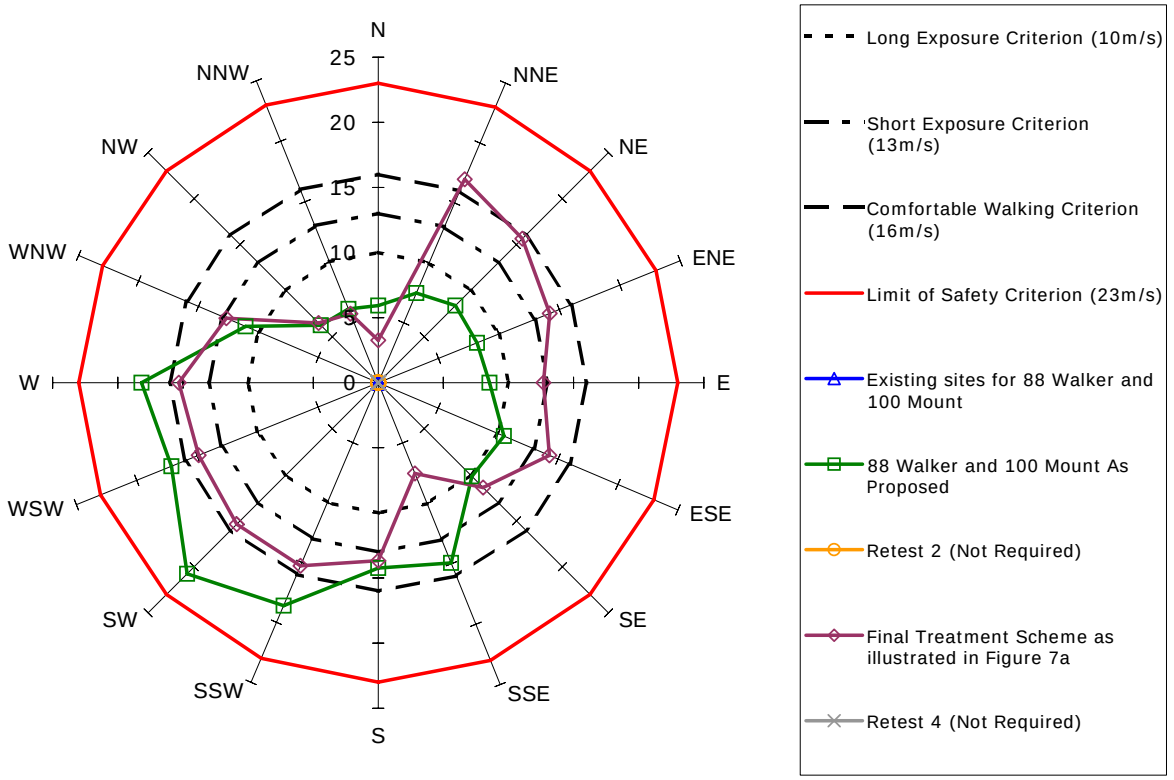


Measured Wind Speeds at Point 12

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

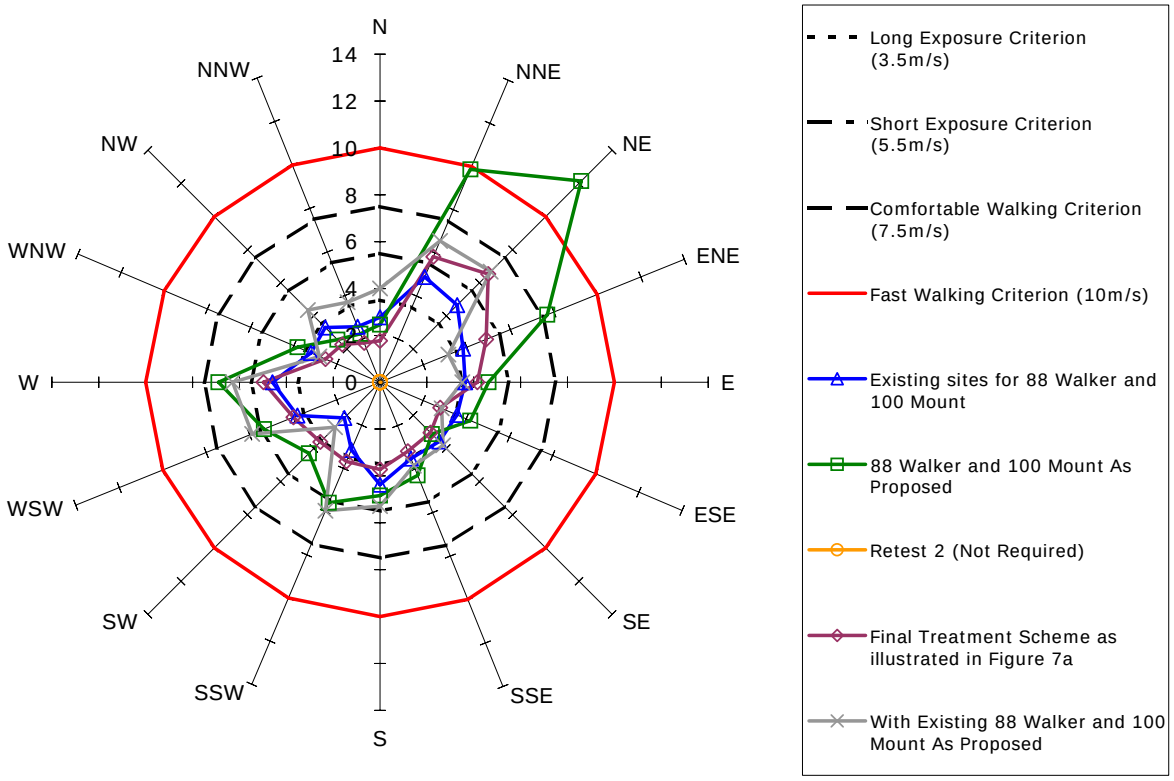


Annual Maximum Gust Wind Speeds (m/s)

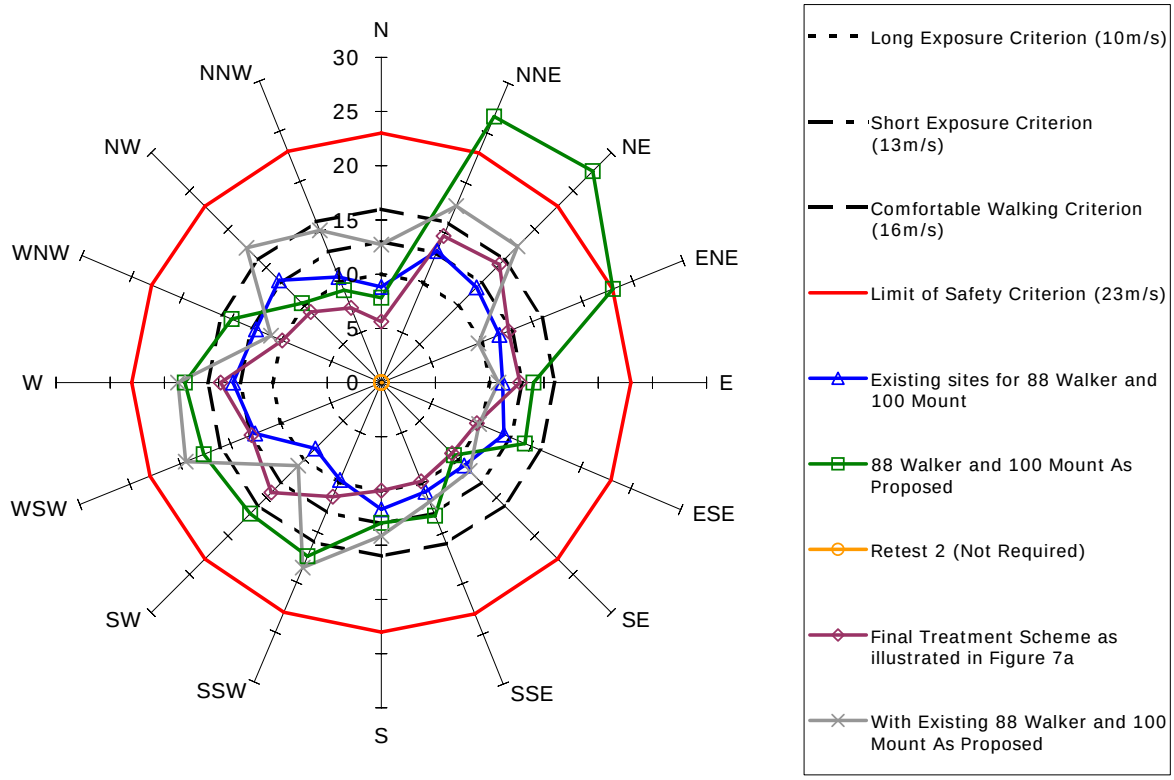


Measured Wind Speeds at Point 13

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

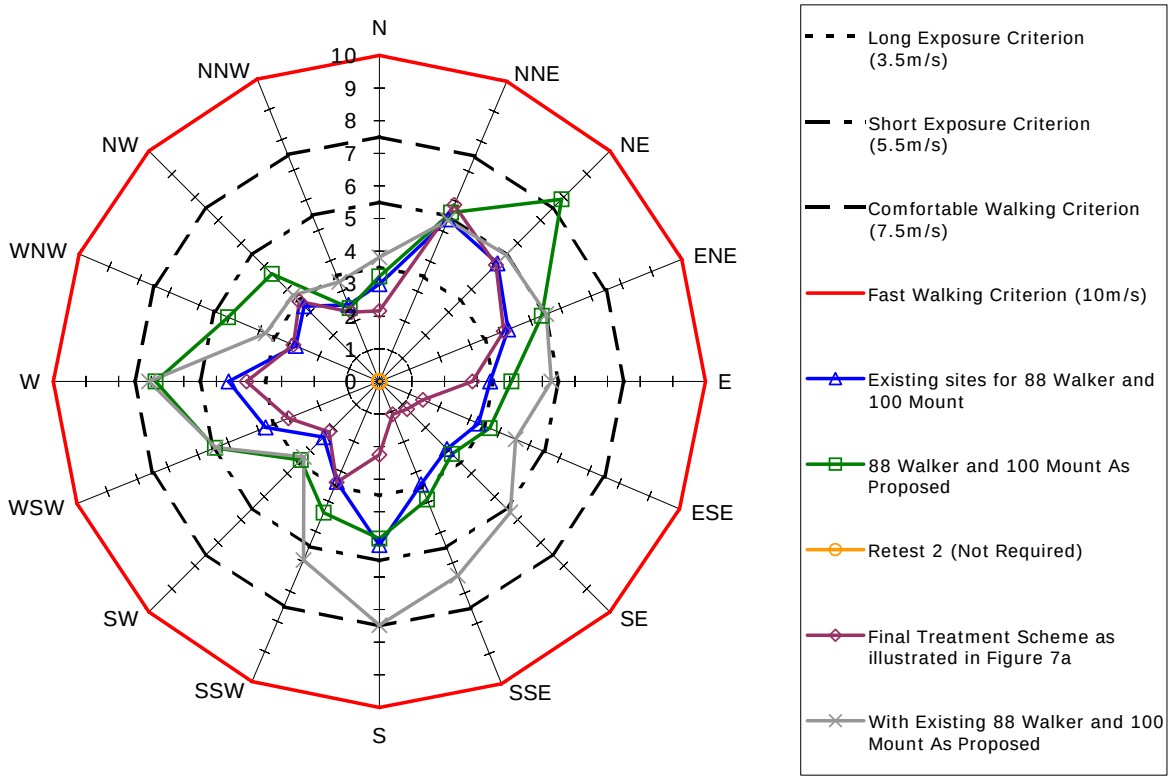


Annual Maximum Gust Wind Speeds (m/s)

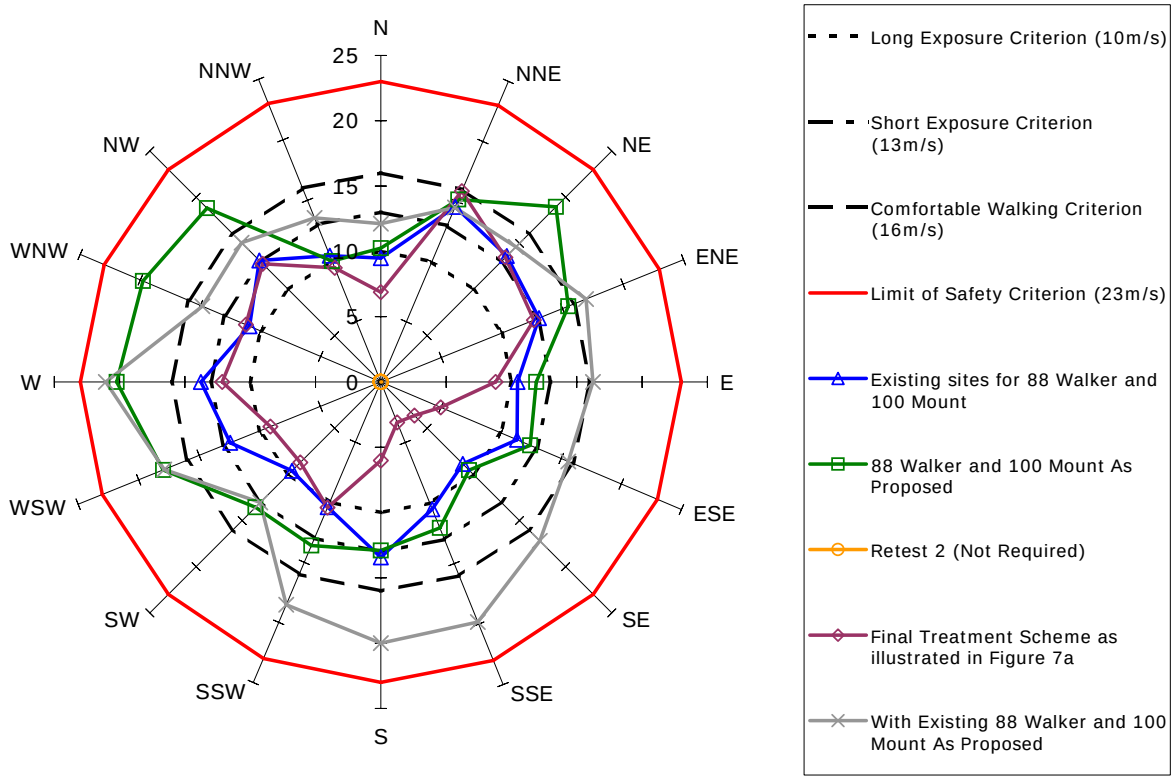


Measured Wind Speeds at Point 14

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

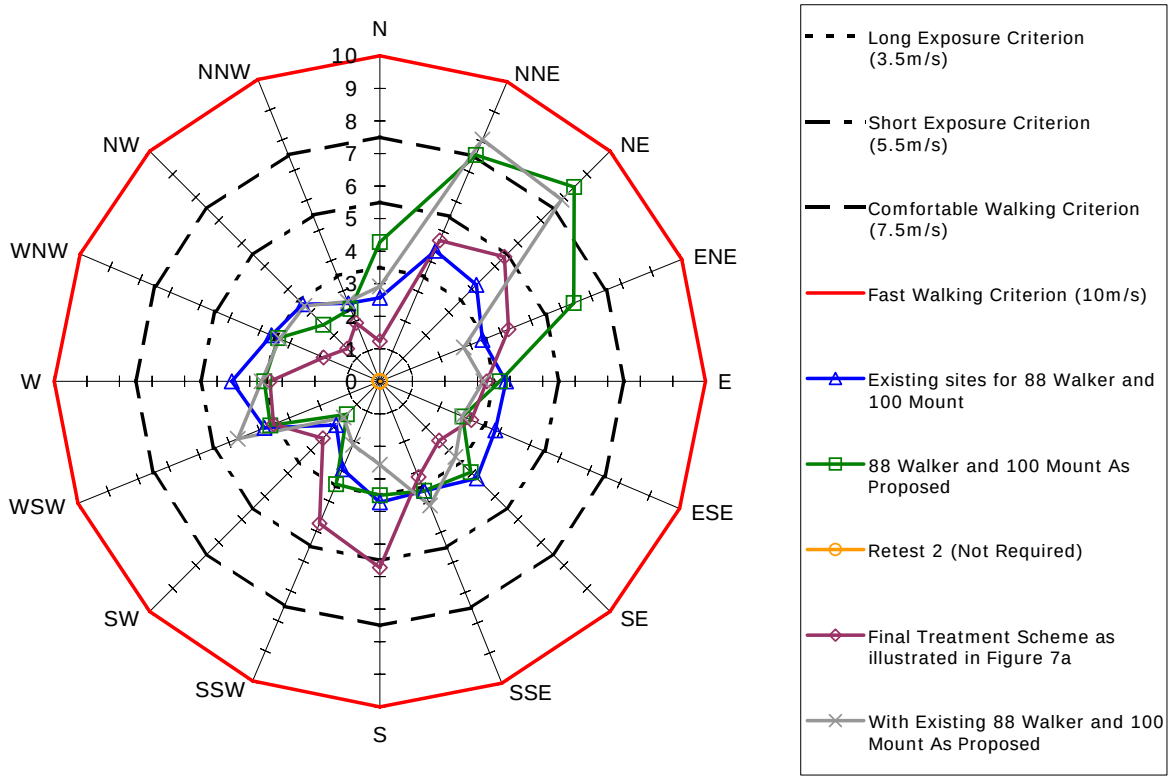


Annual Maximum Gust Wind Speeds (m/s)

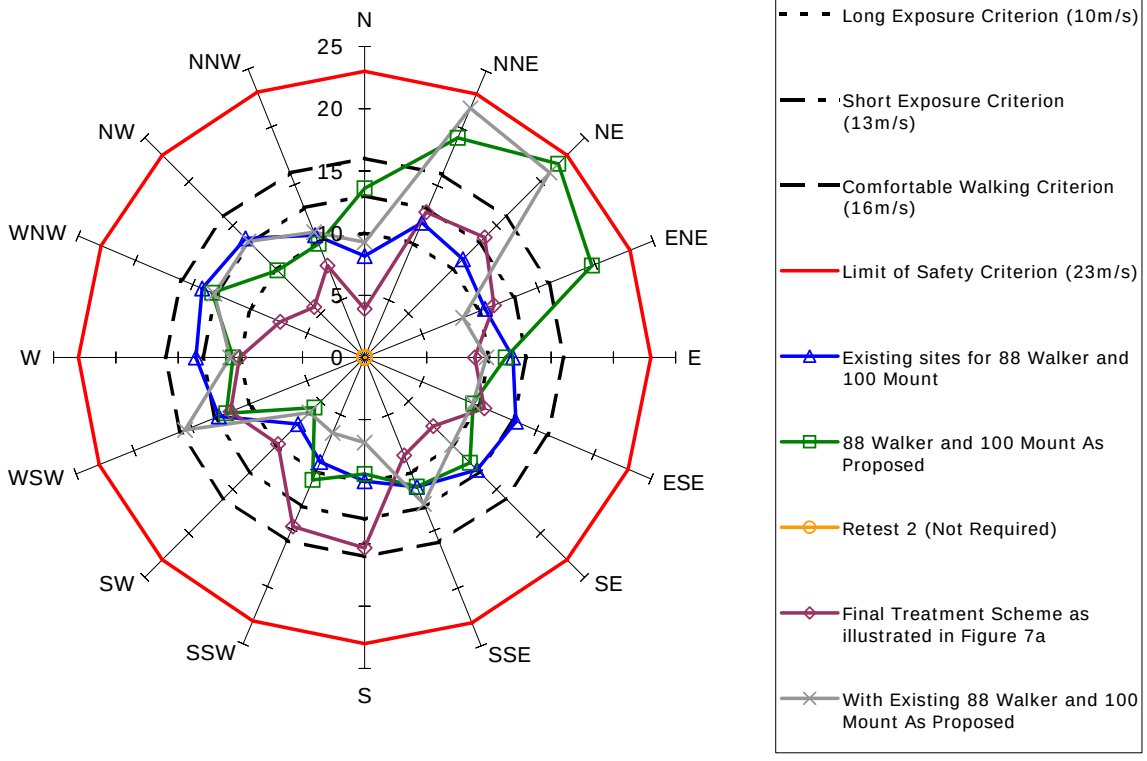


Measured Wind Speeds at Point 15

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

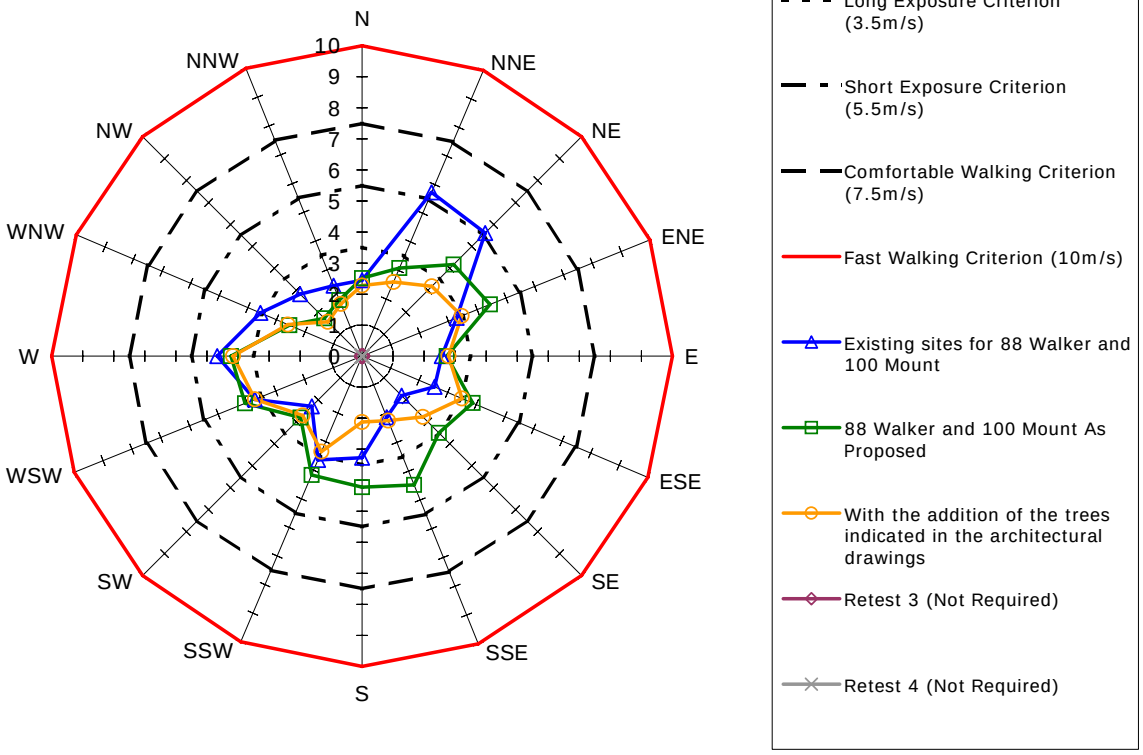


Annual Maximum Gust Wind Speeds (m/s)

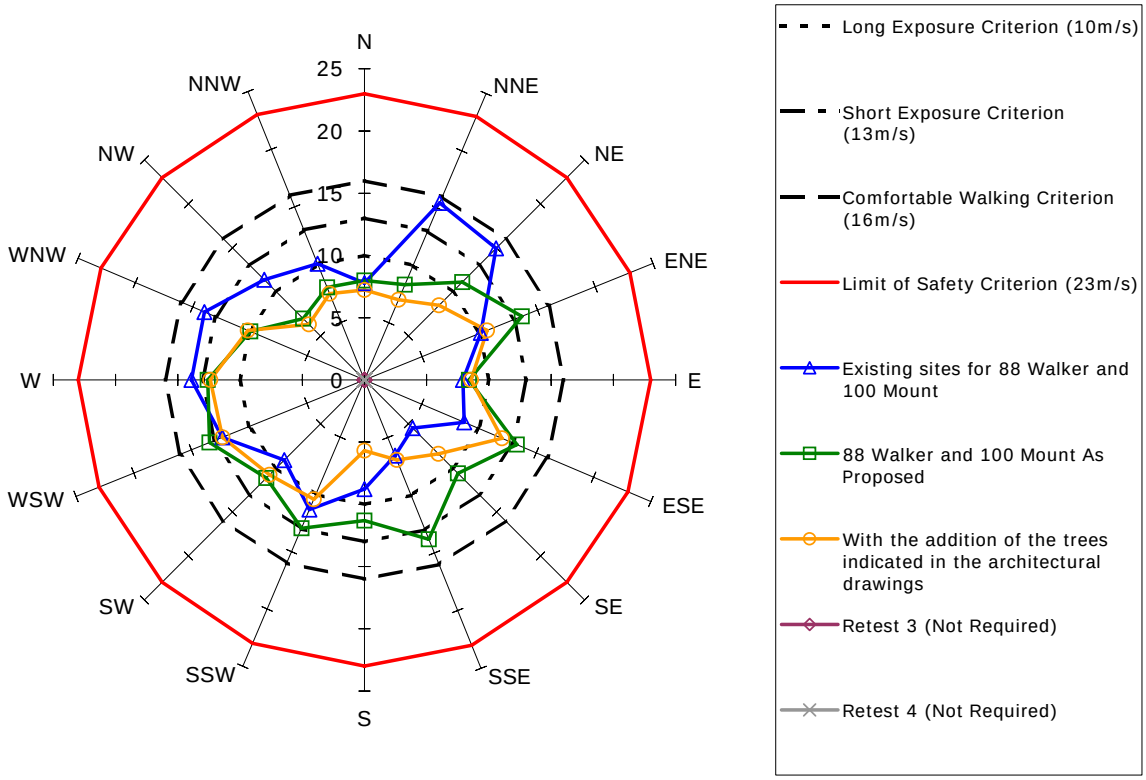


Measured Wind Speeds at Point 16

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

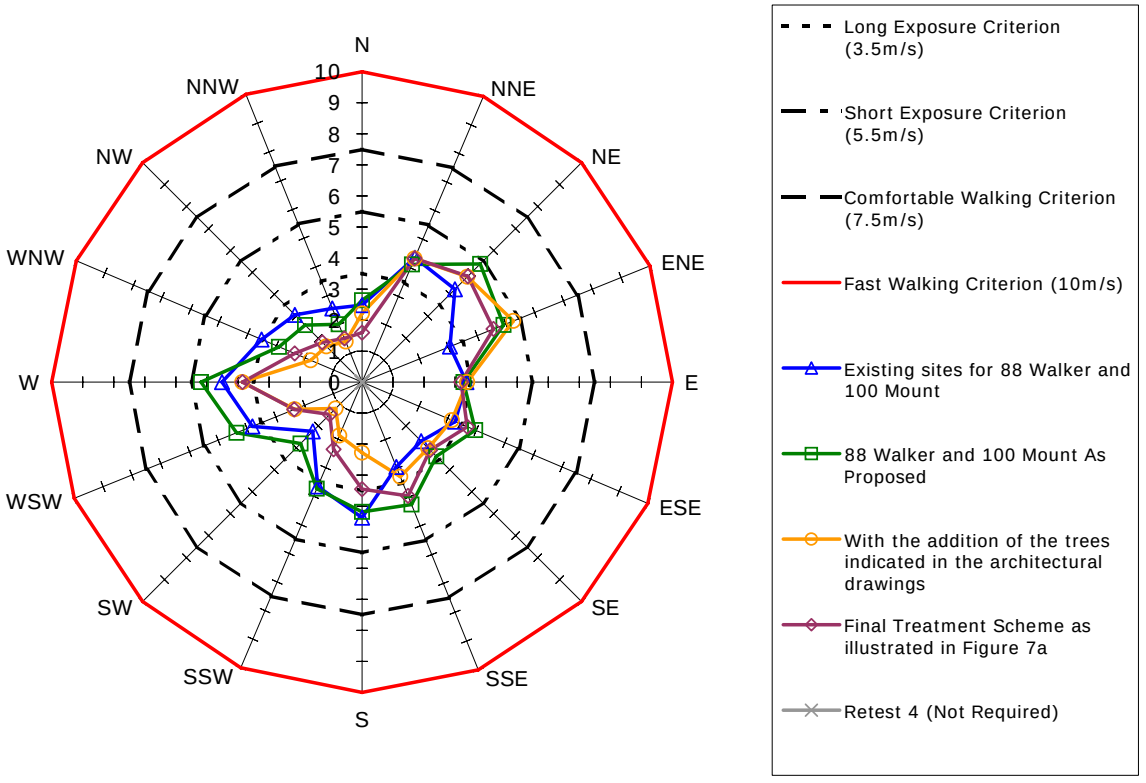


Annual Maximum Gust Wind Speeds (m/s)

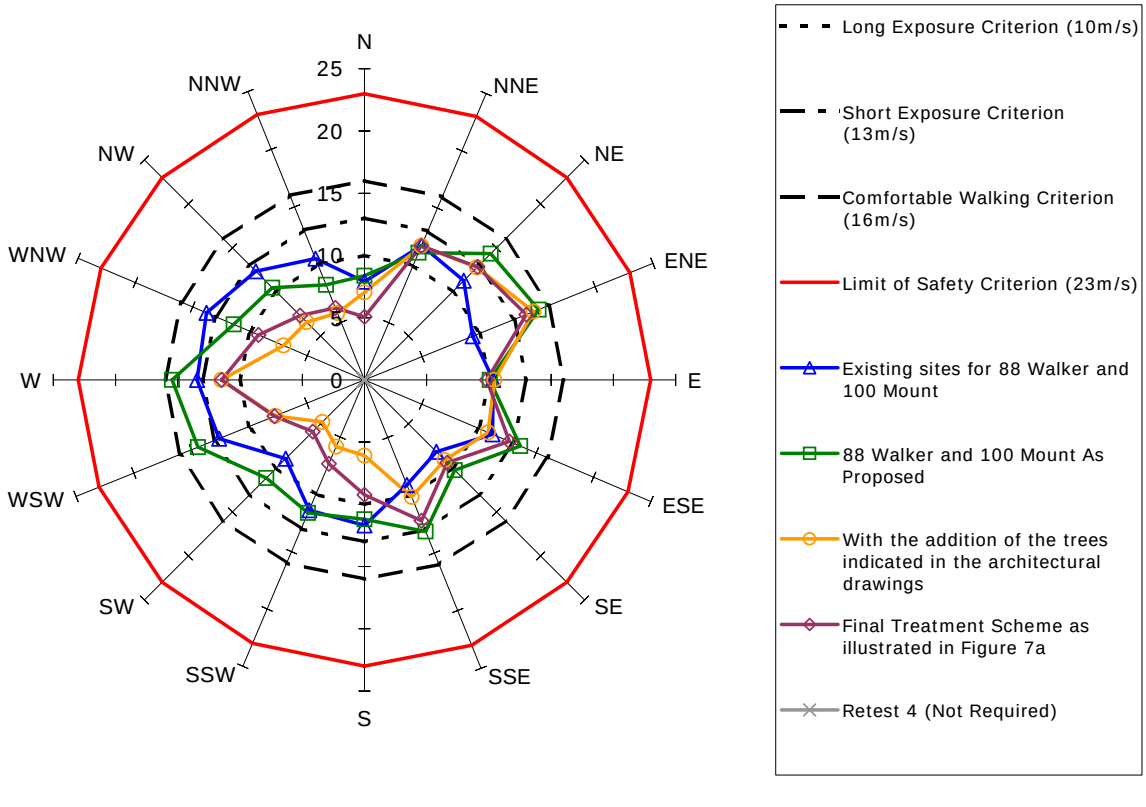


Measured Wind Speeds at Point 17

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

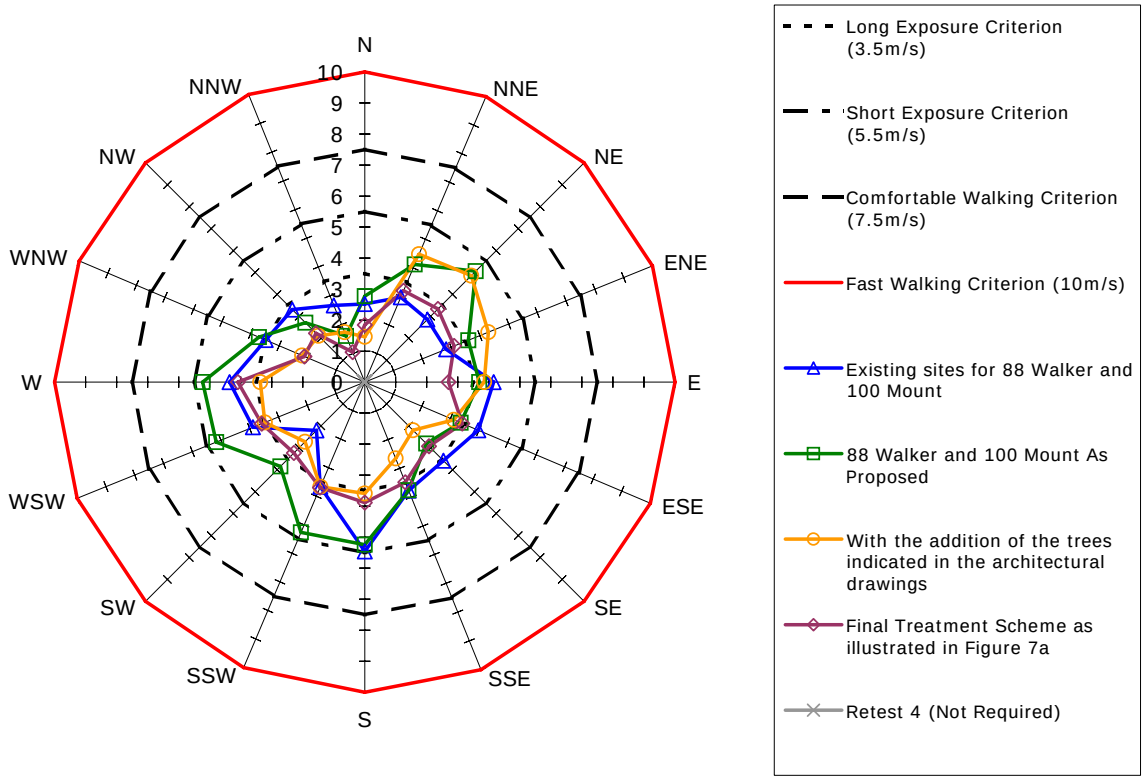


Annual Maximum Gust Wind Speeds (m/s)

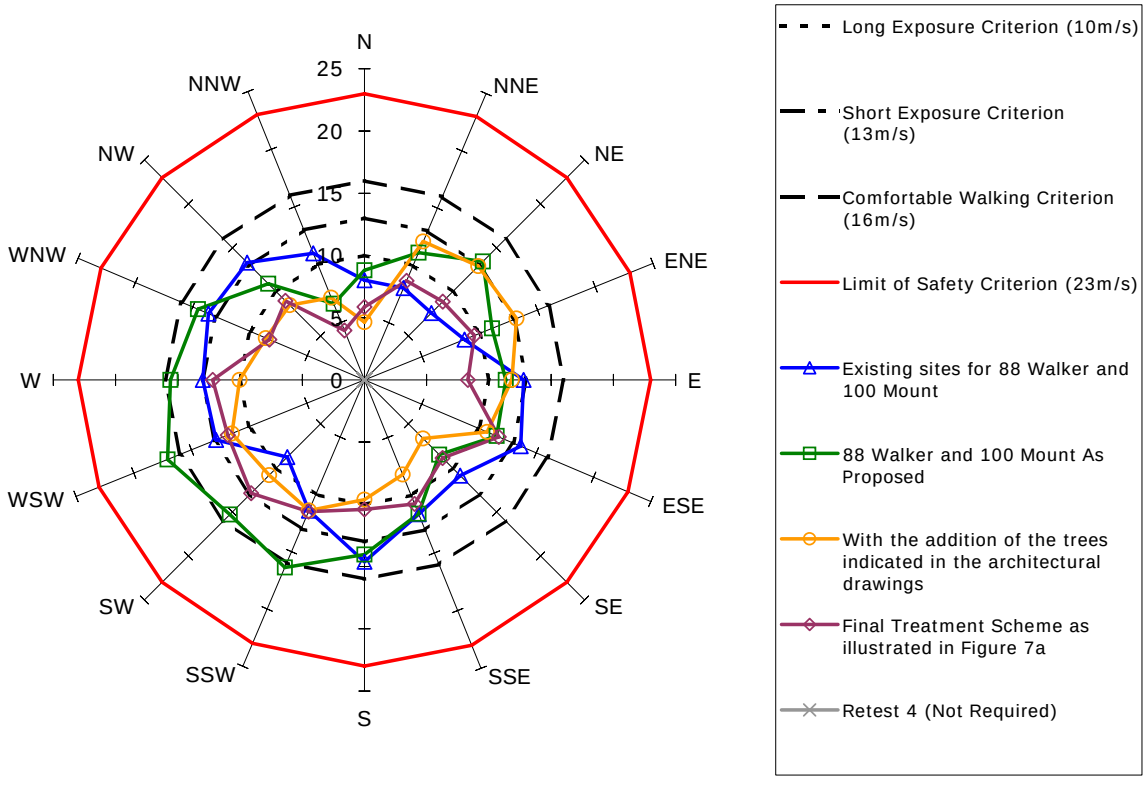


Measured Wind Speeds at Point 18

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

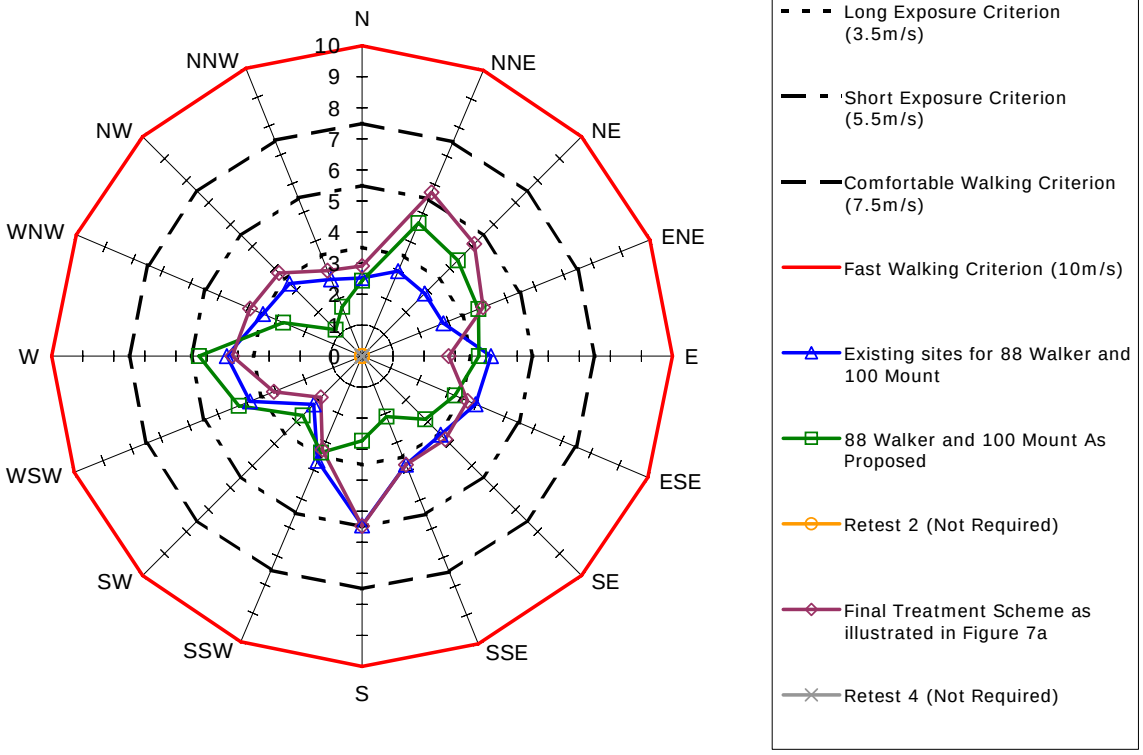


Annual Maximum Gust Wind Speeds (m/s)

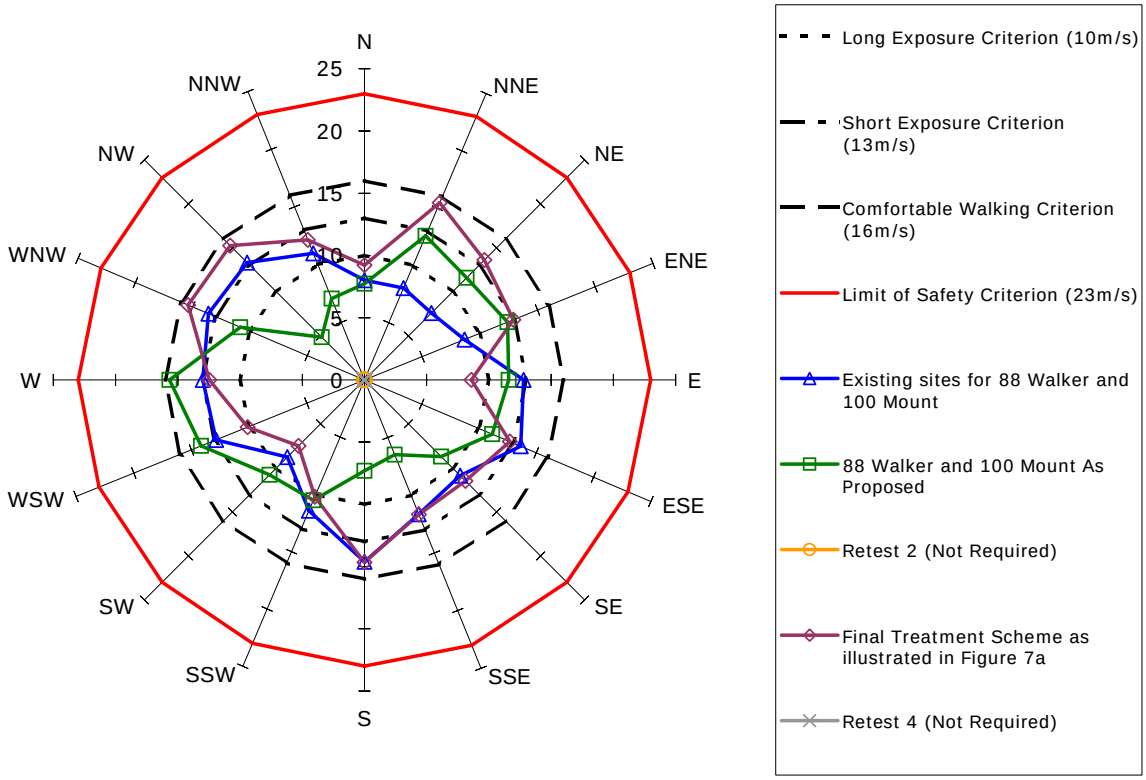


Measured Wind Speeds at Point 19

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

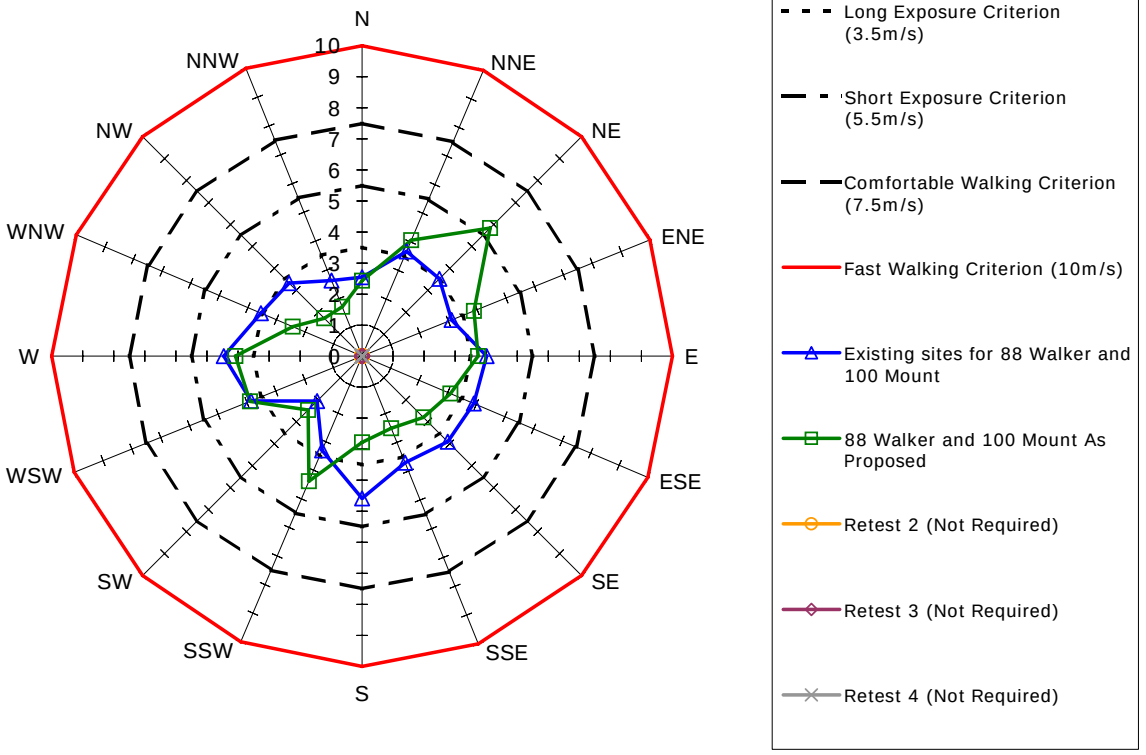


Annual Maximum Gust Wind Speeds (m/s)

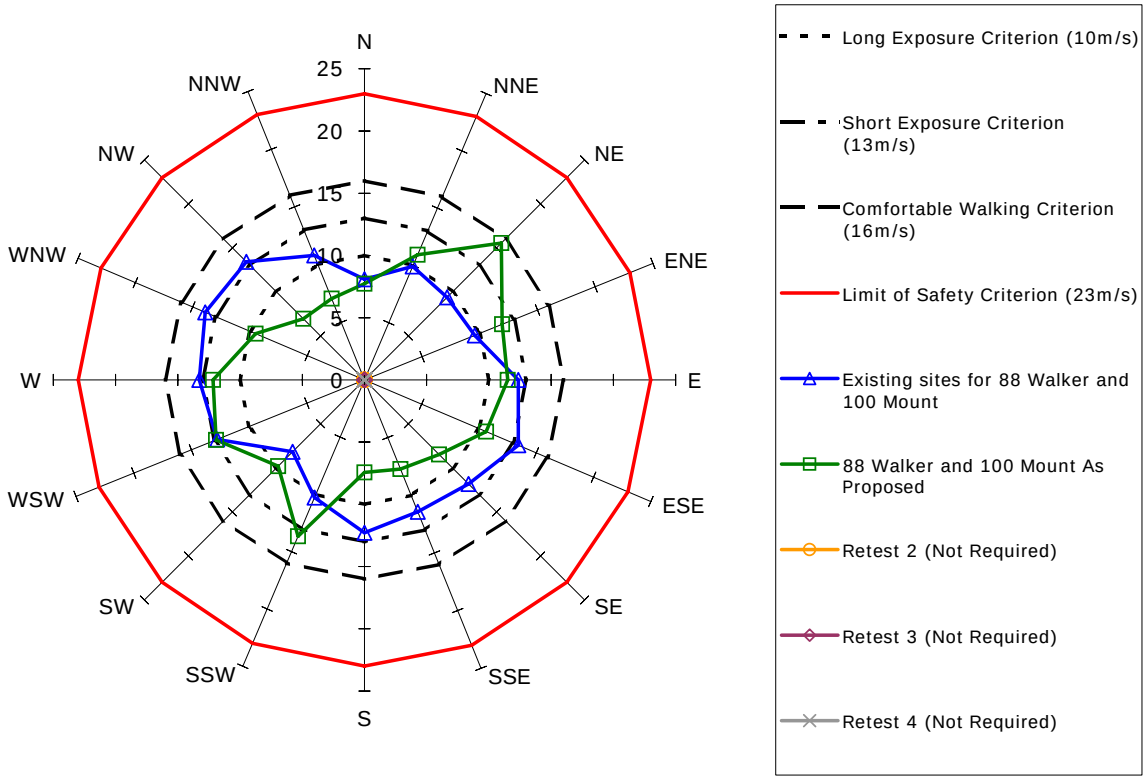


Measured Wind Speeds at Point 20

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

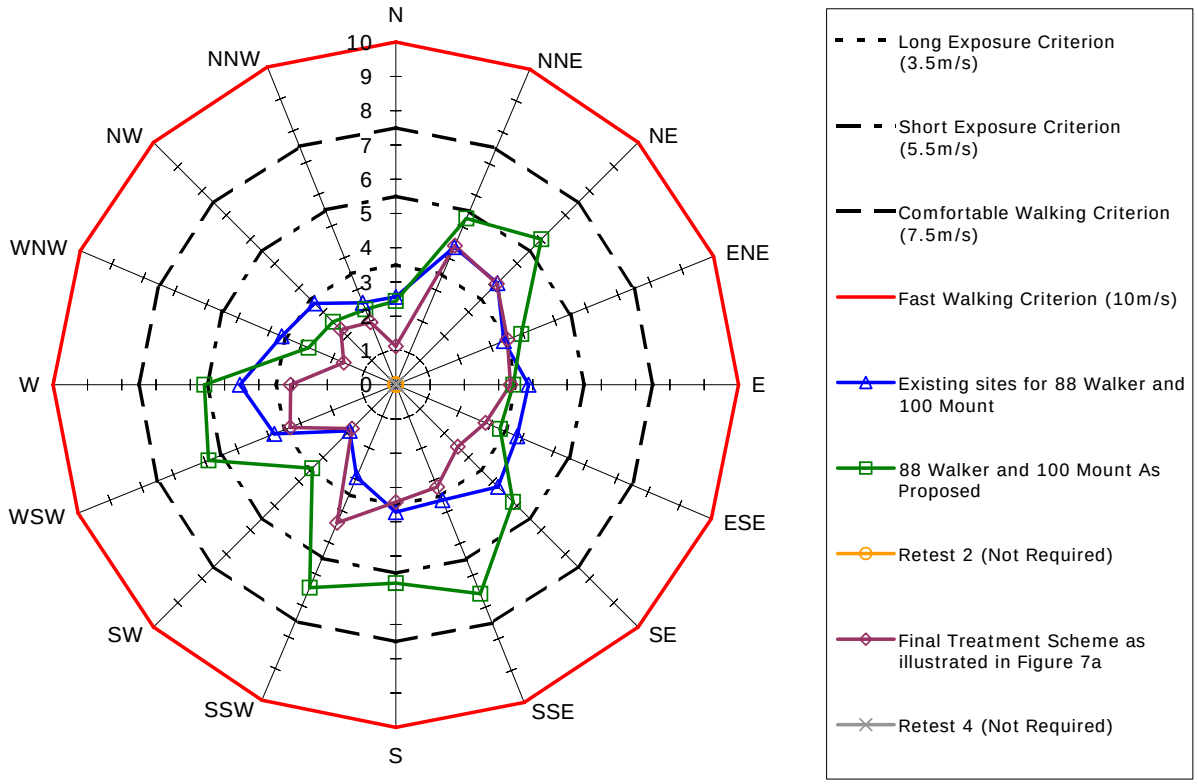


Annual Maximum Gust Wind Speeds (m/s)

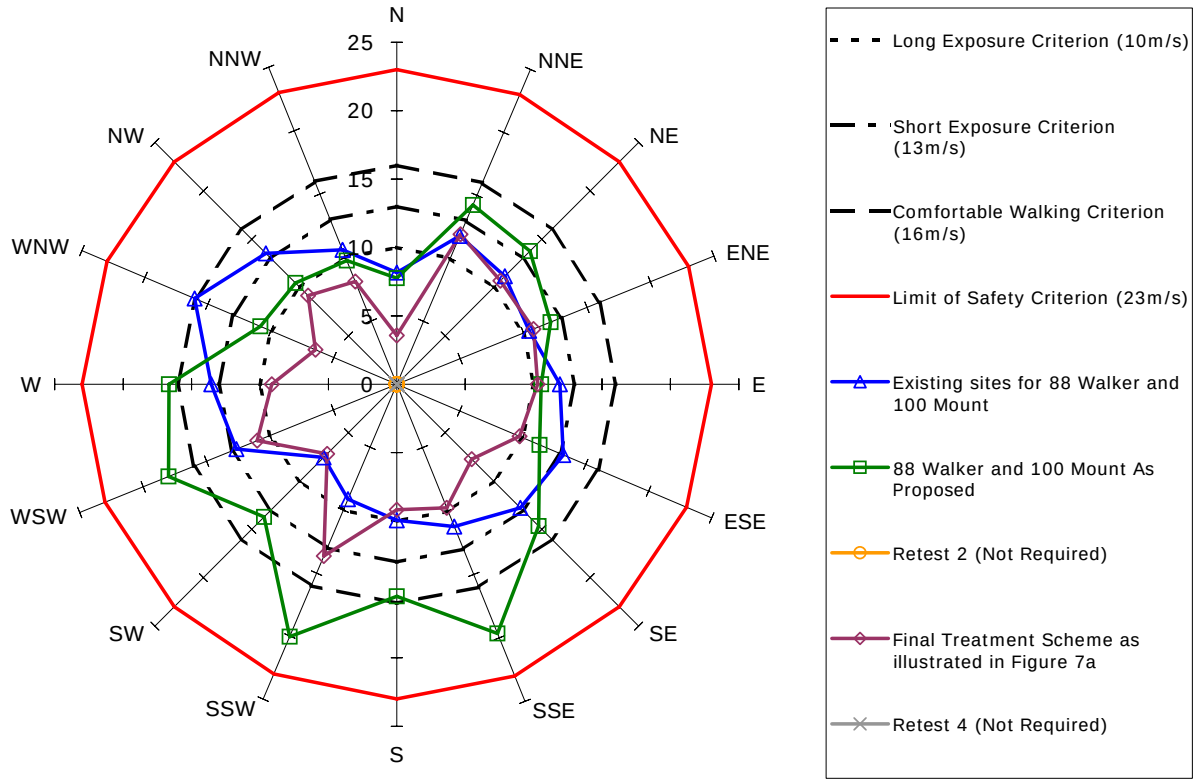


Measured Wind Speeds at Point 21

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

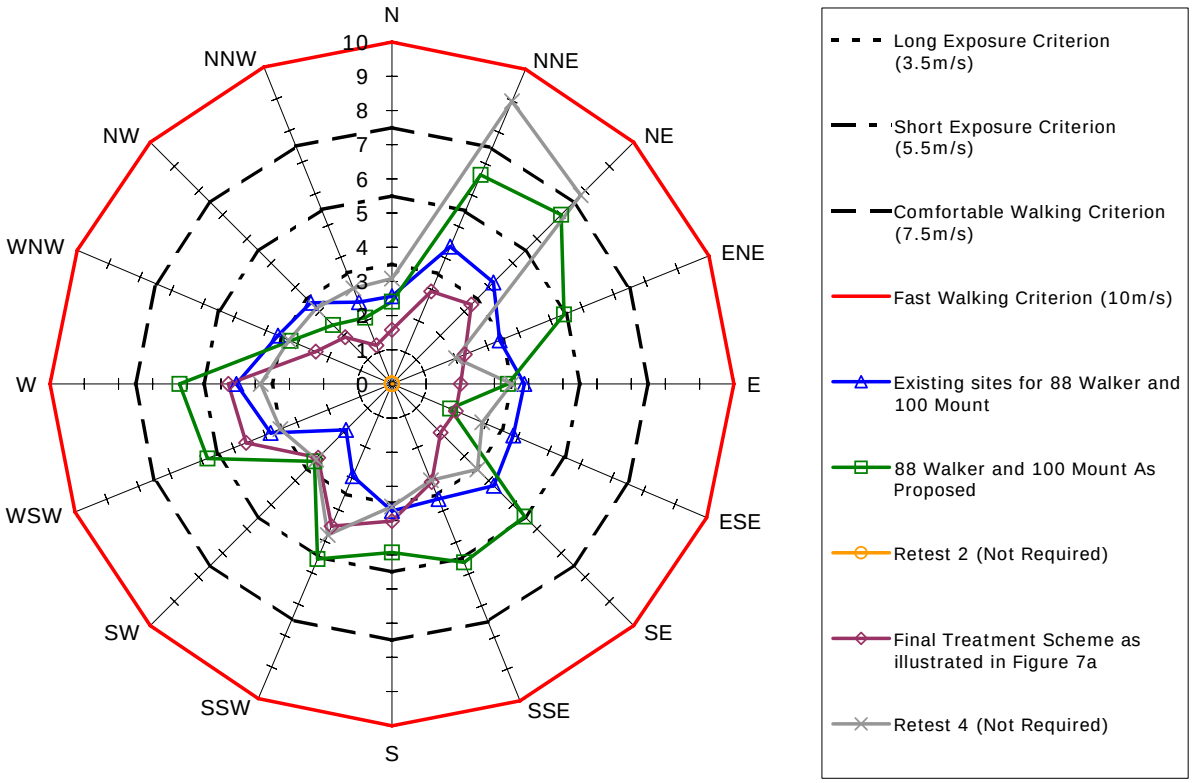


Annual Maximum Gust Wind Speeds (m/s)

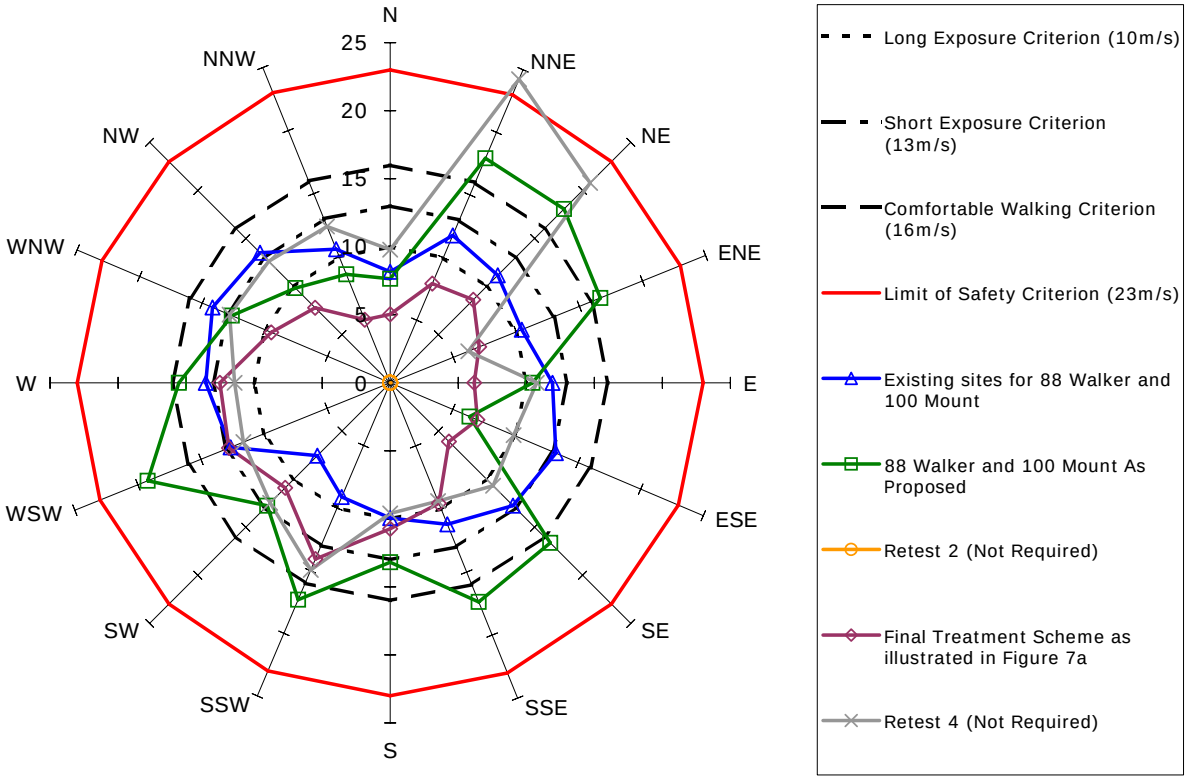


Measured Wind Speeds at Point 22

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

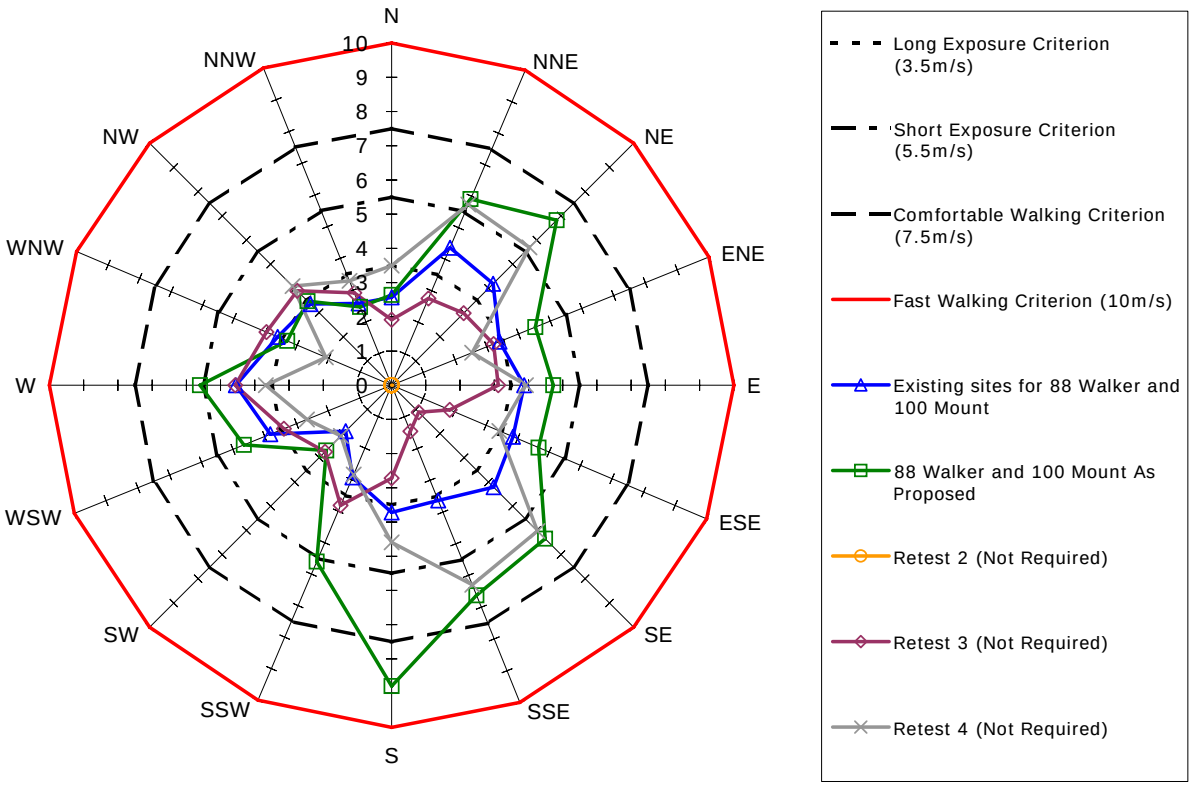


Annual Maximum Gust Wind Speeds (m/s)

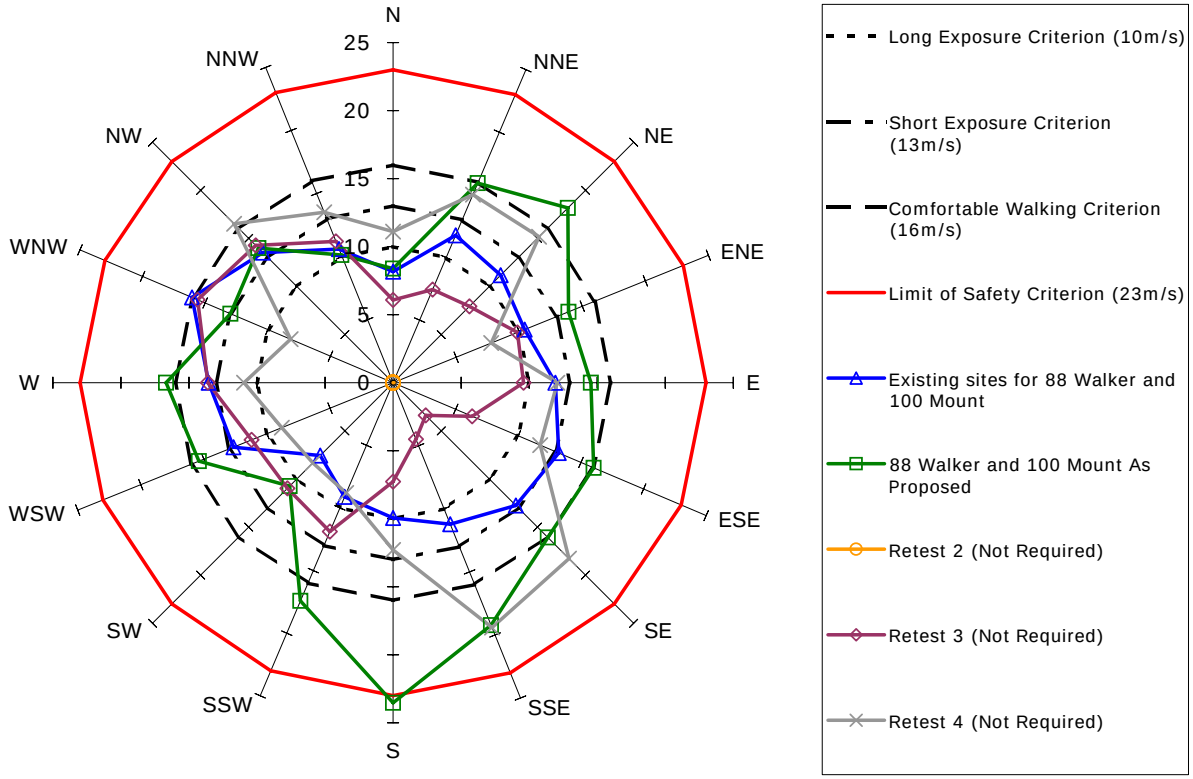


Measured Wind Speeds at Point 23

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

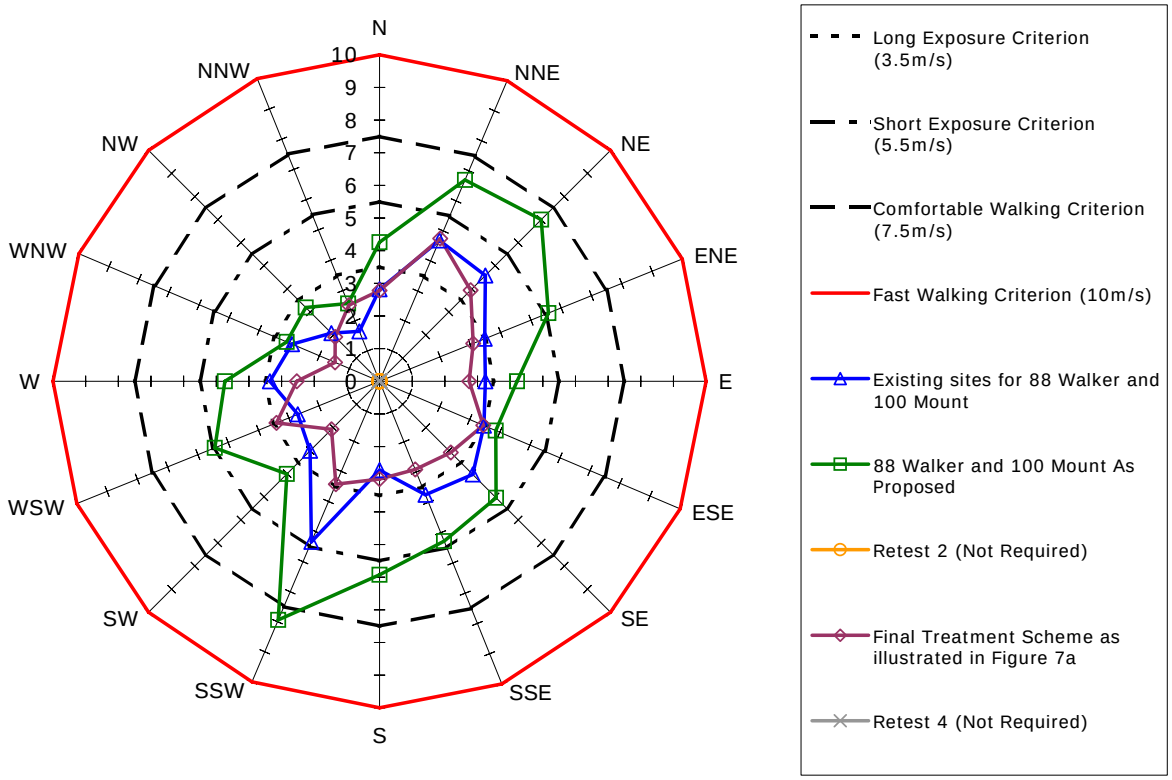


Annual Maximum Gust Wind Speeds (m/s)

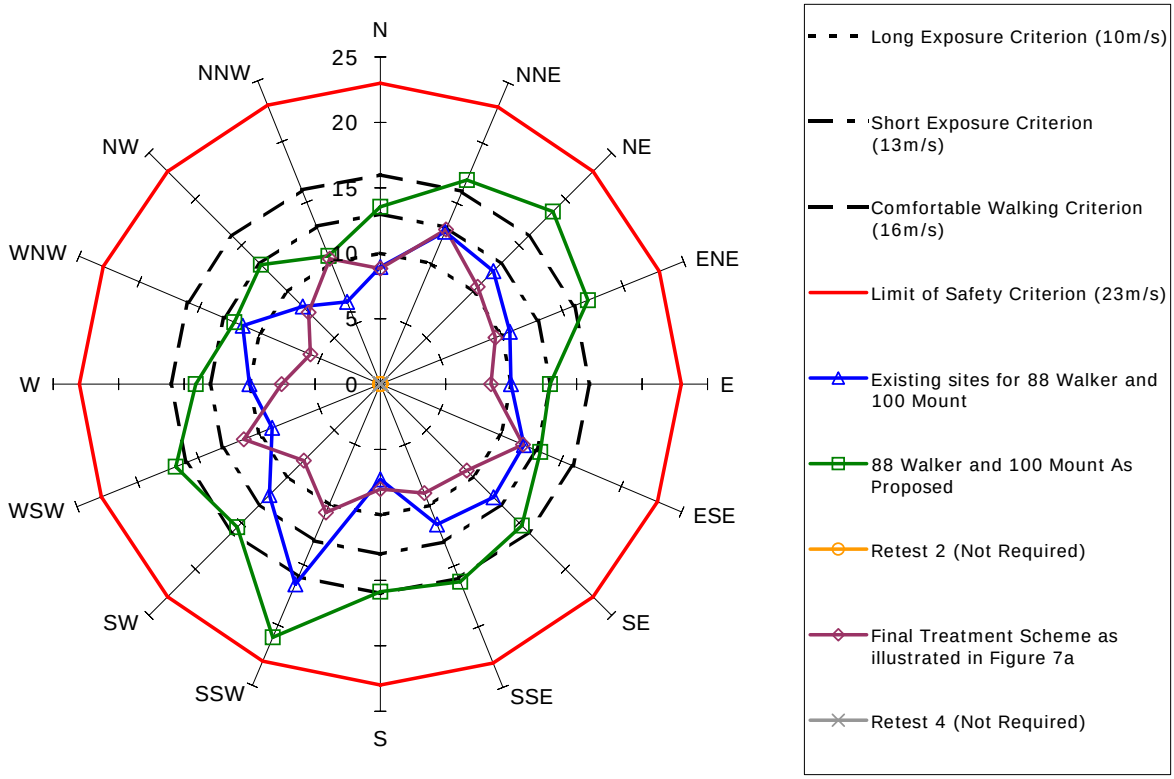


Measured Wind Speeds at Point 24

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

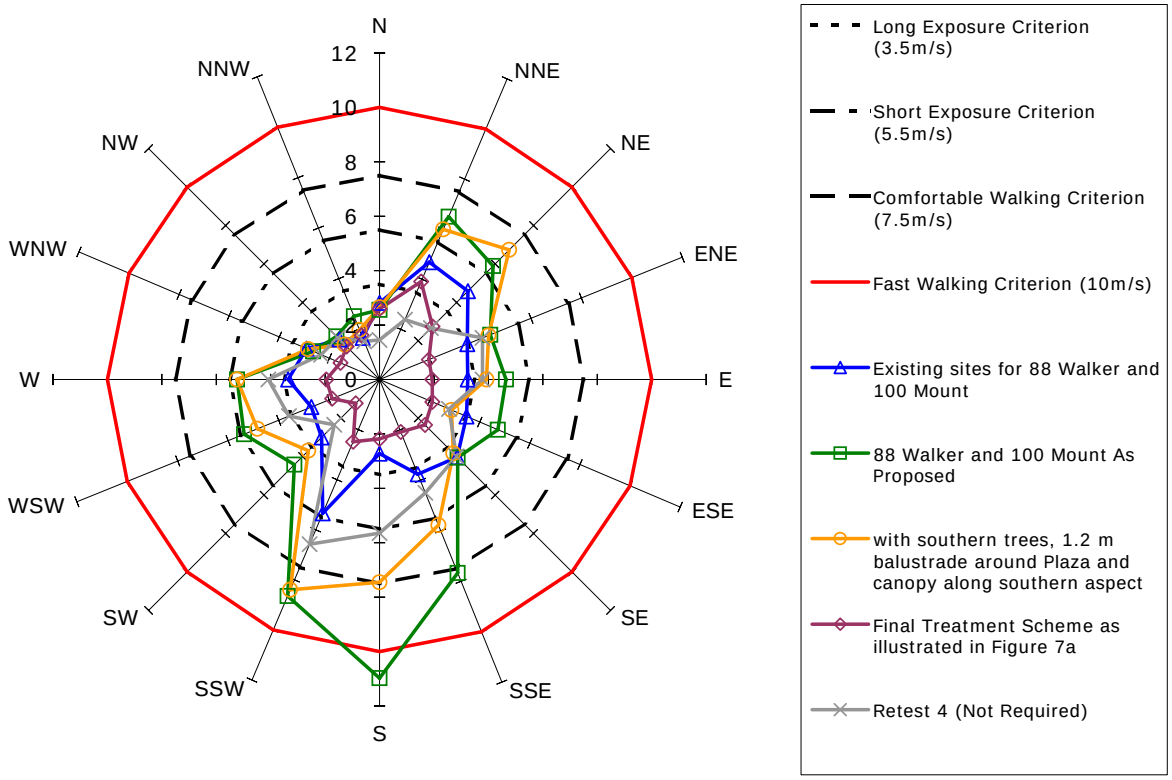


Annual Maximum Gust Wind Speeds (m/s)

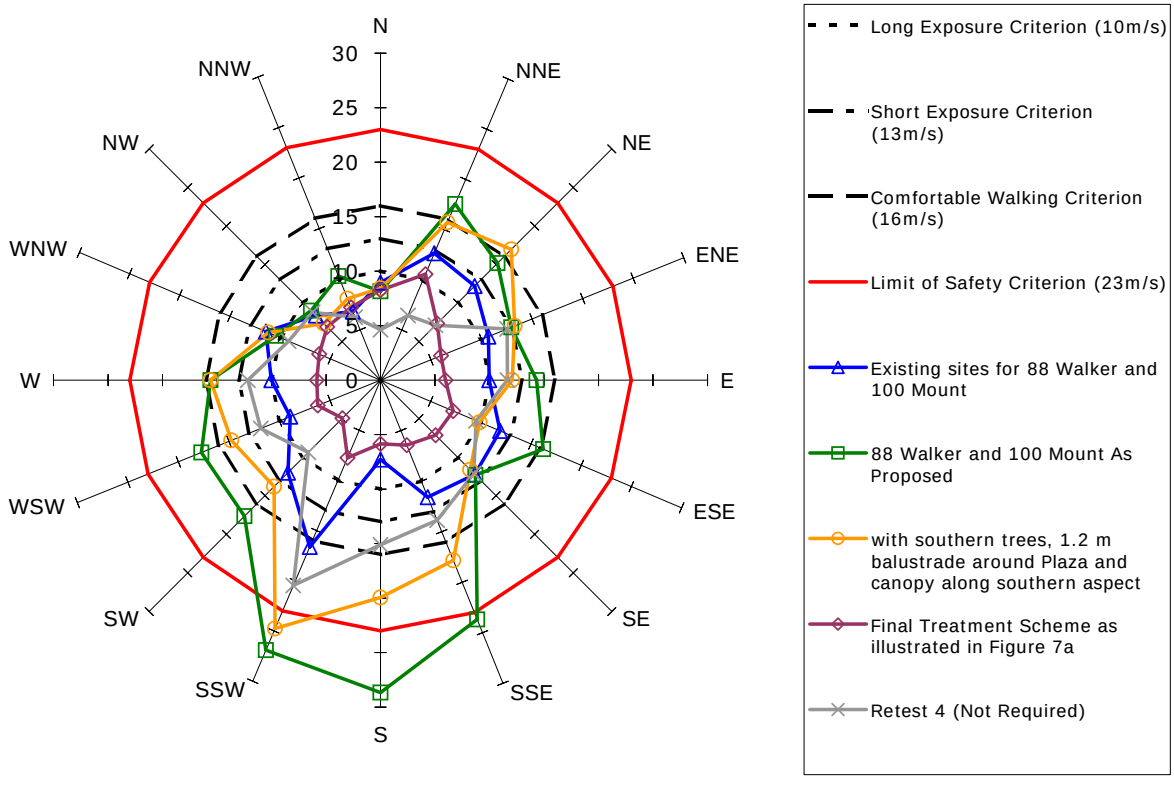


Measured Wind Speeds at Point 25

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

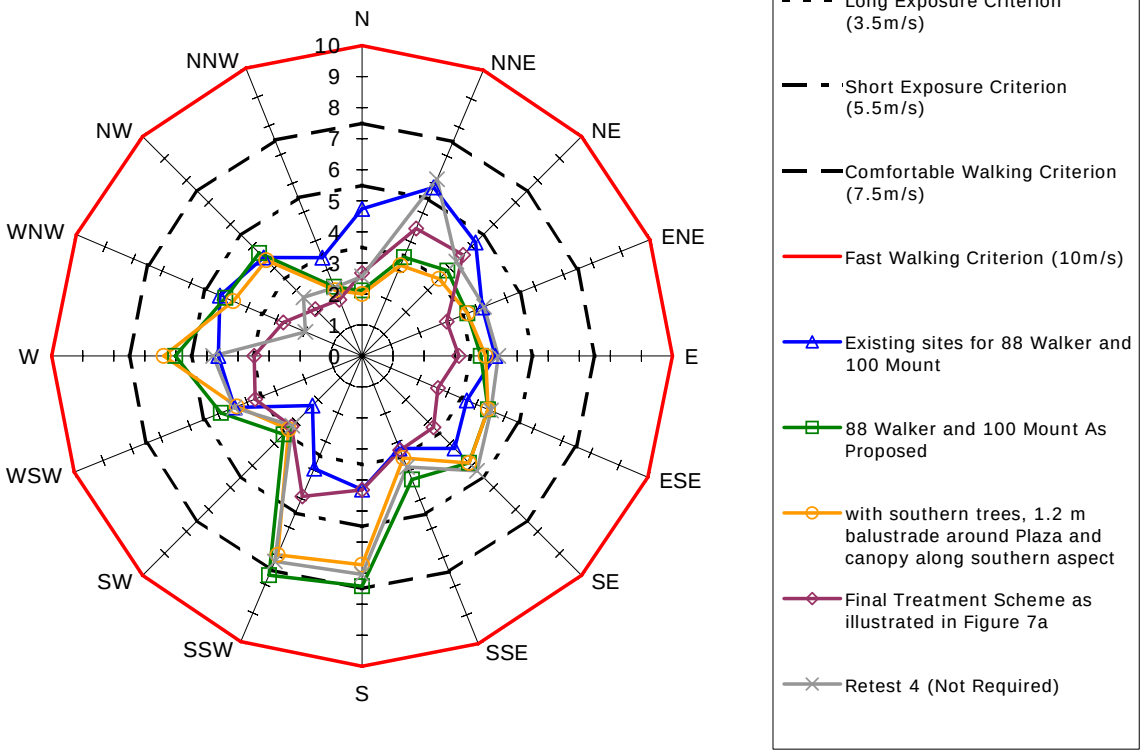


Annual Maximum Gust Wind Speeds (m/s)

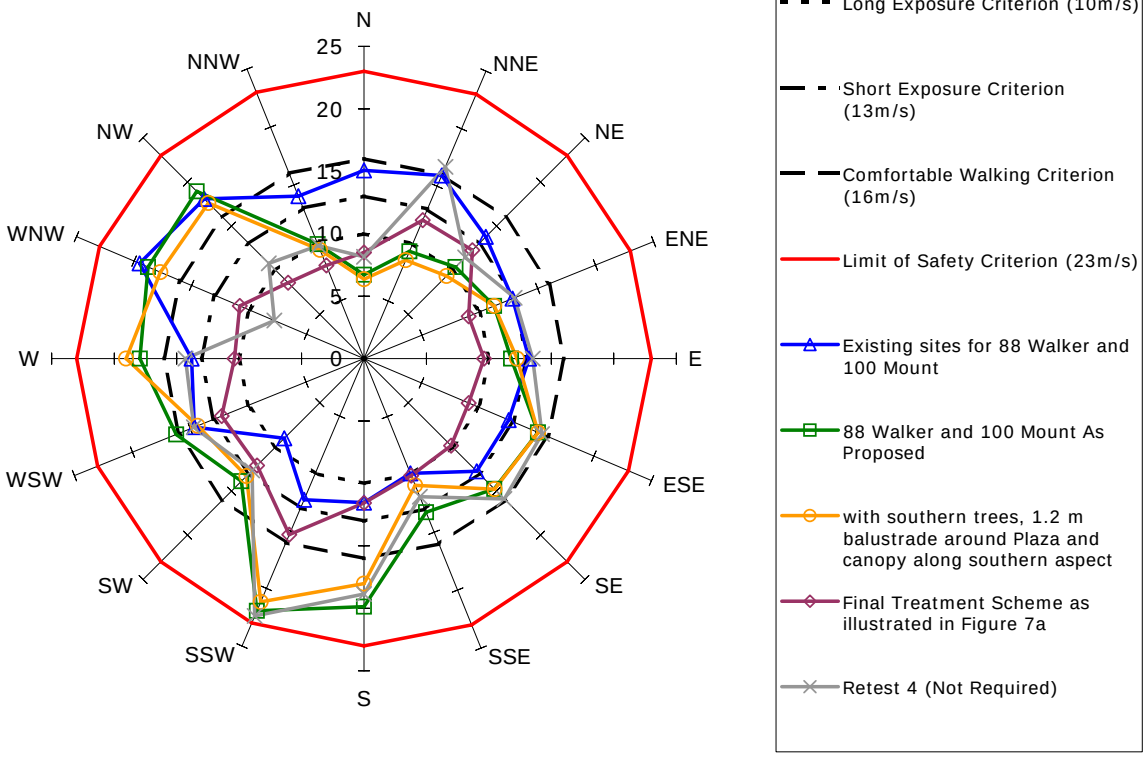


Measured Wind Speeds at Point 26

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

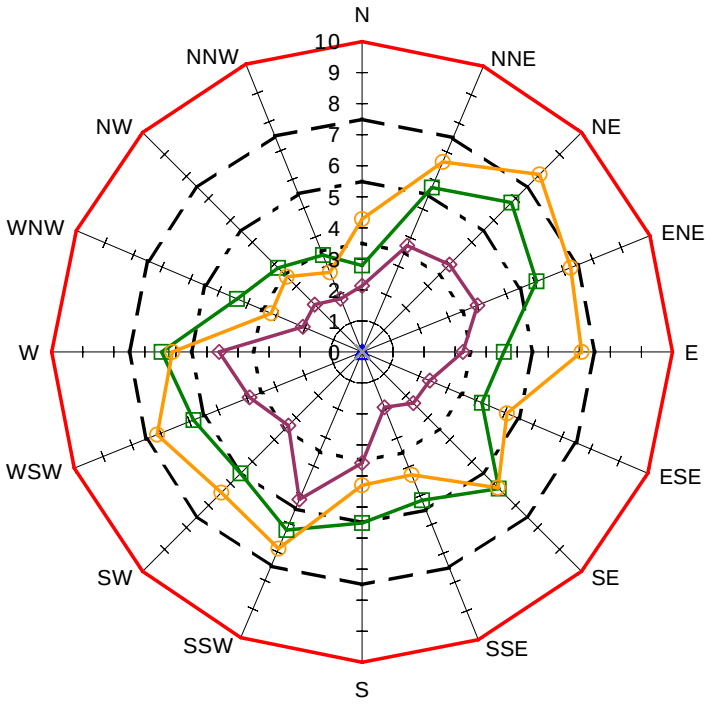


Annual Maximum Gust Wind Speeds (m/s)



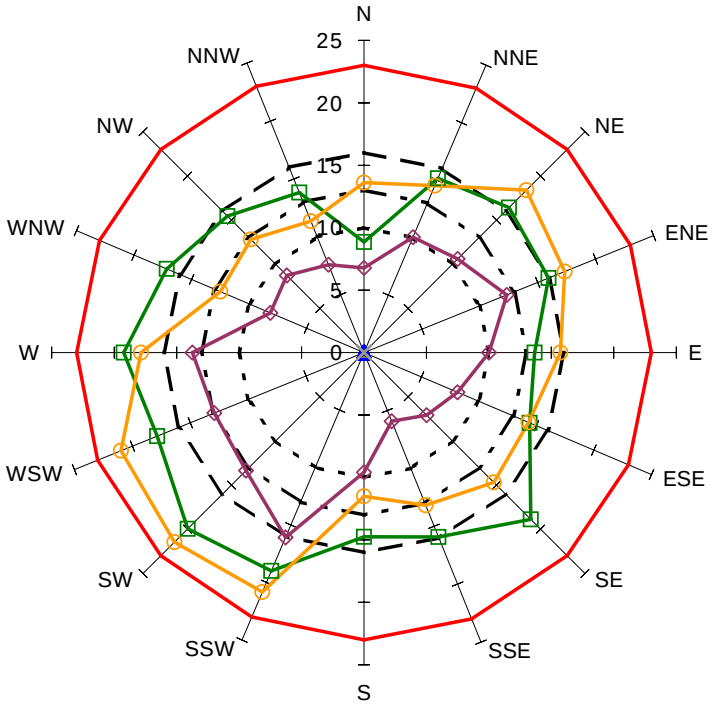
Measured Wind Speeds at Point 27

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)



- Long Exposure Criterion (3.5m/s)
- Short Exposure Criterion (5.5m/s)
- Comfortable Walking Criterion (7.5m/s)
- Fast Walking Criterion (10m/s)
- No exisiting conditions
- 88 Walker and 100 Mount As Proposed
- Modified Proposed 88 Walker and 100 Mount
- Final Treatment Scheme as illustrated in Figure 7b
- Retest 4 (Not Required)

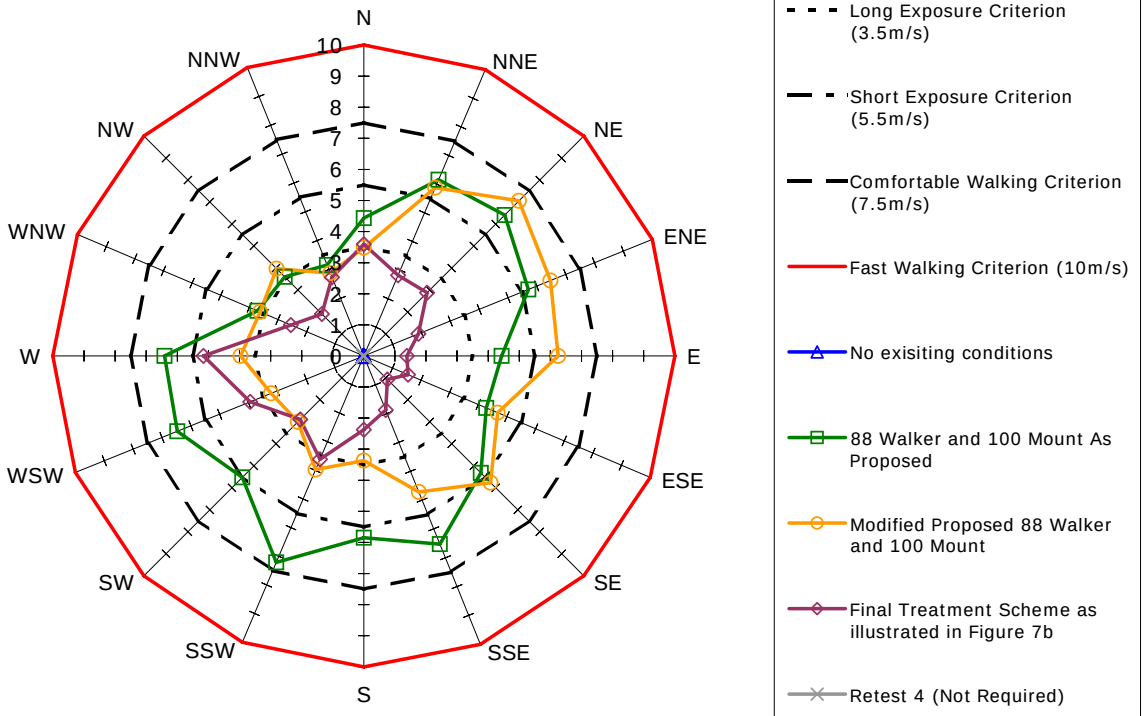
Annual Maximum Gust Wind Speeds (m/s)



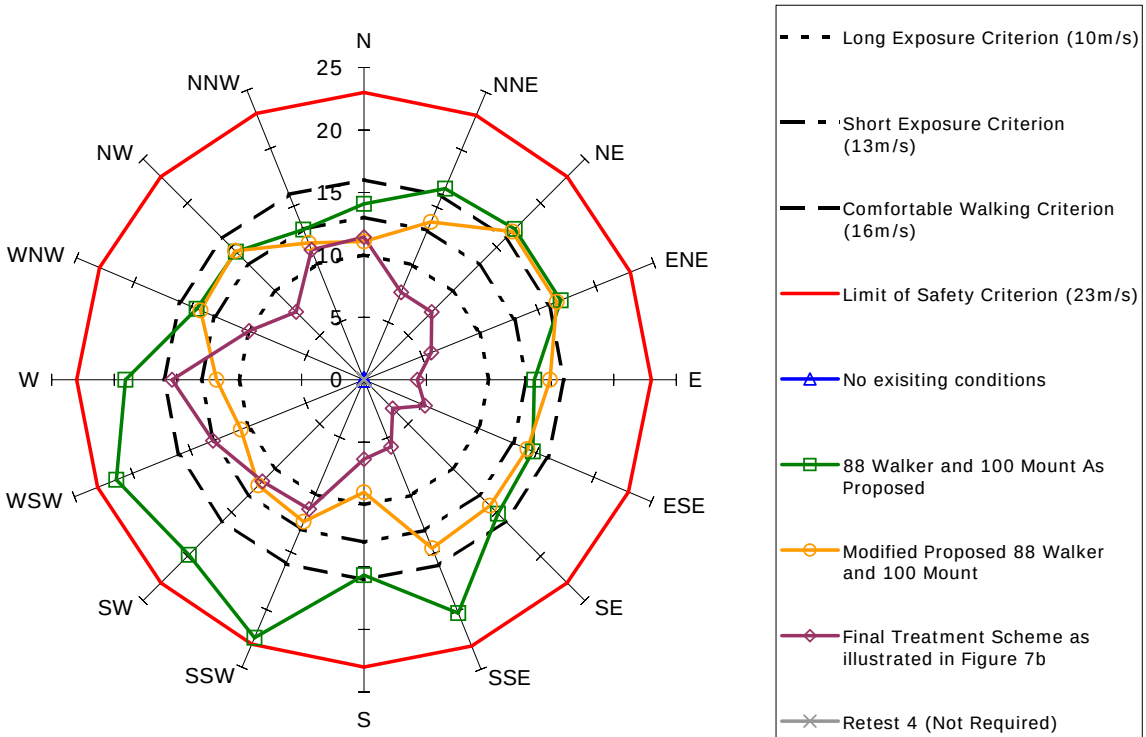
- Long Exposure Criterion (10m/s)
- Short Exposure Criterion (13m/s)
- Comfortable Walking Criterion (16m/s)
- Limit of Safety Criterion (23m/s)
- No exisiting conditions
- 88 Walker and 100 Mount As Proposed
- Modified Proposed 88 Walker and 100 Mount
- Final Treatment Scheme as illustrated in Figure 7b
- Retest 4 (Not Required)

Measured Wind Speeds at Point 28

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

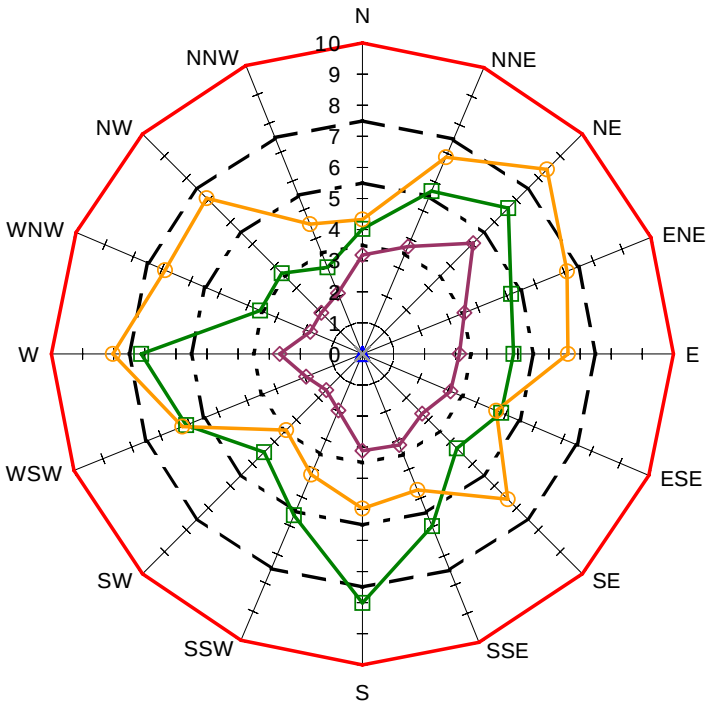


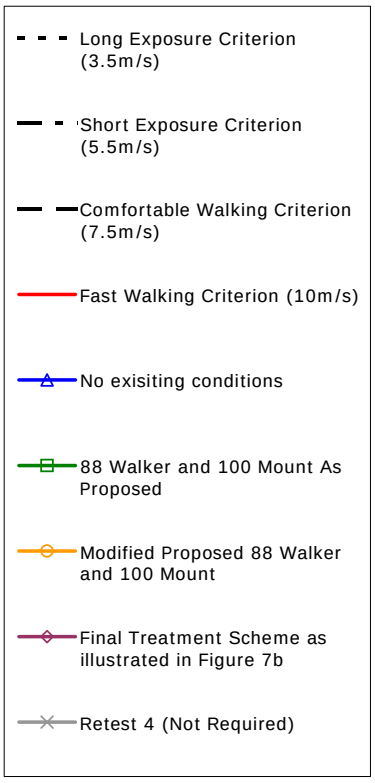
Annual Maximum Gust Wind Speeds (m/s)



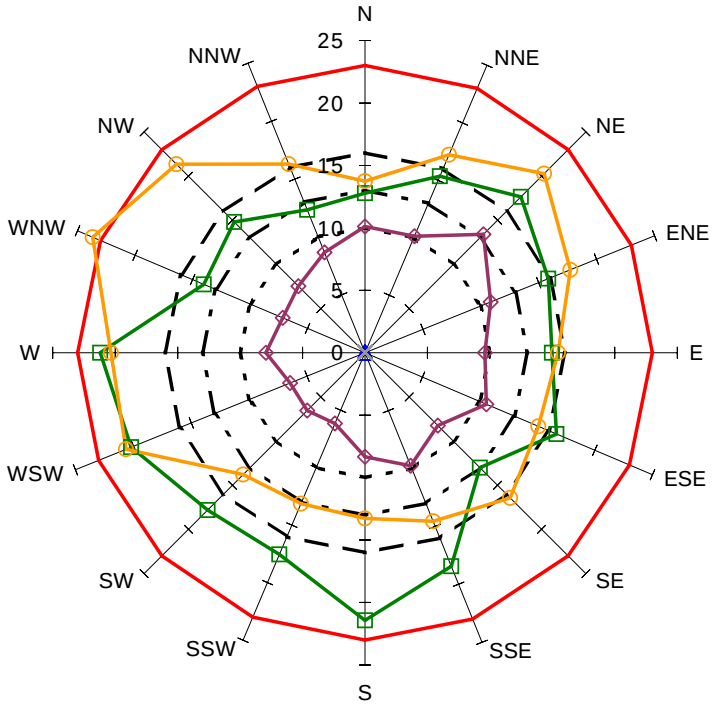
Measured Wind Speeds at Point 29

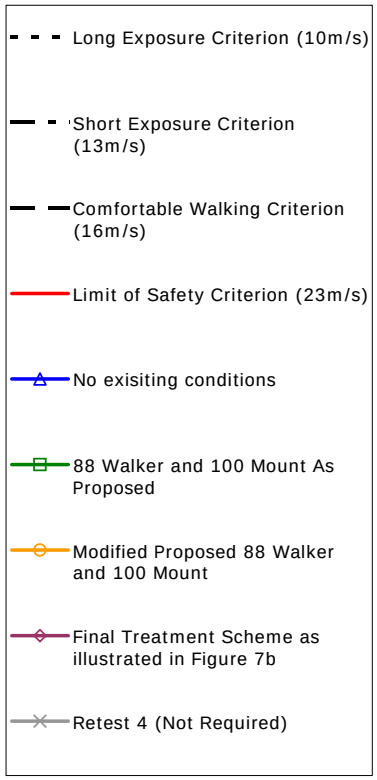
Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)





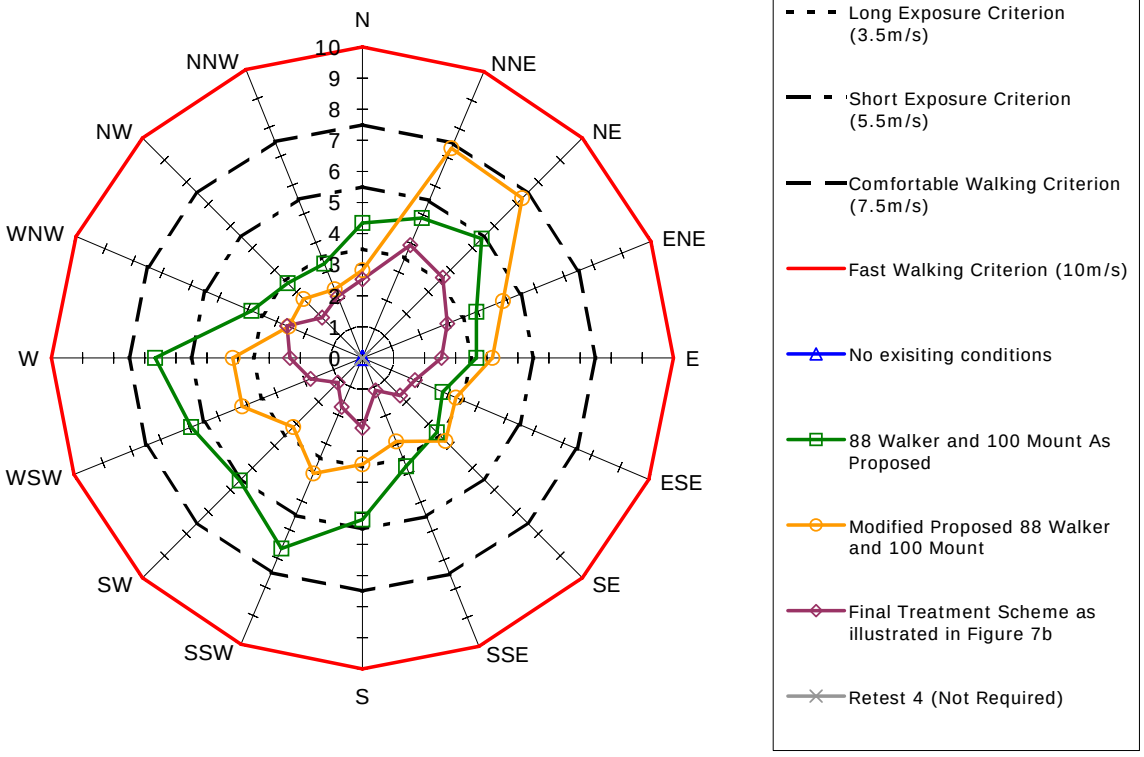
Annual Maximum Gust Wind Speeds (m/s)



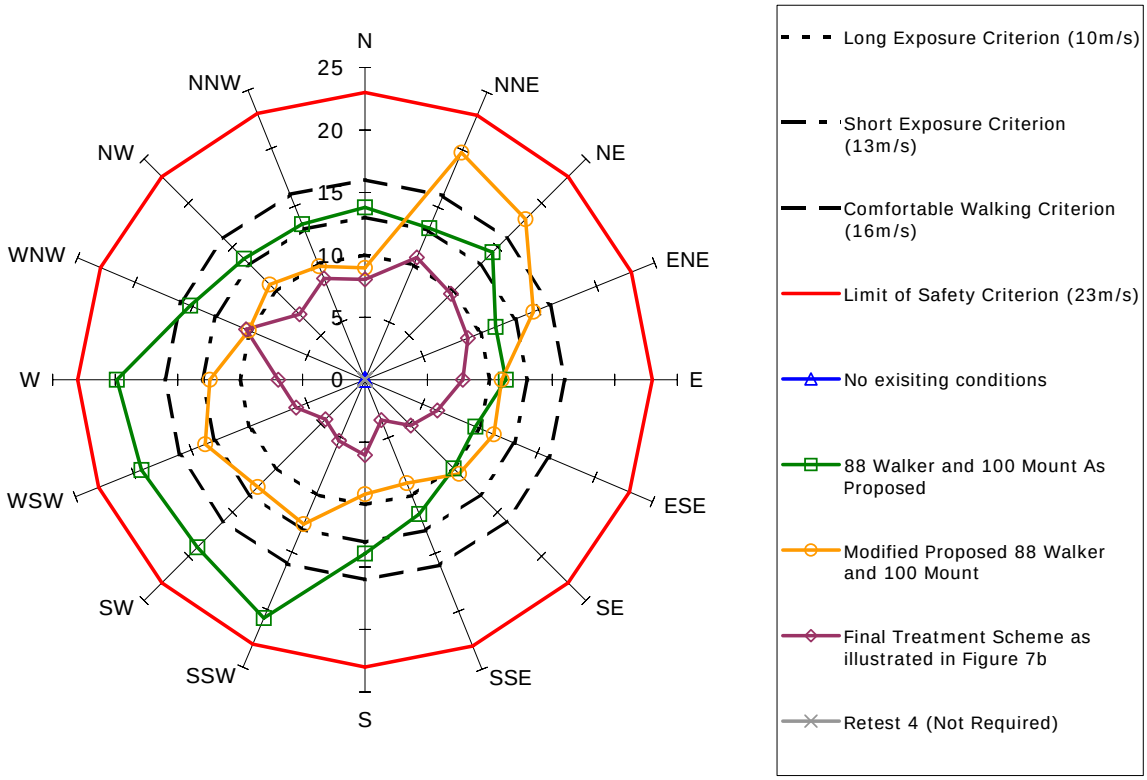


Measured Wind Speeds at Point 30

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

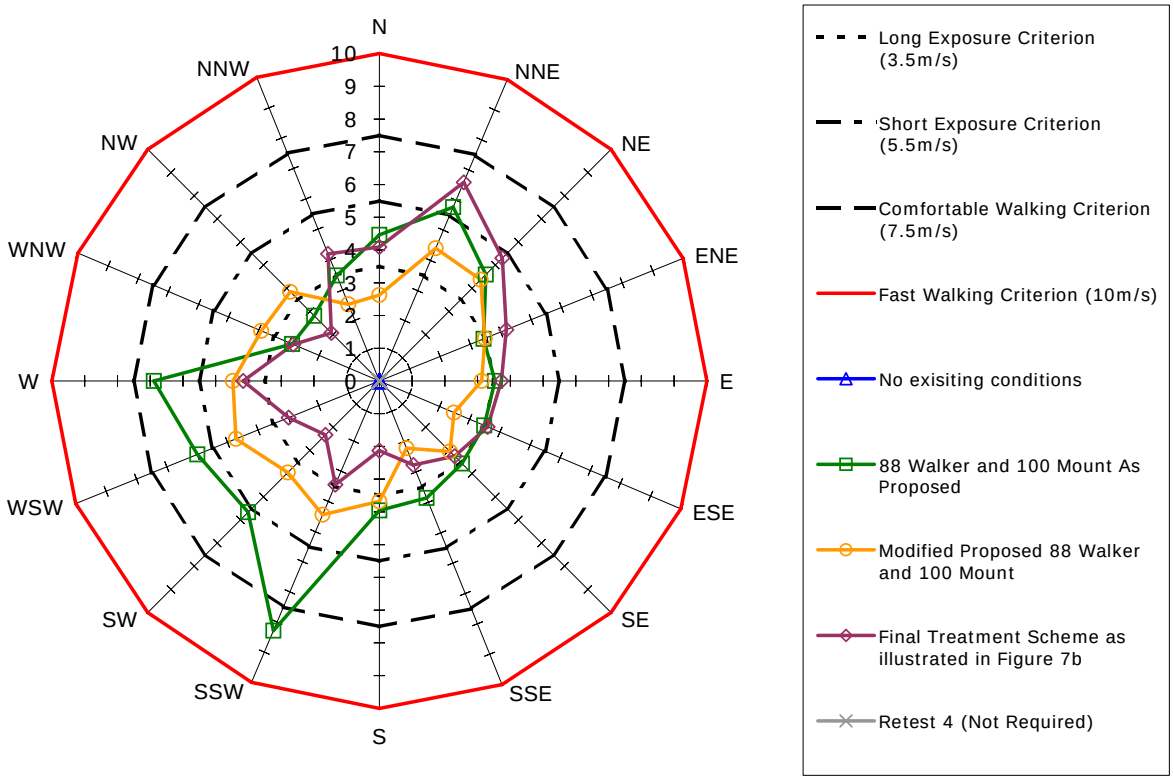


Annual Maximum Gust Wind Speeds (m/s)

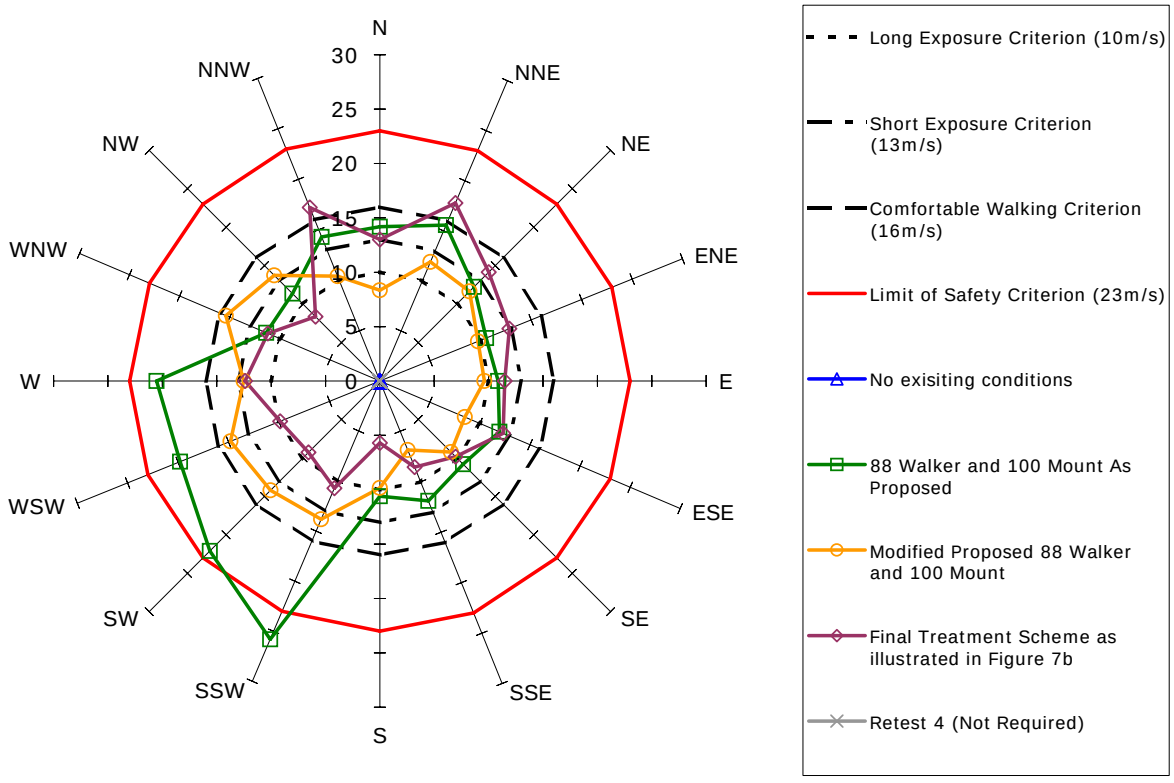


Measured Wind Speeds at Point 31

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

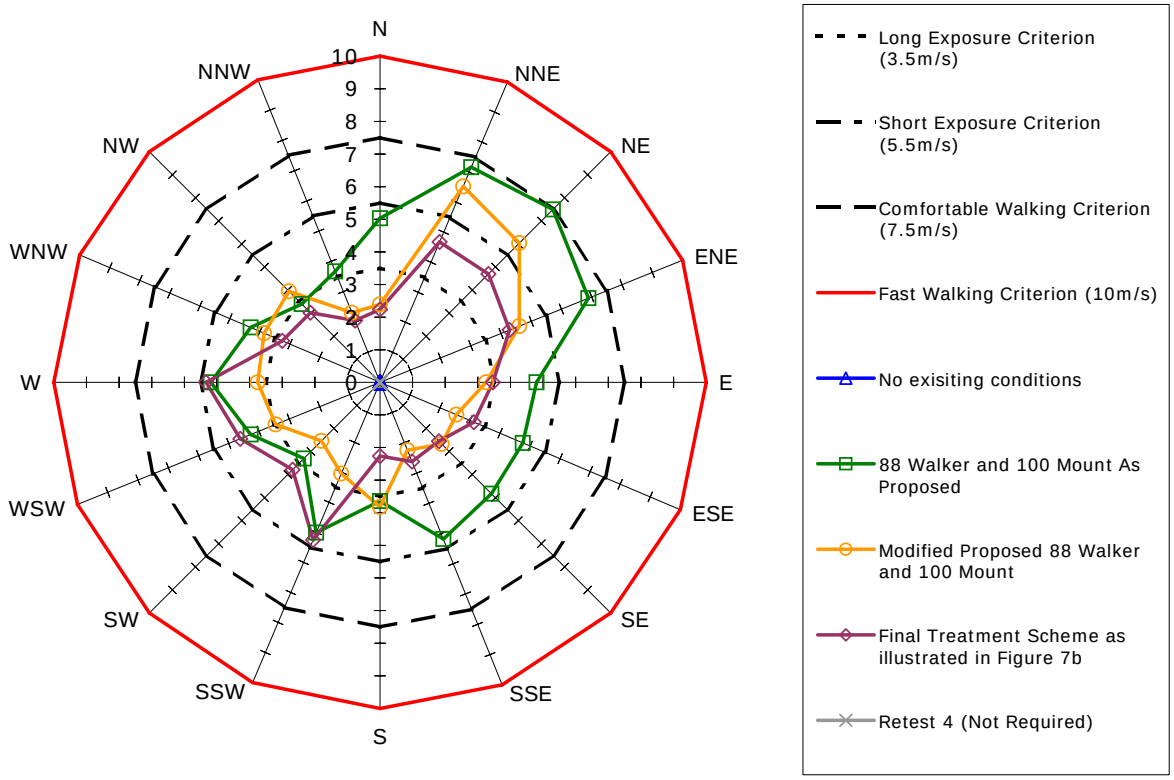


Annual Maximum Gust Wind Speeds (m/s)

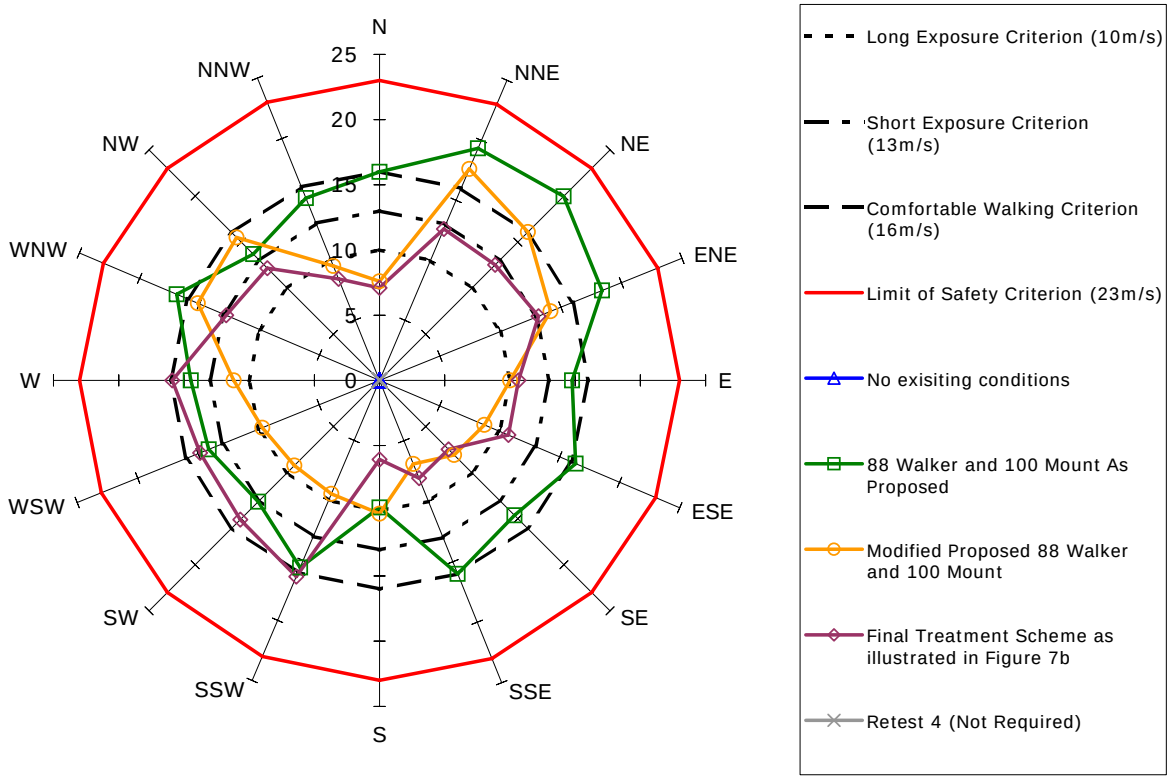


Measured Wind Speeds at Point 32

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

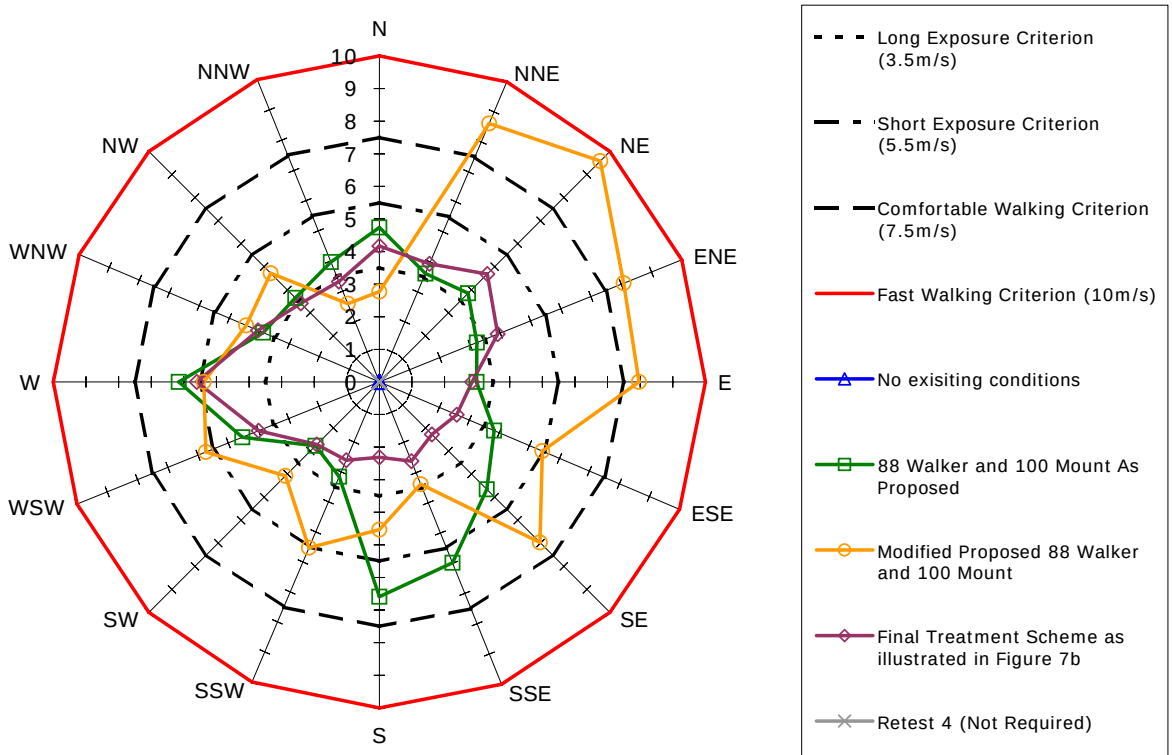


Annual Maximum Gust Wind Speeds (m/s)

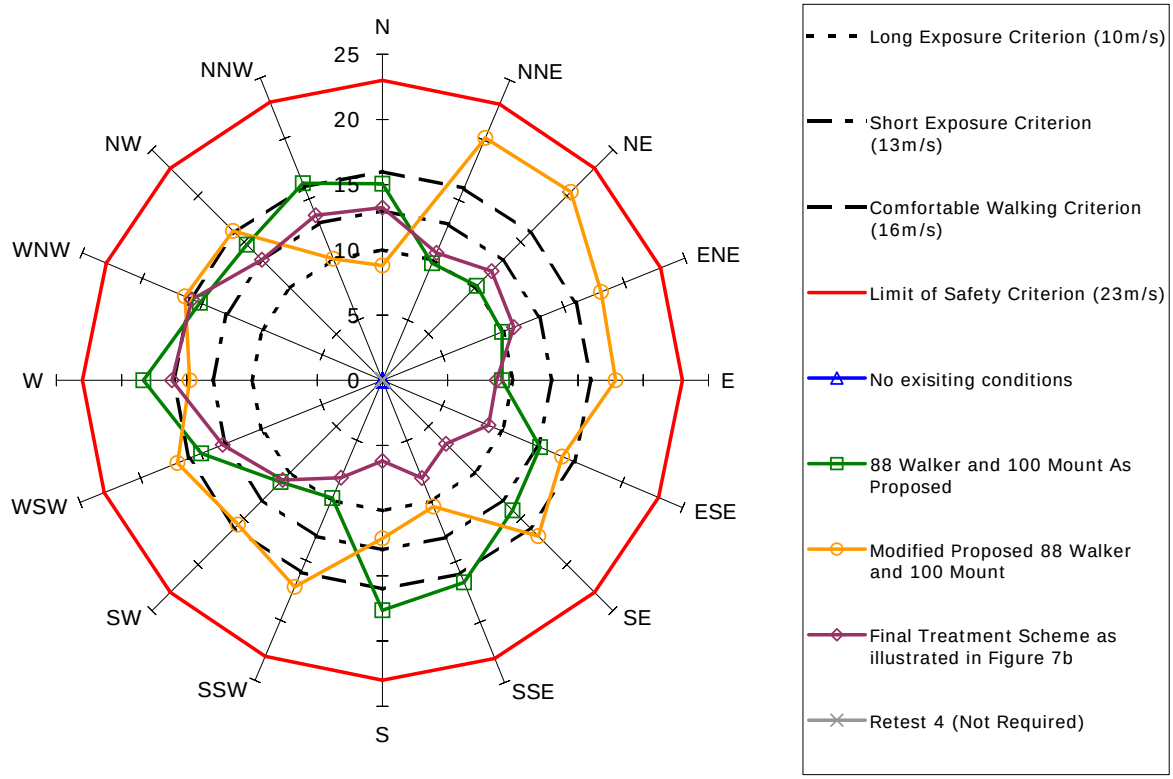


Measured Wind Speeds at Point 33

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

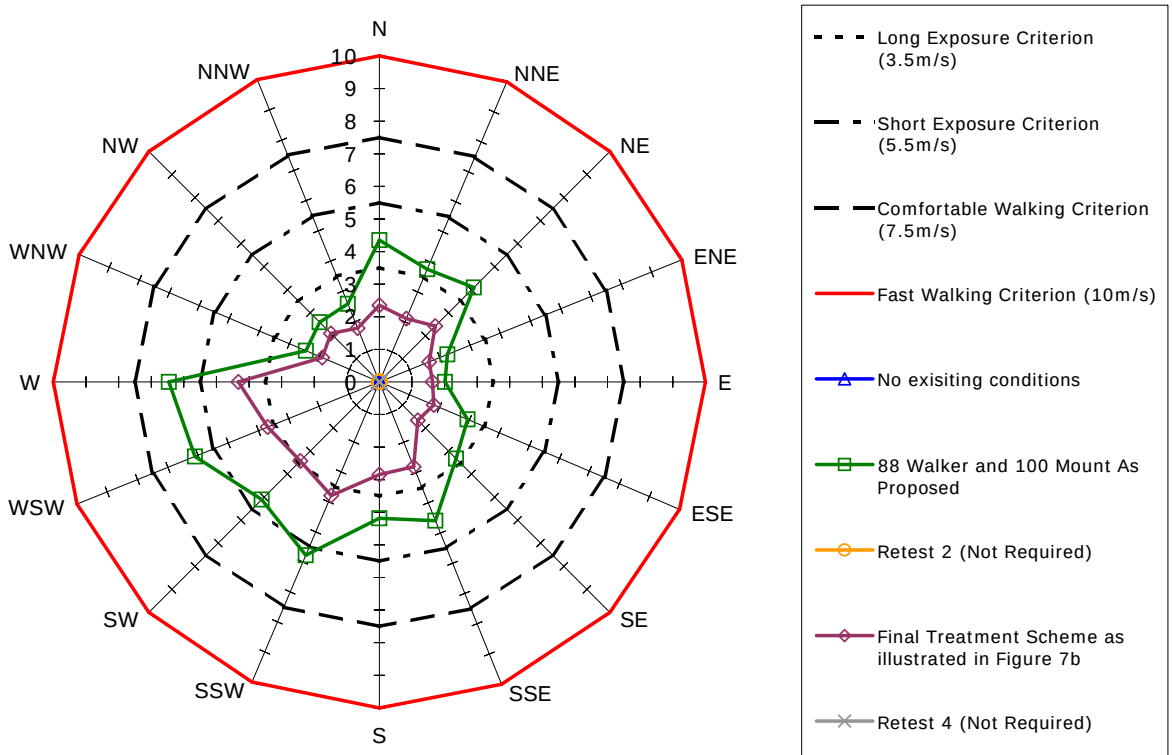


Annual Maximum Gust Wind Speeds (m/s)

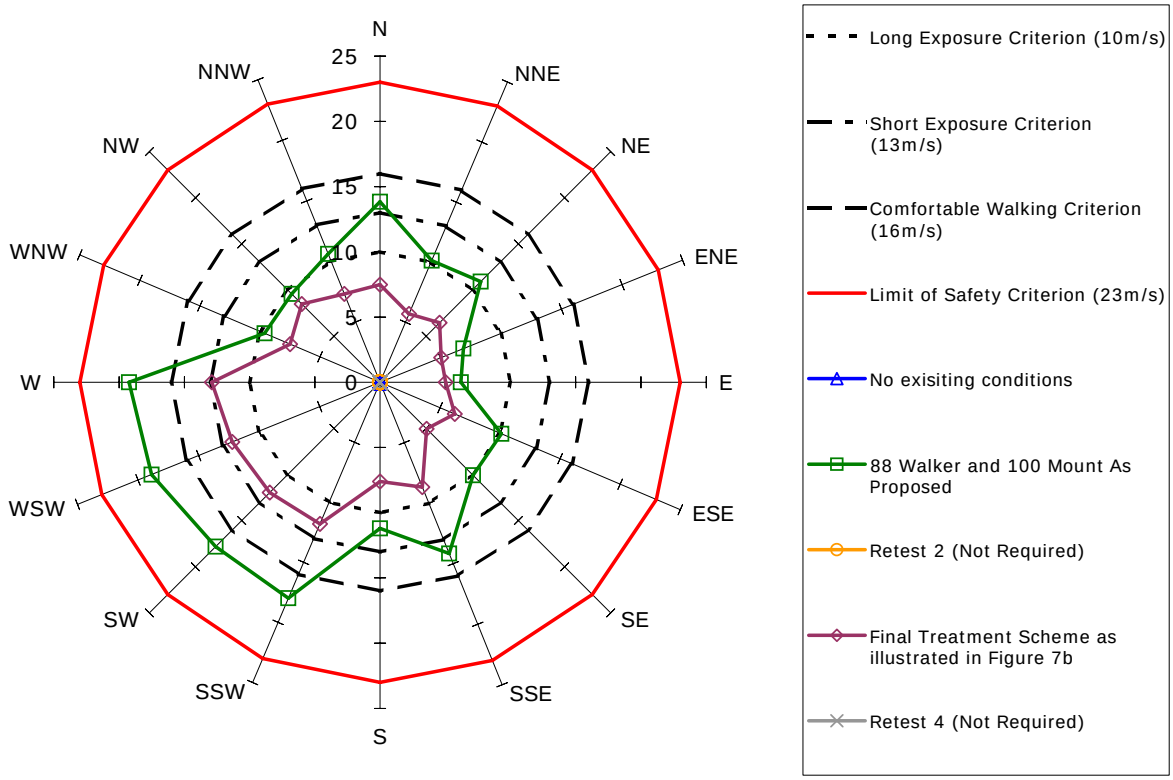


Measured Wind Speeds at Point 34

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

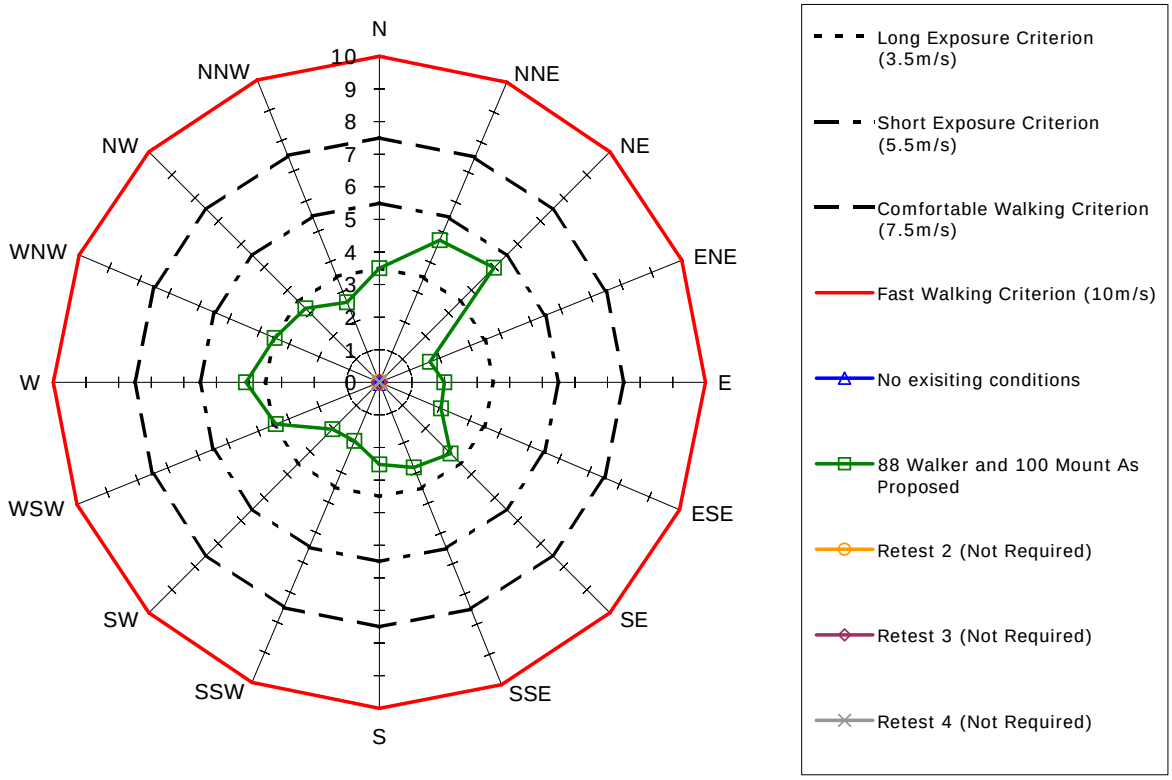


Annual Maximum Gust Wind Speeds (m/s)

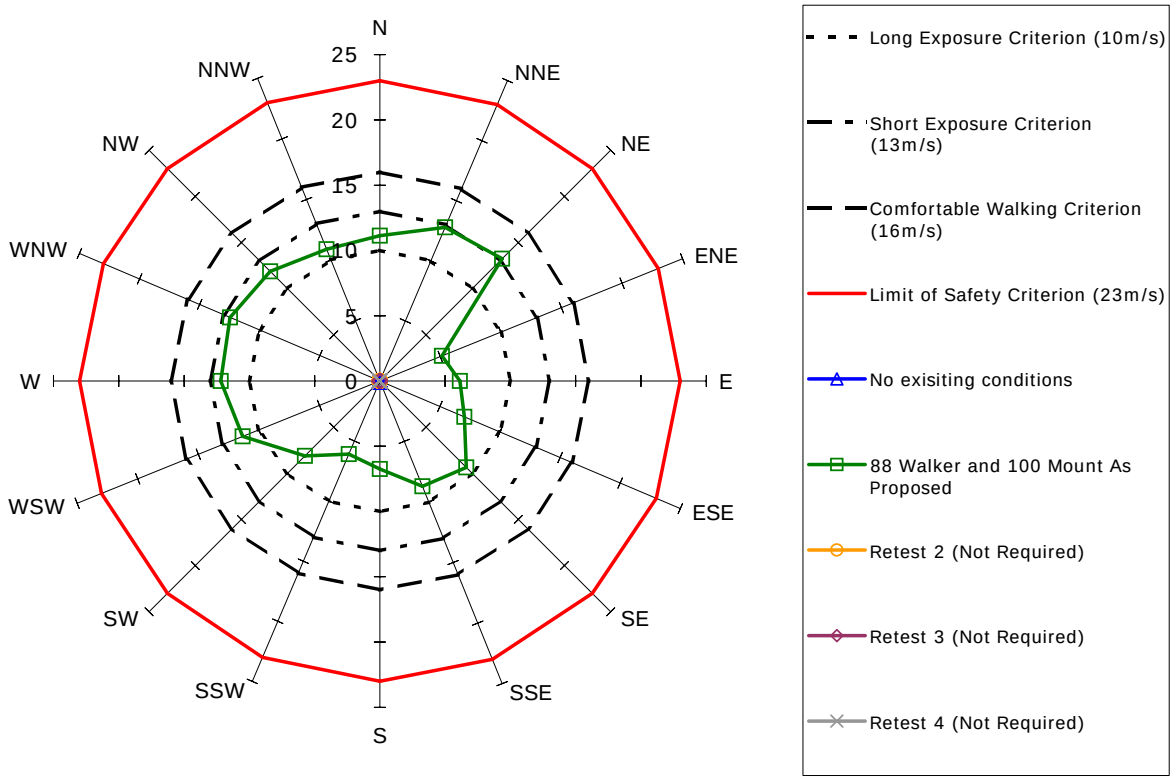


Measured Wind Speeds at Point 35

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

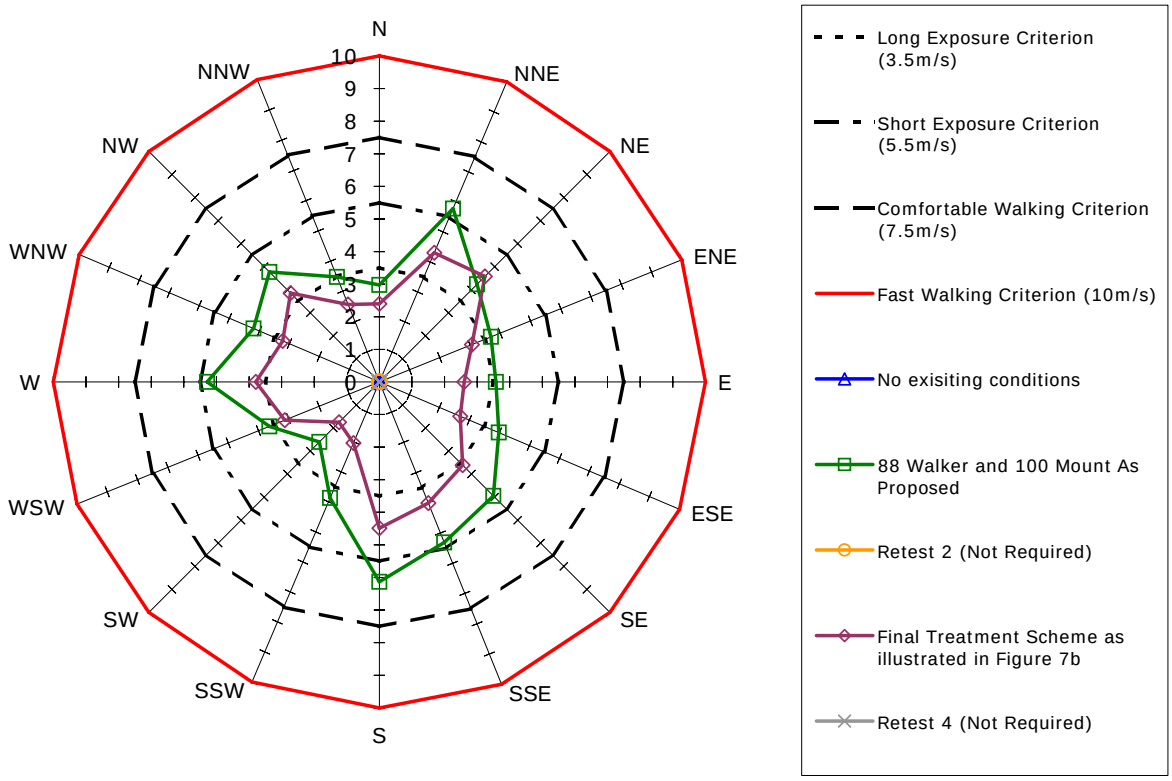


Annual Maximum Gust Wind Speeds (m/s)

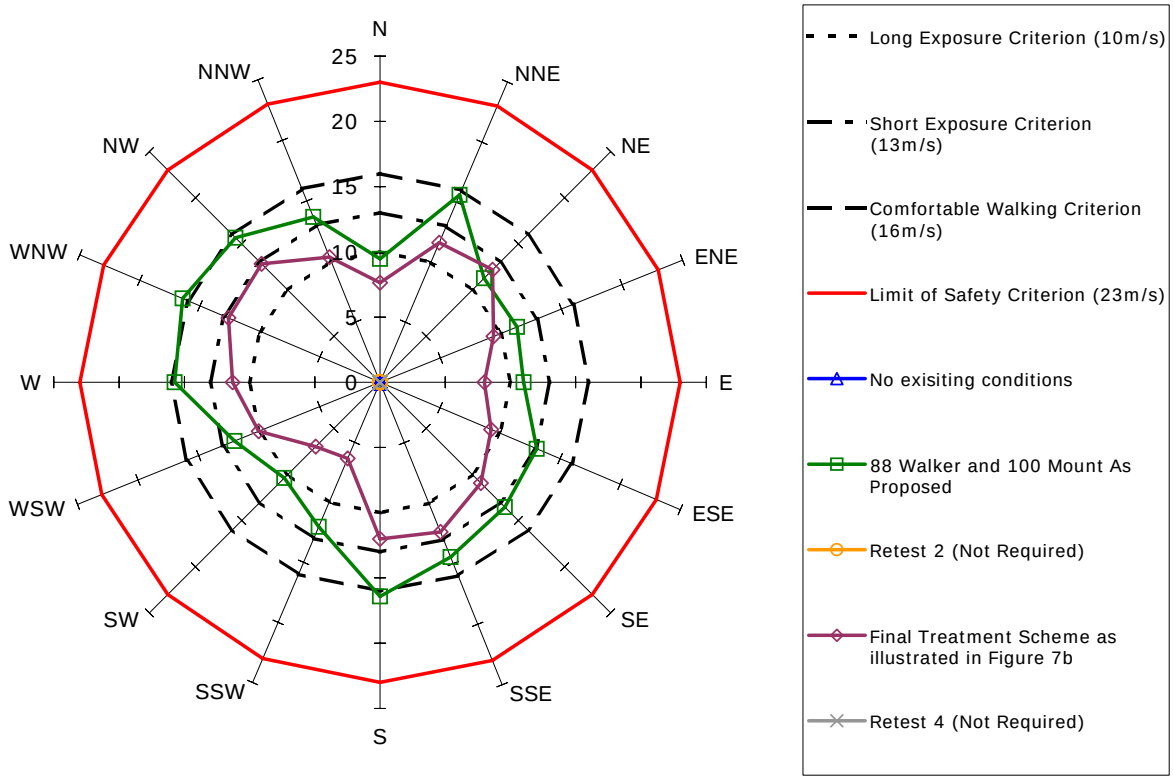


Measured Wind Speeds at Point 36

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

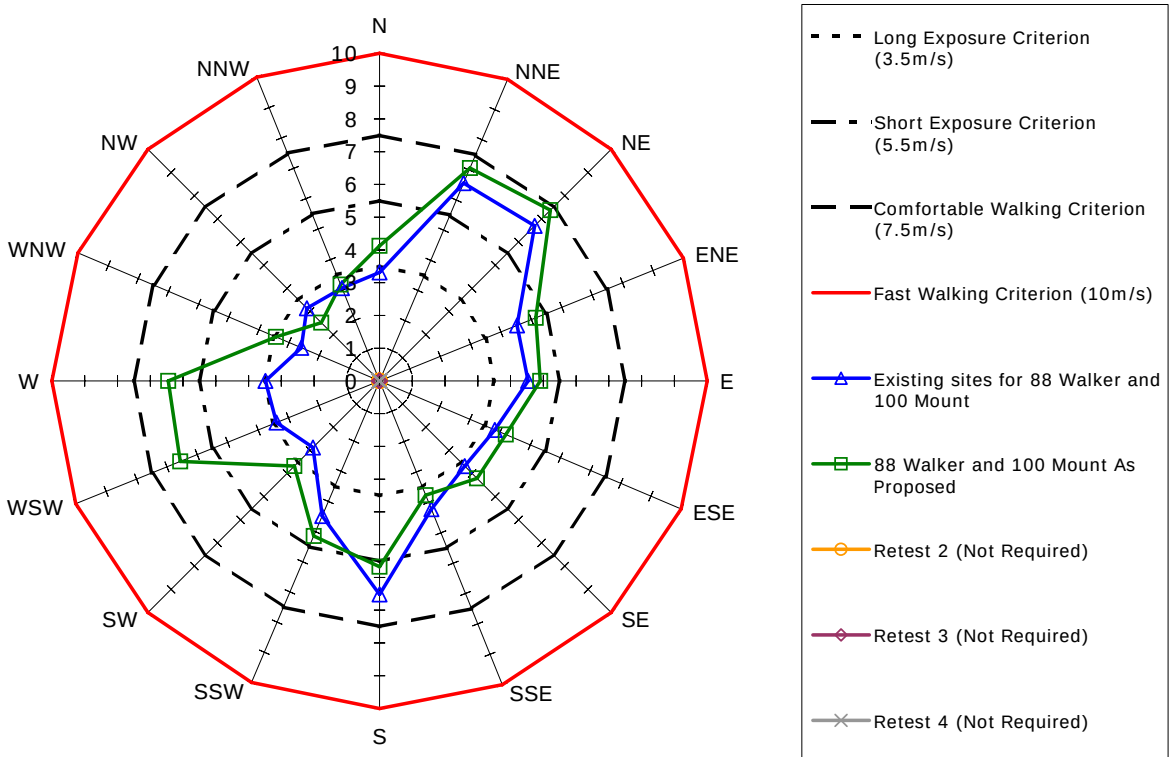


Annual Maximum Gust Wind Speeds (m/s)

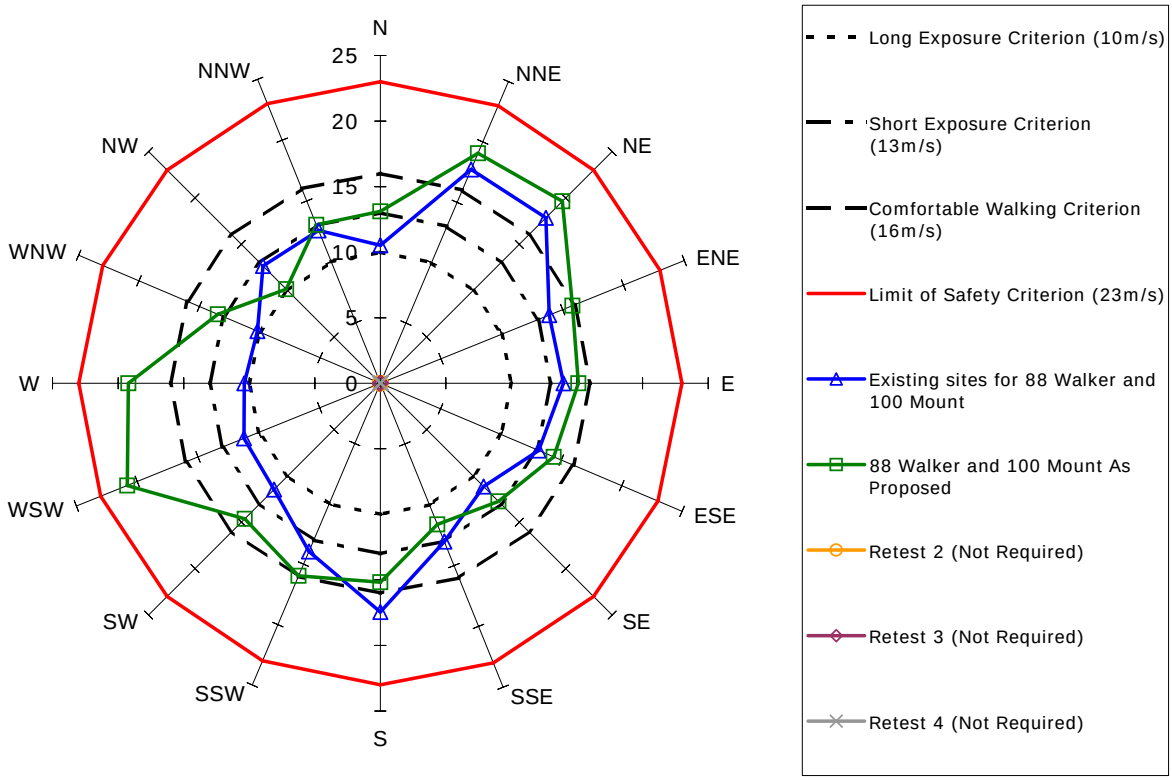


Measured Wind Speeds at Point 37

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

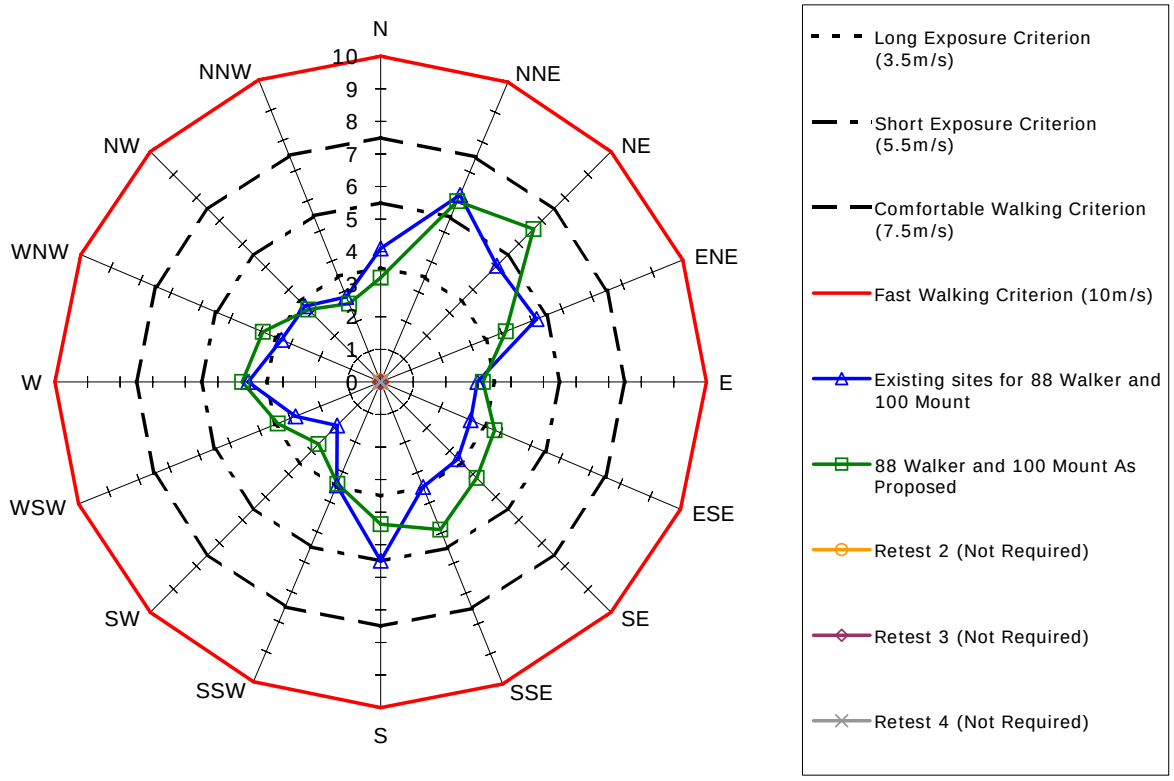


Annual Maximum Gust Wind Speeds (m/s)

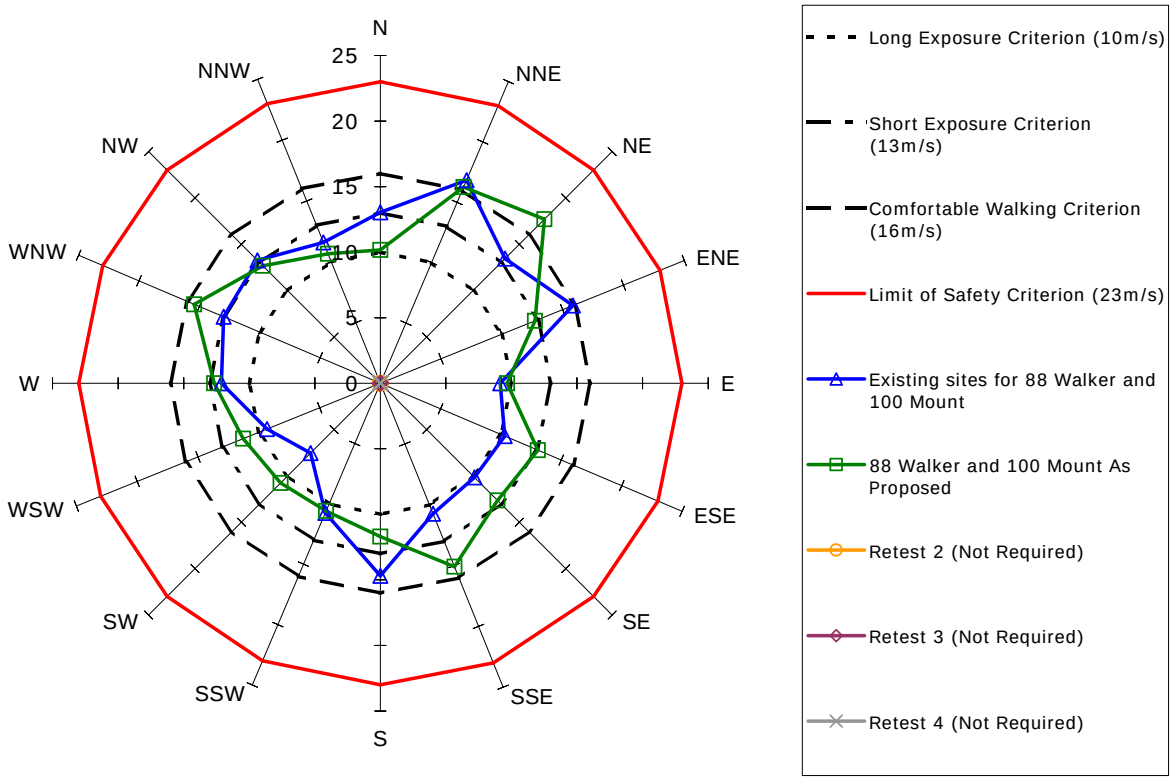


Measured Wind Speeds at Point 38

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

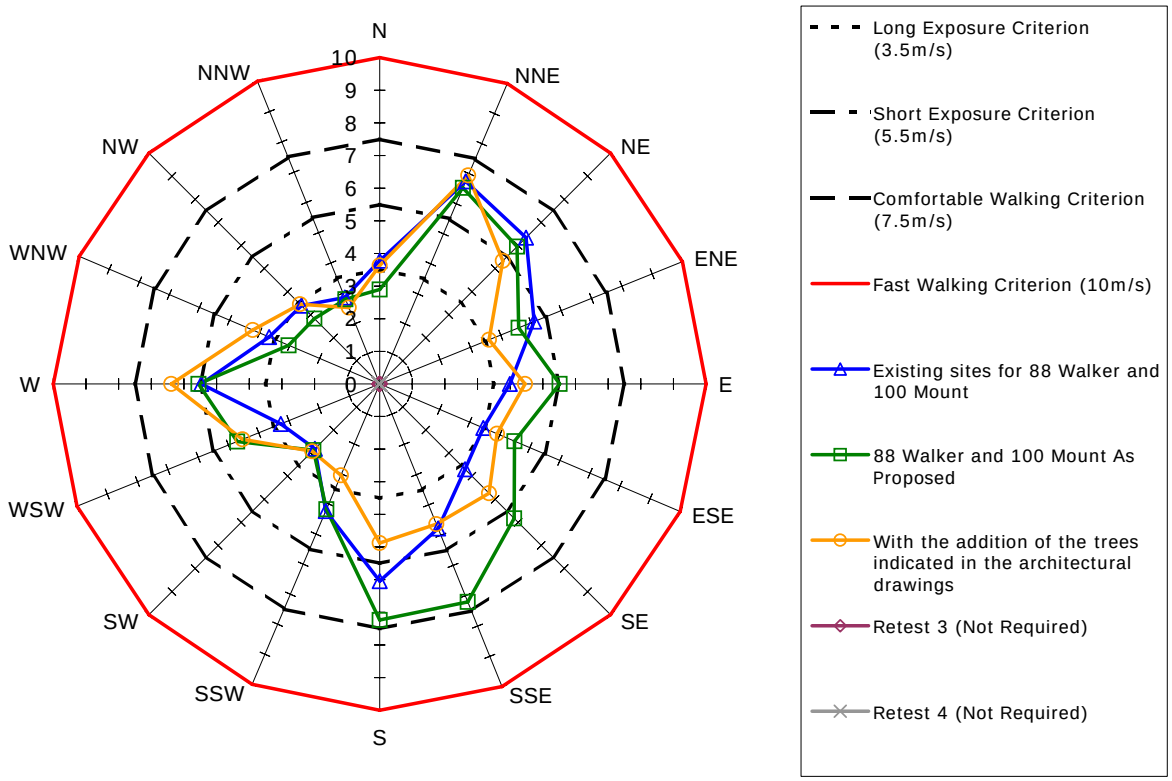


Annual Maximum Gust Wind Speeds (m/s)

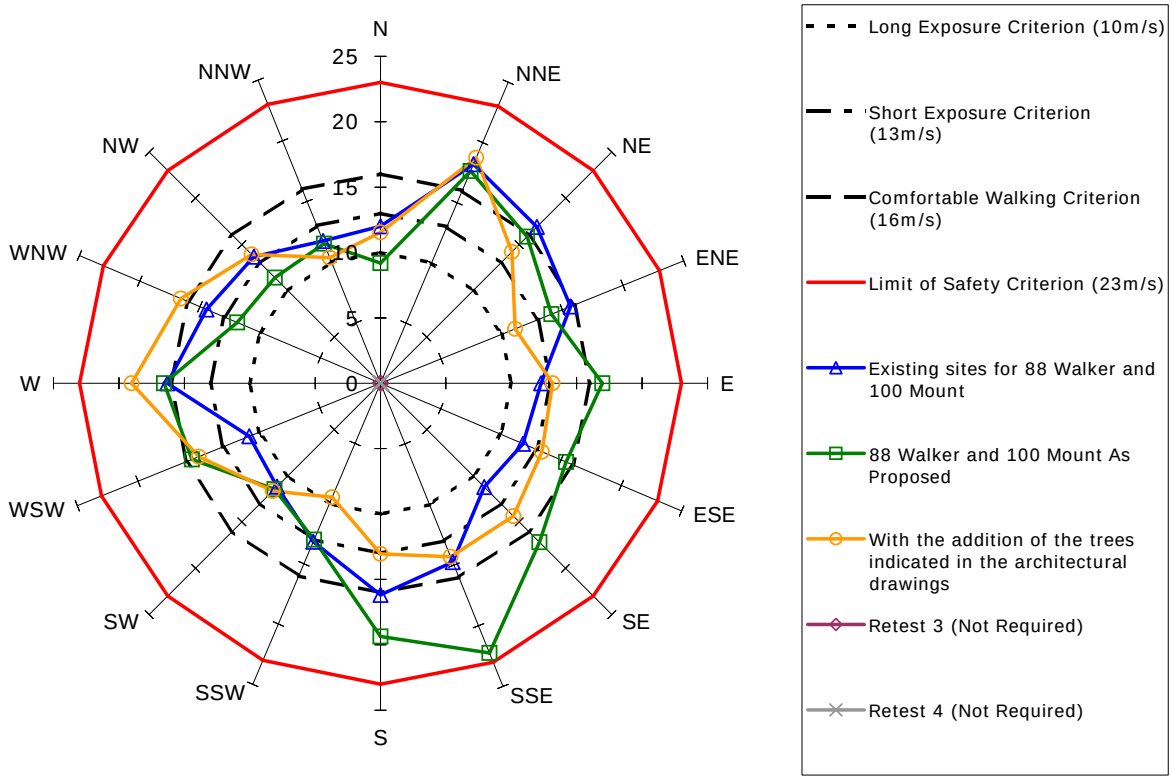


Measured Wind Speeds at Point 39

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

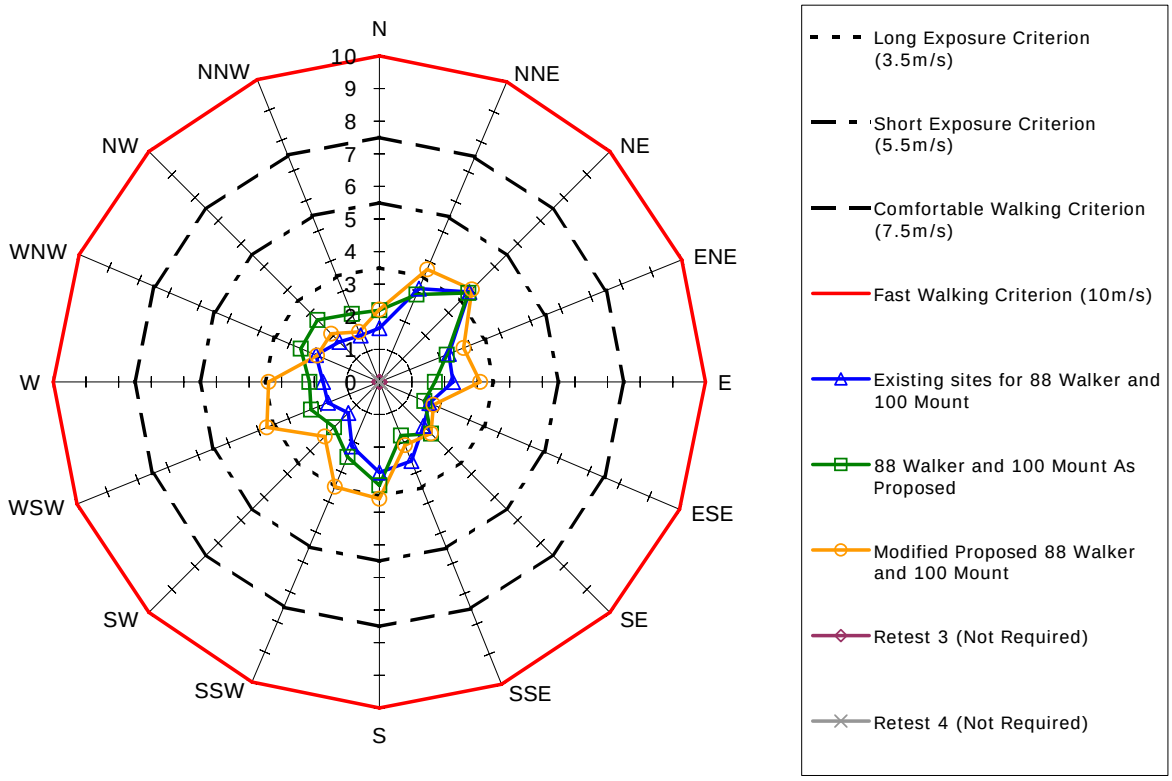


Annual Maximum Gust Wind Speeds (m/s)

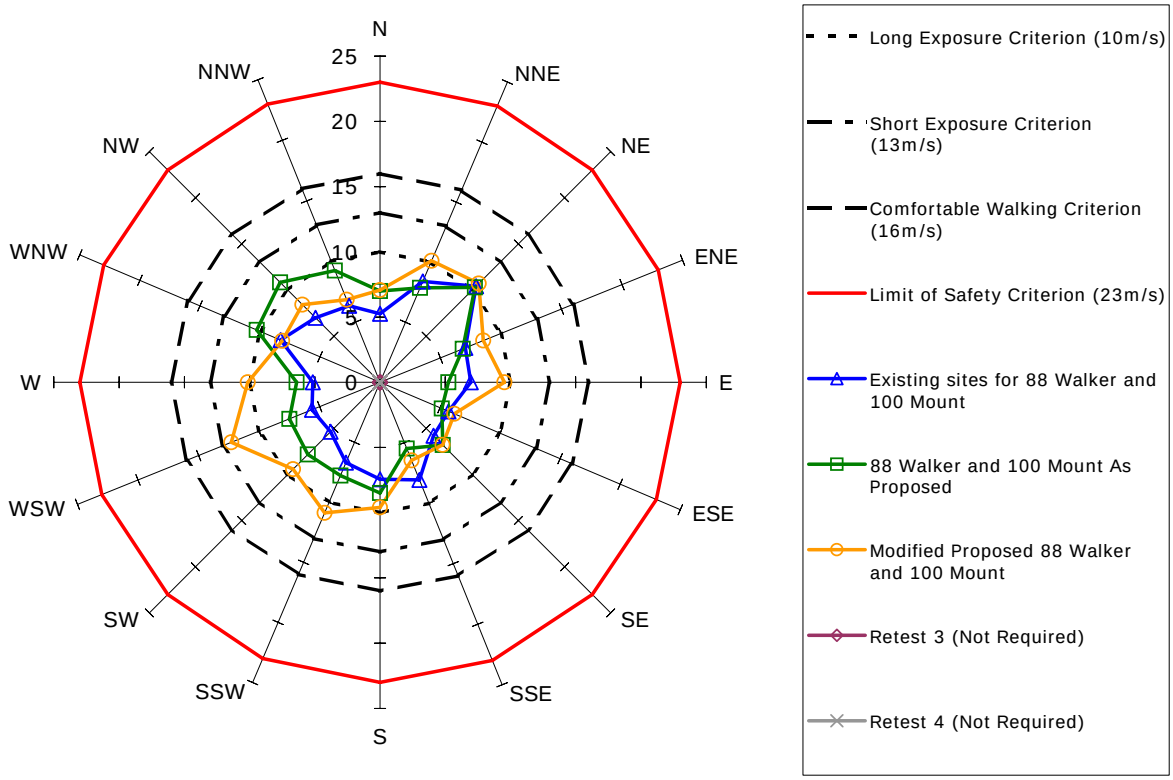


Measured Wind Speeds at Point 40

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

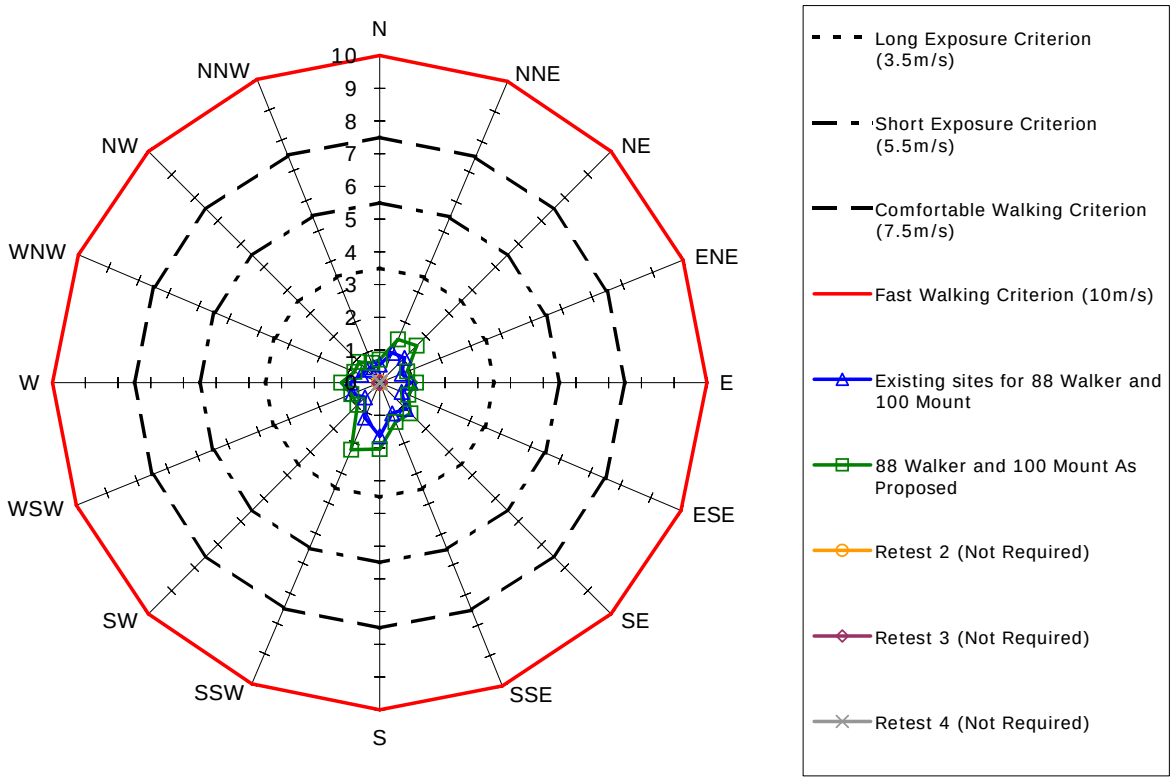


Annual Maximum Gust Wind Speeds (m/s)

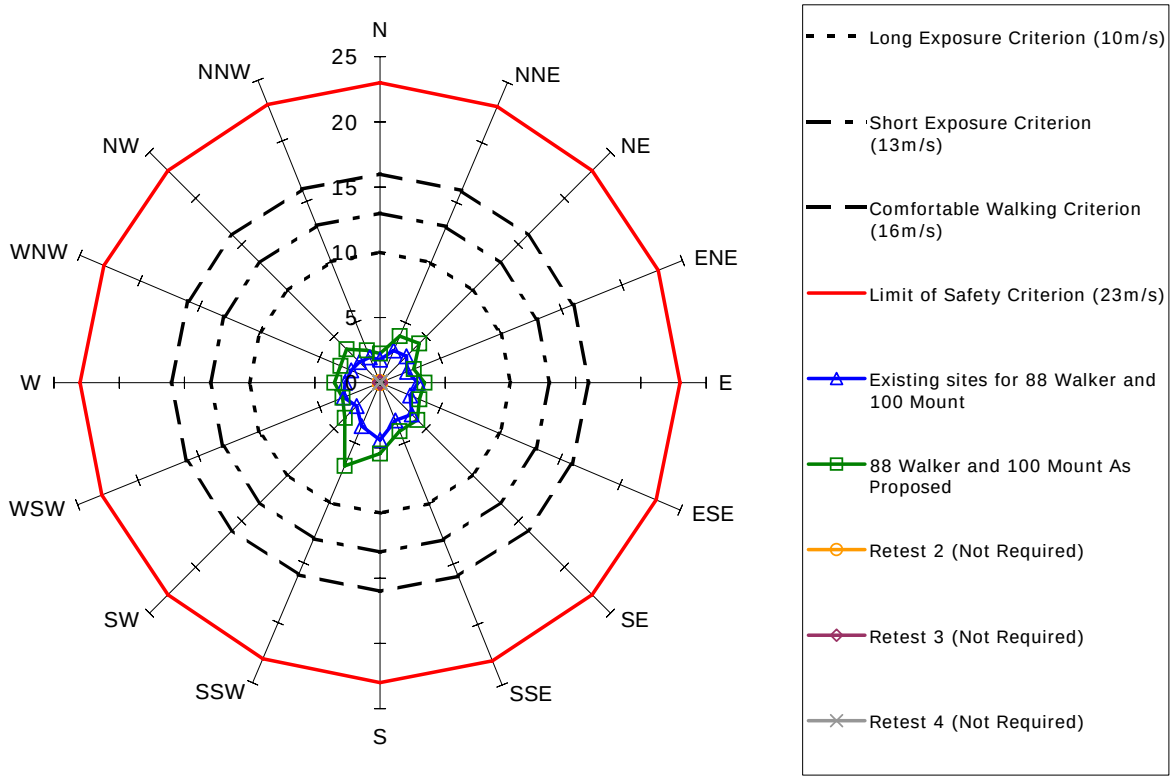


Measured Wind Speeds at Point 41

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

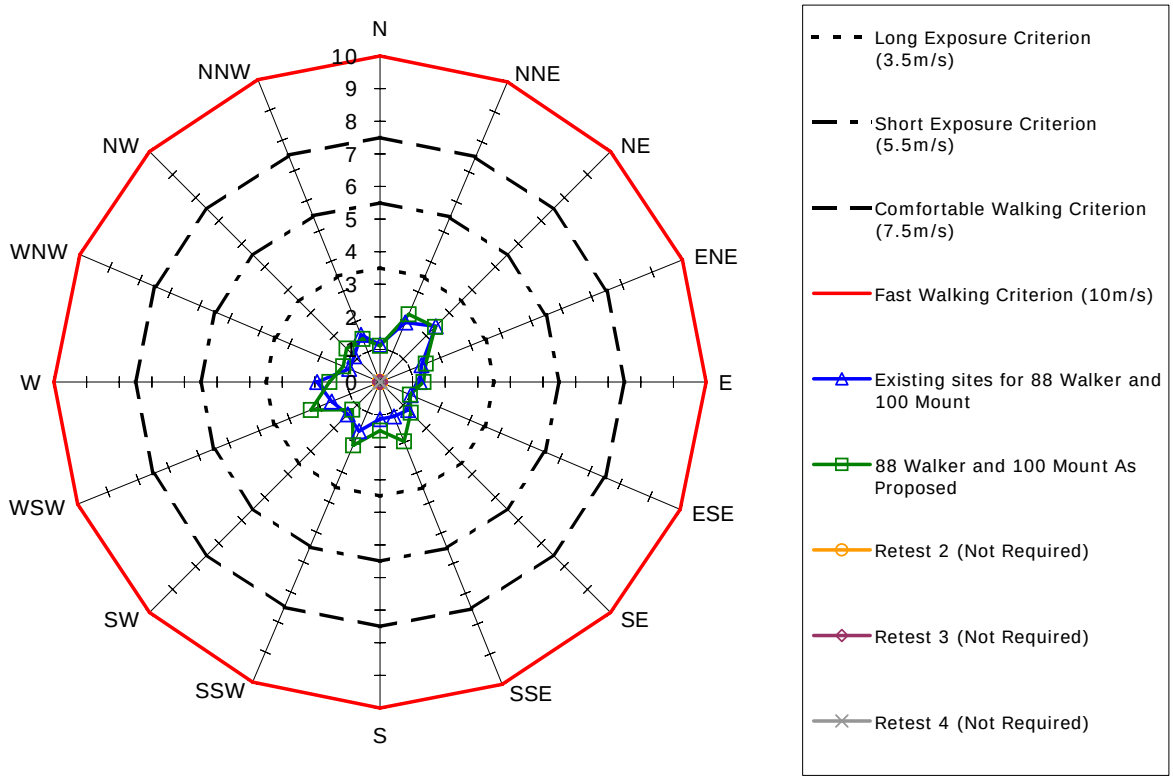


Annual Maximum Gust Wind Speeds (m/s)

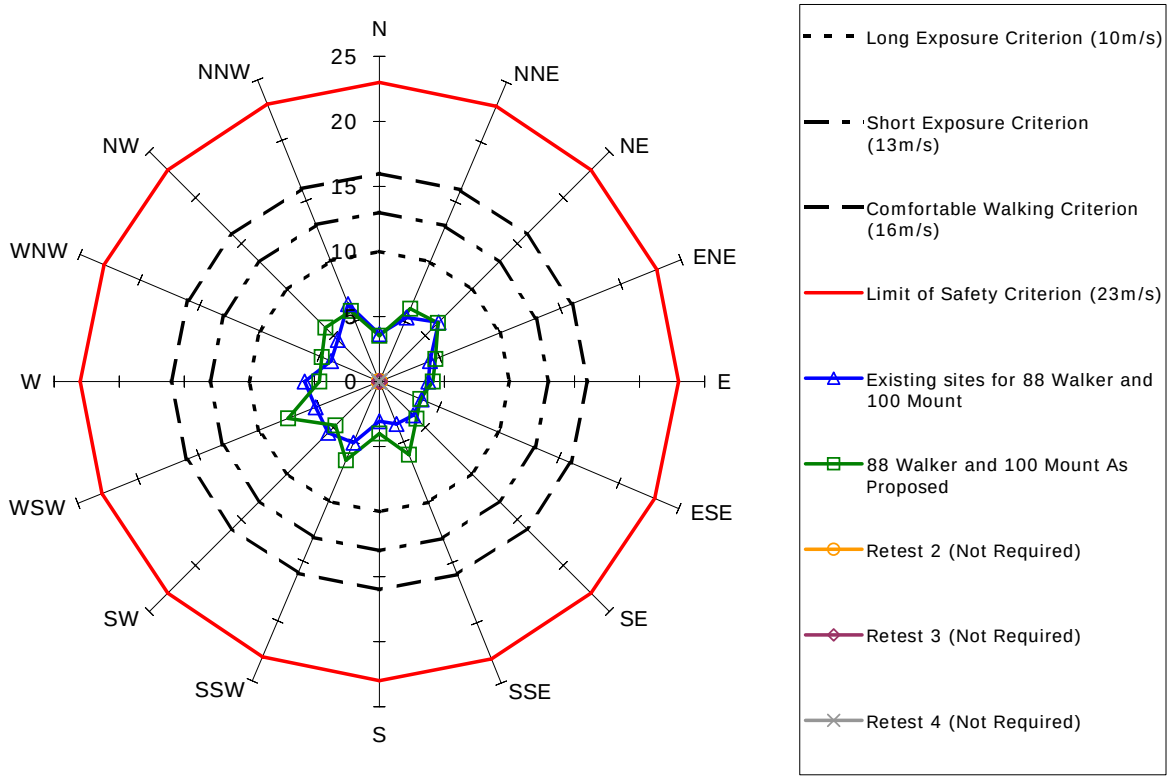


Measured Wind Speeds at Point 42

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

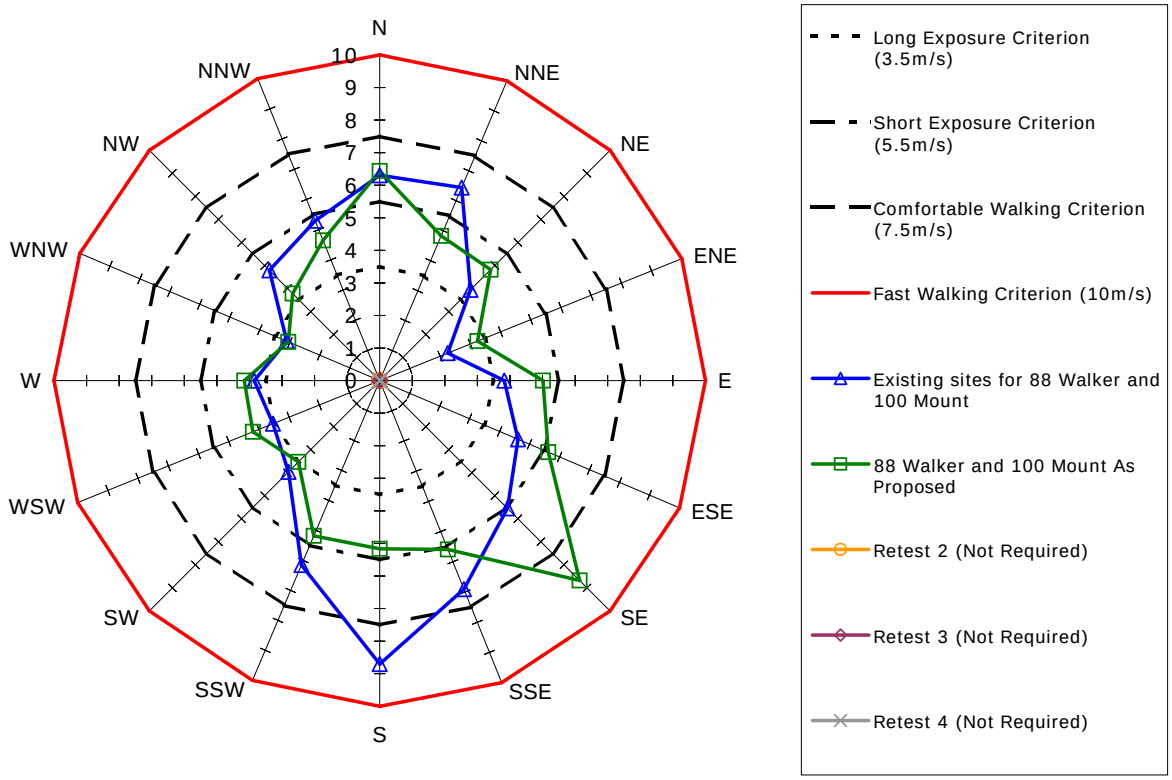


Annual Maximum Gust Wind Speeds (m/s)

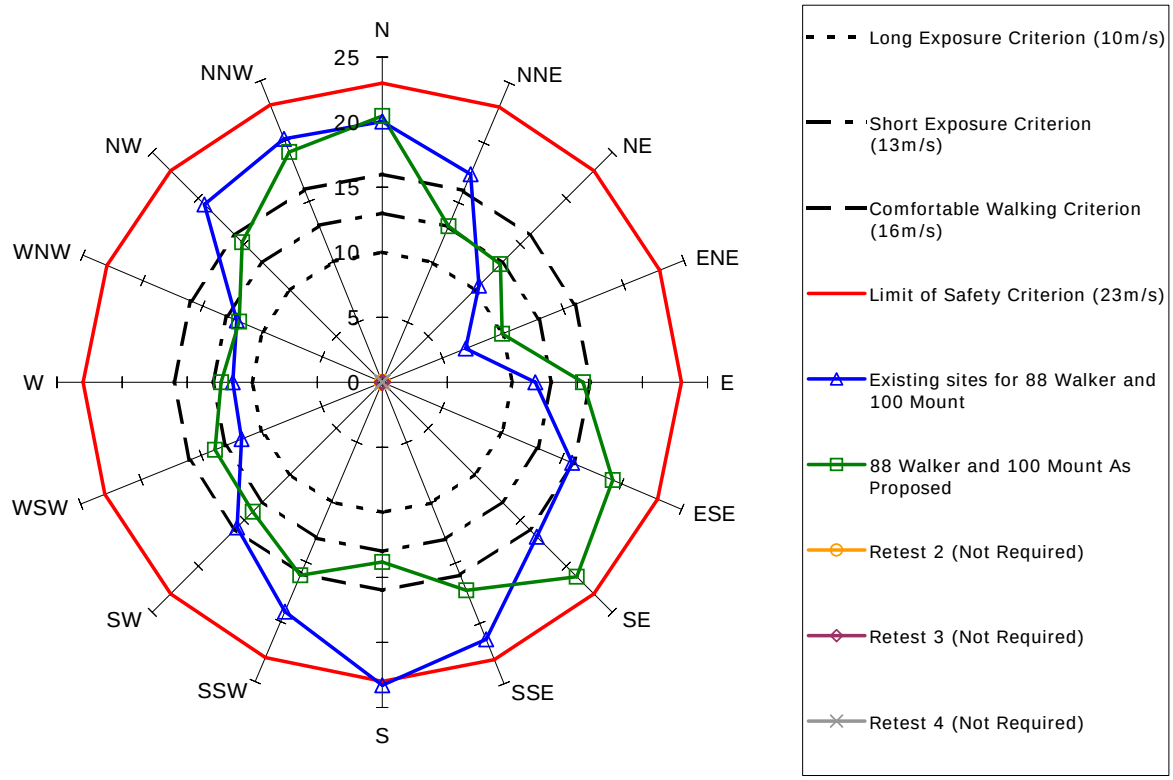


Measured Wind Speeds at Point 43

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

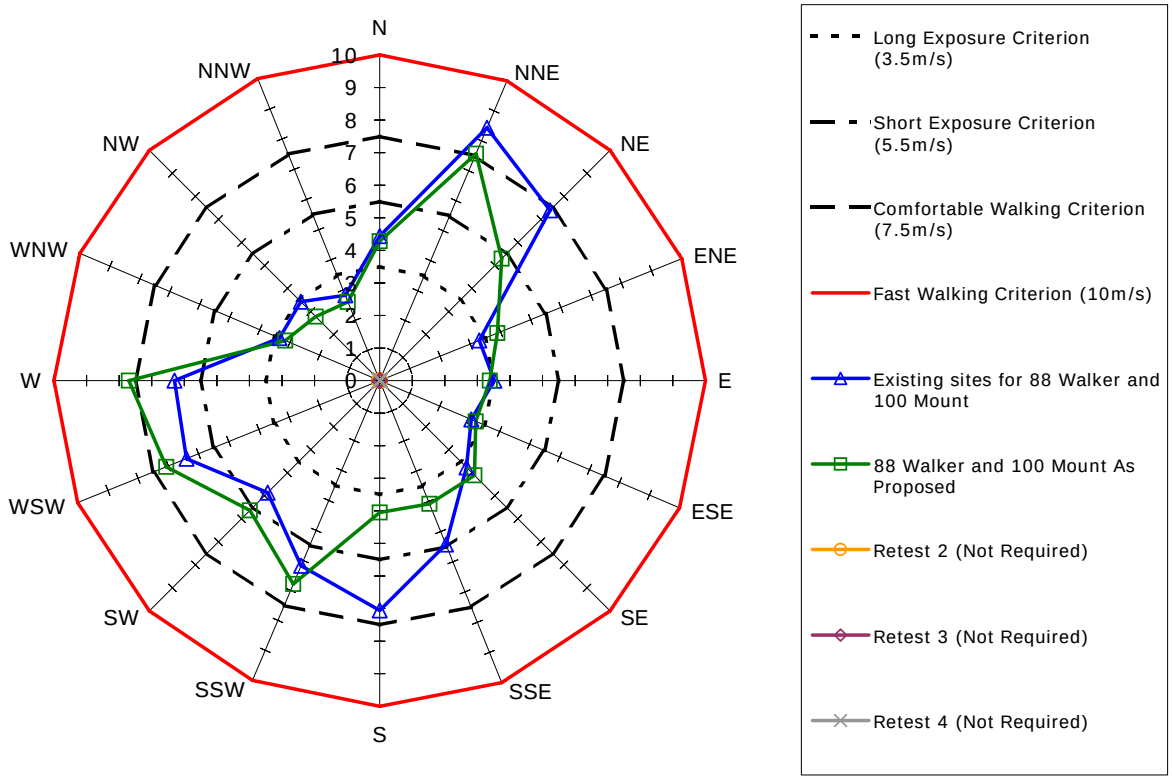


Annual Maximum Gust Wind Speeds (m/s)

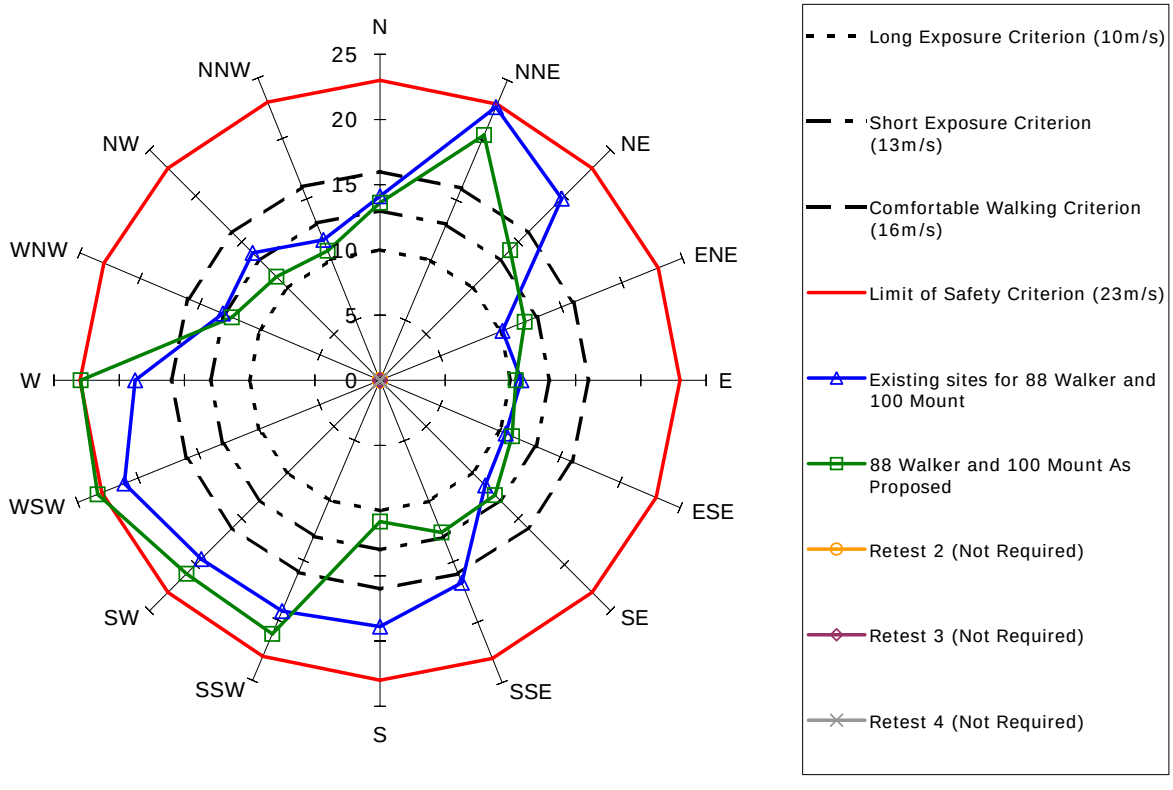


Measured Wind Speeds at Point 44

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

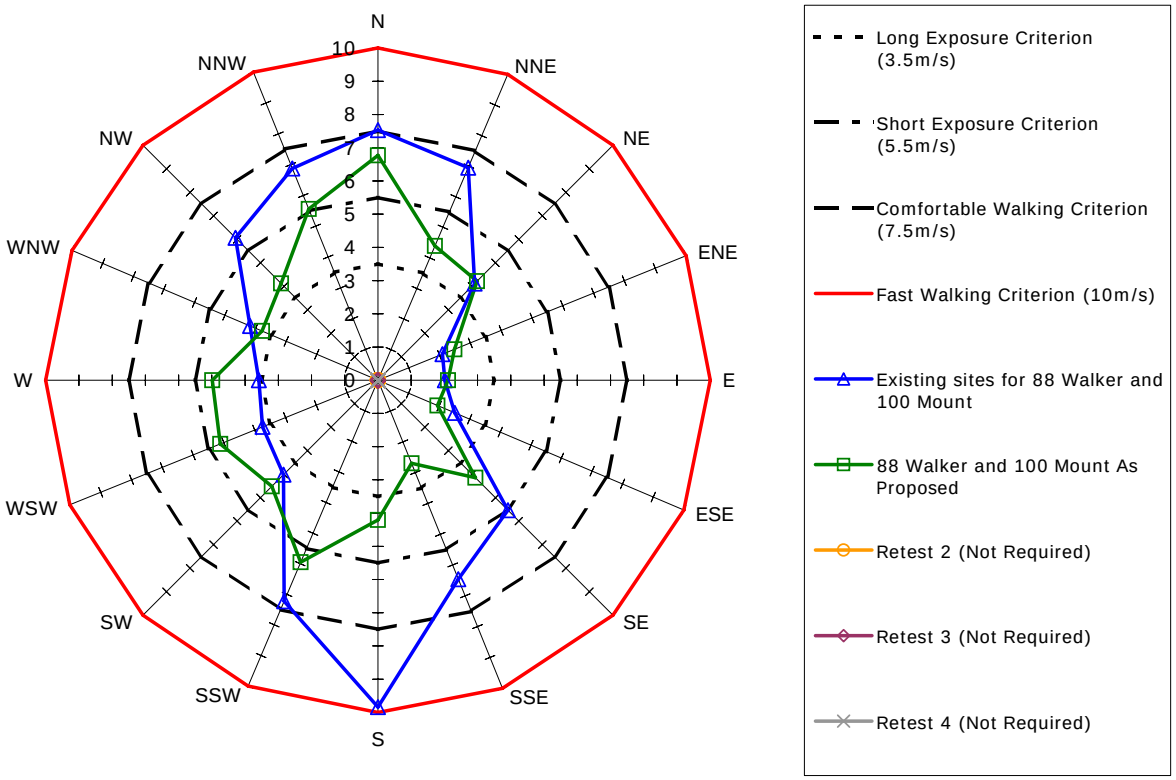


Annual Maximum Gust Wind Speeds (m/s)

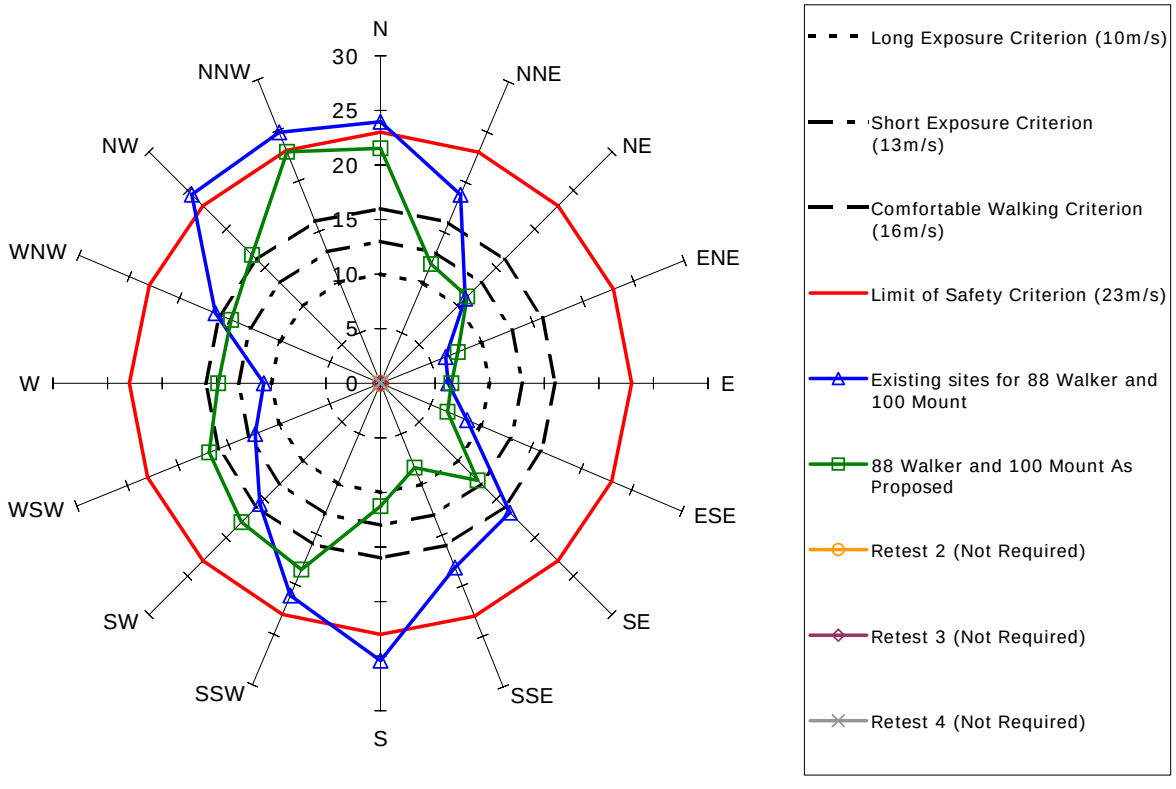


Measured Wind Speeds at Point 45

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

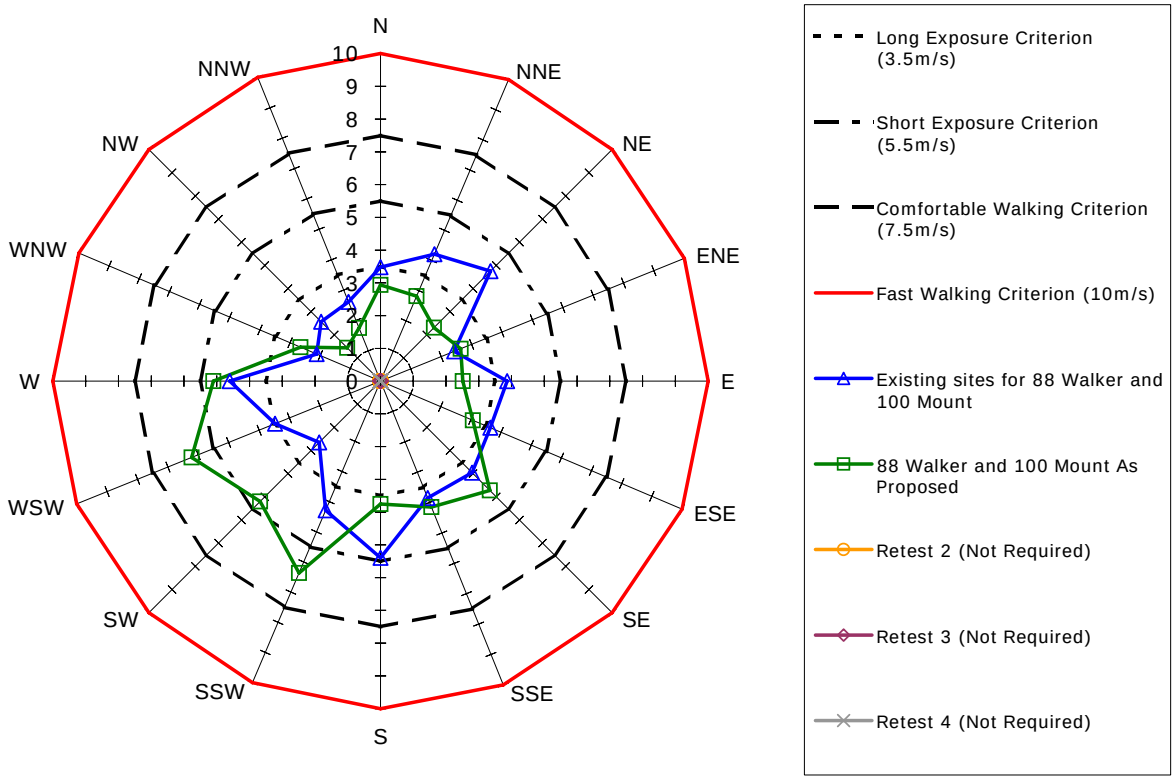


Annual Maximum Gust Wind Speeds (m/s)

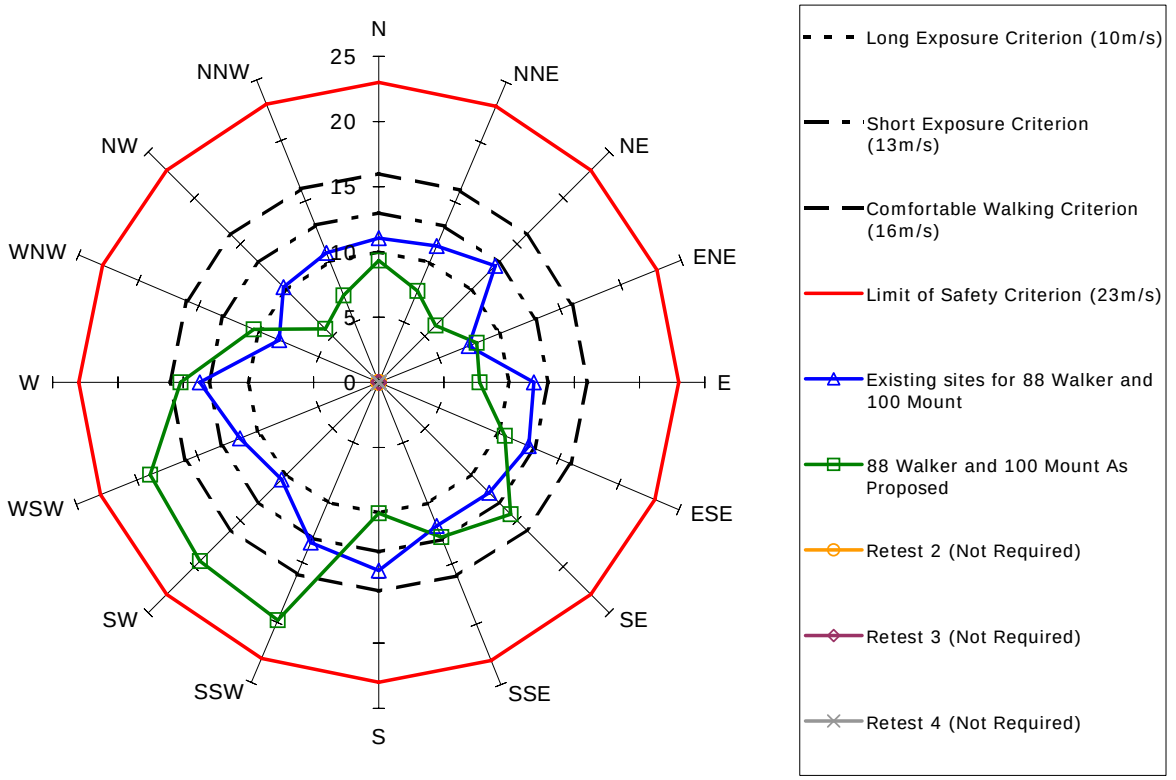


Measured Wind Speeds at Point 46

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

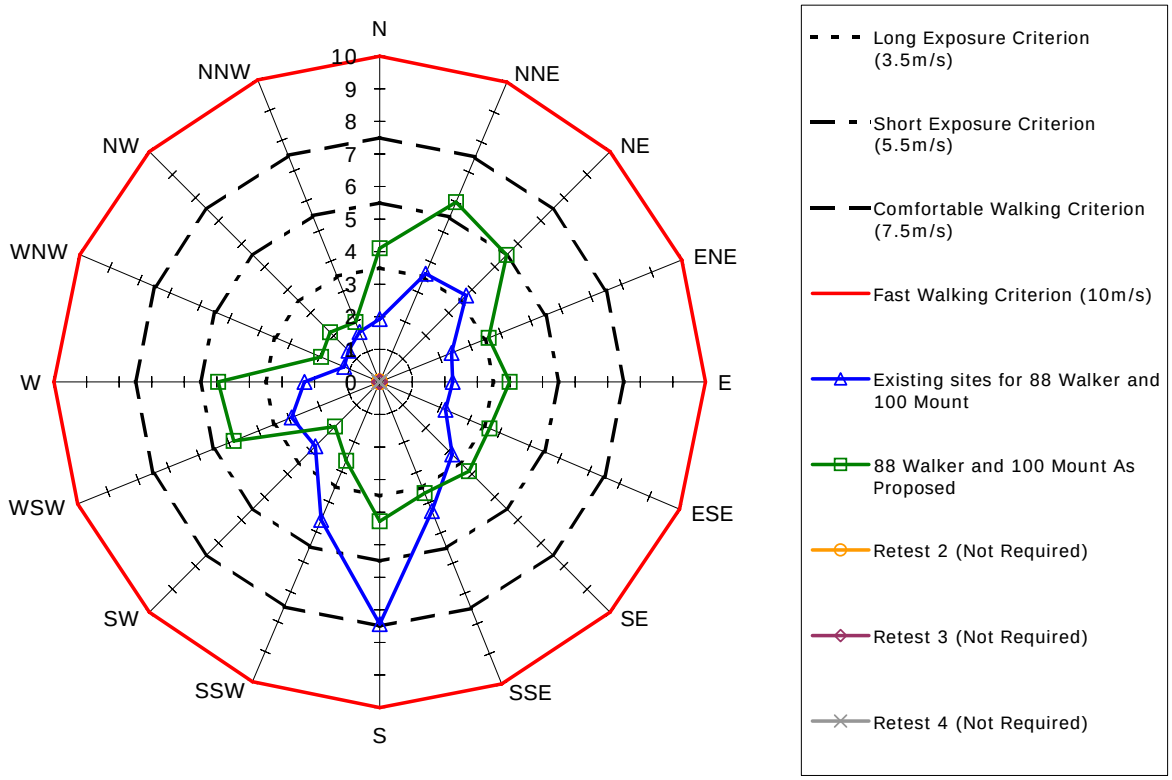


Annual Maximum Gust Wind Speeds (m/s)

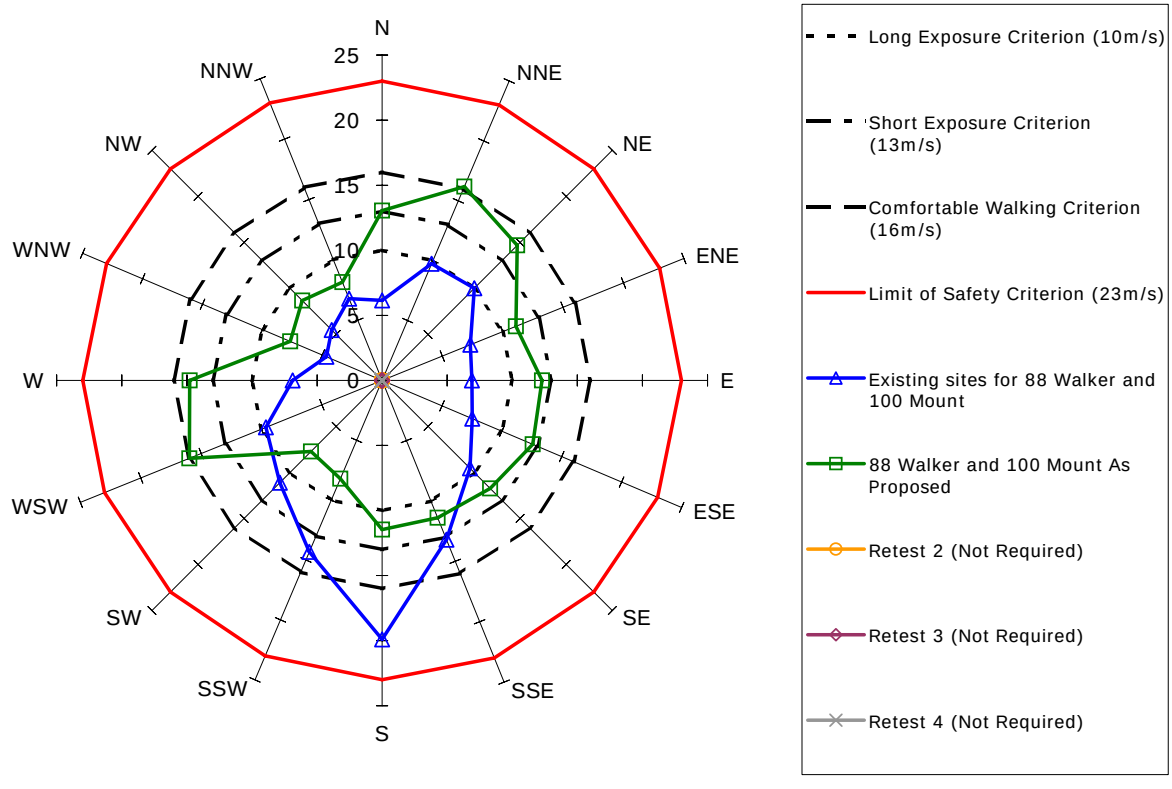


Measured Wind Speeds at Point 47

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

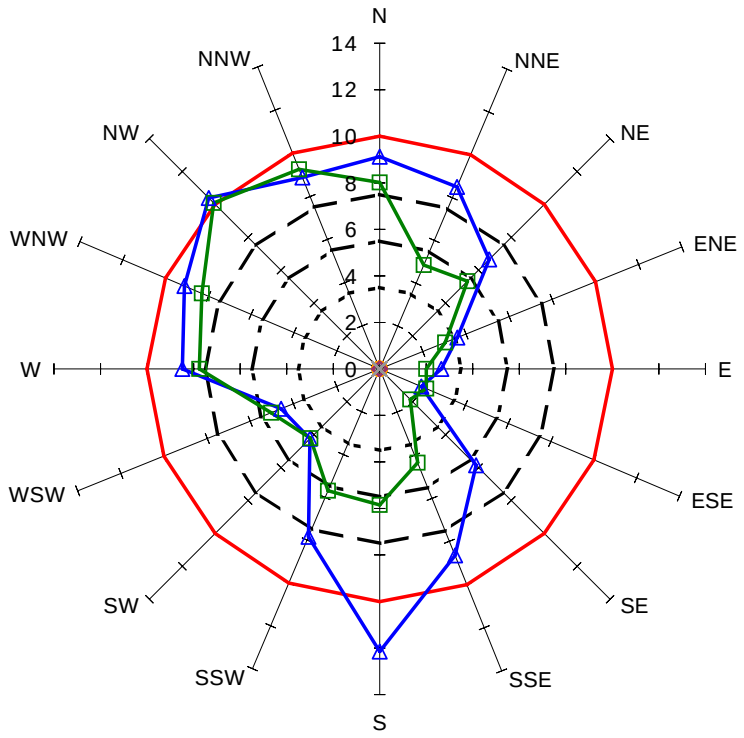


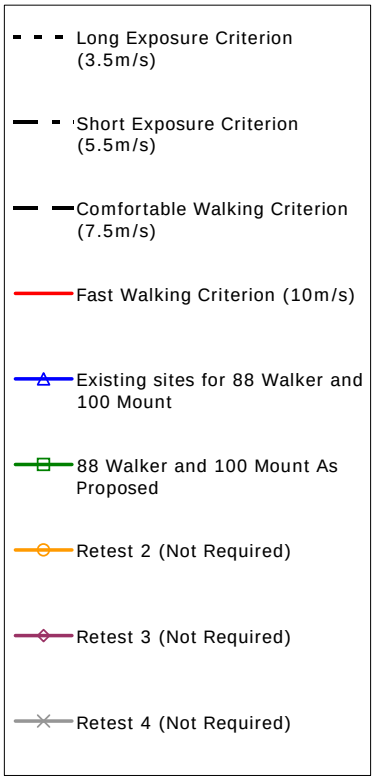
Annual Maximum Gust Wind Speeds (m/s)



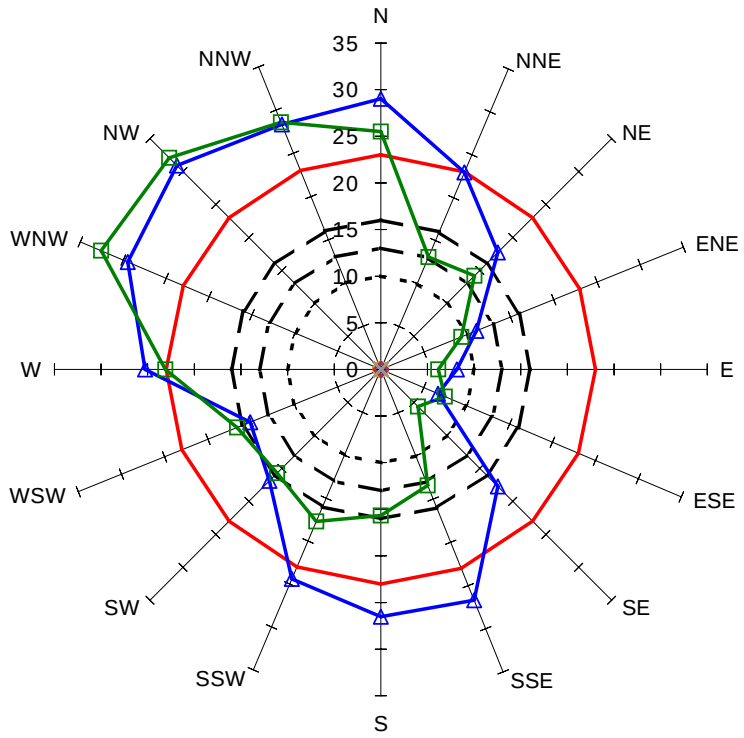
Measured Wind Speeds at Point 48

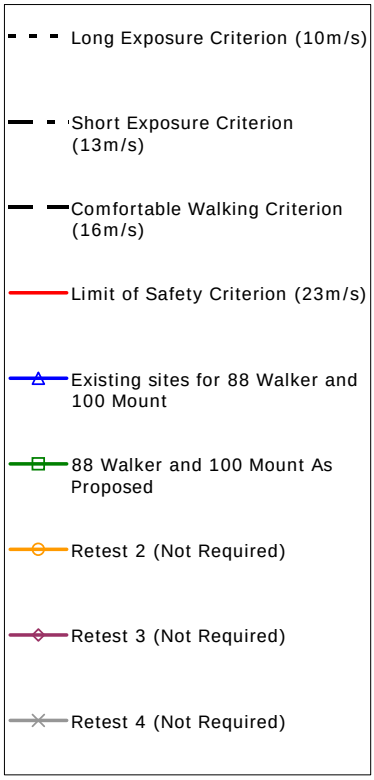
Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)





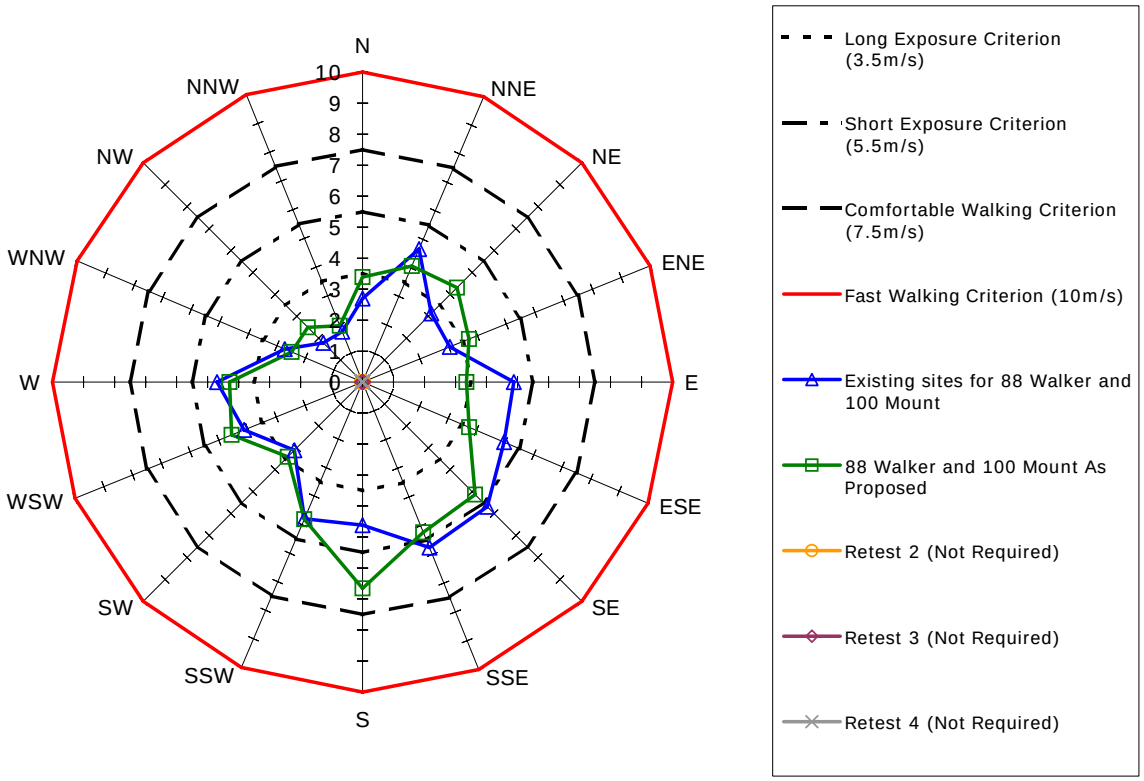
Annual Maximum Gust Wind Speeds (m/s)



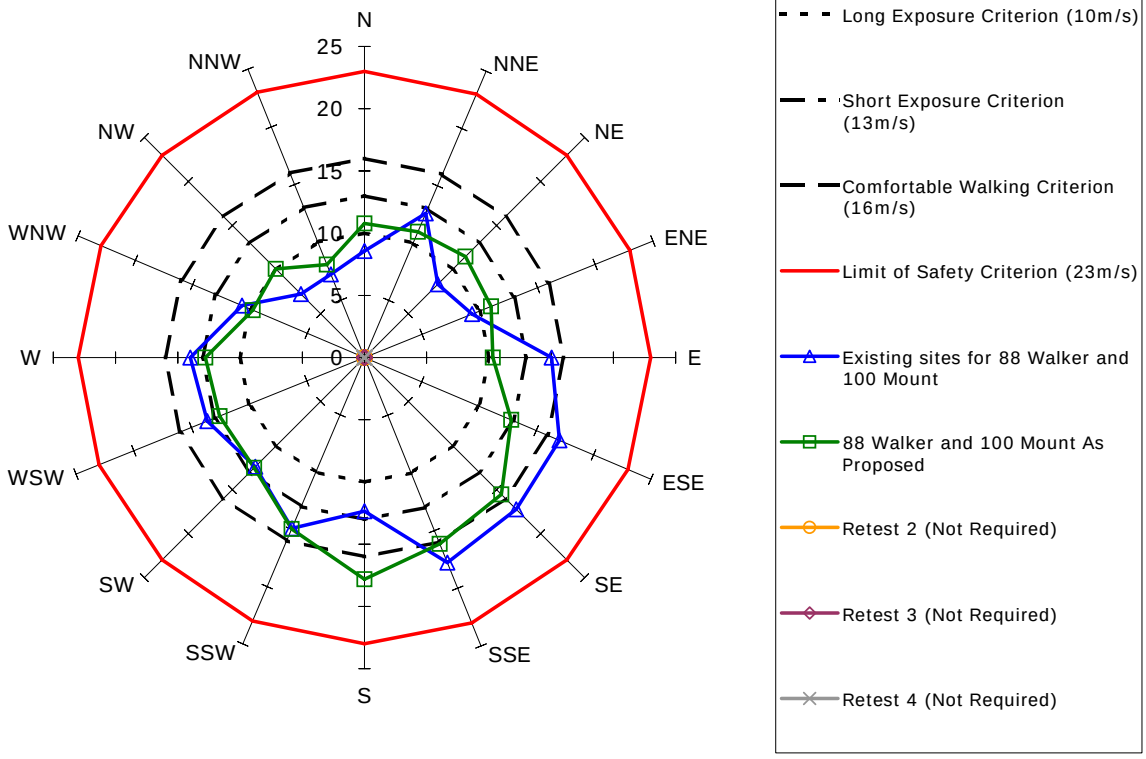


Measured Wind Speeds at Point 49

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

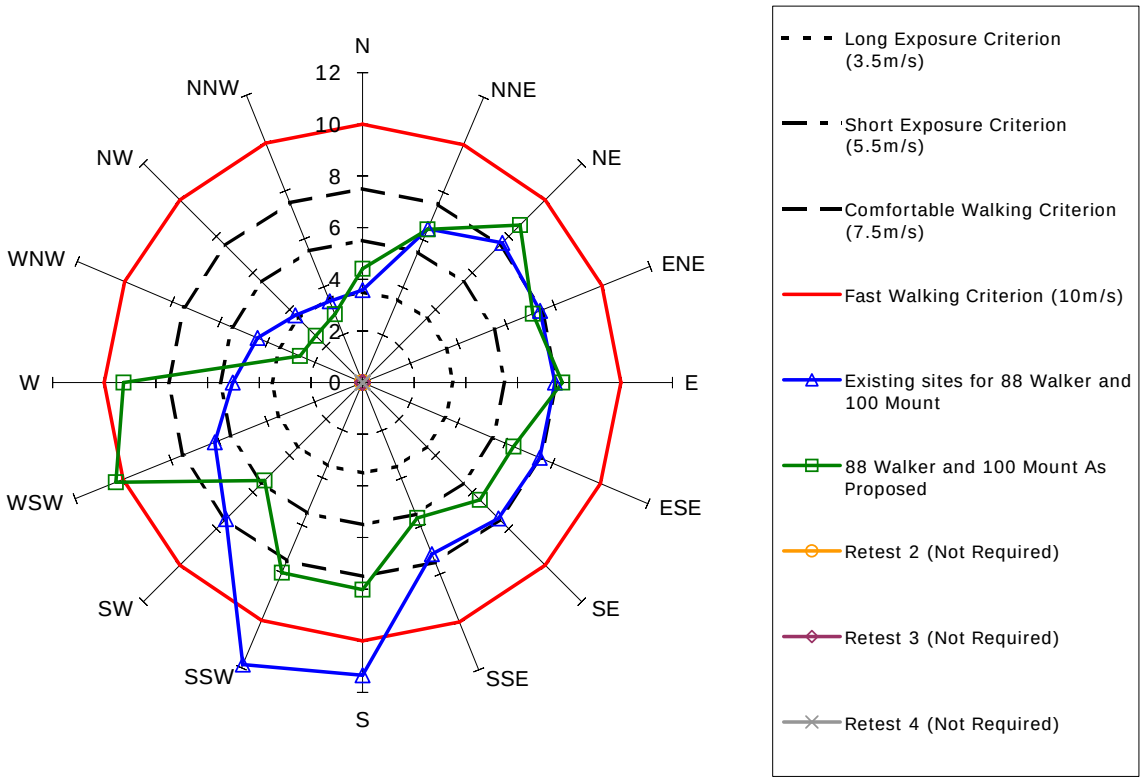


Annual Maximum Gust Wind Speeds (m/s)

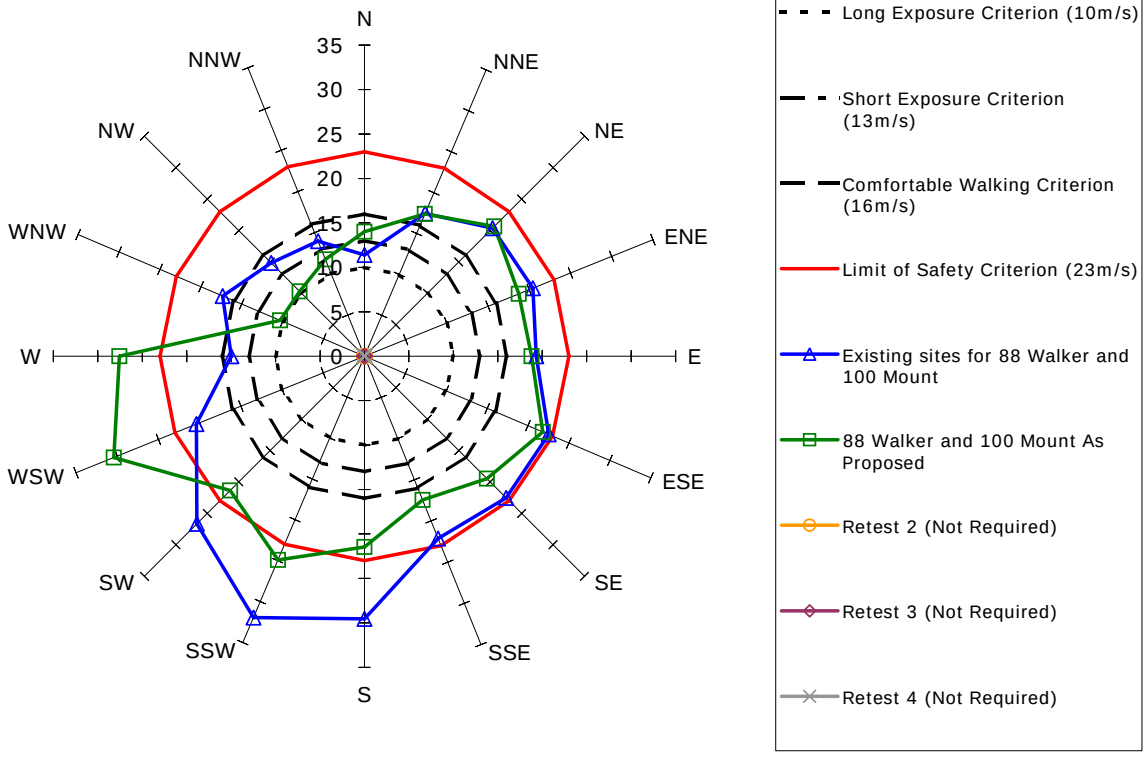


Measured Wind Speeds at Point 50

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

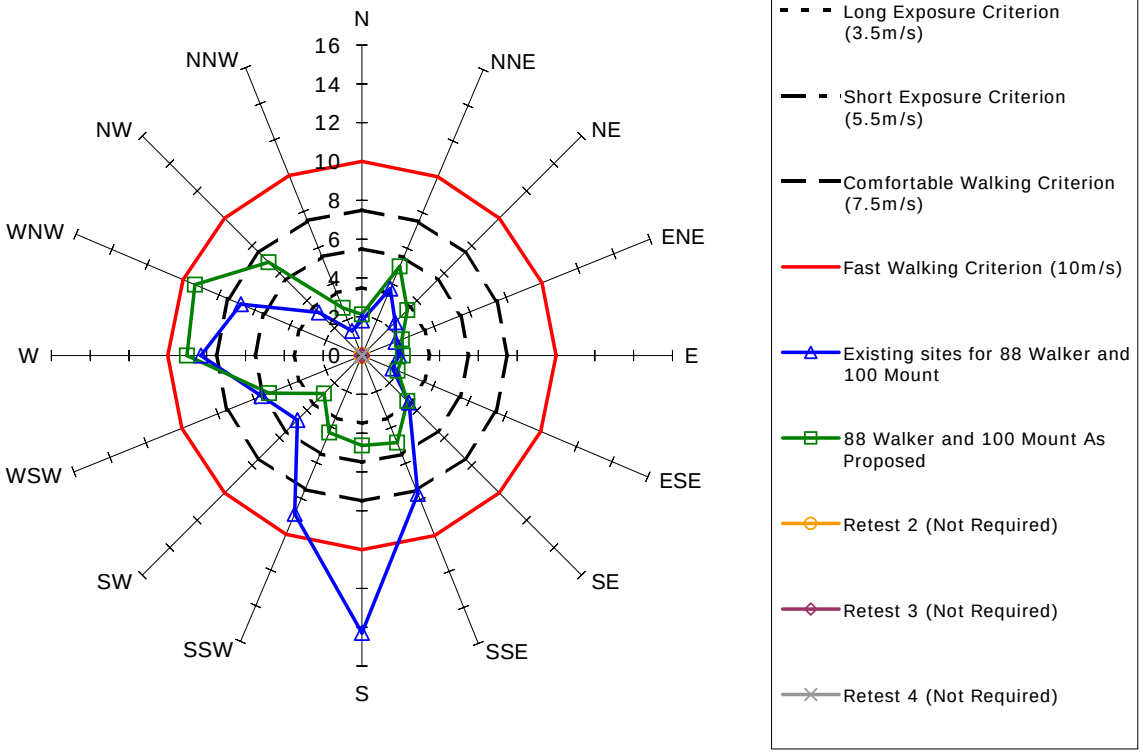


Annual Maximum Gust Wind Speeds (m/s)

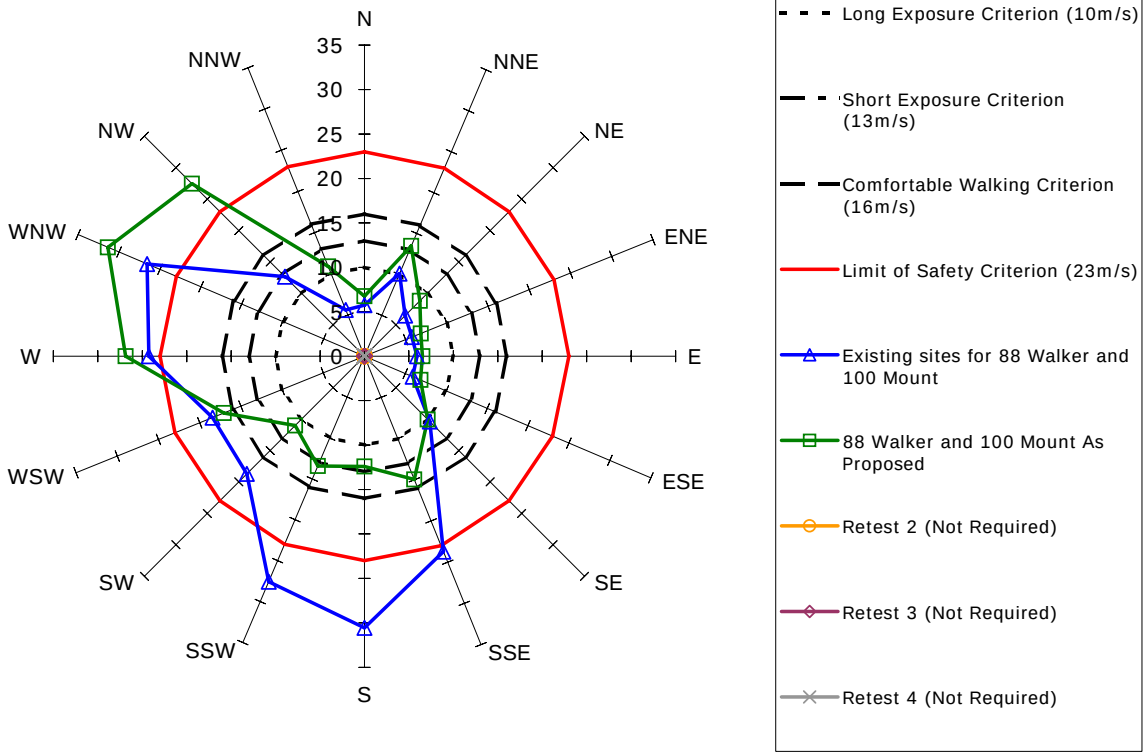


Measured Wind Speeds at Point 51

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

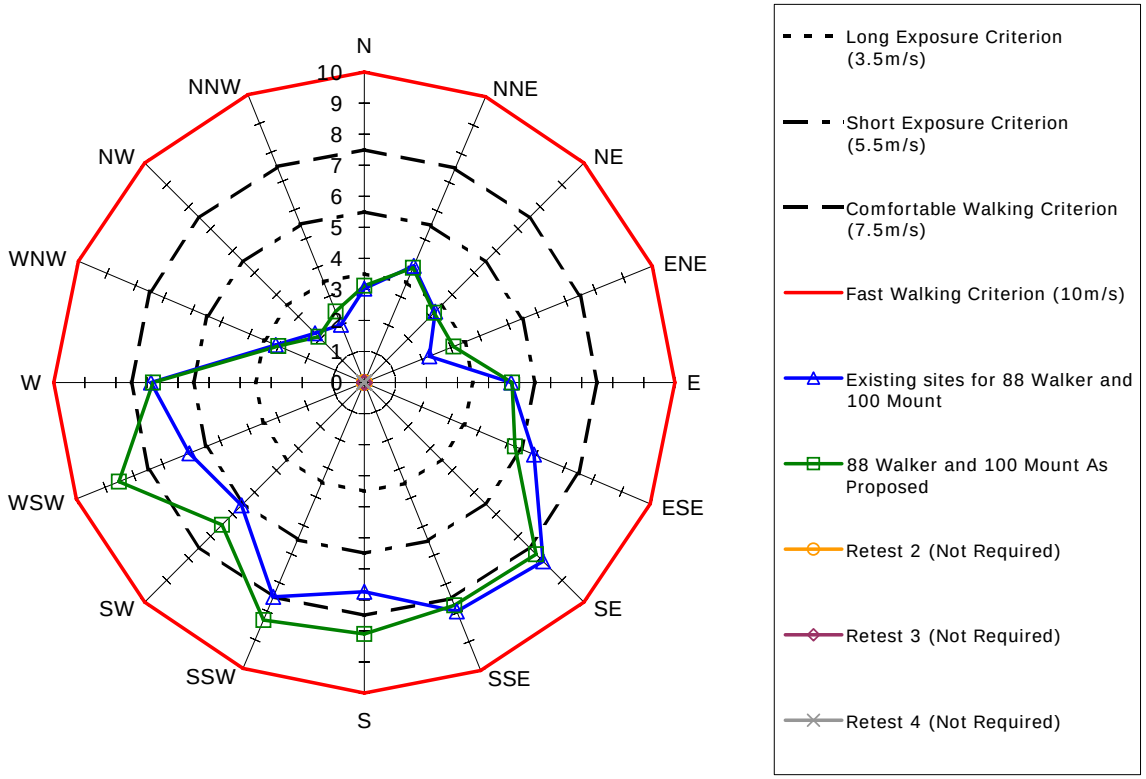


Annual Maximum Gust Wind Speeds (m/s)

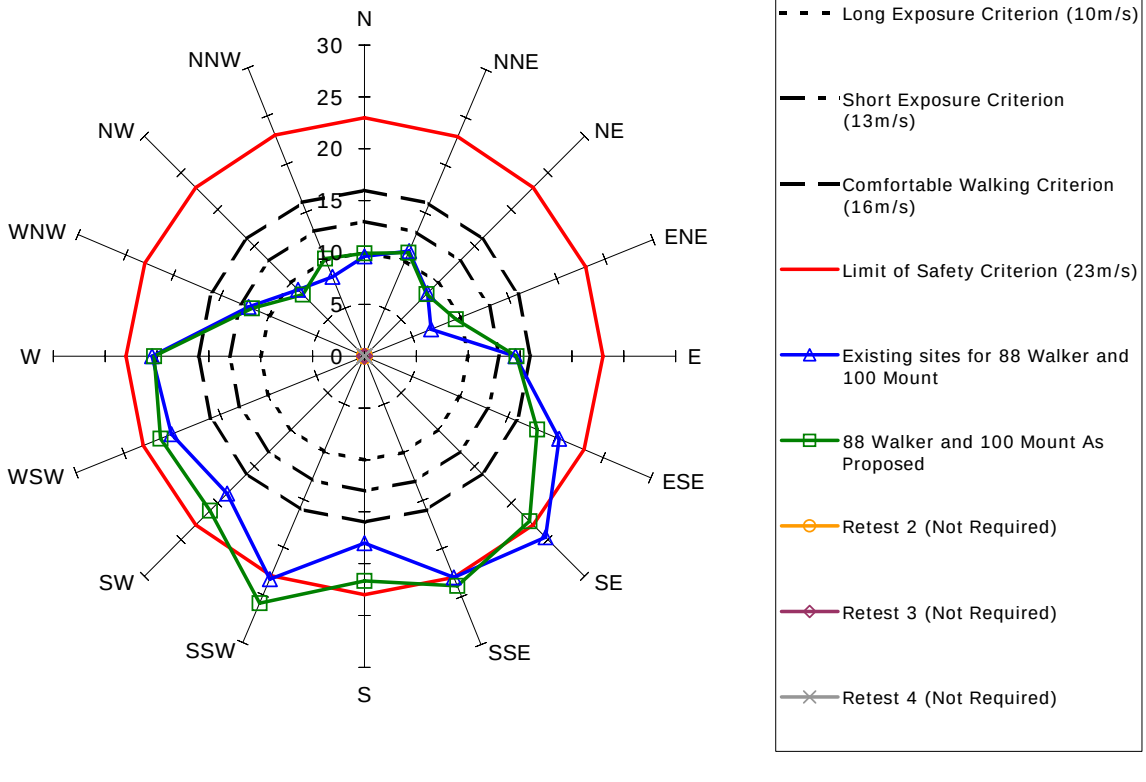


Measured Wind Speeds at Point 52

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

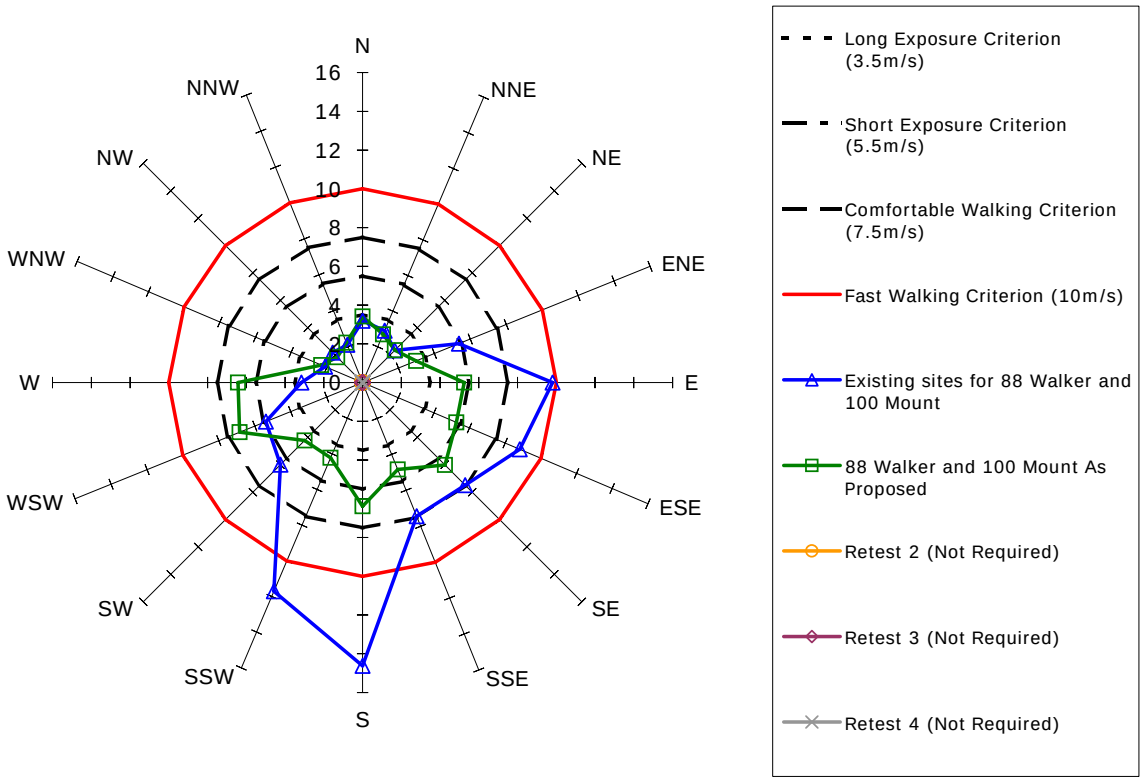


Annual Maximum Gust Wind Speeds (m/s)

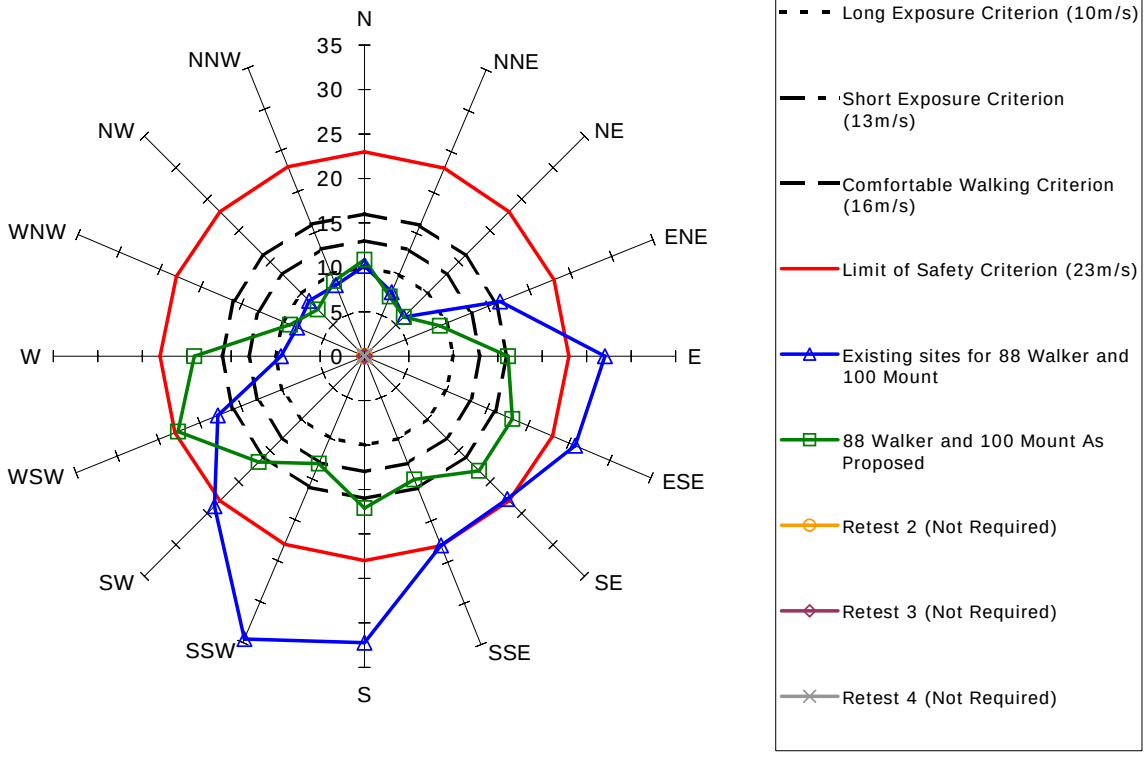


Measured Wind Speeds at Point 53

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

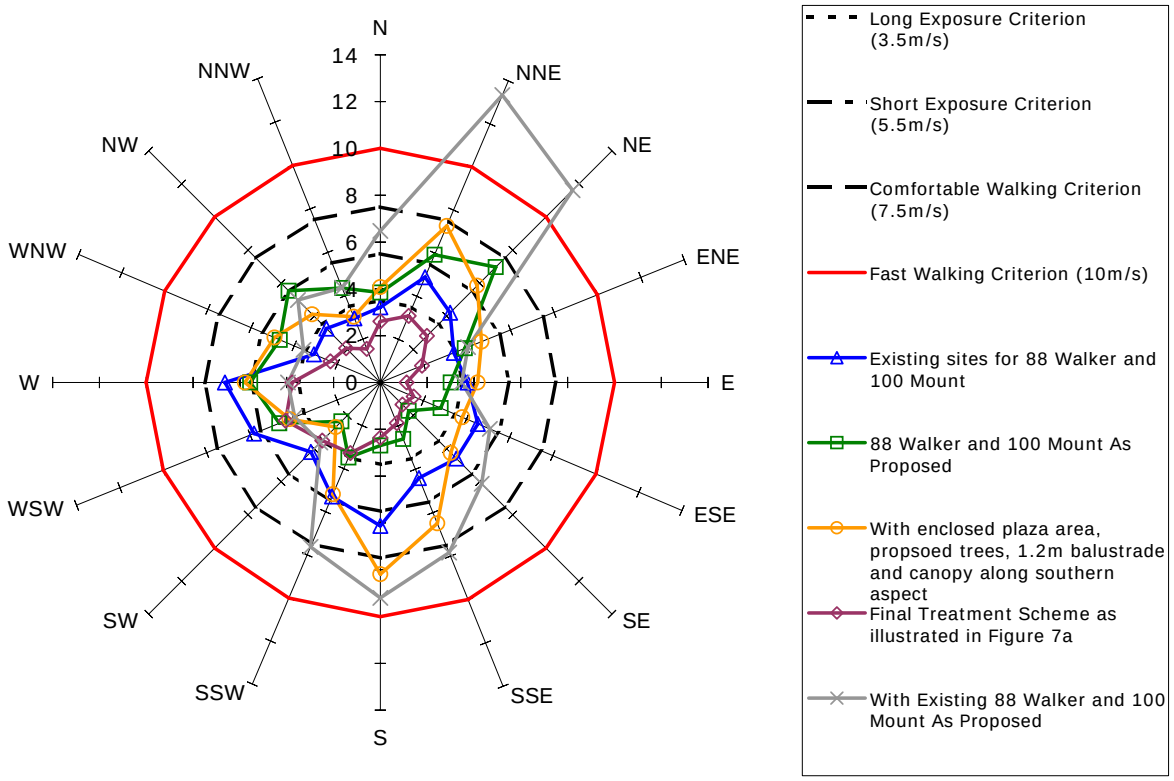


Annual Maximum Gust Wind Speeds (m/s)

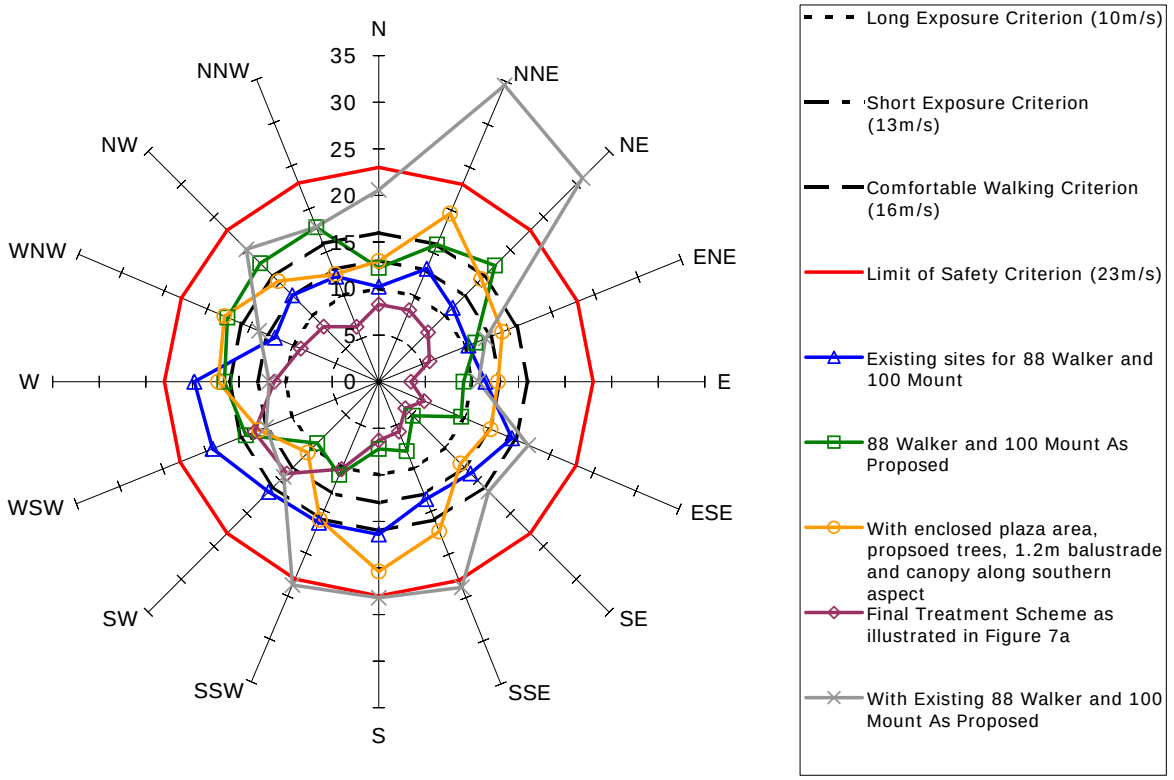


Measured Wind Speeds at Point 56

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

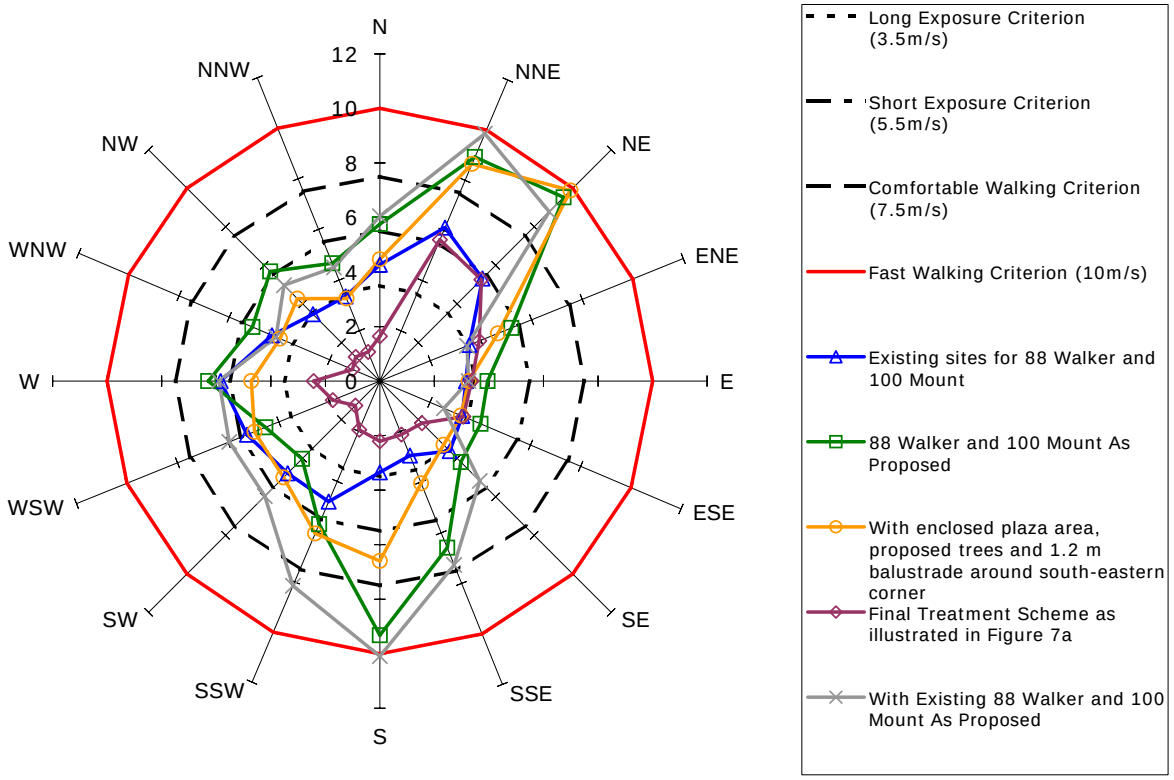


Annual Maximum Gust Wind Speeds (m/s)

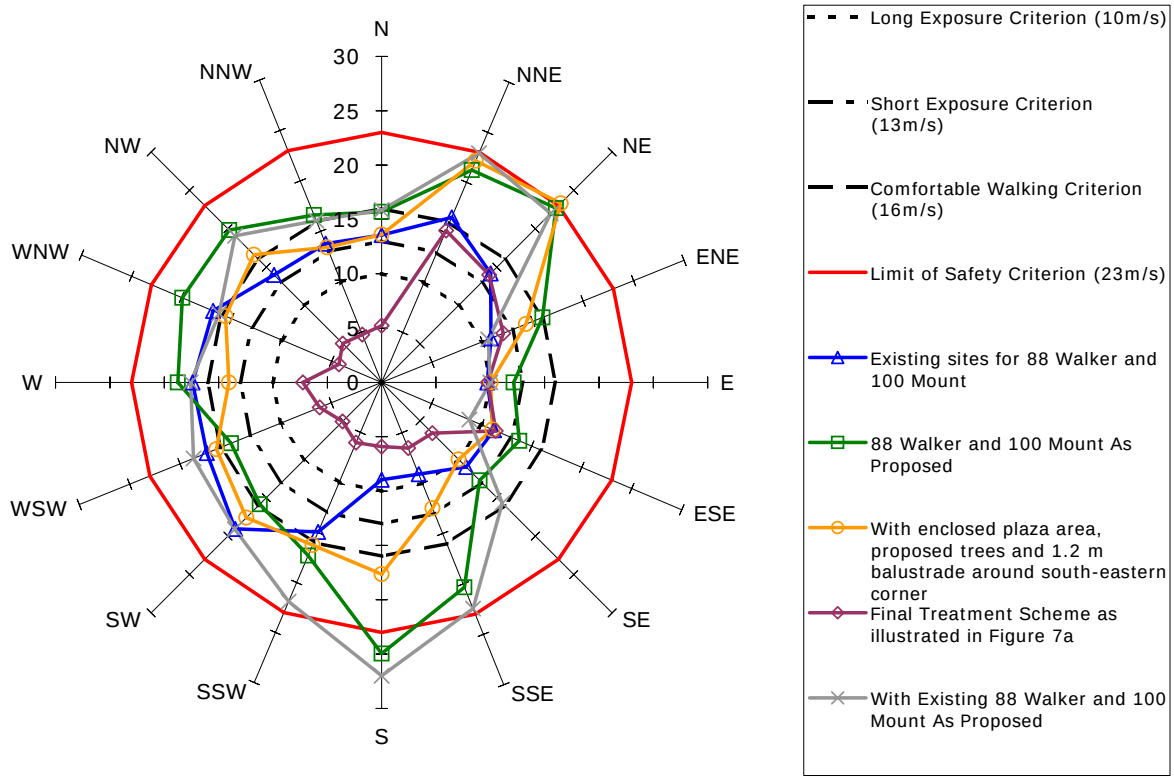


Measured Wind Speeds at Point 57

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

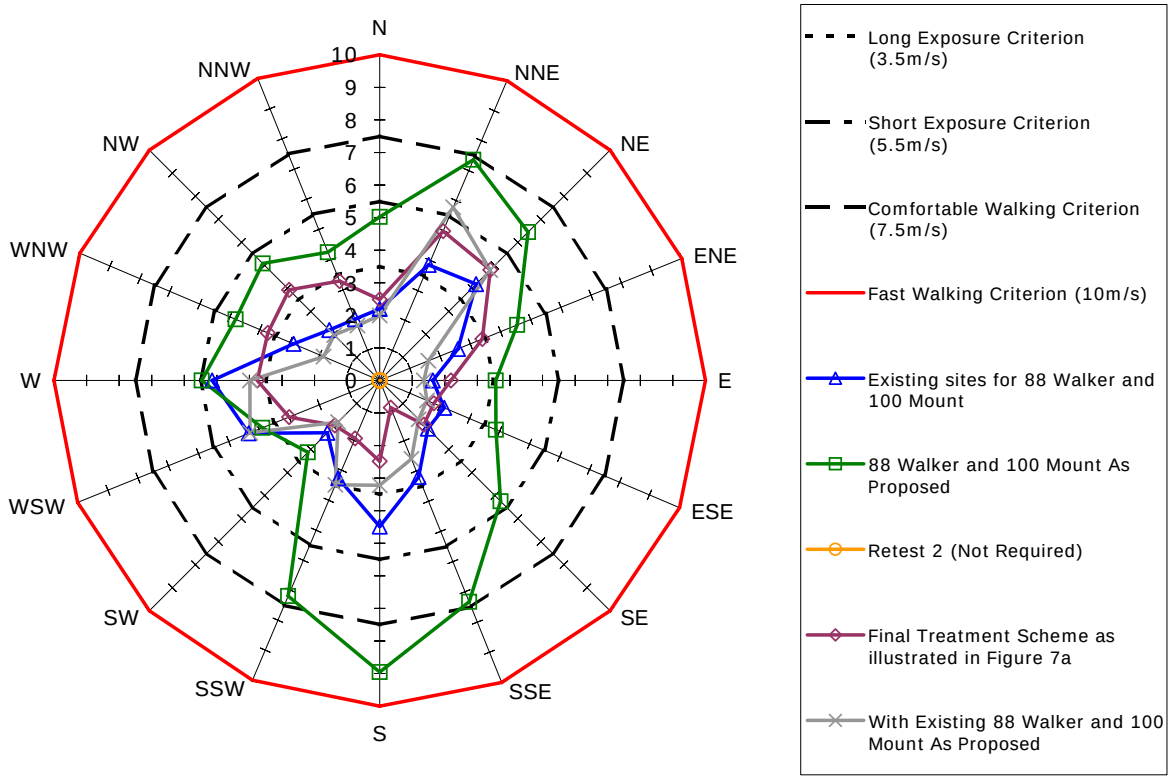


Annual Maximum Gust Wind Speeds (m/s)

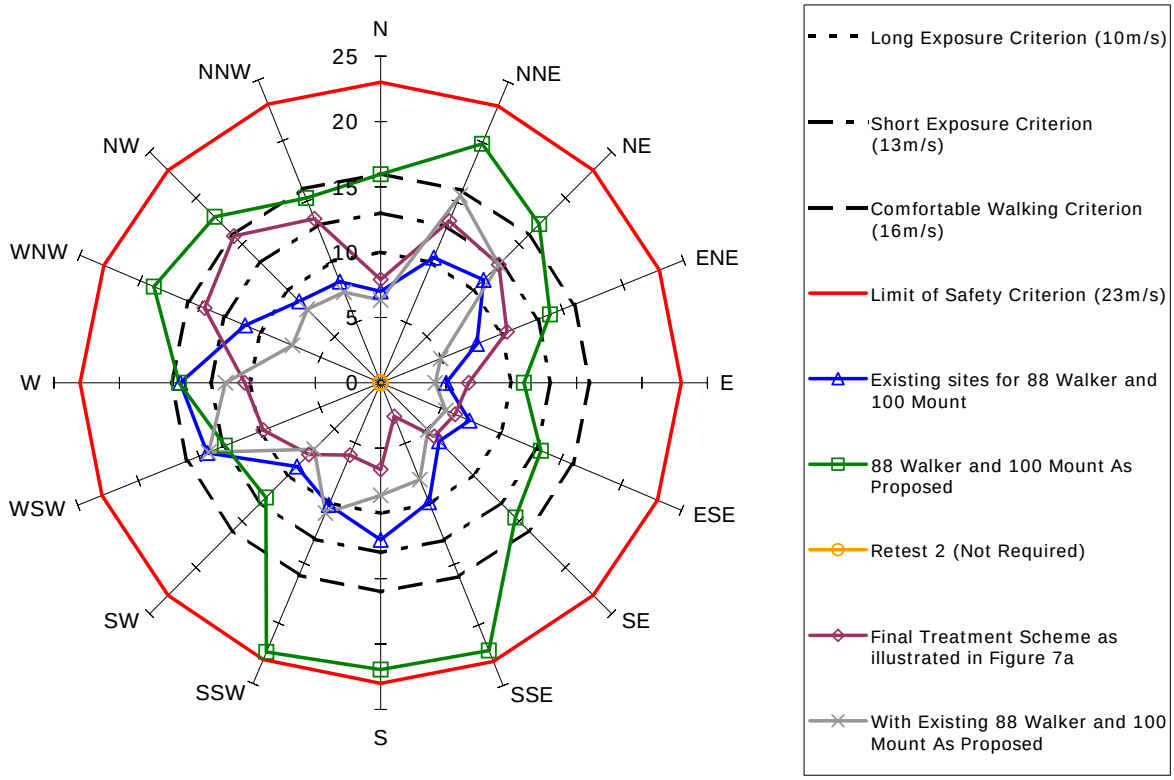


Measured Wind Speeds at Point 58

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

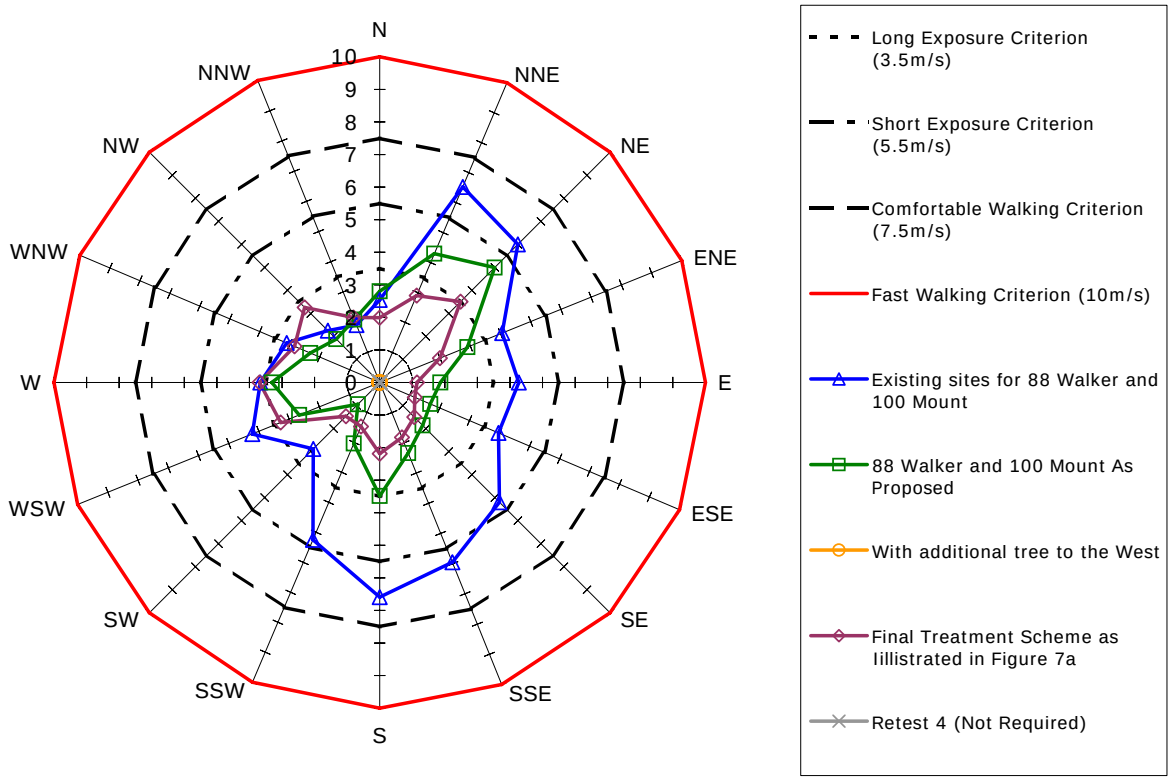


Annual Maximum Gust Wind Speeds (m/s)

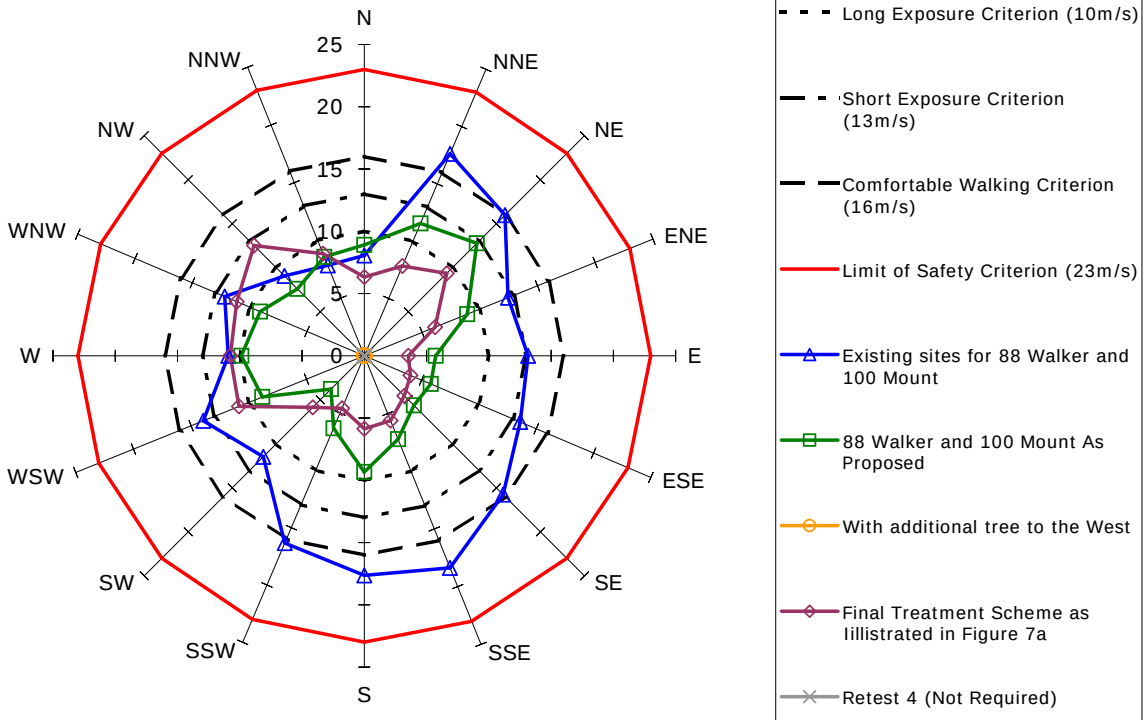


Measured Wind Speeds at Point 59

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

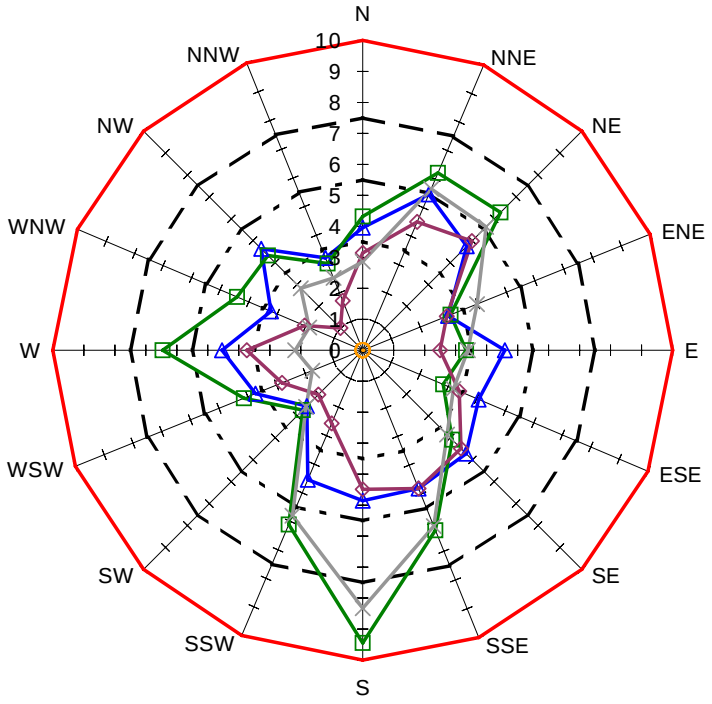


Annual Maximum Gust Wind Speeds (m/s)



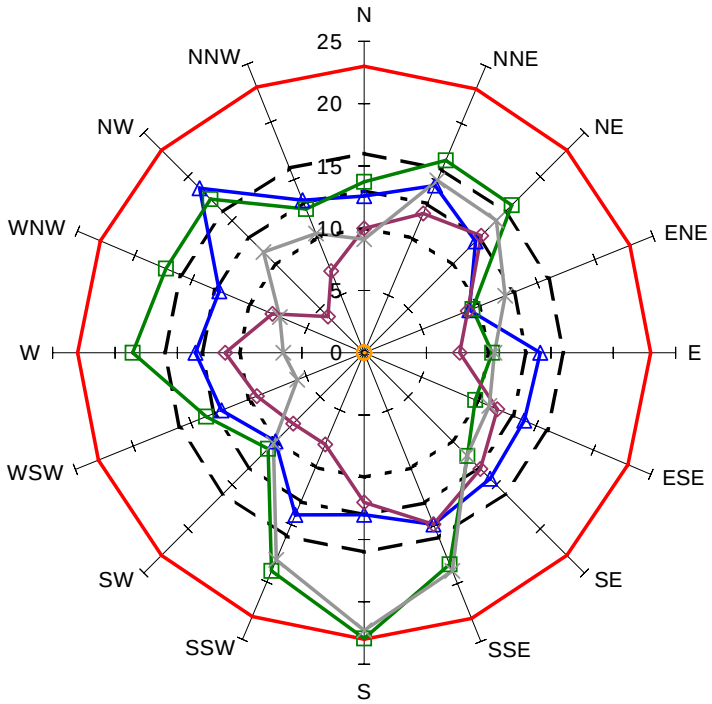
Measured Wind Speeds at Point 60

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)



- Long Exposure Criterion (3.5m/s)
- Short Exposure Criterion (5.5m/s)
- Comfortable Walking Criterion (7.5m/s)
- Fast Walking Criterion (10m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- Final Treatment Scheme as Iillistrated in Figure 7a
- With Existing 88 Walker and 100 Mount As Proposed

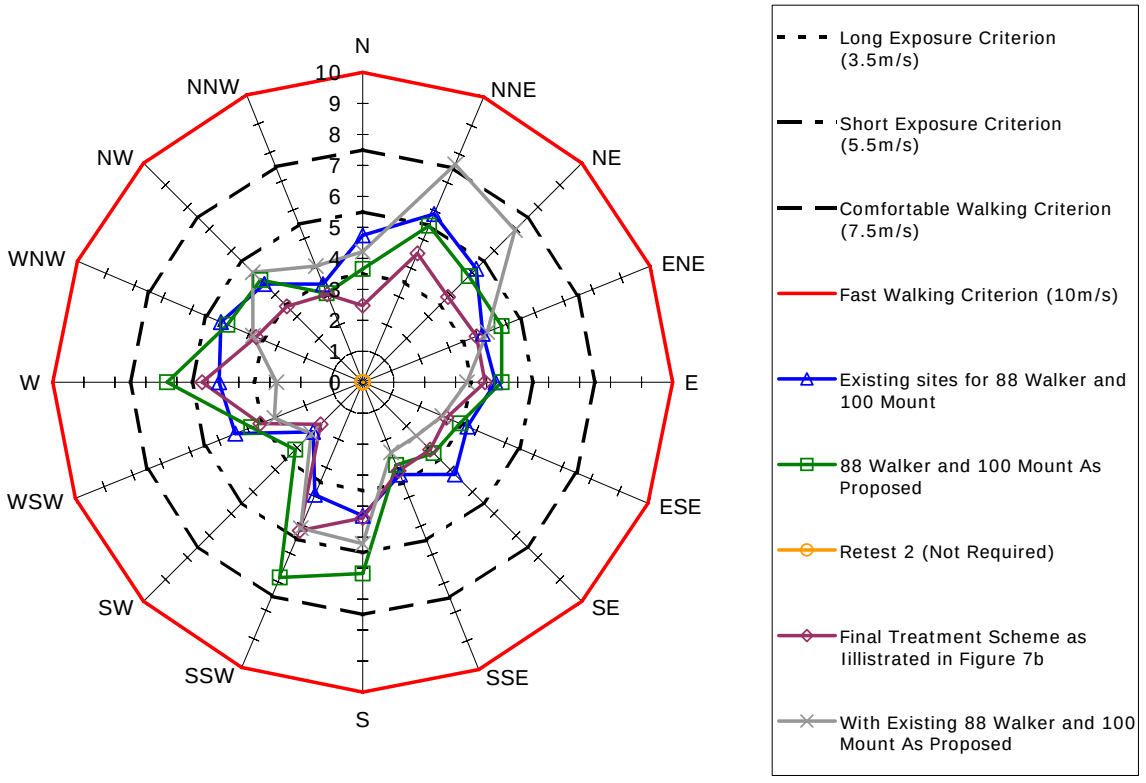
Annual Maximum Gust Wind Speeds (m/s)



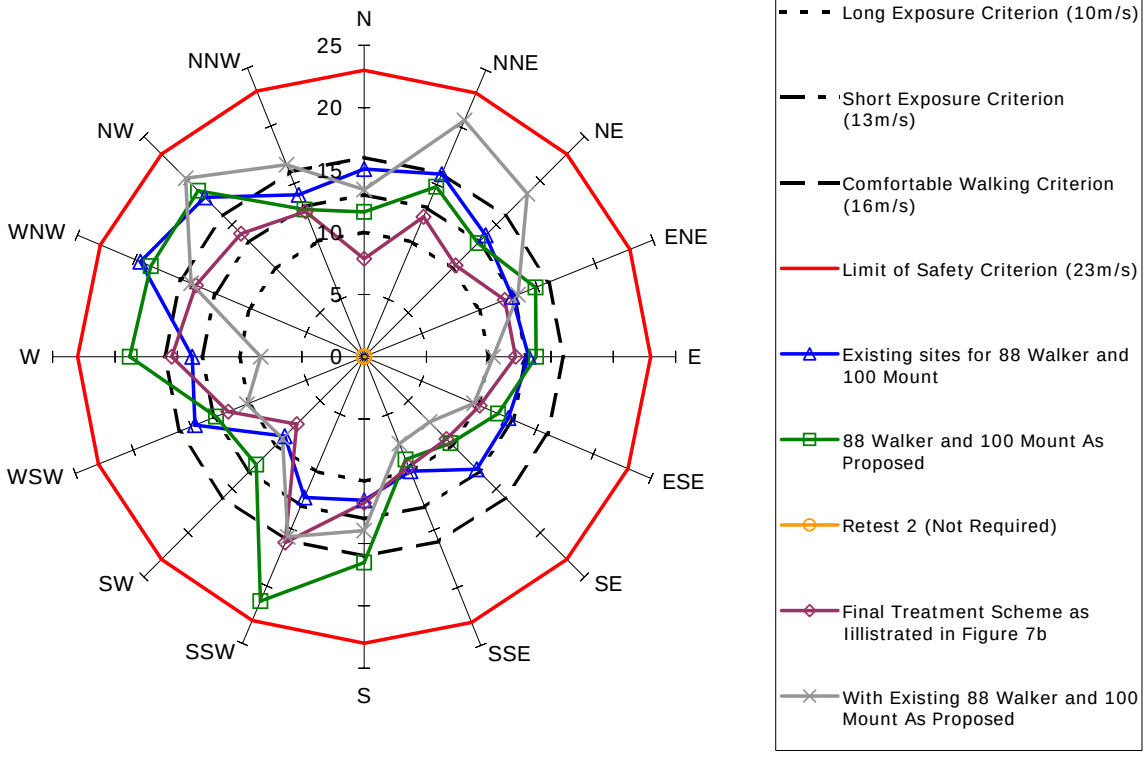
- Long Exposure Criterion (10m/s)
- Short Exposure Criterion (13m/s)
- Comfortable Walking Criterion (16m/s)
- Limit of Safety Criterion (23m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- Final Treatment Scheme as Iillistrated in Figure 7a
- With Existing 88 Walker and 100 Mount As Proposed

Measured Wind Speeds at Point 61

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

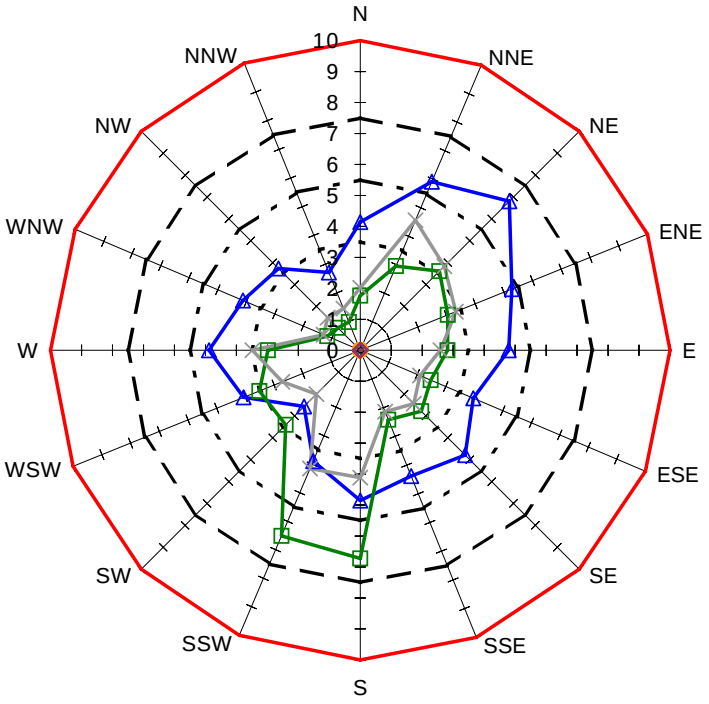


Annual Maximum Gust Wind Speeds (m/s)



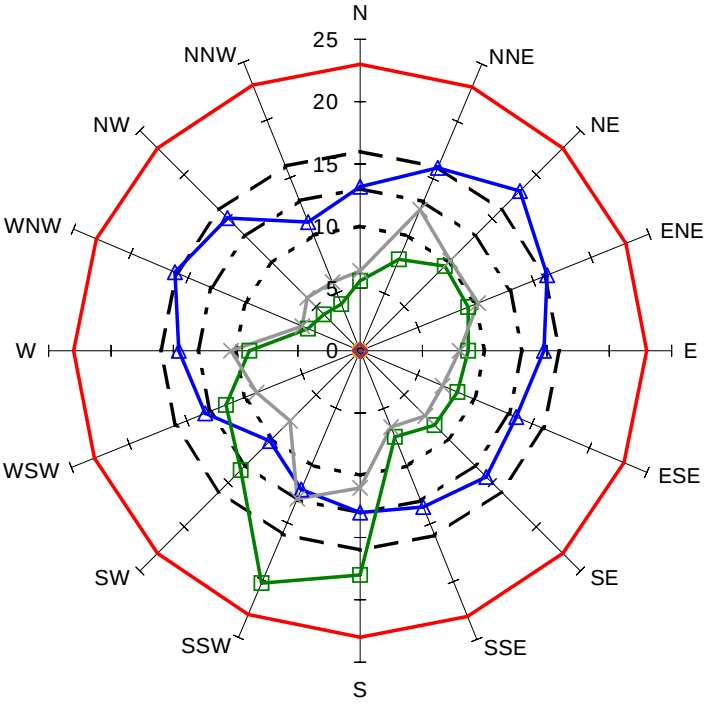
Measured Wind Speeds at Point 62

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)



- Long Exposure Criterion (3.5m/s)
- Short Exposure Criterion (5.5m/s)
- Comfortable Walking Criterion (7.5m/s)
- Fast Walking Criterion (10m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- Retest 3 (Not Required)
- With Existing 88 Walker and 100 Mount As Proposed

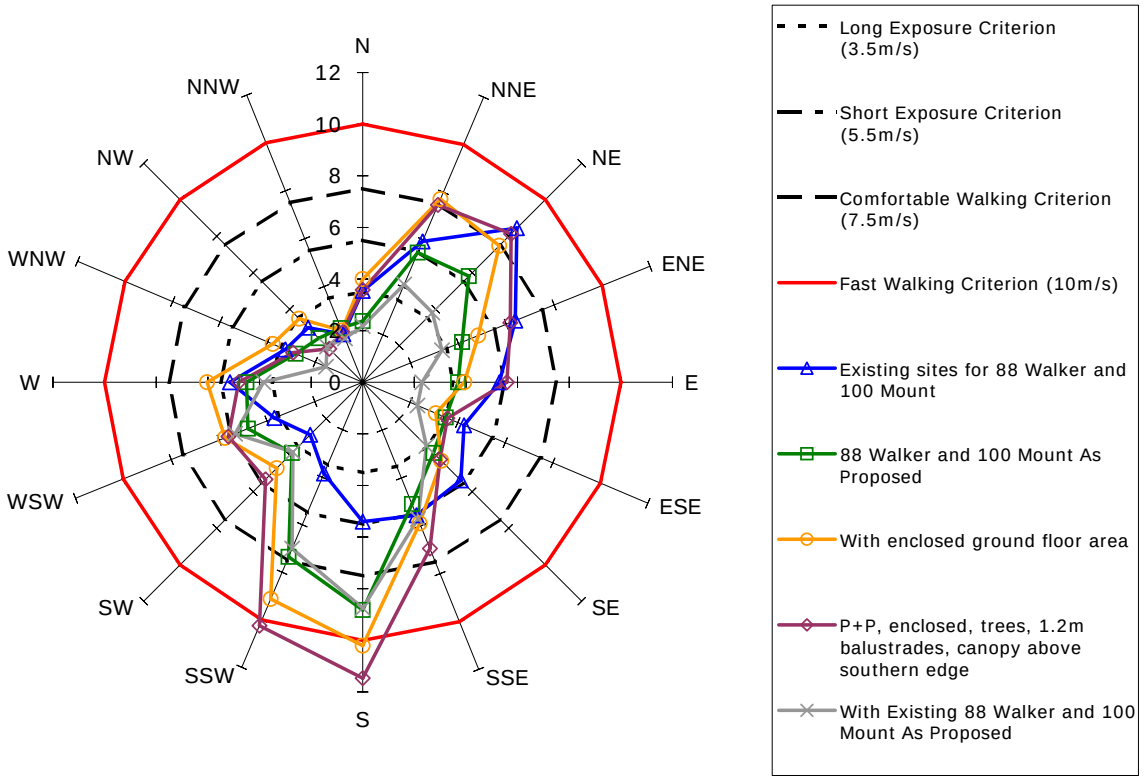
Annual Maximum Gust Wind Speeds (m/s)



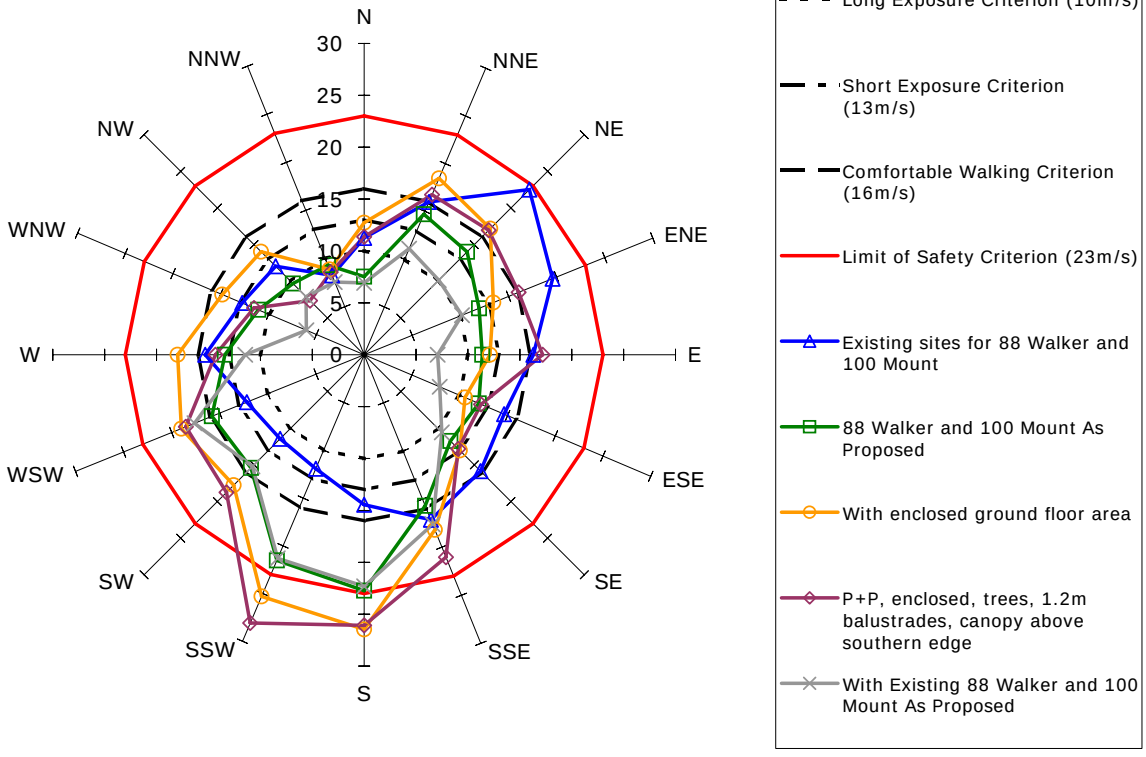
- Long Exposure Criterion (10m/s)
- Short Exposure Criterion (13m/s)
- Comfortable Walking Criterion (16m/s)
- Limit of Safety Criterion (23m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- Retest 3 (Not Required)
- With Existing 88 Walker and 100 Mount As Proposed

Measured Wind Speeds at Point 63

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

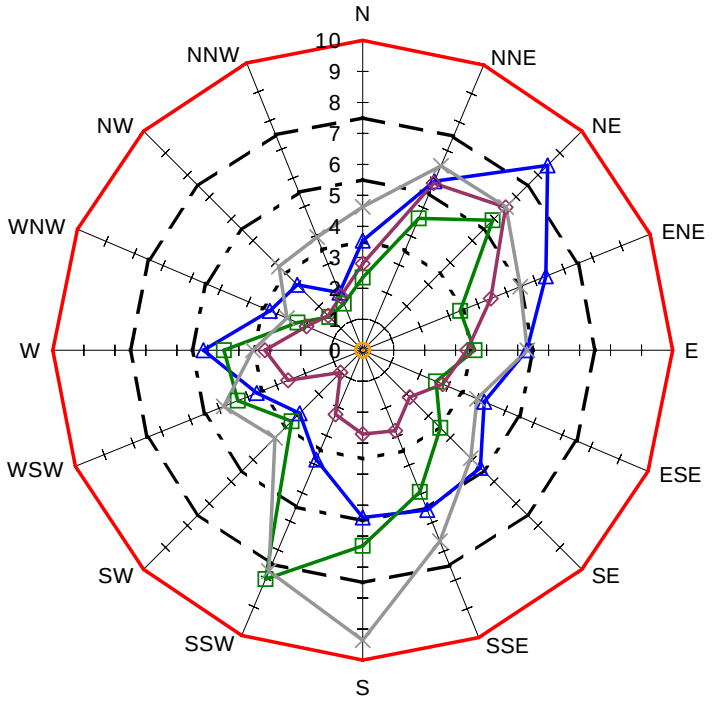


Annual Maximum Gust Wind Speeds (m/s)



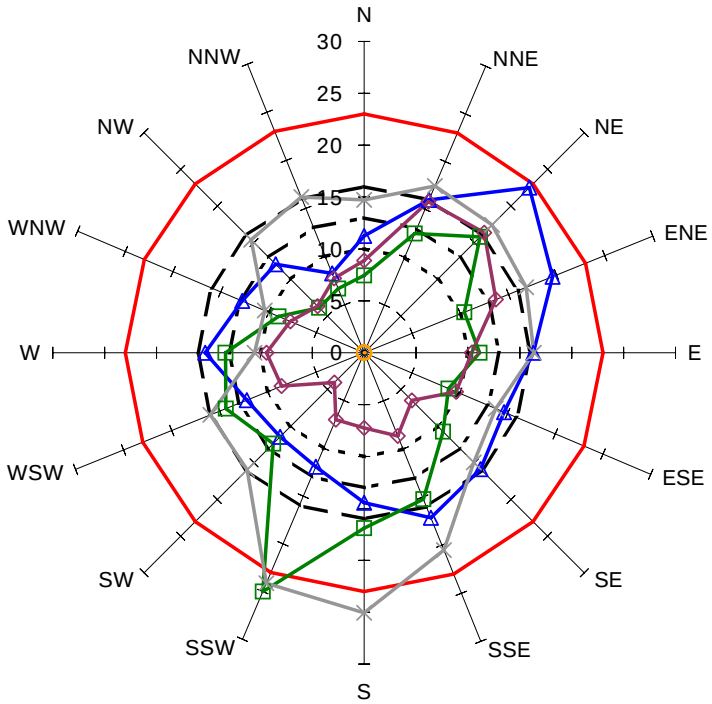
Measured Wind Speeds at Point 64

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)



- Long Exposure Criterion (3.5m/s)
- Short Exposure Criterion (5.5m/s)
- Comfortable Walking Criterion (7.5m/s)
- Fast Walking Criterion (10m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- Final Treatment Scheme as Iillistrated in Figure 7a
- With Existing 88 Walker and 100 Mount As Proposed

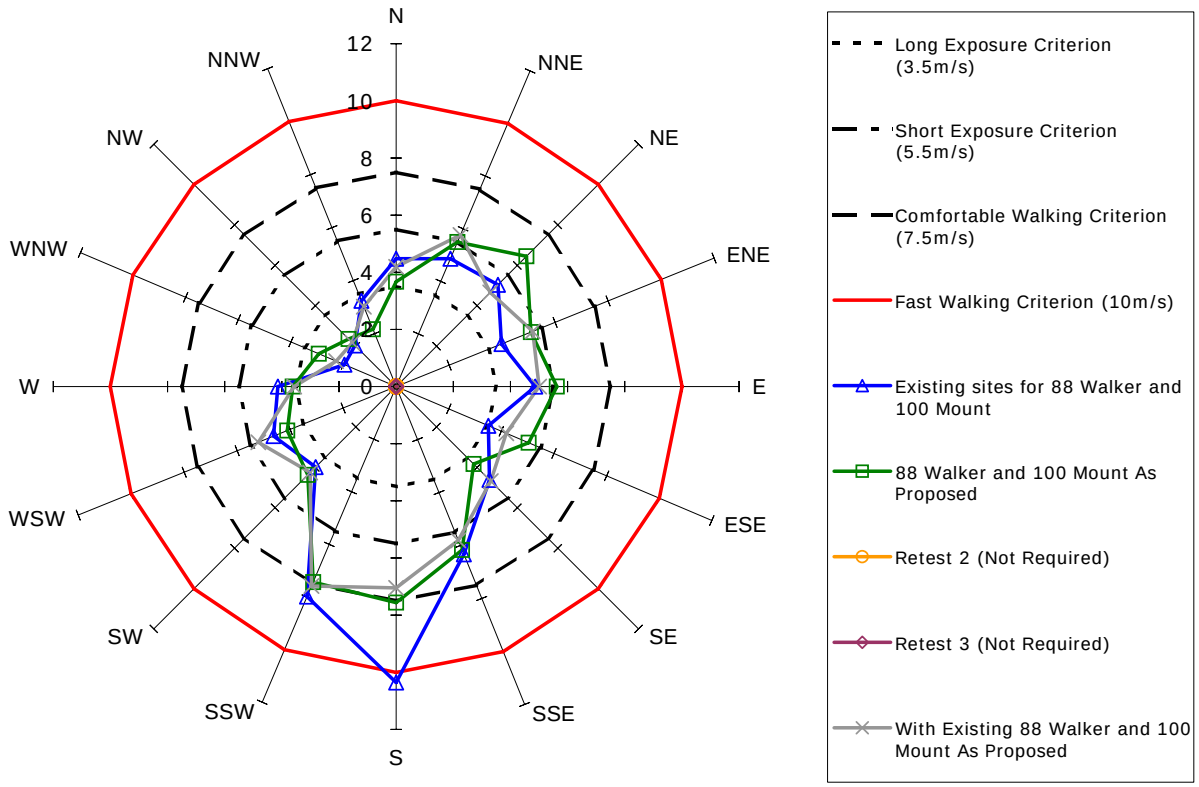
Annual Maximum Gust Wind Speeds (m/s)



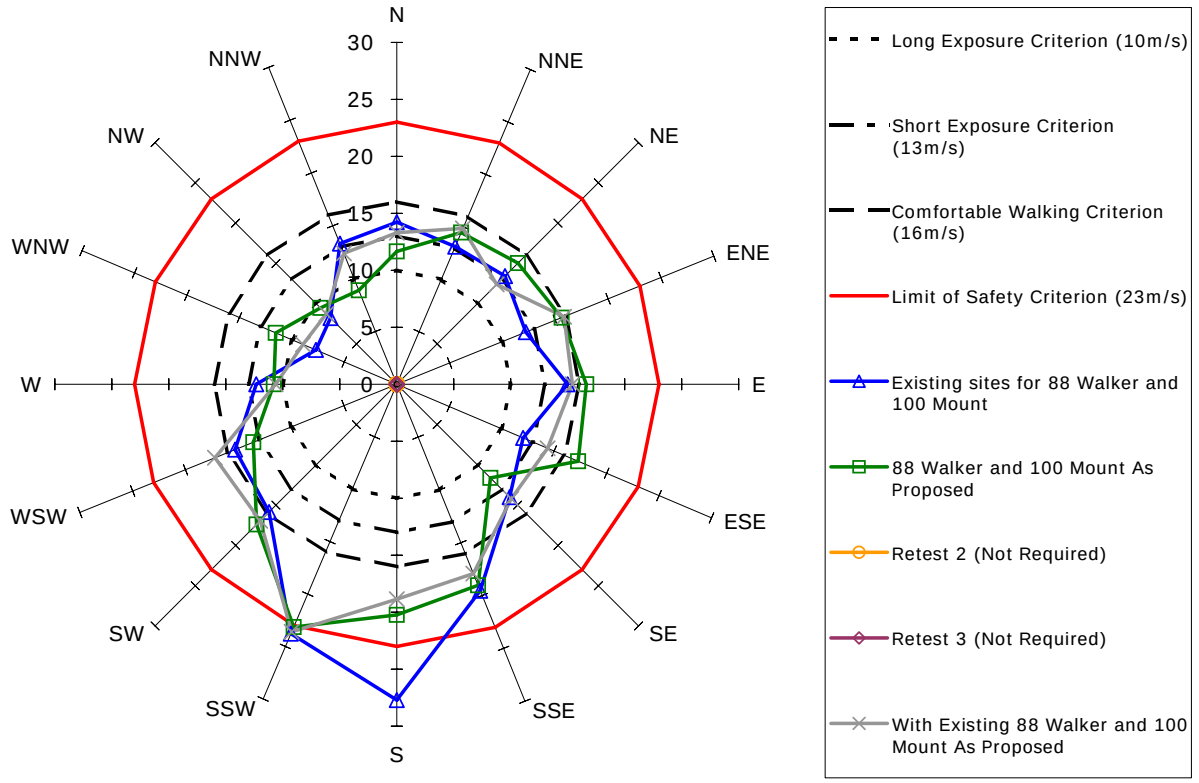
- Long Exposure Criterion (10m/s)
- Short Exposure Criterion (13m/s)
- Comfortable Walking Criterion (16m/s)
- Limit of Safety Criterion (23m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- Final Treatment Scheme as Iillistrated in Figure 7a
- With Existing 88 Walker and 100 Mount As Proposed

Measured Wind Speeds at Point 65

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

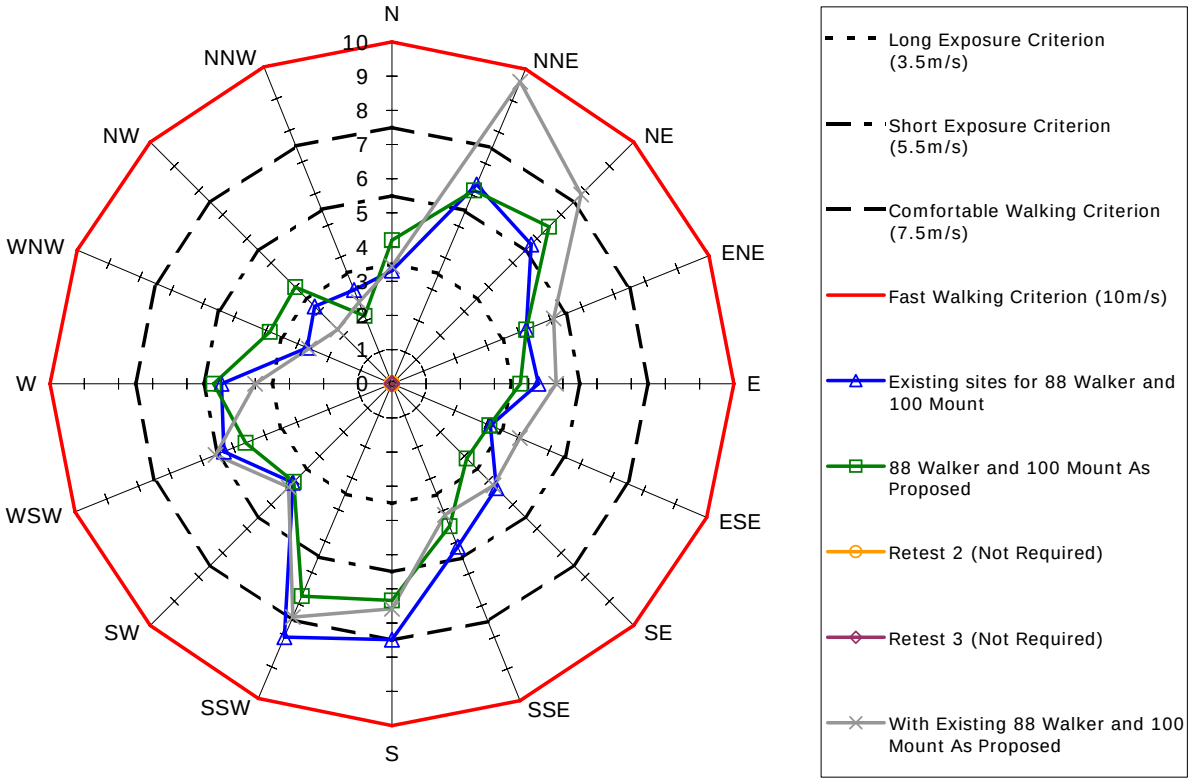


Annual Maximum Gust Wind Speeds (m/s)

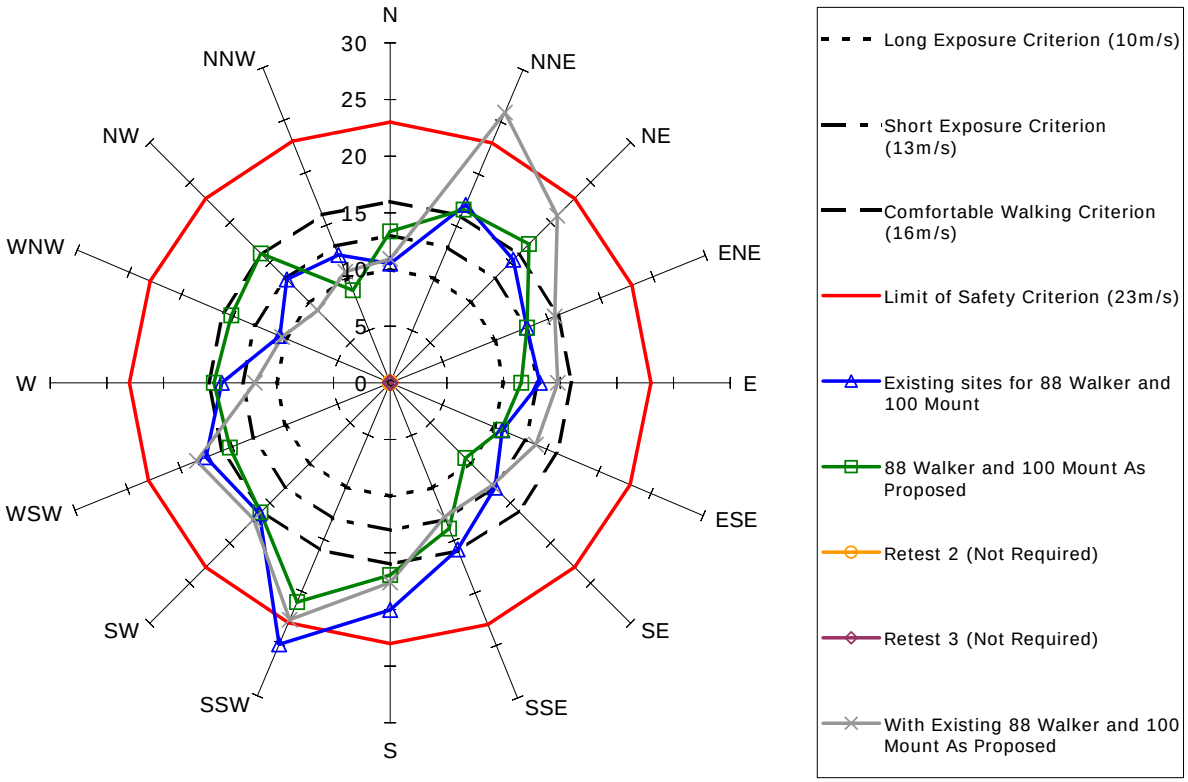


Measured Wind Speeds at Point 66

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

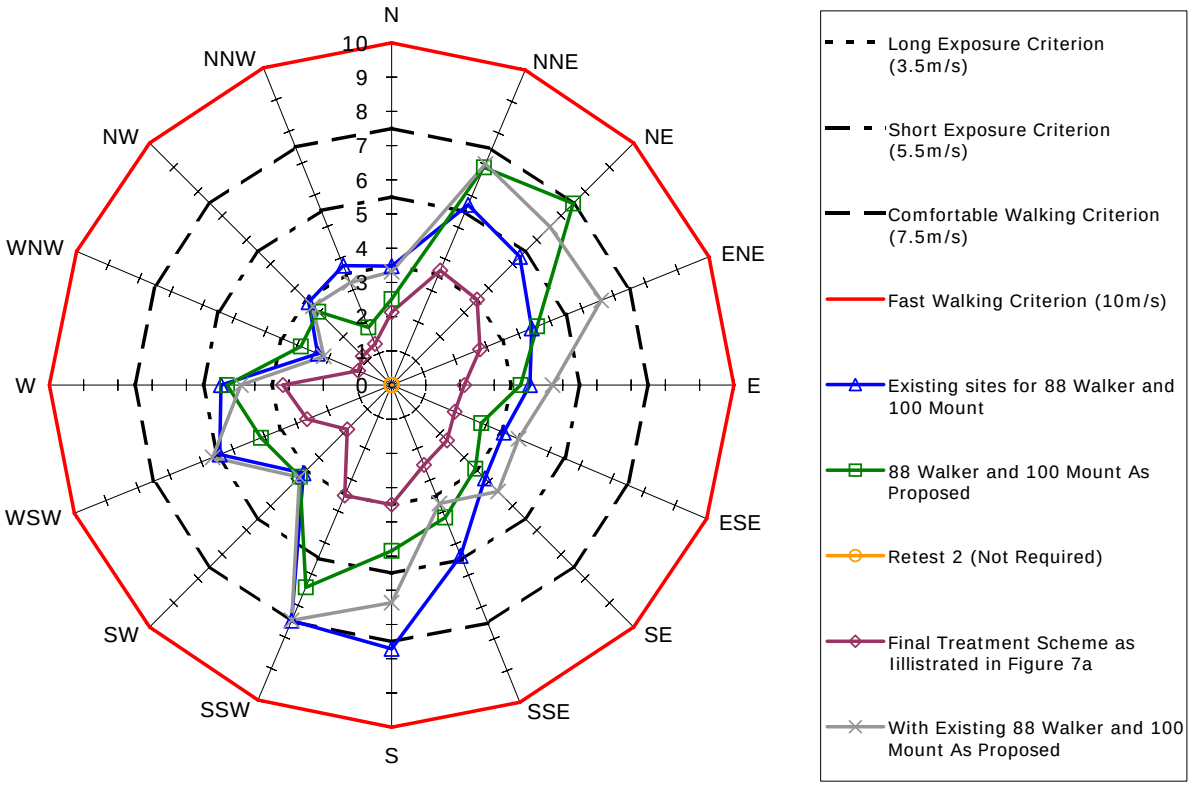


Annual Maximum Gust Wind Speeds (m/s)

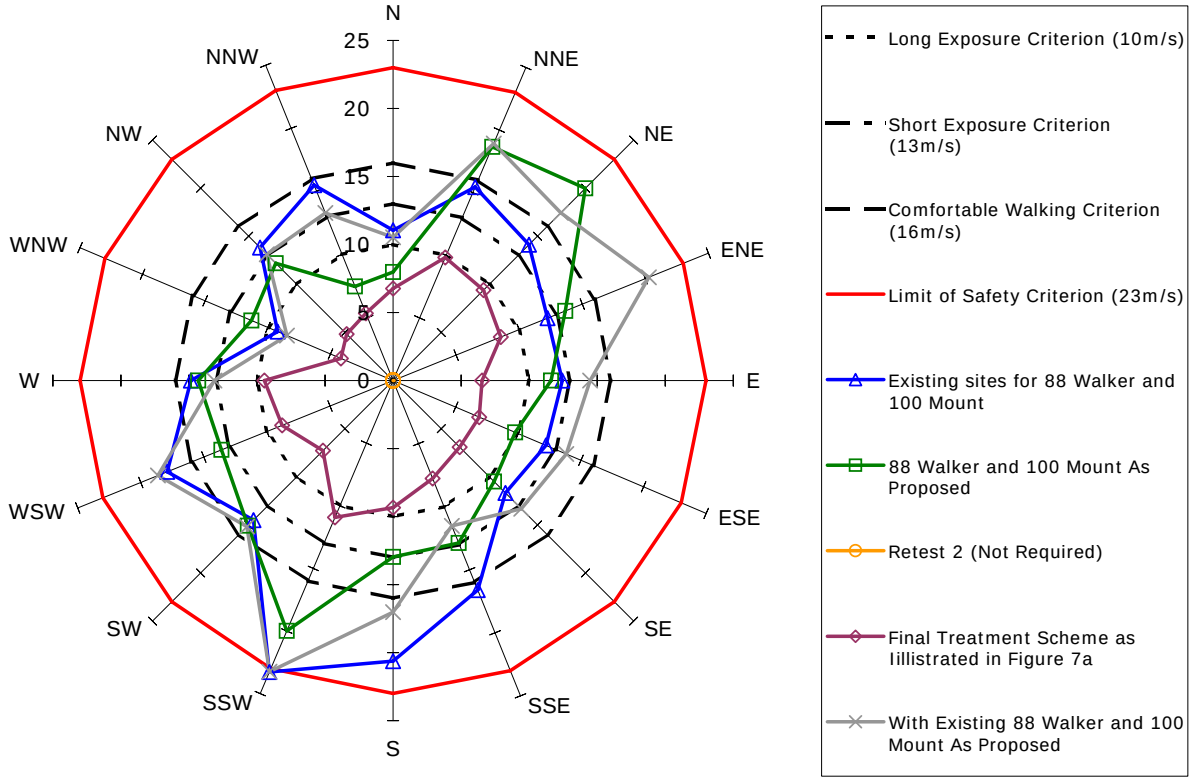


Measured Wind Speeds at Point 67

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

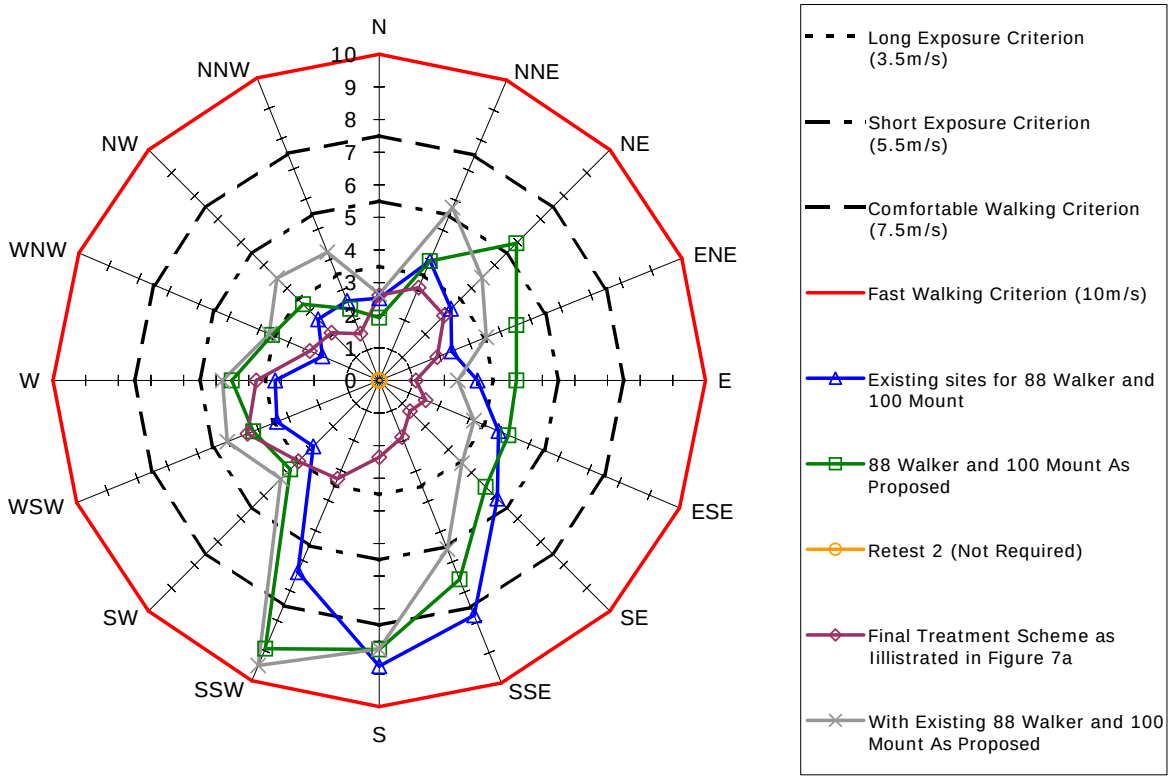


Annual Maximum Gust Wind Speeds (m/s)

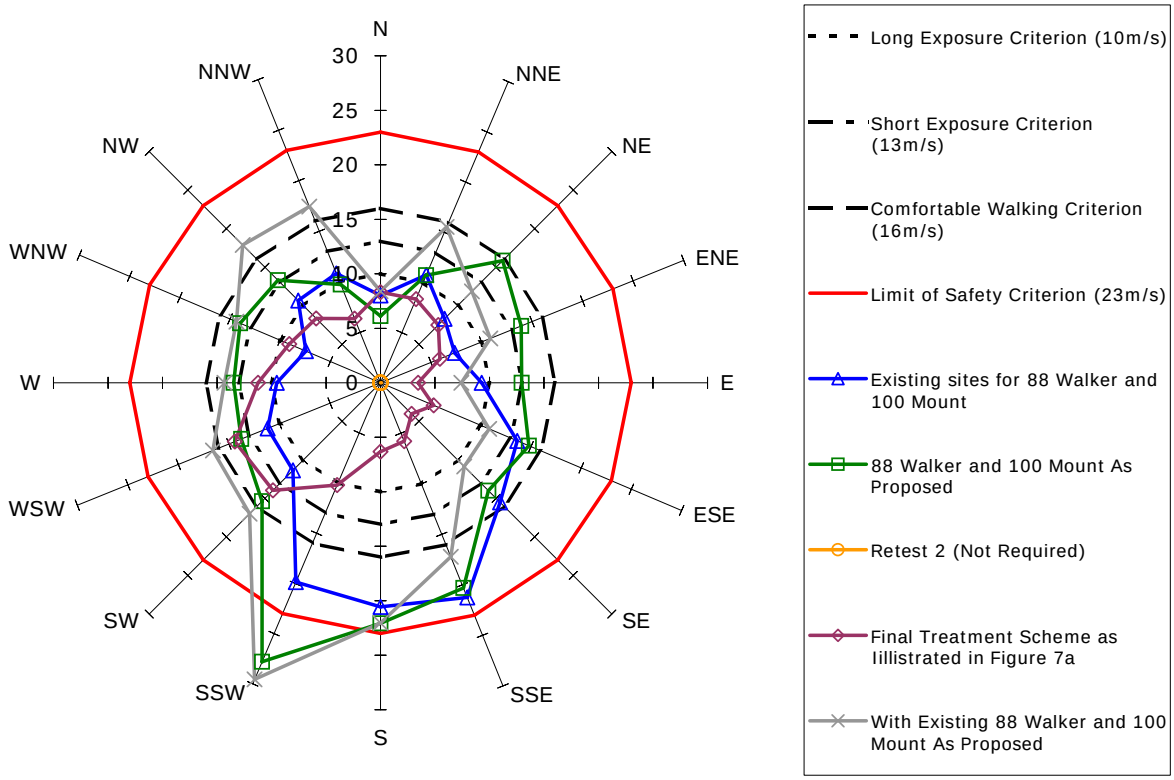


Measured Wind Speeds at Point 68

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

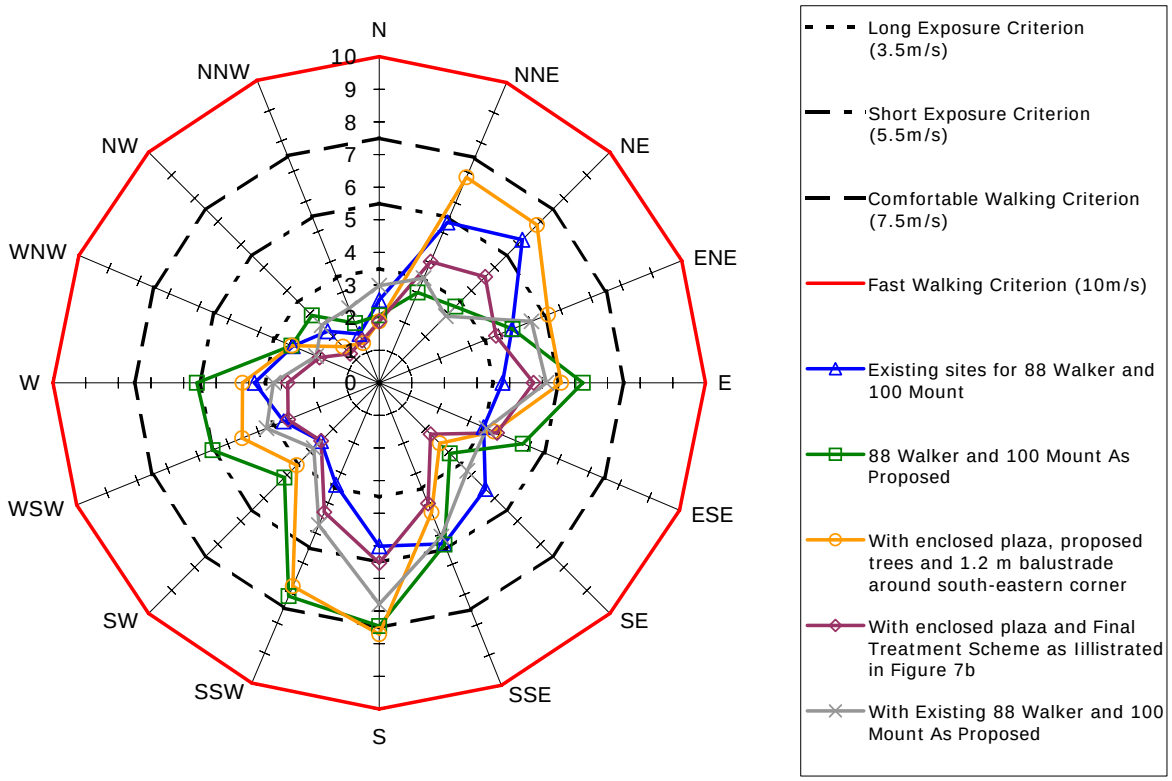


Annual Maximum Gust Wind Speeds (m/s)

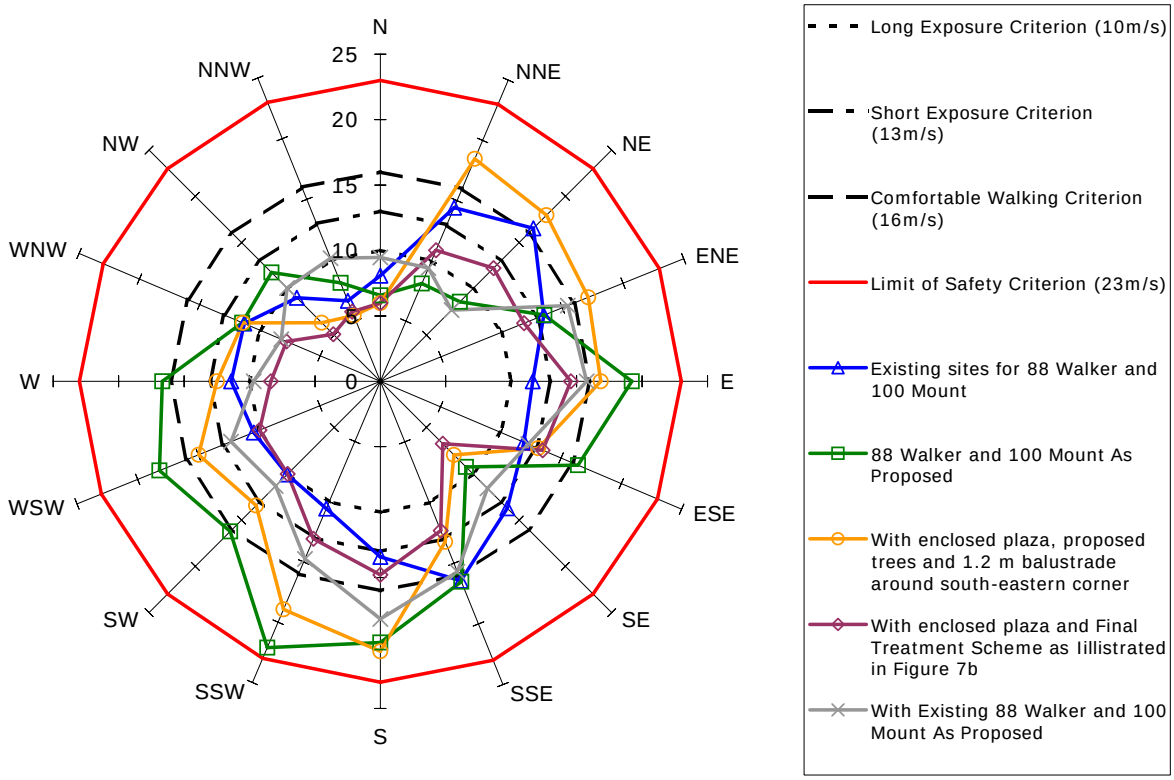


Measured Wind Speeds at Point 69

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

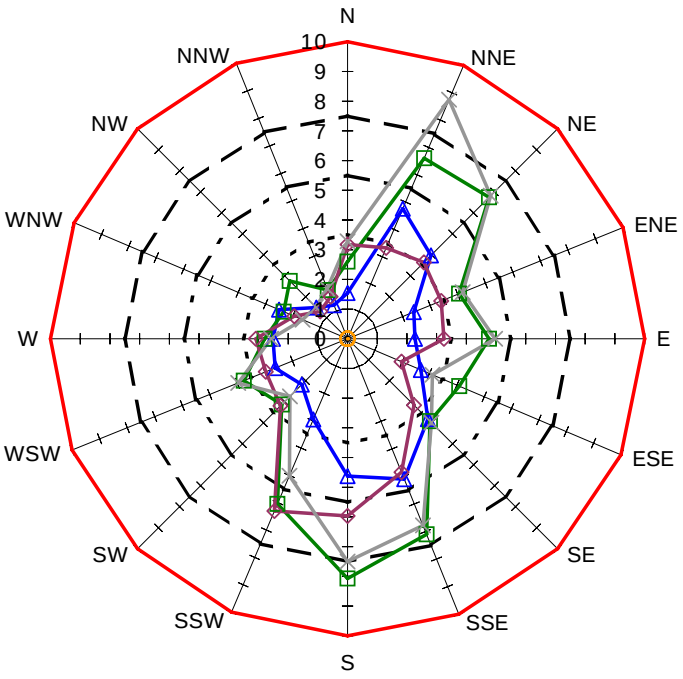


Annual Maximum Gust Wind Speeds (m/s)



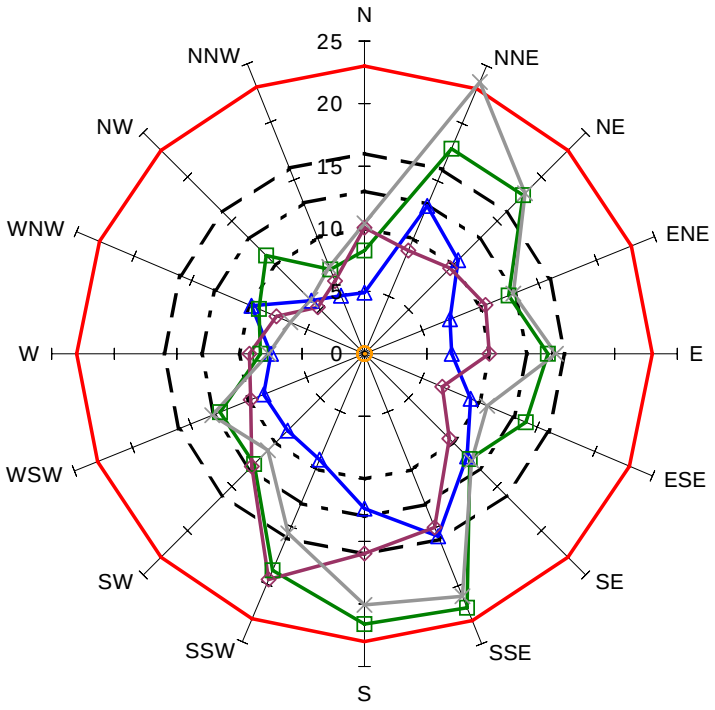
Measured Wind Speeds at Point 70

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)



- Long Exposure Criterion (3.5m/s)
- Short Exposure Criterion (5.5m/s)
- Comfortable Walking Criterion (7.5m/s)
- Fast Walking Criterion (10m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- With enclosed plaza and Final Treatment Scheme as Iillistrated in Figure 7b
- With Existing 88 Walker and 100 Mount As Proposed

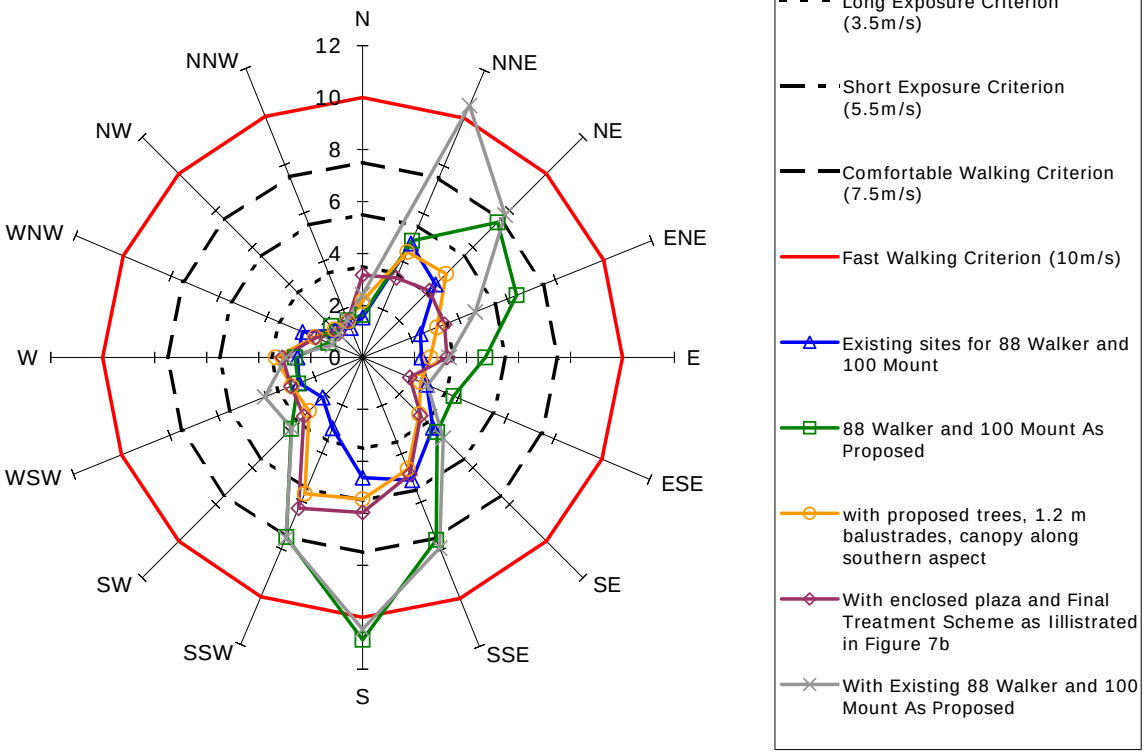
Annual Maximum Gust Wind Speeds (m/s)



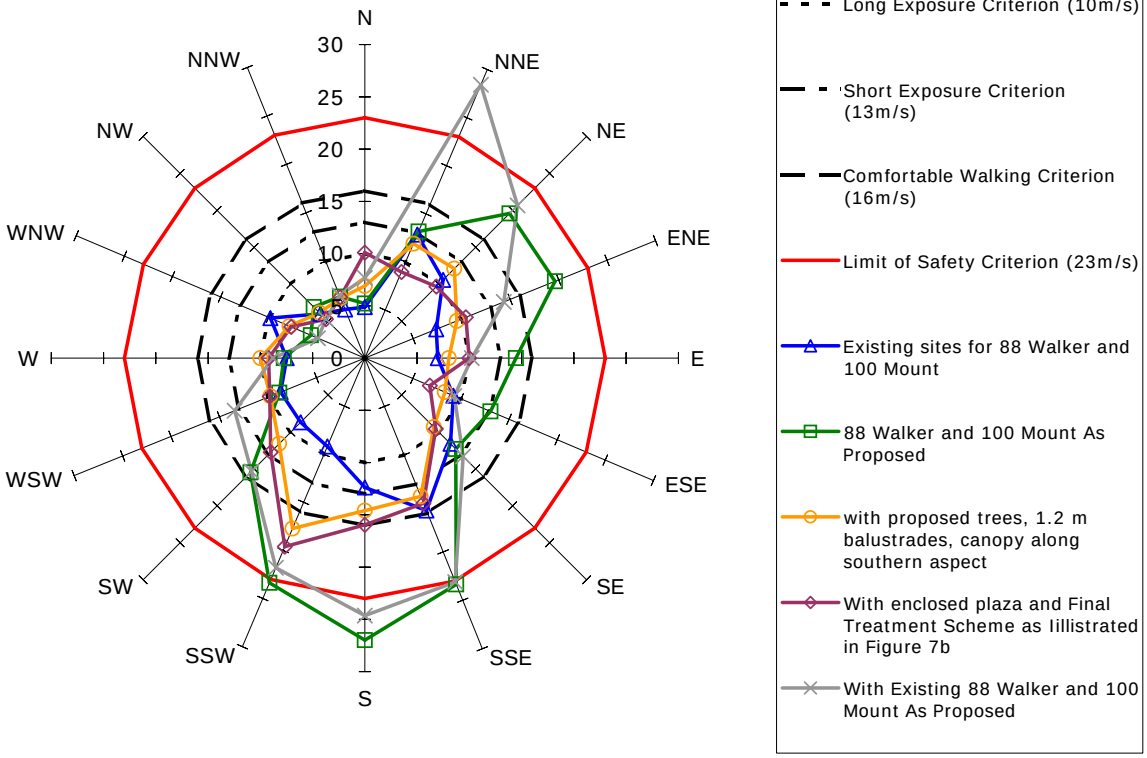
- Long Exposure Criterion (10m/s)
- Short Exposure Criterion (13m/s)
- Comfortable Walking Criterion (16m/s)
- Limit of Safety Criterion (23m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- With enclosed plaza and Final Treatment Scheme as Iillistrated in Figure 7b
- With Existing 88 Walker and 100 Mount As Proposed

Measured Wind Speeds at Point 71

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

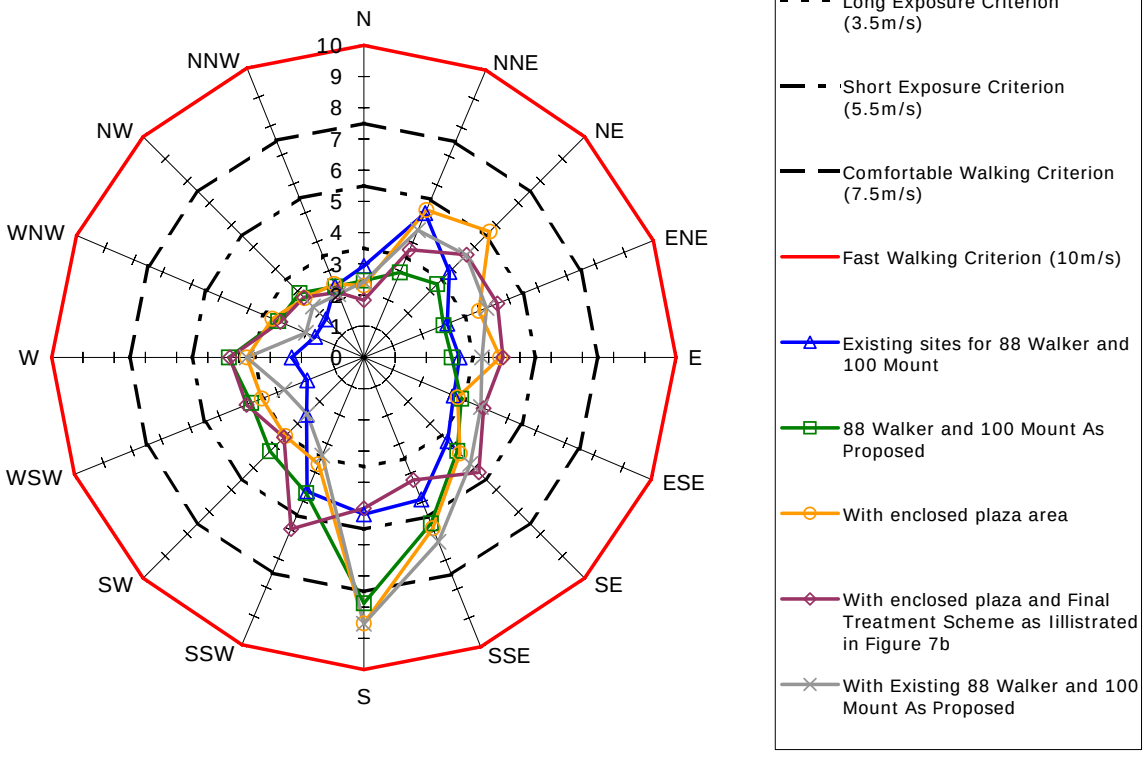


Annual Maximum Gust Wind Speeds (m/s)

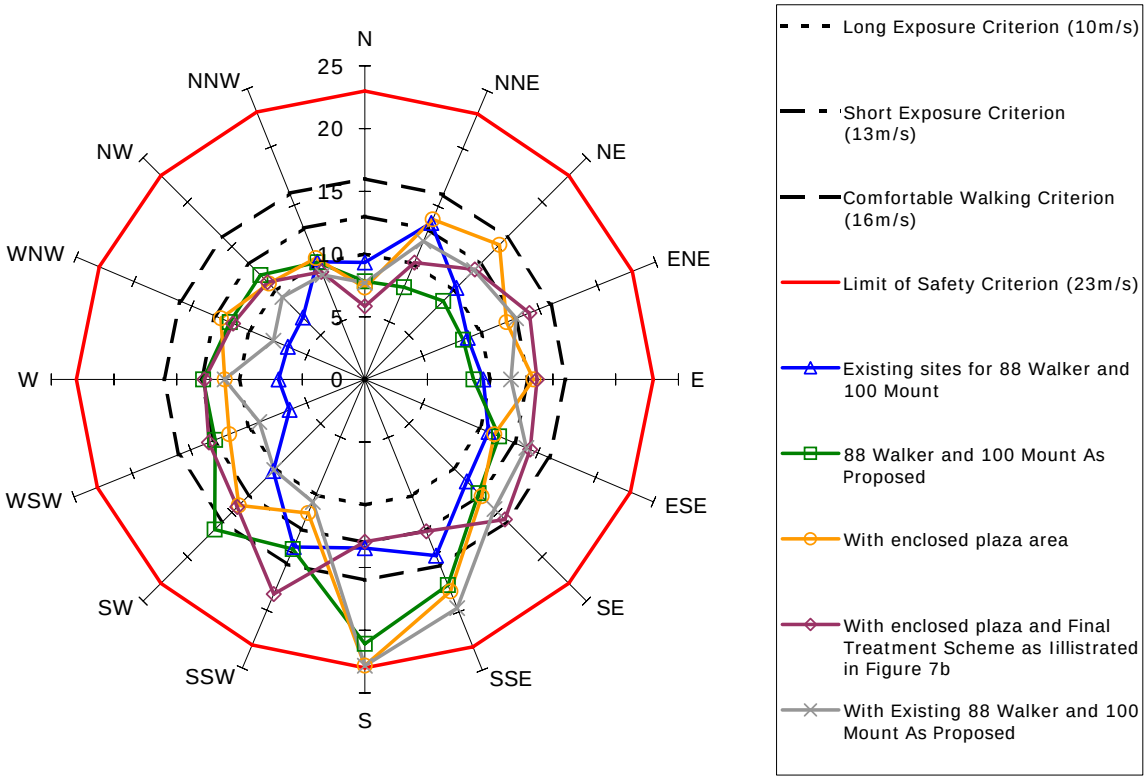


Measured Wind Speeds at Point 72

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

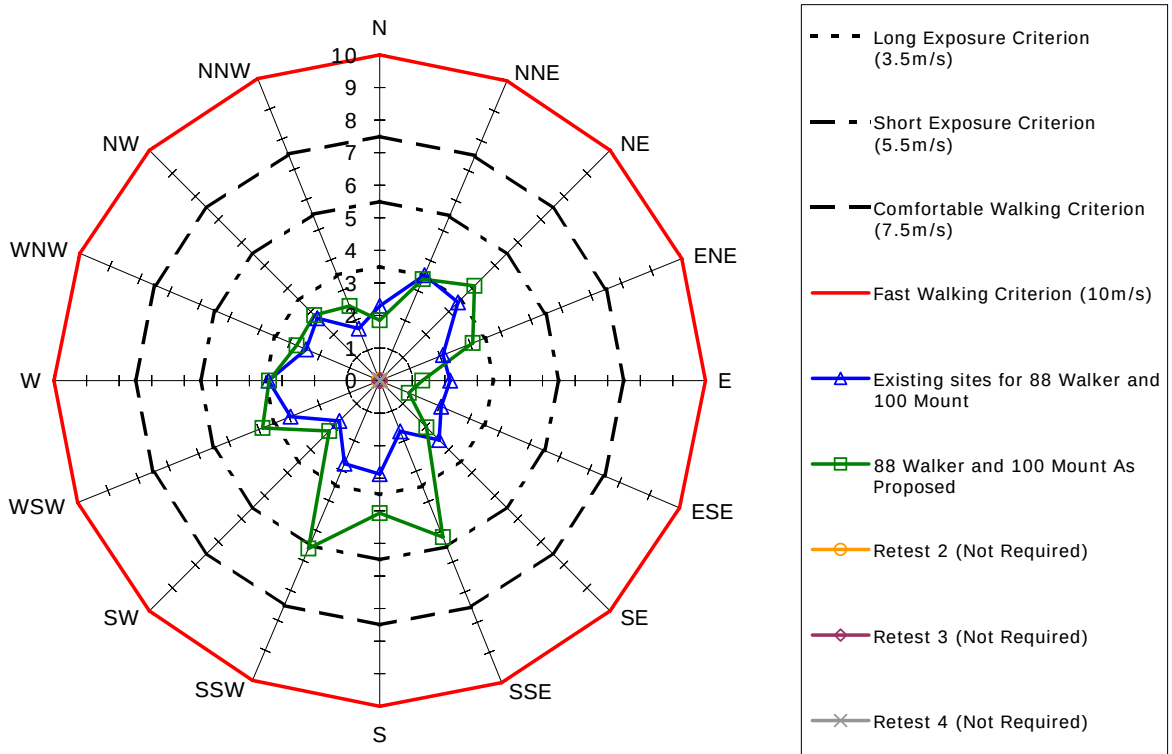


Annual Maximum Gust Wind Speeds (m/s)

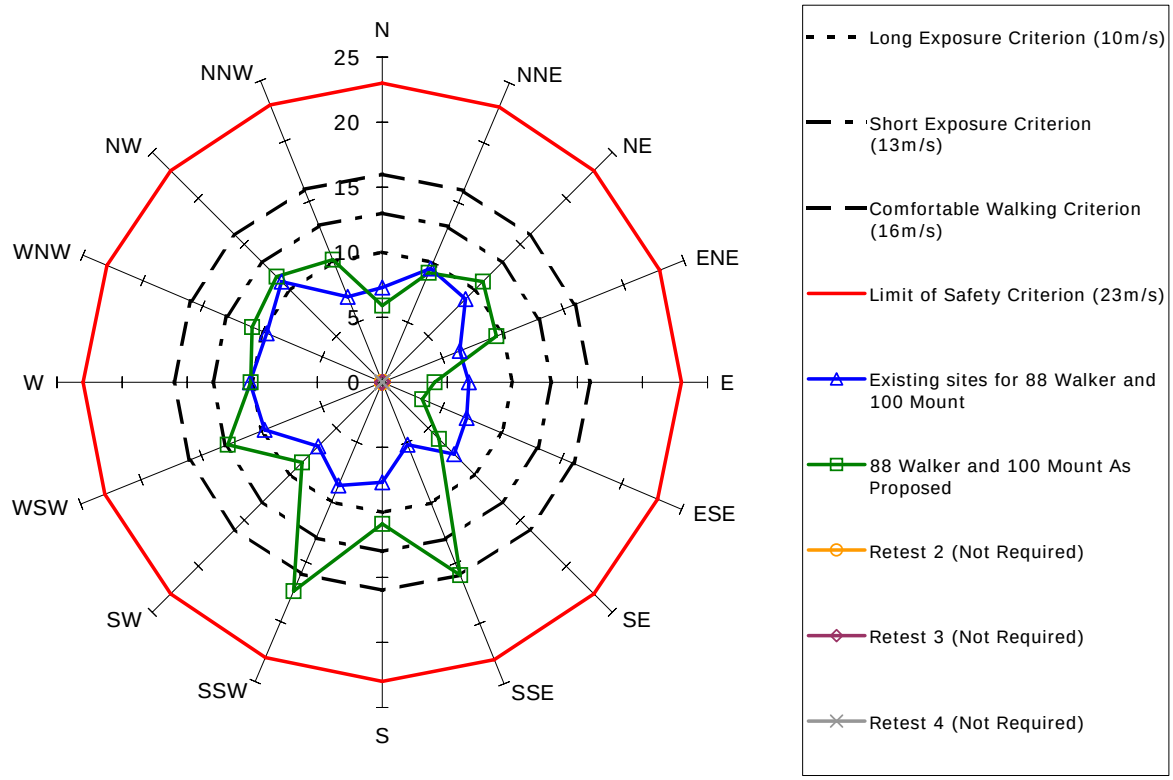


Measured Wind Speeds at Point 77

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

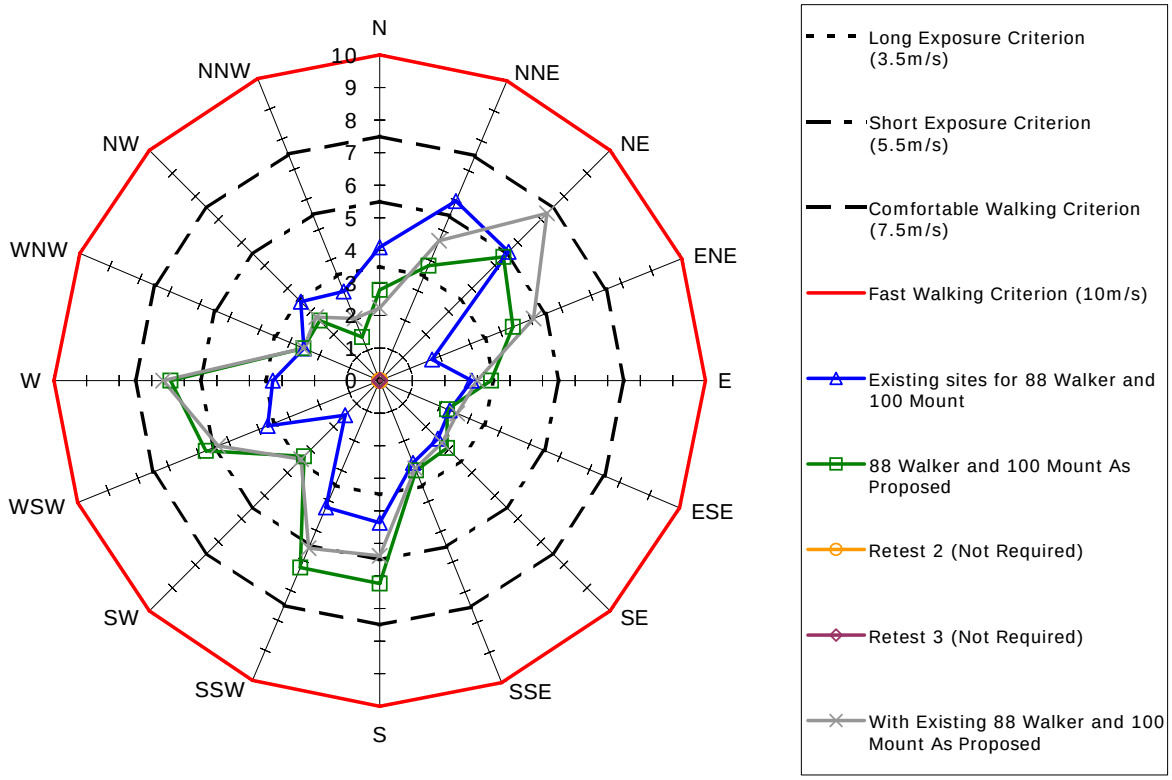


Annual Maximum Gust Wind Speeds (m/s)

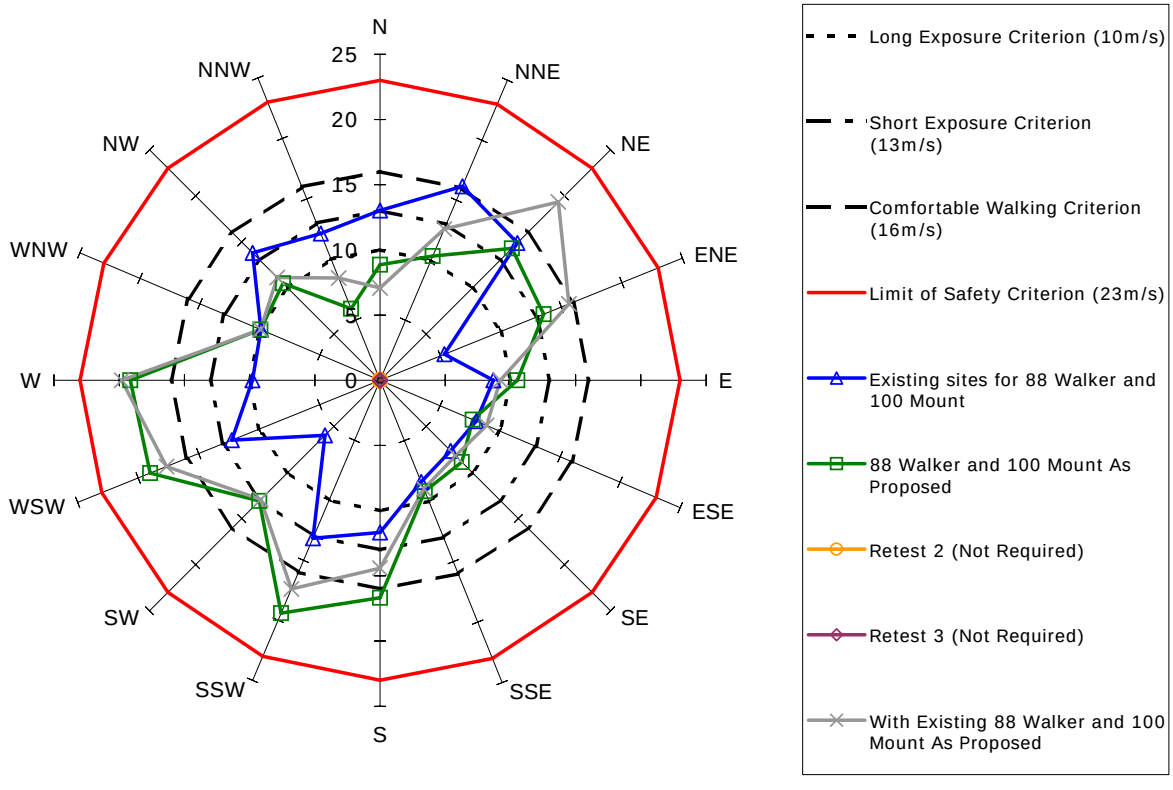


Measured Wind Speeds at Point 78

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

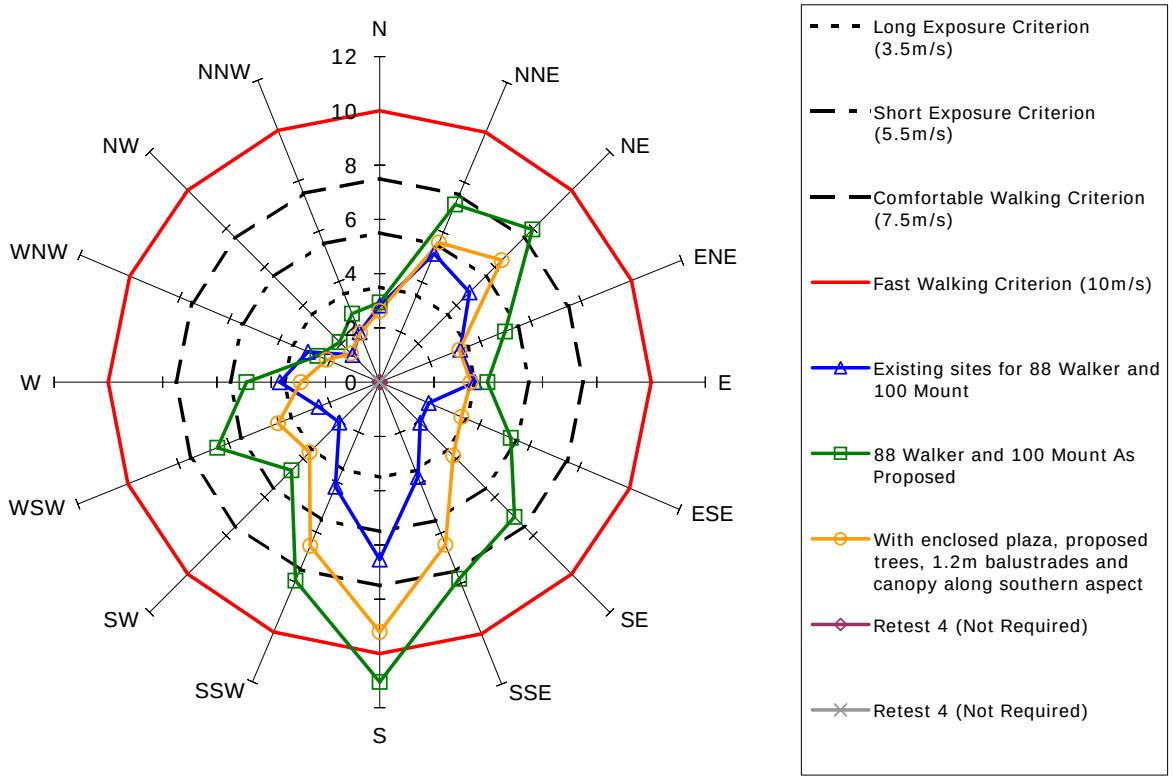


Annual Maximum Gust Wind Speeds (m/s)

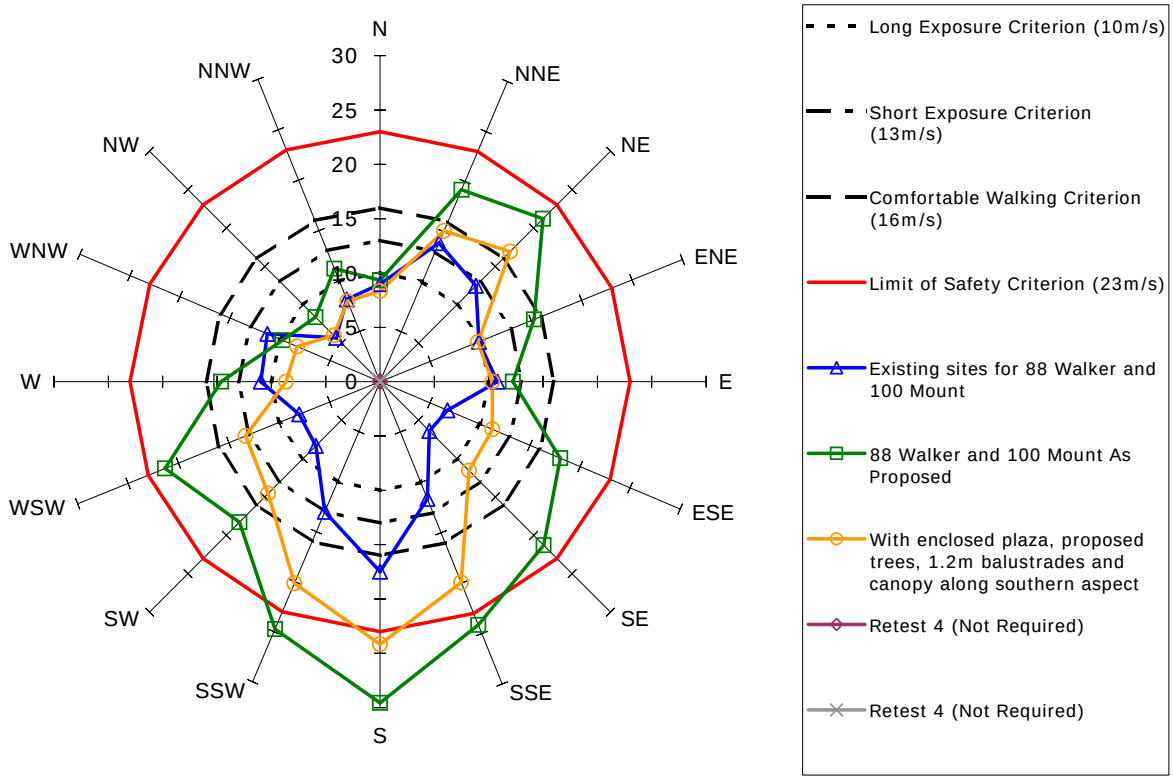


Measured Wind Speeds at Point 79

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

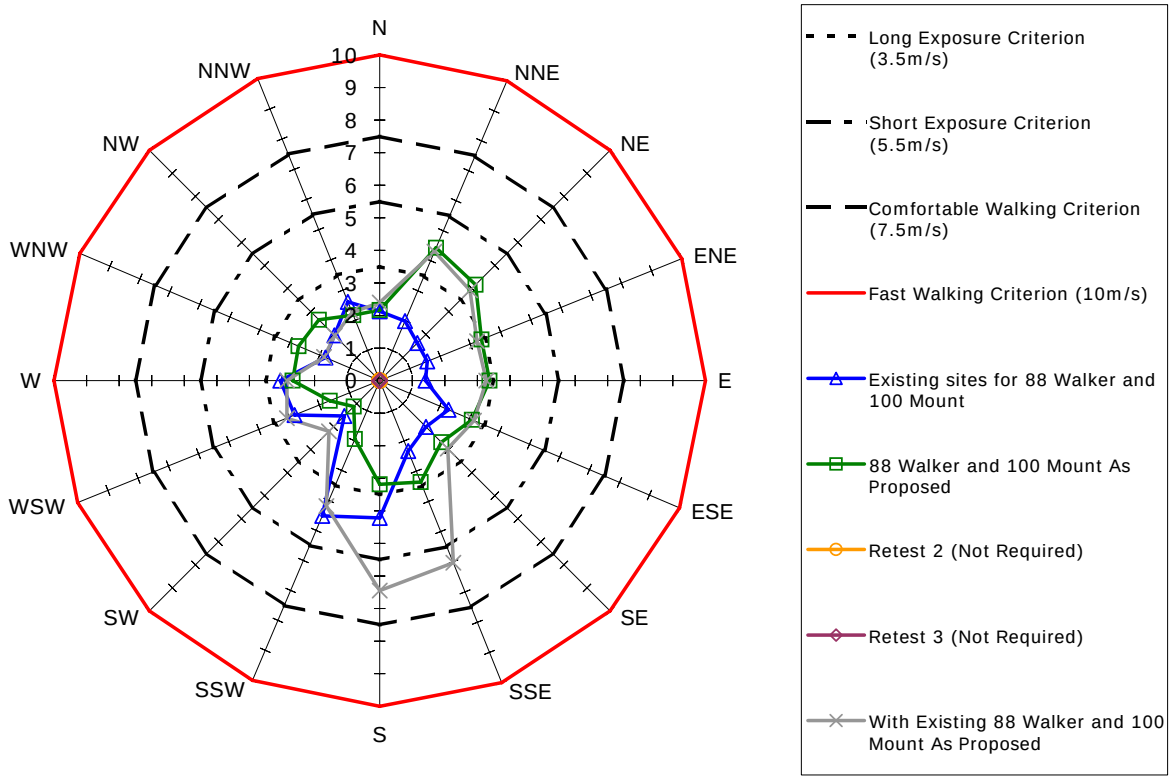


Annual Maximum Gust Wind Speeds (m/s)

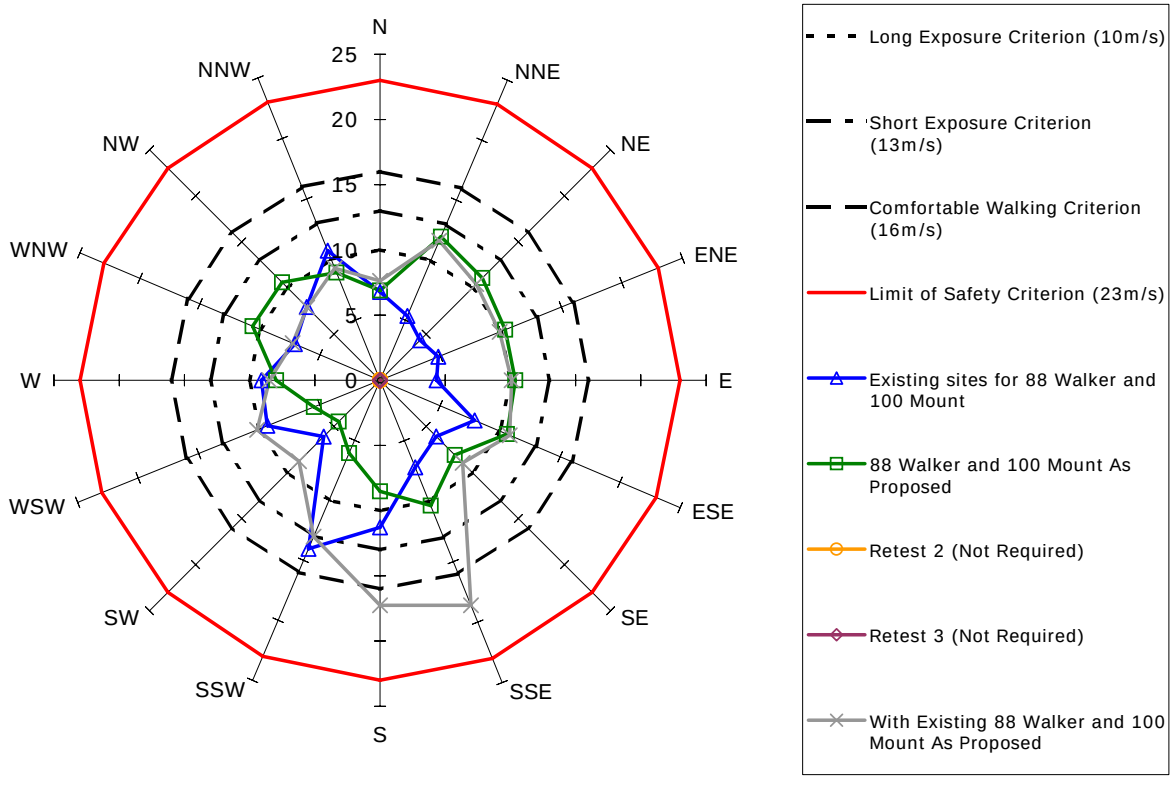


Measured Wind Speeds at Point 80

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

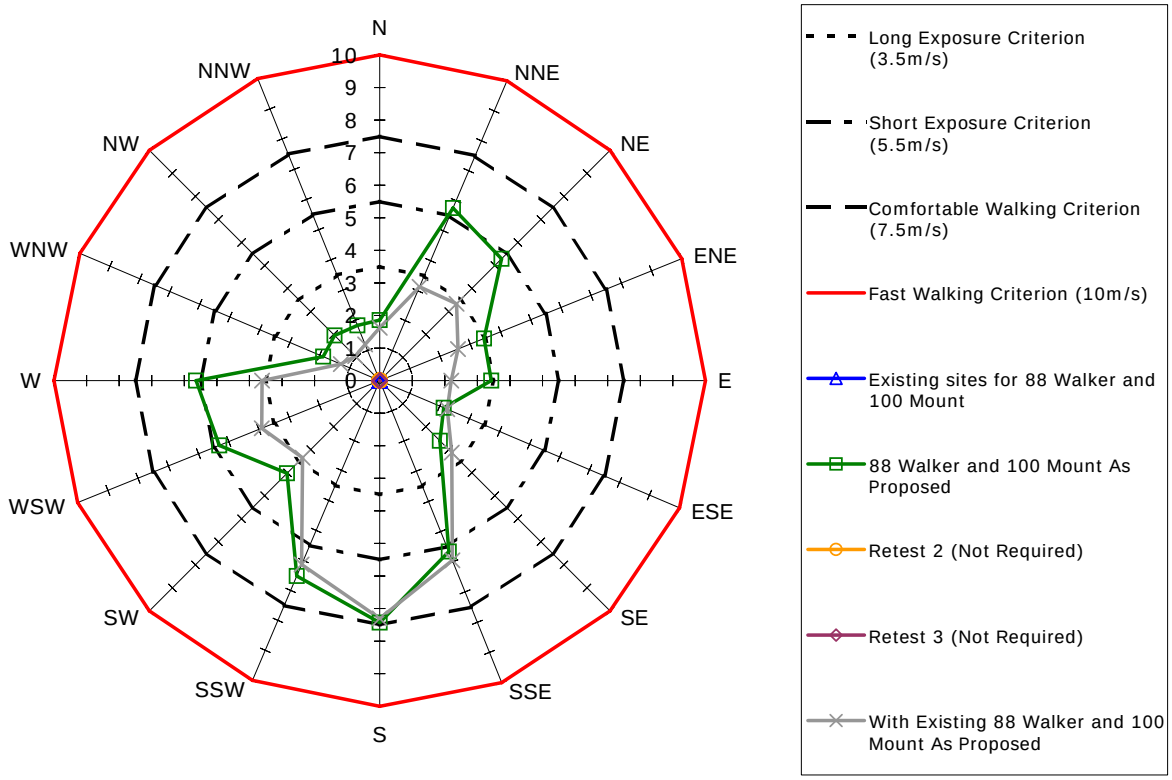


Annual Maximum Gust Wind Speeds (m/s)

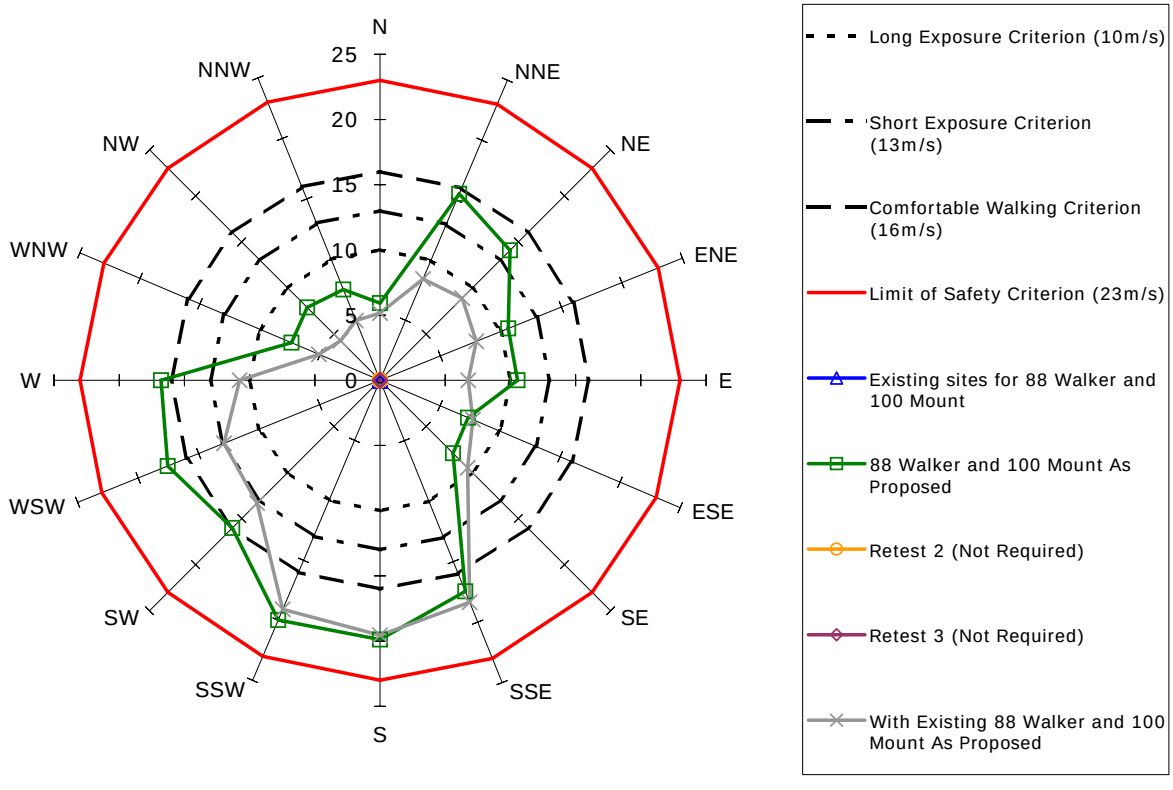


Measured Wind Speeds at Point 81

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

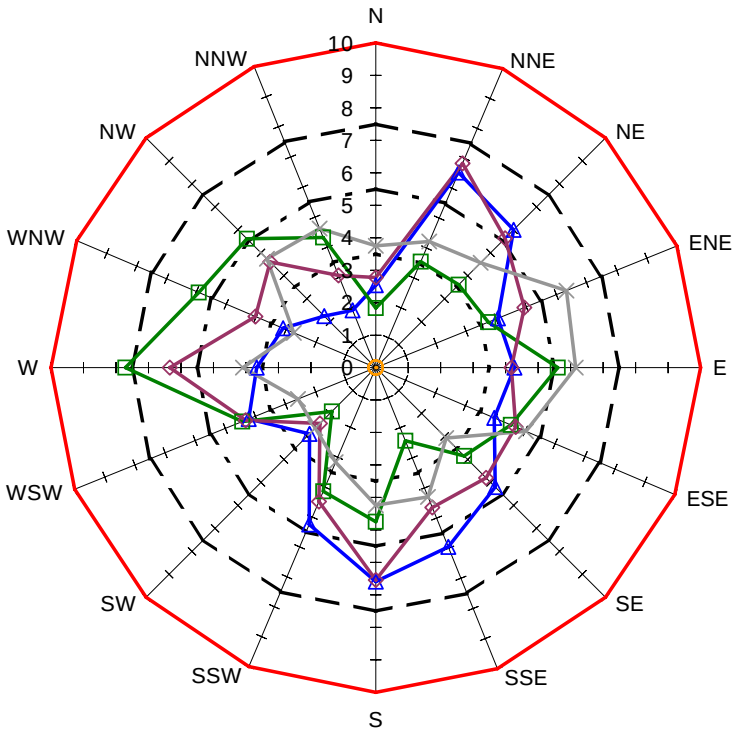


Annual Maximum Gust Wind Speeds (m/s)



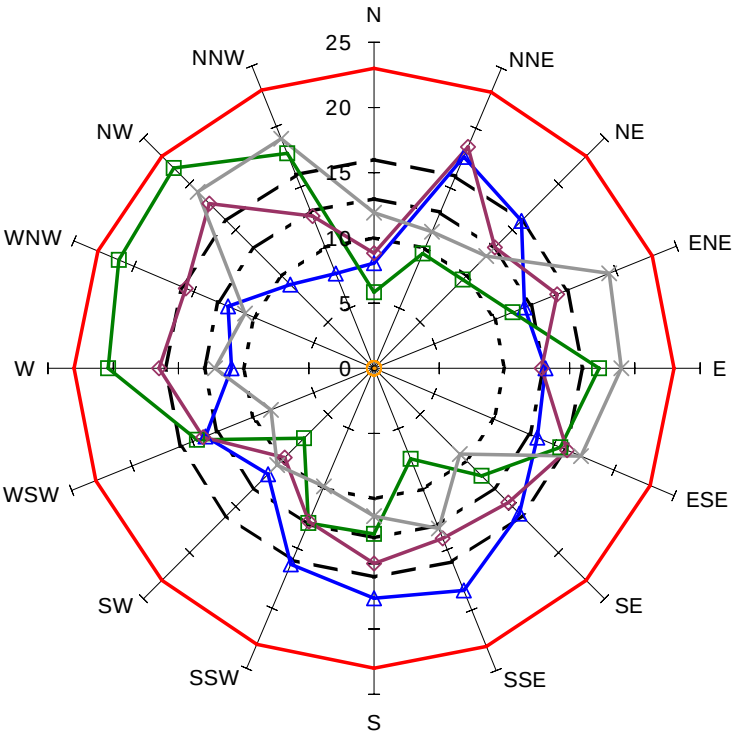
Measured Wind Speeds at Point 82

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)



- Long Exposure Criterion (3.5m/s)
- Short Exposure Criterion (5.5m/s)
- Comfortable Walking Criterion (7.5m/s)
- Fast Walking Criterion (10m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- Final Treatment Scheme as Iillistrated in Figure 7a
- With Existing 88 Walker and 100 Mount As Proposed

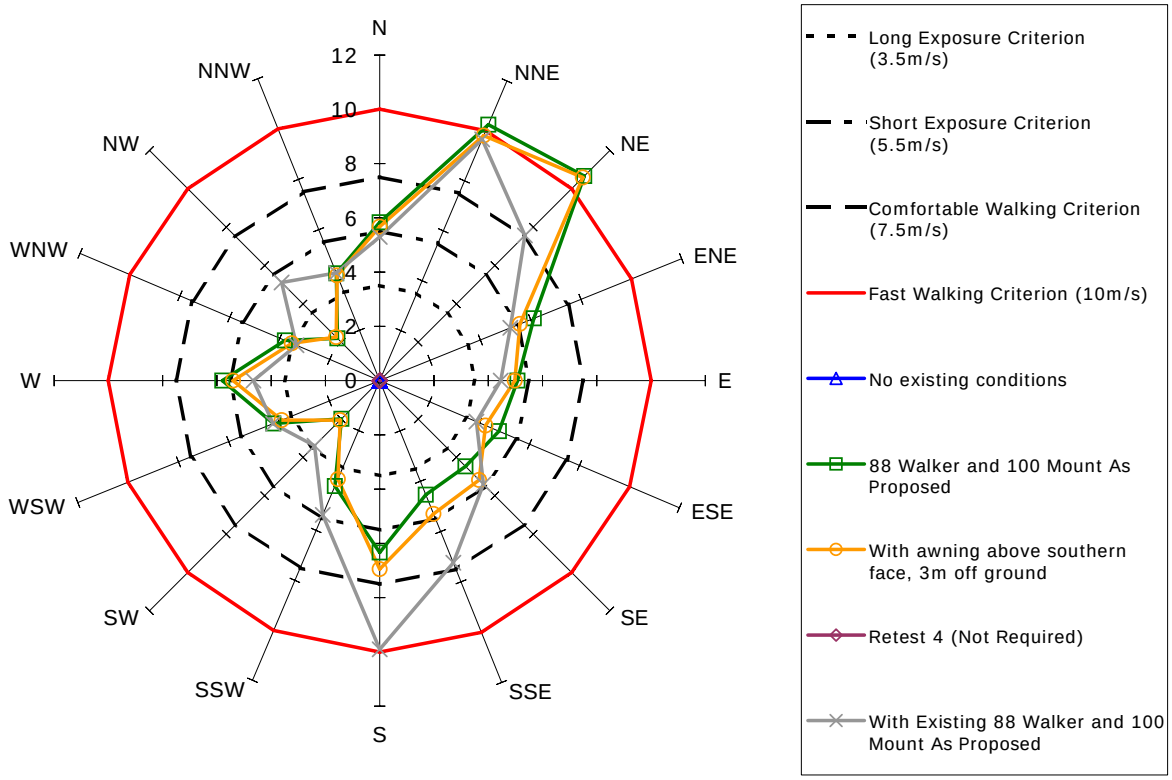
Annual Maximum Gust Wind Speeds (m/s)



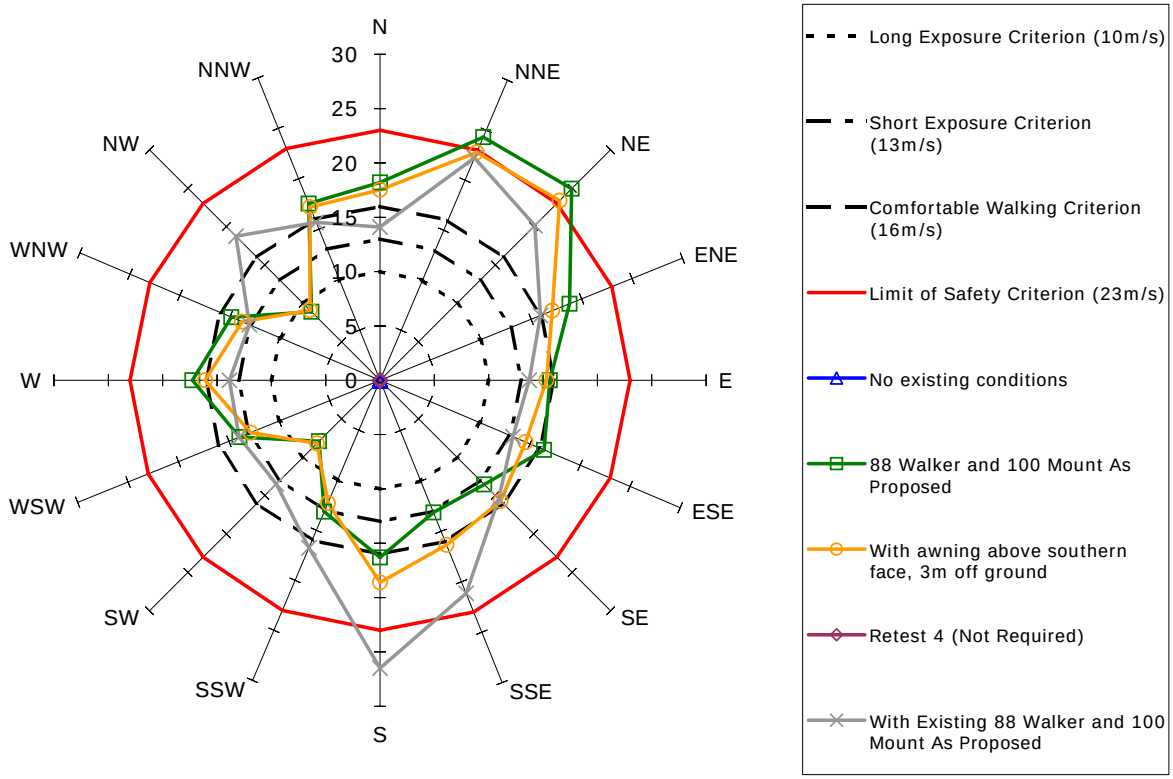
- Long Exposure Criterion (10m/s)
- Short Exposure Criterion (13m/s)
- Comfortable Walking Criterion (16m/s)
- Limit of Safety Criterion (23m/s)
- Existing sites for 88 Walker and 100 Mount
- 88 Walker and 100 Mount As Proposed
- Retest 2 (Not Required)
- Final Treatment Scheme as Iillistrated in Figure 7a
- With Existing 88 Walker and 100 Mount As Proposed

Measured Wind Speeds at Point 83

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

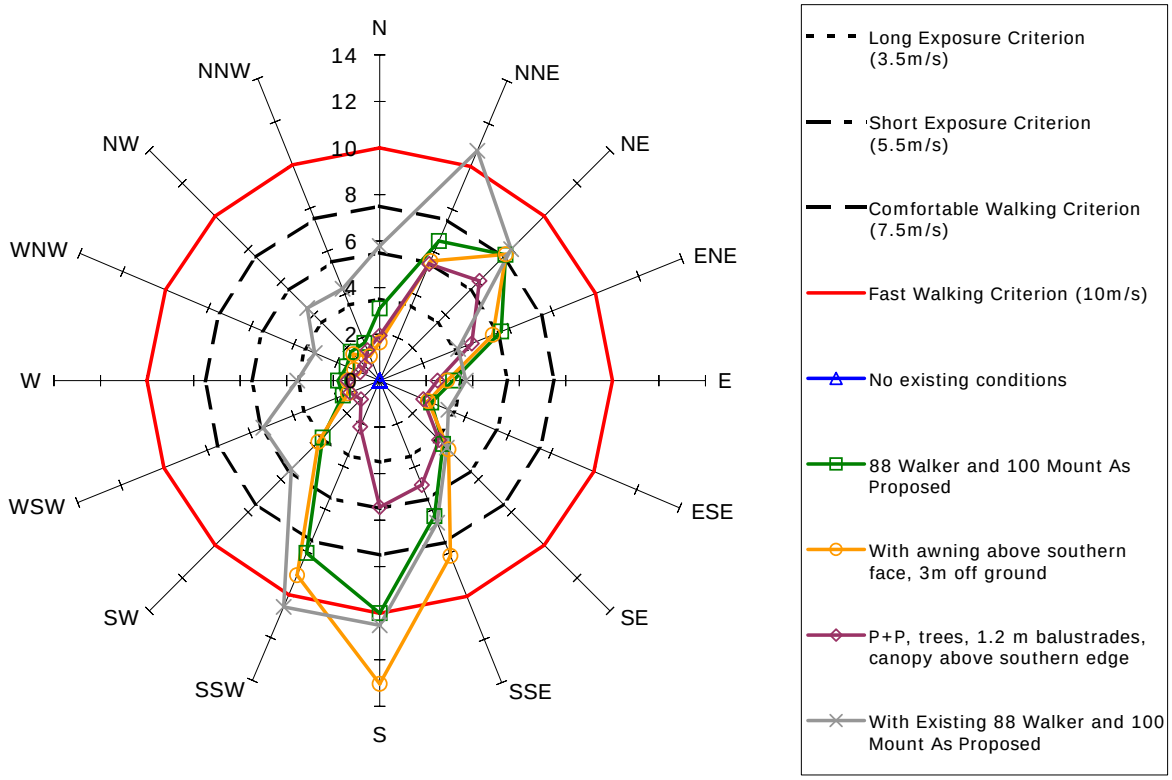


Annual Maximum Gust Wind Speeds (m/s)

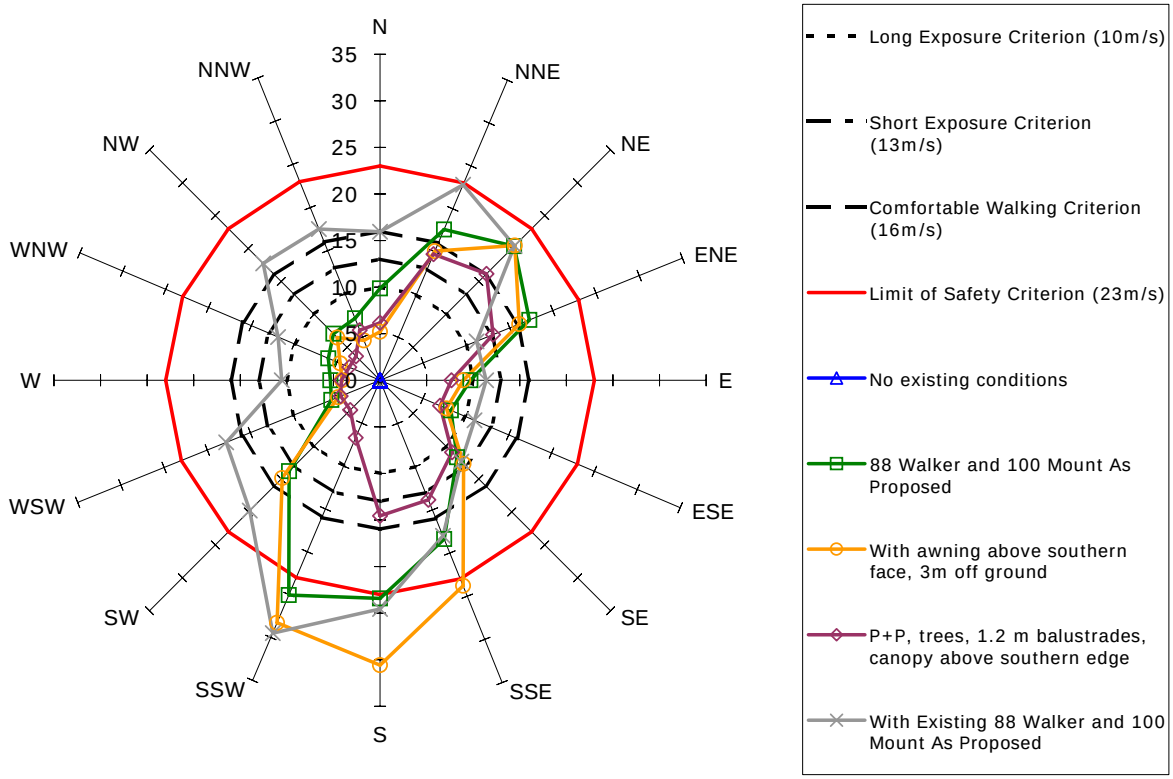


Measured Wind Speeds at Point 84

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

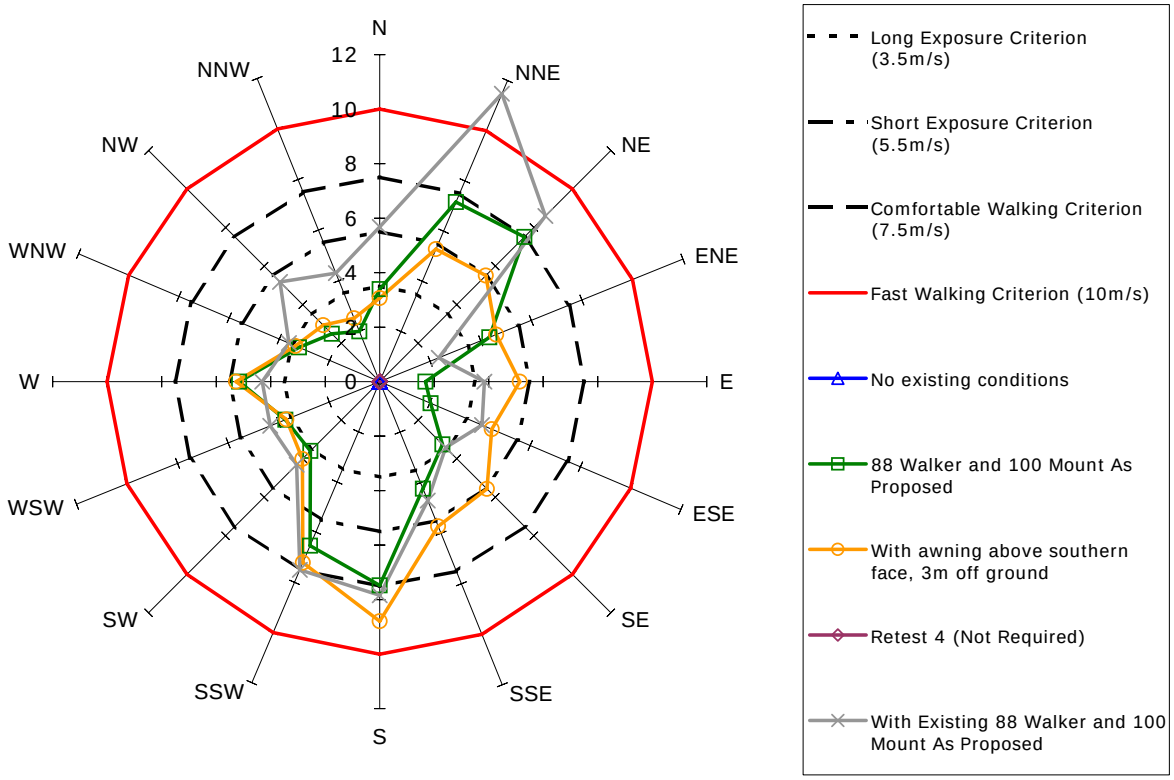


Annual Maximum Gust Wind Speeds (m/s)

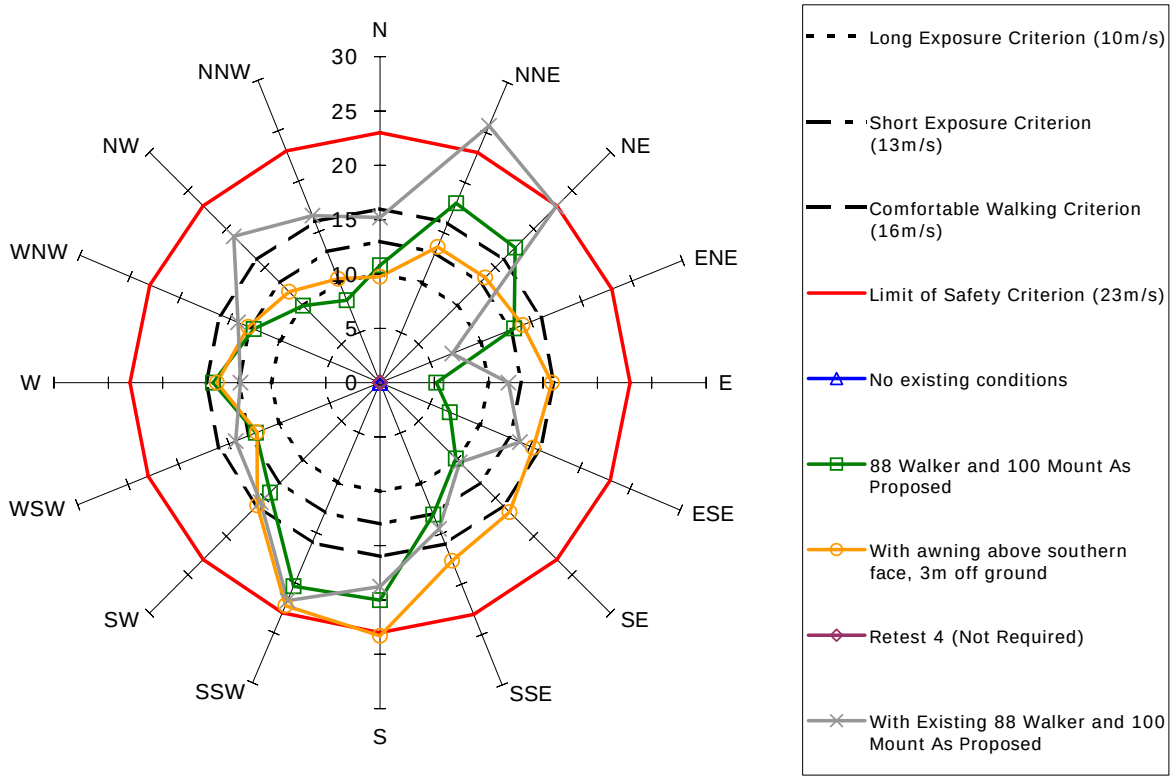


Measured Wind Speeds at Point 85

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

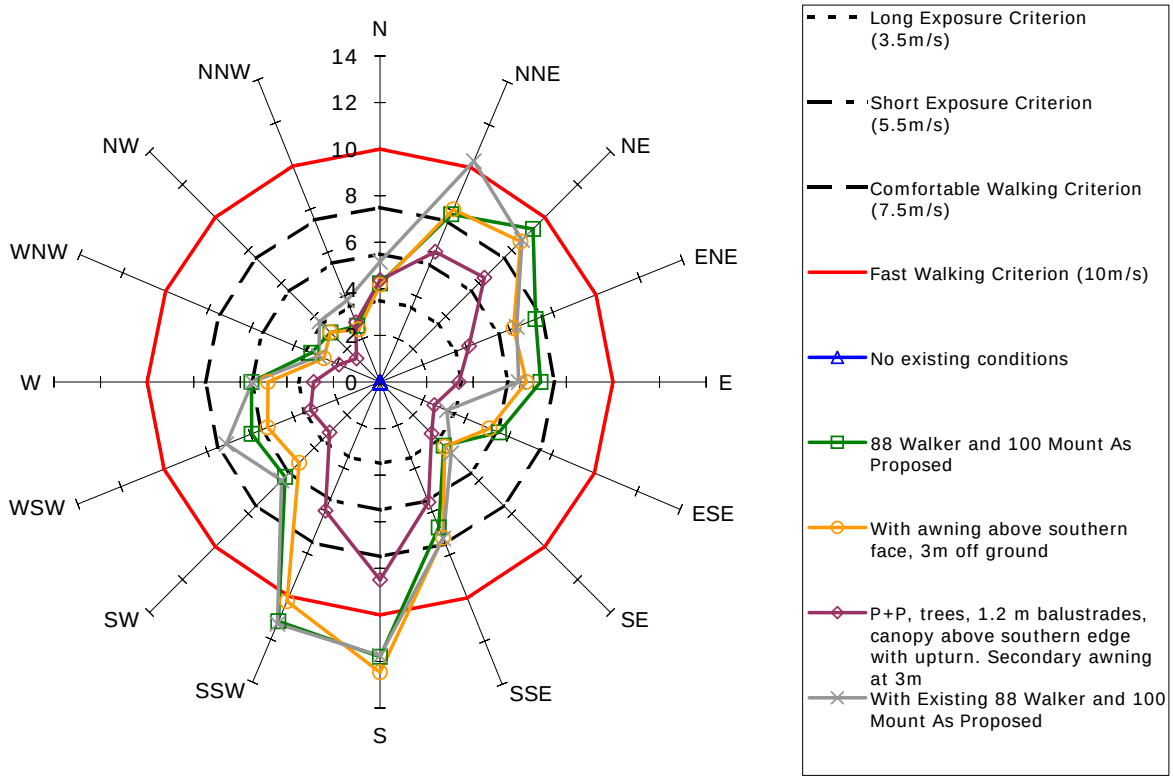


Annual Maximum Gust Wind Speeds (m/s)

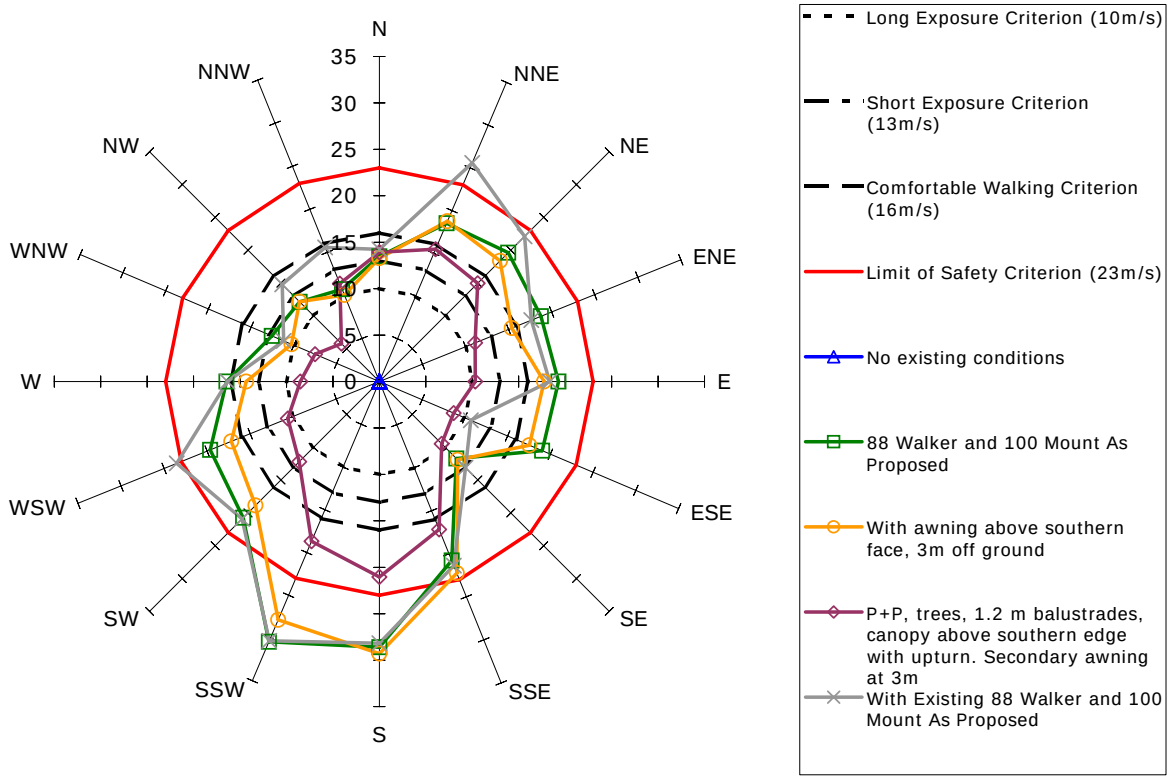


Measured Wind Speeds at Point 86

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

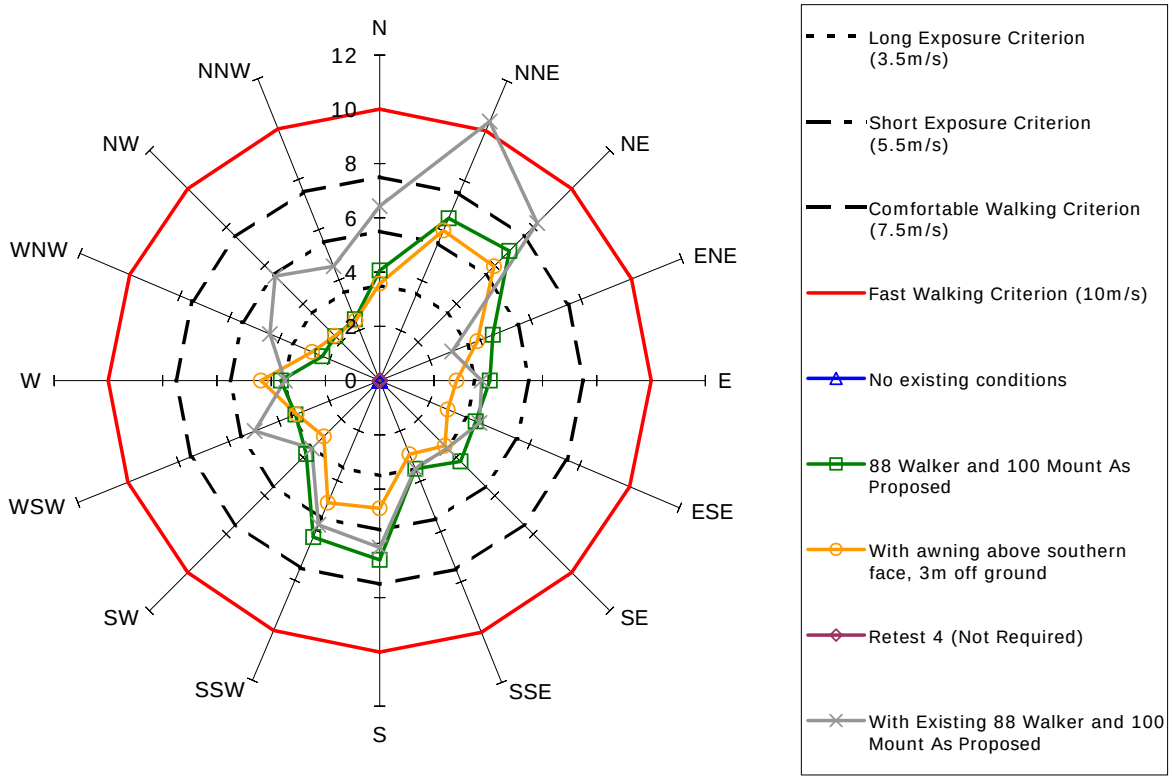


Annual Maximum Gust Wind Speeds (m/s)

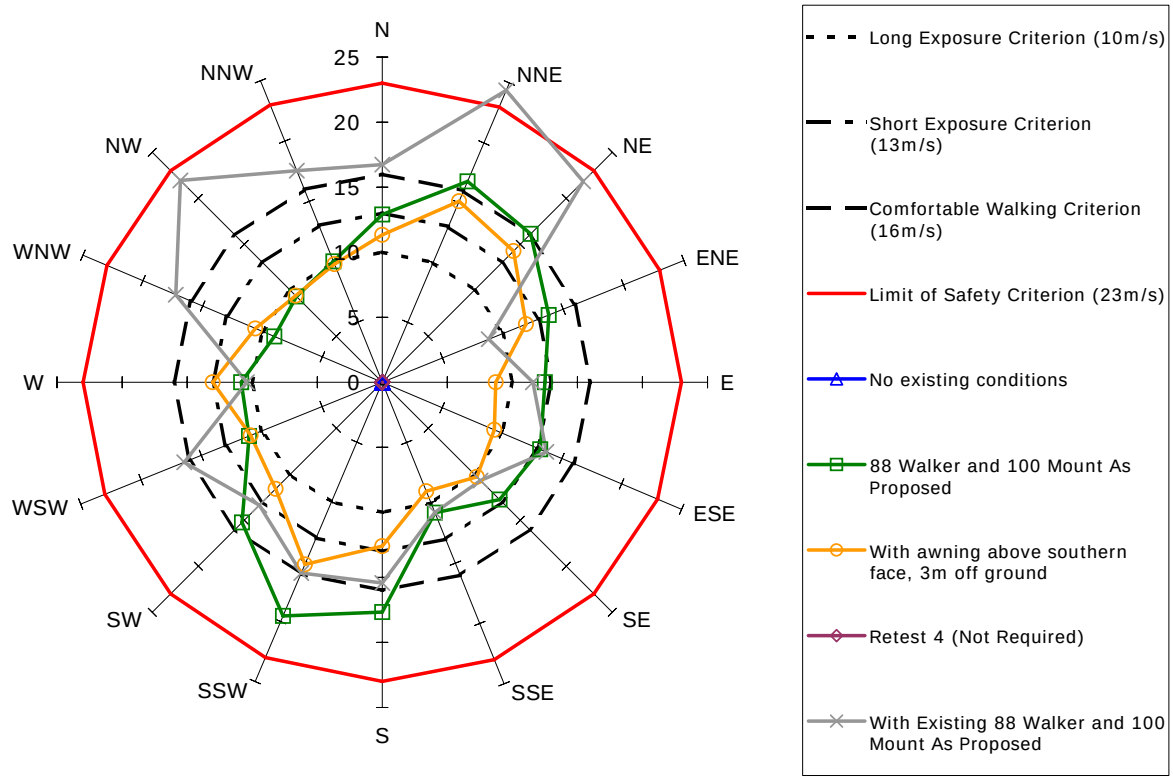


Measured Wind Speeds at Point 87

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

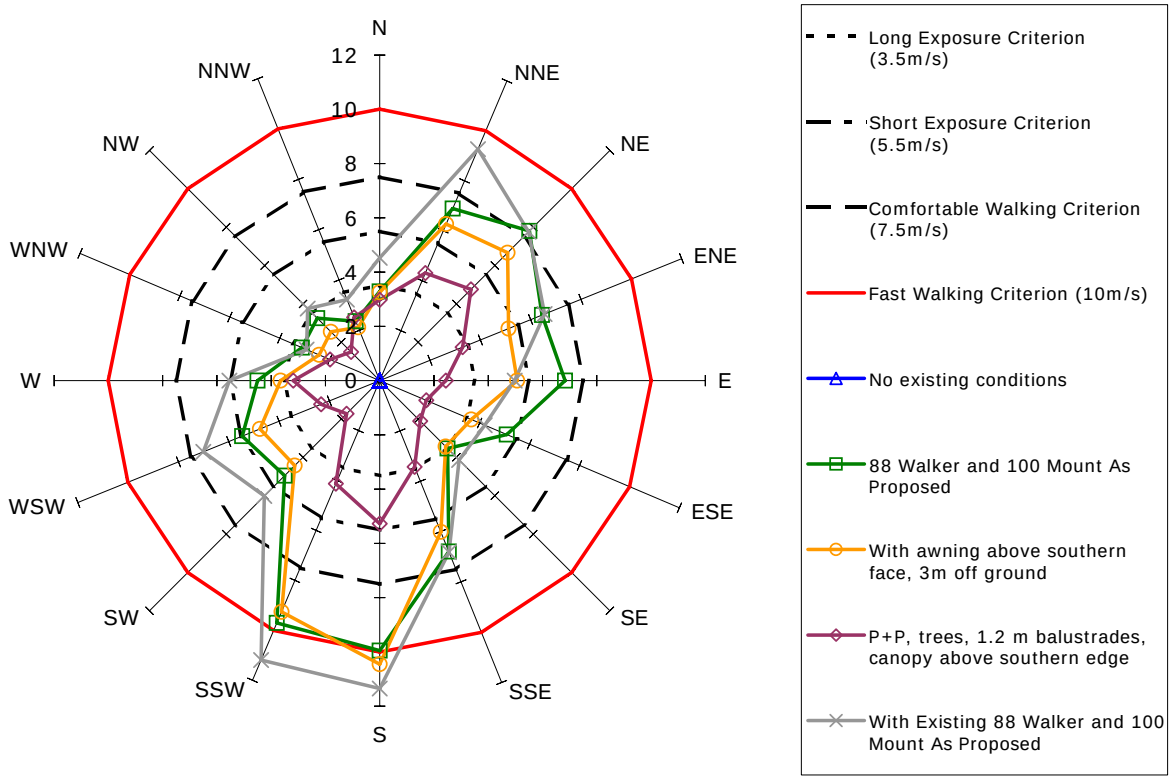


Annual Maximum Gust Wind Speeds (m/s)

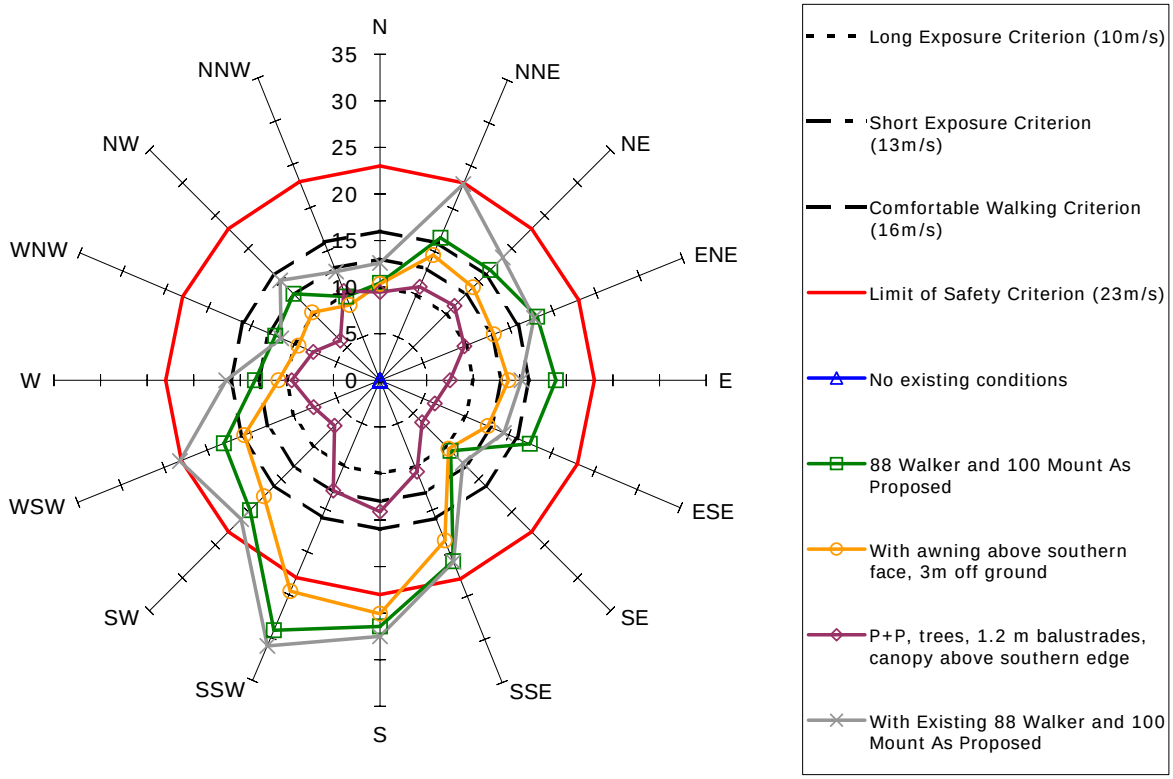


Measured Wind Speeds at Point 88

Weekly Maximum Gust Equivalent Mean Wind Speeds (m/s)

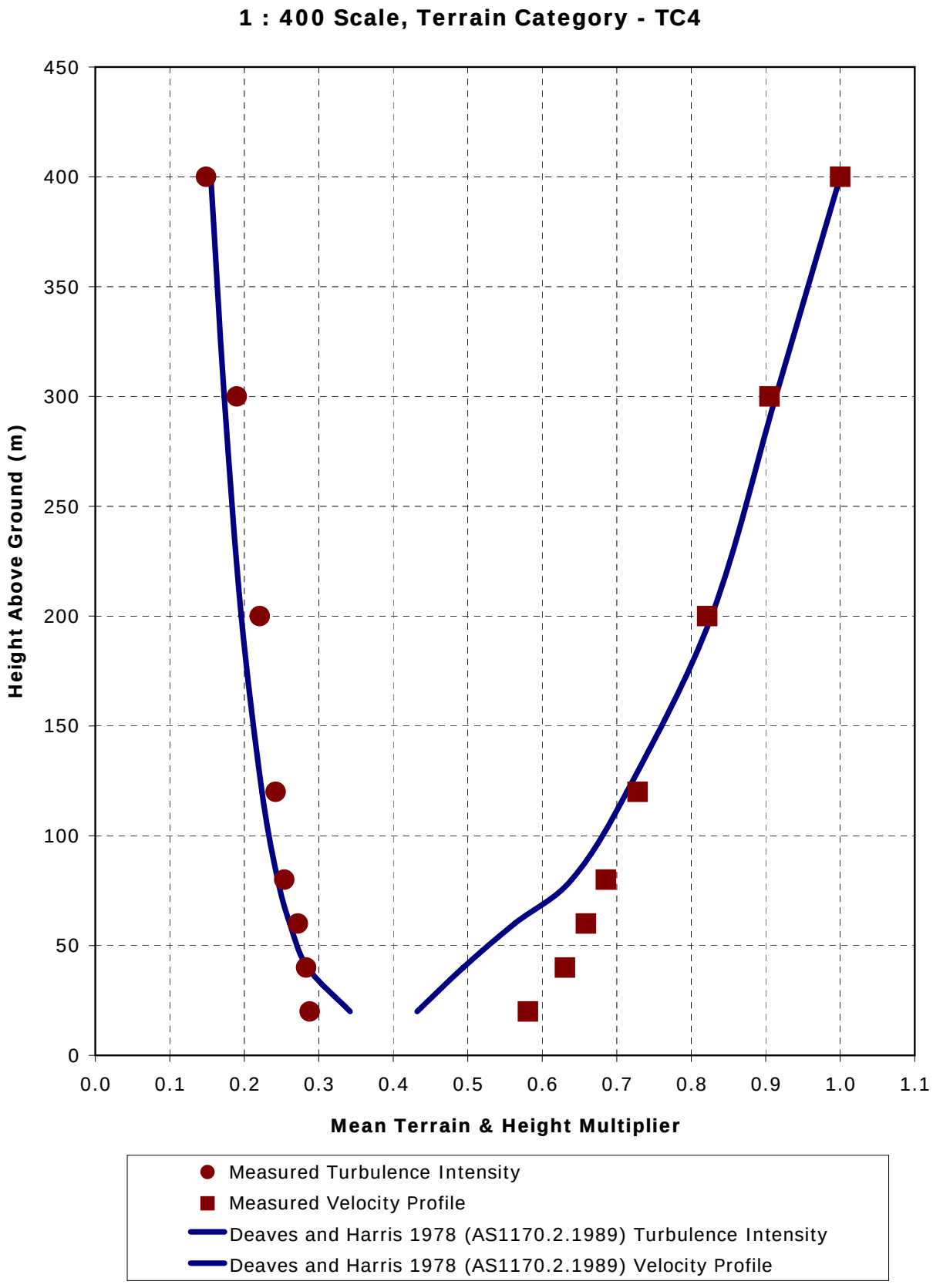


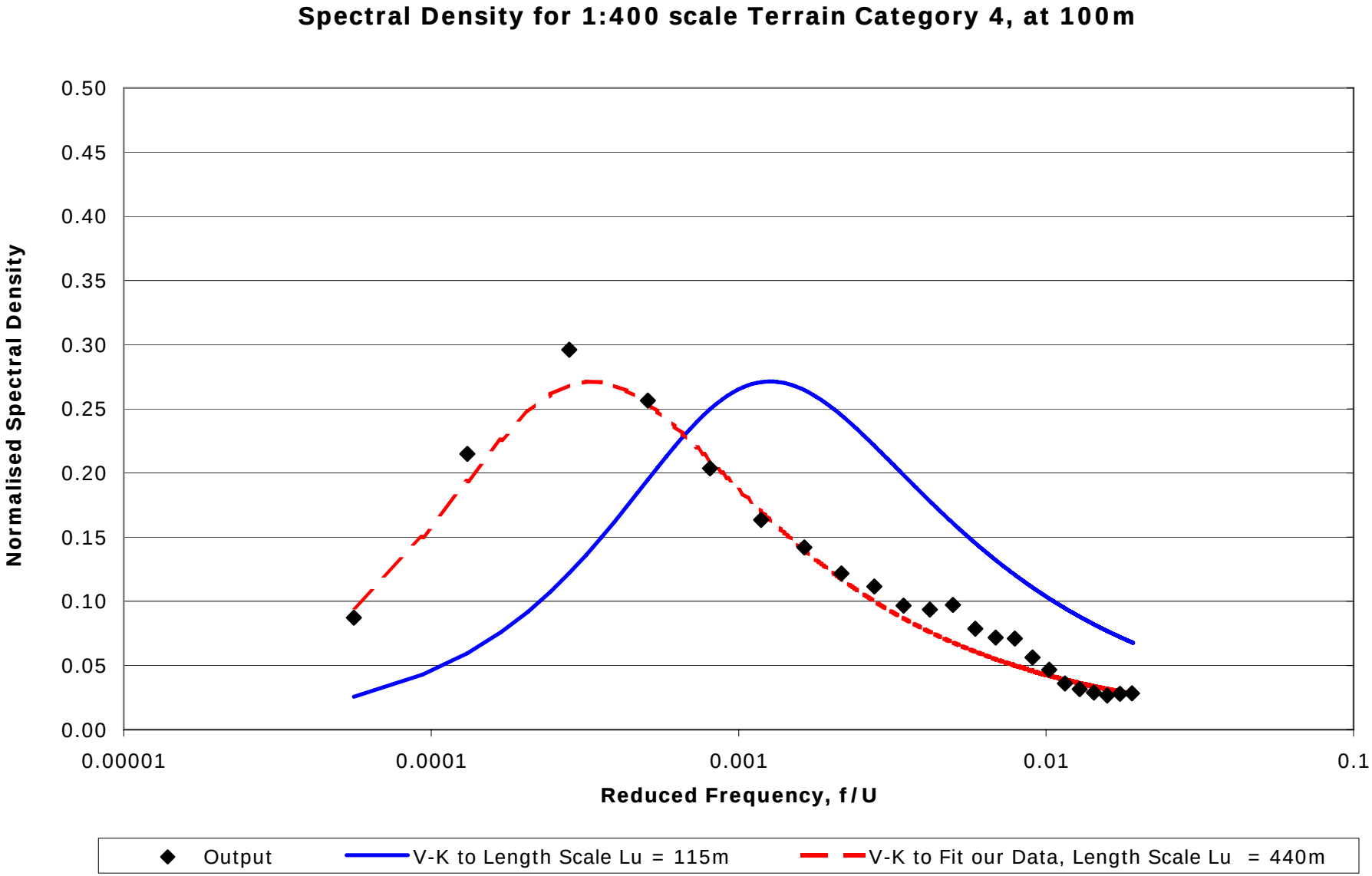
Annual Maximum Gust Wind Speeds (m/s)



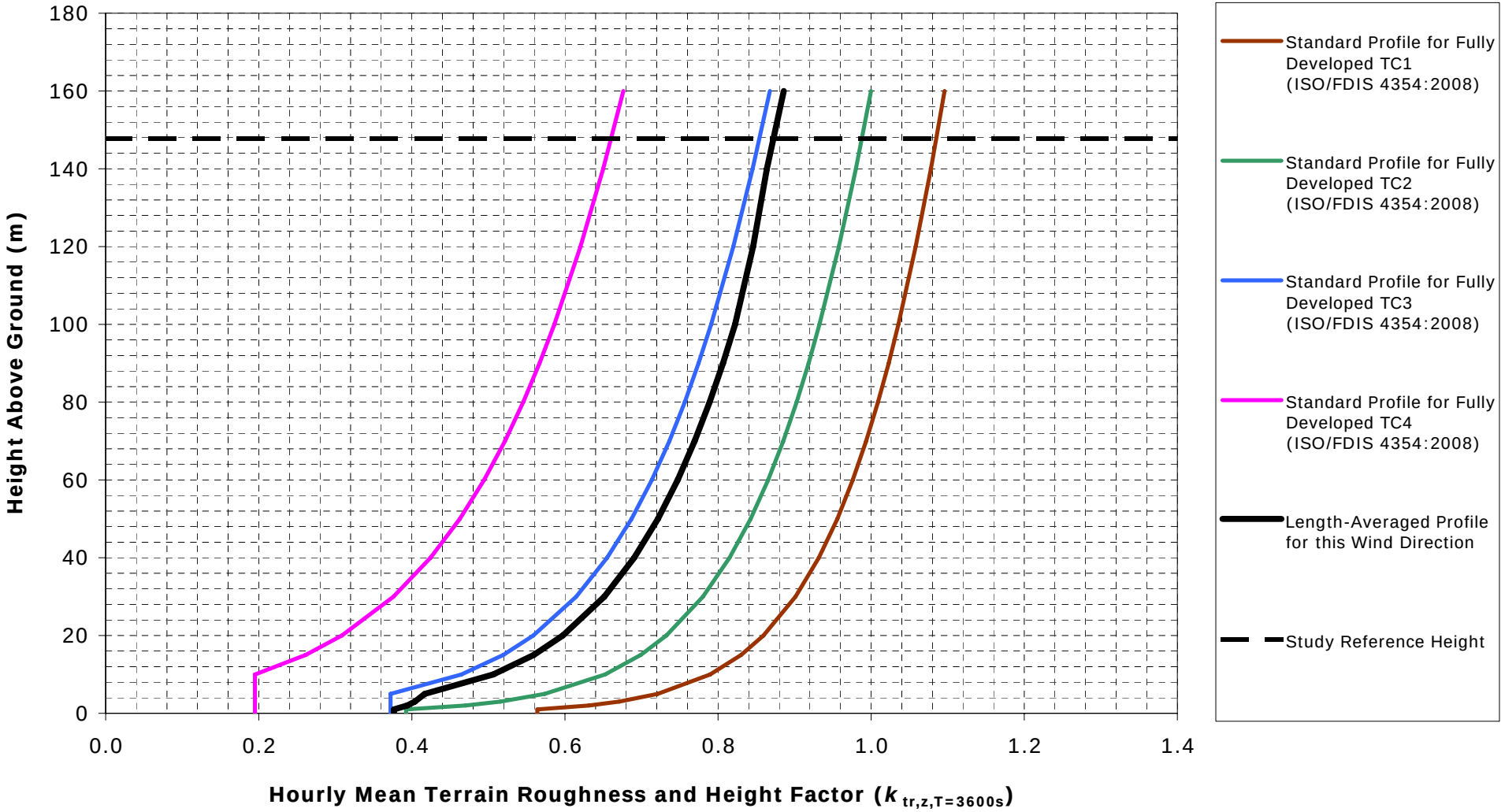
Appendix B

Wind Tunnel Boundary Layer Profile

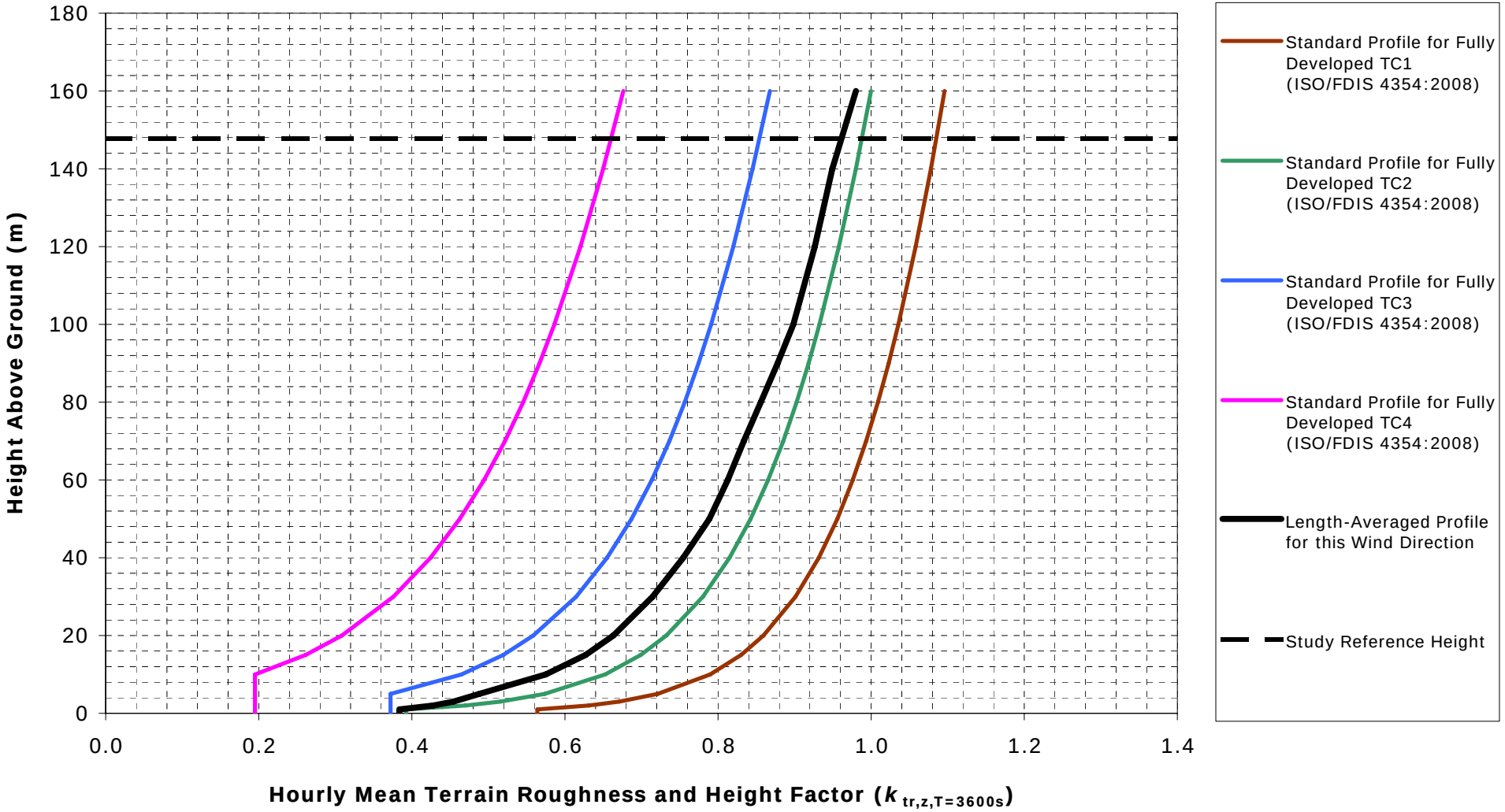

1 : 400 Scale, Terrain Category - TC4
Height Above Ground (m)
450
400
350
300
250
200
150
100
50
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Mean Terrain & Height Multiplier
Measured Turbulence Intensity
Measured Velocity Profile
Deaves and Harris 1978 (AS1170.2.1989) Turbulence Intensity
Deaves and Harris 1978 (AS1170.2.1989) Velocity Profile


Spectral Density for 1:400 scale Terrain Category 4, at 100m
Normalised Spectral Density
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00001
0.0001
0.001
0.01
0.1
Reduced Frequency, f/U
Output
V-K to Length Scale Lu = 115m
V-K to Fit our Data, Length Scale Lu = 440m

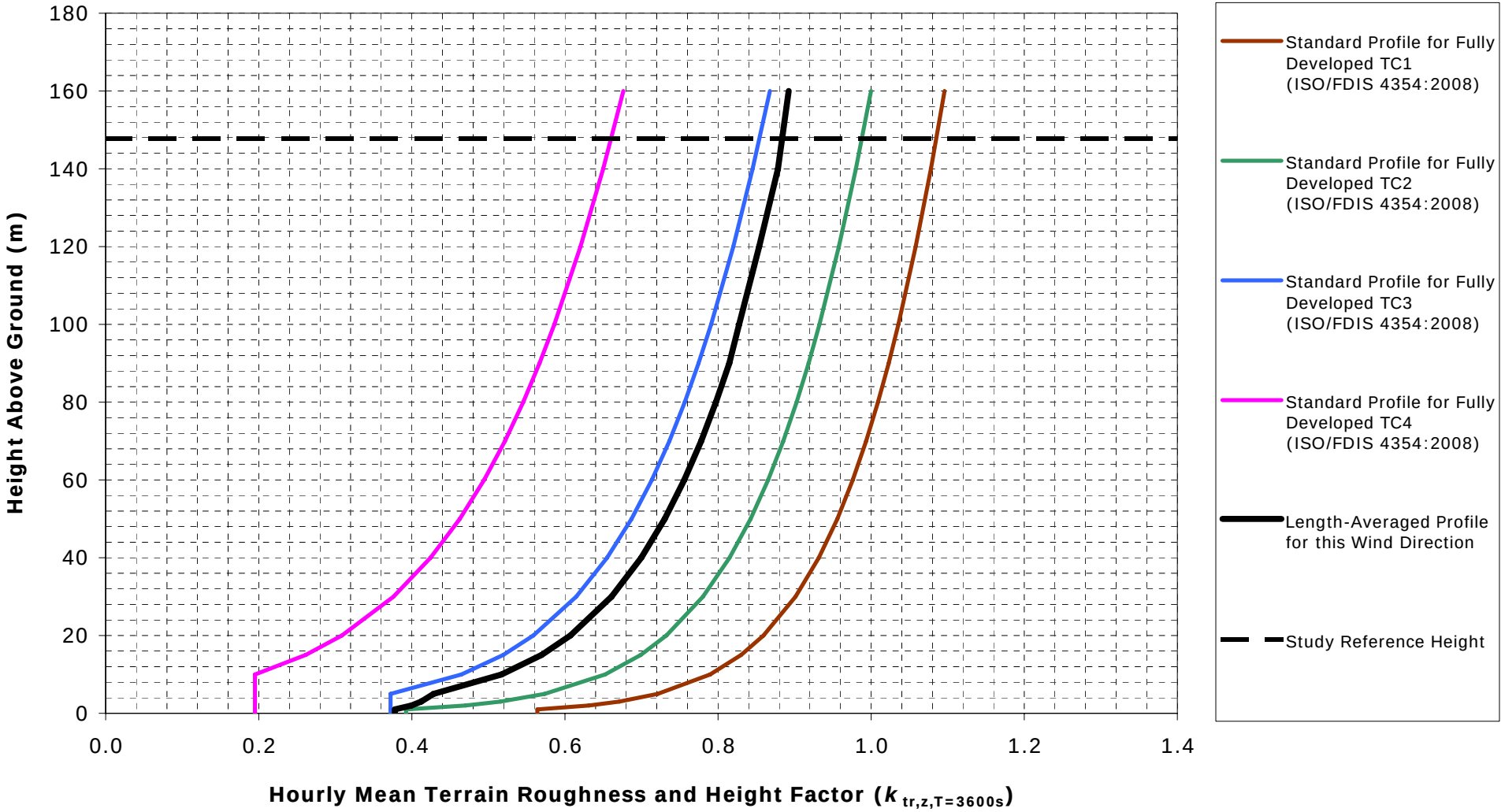
Hourly Mean Velocity Profile for Northerly Winds

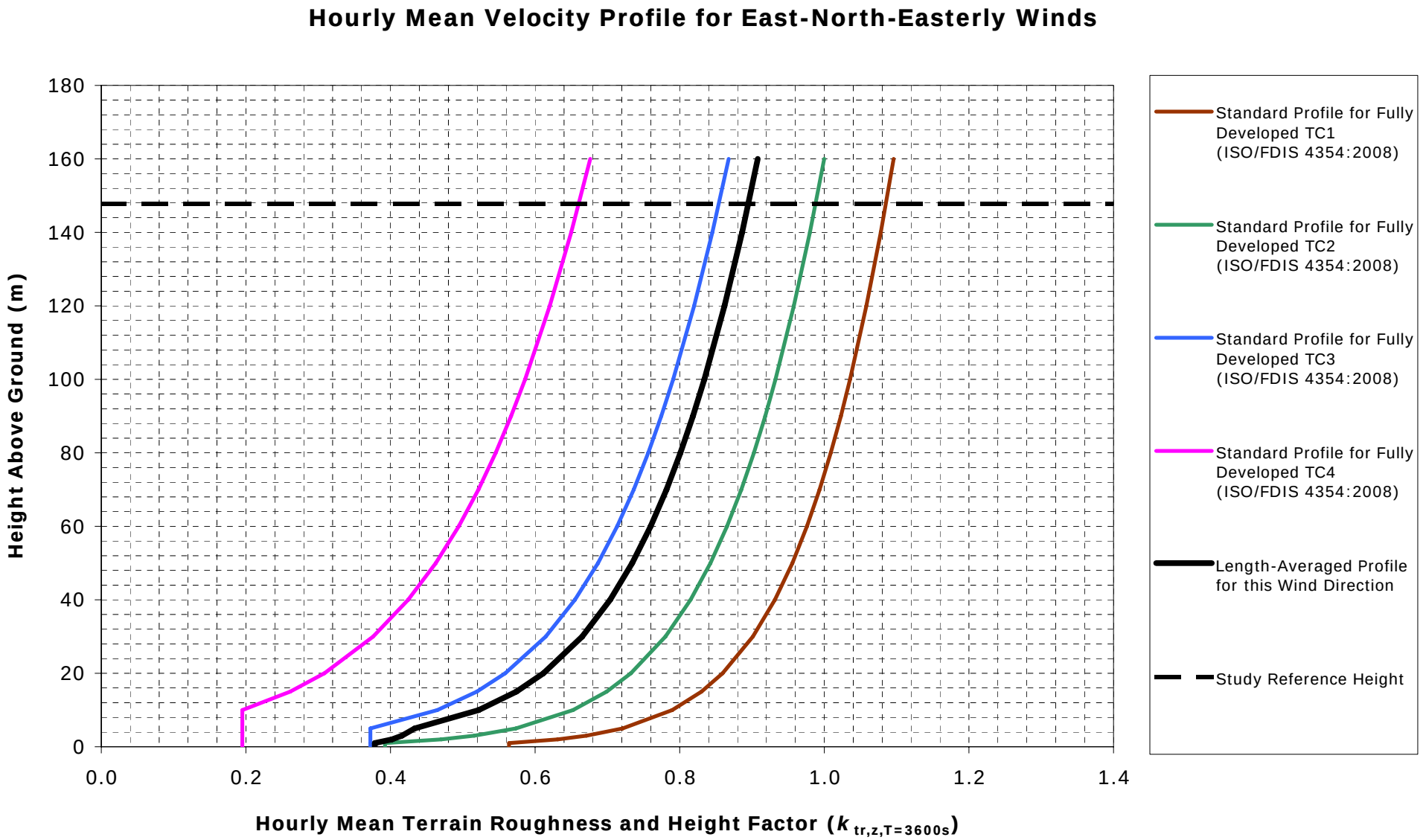


Hourly Mean Velocity Profile for North-North-Easterly Winds

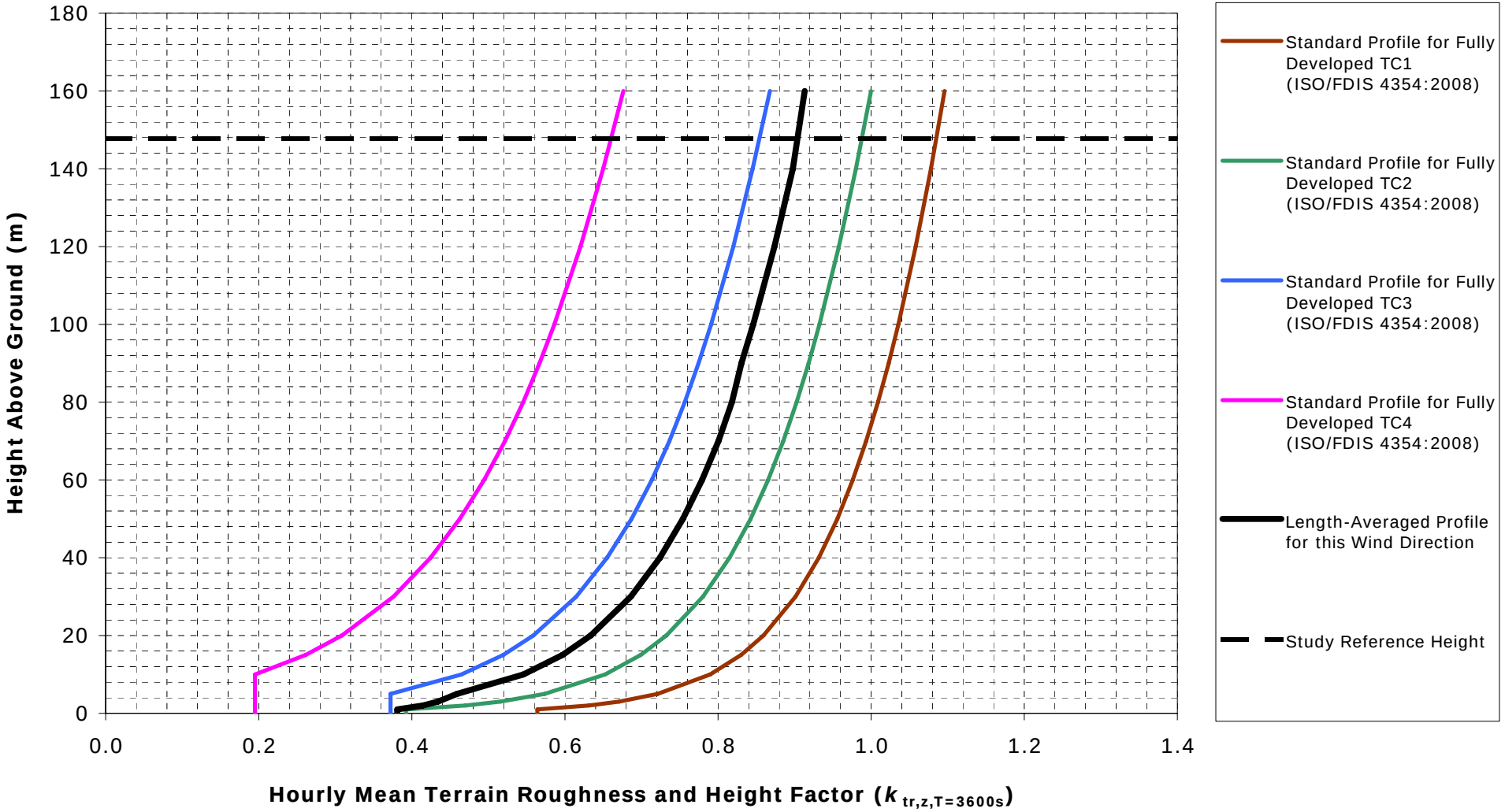


Hourly Mean Velocity Profile for North-Easterly Winds

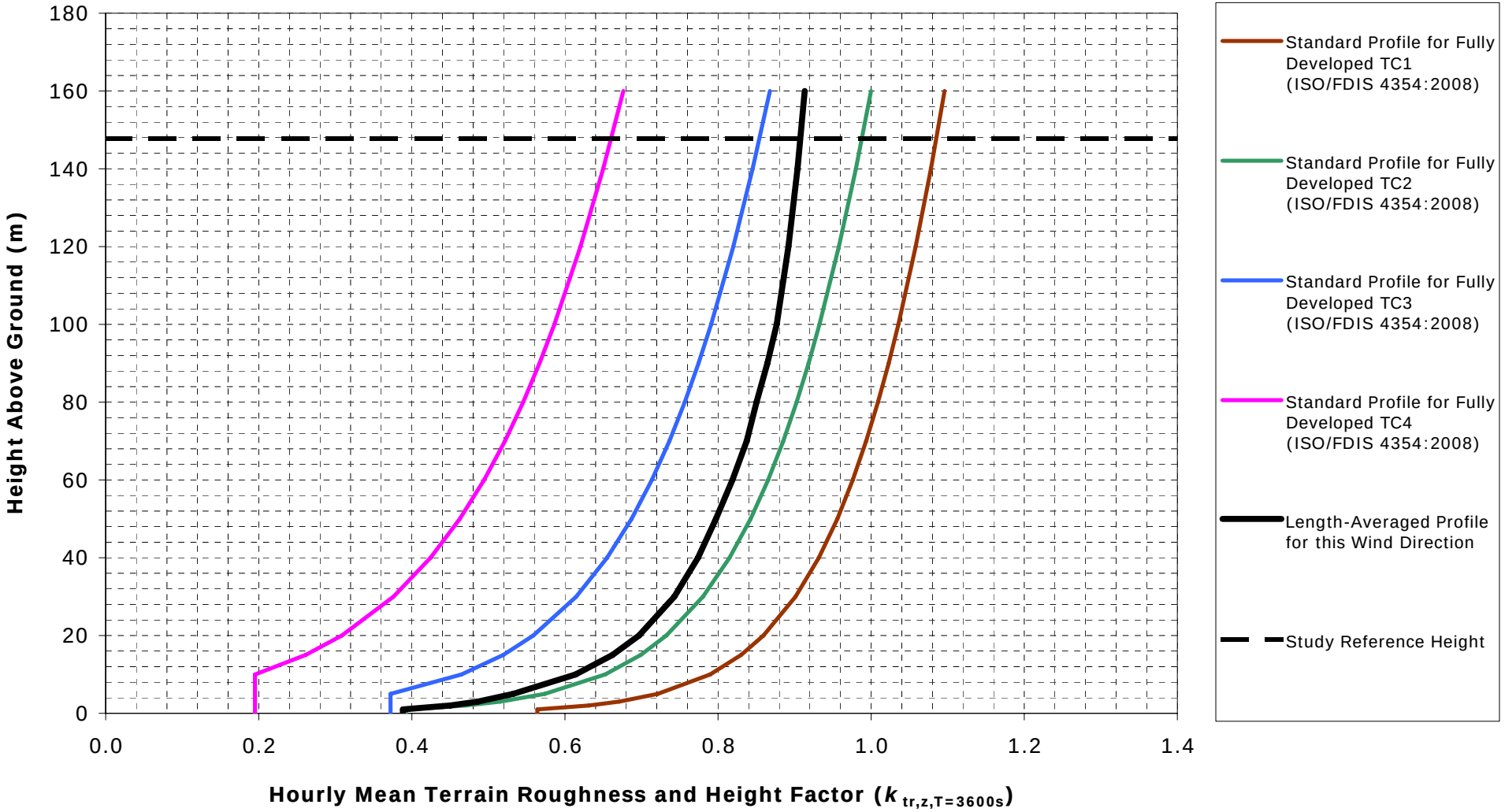



Hourly Mean Velocity Profile for East-North-Easterly Winds
Height Above Ground (m)
180
160
140
120
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Hourly Mean Terrain Roughness and Height Factor ($k_{tr,z,T=3600s}$)
Standard Profile for Fully Developed TC1 (ISO/FDIS 4354:2008)
Standard Profile for Fully Developed TC2 (ISO/FDIS 4354:2008)
Standard Profile for Fully Developed TC3 (ISO/FDIS 4354:2008)
Standard Profile for Fully Developed TC4 (ISO/FDIS 4354:2008)
Length-Averaged Profile for this Wind Direction
Study Reference Height

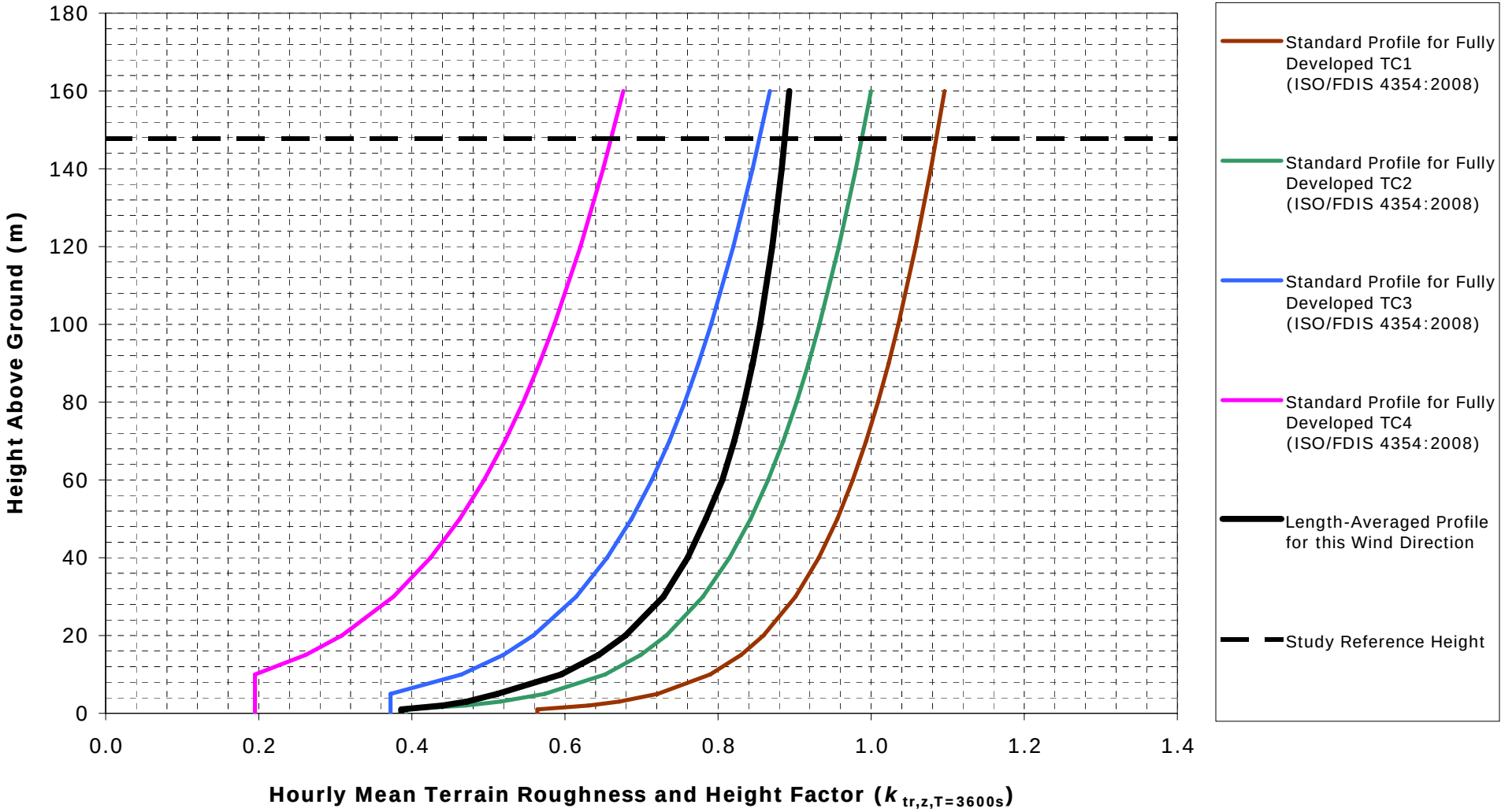
Hourly Mean Velocity Profile for Easterly Winds



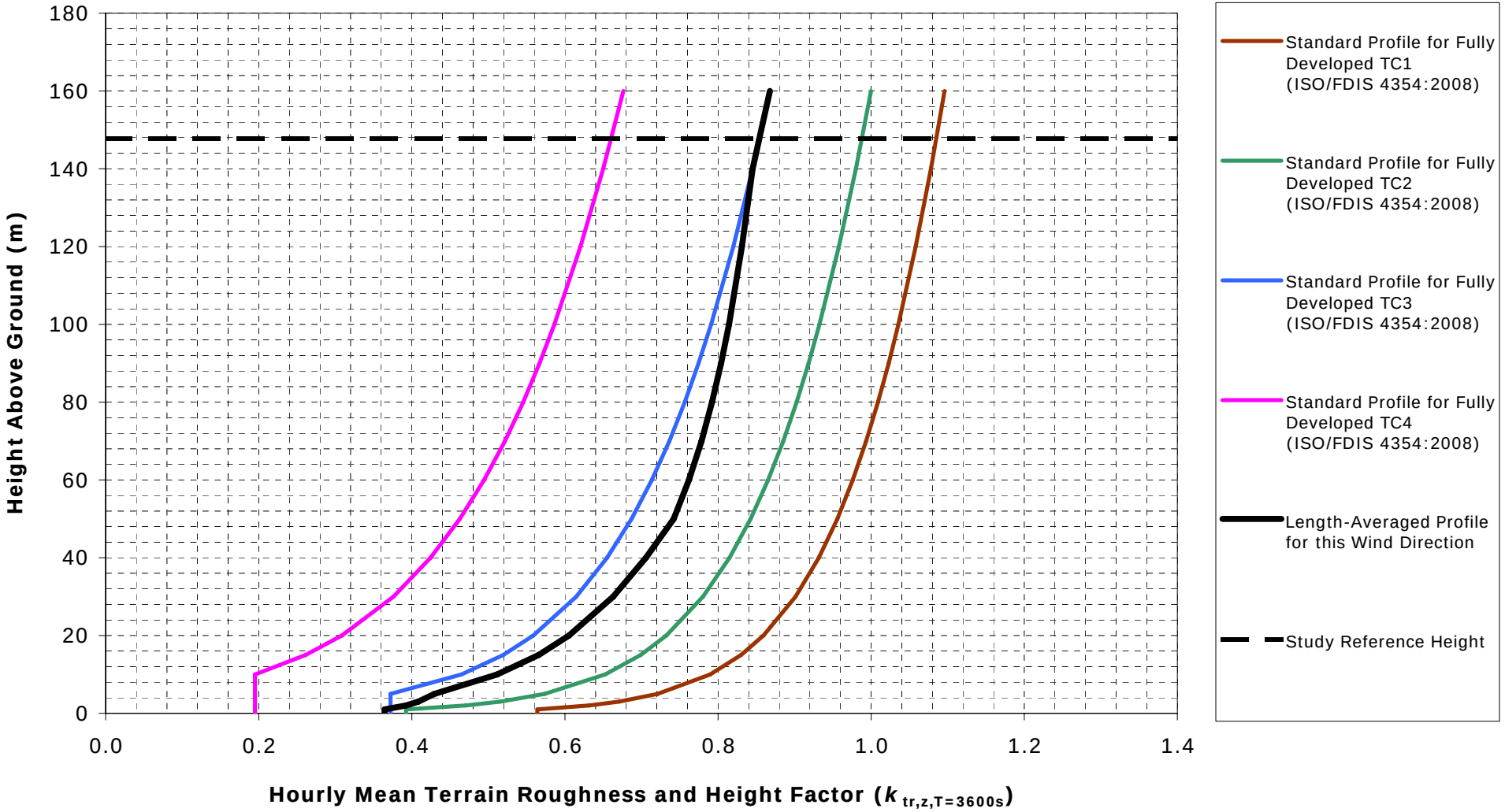
Hourly Mean Velocity Profile for East-South-Easterly Winds



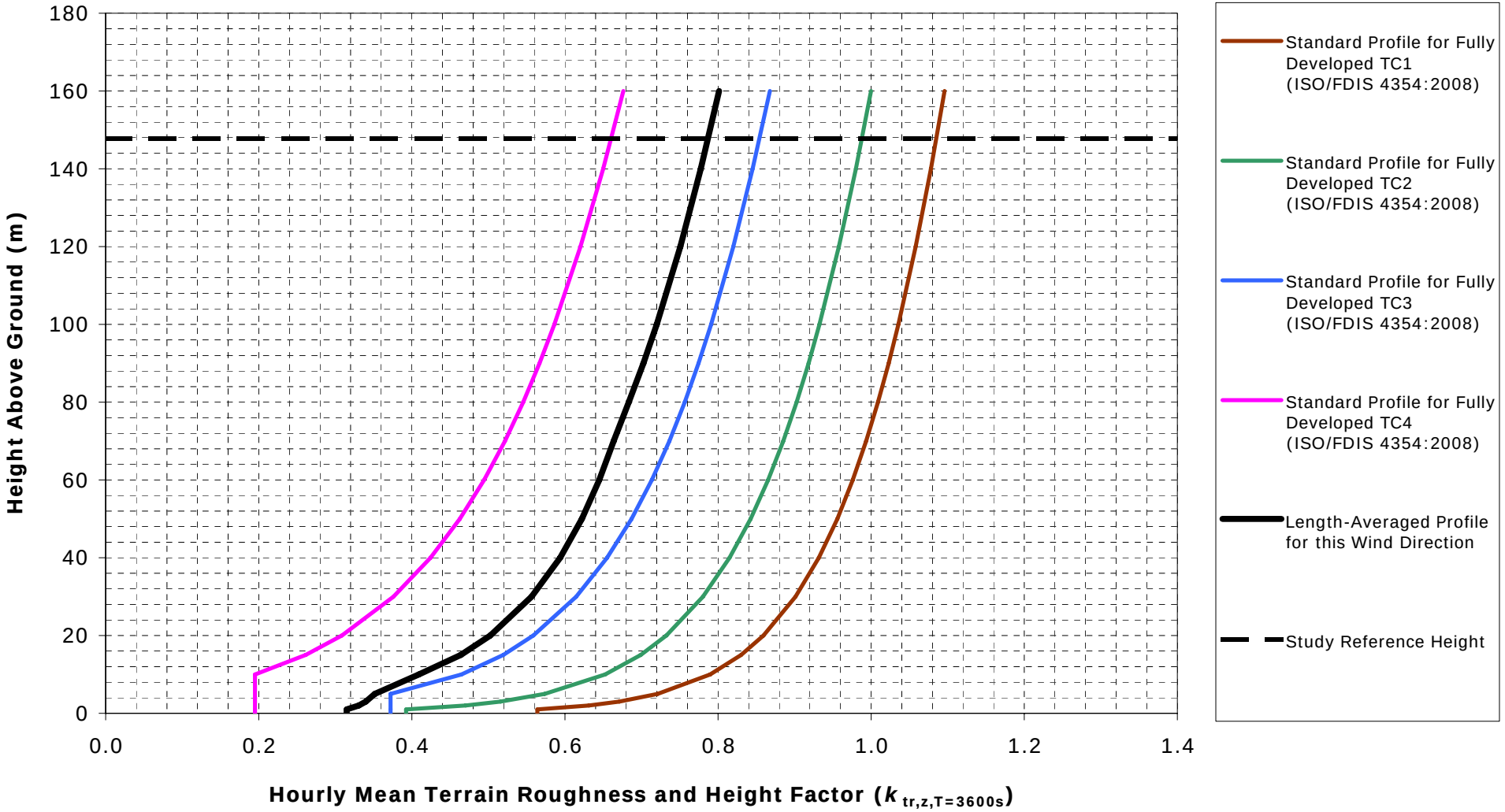
Hourly Mean Velocity Profile for South-Easterly Winds



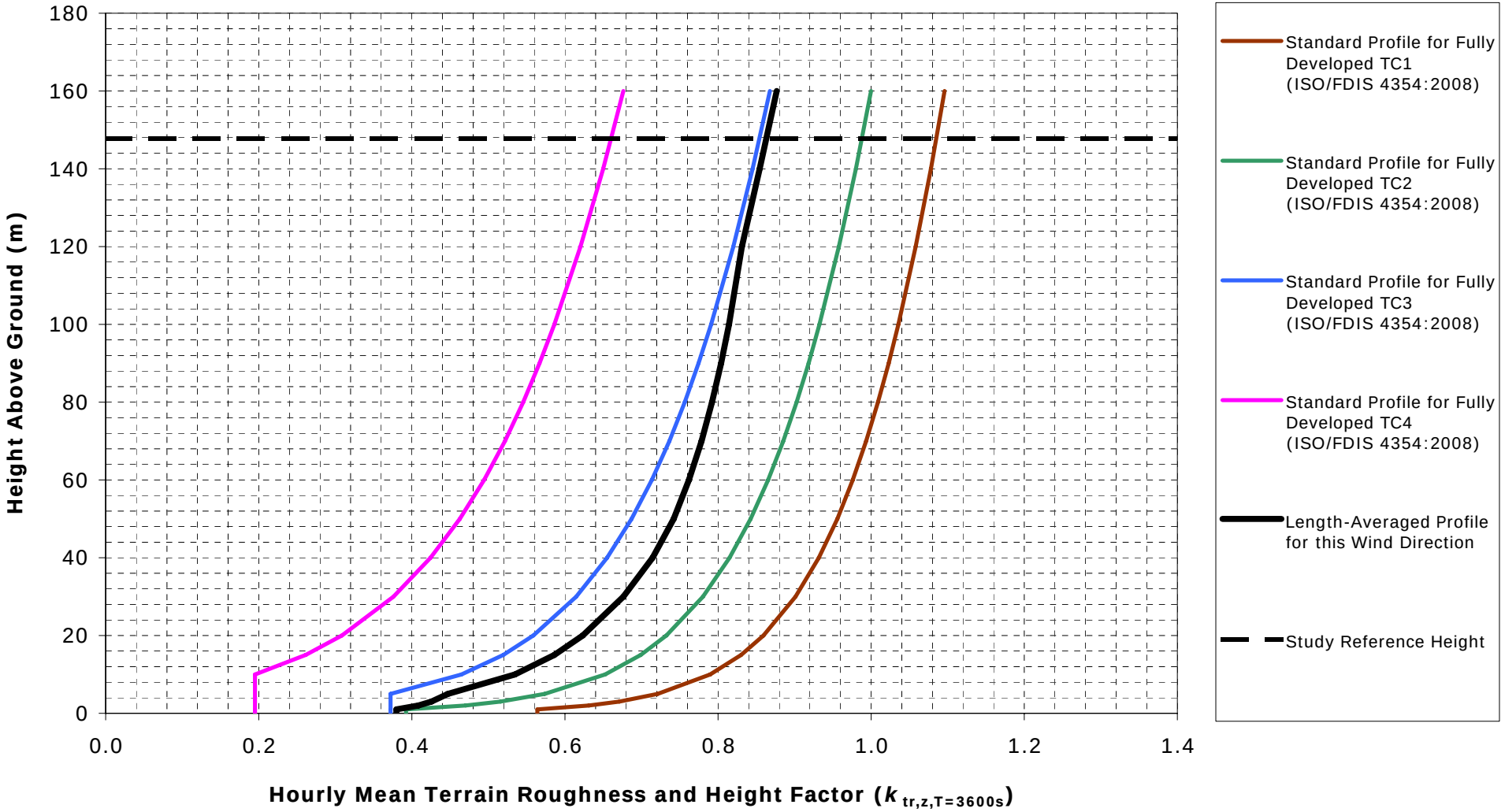
Hourly Mean Velocity Profile for South-South-Easterly Winds



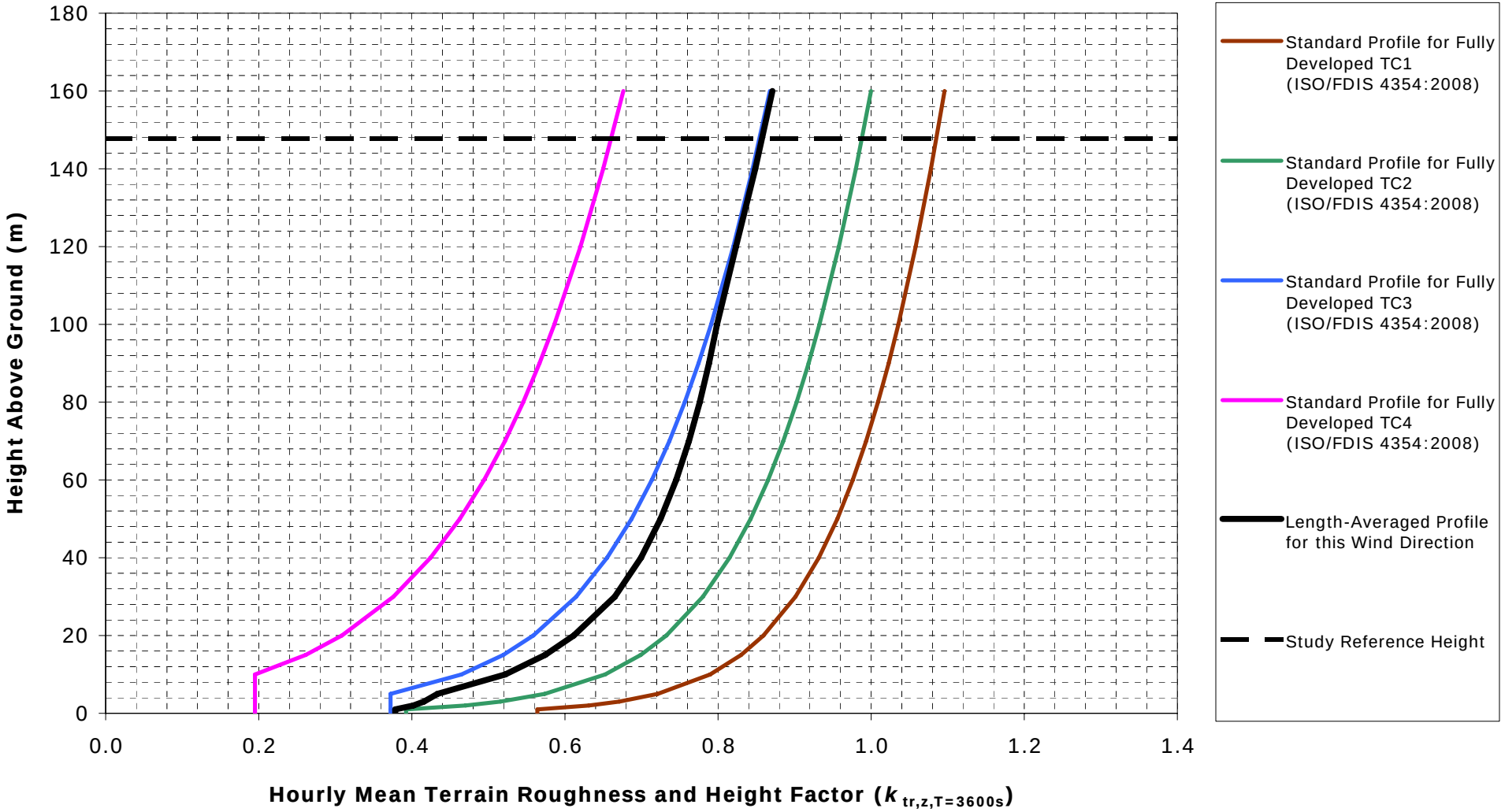
Hourly Mean Velocity Profile for Southerly Winds

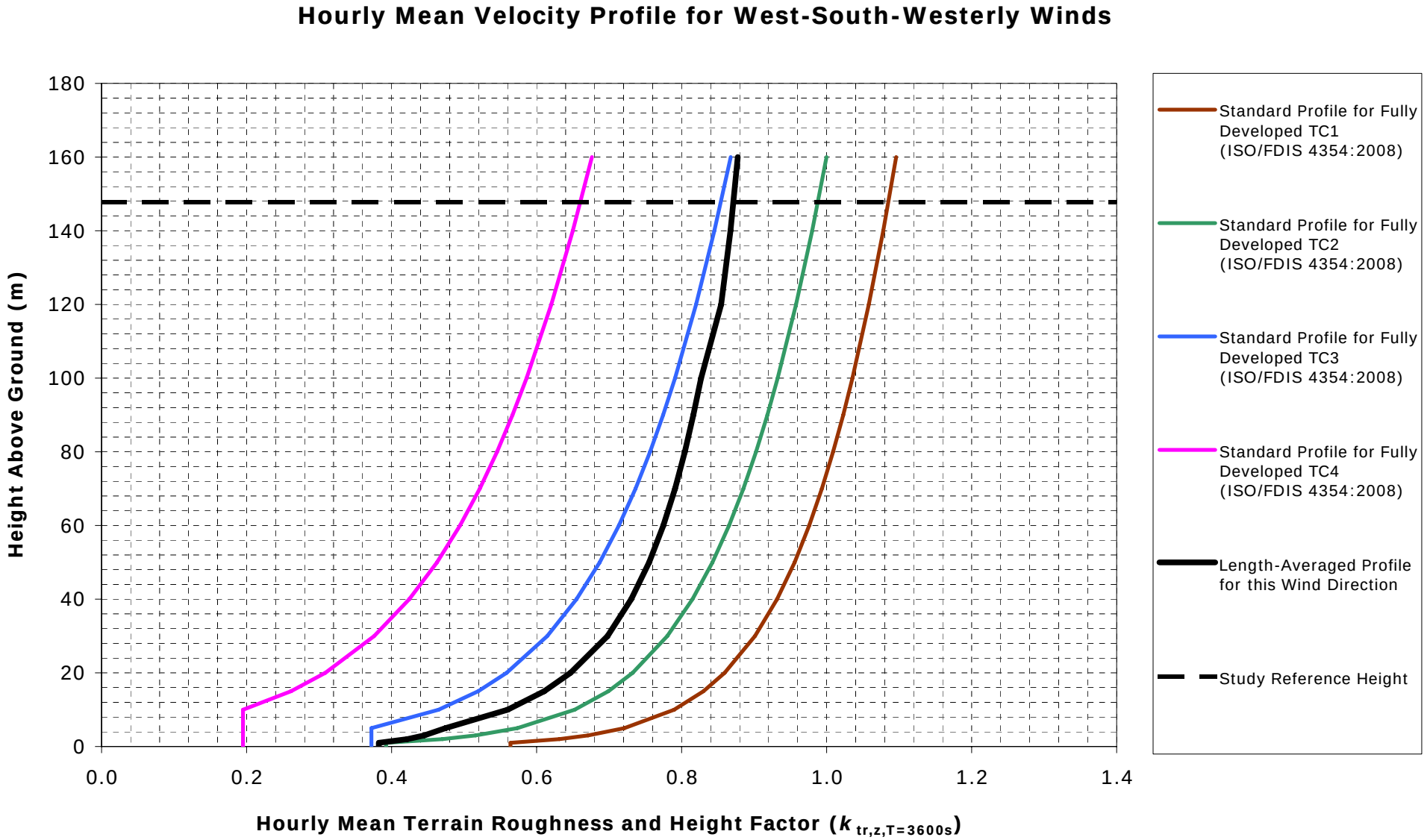


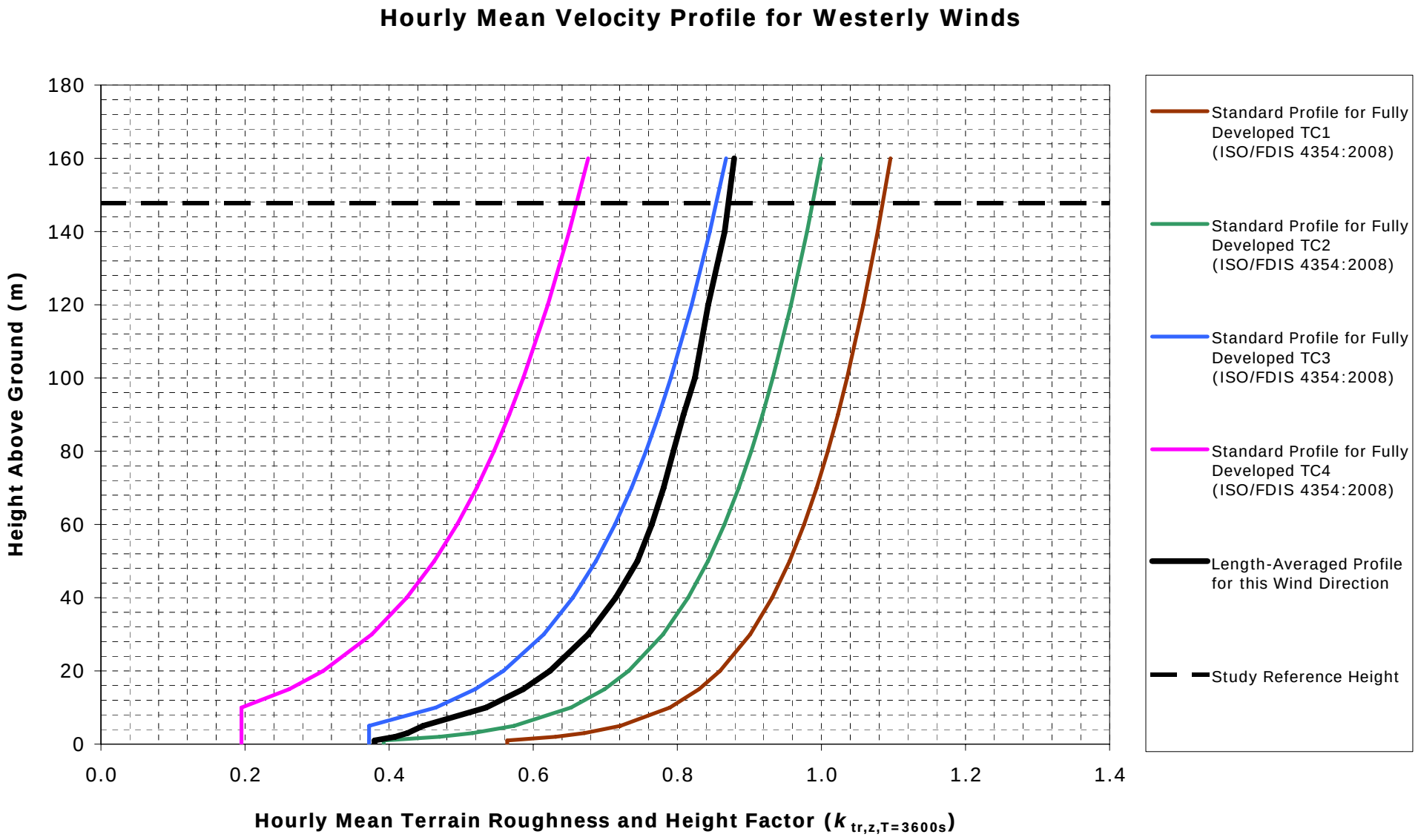
Hourly Mean Velocity Profile for South-South-Westerly Winds



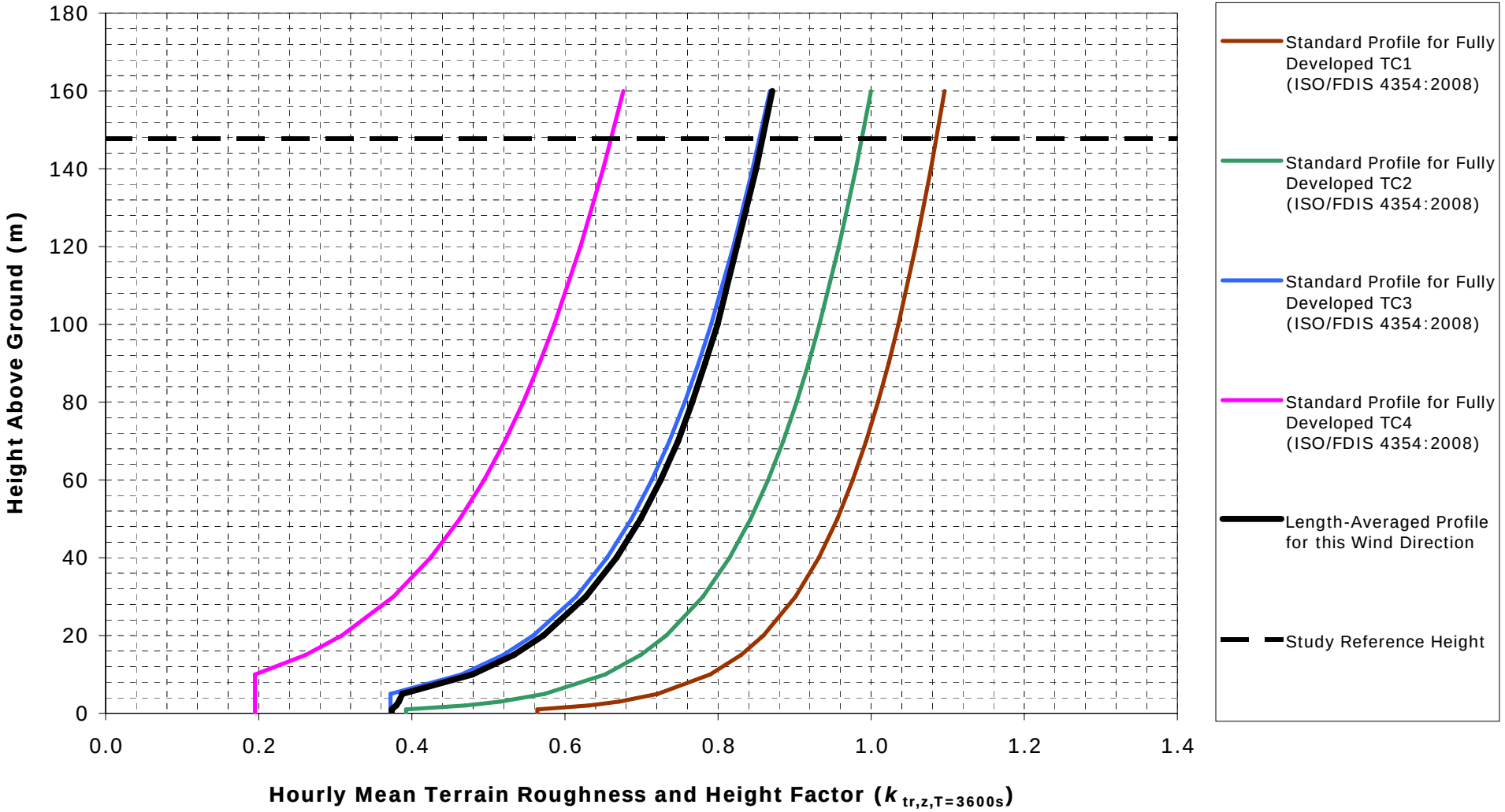
Hourly Mean Velocity Profile for South-Westerly Winds



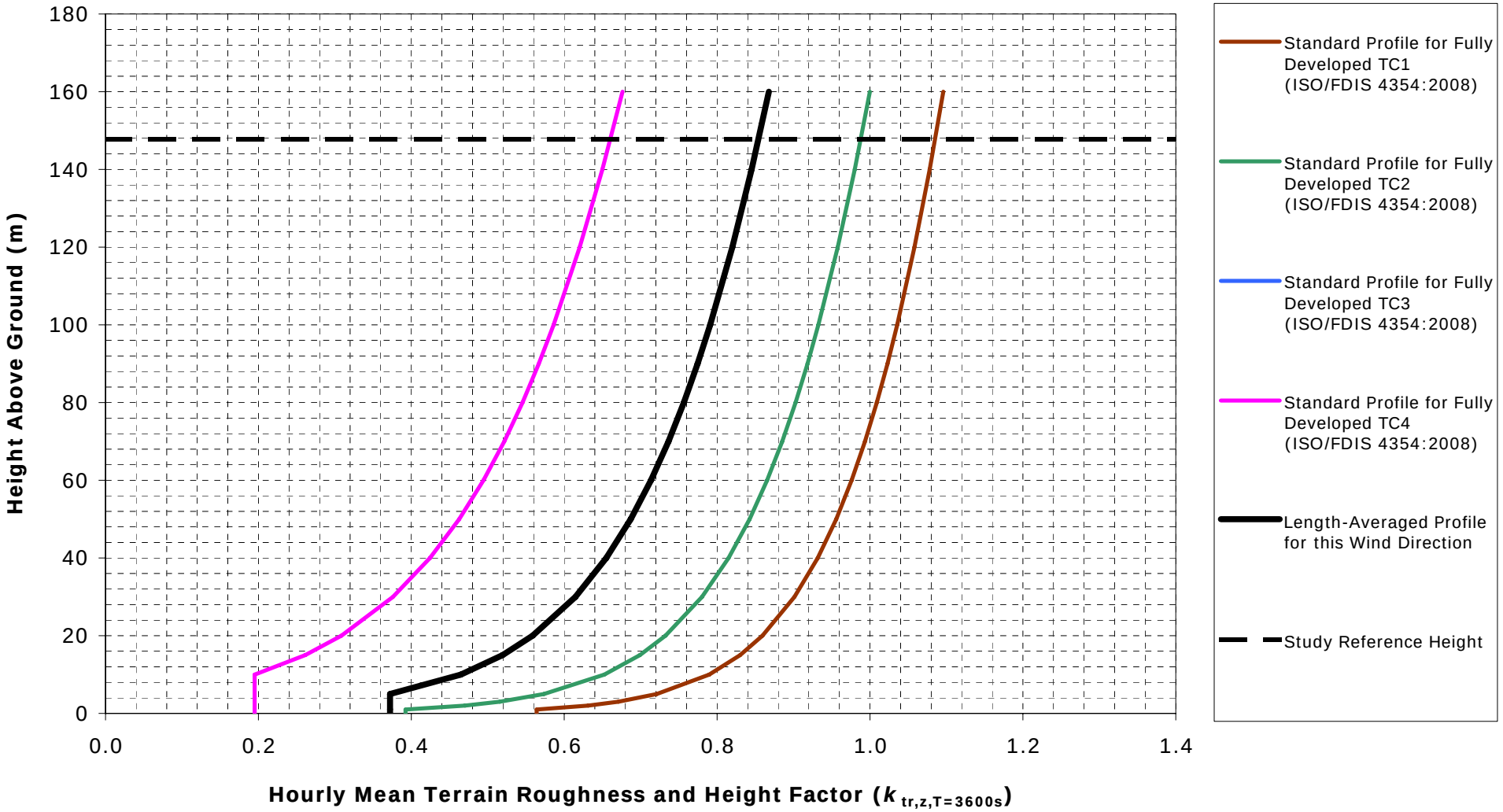

Hourly Mean Velocity Profile for West-South-Westerly Winds
Height Above Ground (m)
180
160
140
120
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Hourly Mean Terrain Roughness and Height Factor ($k_{tr,z,T=3600s}$)
Standard Profile for Fully Developed TC1 (ISO/FDIS 4354:2008)
Standard Profile for Fully Developed TC2 (ISO/FDIS 4354:2008)
Standard Profile for Fully Developed TC3 (ISO/FDIS 4354:2008)
Standard Profile for Fully Developed TC4 (ISO/FDIS 4354:2008)
Length-Averaged Profile for this Wind Direction
Study Reference Height


Hourly Mean Velocity Profile for Westerly Winds
Height Above Ground (m)
180
160
140
120
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Hourly Mean Terrain Roughness and Height Factor ($k_{tr,z,T=3600s}$)
Standard Profile for Fully Developed TC1 (ISO/FDIS 4354:2008)
Standard Profile for Fully Developed TC2 (ISO/FDIS 4354:2008)
Standard Profile for Fully Developed TC3 (ISO/FDIS 4354:2008)
Standard Profile for Fully Developed TC4 (ISO/FDIS 4354:2008)
Length-Averaged Profile for this Wind Direction
Study Reference Height

Hourly Mean Velocity Profile for West-North-Westerly Winds



Hourly Mean Velocity Profile for North-Westerly Winds



Hourly Mean Velocity Profile for North-North-Westerly Winds