WINDTECH

Pedestrian Wind Environment Study

for the proposed development of

Lots 101 & 102, Rhodes Peninsula

May 28, 2010

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Document Control

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0	27/05/2010	Initial	AB	
1	28/05/2010	Added Appendix C	AB	

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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 proposed development of Lots 101 & 102, located at 52 Walker Street, Rhodes Peninsula. The site is bounded by Meredith Avenue to the north, Walker Street and the main northern railway line to the east, Nina Grey Avenue to the south, and Shoreline Drive to the west. The subject development is predominantly residential, and consists of four components, detailed as follows:

- Building A is a 25 storey tower, located at the south-eastern corner of the site. Private balconies and terraces are proposed on the eastern and western aspects of the tower. Note that a childcare centre is proposed at the base of the tower, and includes an associated designated outdoor area.
- Building B is a 6 storey building, located at the south-western corner. Private balconies and terraces are proposed on all aspects of Building B. Note that Buildings A and B share a 1 storey podium, which contains basement level car parking. A communal landscaped area is proposed on top of the podium, between Buildings A and B.
- Building C is a 25 storey tower, located at the north-western corner of the site. Private balconies and terraces are proposed on the eastern and western aspects of the tower.
- Building D is a 6 storey building, located at the north-eastern corner of the site. Private balconies and terraces are proposed on all aspects of Building D. Buildings C and D share a 1 storey podium, which contains basement level car parking. A communal landscaped area is proposed on top of the podium, between Buildings C and D.

Wind speed measurements were carried out using a 1:300 scale model of the development. The model has been constructed based on architectural drawings prepared by Meriton Apartments, dated May 7, 2010. A proximity model incorporating the surrounding buildings and local land topography was placed around the model of the proposed development. The surrounds model extends to a radius of approximately 375m from the centre of the subject site. Note that this model includes building massing models of what is expected to be constructed on the neighbouring development sites.

Testing was performed using Windtech's boundary layer wind tunnel facility, which has a 3.0m wide working section and has a fetch length of 14m. Peak gust and mean 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 the Sydney region to provide the equivalent full-scale wind speeds for the critical outdoor locations within and around the development site. The reference wind climate data used in this study is based on an analysis of 70 years of continuously recorded 10 minute mean wind speeds obtained at the meteorological recording station at Kingsford Smith airport, from 1939 to 2008, corrected for the 200m reference height that has been used.

The measured wind speeds for the critical outdoor locations within and around the development site are compared with criteria for long and short duration stationary activities and for pedestrian comfort (depending on the intended

uses of the various outdoor trafficable areas within and around the development), which are based on the weekly maximum Gust Equivalent Mean (GEM) wind speeds. The measured wind speeds are also compared against the safety limit criterion of 23m/s for the annual maximum peaks.

The model of the proposed development was tested in the wind tunnel without the effect of any forms of wind ameliorating devices such as balustrades, screens, canopies, etc that are not already shown in the architectural drawings. The effect of vegetation was also not included in the tests. For areas not achieving appropriate wind conditions, in-principle ameliorative treatments have been suggested.

The results of the study indicate that some of the outdoor trafficable areas within and around the proposed development are exposed to adverse winds. To achieve appropriate wind conditions for all outdoor trafficable areas within and around the development, the following ameliorative treatments have been recommended in this study:

- A strategic layout of trees and shrubs within and around the site has been presented in this report. It has been recommended that most of these trees be capable of growing to dimensions of at least 5m tall with a foliage canopy width of 4m. Some larger trees have also been recommended, capable of growing to dimensions of at least 8m tall with a foliage canopy width of 6m. It should be noted that this is a *minimum* planting layout; additional trees placed within and around the site is expected to further enhance wind conditions.
- Impermeable balustrades are recommended for all balcony and terrace edges of the proposed development.
- The south-western corner balconies on Levels 2 to 23 of Tower A, and Levels 1 to 22 of Tower C, are exposed to strong adverse southerly winds. It is recommended to add a full-height impermeable screen along the south-eastern edge of each balcony, which can join onto the already proposed column at the southern end of these balconies.
- A 2.5m tall privacy screen is recommended between the two southern terraces on Level 24 of Tower A, and another at the same location on Level 23 of Tower C.

Note that for trees to be effective in wind mitigation, they should be of a densely foliating and evergreen variety. Palm trees, for example, are typically not effective for mitigating adverse ground level winds due to the canopy of the tree being so high above ground. Note also that the use of light-weight furniture on high-rise private balconies and terraces is not recommended, unless it is securely attached to the balcony floor slab.

With the inclusion of the abovementioned treatments, wind conditions for all outdoor trafficable areas within and around the proposed development will be suitable for their intended uses.

It should be noted that the recommended tree layout described in this report is the minimum planting layout which is necessary to achieve adequate wind conditions for all ground level areas around the site. The supplied landscape drawings indicate that there will be trees in most of the recommended locations, plus there will be many additional smaller trees around the site. These additional trees are expected to further enhance the wind conditions for the ground level areas around the site.

2.0 Model Description

2.1 Model of the Study Building and Surrounds

The subject development is predominantly residential, and consists of four components, detailed as follows:

- Building A is a 25 storey tower, located at the south-eastern corner of the site. Private balconies and terraces are proposed on the eastern and western aspects of the tower. Note that a childcare centre is proposed at the base of the tower, and includes an associated designated outdoor area.
- Building B is a 6 storey building, located at the south-western corner. Private balconies and terraces are proposed on all aspects of Building B. Note that Buildings A and B share a 1 storey podium, which contains basement level car parking. A communal landscaped area is proposed on top of the podium, between Buildings A and B.
- Building C is a 25 storey tower, located at the north-western corner of the site. Private balconies and terraces are proposed on the eastern and western aspects of the tower.
- Building D is a 6 storey building, located at the north-eastern corner of the site. Private balconies and terraces are proposed on all aspects of Building D. Buildings C and D share a 1 storey podium, which contains basement level car parking. A communal landscaped area is proposed on top of the podium, between Buildings C and D.

The site is bounded by Meredith Avenue to the north, Walker Street and the main northern railway line to the east, Nina Grey Avenue to the south, and Shoreline Drive to the west. Surrounding the site on the western side of Walker Street are many other high-density residential buildings, which typically range in heights of 5 to 10 storeys. On the eastern side of Walker Street and the railway line is predominantly single-storey residential housing.

Wind speed measurements were carried out using a 1:300 scale model of the development. The model has been constructed based on architectural drawings prepared by Meriton Apartments, dated May 7, 2010. A proximity model incorporating the surrounding buildings and local land topography was placed around the model of the proposed development. The surrounds model extends to a radius of approximately 375m from the centre of the subject site. Note that this model includes building massing models of what is expected to be constructed on the neighbouring development sites. Photographs of the wind tunnel model that has been used for this project are presented in Figures 1a to 1g on the following pages.

The model was placed in a suburban terrain boundary layer wind flow based on the standard ISO/FDIS 4354:2008 model. The reference wind speeds, which are obtained from an analysis of recorded meteorological data for the region, were corrected for changes in the upstream building morphology and land topography. Section 2.2 of this report provides details on how this analysis is undertaken.

Figure 1a: Photograph of the Wind Tunnel Model (view from the south-west, facing north-east)

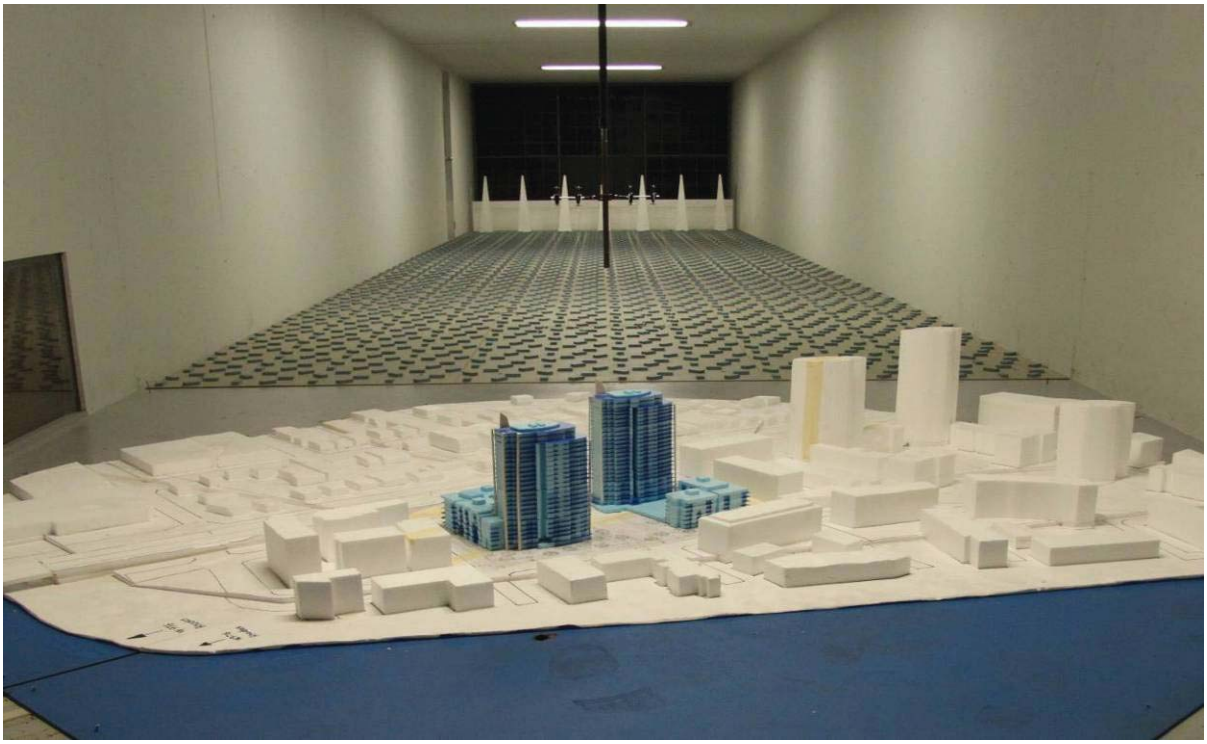

Figure 1b: Photograph of the Wind Tunnel Model (view from the north-west, facing south-east)

Figure 1c: Photograph of the Wind Tunnel Model (view from the north-east, facing south-west)

Figure 1d: Photograph of the Wind Tunnel Model (view from the south-east, facing north-west)

Figure 1e: Photograph of the Wind Tunnel Model (view from the north-east, facing south-west)

Figure 1f: Photograph of the Wind Tunnel Model (view from the north-west, facing south-east)

Figure 1g: Photograph of the Wind Tunnel Model (view from the south-west, facing north-east)

2.2 Wind Climate Model

The boundary layer wind flows matched the model scale and the overall surrounding terrain characteristics beyond the 375m radius of the physical surrounds model tested in the wind tunnel for each wind direction tested. For the fetch beyond the extent of the surround model the wind profiles are simulated based on the standard ISO/FDIS 4354:2008 model. The wind profile shape is calculated based on an analysis of the surrounding terrain for each wind direction tested. Figure 2 shows an aerial image of the site and surrounds for a radius of $40h$ from the proximity model, where h is the reference height of the development (82m above ground for this study). Hence, for this project, the fetch length is 3.3km. The terrain types indicated in Figure 2 are 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:

$$x_i = z_{0,r}\left[\frac{z}{0.3z_{0,r}}\right]^{1.25} \qquad (2.1)$$

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 1).

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 2.

For example, for wind coming from the north-easterly direction, it is assumed that the approaching wind profile at the outer edge of the fetch length (3.3km from the edge of the surrounds model) is the standard ISO/FDIS 4354:2008 suburban terrain profile, since this is coming from over the developed residential area of Ryde. As the wind approaches the site it continues over the suburban terrain of Ryde and Meadowbank, then over the open water of the Parramatta River, and then over the suburban housing area on the eastern side of the Rhodes Peninsula. The final wind profile for this wind direction, shown in Appendix B of this report, indicates that it is mostly a suburban profile since the length of open terrain over the Parramatta River is relatively short compared to the total fetch length of 3.3km considered.

The full sets of wind profile plots that have been used for this study are shown in Appendix B of this report, for each wind direction tested. The mean and gust terrain and height multipliers, and the corresponding roughness lengths, are summarised in Table 1 for the various standard ISO/FDIS 4354:2008 profiles. Note that the terrain and height multipliers indicated in this table are based on the study reference height of 200m above ground.

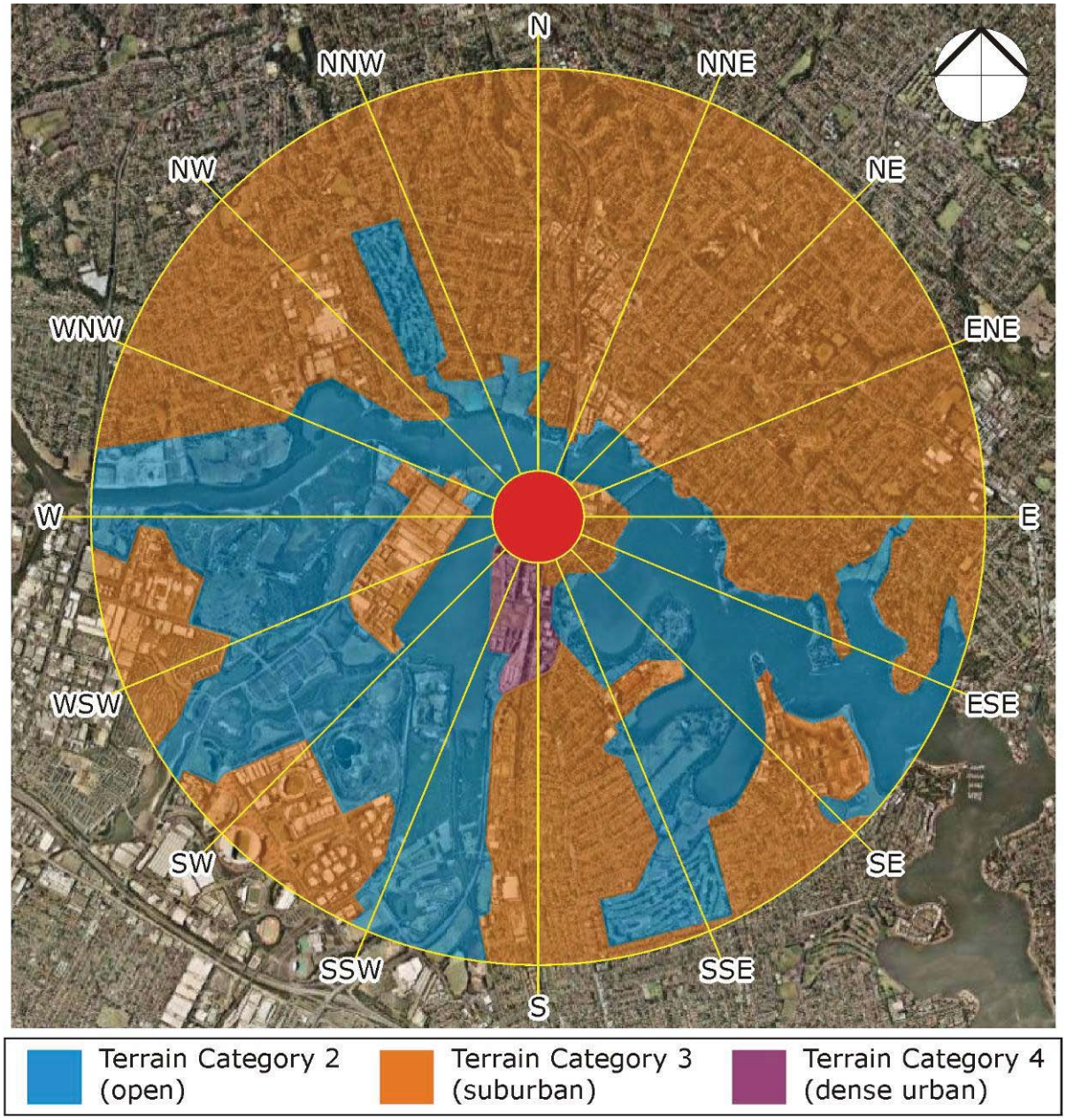

Figure 2: Surrounding Terrain Types (3.3km fetch length)

Table 1: Terrain & Height Multipliers and Turbulence Intensities at the Study Reference Height of 200m, and the Corresponding Roughness Lengths (for the standard ISO/FDIS 4354:2008 profiles)

Terrain Description	Terrain & Height Multipliers (for 200m above ground)			Turbulence Intensity	Roughness Length
	$k_{tr,T=3600s}$	$k_{tr,T=600s}$	$k_{tr,T=3s}$	$I_{v,200m}$	(m) $z_{0,r}$
Open	1.03	1.07	1.36	1.03	0.03
Suburban	0.91	0.95	1.33	0.91	0.30
Dense Urban	0.72	0.77	1.27	0.72	3.00

3.0 Test Procedure

Testing was performed in Windtech's boundary layer wind tunnel facility. No correction is required for blockage effects. The mean free stream wind speed at the study reference height of 200m in the tunnel is approximately 11.8m/s. This corresponds to a velocity scale range of approximately 1:1.1 to 1:1.9 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 32 minutes to 55 minutes in full-scale for the annual maximum peak wind speeds, which is suitable for this type of study.

A detailed analysis involving sixteen wind directions at 22.5 degrees intervals was carried out in the wind tunnel. This procedure provides comprehensive information about the wind environment to be expected for the various wind directions.

The free stream and test-location air currents were monitored using a pair of Dantec hot wire probe anemometers. The probe support was mounted such that the probe wire was vertical as much as possible. This 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.

The output from both 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:

$$\hat{V} = \overline{V} + g.\sigma_V$$

where g has been taken to be 3.5.

For each of the sixteen wind directions, peak gust and mean wind speeds were measured at selected points at a full-scale height of approximately 1.5m, and are normalised by the mean value at a reference scale height of 200m up-wind of the model. The reference velocity measurements are used to relate the mean and peak wind speed measurements to actual mean and gust velocities, based on available meteorological data for the Sydney region.

The reference wind climate data used in this study is based on an analysis of 70 years of continuously recorded 10 minute mean wind speeds obtained at the meteorological recording station at Kingsford Smith airport, from 1939 to 2008. A plot of the data that has been used for this study is presented in Figure 3, referenced to a height of 10m above ground in open terrain. Note that the reference wind climate data used for this study is referenced to 200m above ground, and adjusted for the upwind terrain roughness as detailed in Section 2.2 of this report.

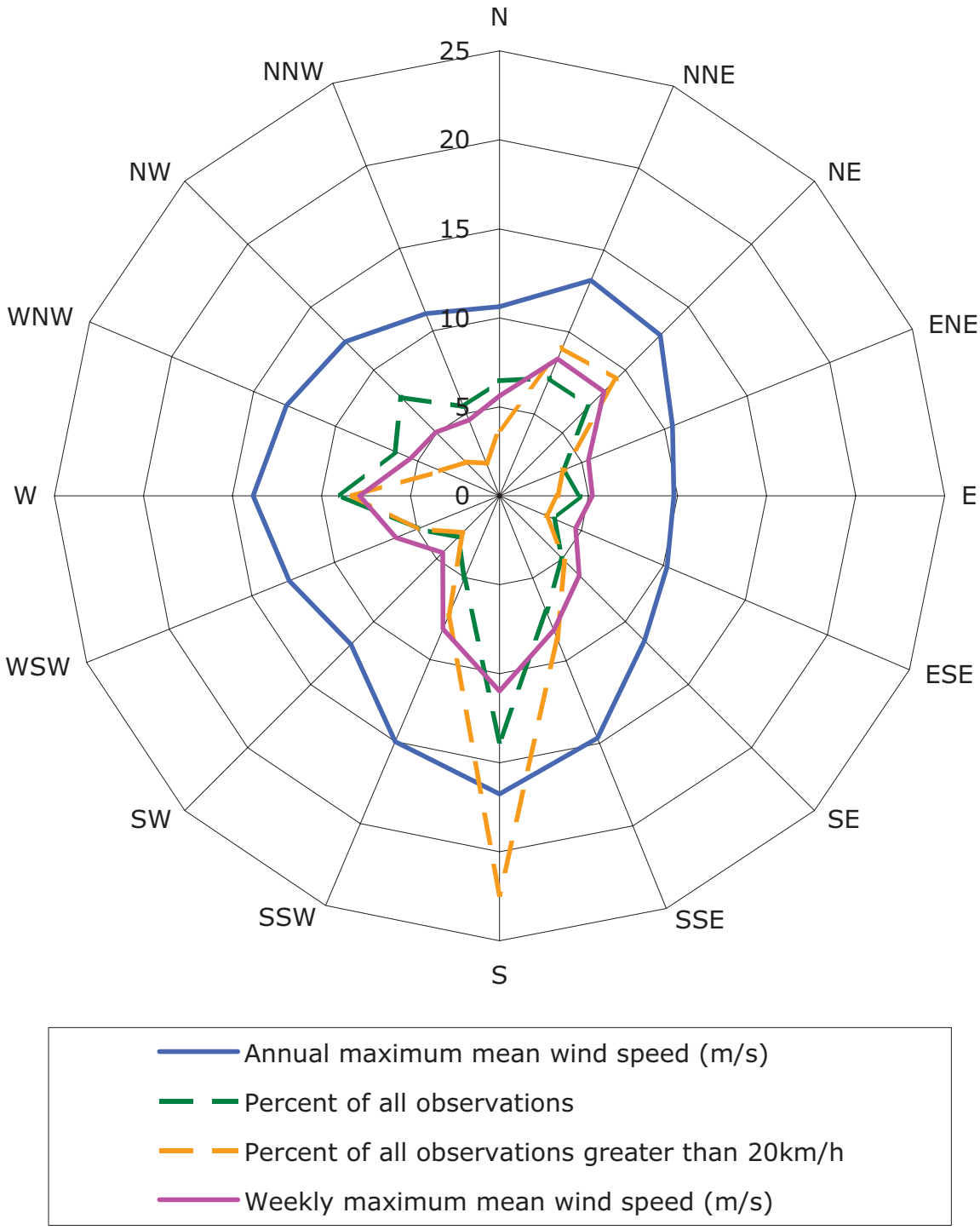

Figure 3: Annual and Weekly Maximum 10 minute Mean Wind Speeds for Sydney, and Frequencies of Occurrence (referenced to open terrain at 10m)

4.0 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 2: 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.

4.1 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 3 below are based on a frequency of exceedance of once per week (a probability of exceedance of 5%).

Table 3: 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*

4.2 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 4a and 4b, below.

Table 4a: 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 4b: 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*

4.3 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 5 below. This set of criteria tends to be more conservative than criteria suggested by other researchers such as those indicated in Figure 4.

Table 5: 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

Table 5: Criteria by Melbourne (1978) (continued)

Classification	Human Activities	Annual Maximum Gust
Long Exposure Activities	Generally acceptable for long duration stationary activities such as in outdoor restaurants & theatres and in parks.	10 m/s > *u*

4.4 Comparison of the Various Wind Speed Criteria

The criteria mentioned in Table 5, as well as other criteria, are compared on a probabilistic basis in Figure 4, below.

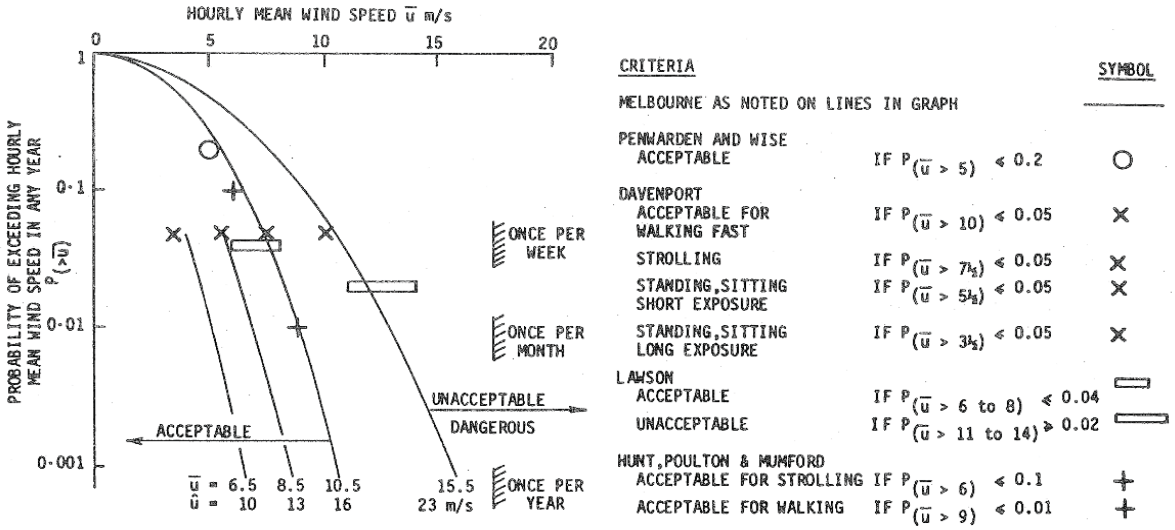

Figure 4: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (after Melbourne, 1978)

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 5. 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.

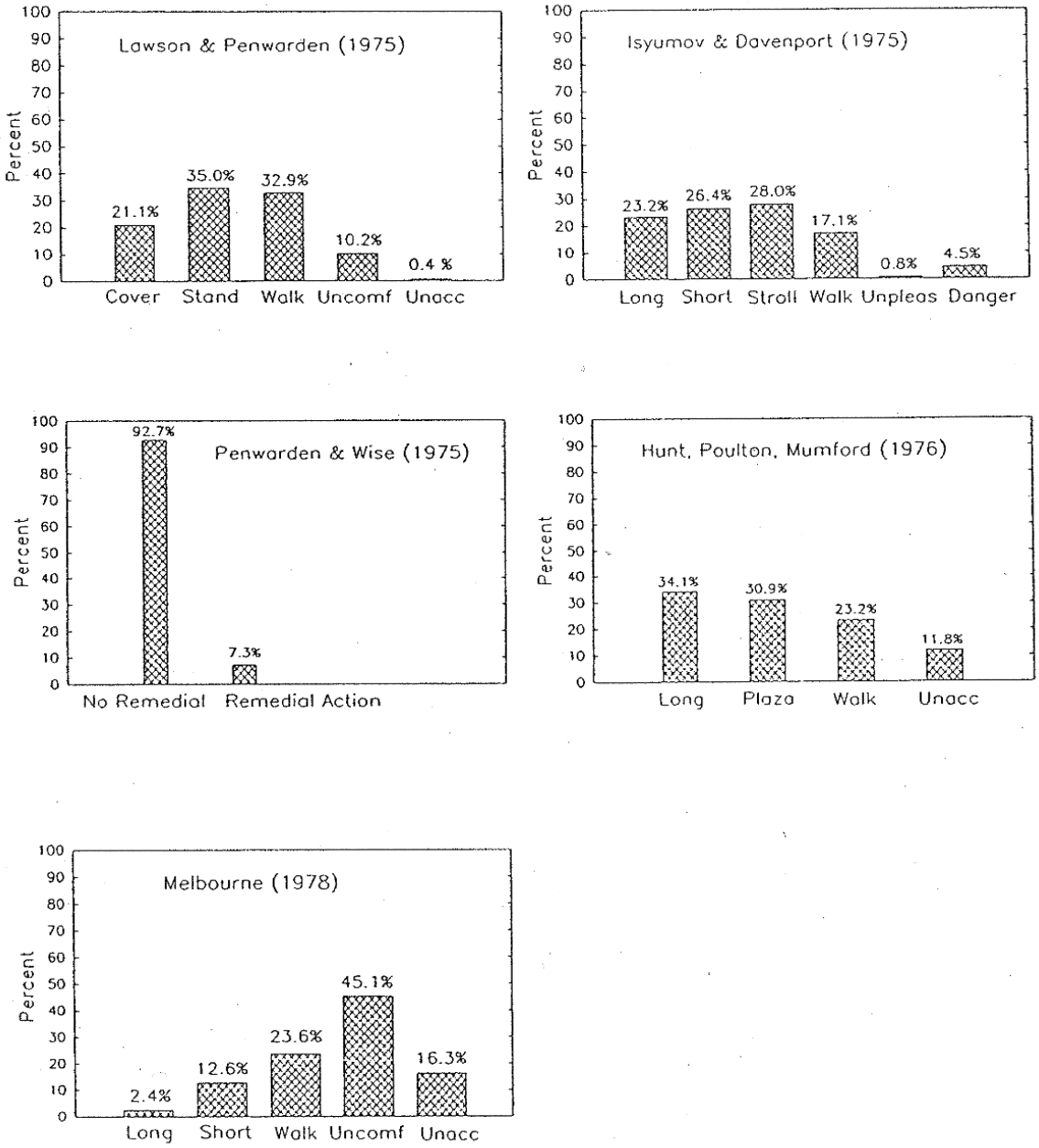

Figure 5: Distribution of Pedestrian Wind Comfort over Five Criteria for 246 locations examined in the Wind Tunnel (after Ratcliff & Peterka, 1990)

4.5 Criteria Used for This Study

For this study, the measured wind conditions for the various critical outdoor trafficable areas are compared against two sets of criteria. For comfort, the aforementioned Davenport (1972) criteria are used in conjunction with a weekly maximum Gust Equivalent Mean (GEM) wind speed (defined below). The safety limit criterion by Melbourne (1972) of 23m/s for the annual maximum peak wind speeds is also used.

Note that the abovementioned Davenport (1972) criteria is used in conjunction with a Gust Equivalent Mean (GEM) wind speed (defined below) as this 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.

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, converted for weekly wind speeds.

The locations of the various study points tested for this study are shown in Figures 6a to 6k on the following pages.

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 private pedestrian thoroughfares. This includes private swimming pools and communal areas.
- Fast walking applies typically to car parks, laneways, public pedestrian thoroughfares and parks, balconies, private terraces etc.
- In all areas, the wind conditions are also checked against the safety limit.

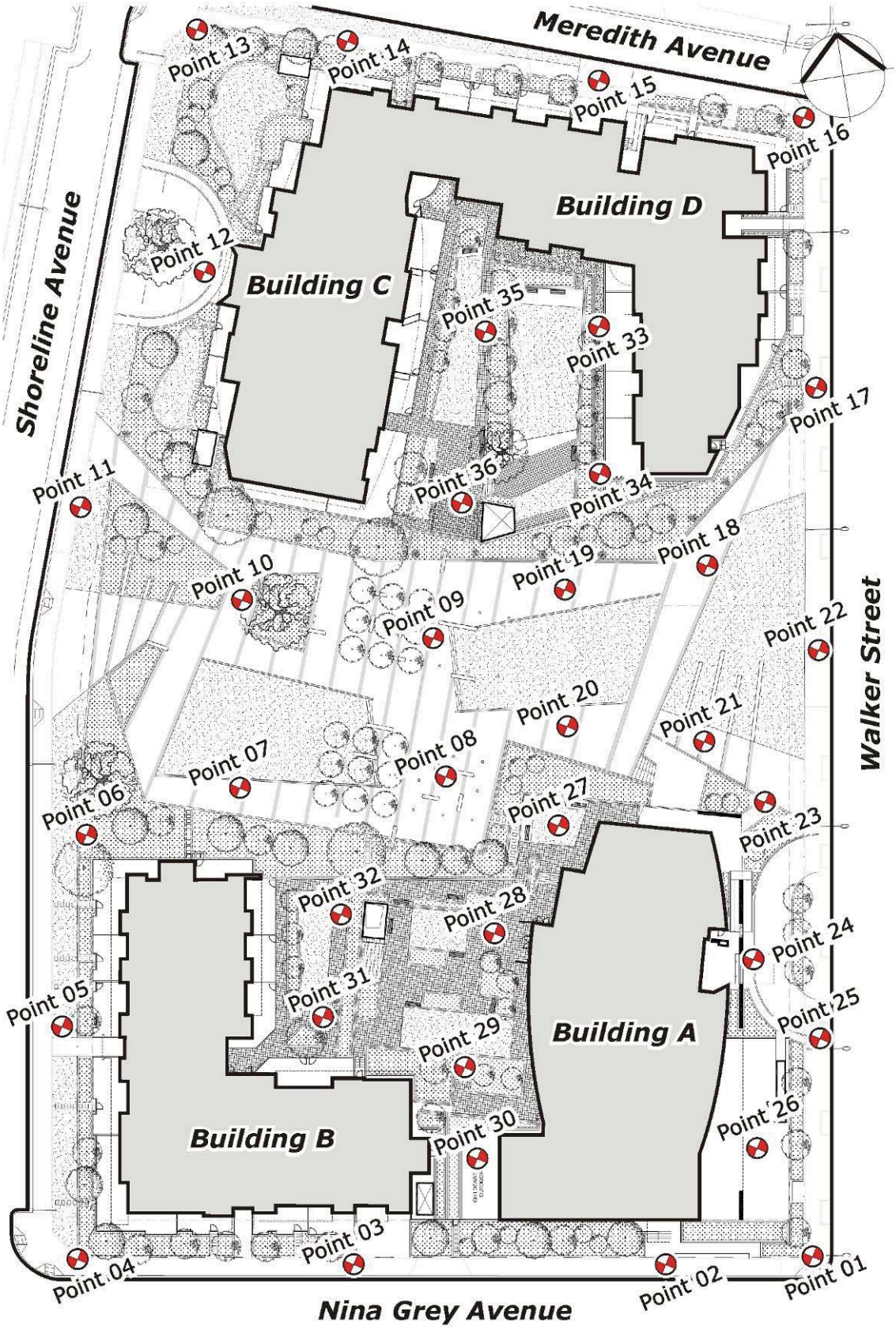

Figure 6a: Study Point Locations (Ground Level)

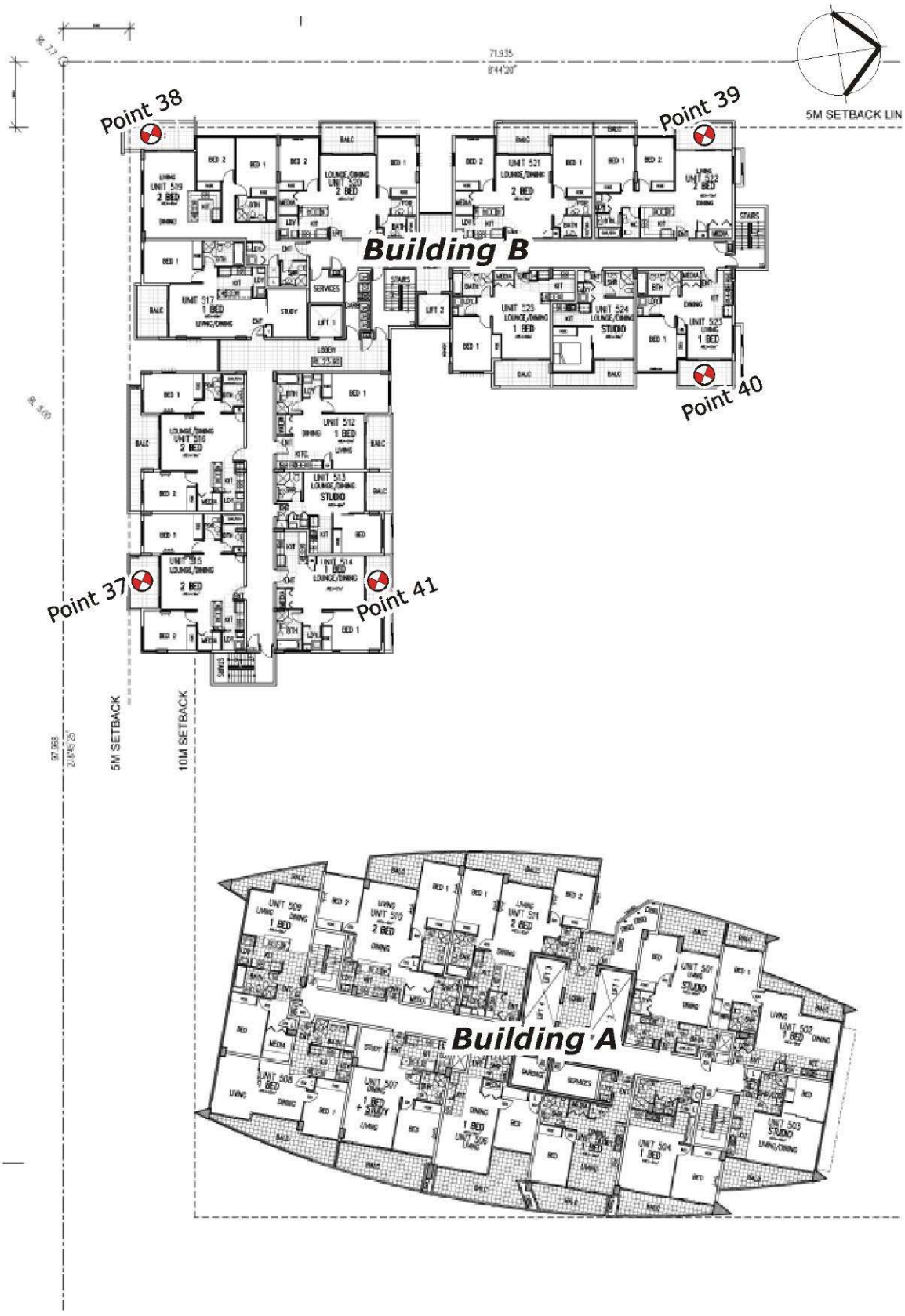

Figure 6b: Study Point Locations
(Private Balconies of Building B)

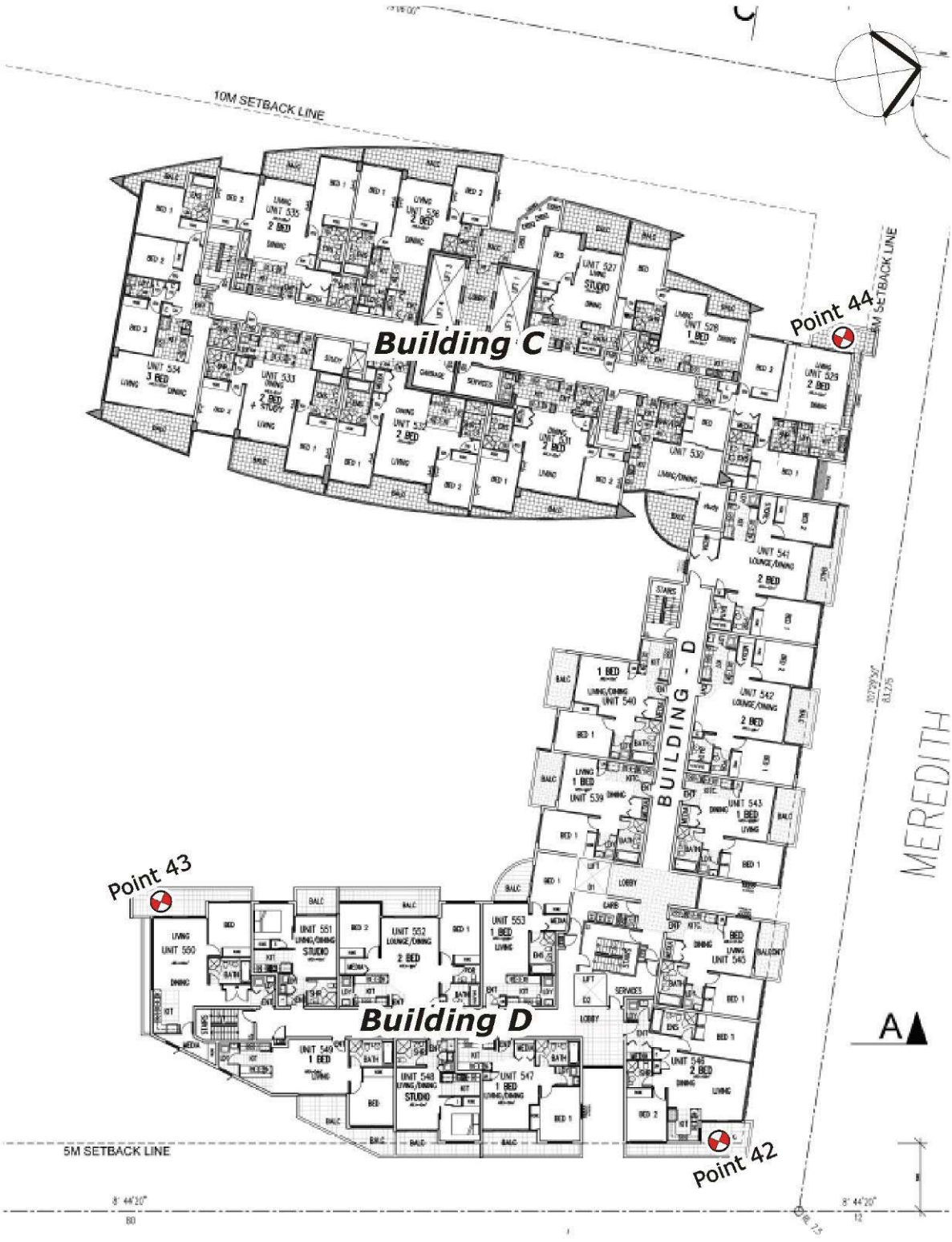

Figure 6c: Study Point Locations
(Private Balconies of Building D)

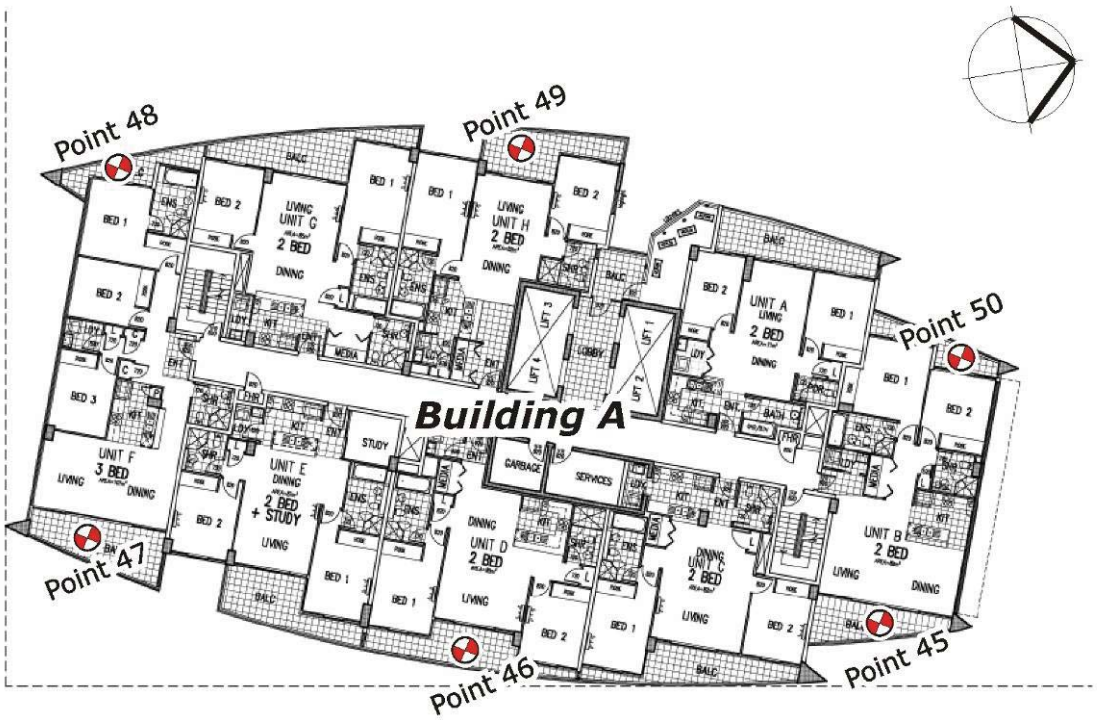

Figure 6d: Study Point Locations
(Lower Level Private Balconies of Tower A)

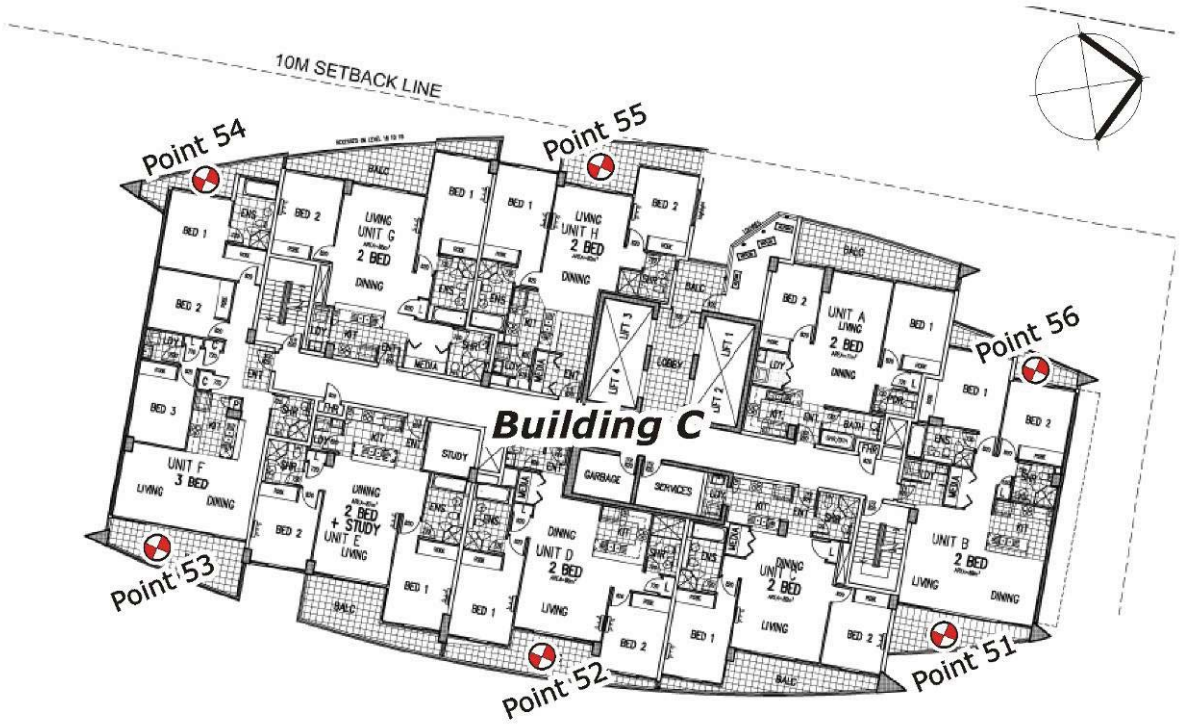

Figure 6e: Study Point Locations
(Lower Level Private Balconies of Tower C)

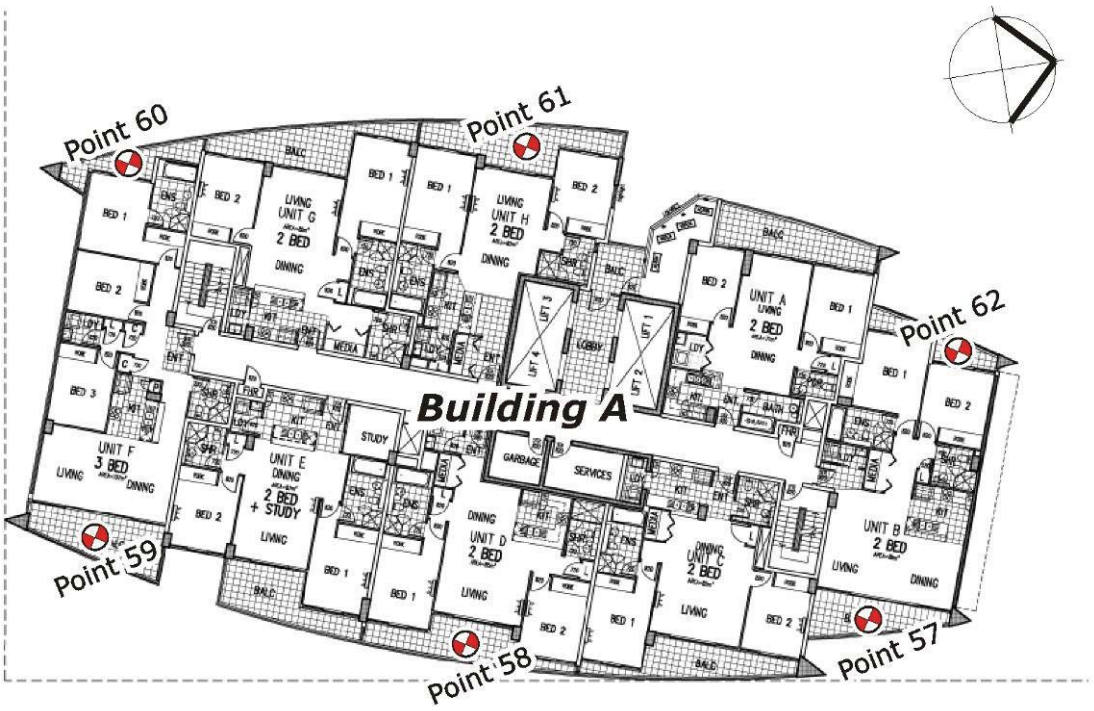

Figure 6f: Study Point Locations
(Upper Level Private Balconies of Tower A)

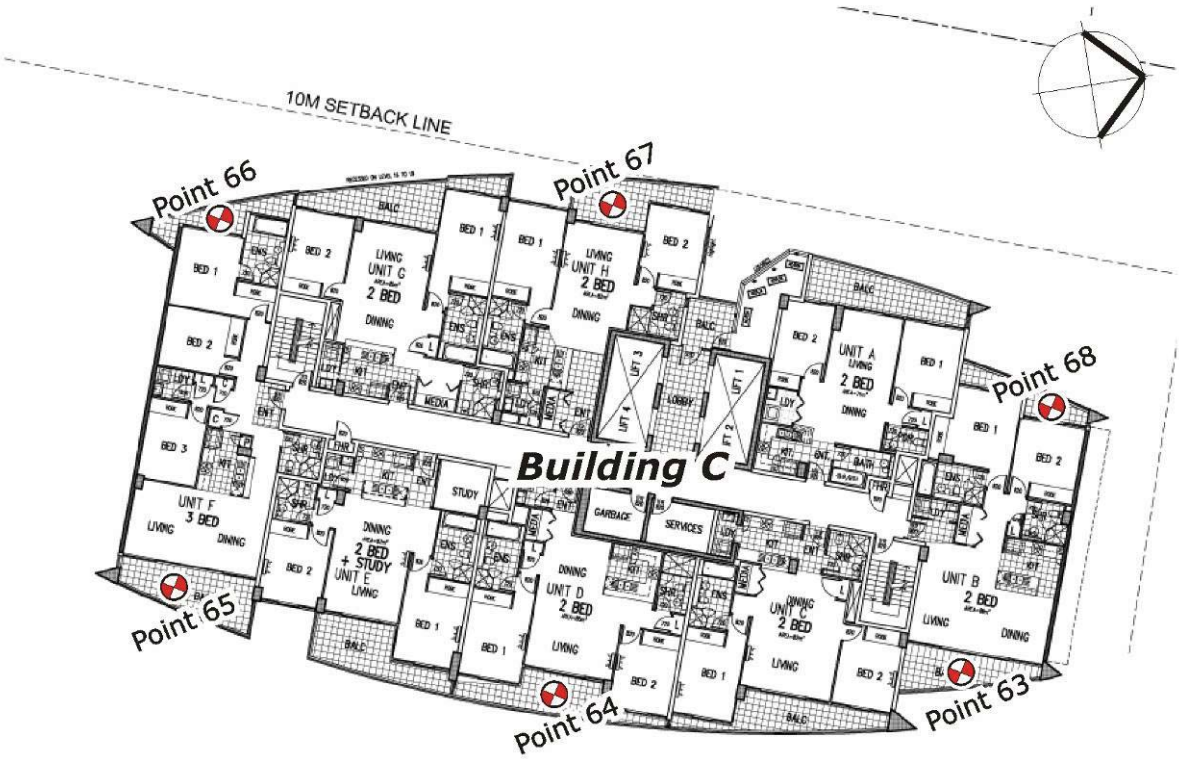

Figure 6g: Study Point Locations
(Upper Level Private Balconies of Tower C)

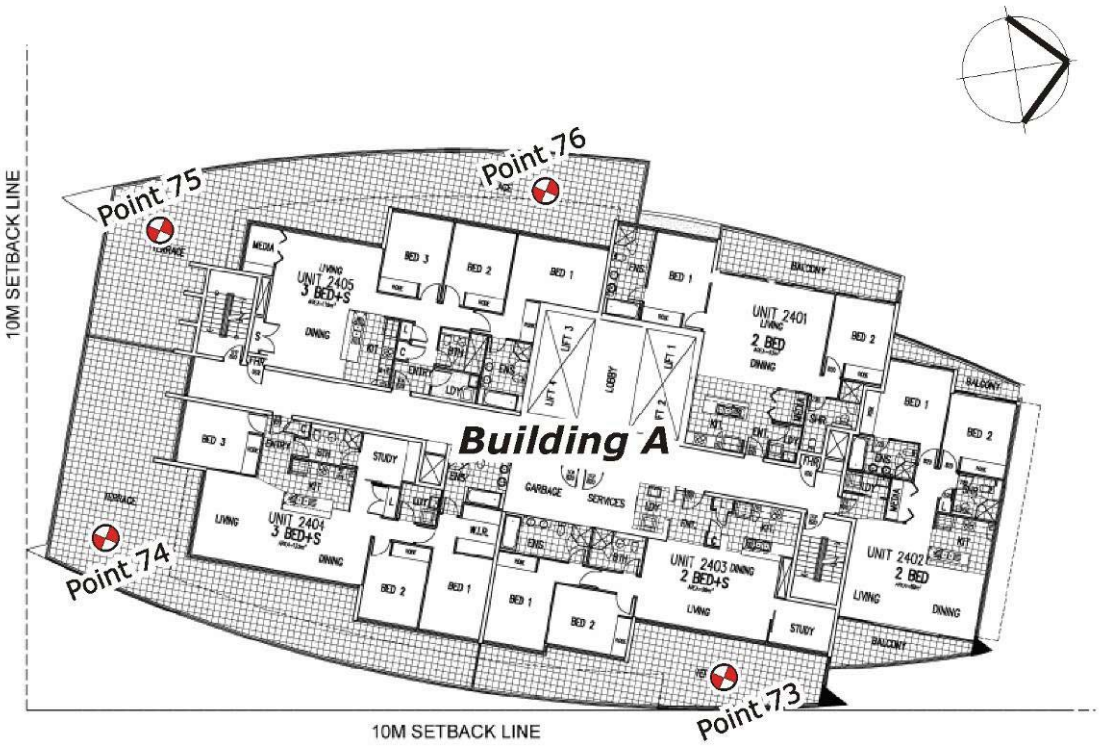

Figure 6h: Study Point Locations
(Level 24 Private Terraces of Building A)

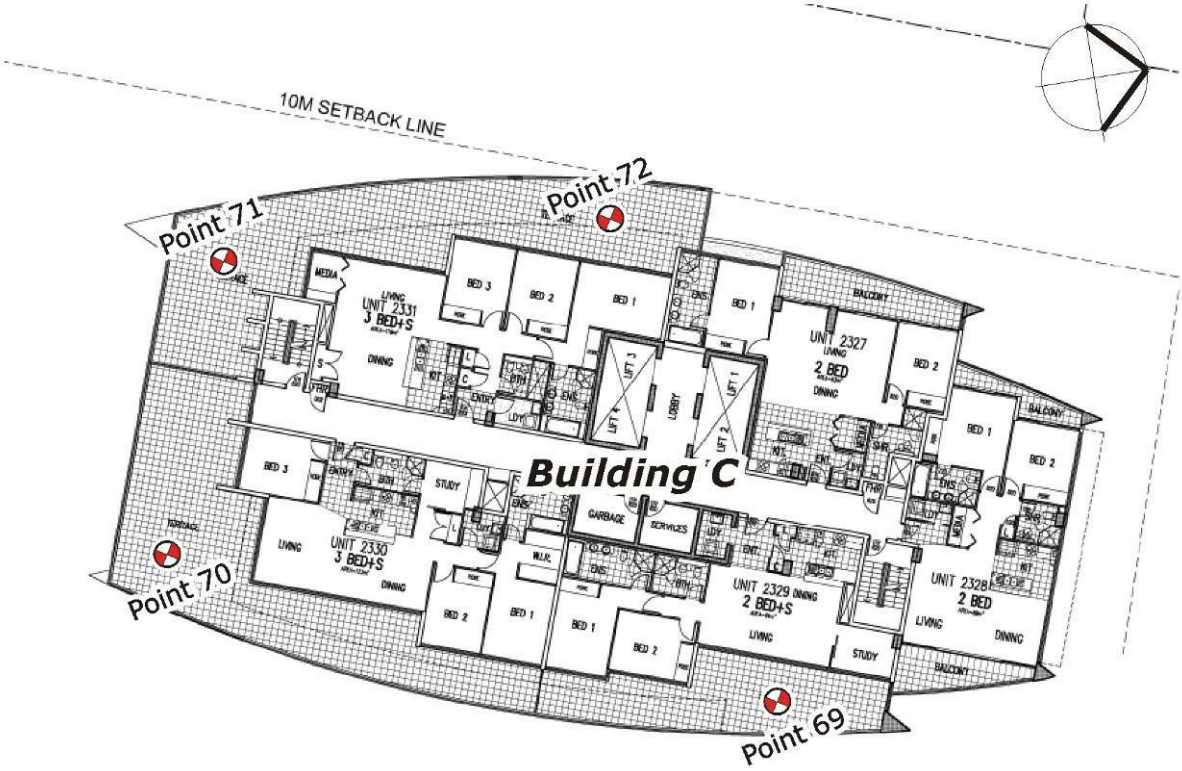

Figure 6i: Study Point Locations
(Level 23 Private Terraces of Building C)

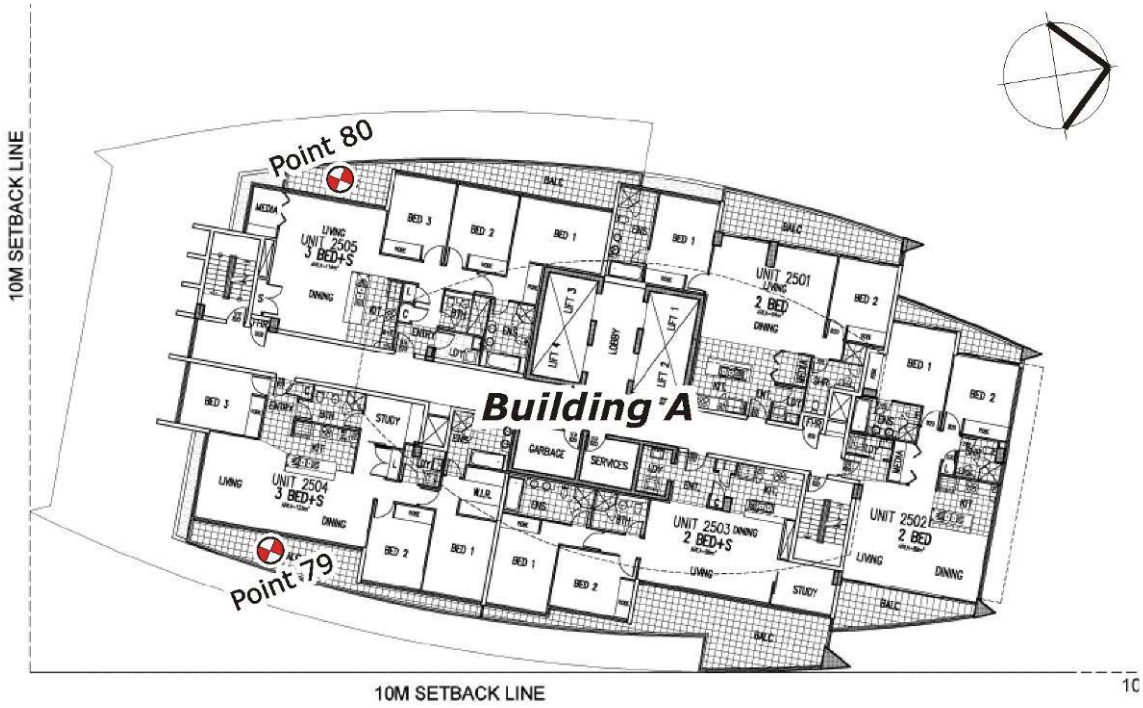

Figure 6j: Study Point Locations
(Top Level Private Balconies of Tower A)

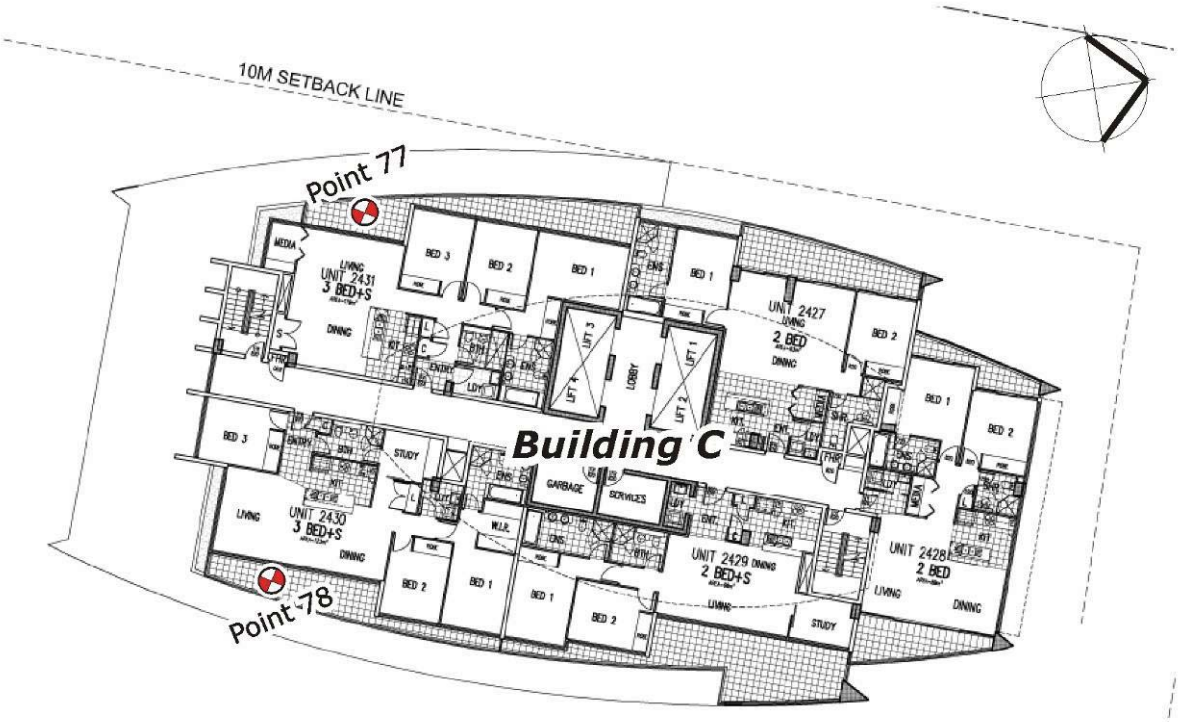

Figure 6k: Study Point Locations
(Top Level Private Balconies of Tower C)

5.0 Results of Study

A detailed study of wind activity around and within the various outdoor areas of the proposed development was carried out. A total of 80 study locations were selected for the detailed analysis as shown in Figures 6a to 6k. These include 15 ground level test point locations on the various pedestrian footpaths around the site, 21 test point locations for the ground level areas within the site and on the communal podium rooftop landscaped areas, and 44 study points on the various private balconies and outdoor terrace areas of the development.

The model of the proposed development was tested without the effect of any forms of wind ameliorating devices such as balustrades, screens, canopies, etc that are not already shown in the architectural drawings. The effect of vegetation was also not included in the tests. For areas not achieving appropriate wind conditions, in-principle ameliorative treatments have been suggested. These treatments are described in detail within this section of the report. The results of the measured wind conditions at the various study points are determined for the weekly maximum GEM wind speeds and the annual maximum peak wind speeds. These are then compared against the criteria outlined in Section 4.5 of this report. Plots of results of the local directional wind speeds for the various test locations, as derived from the wind tunnel tests, are presented in Appendix A.

5.1 Pedestrian Footpaths around the Site

The Study Points

Test Points 1 to 6, 11 to 17, 22, and 25 are used to monitor the ground level wind conditions along the various pedestrian footpaths around the development site. The location of these study points are summarised as follows:

- Point 1 is located at the south-western corner of the site, on the pedestrian footpath at the intersection of Walker Street and Nina Grey Avenue.
- Points 2 and 3 are located along the southern site boundary, on the pedestrian footpath of Nina Grey Avenue.
- Point 4 is located at the south-western corner of the site, on the pedestrian footpath at the intersection of Shoreline Avenue and Nina Grey Avenue.
- Points 5, 6, 11 and 12 are located along the western site boundary, on the pedestrian footpath of Shoreline Drive.
- Point 13 is located at the north-western corner of the site, on the pedestrian footpath at the intersection of Shoreline Avenue and Meredith Avenue.
- Points 14 and 15 are located along the northern site boundary, on the pedestrian footpath of Meredith Avenue.
- Point 16 is located at the north-eastern corner of the site, on the pedestrian footpath at the intersection of Walker Street and Meredith Avenue.
- Points 17, 22 and 25 are located along the eastern site boundary, on the pedestrian footpath of Walker Street.

The locations of these points are also shown in Figure 6a.

Applicable Criteria

The pedestrian footpath areas around the site are to be used primarily as pedestrian thoroughfares. The appropriate wind comfort criterion for this type of use is the comfortable walking criterion of 7.5m/s for the weekly maximum GEM wind speeds. Note that the safety limit criterion of 23m/s for the annual maximum peak wind speeds should also be satisfied for all study points tested.

Results and Recommendations

The results of the study indicate that wind conditions for some of the pedestrian footpath areas around the site will exceed the appropriate wind comfort criterion. This is generally caused by the prevailing winds either being accelerated around the corners of the buildings of the proposed development, or from being side-streamed along the wide face of Towers A and C.

To mitigate adverse winds for the pedestrian footpath areas around the site, a strategic layout of trees has been recommended. The recommended layout trees is shown in Figure 7a and generally matches the currently proposed landscaping plan for the proposed development, although there are some additional trees that have been recommended. It should be noted that this is the recommended minimum layout of trees for the site, and that adding more trees than shown in Figure 7a is expected to further enhance wind conditions for the site.

Note that for trees and other forms of vegetation to be effective in wind mitigation, it should be densely foliating and be of an evergreen species. Suggested sizes of trees are also indicated in Figure 7a. Palm trees, for example, are typically not effective for mitigating adverse ground level winds due to the canopy of the tree being so high above ground.

With the inclusion of a ground level tree planting layout similar to that shown in Figure 7a, wind conditions for all pedestrian footpaths around the site are expected to be acceptable.

5.2 Trafficable Ground Level Areas within the Site

The Study Points

Test Points 7 to 10, and 18 to 21, are used to monitor the ground level wind conditions across the central area of the site. Test Points 28 to 32 are used to monitor wind conditions within the communal podium rooftop landscaped area between Buildings A and B. Note that Point 30 is used to monitor wind conditions for the outdoor play area for the proposed childcare centre located between Buildings A and B. Wind conditions for the communal podium rooftop landscaped area between Buildings C and D are monitored by Points 33 to 36. Points 23, 24 and 26 are located around the porte cochere area of Building A. The locations of these points are also shown in Figure 6a.

Applicable Criteria

The various trafficable outdoor ground level areas within the site, including the communal podium rooftop landscaped areas, are to be used primarily as pedestrian thoroughfares. The appropriate wind comfort criterion for this type of use is the comfortable walking criterion of 7.5m/s for the weekly maximum GEM wind speeds.

The outdoor play area for the proposed childcare centre at the south-eastern corner of the site will be used primarily for short duration activities. The

appropriate wind comfort criterion for this type of use is the short exposure criterion of 5.5m/s for the weekly maximum GEM wind speeds.

Note that the safety limit criterion of 23m/s for the annual maximum peak wind speeds should also be satisfied for all study points tested.

Results and Recommendations

The results of the study indicate that most areas within the site will be exposed to adverse winds. The prevailing westerly and north-easterly prevailing winds tend to be directed through the middle corridor of the site, and the two communal podium rooftop landscaped areas (located between Building A and B, and between Buildings C and D) are exposed to winds that tend to be captured by the two towers of the subject development, which are then circulated around the area.

To mitigate adverse winds for the trafficable areas within the site, a strategic layout of trees has been recommended. The recommended layout trees is shown in Figure 7a and generally matches the currently proposed landscaping plan for the proposed development, although there are some additional trees that have been recommended. It should be noted that this is the recommended minimum layout of trees for the site, and that adding more trees than shown in Figure 7a is expected to further enhance wind conditions for the site.

The many trees located in the middle corridor through the site are expected to be effective in breaking-up the prevailing ground level winds. The several trees lining the northern edge of the communal podium rooftop landscaped area between Buildings A and B will provide shielding for this area from the prevailing winds, and the shrubs will assist for localised improvements. The line of trees across the middle of the communal podium rooftop landscaped area between Buildings C and D will mitigate the adverse winds at ground level being captured in this area.

The results of the study indicate that wind conditions for the proposed outdoor play area for the childcare centre will slightly exceed the criterion for short exposure activities due to south-easterly winds being accelerated through the gap between Buildings A and B. The addition of the two trees indicated in Figure 7a on the southern side of this area are expected to mitigate this adverse effect, and provide pleasant wind conditions for the children’s play area.

Note that for trees and other forms of vegetation to be effective in wind mitigation, it should be densely foliating and be of an evergreen species. Suggested sizes of trees are also indicated in Figure 7a. Palm trees, for example, are typically not effective for mitigating adverse ground level winds due to the canopy of the tree being so high above ground.

With the inclusion of a ground level tree planting layout similar to that shown in Figure 7a, wind conditions for all trafficable outdoor ground level areas within the site are expected to be acceptable.

A marked-up copy of the recommended minimum tree planting scheme that has been presented in this report is attached in Appendix C. This has been marked-up by the landscape architect, and indicates which of the trees are either possible, limited by the available soil depth, or may not be possible due to it obstructing views.

5.3 Private Balconies and Terraces of Buildings A and B

The Study Points

Test Points 37 to 80 were used to monitor wind conditions on the various critical private balconies and terraces of Buildings A, B, C and D of the proposed development. The location of the various study points for Buildings A and B are summarised as follows:

- Wind conditions on the critical private balconies of Building B are monitored by Points 37 to 41, in the locations shown in Figure 6b and detailed as follows:
    - Point 37 is located at the south-eastern corner of Building B.
    - Point 38 is located at the south-western corner of Building B.
    - Point 39 is located at the north-western corner of Building B.
    - Point 40 is located at the north-eastern corner of the northern wing of Building B.
    - Point 41 is located at the north-eastern corner of the western wing of Building B.
- Wind conditions on the critical private balconies of the lower half of Building A are monitored by Points 45 to 50, in the locations shown in Figure 6d and detailed as follows:
    - Point 45 is located at the north-eastern corner of Building A.
    - Point 46 is located in the middle of the eastern aspect of Building A.
    - Point 47 is located at the south-eastern corner of Building A.
    - Point 48 is located at the south-western corner of Building A.
    - Point 49 is located in the middle of the western aspect of Building A.
    - Point 50 is located at the north-western corner of Building A.
- Wind conditions on the critical private balconies of the upper half of Building A are monitored by Points 57 to 62, in the locations shown in Figure 6f and detailed as follows:
    - Point 57 is located at the north-eastern corner of Building A.
    - Point 58 is located in the middle of the eastern aspect of Building A.
    - Point 59 is located at the south-eastern corner of Building A.
    - Point 60 is located at the south-western corner of Building A.
    - Point 61 is located in the middle of the western aspect of Building A.
    - Point 62 is located at the north-western corner of Building A.
- Wind conditions on the critical private terraces on Level 23 of Building A are monitored by Points 73 to 76, in the locations shown in Figure 6h and detailed as follows:
    - Point 73 is located at the north-eastern end of Building A.
    - Point 74 is located at the south-eastern corner of Building A.
    - Point 75 is located at the south-western corner of Building A.
    - Point 76 is located in the middle of the western aspect of Building A.

- Wind conditions on the critical private balconies on Level 25 of Building A are monitored by Points 79 and 80, in the locations shown in Figure 6j and detailed as follows:
    - Point 79 is located at the south-eastern corner of Building A.
    - Point 80 is located at the south-western corner of Building A.

Applicable Criteria

The appropriate wind comfort criterion for private balconies is the safety limit of 23m/s for annual maximum peak wind speeds. Note that the use of light-weight furniture on high-rise private balconies is not recommended, unless it is securely attached to the balcony floor slab.

Results and Recommendations

The results of the study indicate that the measured wind conditions for most of the private balconies and terraces tested will satisfy the appropriate wind speed criterion. The measured wind conditions for some of the private balconies slightly exceed the relevant wind speed criterion, however it should be noted that these balcony and terrace areas were tested without the inclusion of any form of impermeable balustrade. It is expected that wind conditions for those areas will be improved and will satisfy the criterion for safety if impermeable balustrades are used, and hence they are recommended for all balcony and terrace edges.

The measured wind conditions on the private terraces on Level 24 indicate that the safety criterion will be exceeded. To mitigate this adverse effect and allow wind conditions to satisfy the wind speed criterion for safety, in addition to using impermeable balustrades on the perimeter of the terrace areas, it is recommended that an impermeable 2.5m tall privacy screen is used to separate the two terraces at the southern end of Level 24.

The south-western corner balconies on Levels 2 to 23 are exposed to strong adverse southerly winds, which tend to accelerate around that corner of the tower. It is not expected that impermeable balustrades alone on those balcony perimeters will be sufficient to mitigate this effect, and hence it is recommended to add a full-height impermeable screen along the south-eastern edge, which can join onto the already proposed column. This is also shown in Figure 7b. This screen is expected to be effective in mitigating the adverse southerly winds affecting these balconies, and is hence recommended.

Note also that only the critical private balcony locations were tested in this study. Wind conditions for the remaining balcony locations are expected to be ideal due to the effective use of blade walls, privacy screens and building setbacks.

5.4 Private Balconies and Terraces of Buildings C and D

The Study Points

Test Points 37 to 80 were used to monitor wind conditions on the various critical private balconies and terraces of Buildings A, B, C and D of the proposed development. The location of the various study points for Buildings A and B are summarised as follows:

- Wind conditions on the critical private balconies of Building D are monitored by Points 42 to 44, in the locations shown in Figure 6c and detailed as follows:

- Point 42 is located at the north-eastern corner of Building D.
- Point 43 is located at the south-western corner of Building D.
- Point 44 is located at the north-western corner of Building D.

- Wind conditions on the critical private balconies of the lower half of Building C are monitored by Points 51 to 56, in the locations shown in Figure 6e and detailed as follows:
  - Point 51 is located at the north-eastern corner of Building C.
  - Point 52 is located in the middle of the eastern aspect of Building C.
  - Point 53 is located at the south-eastern corner of Building C.
  - Point 54 is located at the south-western corner of Building C.
  - Point 55 is located in the middle of the western aspect of Building C.
  - Point 56 is located at the north-western corner of Building C.
- Wind conditions on the critical private balconies of the upper half of Building C are monitored by Points 63 to 68, in the locations shown in Figure 6g and detailed as follows:
  - Point 63 is located at the north-eastern corner of Building C.
  - Point 64 is located in the middle of the eastern aspect of Building C.
  - Point 65 is located at the south-eastern corner of Building C.
  - Point 66 is located at the south-western corner of Building C.
  - Point 67 is located in the middle of the western aspect of Building C.
  - Point 68 is located at the north-western corner of Building C.
- Wind conditions on the critical private terraces on Level 23 of Building C are monitored by Points 69 to 72, in the locations shown in Figure 6i and detailed as follows:
  - Point 69 is located at the north-eastern end of Building C.
  - Point 70 is located at the south-eastern corner of Building C.
  - Point 71 is located at the south-western corner of Building C.
  - Point 72 is located at the north-western end of Building C.
- Wind conditions on the critical private balconies on Level 24 of Building C are monitored by Points 77 and 78, in the locations shown in Figure 6k and detailed as follows:
  - Point 77 is located at the south-eastern corner of Building C.
  - Point 78 is located at the south-western corner of Building C.

Applicable Criteria

The appropriate wind comfort criterion for private balconies is the safety limit of 23m/s for annual maximum peak wind speeds. Note that the use of light-weight furniture on high-rise private balconies is not recommended, unless it is securely attached to the balcony floor slab.

Results and Recommendations

The results of the study indicate that the measured wind conditions for most of the private balconies and terraces tested will satisfy the appropriate wind speed criterion. The measured wind conditions for some of the private balconies slightly exceed the relevant wind speed criterion, however it should be noted

that these balcony and terrace areas were tested without the inclusion of any form of impermeable balustrade. It is expected that wind conditions for those areas will be improved and will satisfy the criterion for safety if impermeable balustrades are used, and hence they are recommended for all balcony and terrace edges.

The measured wind conditions on the private terraces on Level 23 indicate that the safety criterion will be exceeded. To mitigate this adverse effect and allow wind conditions to satisfy the wind speed criterion for safety, in addition to using impermeable balustrades on the perimeter of the terrace areas, it is recommended that an impermeable 2.5m tall privacy screen is used to separate the two terraces at the southern end of Level 23.

The south-western corner balconies on Levels 1 to 22 are exposed to strong adverse southerly winds, which tend to accelerate around that corner of the tower. It is not expected that impermeable balustrades alone on those balcony perimeters will be sufficient to mitigate this effect, and hence it is recommended to add a full-height impermeable screen along the south-eastern edge, which can join onto the already proposed column. This is shown in Figure 7b. This screen is expected to be effective in mitigating the adverse southerly winds affecting these balconies, and is hence recommended.

Note also that only the critical private balcony locations were tested in this study. Wind conditions for the remaining balcony locations are expected to be ideal due to the effective use of blade walls, privacy screens and building setbacks.

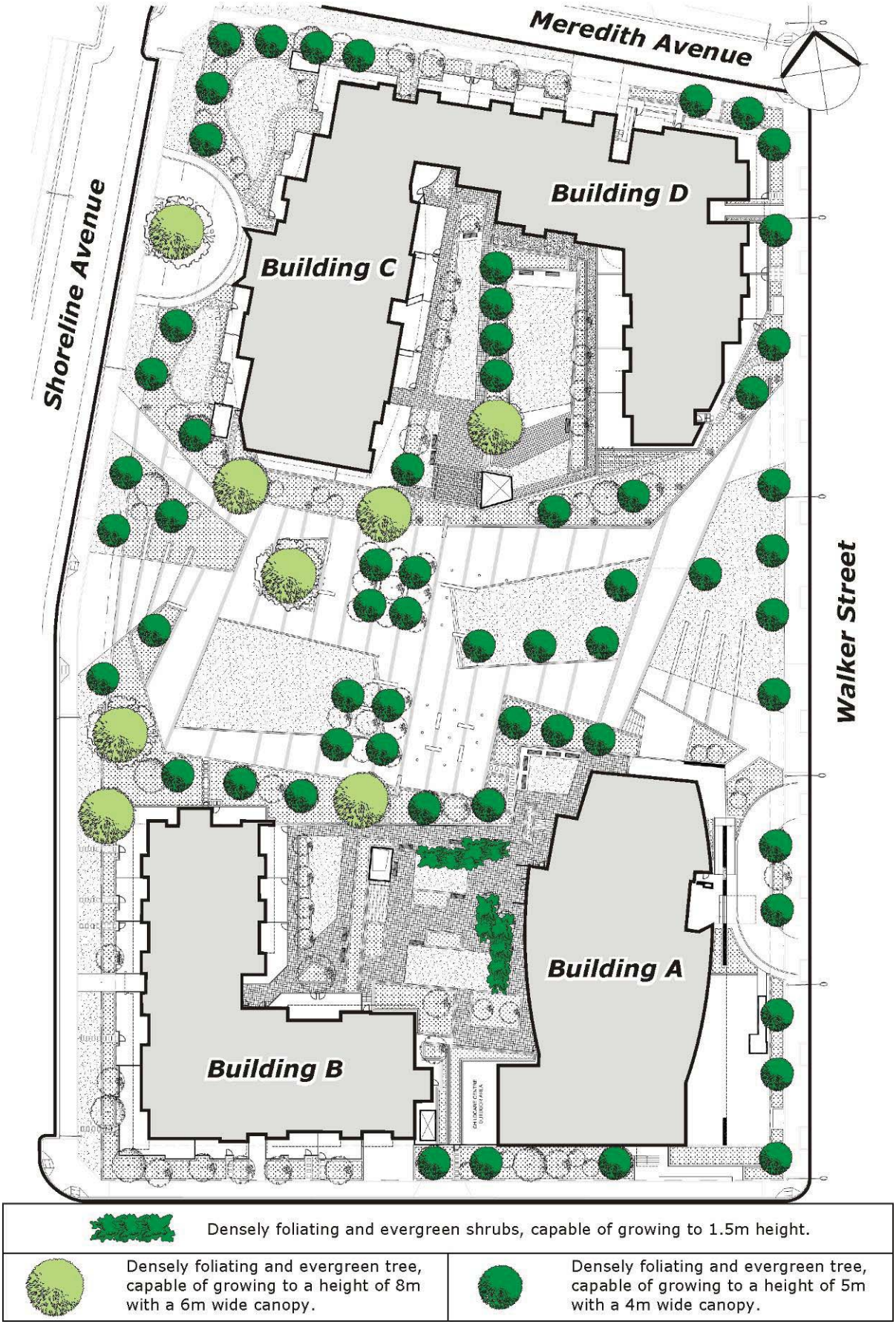

Figure 7a: Recommended *Minimum* Tree Planting Layout for the Ground Level

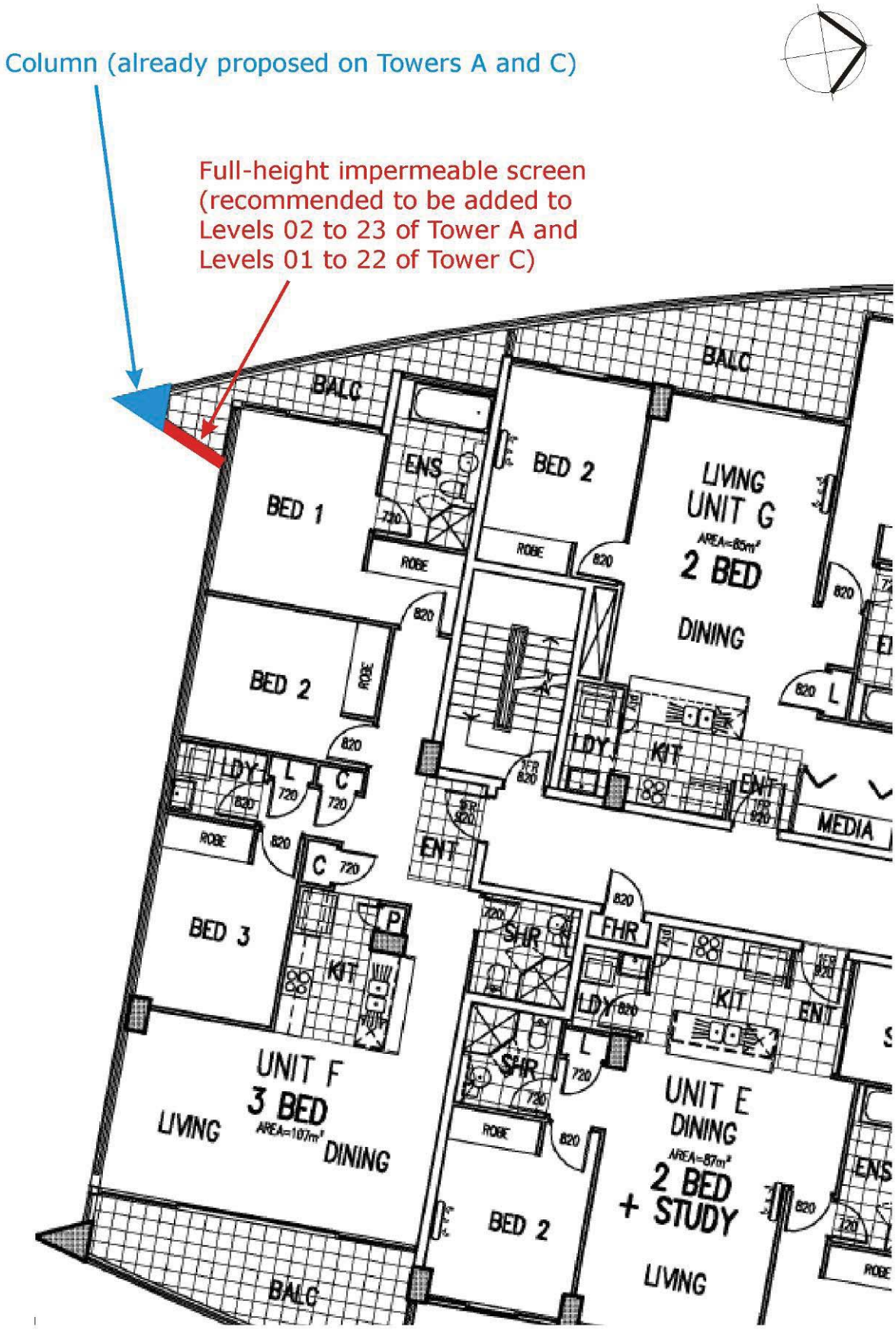

Figure 7b: Recommended Treatment for the South-Western Corner Balconies of Towers A and C

6.0 Conclusion

A detailed investigation has been undertaken into the wind environment impact in relation to the proposed development of Lots 101 & 102, located at 52 Walker Street, Rhodes Peninsula. The results of the study indicate that some of the outdoor trafficable areas within and around the proposed development are exposed to adverse winds. To achieve appropriate wind conditions for all outdoor trafficable areas within and around the development, the following ameliorative treatments have been recommended in this study:

- A strategic layout of trees and shrubs within and around the site has been presented in this report. It has been recommended that most of these trees be capable of growing to dimensions of at least 5m tall with a foliage canopy width of 4m. Some larger trees have also been recommended, capable of growing to dimensions of at least 8m tall with a foliage canopy width of 6m. It should be noted that this is a *minimum* planting layout; additional trees placed within and around the site is expected to further enhance wind conditions.
- Impermeable balustrades are recommended for all balcony and terrace edges of the proposed development.
- The south-western corner balconies on Levels 2 to 23 of Tower A, and Levels 1 to 22 of Tower C, are exposed to strong adverse southerly winds. It is recommended to add a full-height impermeable screen along the south-eastern edge of each balcony, which can join onto the already proposed column at the southern end of these balconies.
- A 2.5m tall privacy screen is recommended between the two southern terraces on Level 24 of Tower A, and another at the same location on Level 23 of Tower C.

Note that for trees to be effective in wind mitigation, they should be of a densely foliating and evergreen variety. Palm trees, for example, are typically not effective for mitigating adverse ground level winds due to the canopy of the tree being so high above ground. Note also that the use of light-weight furniture on high-rise private balconies and terraces is not recommended, unless it is securely attached to the balcony floor slab.

With the inclusion of the abovementioned treatments, wind conditions for all outdoor trafficable areas within and around the proposed development will be suitable for their intended uses.

It should be noted that the recommended tree layout described in this report is the minimum planting layout which is necessary to achieve adequate wind conditions for all ground level areas around the site. The supplied landscape drawings indicate that there will be trees in most of the recommended locations, plus there will be many additional smaller trees around the site. These additional trees are expected to further enhance the wind conditions for the ground level areas around the site.

A marked-up copy of the recommended minimum tree planting scheme that has been presented in this report is attached in Appendix C. This has been marked-up by the landscape architect, and indicates which of the trees are either possible, limited by the available soil depth, or may not be possible due to it obstructing views.

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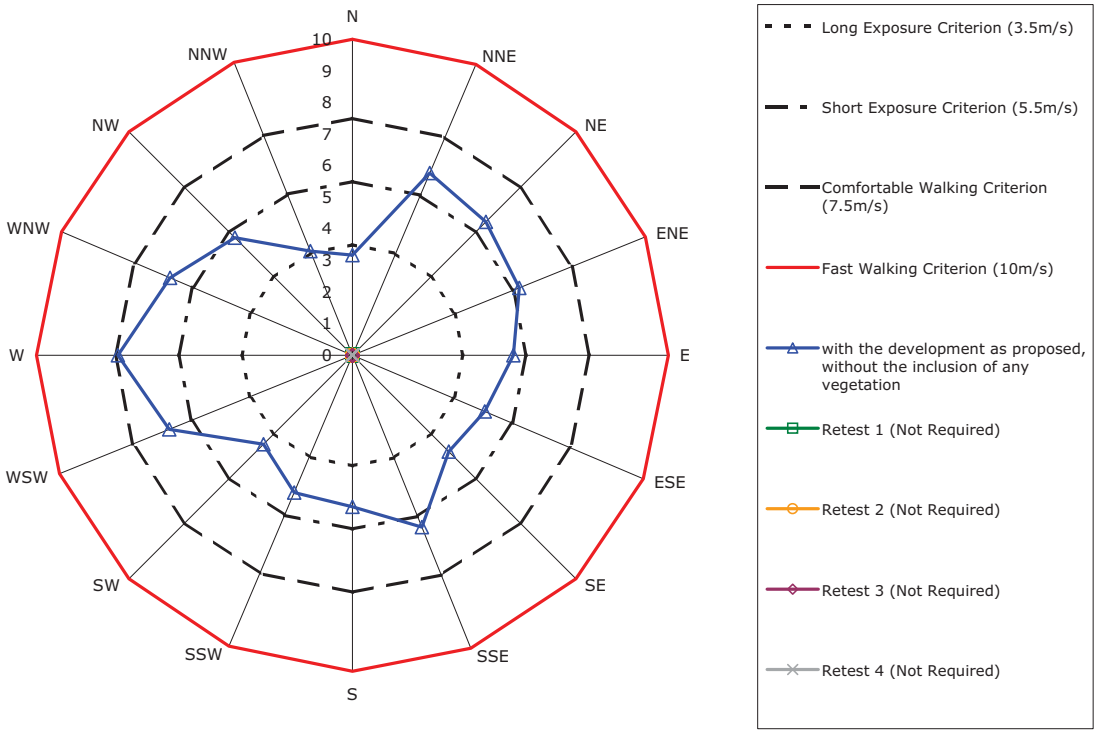
Appendix A

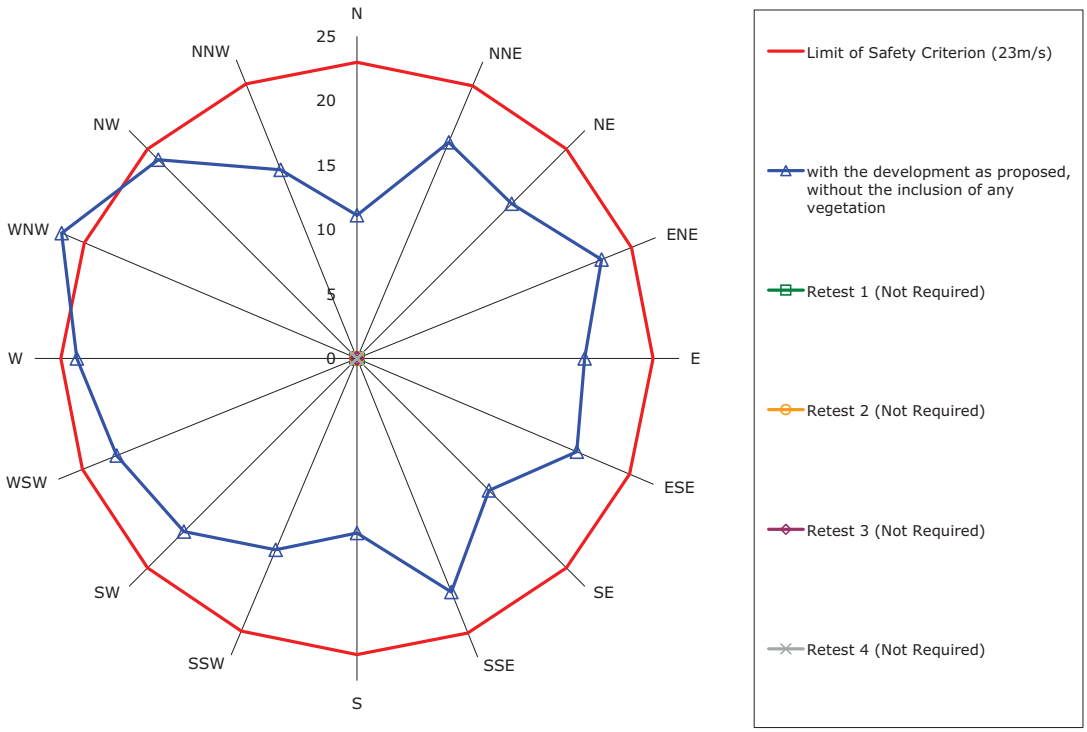
Plots of Wind Tunnel Results

Measured Wind Speeds at Point 01

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

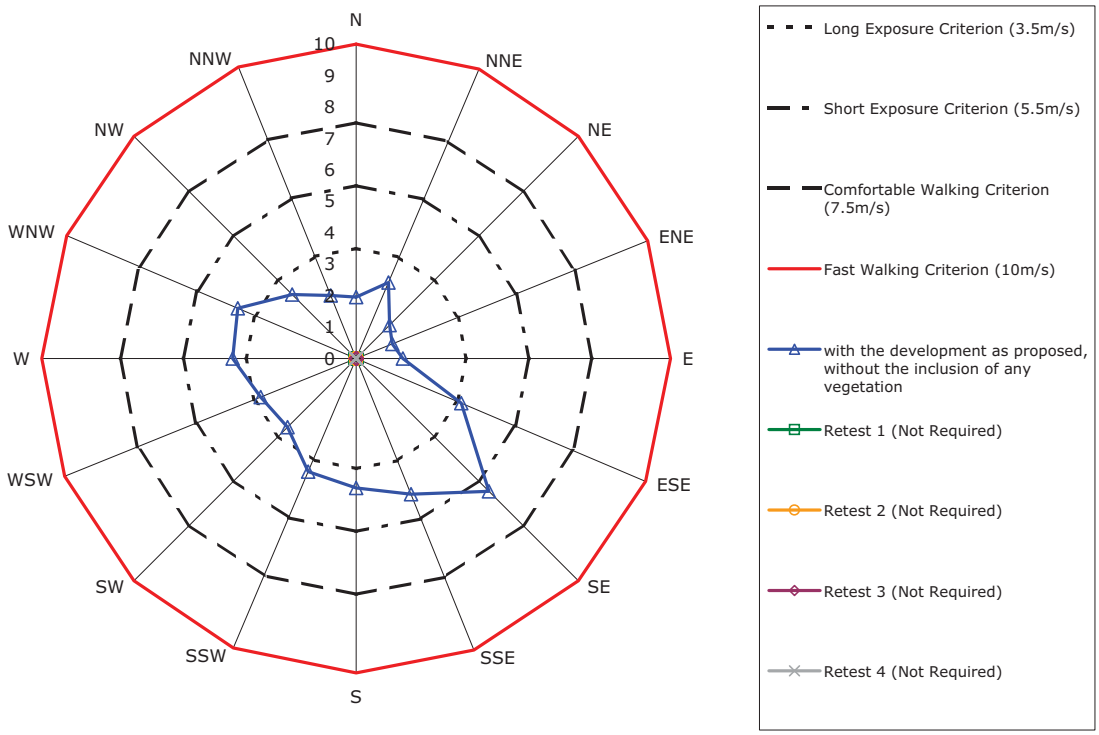


Annual Maximum Gust Wind Speeds (m/s)

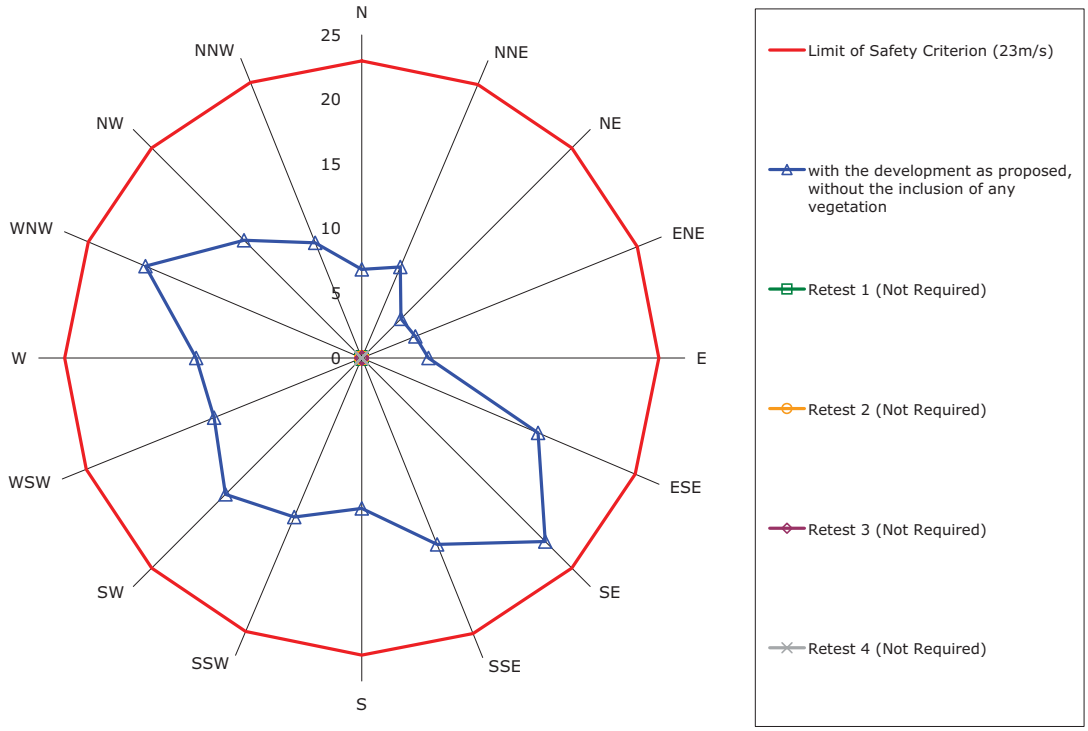


Measured Wind Speeds at Point 02

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

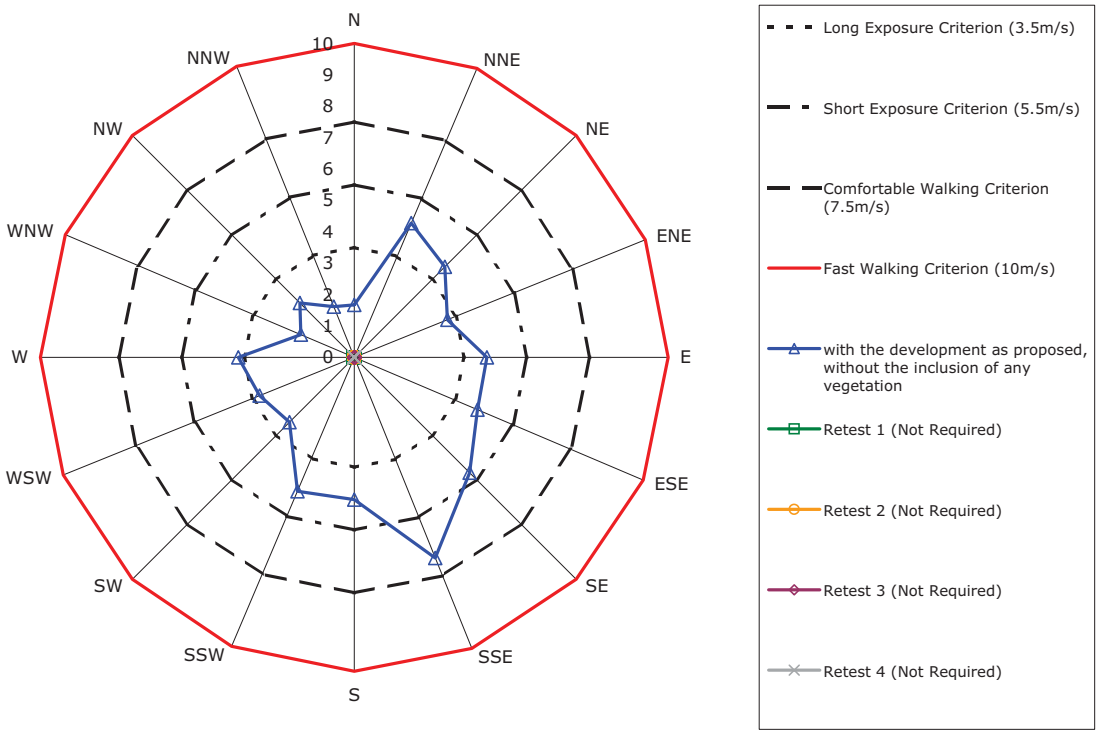


Annual Maximum Gust Wind Speeds (m/s)

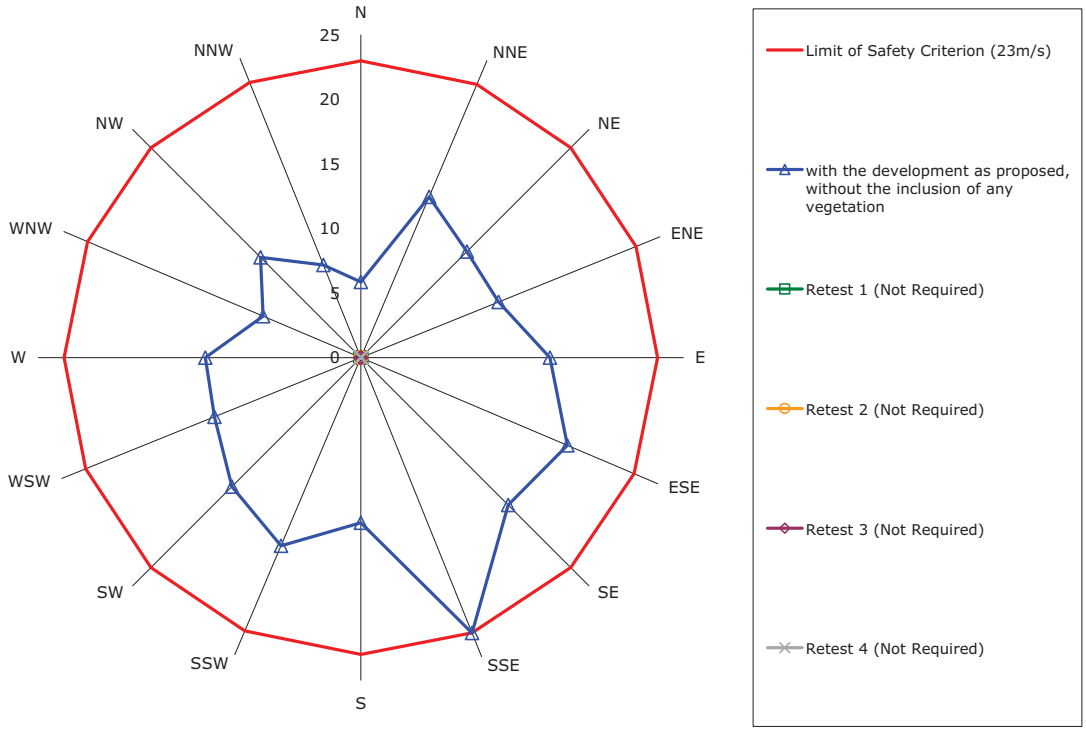


Measured Wind Speeds at Point 03

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

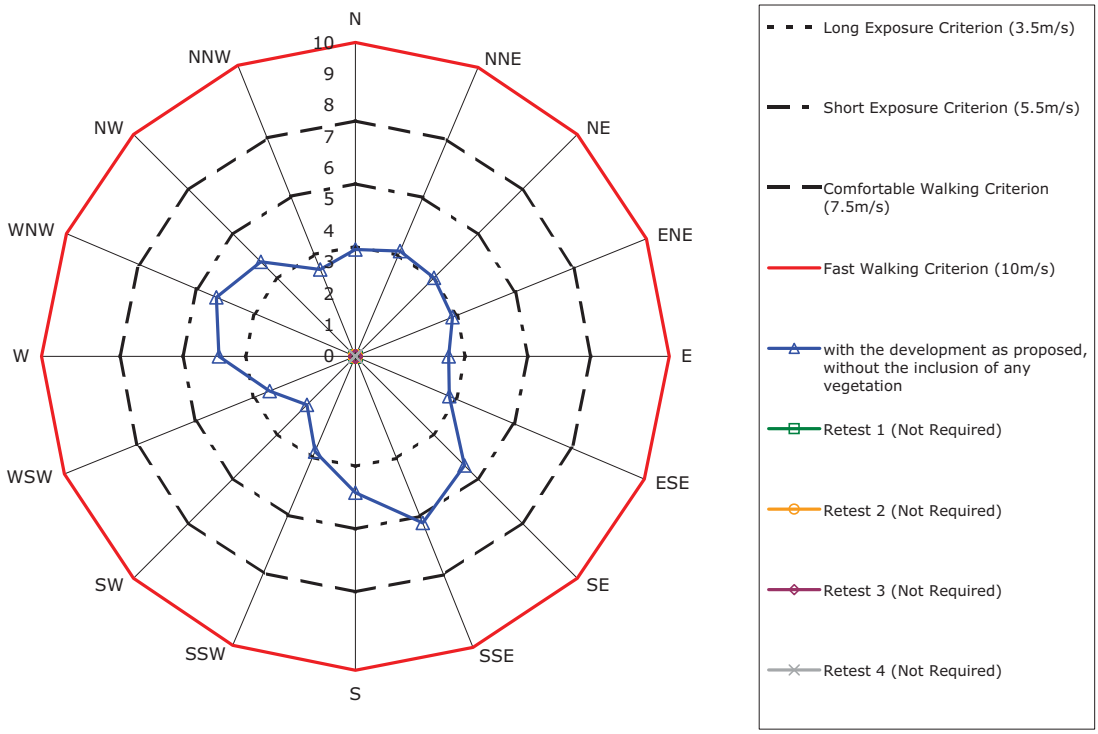


Annual Maximum Gust Wind Speeds (m/s)

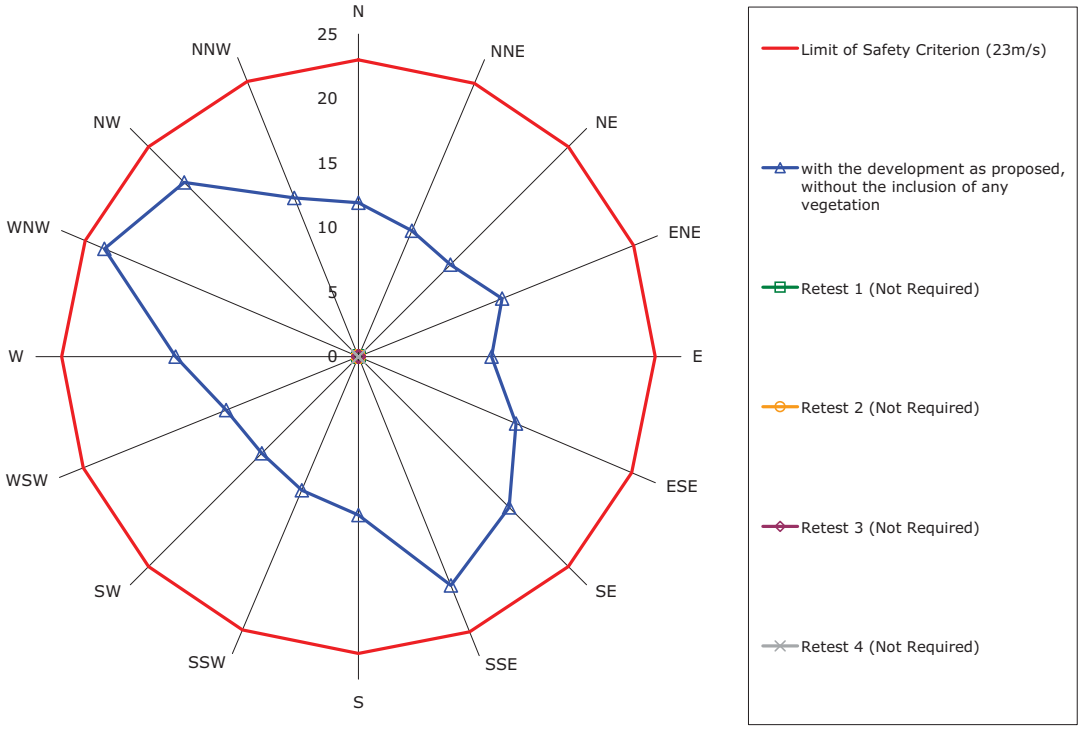


Measured Wind Speeds at Point 04

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

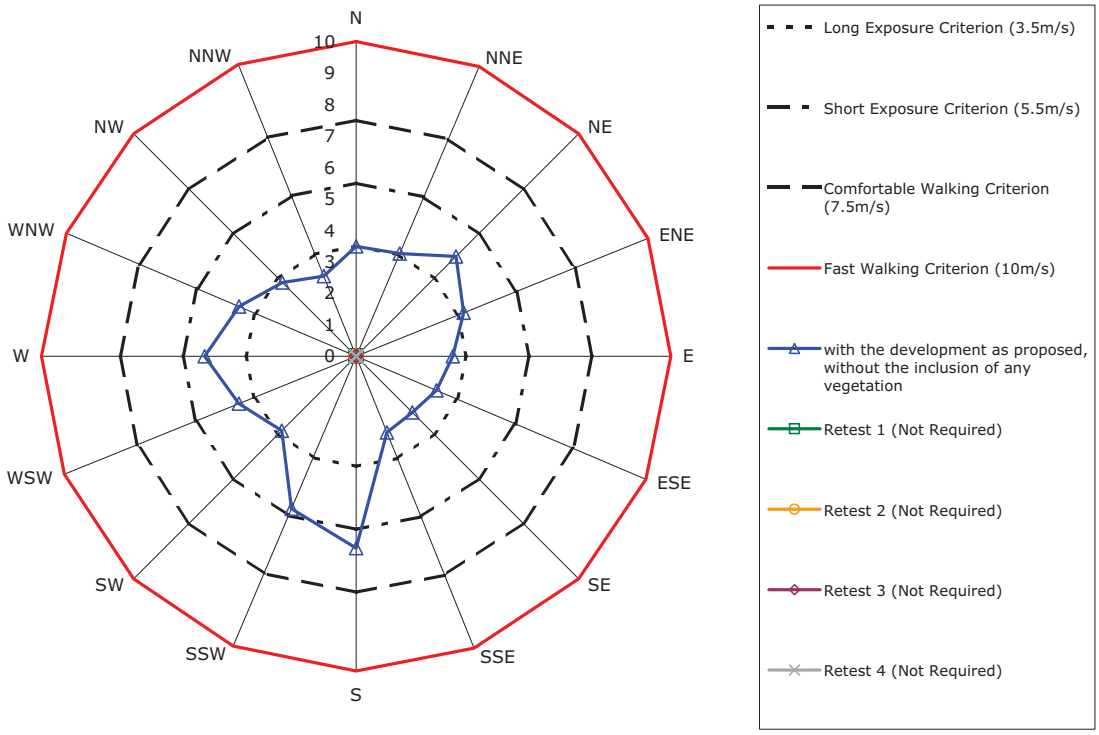


Annual Maximum Gust Wind Speeds (m/s)

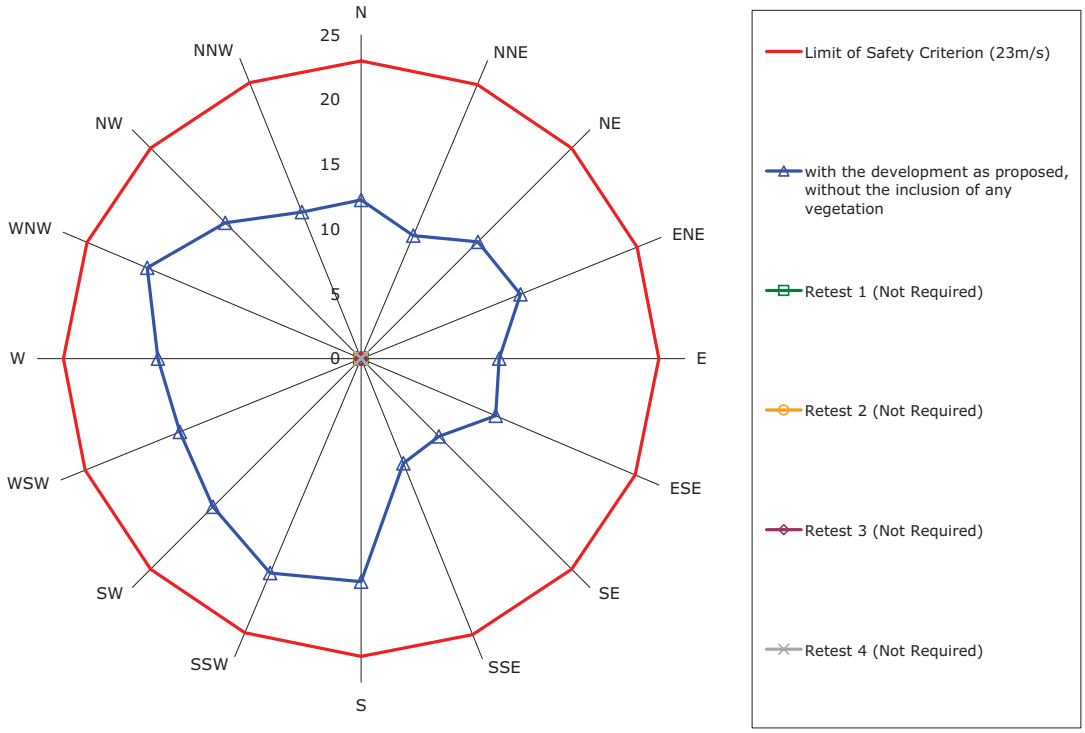


Measured Wind Speeds at Point 05

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

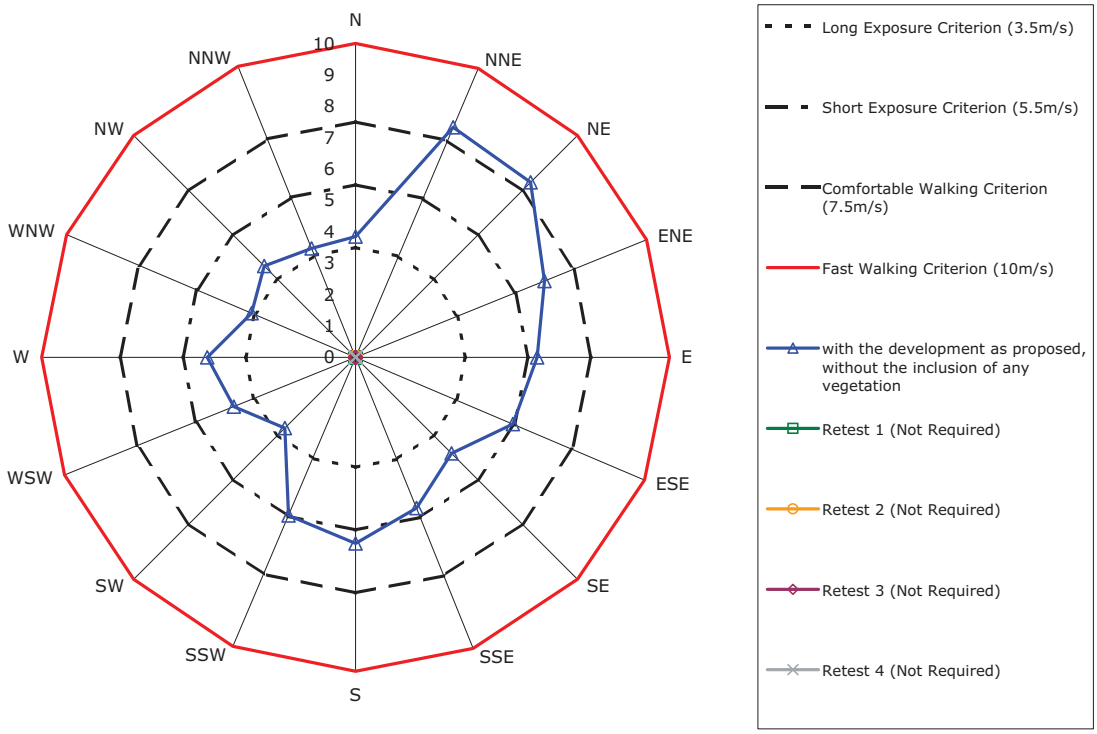


Annual Maximum Gust Wind Speeds (m/s)

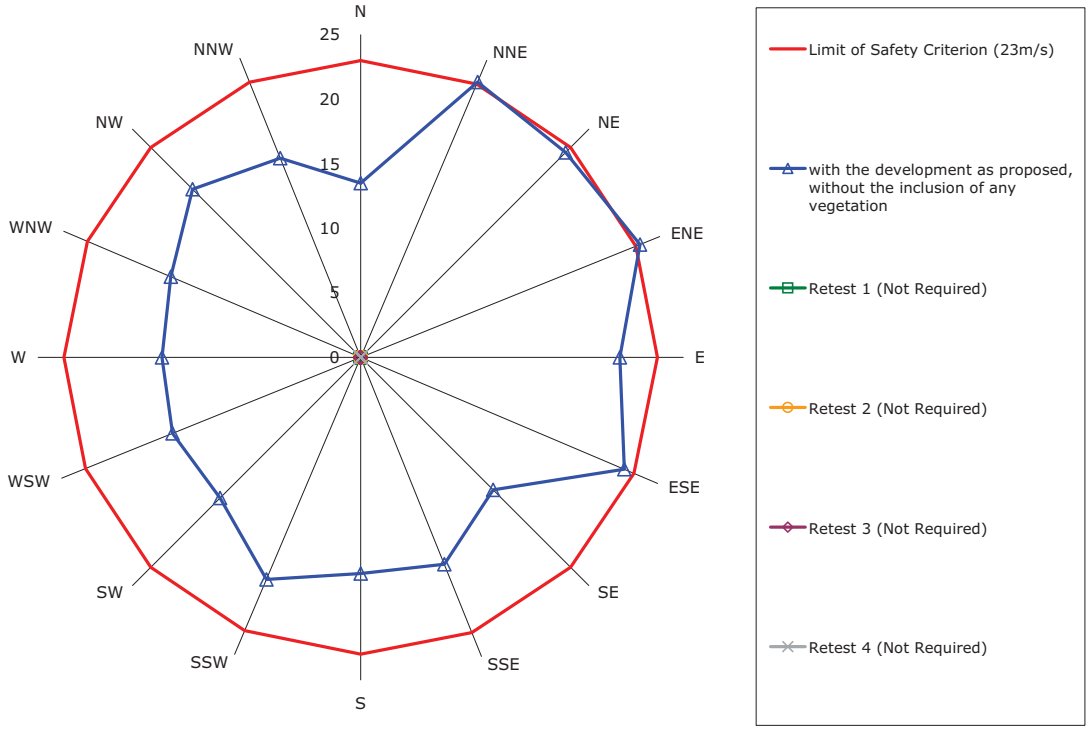


Measured Wind Speeds at Point 06

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

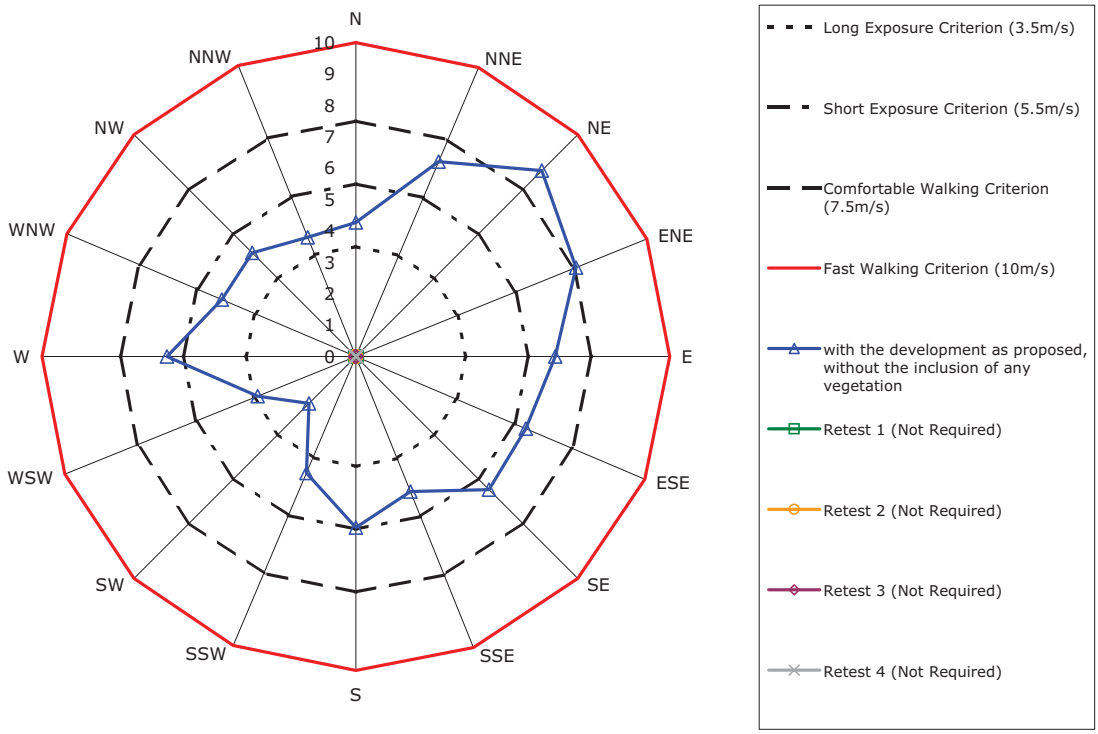


Annual Maximum Gust Wind Speeds (m/s)

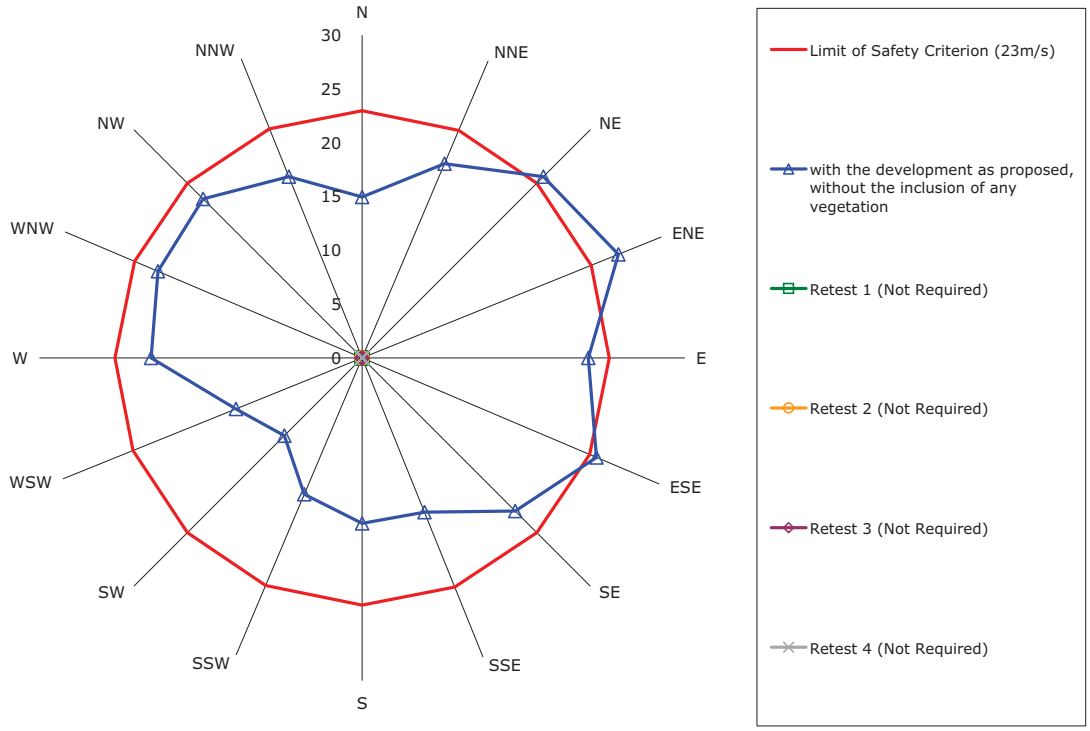


Measured Wind Speeds at Point 07

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

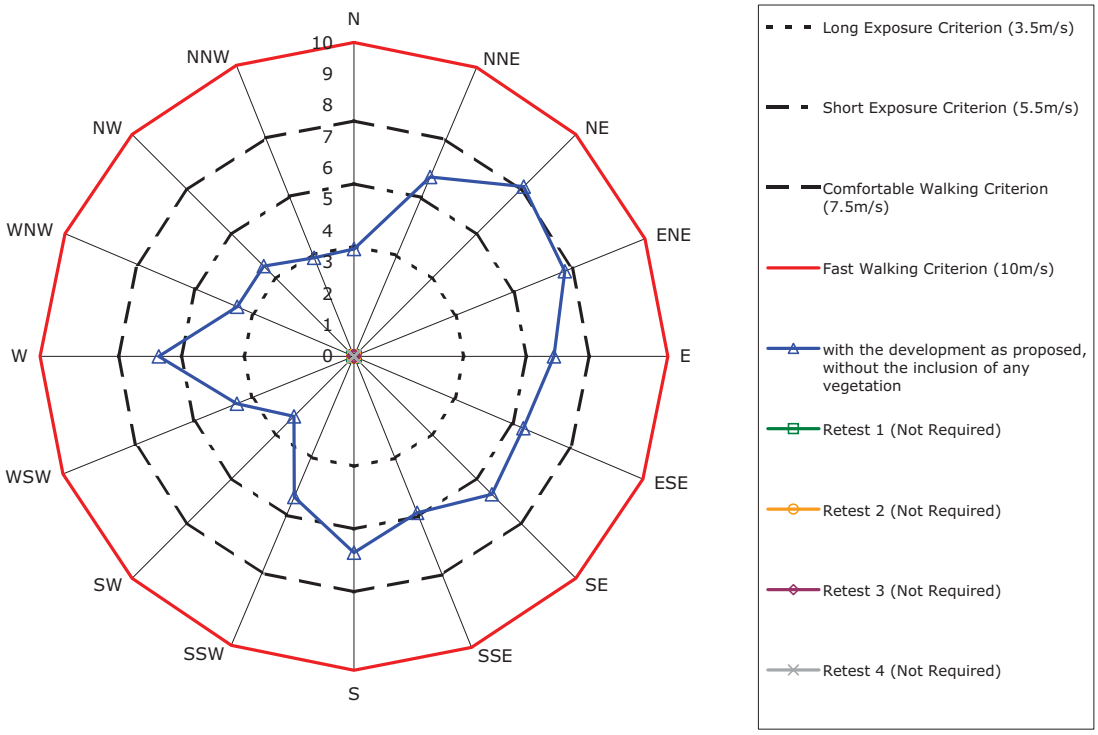


Annual Maximum Gust Wind Speeds (m/s)

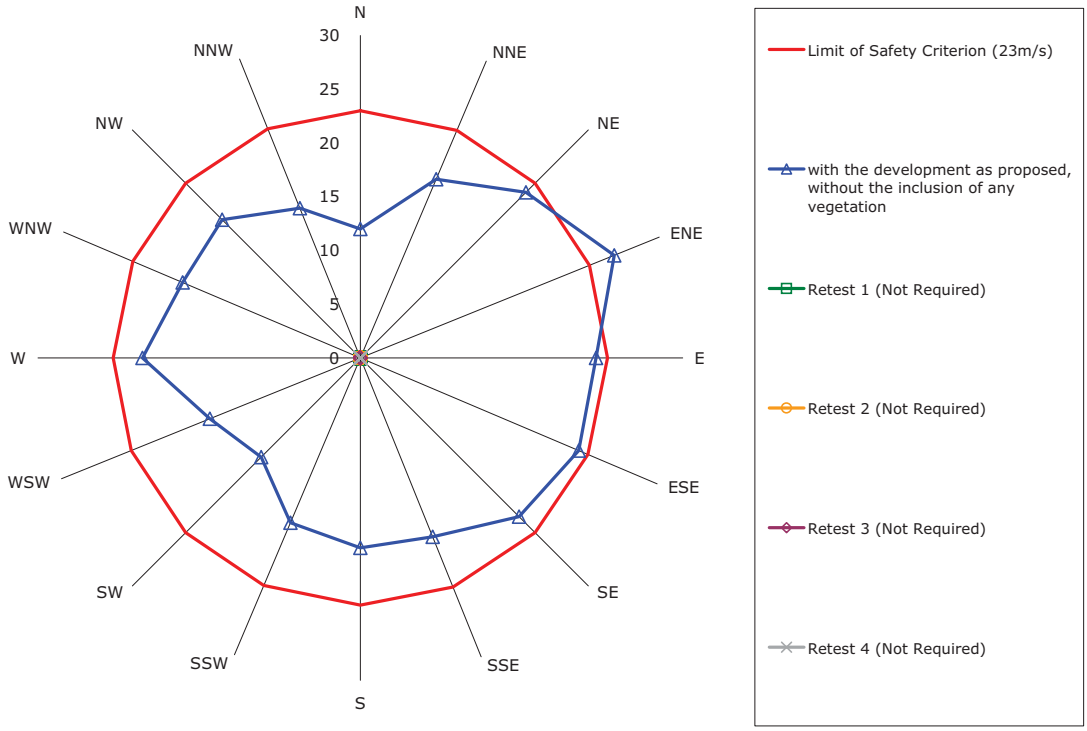


Measured Wind Speeds at Point 08

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

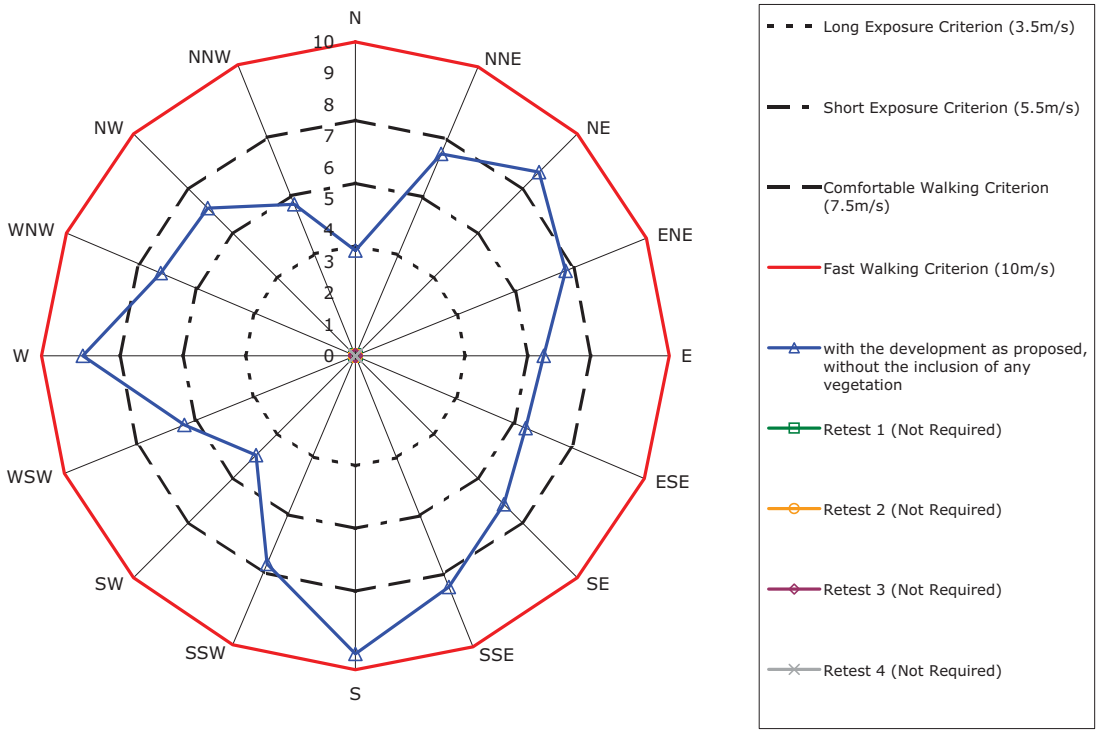


Annual Maximum Gust Wind Speeds (m/s)

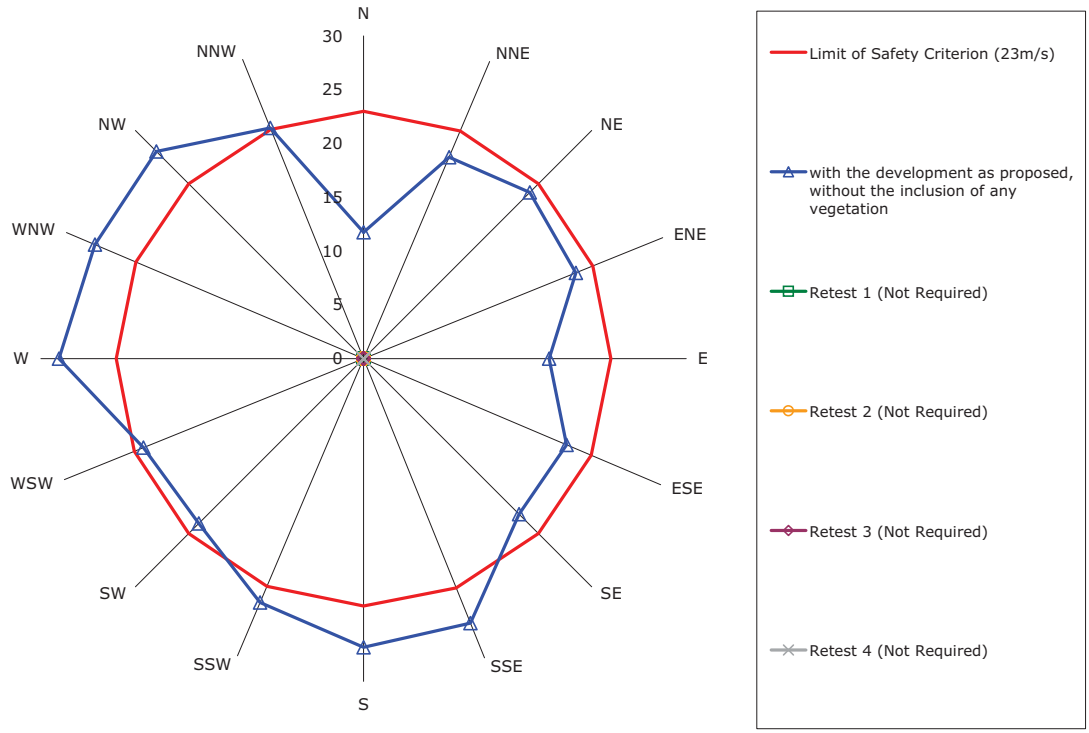


Measured Wind Speeds at Point 09

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

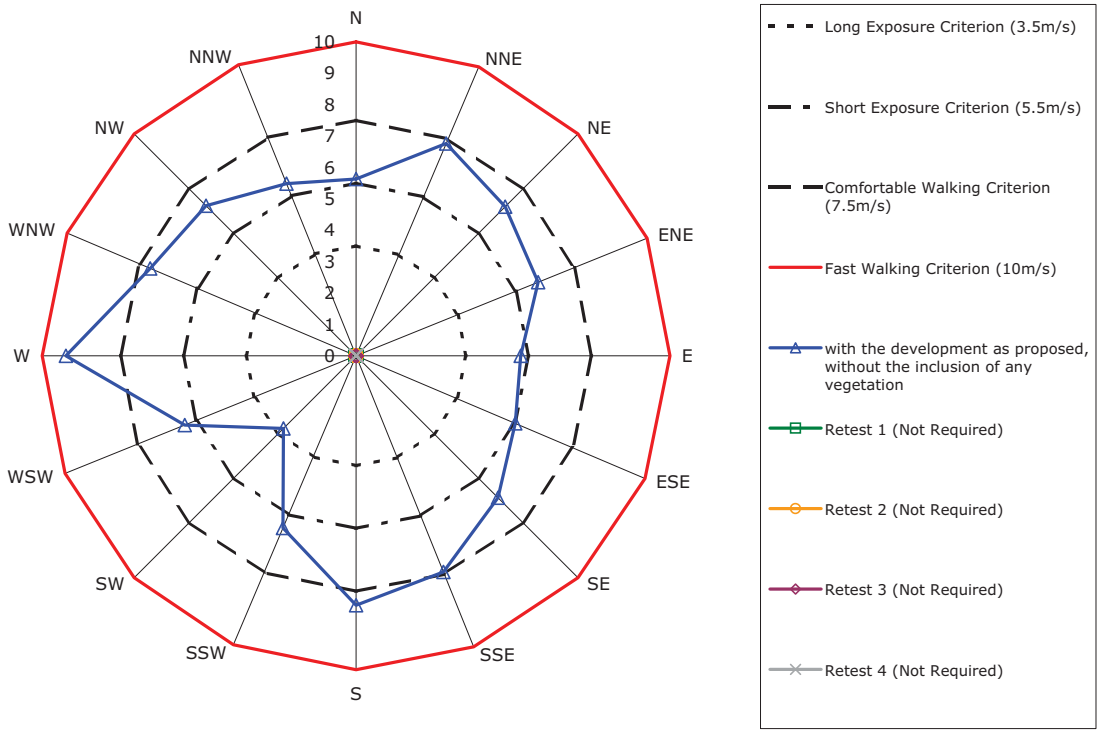


Annual Maximum Gust Wind Speeds (m/s)

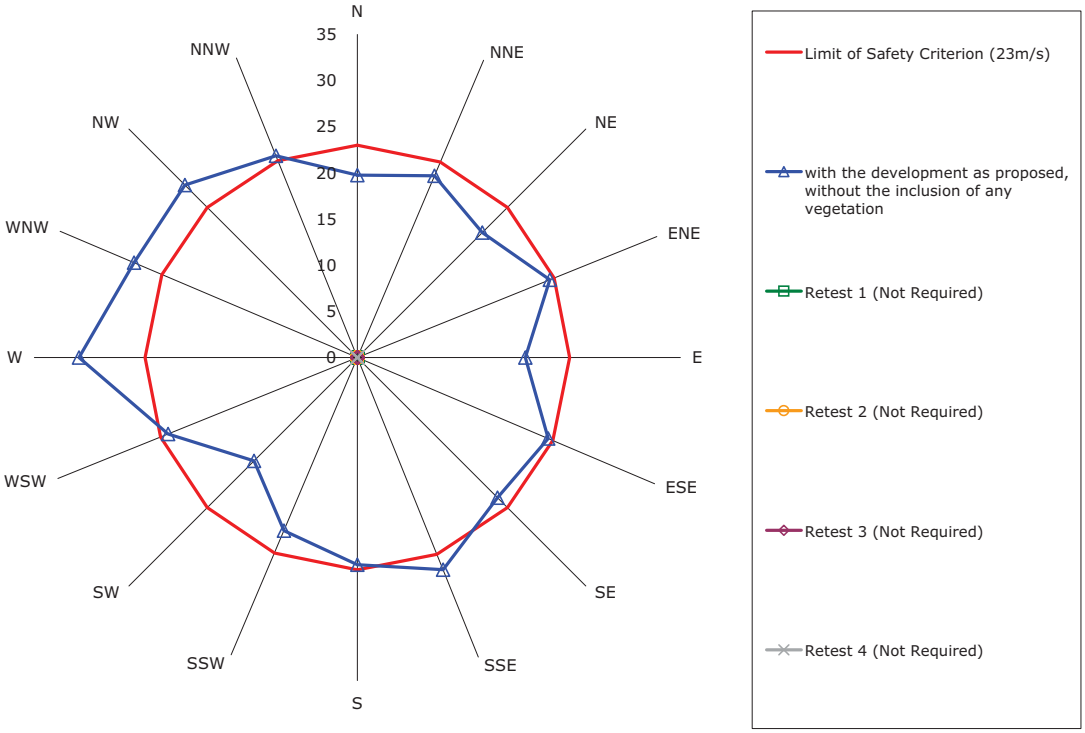


Measured Wind Speeds at Point 10

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

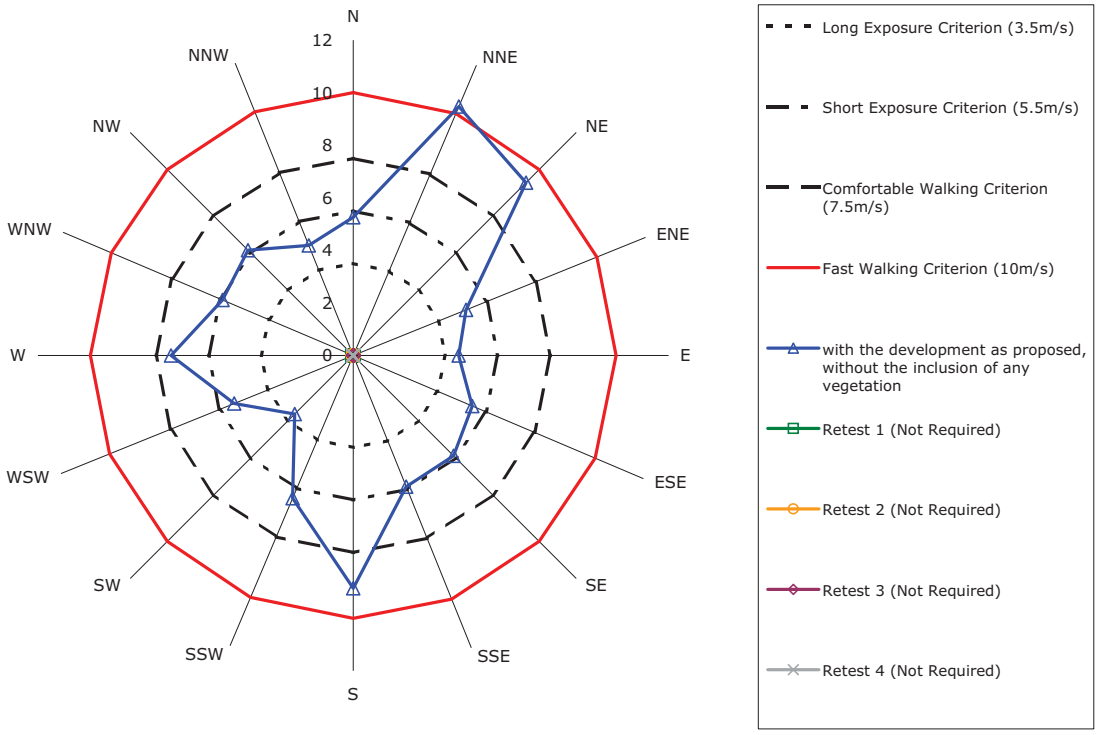


Annual Maximum Gust Wind Speeds (m/s)

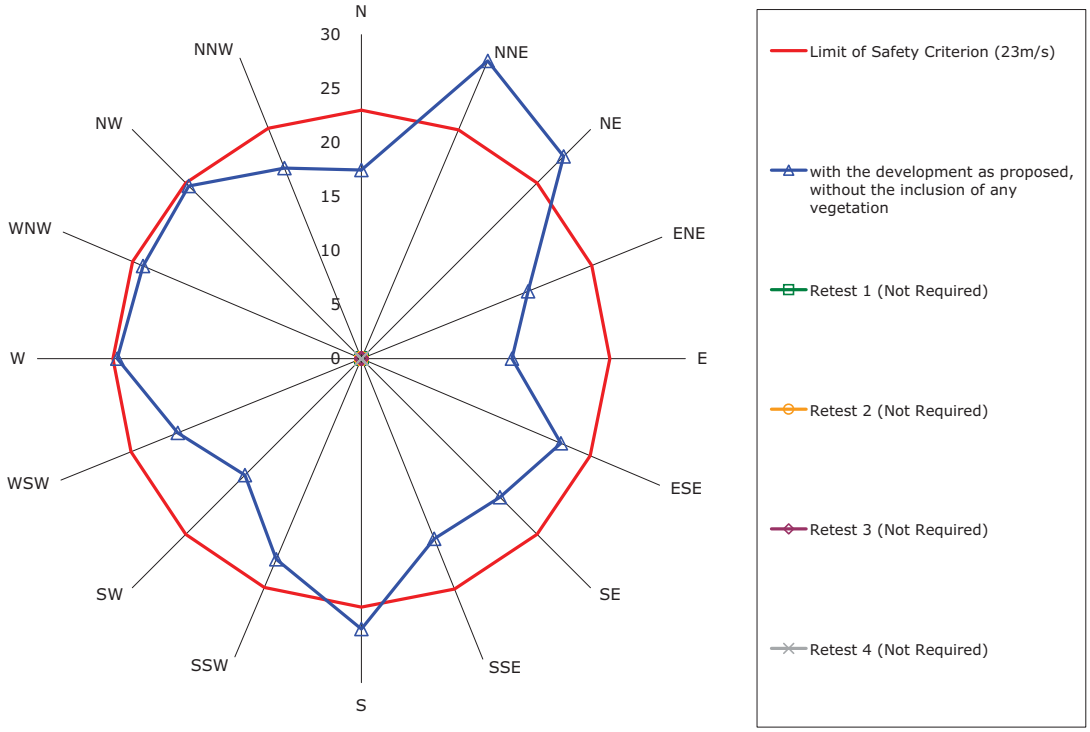


Measured Wind Speeds at Point 11

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

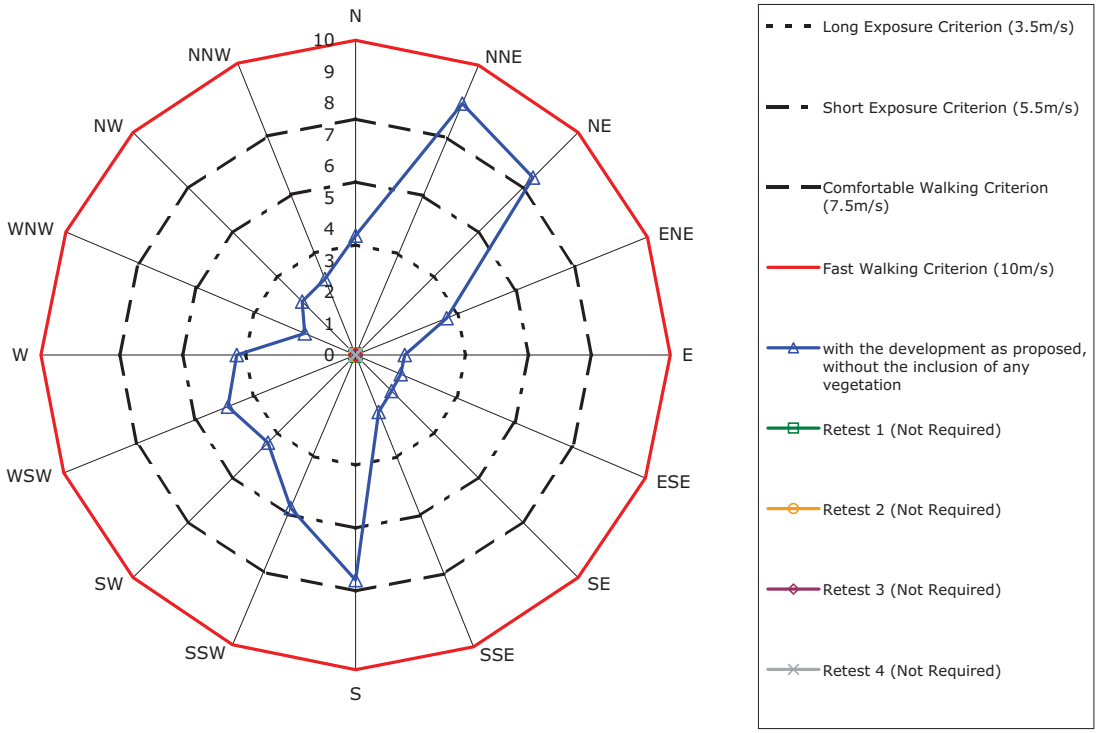


Annual Maximum Gust Wind Speeds (m/s)

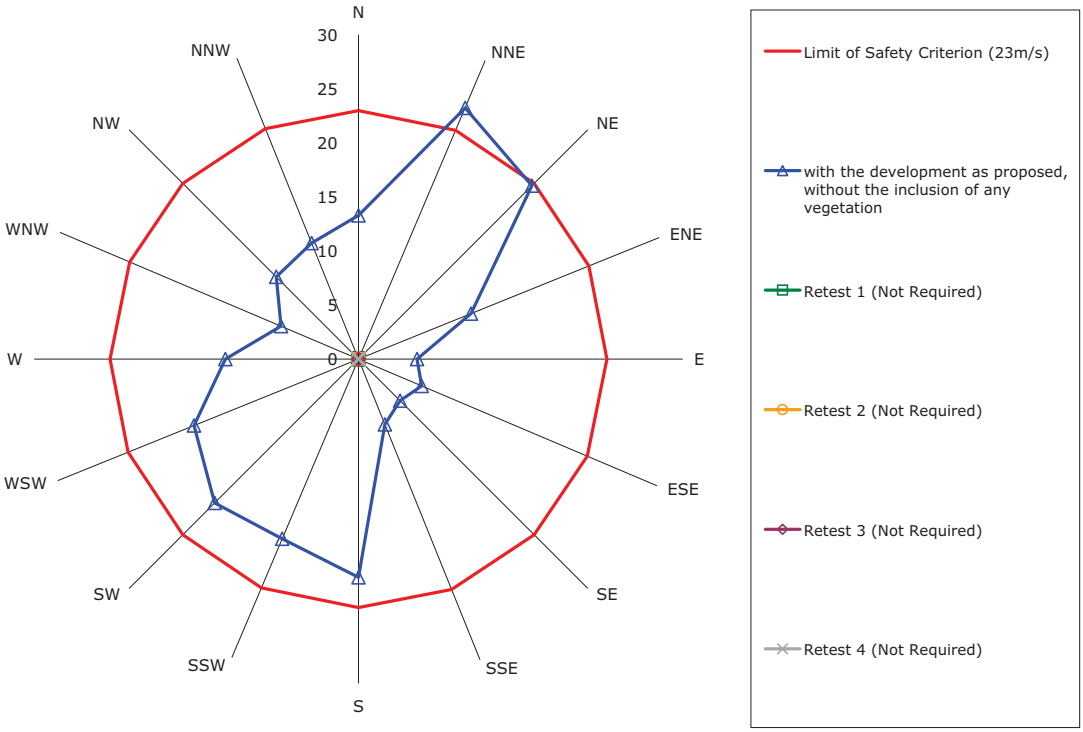


Measured Wind Speeds at Point 12

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

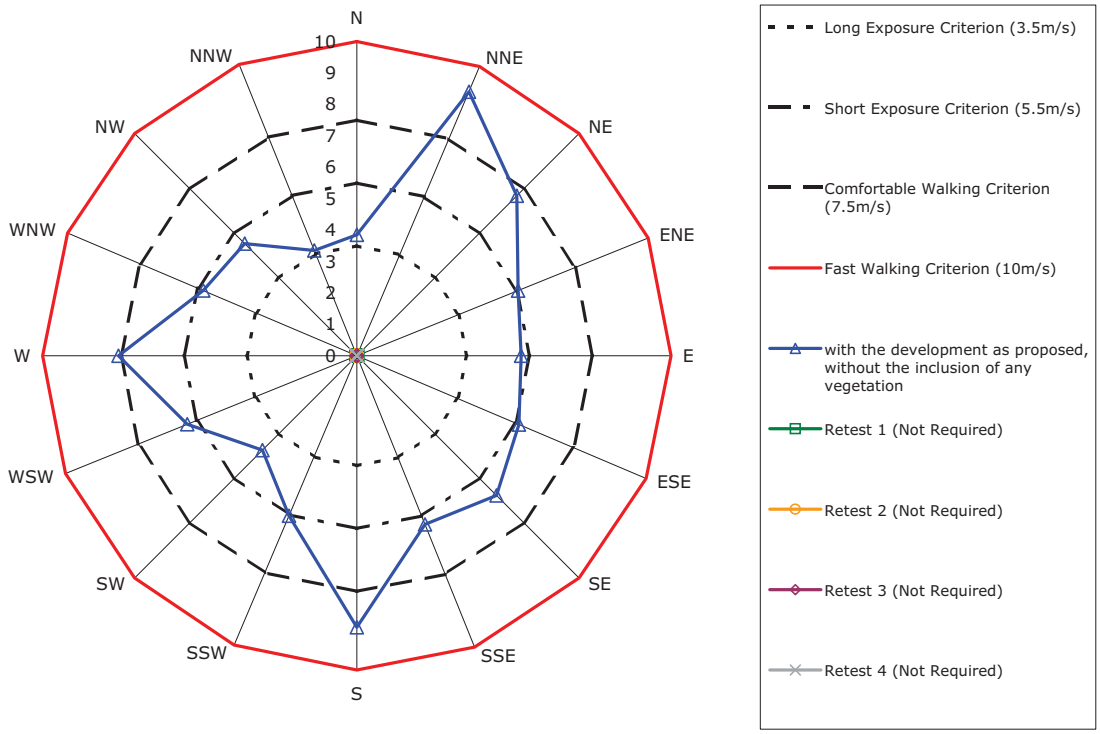


Annual Maximum Gust Wind Speeds (m/s)

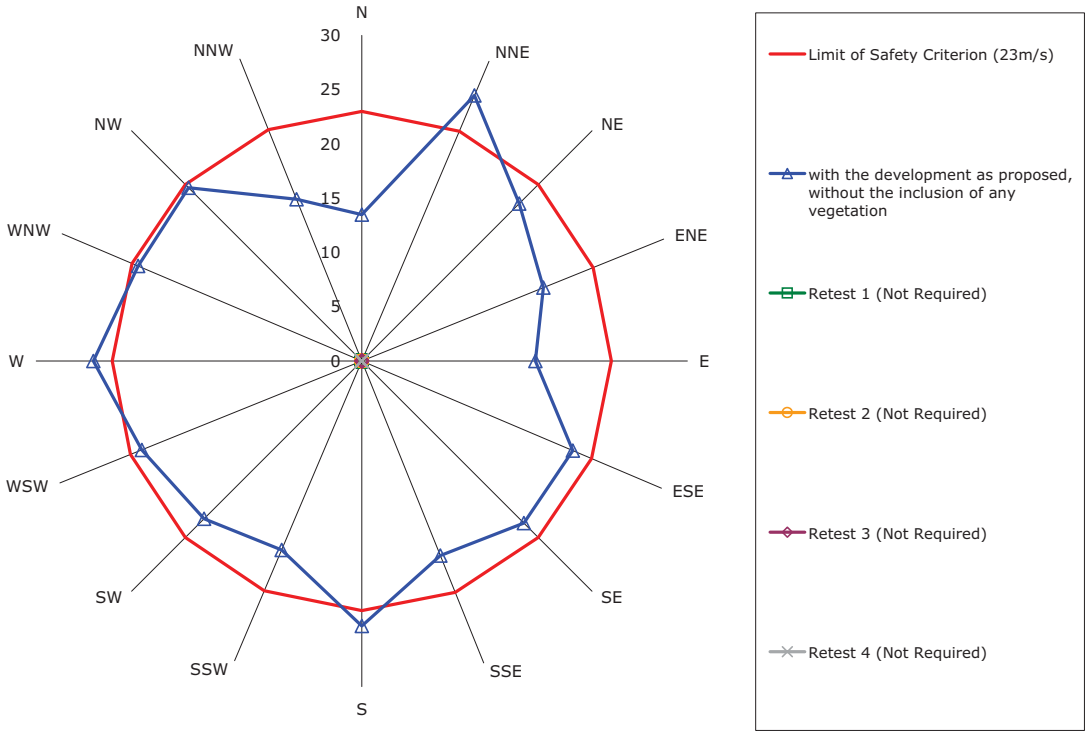


Measured Wind Speeds at Point 13

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

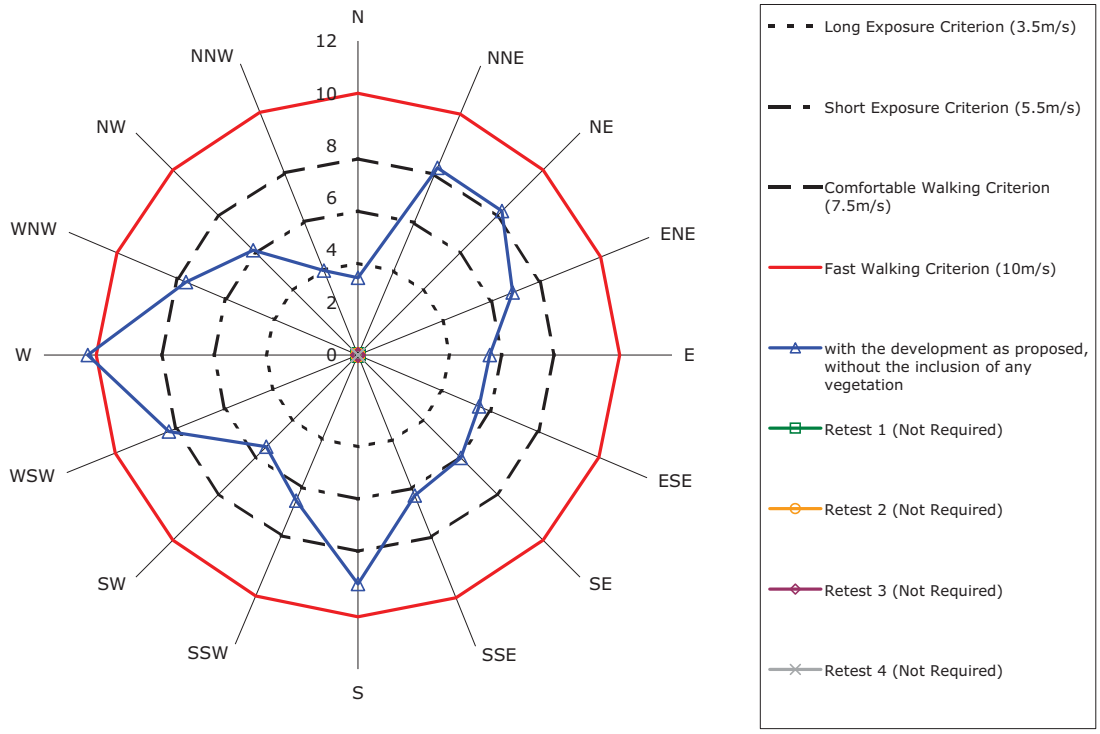


Annual Maximum Gust Wind Speeds (m/s)

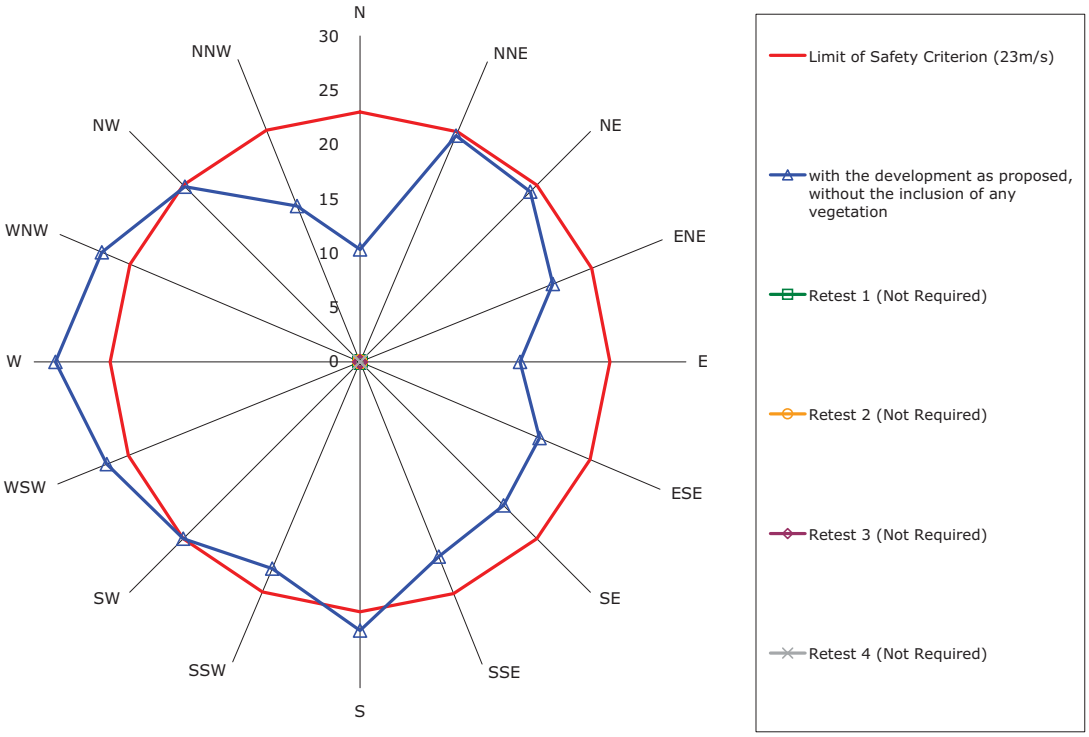


Measured Wind Speeds at Point 14

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

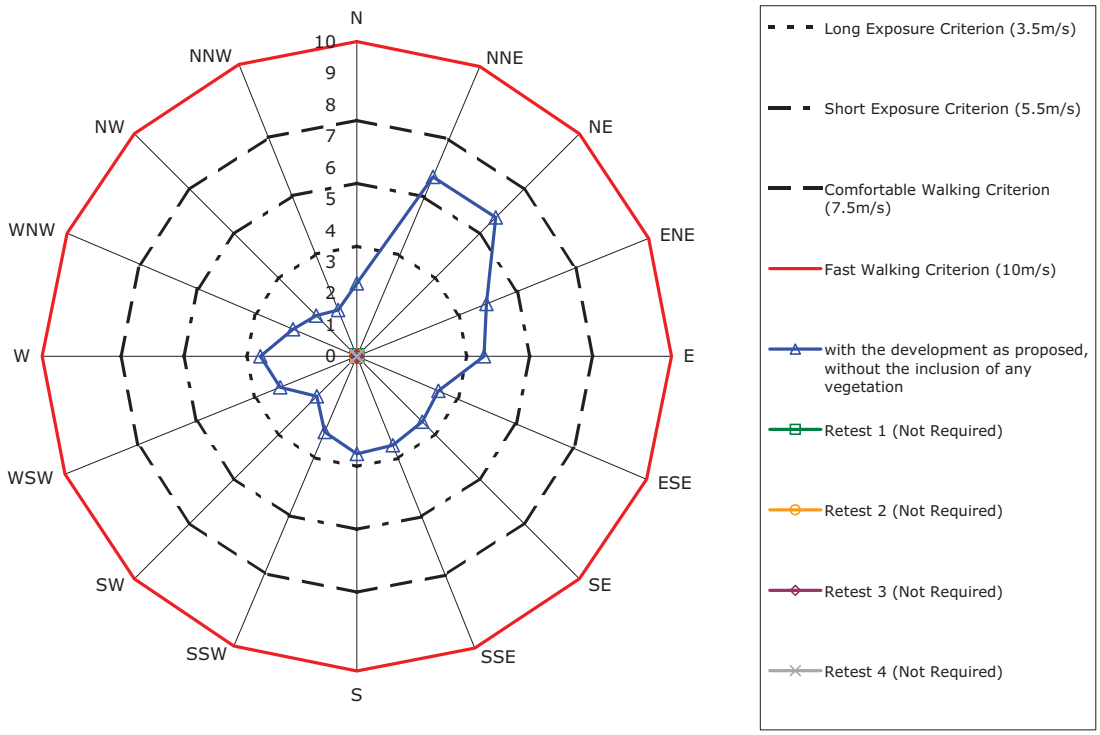


Annual Maximum Gust Wind Speeds (m/s)

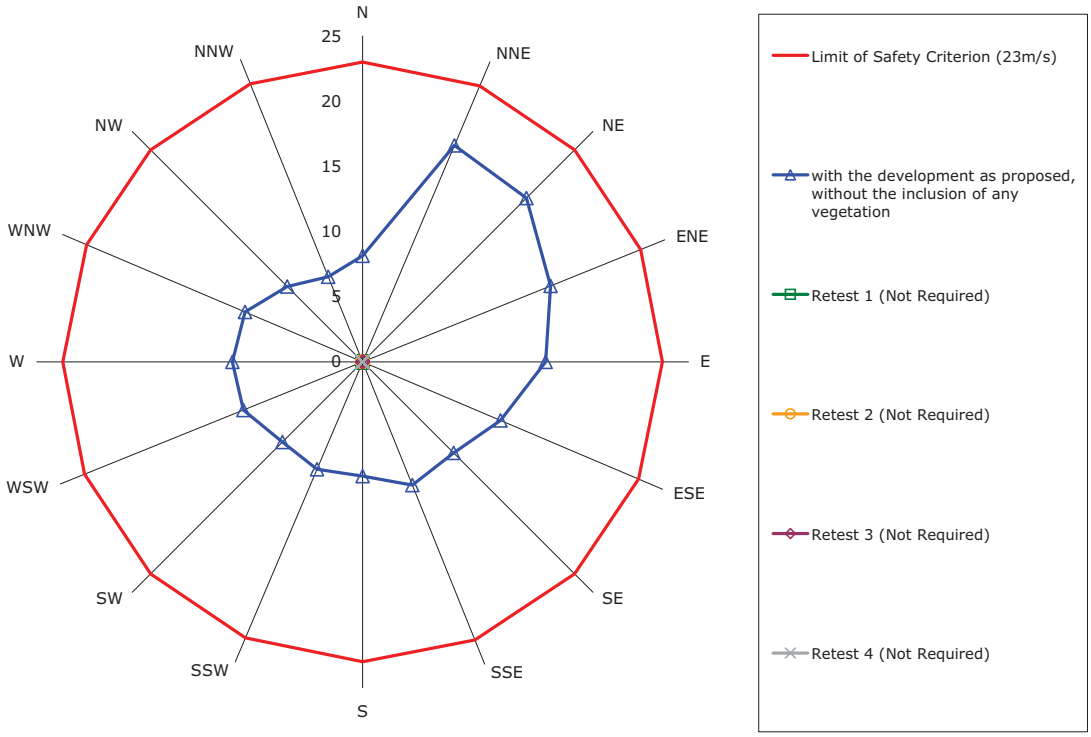


Measured Wind Speeds at Point 15

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

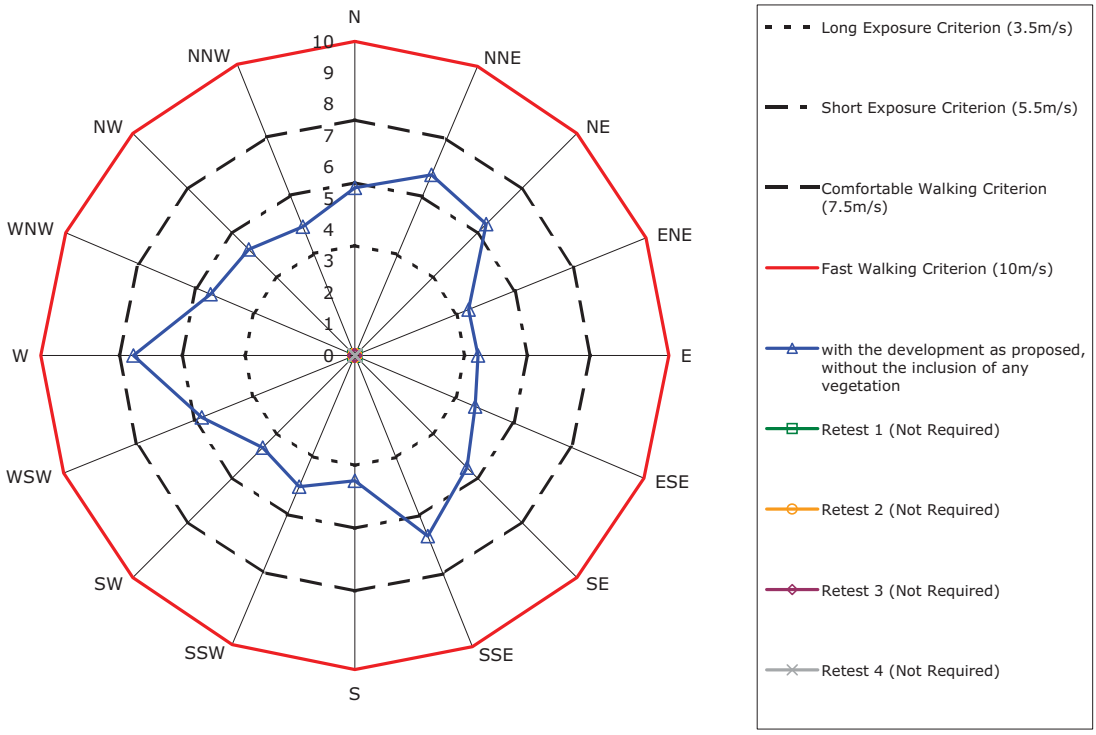


Annual Maximum Gust Wind Speeds (m/s)

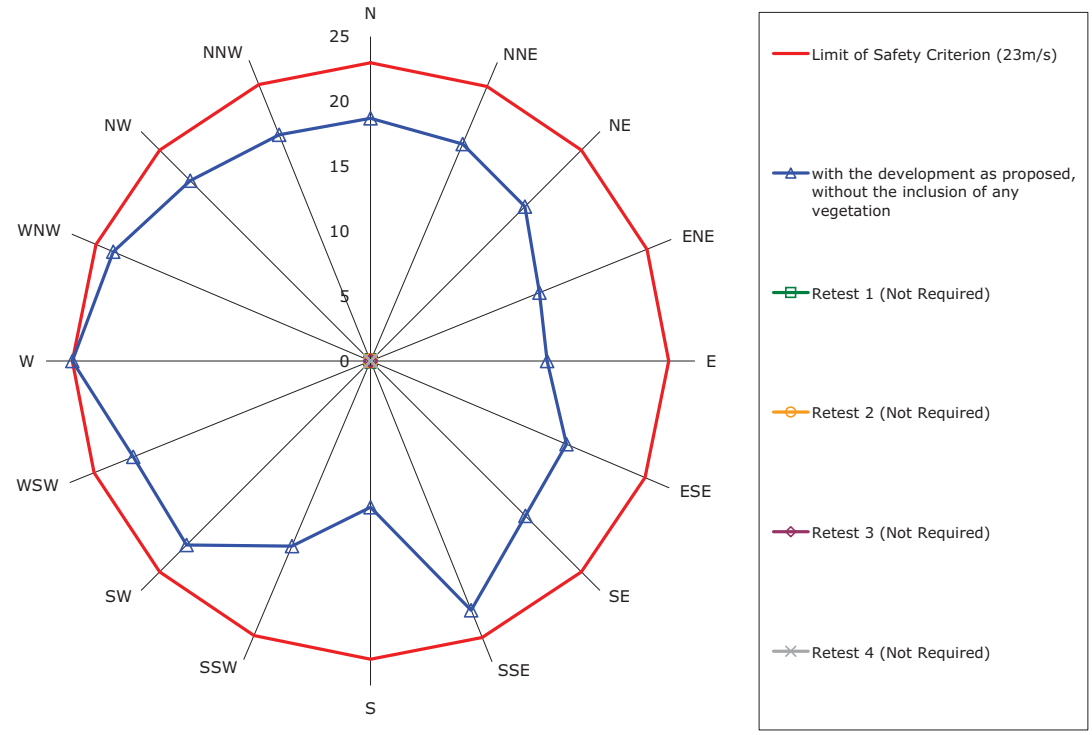


Measured Wind Speeds at Point 16

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

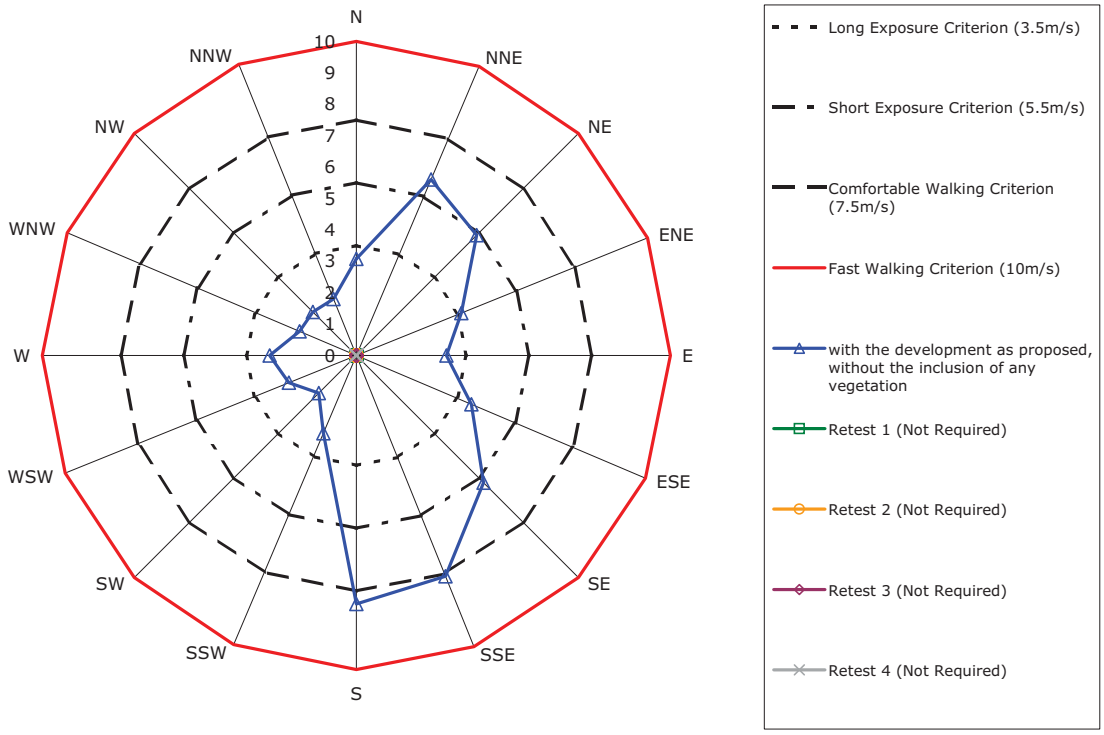


Annual Maximum Gust Wind Speeds (m/s)

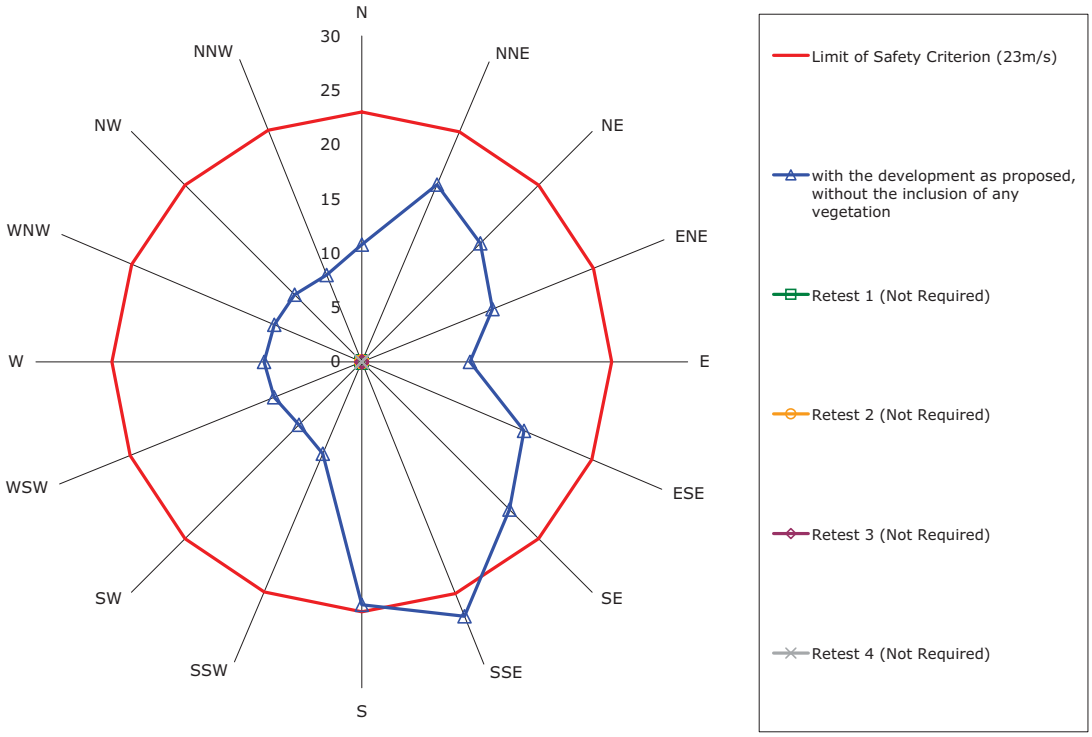


Measured Wind Speeds at Point 17

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

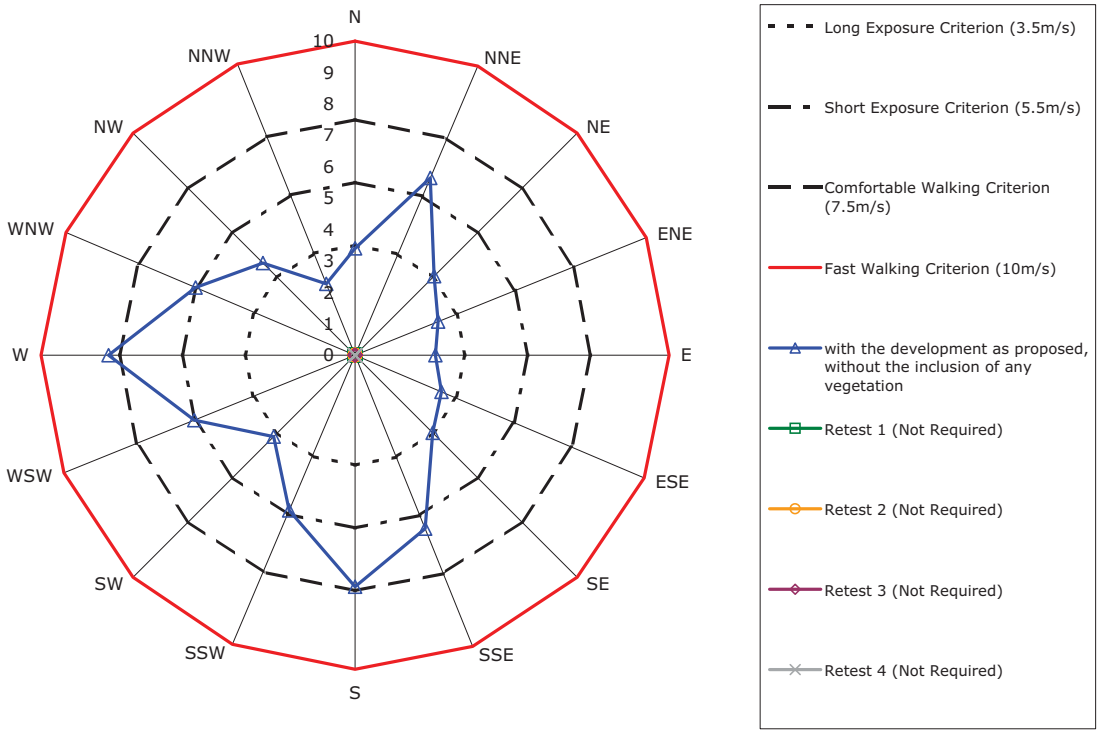


Annual Maximum Gust Wind Speeds (m/s)

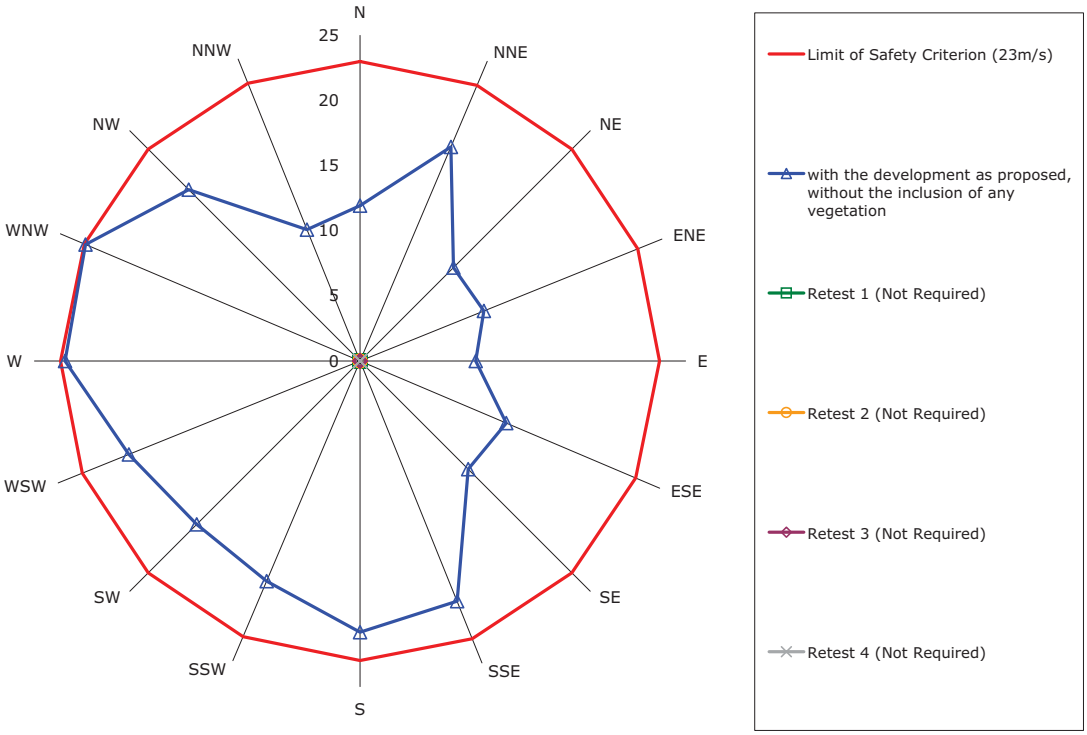


Measured Wind Speeds at Point 18

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

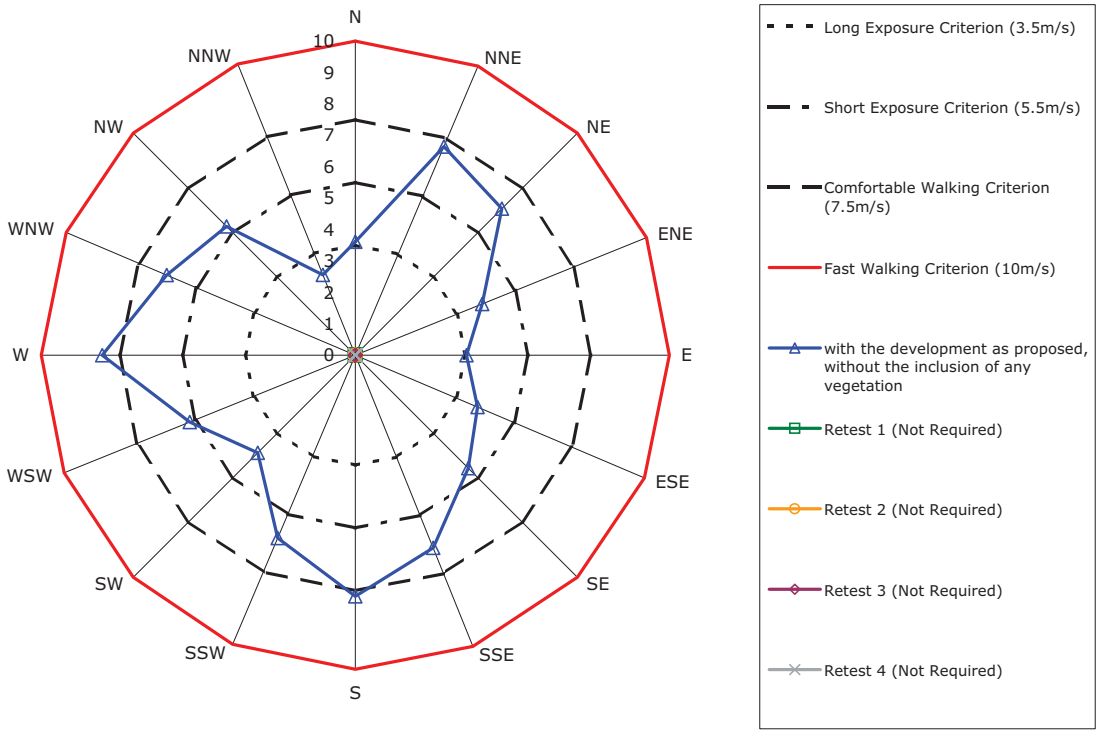


Annual Maximum Gust Wind Speeds (m/s)

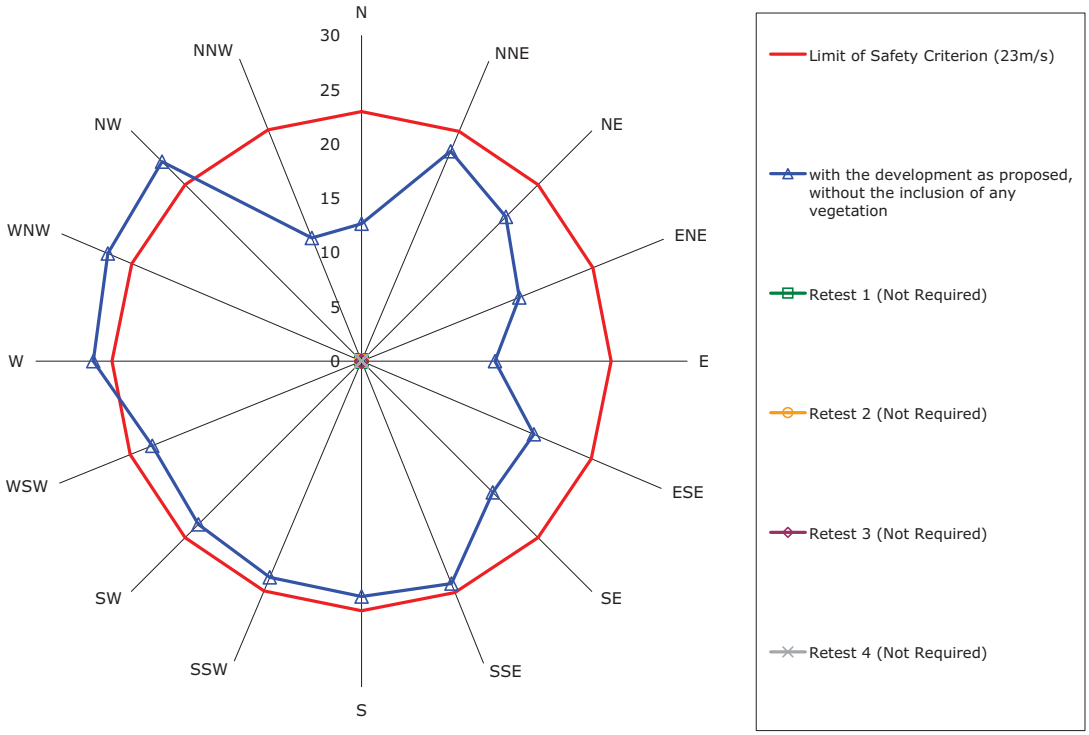


Measured Wind Speeds at Point 19

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

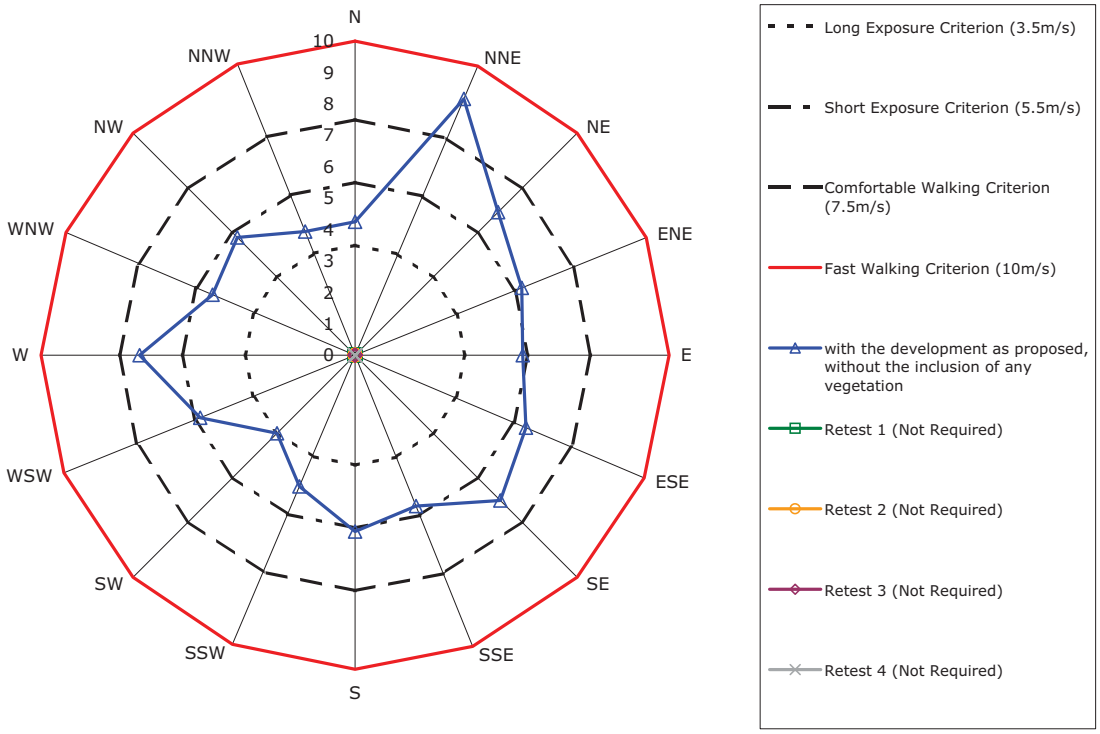


Annual Maximum Gust Wind Speeds (m/s)

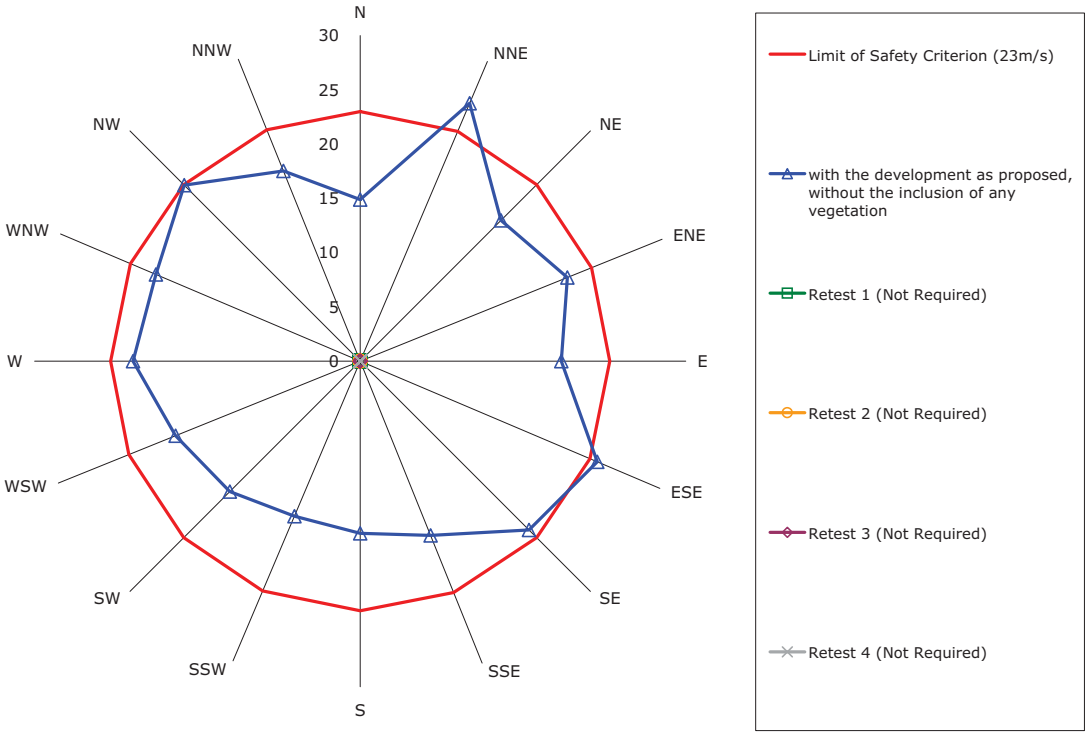


Measured Wind Speeds at Point 20

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

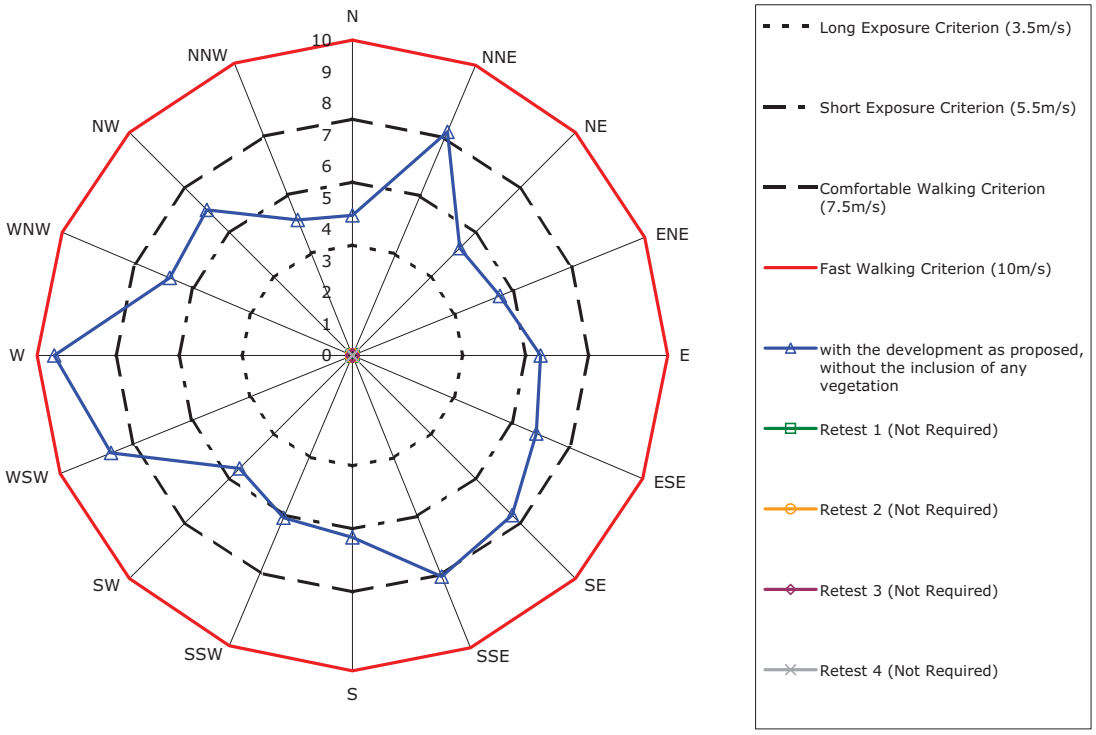


Annual Maximum Gust Wind Speeds (m/s)

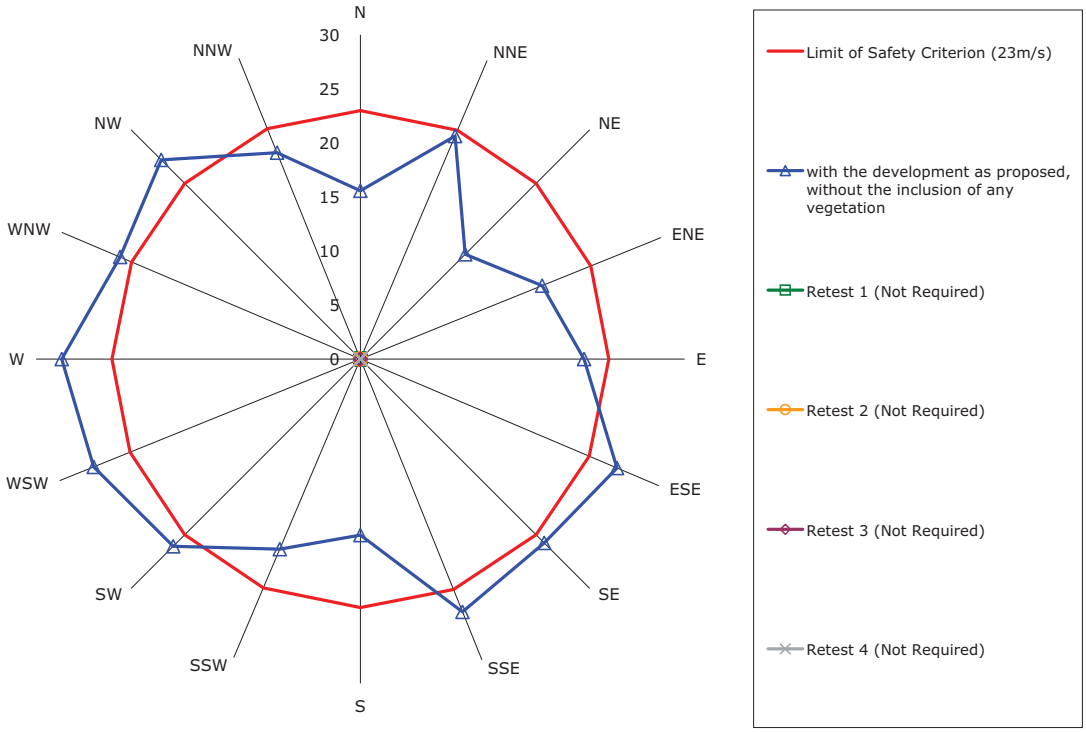


Measured Wind Speeds at Point 21

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

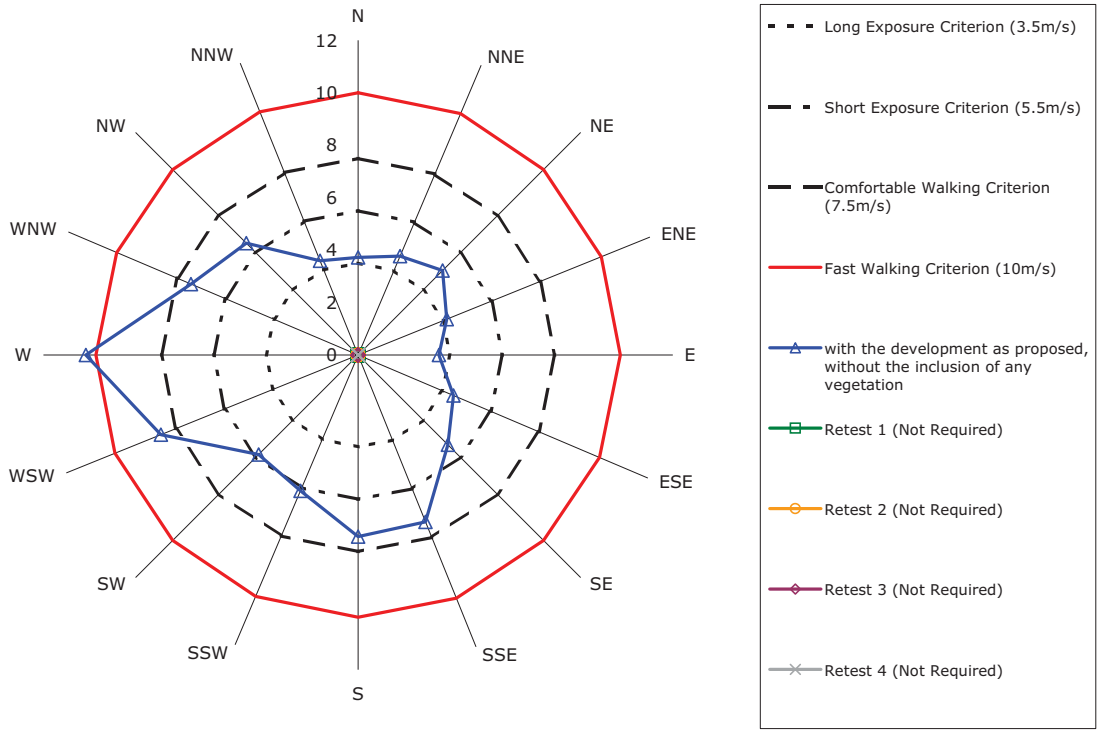


Annual Maximum Gust Wind Speeds (m/s)

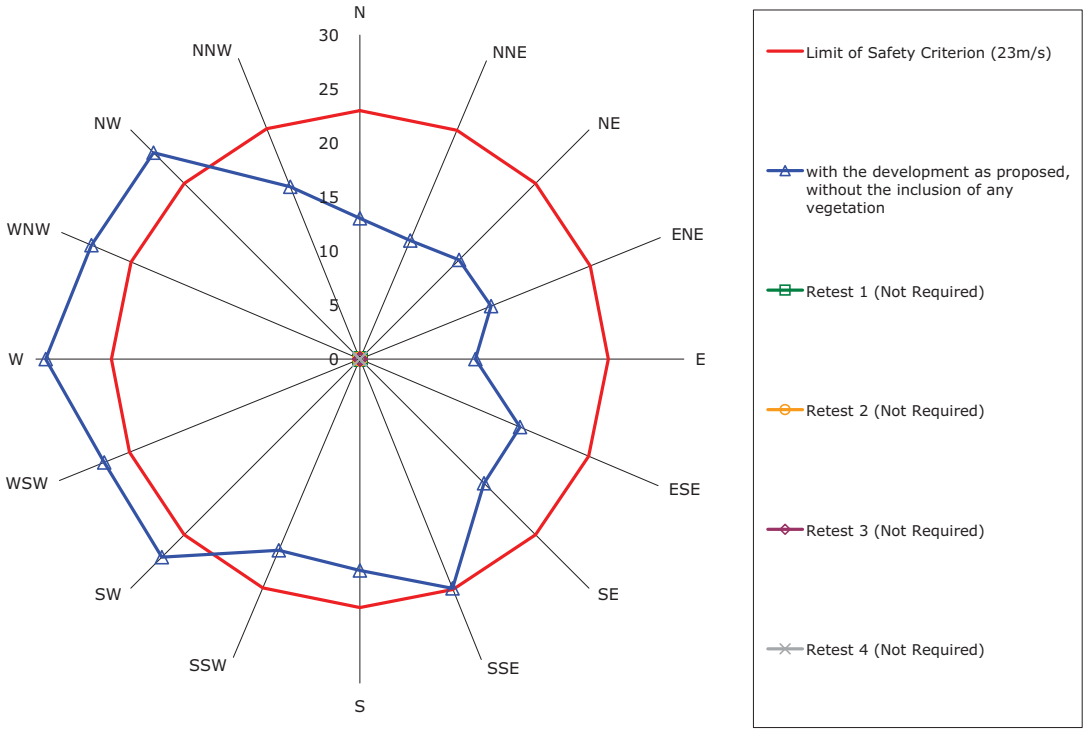


Measured Wind Speeds at Point 22

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

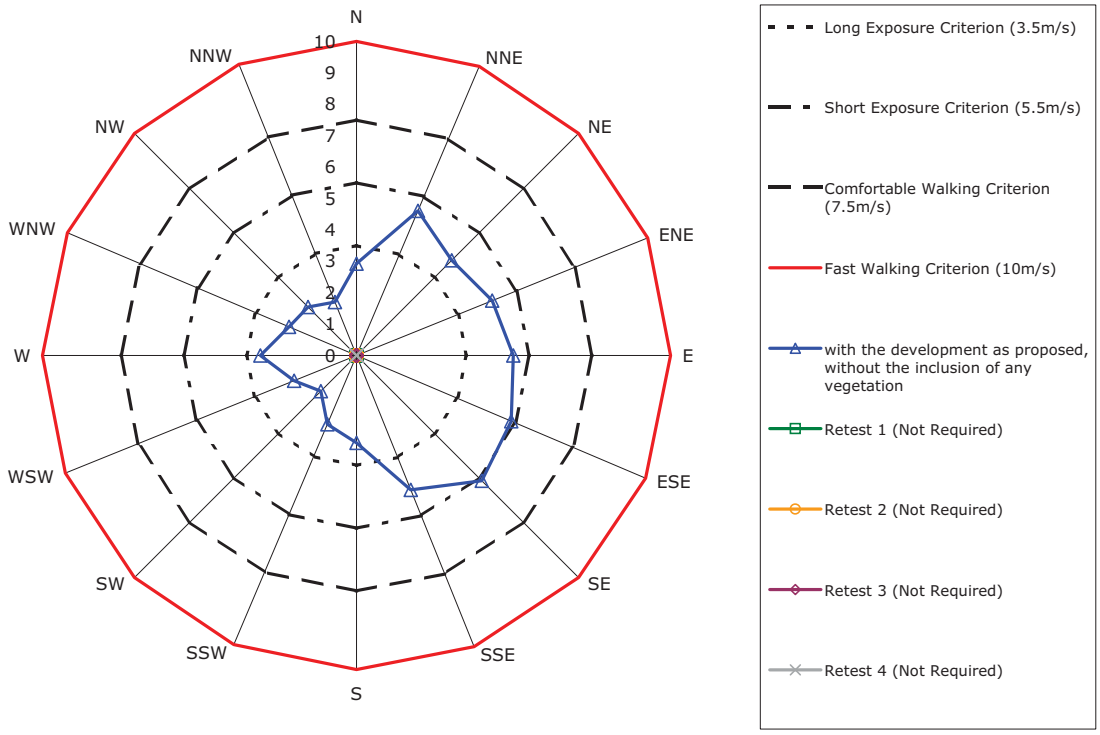


Annual Maximum Gust Wind Speeds (m/s)

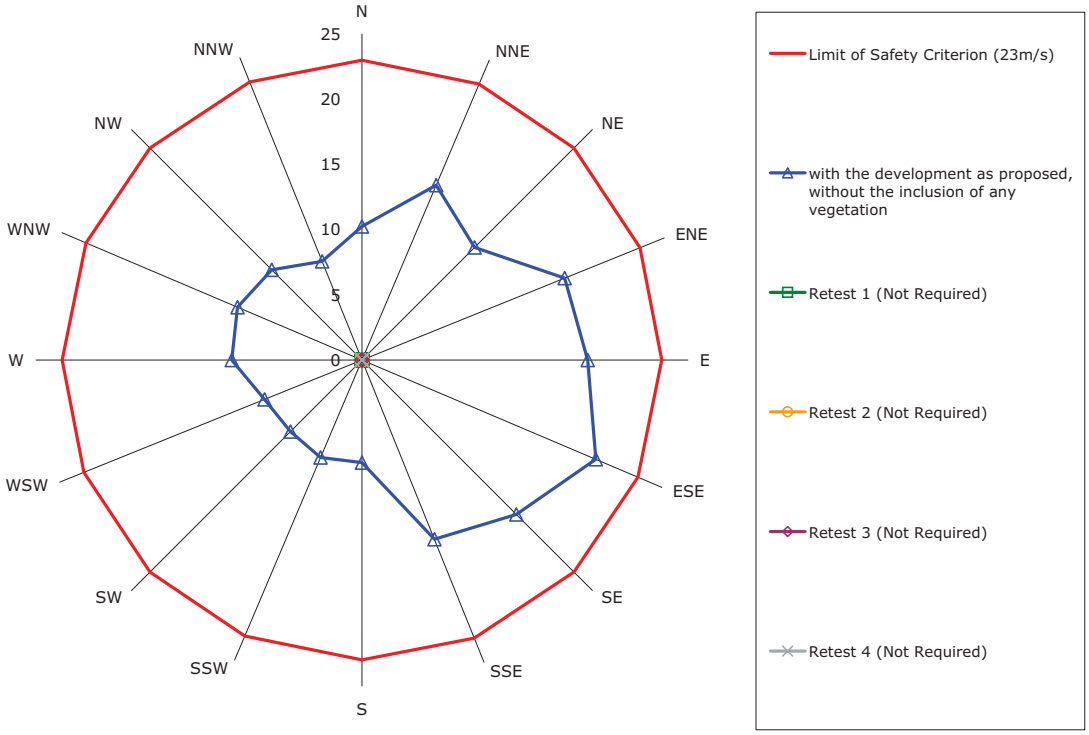


Measured Wind Speeds at Point 23

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

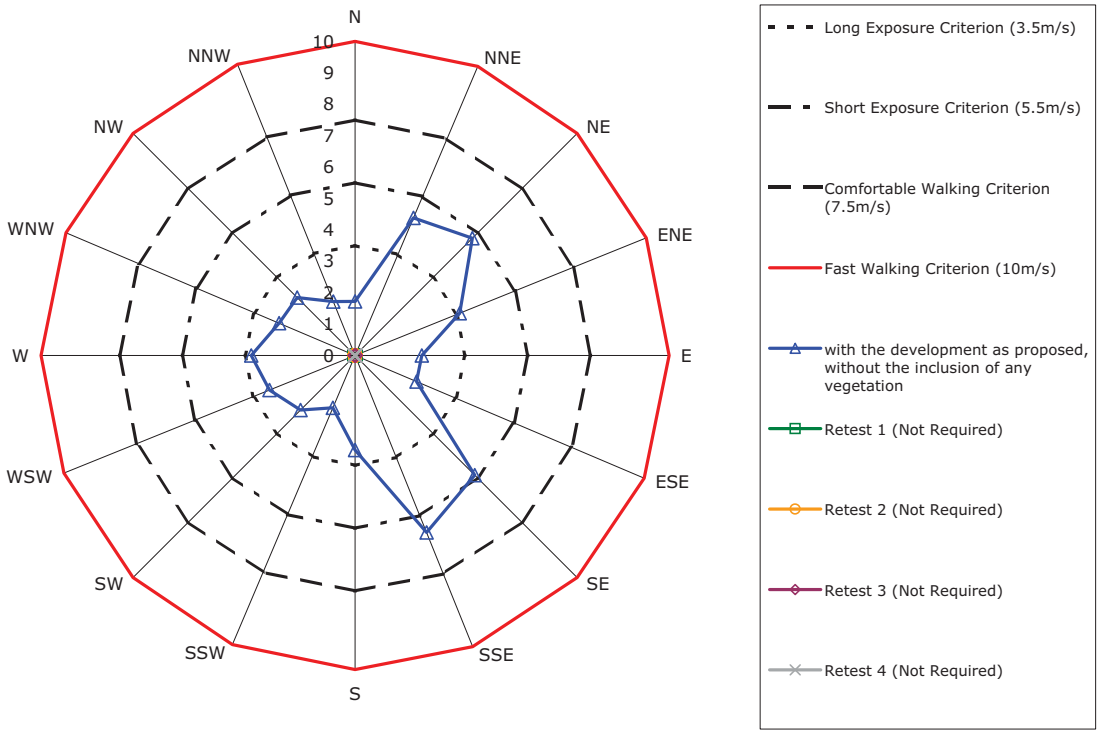


Annual Maximum Gust Wind Speeds (m/s)

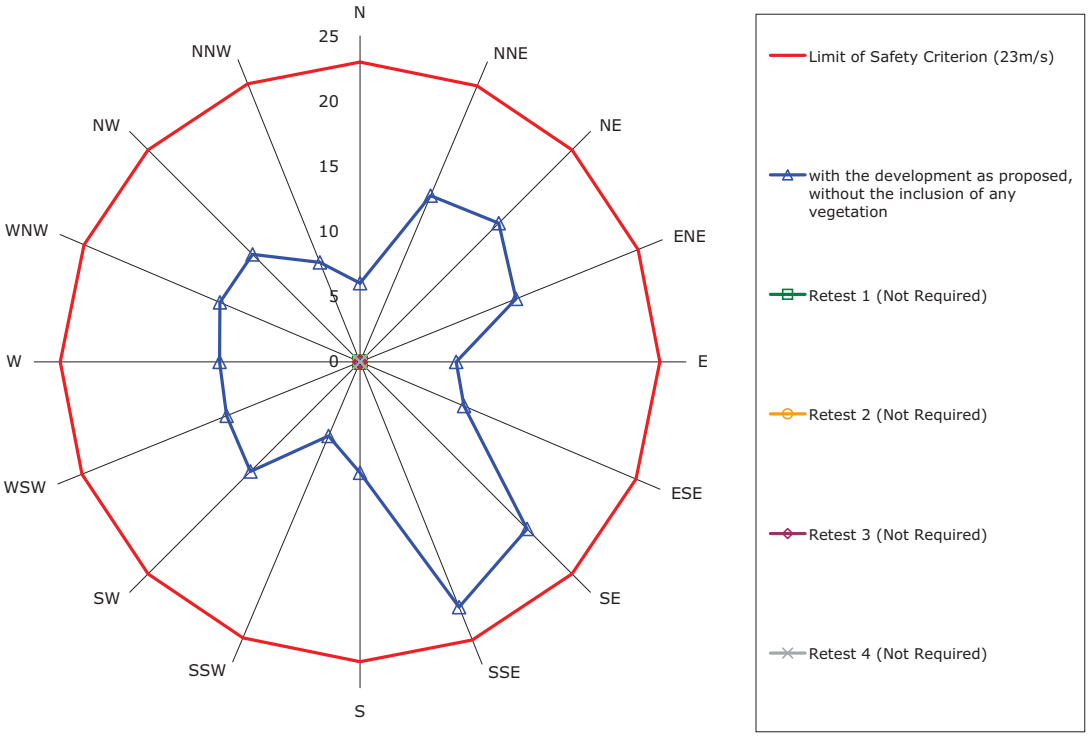


Measured Wind Speeds at Point 24

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

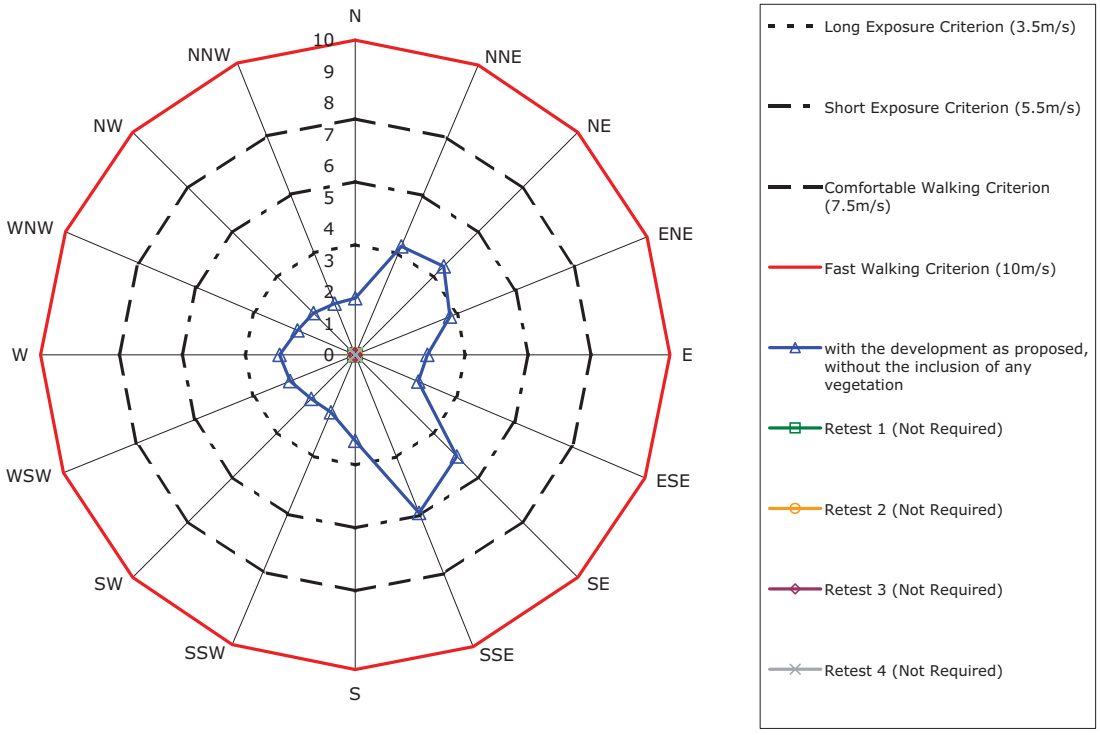


Annual Maximum Gust Wind Speeds (m/s)

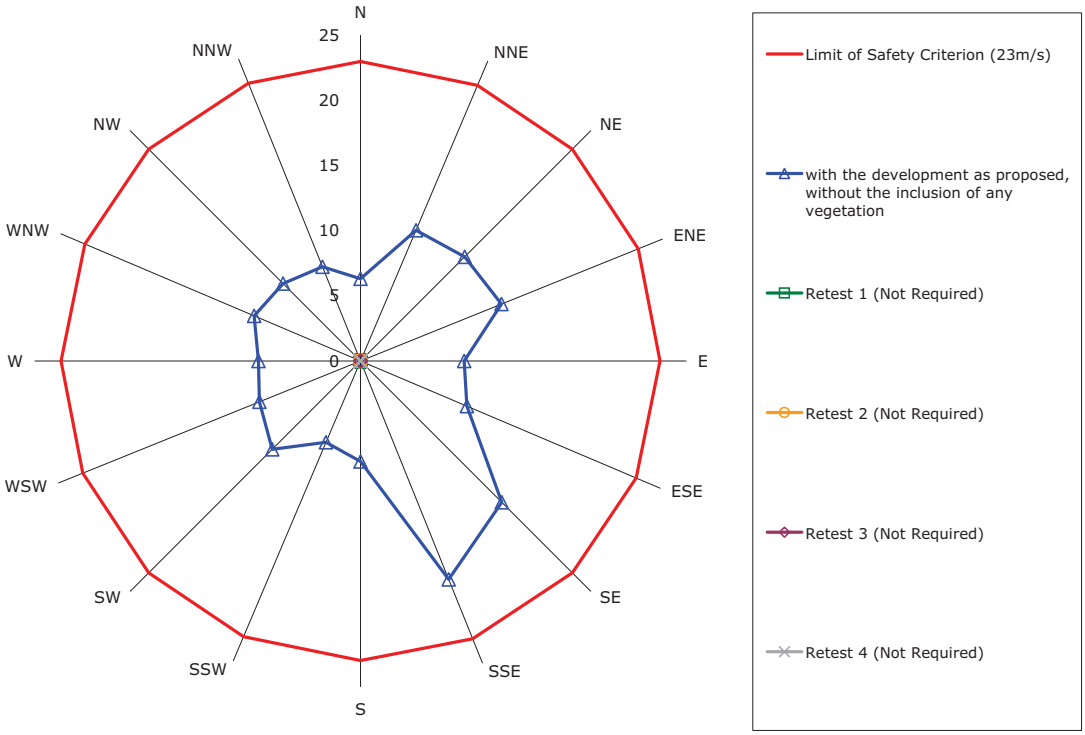


Measured Wind Speeds at Point 25

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

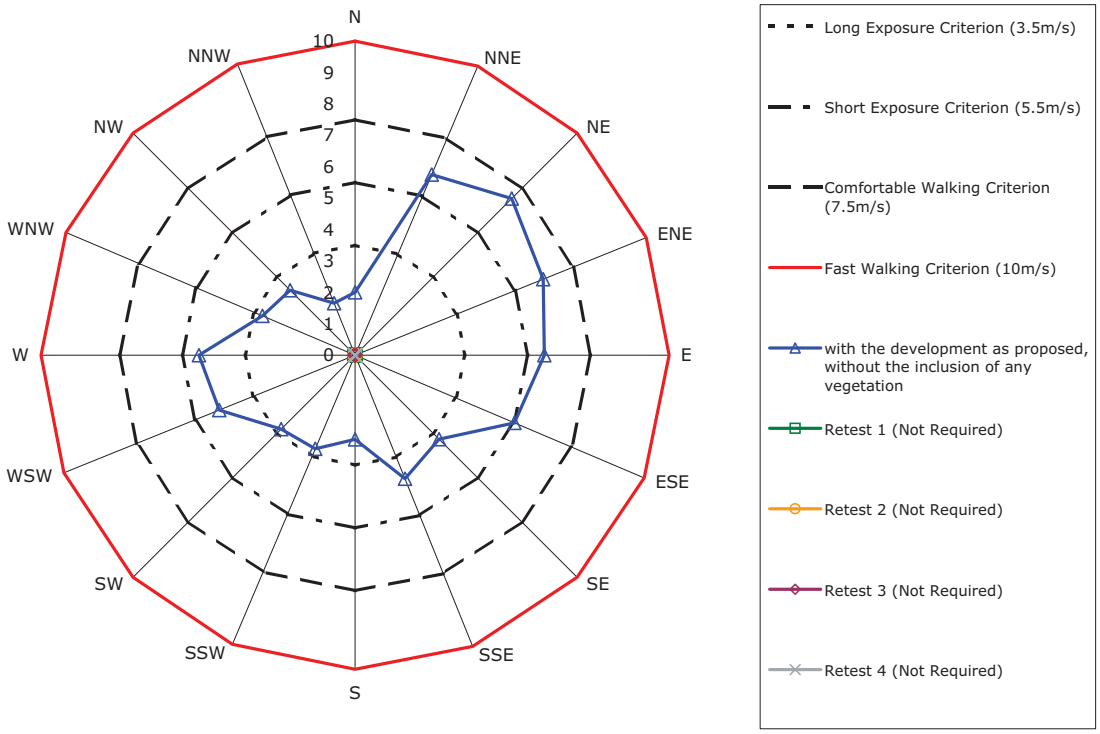


Annual Maximum Gust Wind Speeds (m/s)

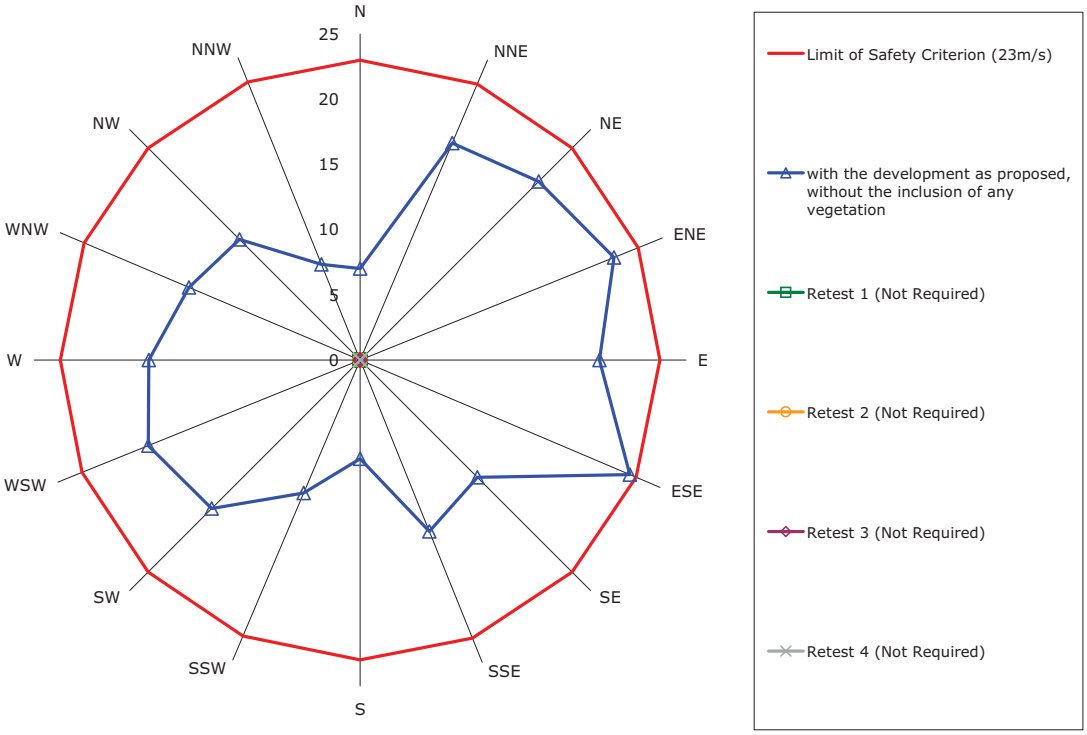


Measured Wind Speeds at Point 26

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

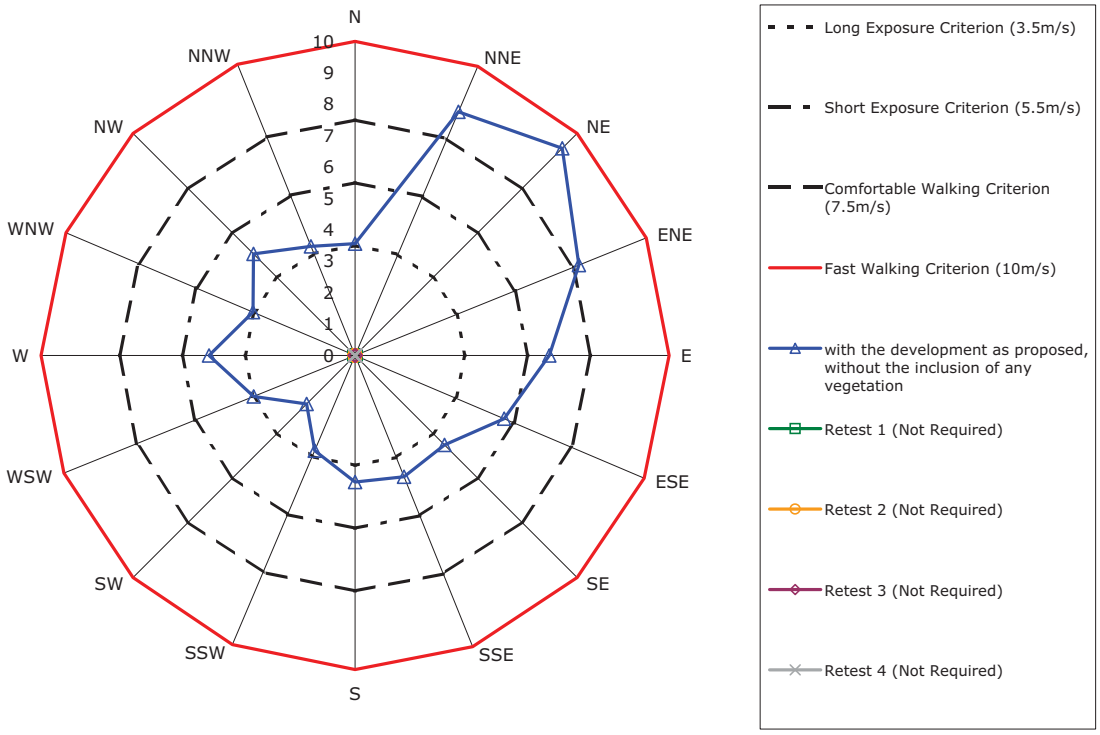


Annual Maximum Gust Wind Speeds (m/s)

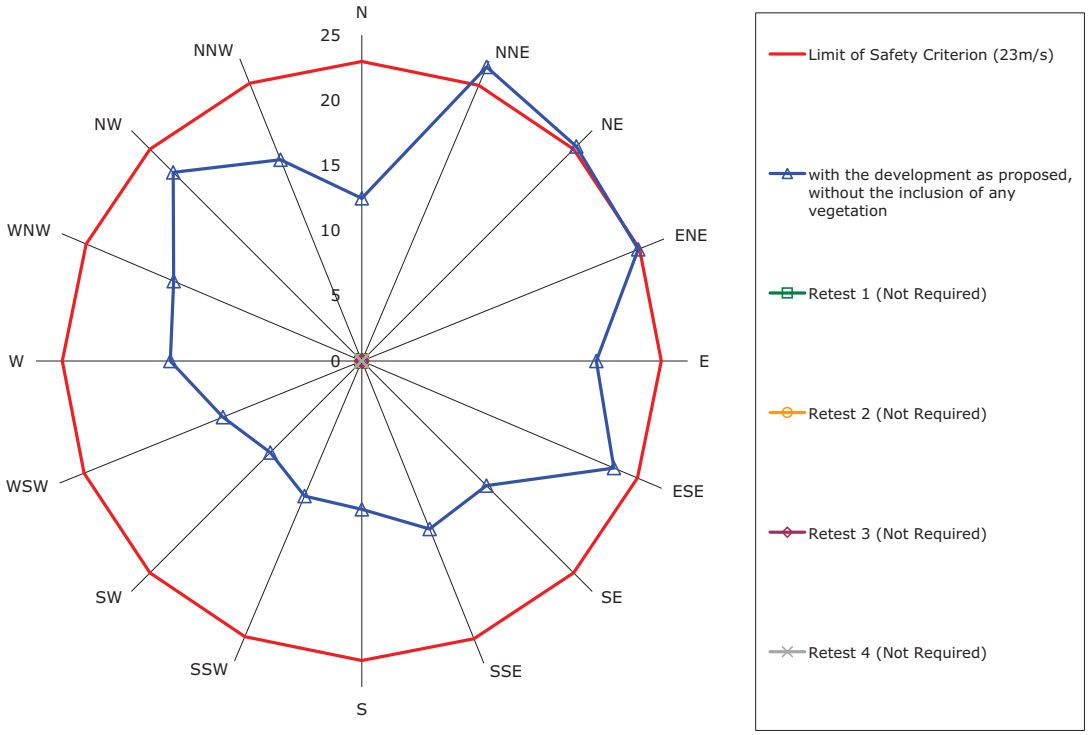


Measured Wind Speeds at Point 27

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

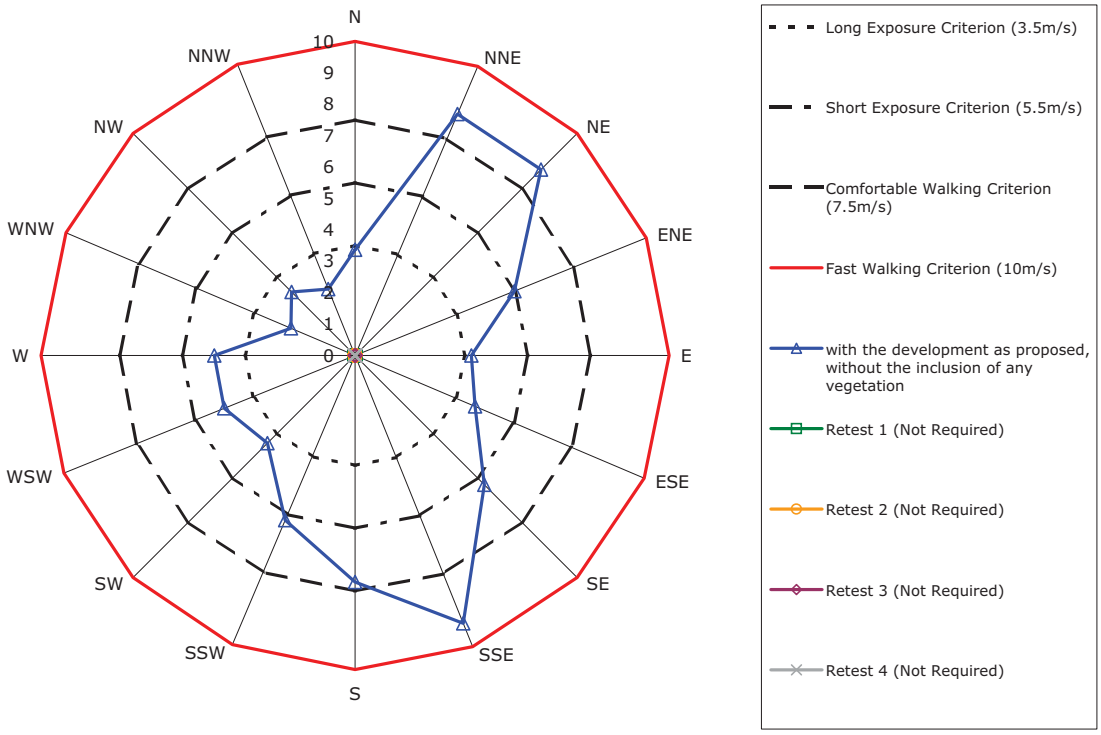


Annual Maximum Gust Wind Speeds (m/s)

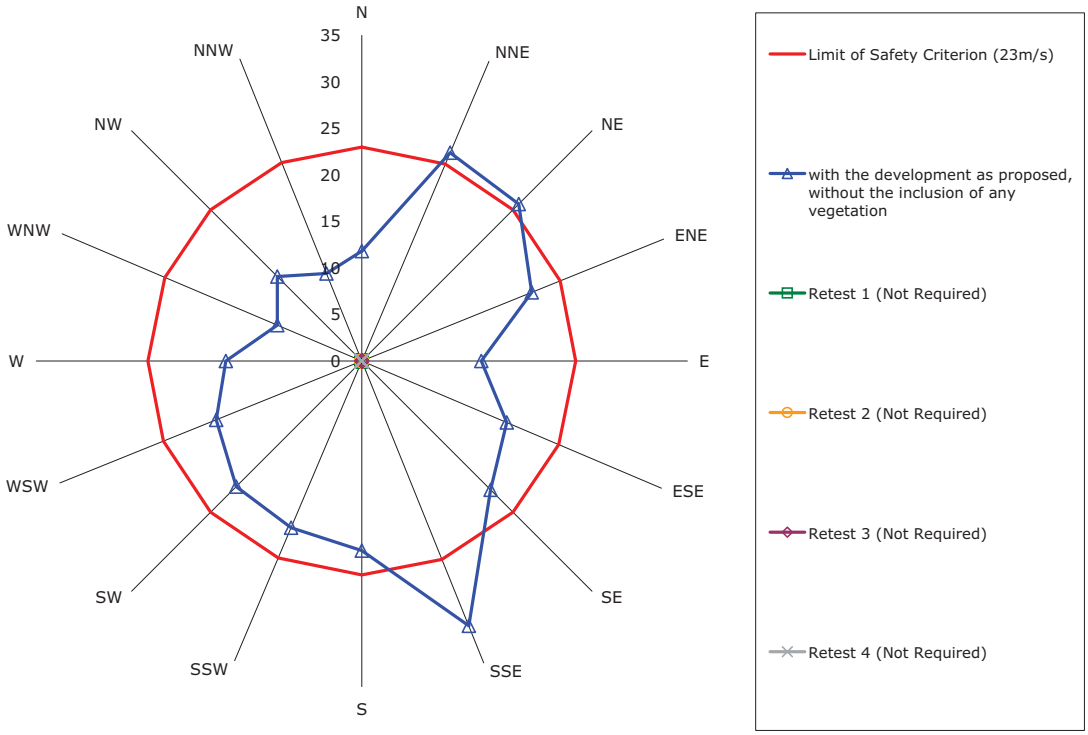


Measured Wind Speeds at Point 28

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

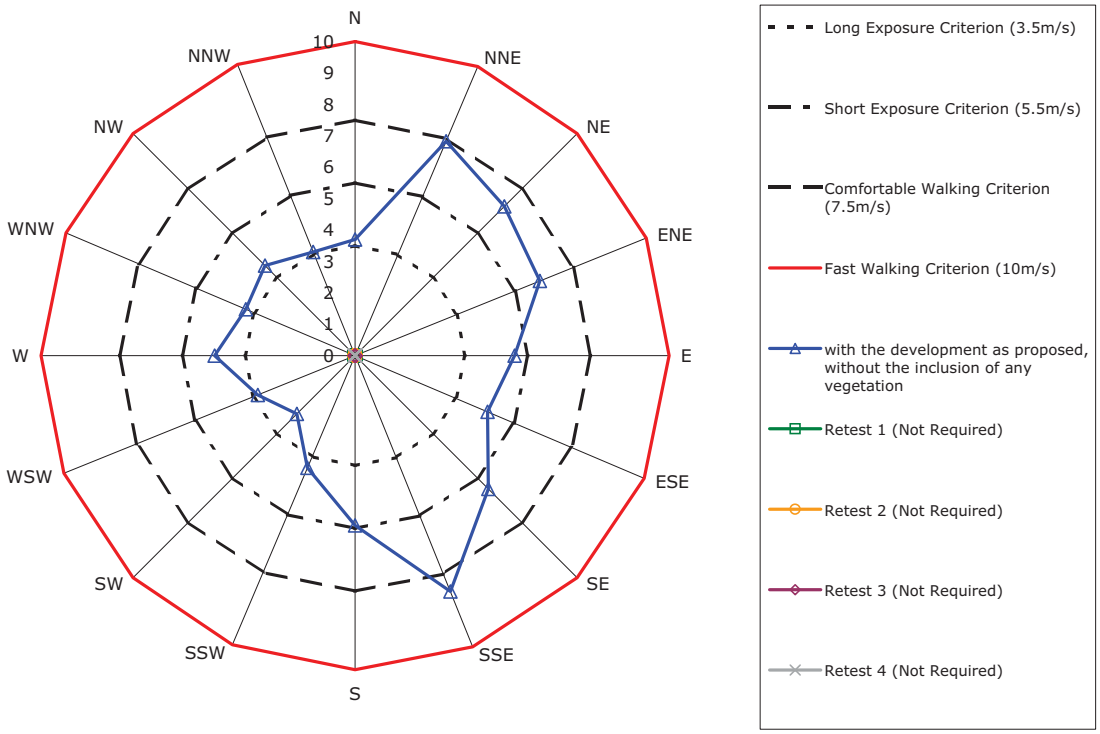


Annual Maximum Gust Wind Speeds (m/s)

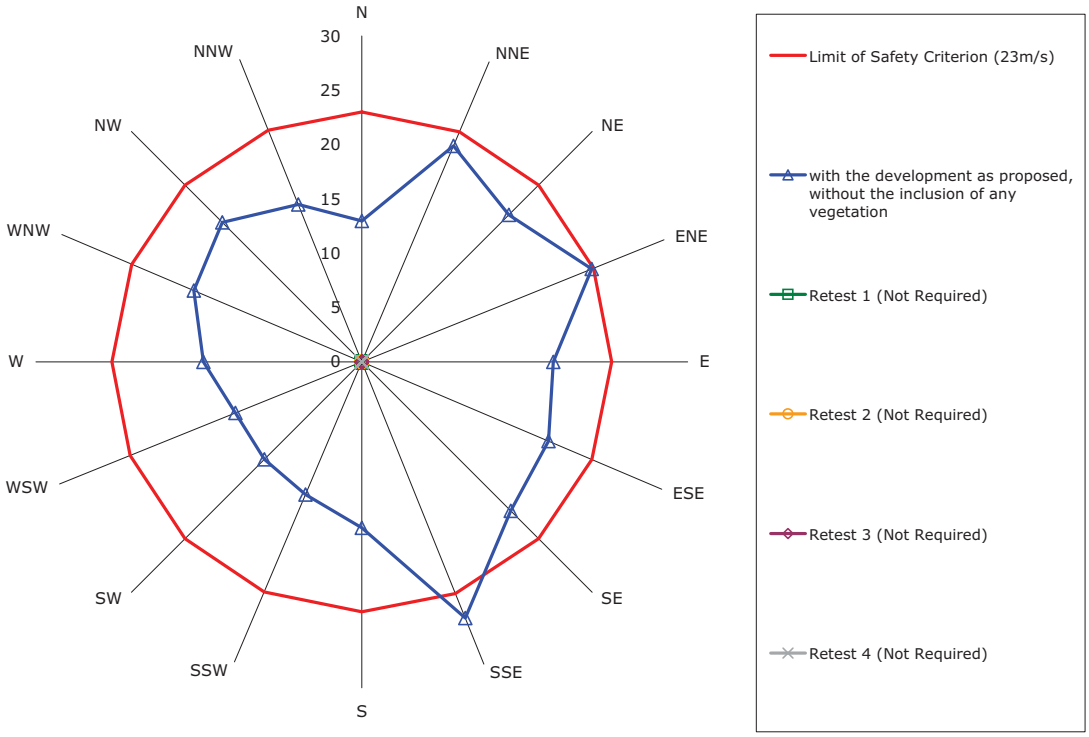


Measured Wind Speeds at Point 29

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

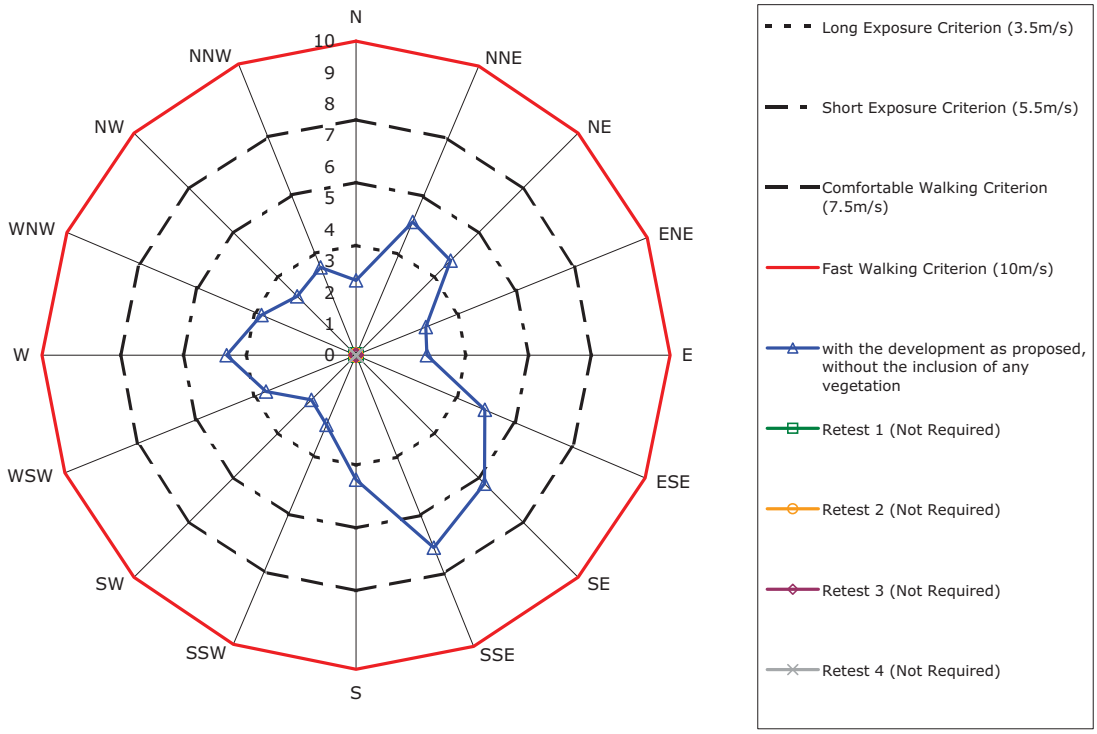


Annual Maximum Gust Wind Speeds (m/s)

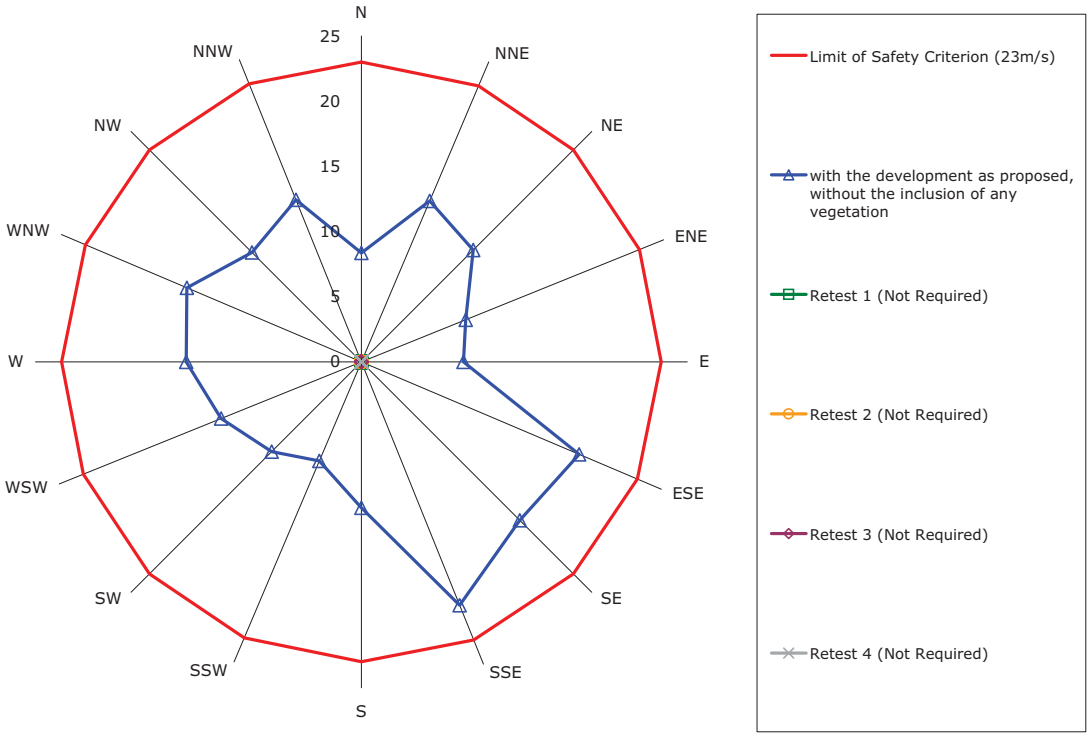


Measured Wind Speeds at Point 30

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

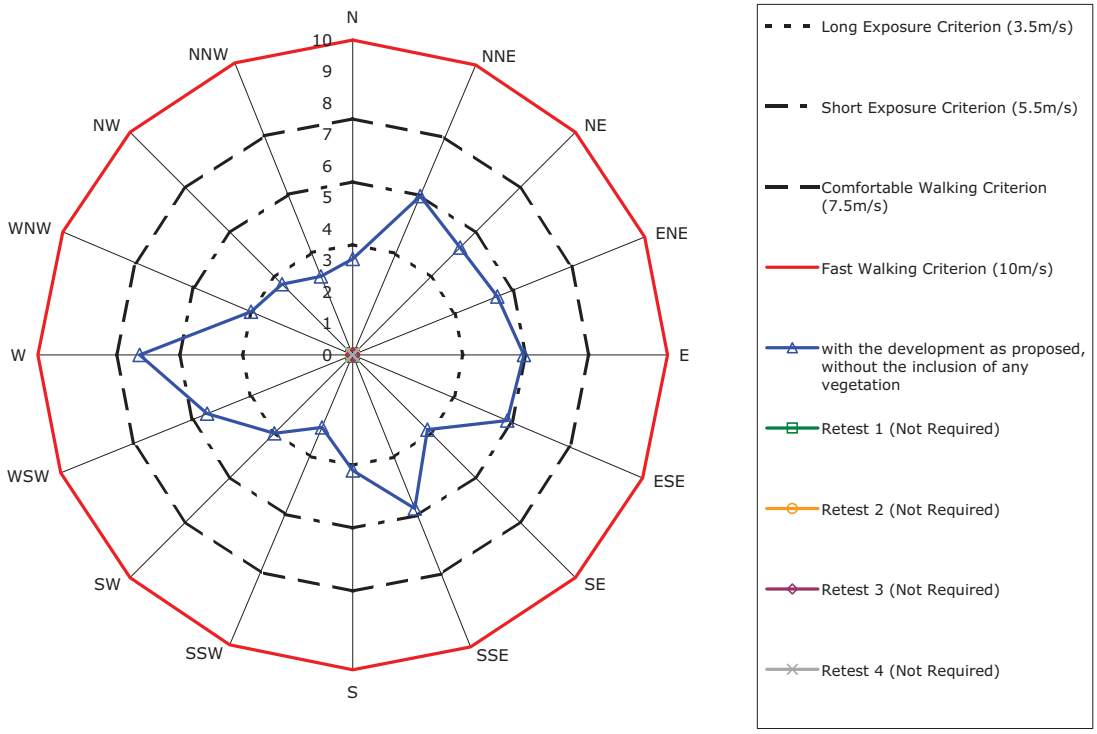


Annual Maximum Gust Wind Speeds (m/s)

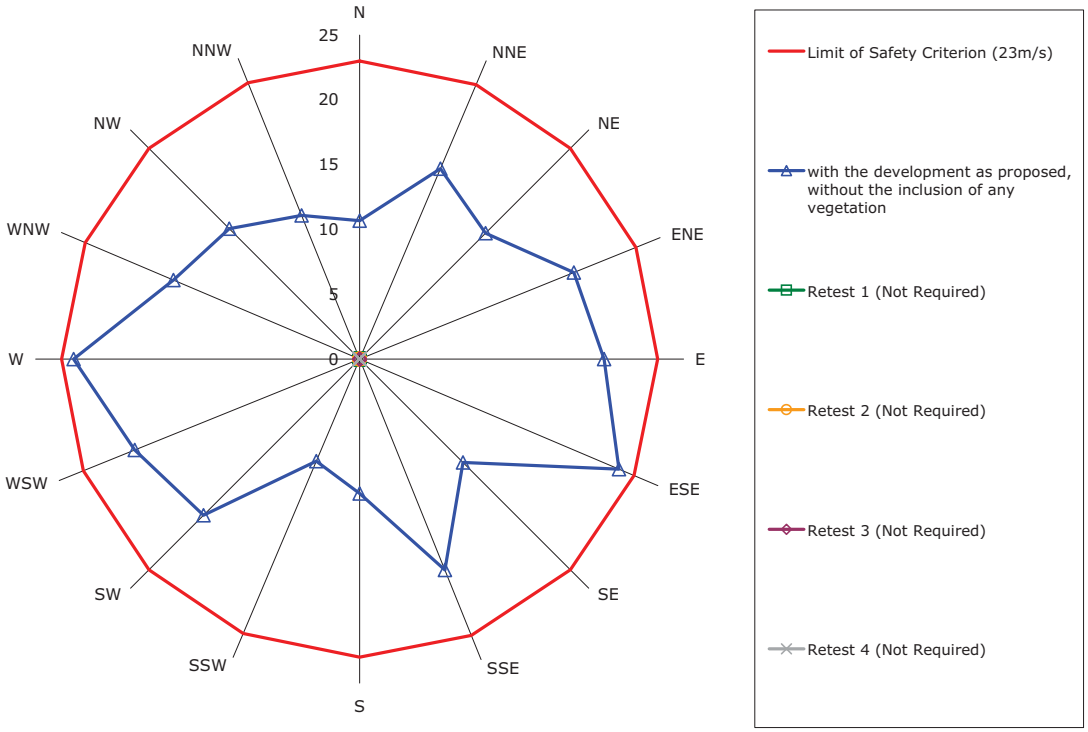


Measured Wind Speeds at Point 31

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

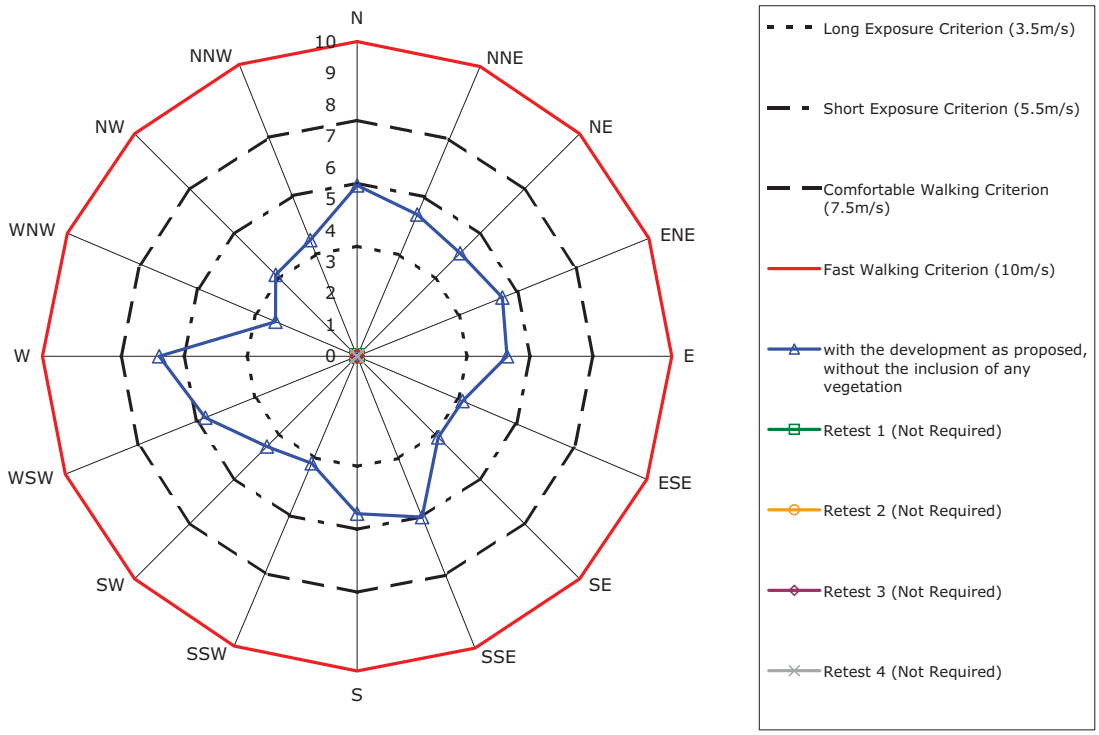


Annual Maximum Gust Wind Speeds (m/s)

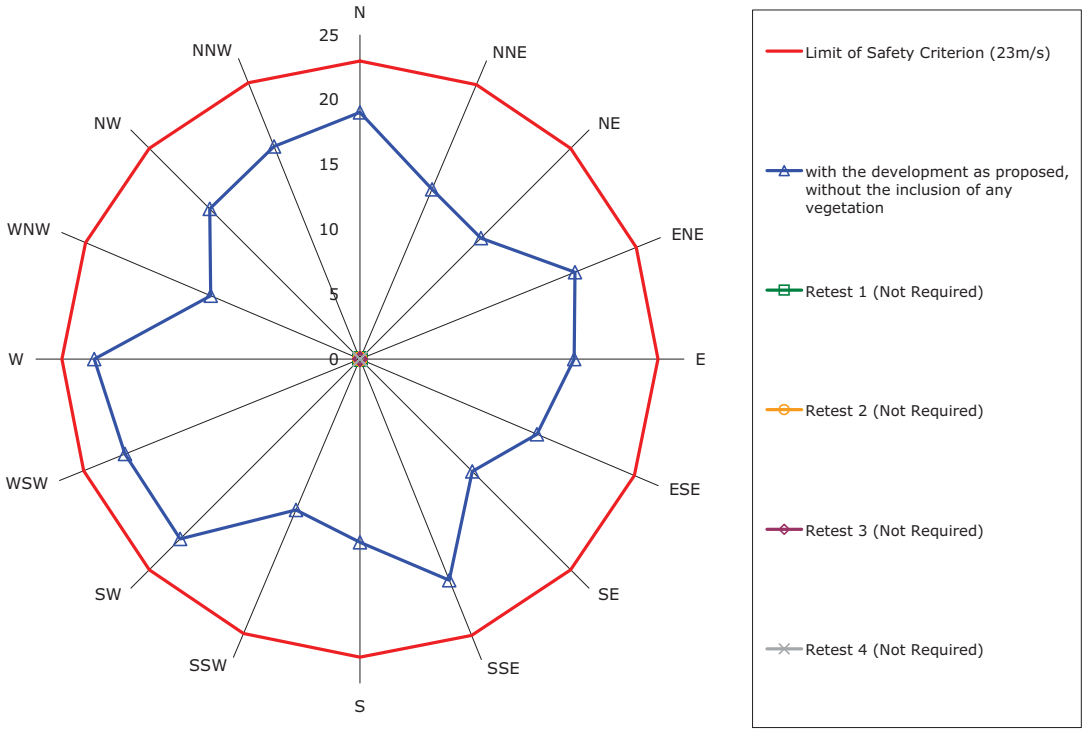


Measured Wind Speeds at Point 32

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

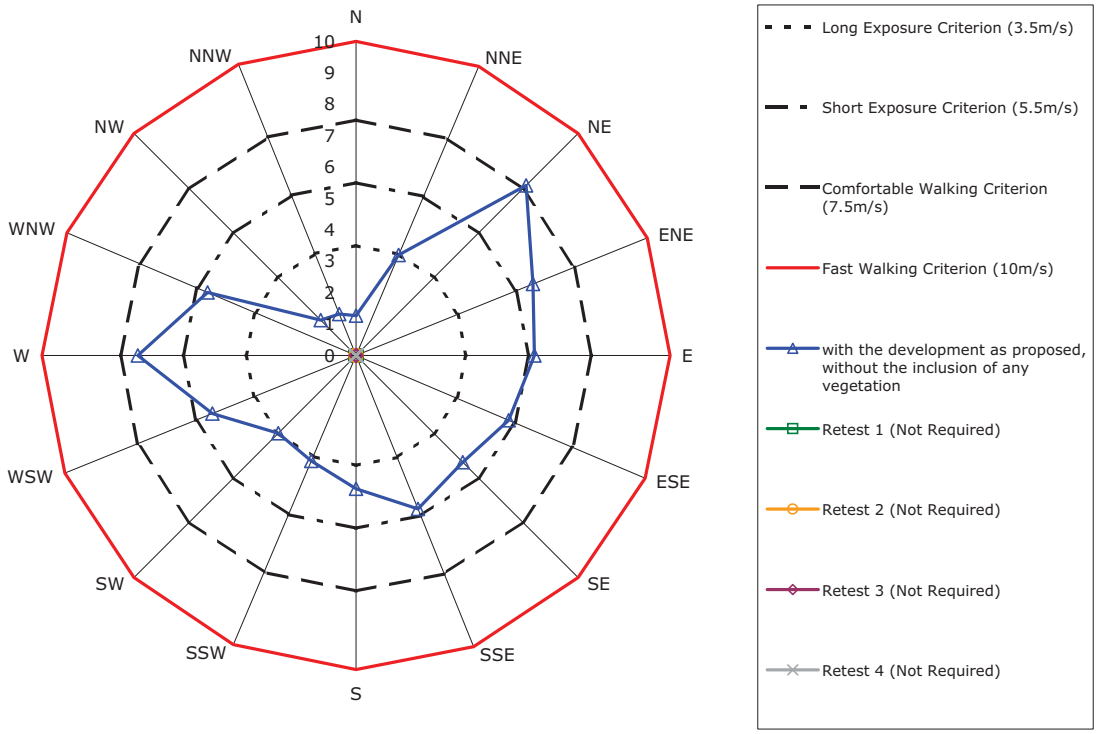


Annual Maximum Gust Wind Speeds (m/s)



Measured Wind Speeds at Point 33

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



Annual Maximum Gust Wind Speeds (m/s)