



WIND MICROCLIMATE ASSESSMENT

St Johns Campus, Manchester

WG555-01F03(REV3)- WE REPORT

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Prepared for:

St Johns Manchester Ltd

DOCUMENT CONTROL

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EXECUTIVE SUMMARY

This report presents the results of a detailed investigation into the wind environment's impact on the proposed St Johns Campus development in Manchester. Testing was performed at Windtech's boundary layer wind tunnel facility. The wind tunnel has a 3.0m wide working section and a fetch length of 14m, and measurements were taken from 16 wind directions at 22.5-degree increments. Testing was carried out using a 1:300 detailed scale model of the development. The effects of nearby buildings and land topography have been accounted for using a proximity model which represents an area with a radius of 375m.

Peak gust and mean wind speeds were measured at selected critical outdoor trafficable locations within and around the proposed development. Wind velocity coefficients representing the local wind speeds are derived from the wind tunnel and combined with a statistical model of the regional wind climate (which accounts for the directional strength and frequency of occurrence of the prevailing regional winds) to provide the equivalent full-scale wind speeds at the Site. The wind speed measurements are compared with criteria for year-round safety and seasonal comfort.

The results from four test configurations have been included within this report:

- Scenario 1 – The Existing Site with Existing Surrounds.
- Scenario 2 – The Proposed Development with Existing Surrounds.
- Scenario 3 – The Proposed Development with Future Surrounds.
- Scenario 4 – The Proposed Development with Existing Surrounds and Mitigation.

The key findings from the wind microclimate assessment are as follows:

SCENARIO 1: THE EXISTING SITE WITH EXISTING SURROUNDS

SAFETY

- The wind conditions are safe.

Comfort

- The wind conditions are suitable for the intended use in all areas with the exception of an off-site entrance (Point 41).

SCENARIO 2: THE PROPOSED DEVELOPMENT WITH EXISTING SURROUNDS

SAFETY

- The wind conditions are safe.

Comfort

- The wind conditions are suitable for the intended use at most of the entrances to the proposed development. However, the wind conditions at an entrance along the north-western façade of the proposed development (Point 6) are unsuitable for the intended use.
- The wind conditions at an off-site fire exit (Point 22) are unsuitable for the intended use. Considering that the fire exit is not expected to be used as a typical entrance, the Strolling conditions in that area during the winter season may be considered suitable for the intended use.
- The wind conditions at the off-site entrance to the NCP carpark (Point 29) are unsuitable for the intended use. Near the entrance, there are no features that would be expected to improve the wind conditions.
- The wind conditions along the thoroughfares and the roads are suitable for the intended use.
- On the elevated levels, the wind conditions are unsuitable for the intended Sitting use. However, the wind conditions are suitable for the intended Standing use at Point 58.

SCENARIO 3: THE PROPOSED DEVELOPMENT WITH FUTURE SURROUNDS

SAFETY

- The wind conditions are safe.

COMFORT

- The wind conditions are suitable for the intended use at most of the entrances to the proposed development. However, the wind conditions at an entrance along the north-western façade of the proposed development (Point 6) are unsuitable for the intended use.
- The wind conditions at an off-site fire exit (Point 22) are unsuitable for the intended use. Considering that the fire exit is not expected to be used as a typical entrance, the Strolling conditions in that area during the winter season may be considered suitable for the intended use.
- The wind conditions at the off-site entrance to the NCP carpark (Point 29) are unsuitable for the intended use. Near the entrance, there are no features that would be expected to improve the wind conditions.
- The wind conditions at the off-site commercial entrance at Point 52 are unsuitable for the intended use. At Point 52, there are nearby features that can be expected to improve the wind conditions. However, it has not been demonstrated that the inclusion of the nearby features would be sufficient to ensure that the wind conditions will be suitable for the intended use.
- The wind conditions along the thoroughfares and the roads are suitable for the intended use.
- On the elevated levels, the wind conditions are unsuitable for the intended Sitting use. However, the wind conditions are suitable for the intended Standing use at Point 58.

SCENARIO 4: THE PROPOSED DEVELOPMENT WITH EXISTING SURROUNDS AND MITIGATION

SAFETY

- The wind conditions are safe.

Comfort

- The wind conditions on the elevated levels become suitable for the intended Sitting use in all outdoor seating areas other than at Points 60 and 61. The wind conditions also remain suitable for the intended Standing use at Point 58.
- The ground level areas were also re-tested with the mitigation configuration. With the re-test, it was noted that the previous results from Point 31 were likely faulty. The re-tested results showed that the wind conditions at Point 31, which is representative of two off-site commercial entrances, are unsuitable for the intended use. At Point 31, there are nearby features that can be expected to improve the wind conditions. However, it has not been demonstrated that the inclusion of the nearby features would be sufficient to ensure that the wind conditions will be suitable for the intended use.

CONCLUSIONS AND RECOMMENDATIONS

Without mitigation, the wind conditions are safe in all areas and suitable for the intended use in most areas. However, there are many areas where the wind conditions are unsuitable for the intended use.

With mitigation on the elevated levels, the wind conditions on the elevated levels improve and remain safe. However, there are areas where the wind conditions remain unsuitable for the intended use, including an entrance along the north-western façade of the proposed development (Point 6), off-site entrances (Points 29, 31, and 52), and outdoor seating areas on the roof terrace (Points 60 and 61).

At the entrance along the north-western façade of the proposed development (Point 6), further mitigation would be worth consideration. At the outdoor seating areas at Points 60 and 61, further mitigation on the roof terrace, or a change in the intended use, would also be worth consideration.

For the off-site entrance near Point 29, further mitigation along New Quay Street would be worth consideration. At the off-site commercial entrances near Points 31 and 52, nearby features are expected to improve the wind conditions. However, further testing would need to be carried out to demonstrate that the nearby features would be sufficient to ensure that the wind conditions would be suitable for the intended use. If the nearby features are not sufficient, or cannot be relied upon, then further mitigation along Gartside Street would also be worth consideration.

It is worth noting that in the areas where the wind conditions are unsuitable for the intended use, the wind conditions are only one category above the comfort requirement. A tabulated summary of each area with wind conditions unsuitable for the intended use has been provided in the main body of this report.

If further mitigation is implemented, then it is recommended that further testing is undertaken to demonstrate that the mitigation will be sufficient to ensure that the wind conditions would be suitable for the intended use.

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INTRODUCTION

The wind microclimate assessment report has been prepared by Windtech Consultants on behalf of St Johns Manchester Ltd, a subsidiary of HBD, in relation to the proposed 16 storey office development at St Johns Campus, 2 New Quay Street, Manchester, M3 3BE.

The Site is bound by New College Street to the northeast, Gartside Street to the southeast, New Quay Street to the southwest, and an existing NCP car park to the northwest. The Site is surrounded predominantly by commercial buildings, including the NCP car park, 1 Hardman Boulevard, 3 Hardman Square, buildings at Enterprise City, and the new St Johns neighbourhood which comprises a mix of cultural, commercial, and residential accommodations.

The development involves the demolition of the existing buildings and structures and the erection of a 16-storey tall office building (Use Class E(g)), with flexible ground floor uses (Use Class E) and rooftop amenity space.

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

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

The wind speeds measured during testing were combined with a statistical model of the regional wind climate to provide the equivalent full-scale wind speeds at the Site. The wind speed measurements are compared with criteria for pedestrian comfort and safety, based on criteria for year-round safety and seasonal comfort.

WIND TUNNEL MODEL

Wind tunnel testing was carried out using a 1:300 scale model of the development and surroundings. The study model incorporates all necessary architectural features on the façade of the development to ensure an accurate wind flow is achieved around the model and was constructed using a Computer Aided Manufacturing (CAM) process to ensure that a high level of detail and accuracy is achieved.

The results from four test configurations have been included within this report:

- Scenario 1 – The Existing Site with Existing Surrounds.
- Scenario 2 – The Proposed Development with Existing Surrounds.
- Scenario 3 – The Proposed Development with Future Surrounds.
- Scenario 4 - The Proposed Development with Existing Surrounds and Mitigation.

Photographs of the wind tunnel model are presented in Figures 1 a-h. Plan views of the proximity model are provided in Figures 2a-c.



Figure 1a: Photograph of the Wind Tunnel Model: The Existing Site with Existing Surrounds (view from the south)



Figure 1b: Photograph of the Wind Tunnel Model: The Existing Site with Existing Surrounds (view from the north)



Figure 1c: Photograph of the Wind Tunnel Model: The Proposed Development with Existing Surrounds (view from the south)



Figure 1d: Photograph of the Wind Tunnel Model: The Proposed Development with Existing Surrounds (view from the north)



Figure 1e: Photograph of the Wind Tunnel Model: The Proposed Development with Future Surrounds (view from the south)



Figure 1f: Photograph of the Wind Tunnel Model – The Proposed Development with Future Surrounds (view from the north)



Figure 1g: Photograph of the Wind Tunnel Model: The Proposed Development with Existing Surrounds and Mitigation (view from the south)



Figure 1h: Photograph of the Wind Tunnel Model: The Proposed Development with Existing Surrounds and Mitigation (view from the north)

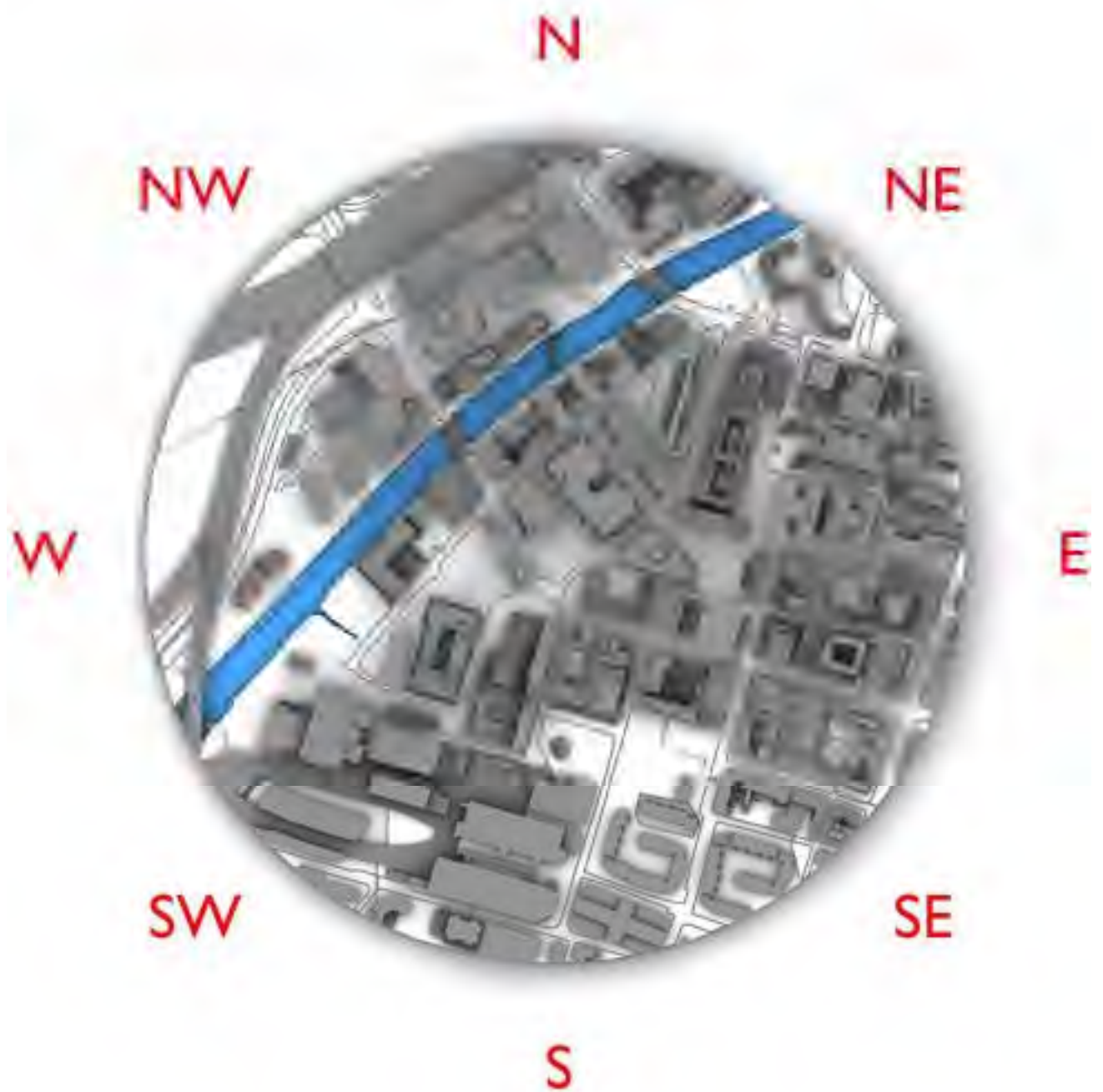


Figure 2a: Proximity Model Plan – The Existing Site with Existing Surrounds



Figure 2b: Proximity Model Plan – The Proposed Development with Existing Surrounds



Figure 2c: Proximity Model Plan – The Proposed Development with Future Surrounds

BOUNDARY LAYER WIND PROFILES AT THE SITE

The roughness of the surface of the earth has the effect of slowing down the wind near the ground. This effect is observed up to the boundary layer height, which can range between 500m to 3km above the earth's surface depending on the roughness of the surface (ie: oceans, open farmland, etc). Within this range, the prevailing wind forms a boundary layer wind profile. Various wind codes and standards and other publications classify various types of boundary layer wind flows depending on the surface roughness z_0 . Descriptions of typical boundary layer wind profiles, based on D.M. Deaves and R.I. Harris (1978), are summarised as follows:

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

The boundary layer wind profile does not change instantly due to changes in the terrain roughness. It can take many kilometres (at least 100km) of constant surface roughness for the boundary layer wind profile to achieve a state of equilibrium. Hence an analysis of the effect of changes in the upwind terrain roughness is necessary to determine an accurate boundary layer wind profile at the development site location.

The method from EN1991-1-4:2005 to account for changes in the upwind terrain roughness is overly simplistic. Hence, an assessment of the upwind terrain roughness has been undertaken based on the far more detailed (and accurate) method given in ESDU-82026:2002. Aerial images showing the surrounding terrain are presented in Figure 3 for ranges of 5km and 50km from the edge of the proximity model used for the wind tunnel study. The resulting roughness factors and turbulence intensities at the site location are presented in Table 1, referenced to a height of 37.5m. Details of the boundary layer wind profiles at the Site are combined with the regional wind model to determine the site wind speeds.

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

Wind Sector (degrees)	Terrain and Height Multiplier			Turbulence Intensity I_v	Equivalent Terrain Category (EN 1991-1-4:2005 naming convention)
	$k_{tr,T=1hr}$ (hourly)	$k_{tr,T=10min}$ (10min)	$k_{tr,T=3s}$ (3sec)		
0	0.64	0.68	1.06	0.221	III
30	0.55	0.60	1.00	0.269	IV
60	0.61	0.65	1.04	0.239	III
90	0.61	0.65	1.04	0.239	III
120	0.60	0.65	1.04	0.241	III
150	0.62	0.66	1.05	0.230	III
180	0.63	0.67	1.05	0.229	III
210	0.61	0.65	1.04	0.236	III
240	0.67	0.71	1.09	0.207	III
270	0.66	0.70	1.08	0.213	III
300	0.65	0.69	1.07	0.216	III
330	0.64	0.68	1.06	0.223	III

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

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

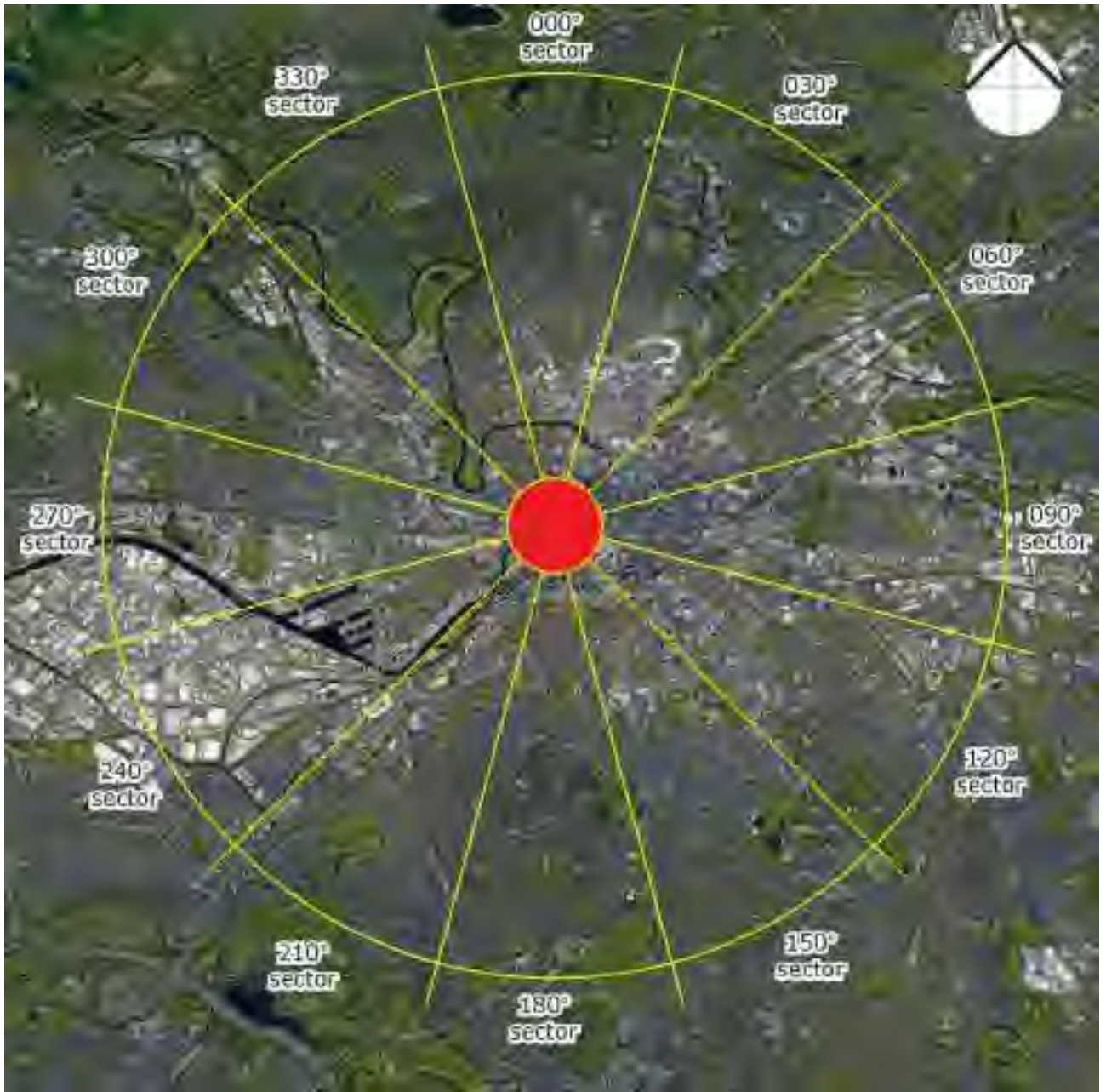


Figure 3a: Aerial Image of the Surrounding Terrain (radius of 5km from the edge of the proximity model)



Figure 3b: Aerial Image of the Surrounding Terrain (radius of 50km)

REGIONAL WIND MODEL

The regional wind model used in this study was determined from an analysis of measured directional mean wind speeds obtained at the meteorological station located at Manchester Airport. A total of 36 years of wind climate data has been collected from the station and the data has been corrected so that it represents winds over standard open terrain at a height of 10m above ground. From this analysis, directional probabilities of exceedance and directional wind speeds for the region are determined. The directional wind speeds are summarised in Table 2. The directional wind speeds and corresponding directional frequencies of occurrence are presented in Figure 4. Note that the regional wind climate has been examined for the year as well as for the summer and winter seasons.

The analysis indicates that the strongest and most frequent winds occur from the south and south-southwest.

Table 2: Regional 5% Exceedance Directional Wind Speeds
(hourly means, at 10m height in standard open terrain) (m/s)

Wind Direction	All Year	Summer	Winter
N	3.5	2.4	3.2
NNE	5.3	4.4	4.4
NE	6.4	5.5	5.4
ENE	6.2	5.4	6.2
E	6.1	5.4	6.6
ESE	5.0	4.4	5.1
SE	5.5	4.4	5.6
SSE	7.4	6.1	8.4
S	8.5	7.1	9.7
SSW	8.5	7.3	9.8
SW	7.5	6.9	8.5
WSW	7.6	6.8	8.7
W	8.0	7.1	9.1
WNW	7.3	7.2	7.7
NW	6.2	6.4	5.7
NNW	4.1	3.8	4.0

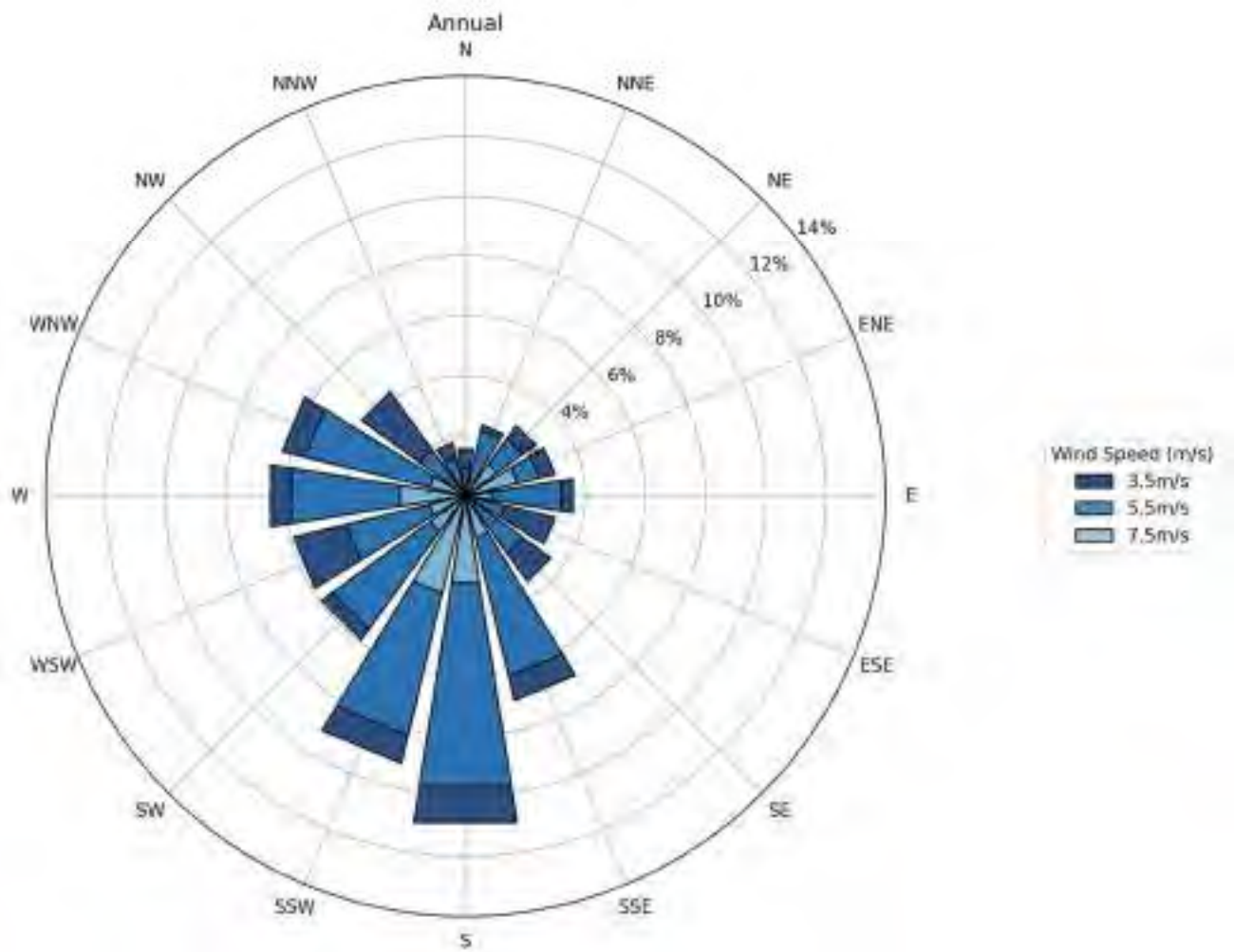


Figure 4a: Hourly Mean Wind Speeds (referenced to 10m height in standard open terrain) and Frequencies of Occurrence for Manchester (all-year)

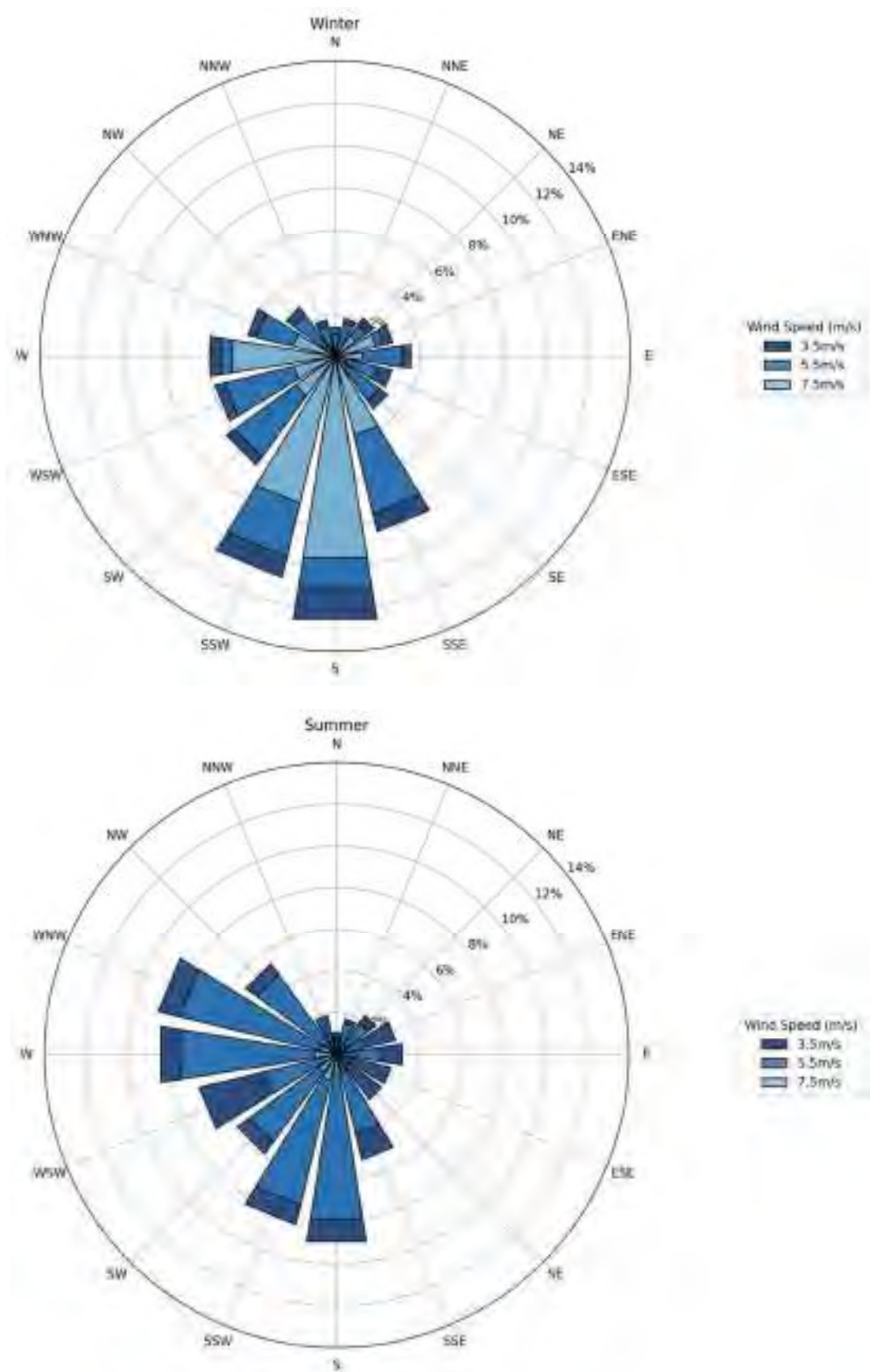


Figure 4b: Hourly Mean Wind Speeds (referenced to 10m height in standard open terrain) and Frequencies of Occurrence for Manchester (winter top, summer bottom)

WIND COMFORT AND SAFETY

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

5.1 Measured Wind Speeds

Wind speeds were measured using Irwin probes, positioned to monitor wind conditions at critical outdoor trafficable areas of the development. The reference mean free-stream wind speeds were measured in the wind tunnel at a full-scale height of 200m.

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

5.2 Wind Speed Criteria Used for this Study

For this study the measured wind conditions of the selected critical outdoor trafficable areas are compared against the Lawson Criteria, by T.V. Lawson (2001), for pedestrian safety and comfort (this is described in detail in Section A.6 of Appendix A). The criteria are applied to Gust Equivalent Mean (GEM) winds. In accordance with ASCE (2003), the GEM wind speed is defined as follows:

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

where:

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

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

For pedestrian safety, the safety limit criterion of 15m/s applies to the year-round GEM winds with a probability of exceedance of less than 0.023% occurring approximately 2hrs annually. For pedestrian comfort, the comfort criteria are used in conjunction with the seasonal GEM wind speeds with a probability of exceedance of less than 5%.

The criteria for pedestrian comfort and safety which are applied to this study are summarised in Tables 3 and 4, respectively.

Table 3: Pedestrian Comfort Criteria (T.V. Lawson, 2001)

Classification	Activities	5% exceedance Mean Wind Speed (m/s)
Uncomfortable	Winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended.	>10
Business Walking	Relatively high speeds can be tolerated if one's objective is to walk, run, or cycle without lingering.	8-10
Strolling	Moderate breezes that would be appropriate for strolling along a city/town street, plaza, or park.	6-8
Standing	Gentle breezes are acceptable for main building entrances, pick-up/drop-off points, and bus stops	4-6
Sitting	Light breezes are desired for outdoor restaurants and seating areas where one can read a paper or comfortably sit for long periods	0-4

Table 4: Pedestrian Safety Criteria (T.V. Lawson, 2001)

Classification	Activities	Threshold Mean Wind Speed (m/s)
Unsafe for Frail	Frail members of the public and cyclists will find the conditions challenging and will be at risk of being blown over.	>15
Unsafe for All	All members of the public and cyclists will find the conditions challenging and will be at risk of being blown over.	>20

5.3 Study Points and Expected Intended Use

For this study, a total of 66 study point locations were selected for analysis in the wind tunnel. Among these study points, 52 of them (Points 1-52) were on the ground level and 14 of them (Points 53-66) were on elevated levels of the proposed development.

The locations of the various study points tested for this study, as well as the target wind speed criteria for the various outdoor trafficable areas of the development, are presented in Figures 5a-e in the form of marked-up plans. It should be noted that only the most critical outdoor locations of the development have been selected for analysis.

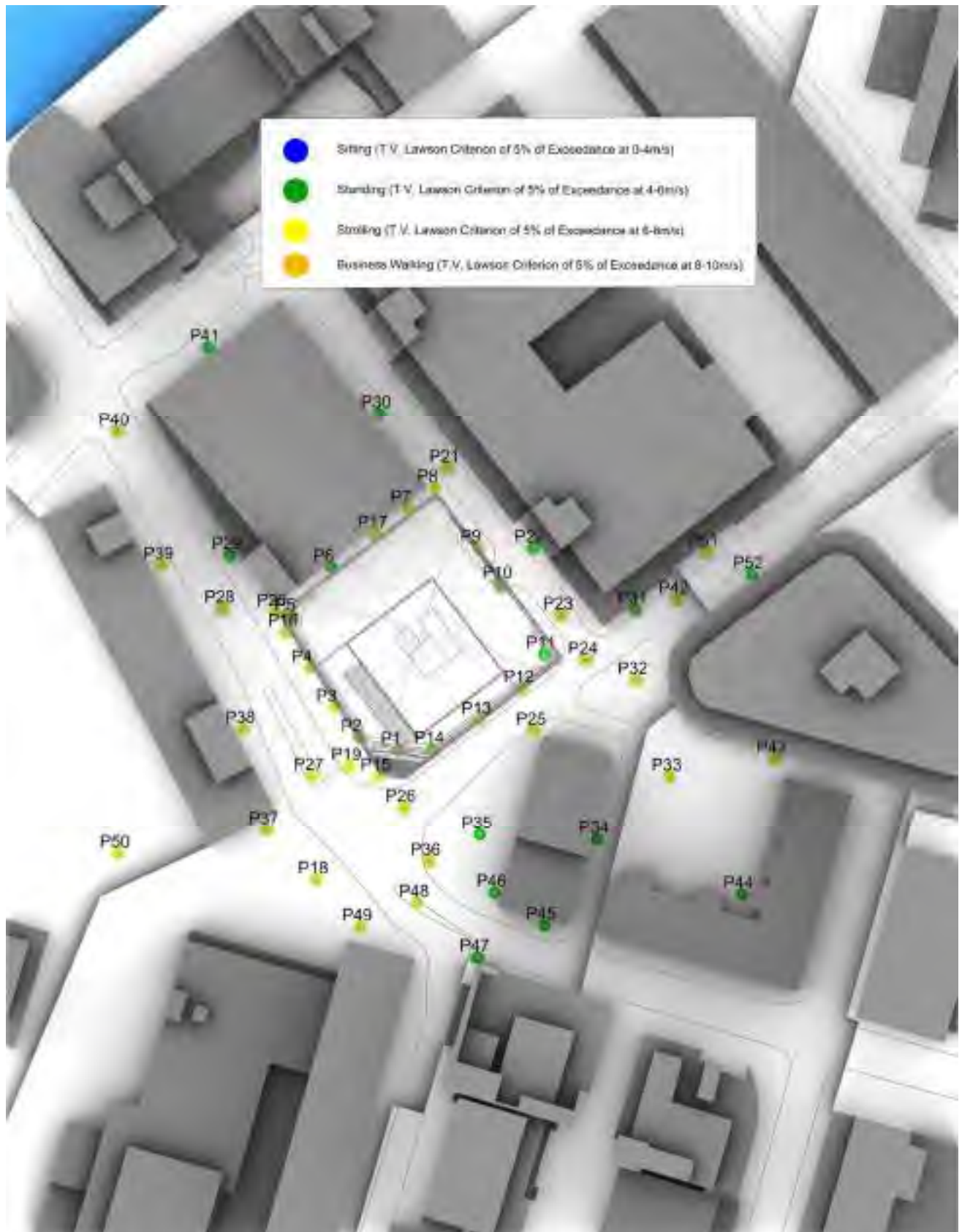


Figure 5a: Study Point Locations and Target Wind Speed Criteria – Ground Level.

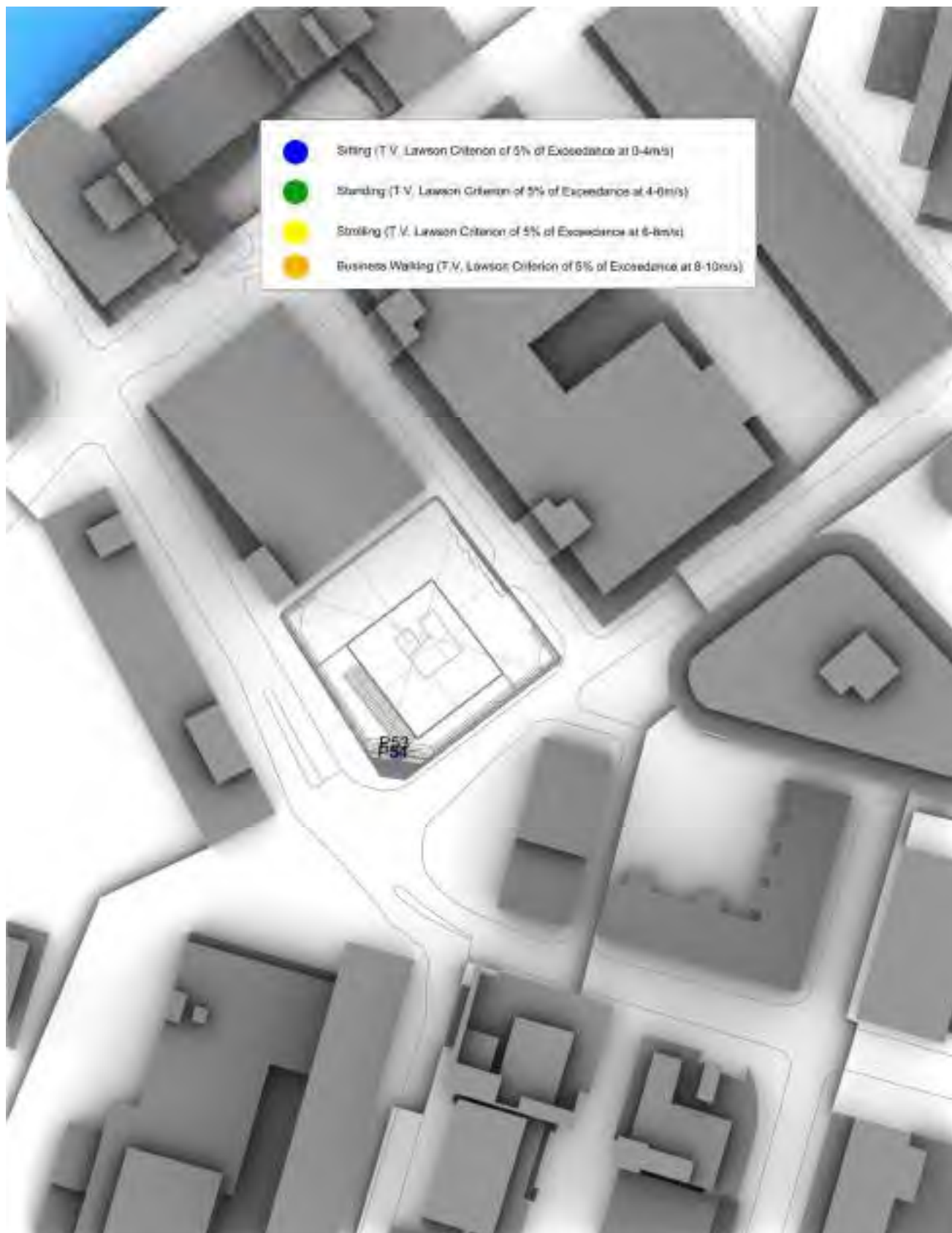


Figure 5b: Study Point Locations and Target Wind Speed Criteria – Elevated Levels – Levels 2 and 6.

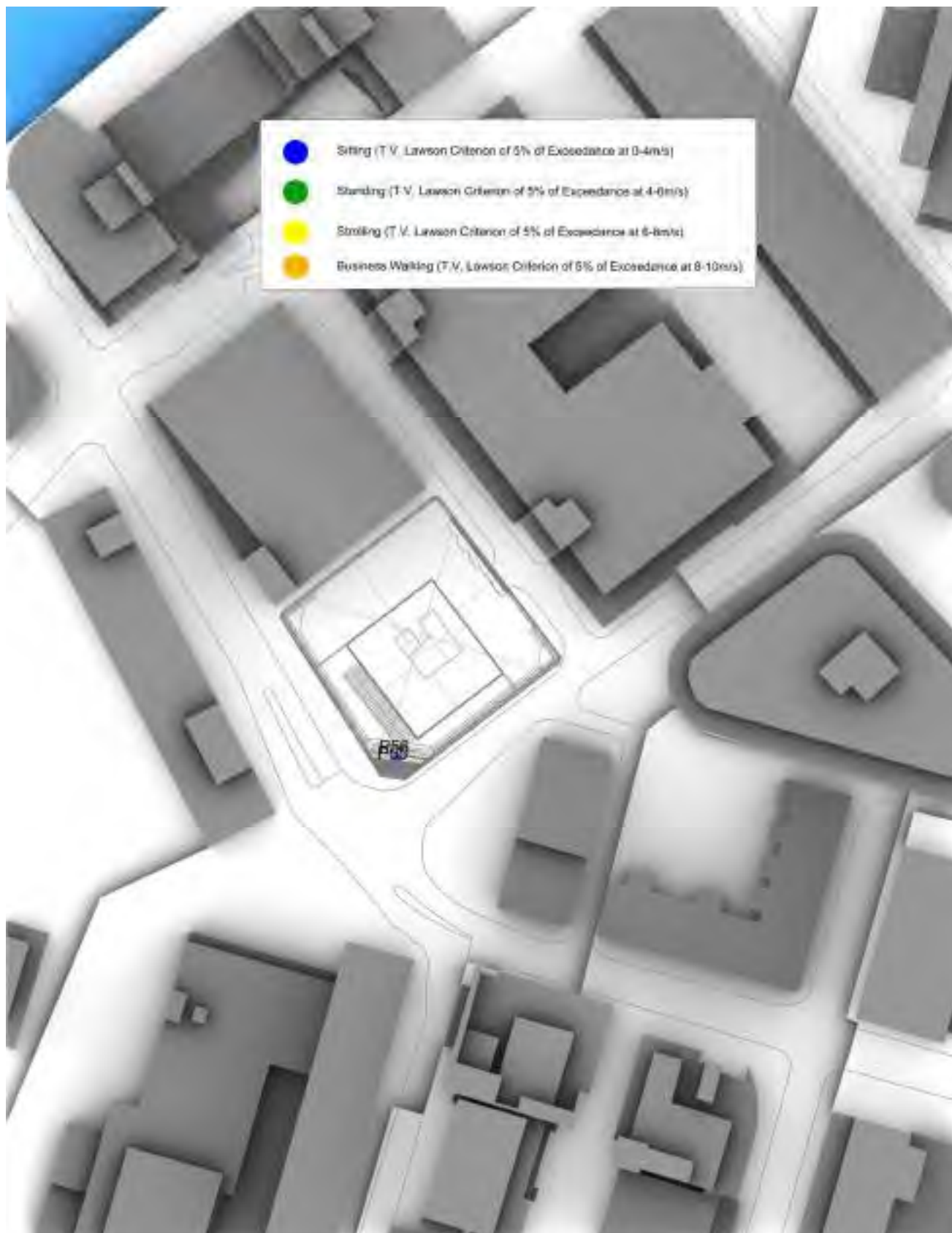


Figure 5c: Study Point Locations and Target Wind Speed Criteria – Elevated Levels – Levels 11 and 14.

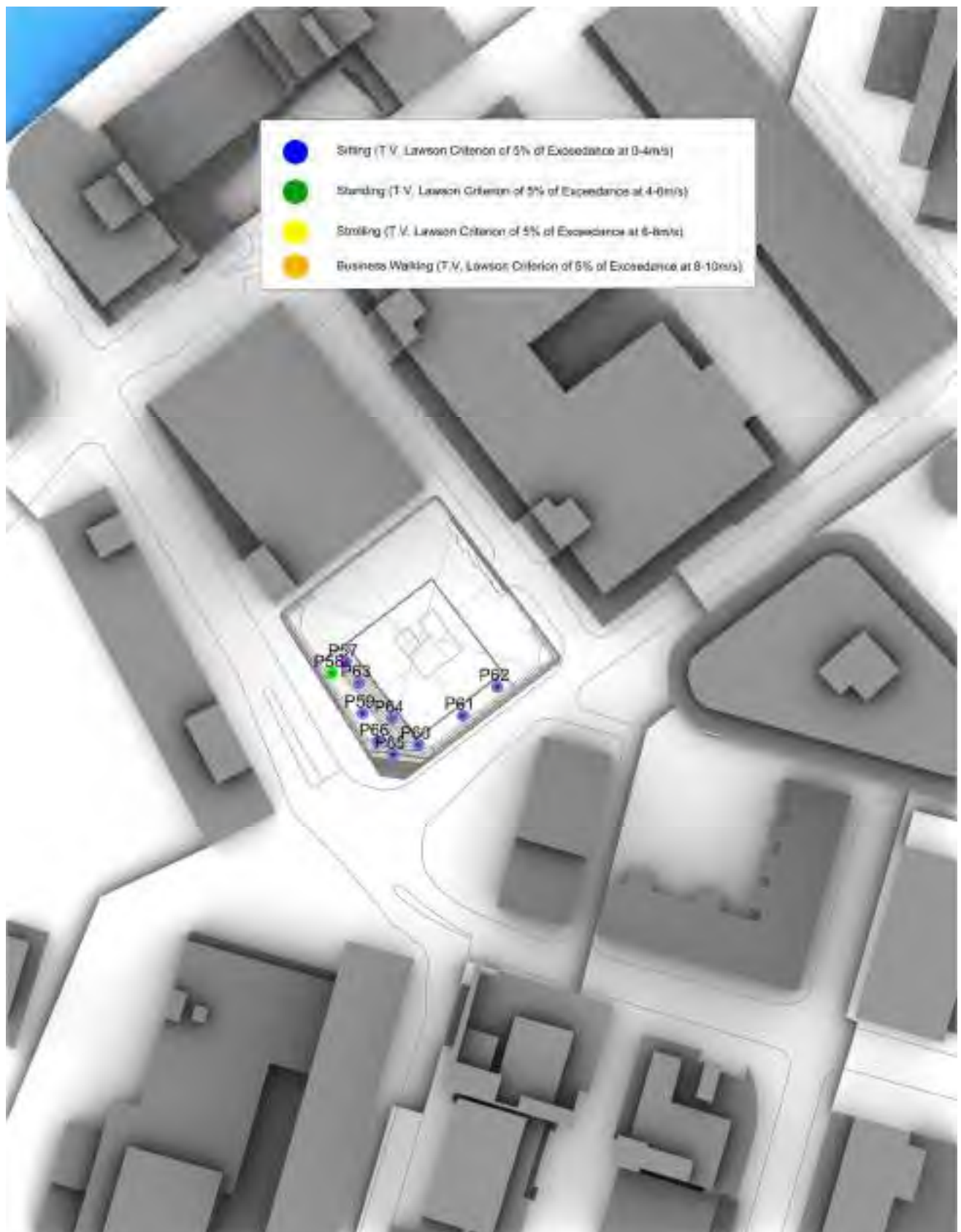


Figure 5d: Study Point Locations and Target Wind Speed Criteria – Elevated Levels – Roof.

RESULTS AND DISCUSSION

The results of the wind tunnel study are presented in the form of seasonal velocity coefficient directional plots in Appendix C for all study points locations and 3D results images for the elevated levels are included in Appendix E for reference. The results are also shown on marked-up plans in Figures 6a-6l, 7a-7c, and 8a-8l.

6.1 Scenario 1: The Existing Site with Existing Surrounds

The wind conditions are safe.

The wind conditions are suitable for the intended use in all areas with the exception of an off-site entrance (Point 41).

6.2 Scenario 2: The Proposed Development with Existing Surrounds

The wind conditions are safe.

The wind conditions are suitable for the intended use at most of the entrances to the proposed development. However, the wind conditions at an entrance along the north-western façade of the proposed development (Point 6) are unsuitable for the intended use. There are also areas with off-site entrances (Points 22 and 29) where the wind conditions are unsuitable for the intended use.

The off-site entrance at Point 22 is shown in Appendix F to be a fire exit. The fire exit is not expected to be used as a typical entrance. As such, the Strolling conditions at Point 22 during the winter season may be considered suitable for the intended use.

Point 29 is representative of an off-site entrance to the NCP carpark. The Strolling conditions at Point 29 during the winter season are unsuitable for the intended Standing use at the entrance. Near the entrance, there are no features that would be expected to improve the wind conditions.

The wind conditions along the thoroughfares and the roads are suitable for the intended use.

On the elevated levels, the wind conditions are unsuitable for the intended Sitting use. However, the wind conditions are suitable for the intended Standing use at Point 58.

6.3 Scenario 3: The Proposed Development with Future Surrounds

The wind conditions are safe.

The wind conditions are suitable for the intended use at most of the entrances to the proposed development. However, the wind conditions at an entrance along the north-western façade of the proposed development (Point 6) are unsuitable for the intended use. There are also areas with off-site entrances (Points 22, 29, and 52) where the wind conditions are unsuitable for the intended use.

The off-site entrance at Point 22 is shown in Appendix F to be a fire exit. The fire exit is not expected to be used as a typical entrance. As such, the Strolling conditions at Point 22 during the winter season may be considered suitable for the intended use.

Point 29 is representative of an off-site entrance to the NCP carpark. The Strolling conditions at Point 29 during the winter season are unsuitable for the intended Standing use at the entrance. Near the entrance, there are no features that would be expected to improve the wind conditions.

Point 52 is representative of an off-site commercial entrance. The Strolling conditions at Point 52 during the winter season are unsuitable for the intended Standing use at the entrance. It is worth noting that the 5.87% probability of exceedance at Point 52 is a marginal exceedance of the allowable 5%. As shown in Appendix F, there is a set of protective screens on either side of the entrance. The protective screens, which were not included in the wind tunnel model, can be expected to improve the wind conditions at the entrance. However, it has not been demonstrated that the inclusion of the protective screens would be sufficient to ensure that wind conditions will be suitable for the intended use.

The wind conditions along the thoroughfares and the roads are suitable for the intended use.

On the elevated levels, the wind conditions are unsuitable for the intended Sitting use. However, the wind conditions are suitable for the intended Standing use at Point 58.

6.4 Scenario 4: The Proposed Development with Existing Surrounds and Mitigation

With mitigation on the elevated levels, the wind conditions on the elevated levels improve and remain safe.

The wind conditions on the balconies and the roof terrace become suitable for the intended Sitting use in all outdoor seating areas other than at Points 60 and 61. The wind conditions also remain suitable for the intended Standing use at Point 58.

The ground level areas were also re-tested. With the re-test, it was noted that the previous results from Point 31 were likely faulty. The re-tested results showed that the wind conditions at Point 31 are unsuitable for the intended use. Point 31 is representative of two off-site commercial entrances. The Strolling conditions at Point 31 during the winter season are unsuitable for the intended Standing use at the entrances. It is worth noting that the exceedances at Point 31 are not marginal with a probability of exceedance of 8.95%, which is noticeably higher than the allowable 5%. As shown in Appendix F, there is a vertical column to the south-west of each of the entrances. The vertical columns, which were not included in the wind tunnel model, can be expected to improve the wind conditions at the entrances. However, it has not been demonstrated that the inclusion of the vertical columns would be sufficient to ensure that the wind conditions will be suitable for the intended use.

6.5 Mitigation Measures

The mitigation measures tested are presented in Figures 9a-b.

At the entrance along the north-western façade of the proposed development (Point 6), further mitigation would be worth consideration. At the outdoor seating areas at Points 60 and 61, further mitigation on the roof terrace, or a change in the intended use, would also be worth consideration.

For the off-site entrance near Point 29, further mitigation along New Quay Street would be worth consideration. At the off-site commercial entrances near Points 31 and 52, nearby features are expected to improve the wind conditions. If the nearby features are not sufficient, or cannot be relied upon, then further mitigation along Gartside Street would also be worth consideration.

6.6 Summary of Areas with Wind Conditions Unsuitable for the Intended Use

It is worth noting that in the areas where the wind conditions are unsuitable for the intended use, the wind conditions are only one category above the comfort requirement. A tabulated summary of each area with wind conditions unsuitable for the intended use has been provided in Table 5.

Table 5: Summary of Areas with Wind Conditions Unsuitable for the Intended Use

Receptor	Season Relevant to the Intended Use	Target Wind Conditions (Lawson Comfort Criteria)	Wind Conditions Identified (Lawson Comfort Criteria)	Level Difference
Scenario 1 - The Existing Site with Existing Surrounds				
P41 - off-site entrance	Winter	Standing	Strolling	One Category Above
Scenario 2 - The Proposed Development with Existing Surrounds				
P6 - on-site entrance	Winter	Standing	Strolling	One Category Above
P22 - off-site fire exit	Winter	Standing	Strolling	One Category Above May be Considered Suitable due to being a Fire Exit
P29 - off-site entrance	Winter	Standing	Strolling	One Category Above
P53 - balcony	Summer	Sitting	Standing	One Category Above
P54 - balcony	Summer	Sitting	Standing	One Category Above
P55 - balcony	Summer	Sitting	Standing	One Category Above
P56 - balcony	Summer	Sitting	Standing	One Category Above
P57 - roof	Summer	Sitting	Standing	One Category Above
P59 - roof	Summer	Sitting	Standing	One Category Above
P60 - roof	Summer	Sitting	Standing	One Category Above
P61 - roof	Summer	Sitting	Standing	One Category Above
P62 - roof	Summer	Sitting	Standing	One Category Above
Scenario 3 - The Proposed Development with Future Surrounds				
P6 - on-site entrance	Winter	Standing	Strolling	One Category Above
P22 - off-site fire exit	Winter	Standing	Strolling	One Category Above May be Considered Suitable due to being a Fire Exit
P29 - off-site entrance	Winter	Standing	Strolling	One Category Above
P52 - off-site entrance	Winter	Standing	Strolling	One Category Above Local Features likely to Improve the Conditions
P53 - balcony	Summer	Sitting	Standing	One Category Above
P54 - balcony	Summer	Sitting	Standing	One Category Above
P55 - balcony	Summer	Sitting	Standing	One Category Above
P56 - balcony	Summer	Sitting	Standing	One Category Above
P57 - roof	Summer	Sitting	Standing	One Category Above
P59 - roof	Summer	Sitting	Standing	One Category Above
P60 - roof	Summer	Sitting	Standing	One Category Above
P61 - roof	Summer	Sitting	Standing	One Category Above
P62 - roof	Summer	Sitting	Standing	One Category Above
Scenario 4 - The Proposed Development with Existing Surrounds and Mitigation				
P31 - off-site entrance	Winter	Standing	Strolling	One Category Above Local Features likely to Improve the Conditions Re-Tested Results likely Valid for Scenarios 2 & 3
P60 - roof	Summer	Sitting	Standing	One Category Above
P61 - roof	Summer	Sitting	Standing	One Category Above

6.7 Wind Tunnel Results

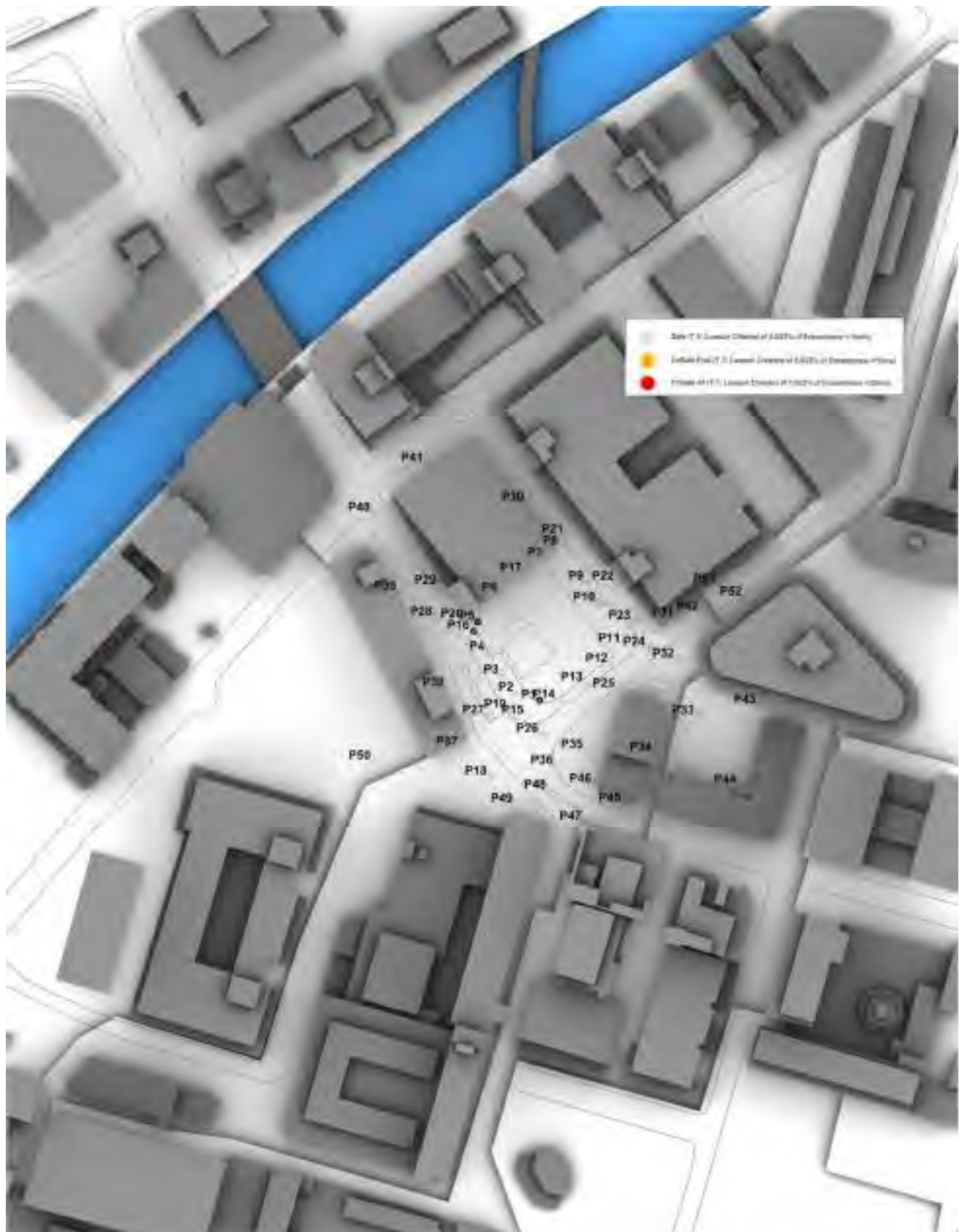


Figure 6a: The Existing Site with Existing Surrounds: Ground Level, Safety Results, Annual.



Figure 6b: The Proposed Development with Existing Surrounds: Ground Level, Safety Results.



Figure 6c: The Proposed Development with Existing Surrounds: Elevated Level - Levels 2 and 6, Safety Results.



Figure 6d: The Proposed Development with Existing Surrounds: Elevated Level – Levels 11 and 14, Safety Results.



Figure 6e: The Proposed Development with Existing Surrounds: Elevated Level - Roof, Safety Results.



Figure 6f: The Proposed Development with Future Surrounds: Ground Level, Safety Results.



Figure 6g: The Proposed Development with Future Surrounds: Elevated Level - Levels 2 and 6, Safety Results.



Figure 6h: The Proposed Development with Future Surrounds: Elevated Level - Levels 11 and 14, Safety Results.



Figure 6i: The Proposed Development with Future Surrounds: Elevated Level - Roof, Safety Results.



Figure 6j: The Proposed Development with Existing Surrounds and Mitigation: Elevated Levels - Levels 2 and 6, Safety Results, Annual.



Figure 6k: The Proposed Development with Existing Surrounds and Mitigation: Elevated Levels - Levels 11 and 14, Safety Results, Annual.

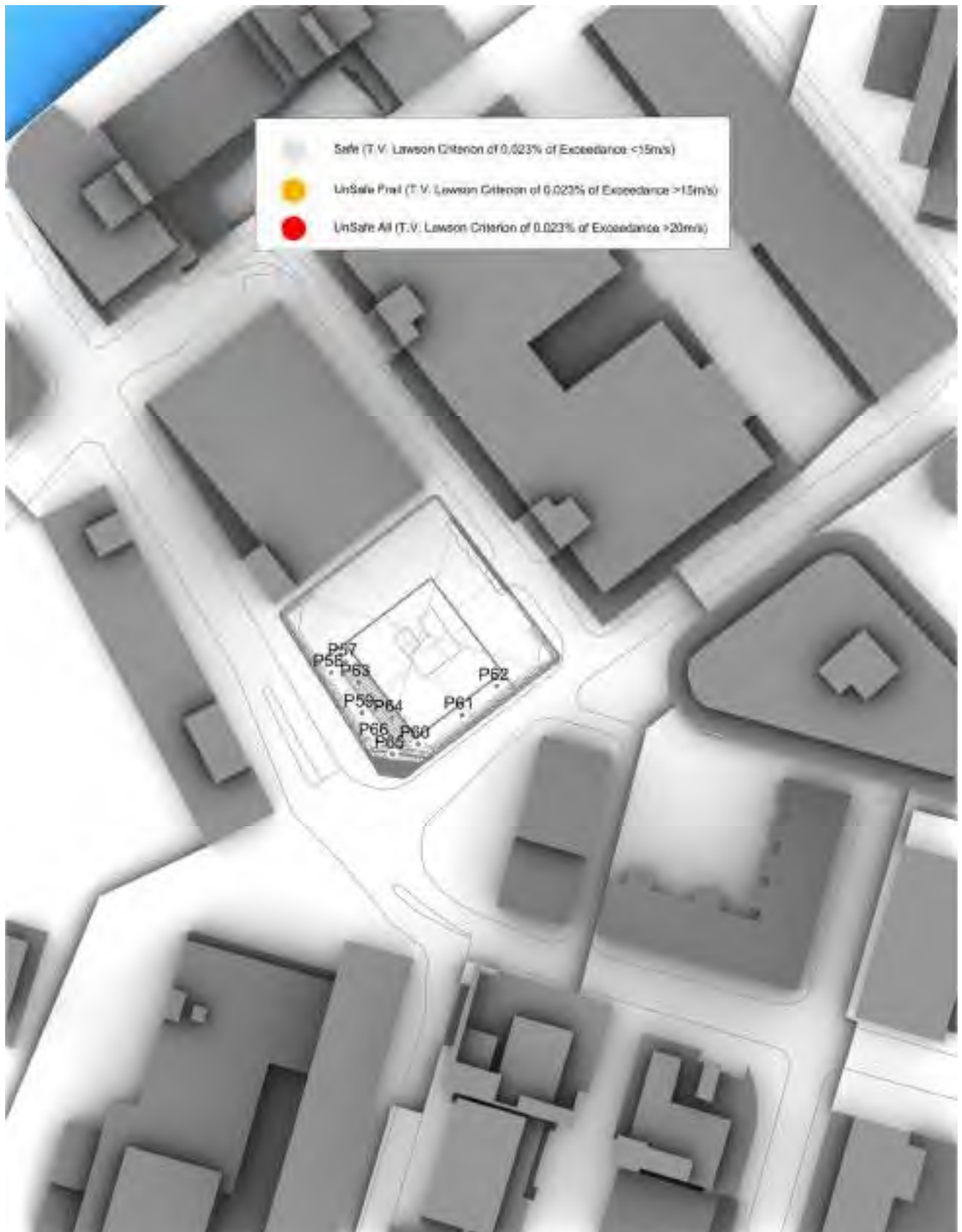


Figure 6l: The Proposed Development with Existing Surrounds and Mitigation: Elevated Levels - Roof, Safety Results, Annual.

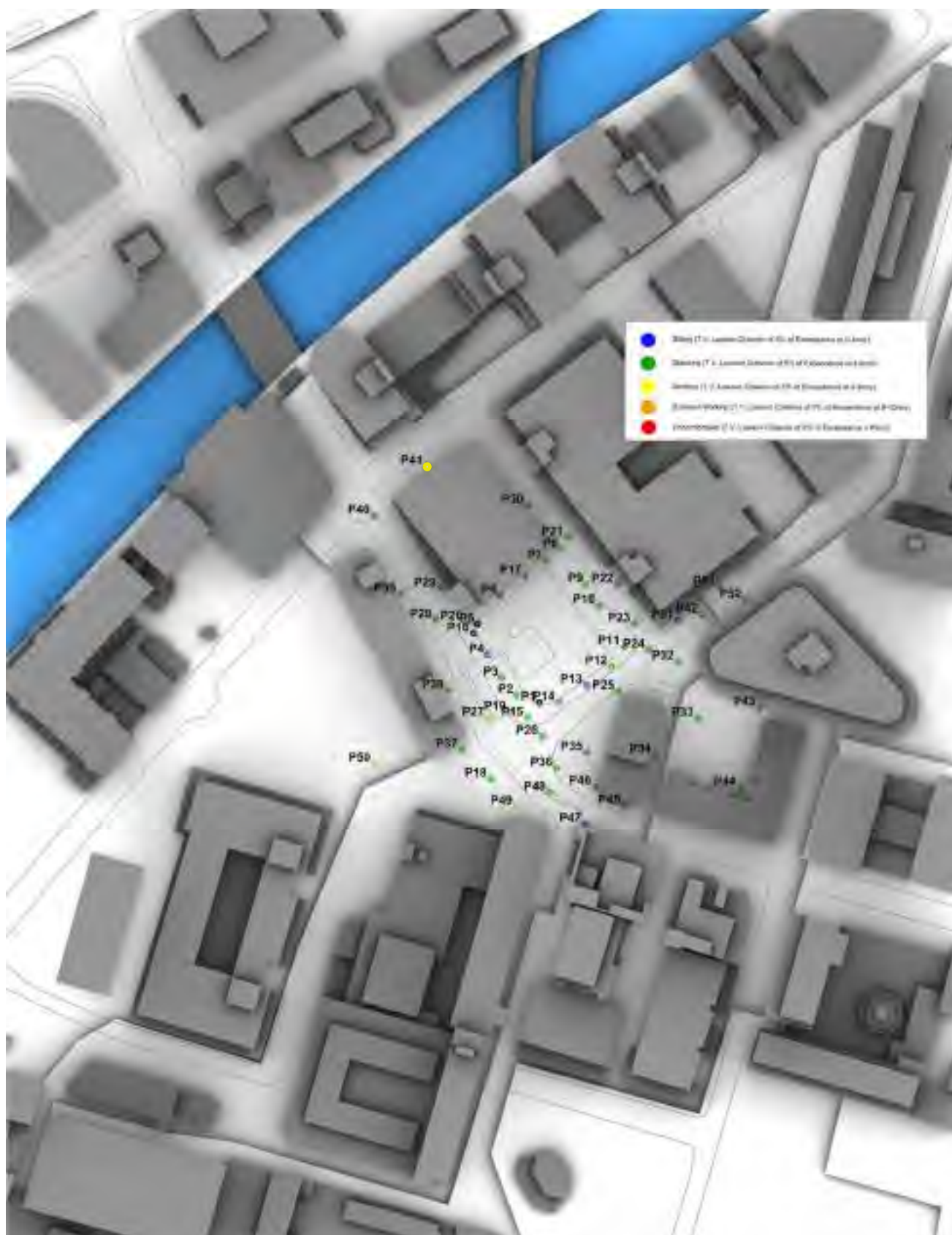


Figure 7a: The Existing Site with Existing Surrounds: Ground Level, Comfort Results, Winter Season.



Figure 7b: The Proposed Development with Existing Surrounds: Ground Level, Comfort Results, Winter Season.



Figure 7c: The Proposed Development with Future Surrounds: Ground Level, Comfort Results, Winter Season.

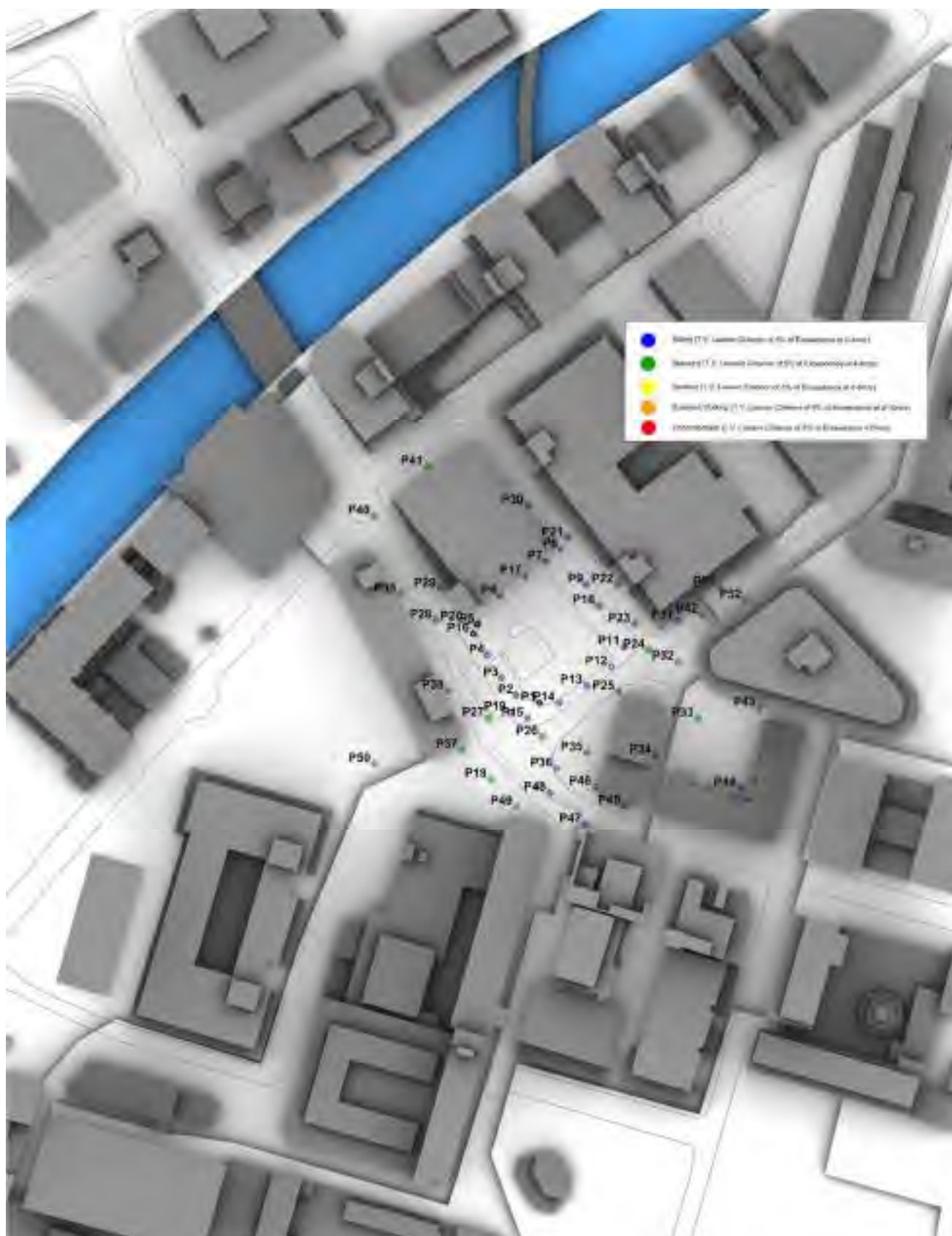


Figure 8a: The Existing Site with Existing Surrounds: Ground Level, Comfort Results, Summer Season.

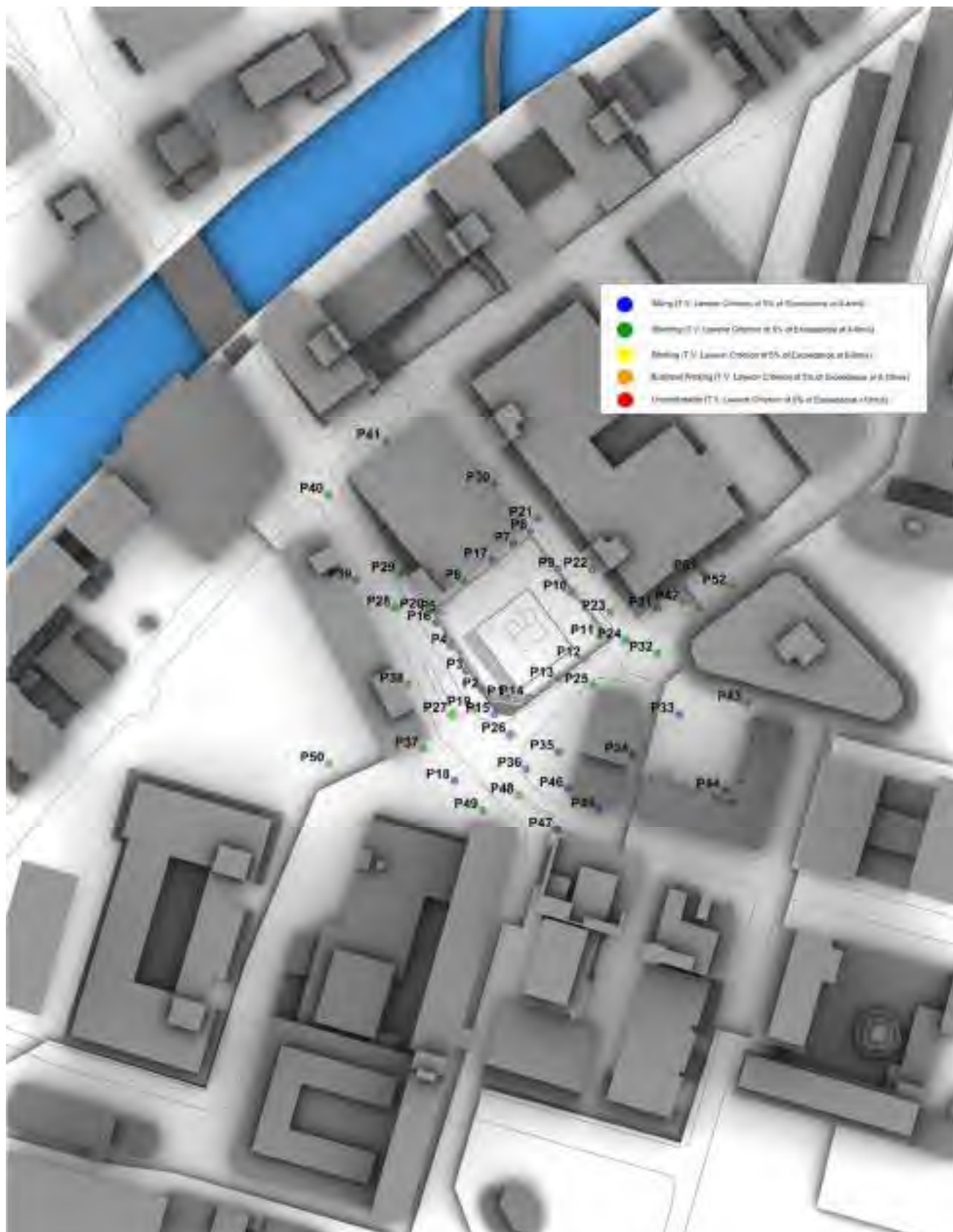


Figure 8b: The Proposed Development with Existing Surrounds: Ground Level, Comfort Results, Summer Season.



Figure 8c: The Proposed Development with Existing Surrounds: Elevated Level - Levels 2 and 6, Comfort Results, Summer Season.



Figure 8d: The Proposed Development with Existing Surrounds: Elevated Level - Levels 11 and 14, Comfort Results, Summer Season.

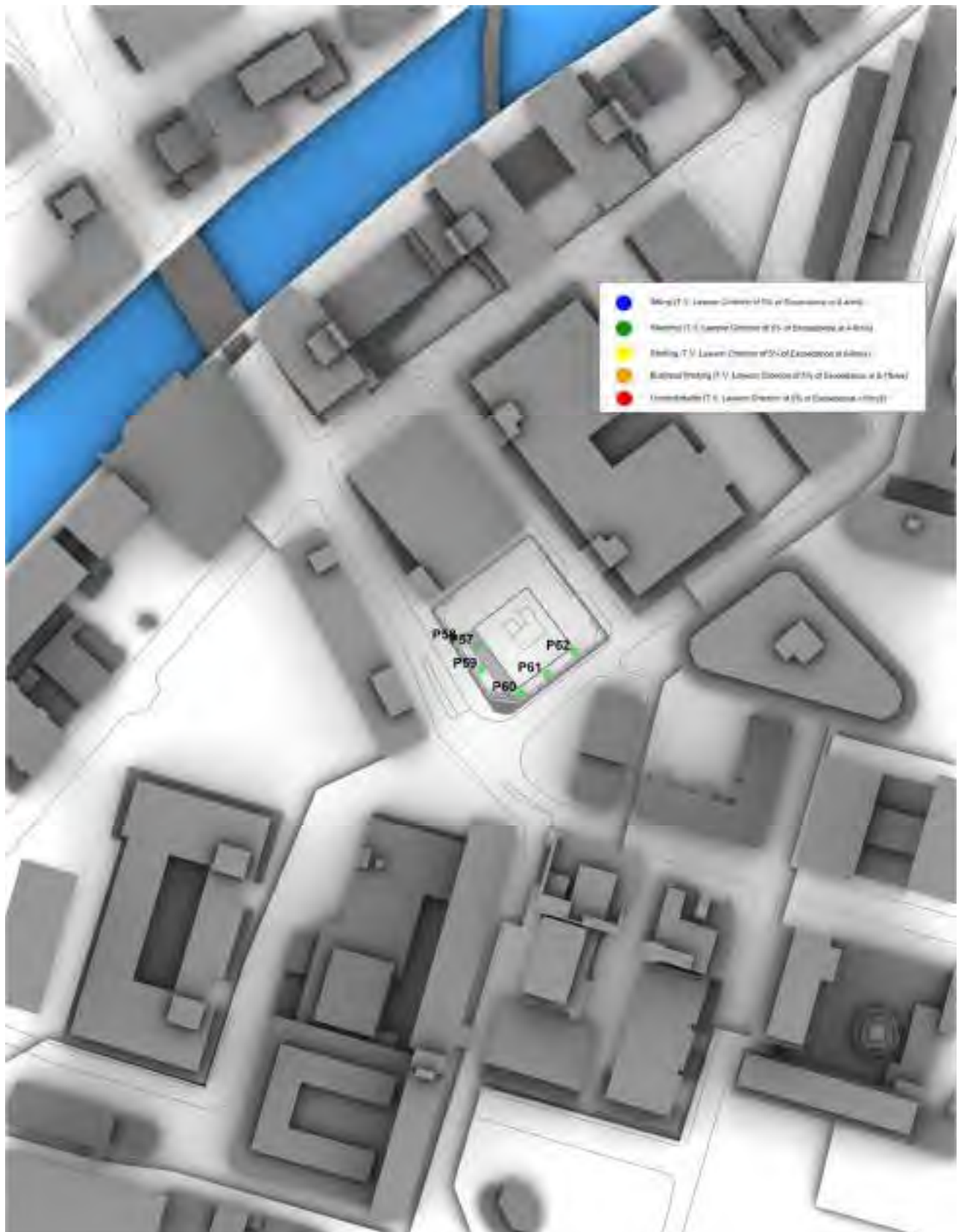


Figure 8e: The Proposed Development with Existing Surrounds: Elevated Level - Roof, Comfort Results, Summer Season.



Figure 8f: The Proposed Development with Future Surrounds: Ground Level, Comfort Results, Summer Season.



Figure 8g: The Proposed Development with Future Surrounds: Elevated Level - Levels 2 and 6, Comfort Results, Summer Season.



Figure 8h: The Proposed Development with Future Surrounds: Elevated Level - Levels 11 and 14, Comfort Results, Summer Season.



Figure 8i: The Proposed Development with Future Surrounds: Elevated Level - Roof, Comfort Results, Summer Season.

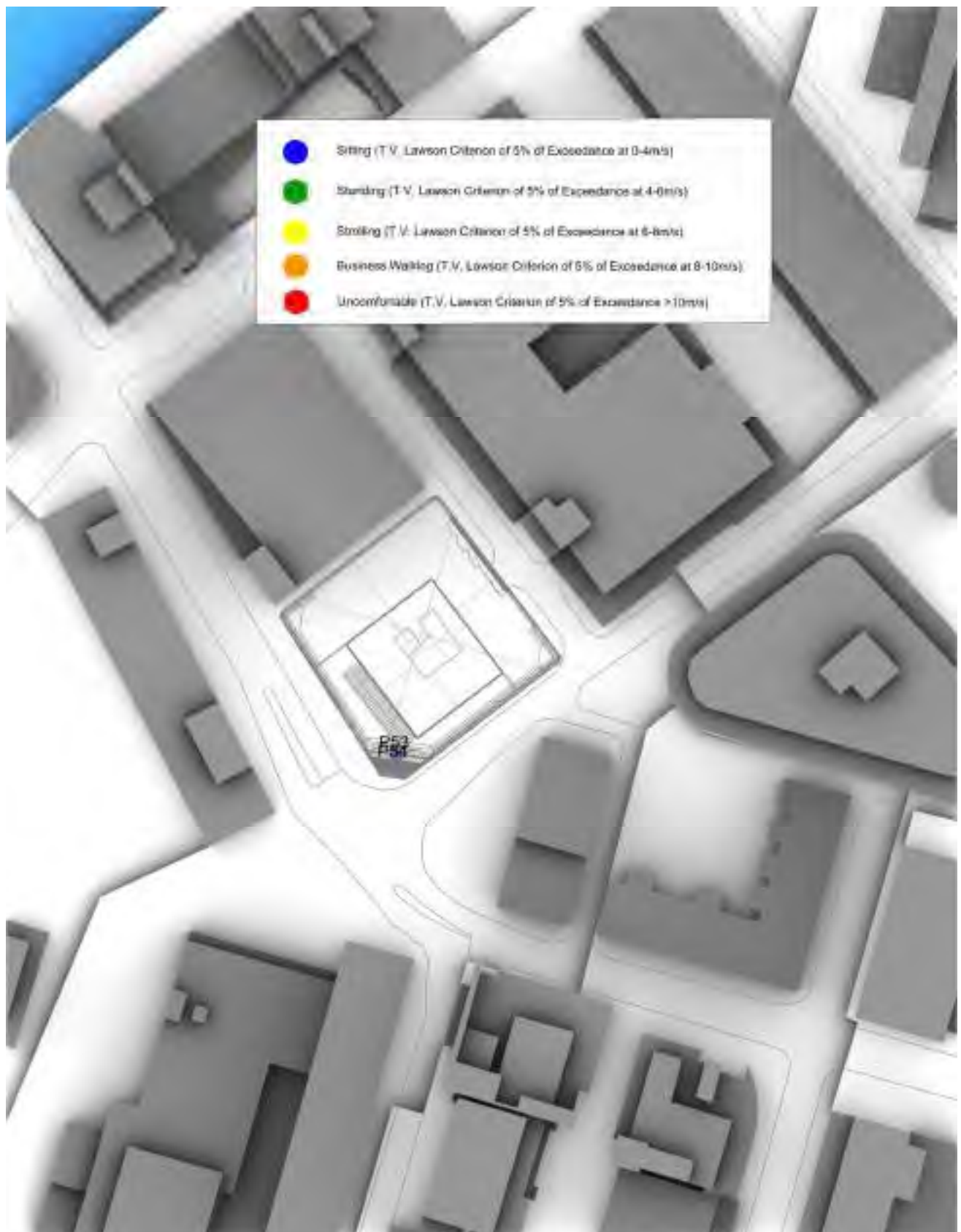


Figure 8j: The Proposed Development with Existing Surrounds and Mitigation: Elevated Levels - Levels 2 and 6, Comfort Results, Summer Season.

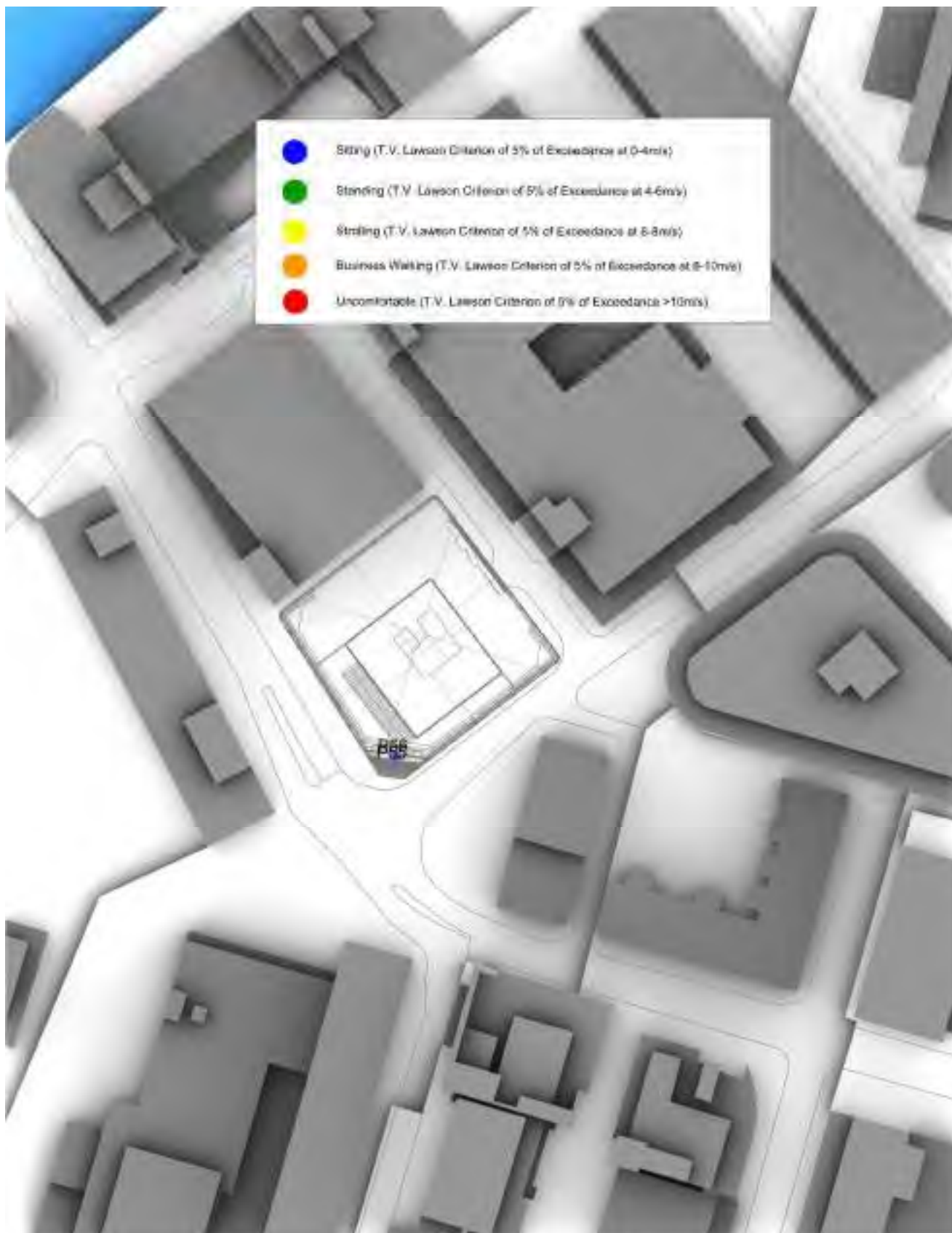


Figure 8k: The Proposed Development with Existing Surrounds and Mitigation: Elevated Levels - Levels 11 and 14, Comfort Results, Summer Season.



Figure 8I: The Proposed Development with Existing Surrounds and Mitigation: Elevated Levels - Roof, Comfort Results, Summer Season.

6.8 Renders of the Mitigation Measures Tested

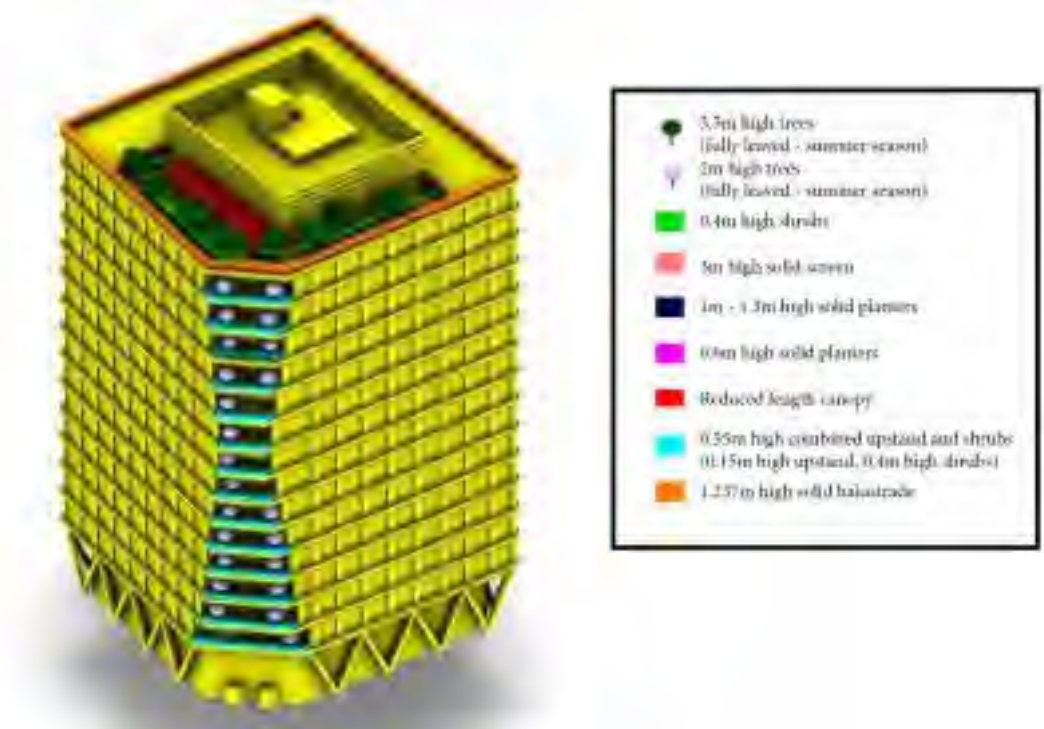


Figure 9a: Tested Mitigation Measures – Mitigation, Ground & Elevated levels – View from South.

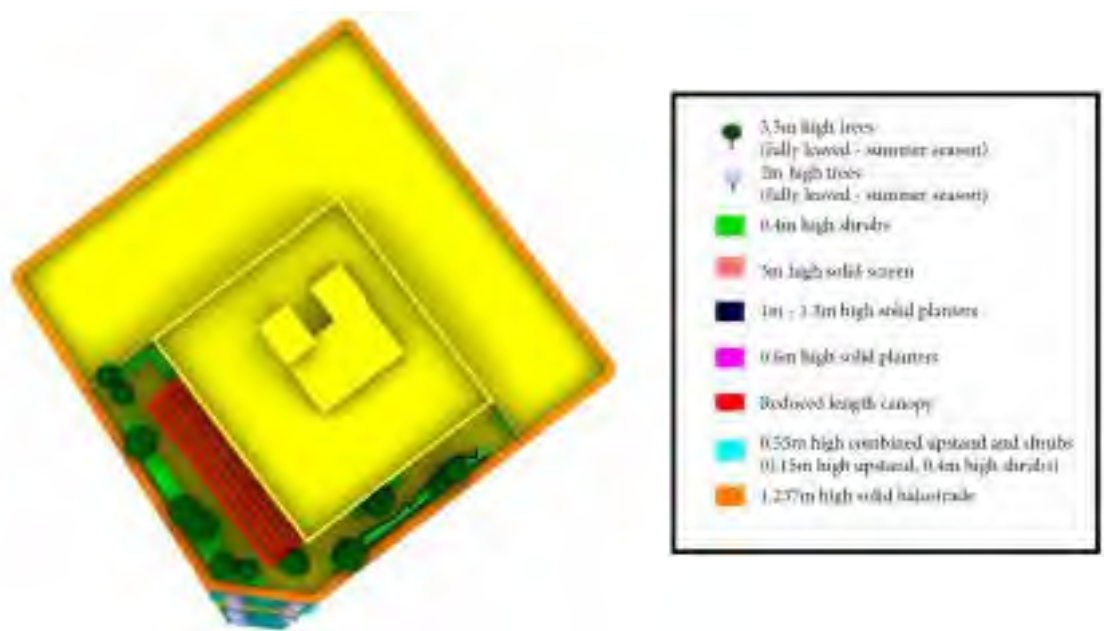


Figure 9b: Tested Mitigation Measures – Mitigation, Ground & Elevated levels – View from Top.

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Deaves, D.M. and Harris, R.I., 1978, "A mathematical model of the structure of strong winds." Construction Industry and Research Association (U.K), Report 76.

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APPENDIX A PUBLISHED ENVIRONMENTAL CRITERIA

A.1 Wind Effects on People

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

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

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

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

Type of Winds	Beaufort Number	Hourly Mean Wind Speed (m/s)	Effects
Calm	0	0 - 0.3	None
Calm, light air	1	0.3 - 1.6	No noticeable wind
Light breeze	2	1.6 - 3.4	Wind felt on face
Gentle breeze	3	3.4 - 5.5	Hair is disturbed, clothing flaps, newspapers difficult to read
Moderate breeze	4	5.5 - 8.0	Raises dust, dry soil and loose paper, hair disarranged
Fresh breeze	5	8.0 - 10.8	Force of wind felt on body, danger of stumbling
Strong breeze	6	10.8 - 13.9	Umbrellas used with difficulty, hair blown straight, difficult to walk steadily, wind noise on ears unpleasant
Near gale	7	13.9 - 17.2	Inconvenience felt when walking
Gale	8	17.2 - 20.8	Generally impedes progress, difficulty balancing in gusts
Strong gale	9	20.8 - 24.5	People blown over
Storm	10	24.5 - 28.4	Seldom experienced inland

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

A.G. Davenport (1972) also determined a set of criteria in terms of the Beaufort scale and for various return periods.

Table A.2 presents a summary of the criteria based on a probability of exceedance of 5%.

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

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

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

In 1973, T.V. Lawson, while referring to the Beaufort wind speeds of A.D. Penwarden (1973) (as listed in Table A.1), quoted that a Beaufort 4 wind speed would be acceptable if it is not exceeded for more than 4% of the time, and that a Beaufort 6 wind speed would be unacceptable if it is exceeded more than 2% of the time. Later, in 1975, T.V. Lawson presented a set of criteria very similar to those presented in A.G. Davenport (1972) (as listed in Table A.2). These criteria are presented in Table A.3 and Table A.4 for safety and comfort respectively.

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

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

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

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

A.5 W.H. Melbourne (1978) Criteria for Gust Wind Speeds

W.H. Melbourne (1978) introduced a set of criteria for the assessment of environmental wind conditions that were developed for a temperature range of 10°C to 30°C and for people suitably dressed for outdoor conditions. These criteria are presented in Table A.5, and are based on maximum gust wind speeds with a probability of exceedance of once per year.

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

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

A.6 Lawson Criteria (2001) for Mean Wind Speeds

In 2001 the T.V. Lawson criteria described in Section A.4 was revised by T.V. Lawson. Details of the comfort criteria are presented in the table below and are based on the exceedance of the threshold wind speeds, occurring less than 5% of the time. This criterion defines a reasonable allowance for extreme and relatively infrequent winds that are tolerable within each category.

Table A.6: Pedestrian Comfort Criteria (T.V. Lawson, 2001)

Classification	Activities	5% exceedance Mean Wind Speed (m/s)
Uncomfortable	Winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended.	>10
Business Walking	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering.	8-10
Strolling	Moderate breezes that would be appropriate for strolling along a city/town street, plaza or park.	6-8
Standing	Gentle breezes acceptable for main building entrances, pick-up/drop-off points and bus stops	4-6
Sitting	Light breezes desired for outdoor restaurants and seating areas where one can read a paper or comfortably sit for long periods	0-4

Details of the safety criteria are presented in the table below and are based on exceedance of 0.023% of the threshold wind speeds, occurring approximately 2hrs annually.

Table A.7: Pedestrian Safety Criteria (T.V. Lawson, 2001)

Classification	Activities	Threshold Mean Wind Speed (m/s)
Unsafe for Frail	Frail members of the public and cyclists will find the conditions challenging and will be at risk of being blown over.	15
Unsafe for All	All members of the public and cyclists will find the conditions challenging and will be at risk of being blown over.	20

A.7 Comparison of the Published Wind Speed Criteria

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

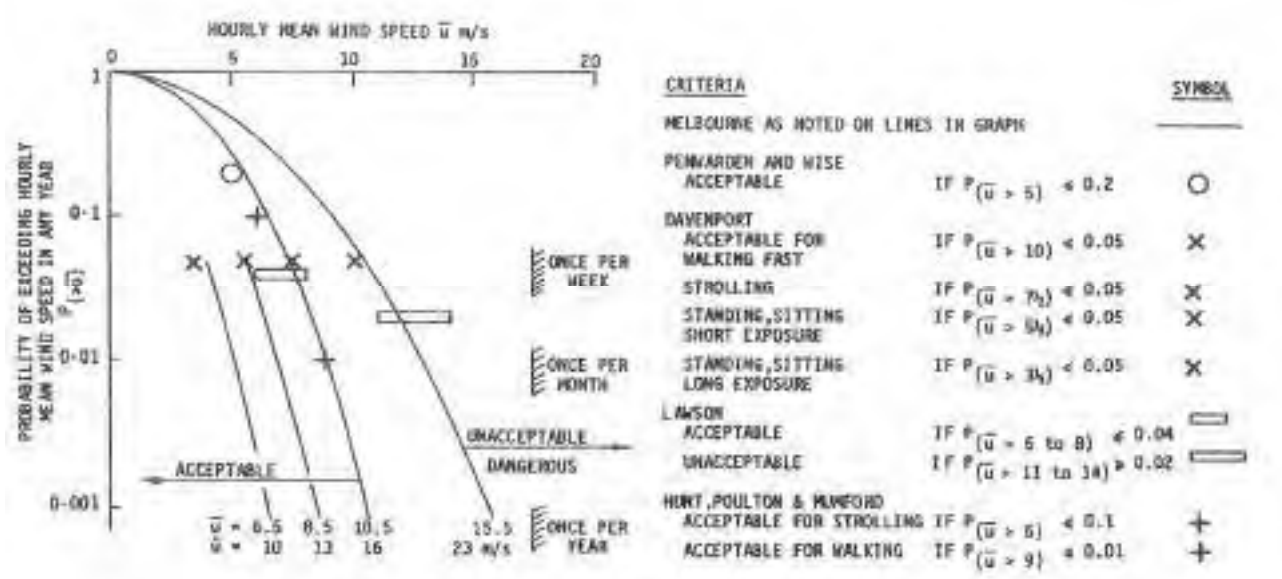


Figure A.1: Comparison of Various Mean and Gust Wind Environment Criteria, assuming 15% turbulence and a Gust Factor of 1.5 (W.H. Melbourne, 1978)

A.8 References relating to Pedestrian Comfort Criteria

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APPENDIX B DATA ACQUISITION

The wind tunnel testing procedures utilised for this study were based on the Wind Microclimate Guidelines for developments in the City of London and the guidelines set out in the Australasian Wind Engineering Society Quality Assurance Manual (AWES-QAM-1-2019), ASCE 7-16 (Chapter C31), and CTBUH (2013).

The wind speed measurements for the wind tunnel study are determined as coefficients using data acquired by pressure-based wind speed sensors, referred to as Irwin probes, and converted to full-scale wind speeds using details of the regional wind climate obtained from an analysis of directional wind speed recordings from the local meteorological recording station(s).

B.1 Measurement of the Velocity Coefficients

The study model and proximity model were setup within the wind tunnel which was configured to the appropriate boundary layer profile, and the wind velocity measurements were monitored using pressure-based wind speed sensors referred to as Irwin probes.

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

$$C_V = \frac{\alpha + \beta \sqrt{\Delta p}}{V_{200m}} \quad \text{B.1}$$

where:

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

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

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

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

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

B.2 Calculation of the Full-Scale Results

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

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

The methodology adopted for the derivation of the full-scale results for the maximum gust and the GEM wind speeds are outlined in the following sub-sections.

B.3 Maximum Gust Wind Speeds

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

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

where:

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

$V_{ref,RH}$ is the full-scale reference wind speed at the study reference height. This value is determined by combining the directional wind speed data for the region and the upwind terrain and height multipliers for the Site.

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

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

C_V is the velocity coefficient, obtained from Equation B.1.

The value of $V_{ref,RH}$ varies with each prevailing wind direction. Wind directions where there is a high probability that a strong wind will occur have a higher directional wind speed than other directions. To determine the directional wind speeds, a probability level must be assigned for each wind direction. These probability levels are set following the approach used in AS/NZS1170.2:2011, which assumes that the major contributions to the combined probability of exceedance of a typical load effect comes from only two 45 degree sectors.

B.4 Maximum Gust-Equivalent Mean Wind Speeds

The contribution to the probability of exceedance of a specified wind speed (ie: the desired wind speed for pedestrian comfort, as per the criteria) was calculated for each wind direction. These contributions are then combined over all wind directions to calculate the total probability of exceedance of the specified wind speed. To calculate the probability of exceedance for a specified wind speed a statistical wind climate model was used to describe the relationship between directional wind speeds and the probability of exceedance. A detailed description of the methodology is given by T.V. Lawson (1980).

The criteria used in this study is referenced to a probability of exceedance of 5% of a specified wind speed.

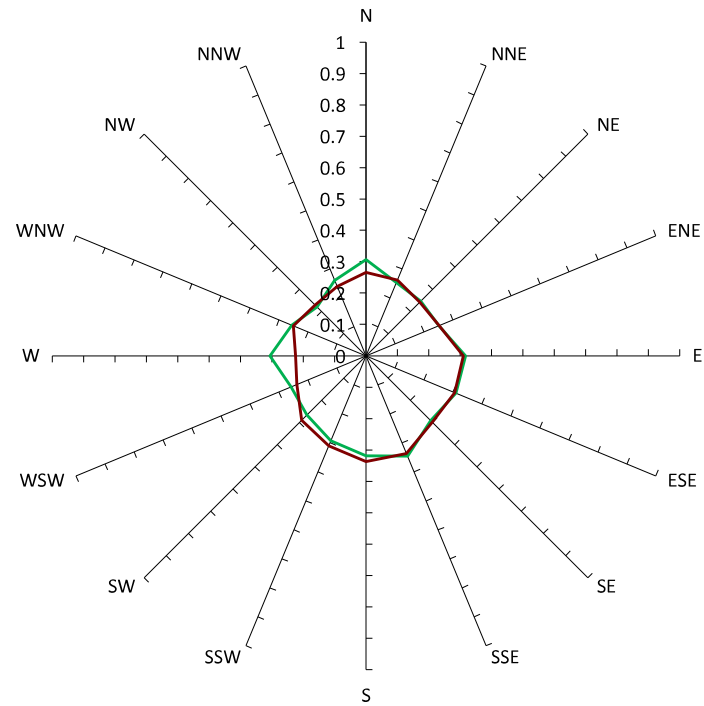
B.5 References relating to Data Acquisition

- American Society of Civil Engineers (ASCE), ASCE-7-16, 2016, "Minimum Design Loads for Buildings and Other Structures".
- Australasian Wind Engineering Society, QAM-1, 2019, "Quality Assurance Manual: Wind Engineering Studies of Buildings", edited by Rofail A.W., et al.
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APPENDIX C MEASURED COEFFICIENTS

Results for P1

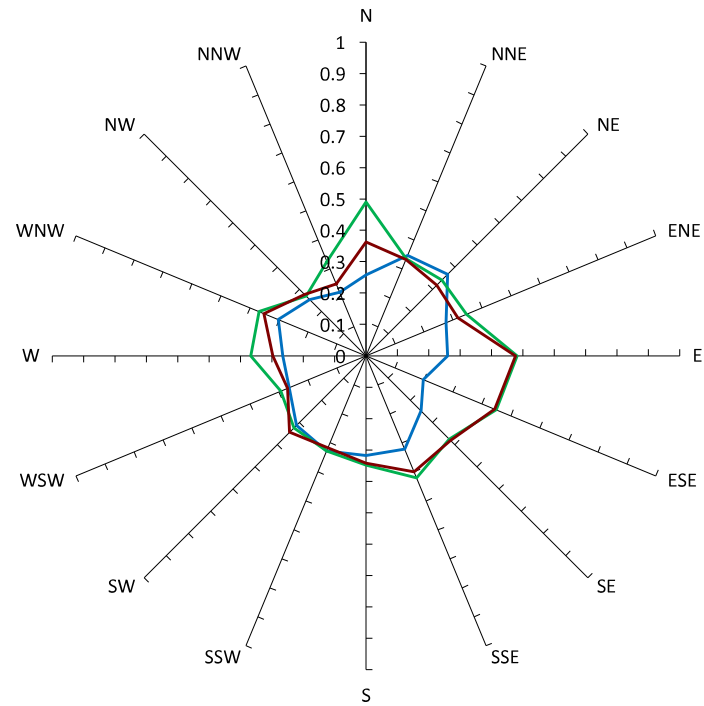
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	< 0.01%	3.13	< 0.01%	4.13	< 0.001%	6.63
The Proposed Development with Future Surrounds	< 0.01%	3.10	< 0.01%	4.13	< 0.001%	6.48
The Proposed Development with Existing Surrounds and Mitigation						

Results for P2

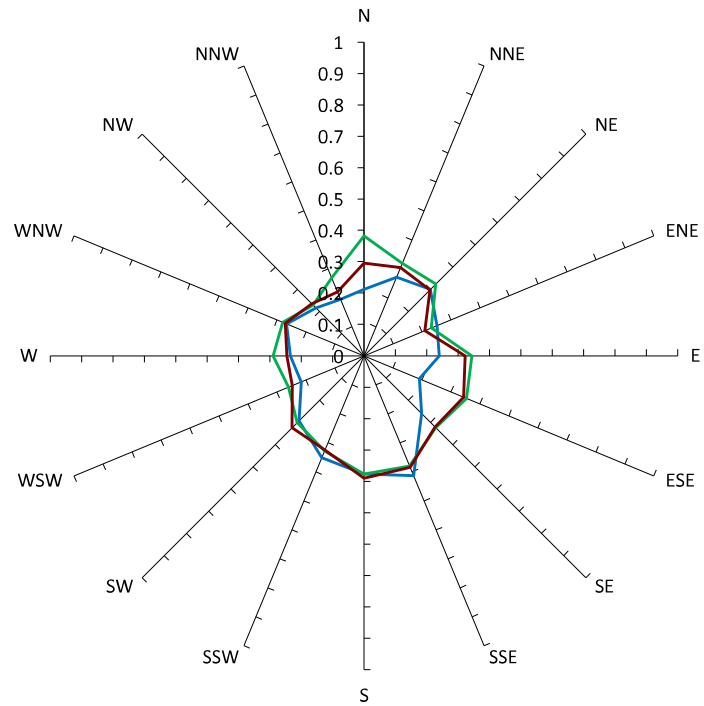
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.26	< 0.01%	4.18	< 0.001%	6.75
The Proposed Development with Existing Surrounds	< 0.01%	3.90	1.61%	5.06	< 0.001%	8.56
The Proposed Development with Future Surrounds	< 0.01%	3.69	1.01%	4.78	< 0.001%	8.04
The Proposed Development with Existing Surrounds and Mitigation						

Results for P3

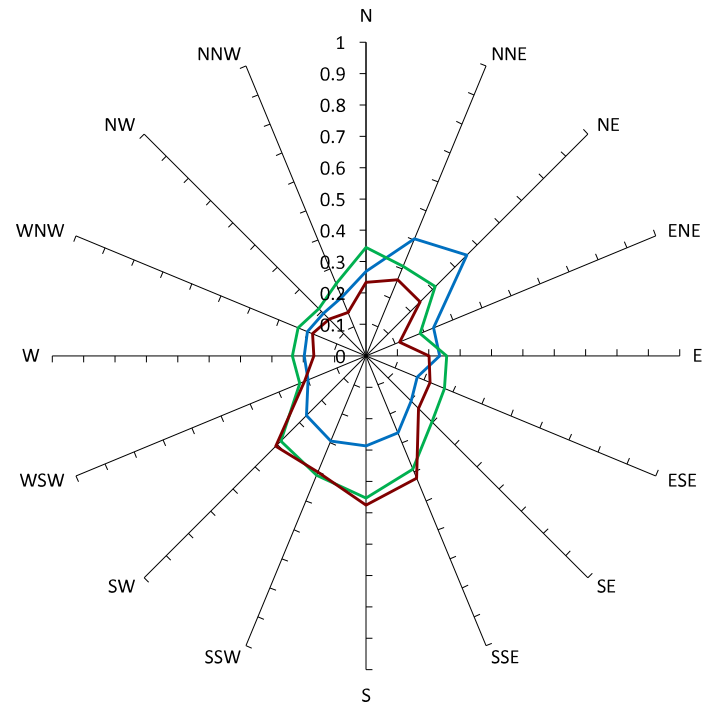
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.45	< 0.01%	4.63	< 0.001%	7.35
The Proposed Development with Existing Surrounds	< 0.01%	3.44	< 0.01%	4.60	< 0.001%	7.25
The Proposed Development with Future Surrounds	< 0.01%	3.45	< 0.01%	4.64	< 0.001%	7.28
The Proposed Development with Existing Surrounds and Mitigation						

Results for P4

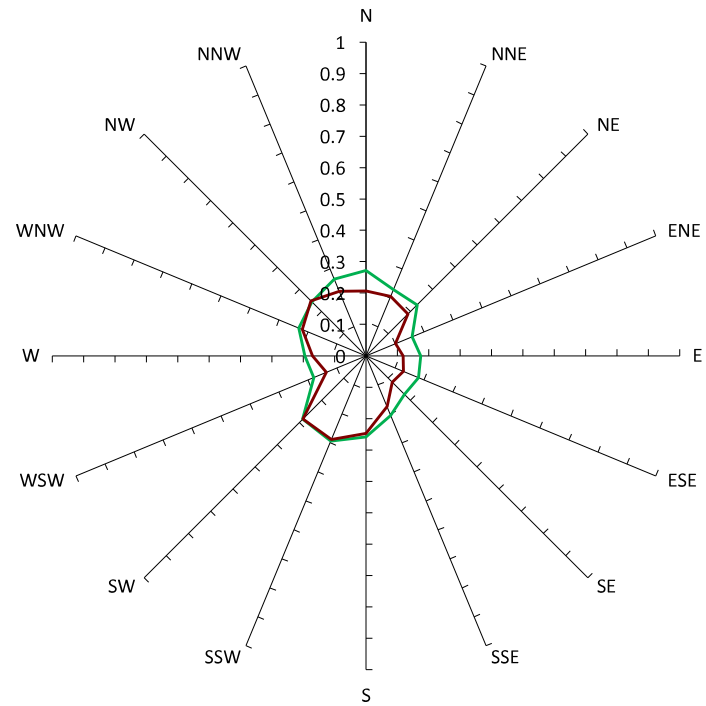
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.02	< 0.01%	3.79	< 0.001%	7.07
The Proposed Development with Existing Surrounds	< 0.01%	3.98	< 0.01%	5.32	< 0.001%	8.36
The Proposed Development with Future Surrounds	< 0.01%	4.11	< 0.01%	5.53	< 0.001%	8.71
The Proposed Development with Existing Surrounds and Mitigation						

Results for P5

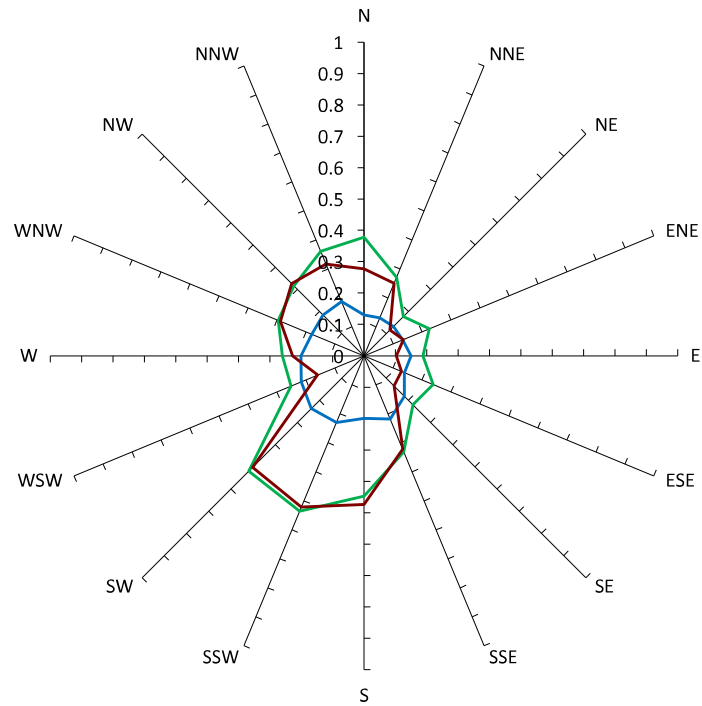
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	< 0.01%	2.70	< 0.01%	3.44	< 0.001%	5.74
The Proposed Development with Future Surrounds	< 0.01%	2.63	< 0.01%	3.32	< 0.001%	5.63
The Proposed Development with Existing Surrounds and Mitigation						

Results for P6

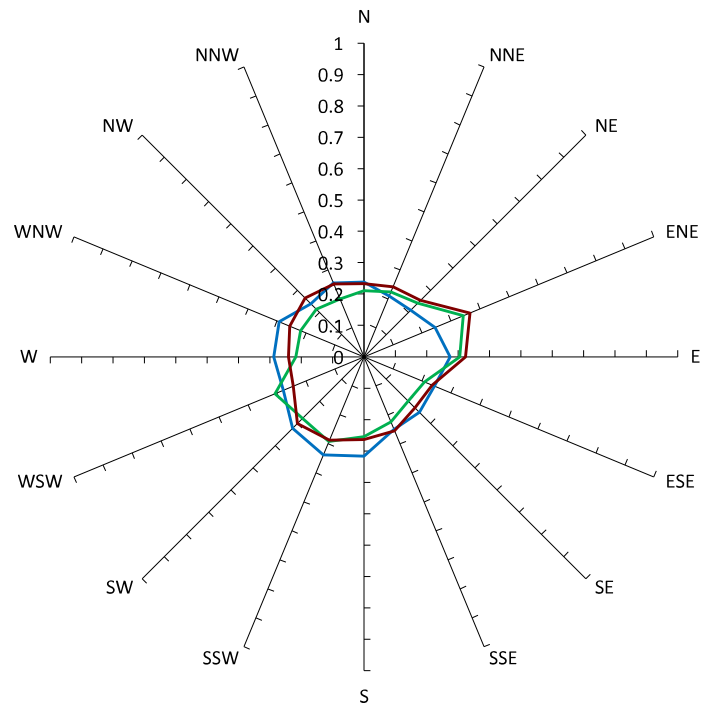
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	2.24	< 0.01%	2.87	< 0.001%	4.89
The Proposed Development with Existing Surrounds	0.99%	4.78	5.73%	6.04	< 0.001%	10.30
The Proposed Development with Future Surrounds	0.82%	4.70	5.63%	6.02	< 0.001%	10.05
The Proposed Development with Existing Surrounds and Mitigation						

Results for P7

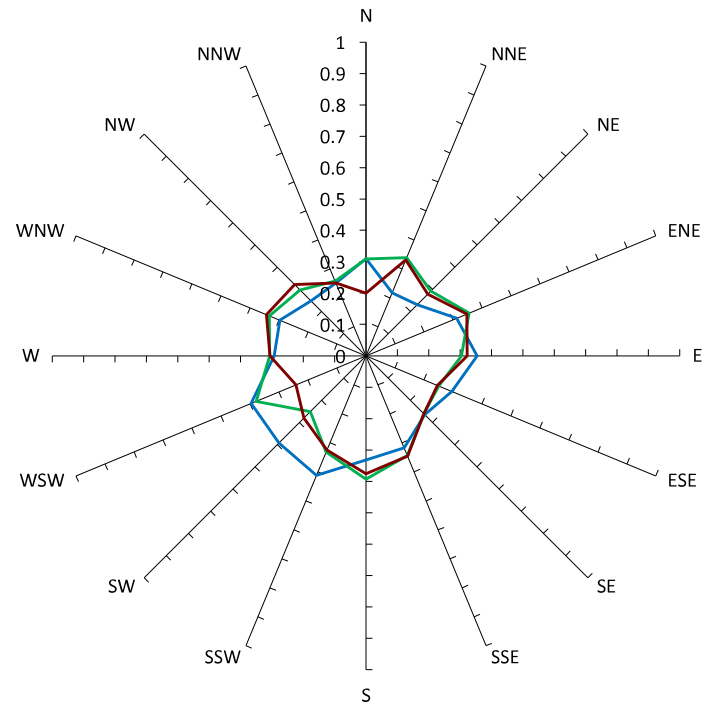
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.21	< 0.01%	4.15	< 0.001%	6.78
The Proposed Development with Existing Surrounds	< 0.01%	2.87	< 0.01%	3.75	< 0.001%	6.56
The Proposed Development with Future Surrounds	< 0.01%	2.94	< 0.01%	3.86	< 0.001%	6.49
The Proposed Development with Existing Surrounds and Mitigation						

Results for P8

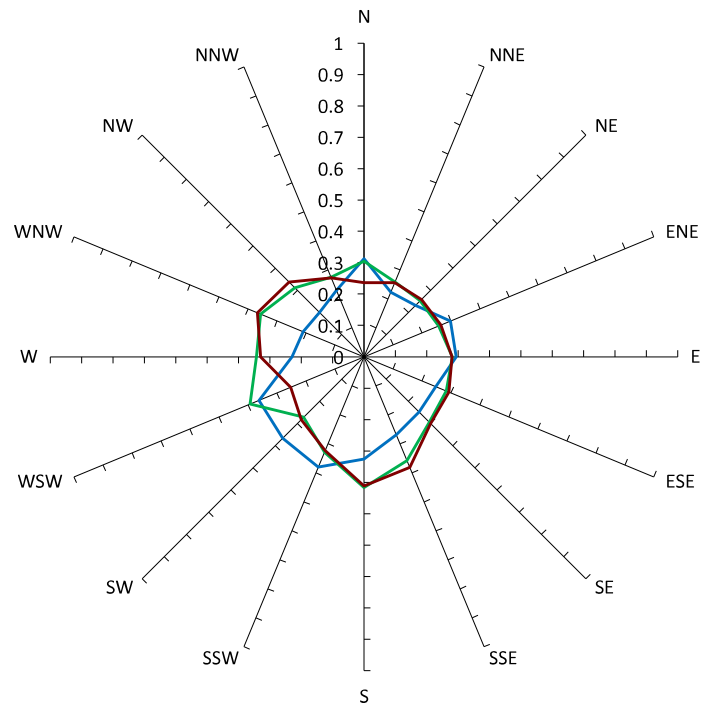
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.83	< 0.01%	4.89	< 0.001%	8.51
The Proposed Development with Existing Surrounds	< 0.01%	3.61	< 0.01%	4.79	< 0.001%	7.97
The Proposed Development with Future Surrounds	< 0.01%	3.47	< 0.01%	4.58	< 0.001%	7.19
The Proposed Development with Existing Surrounds and Mitigation						

Results for P9

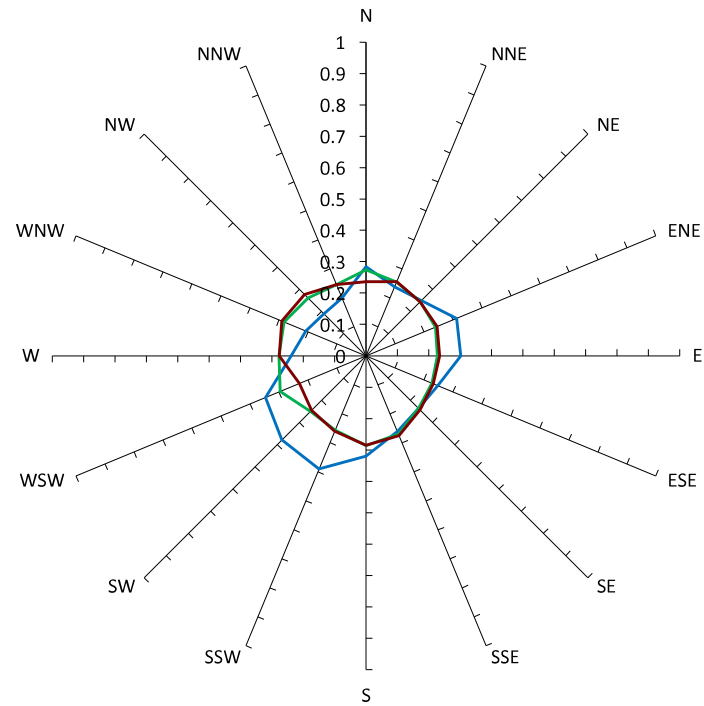
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.53	< 0.01%	4.49	< 0.001%	7.84
The Proposed Development with Existing Surrounds	< 0.01%	3.77	< 0.01%	5.01	< 0.001%	8.34
The Proposed Development with Future Surrounds	< 0.01%	3.67	< 0.01%	4.89	< 0.001%	7.68
The Proposed Development with Existing Surrounds and Mitigation						

Results for P10

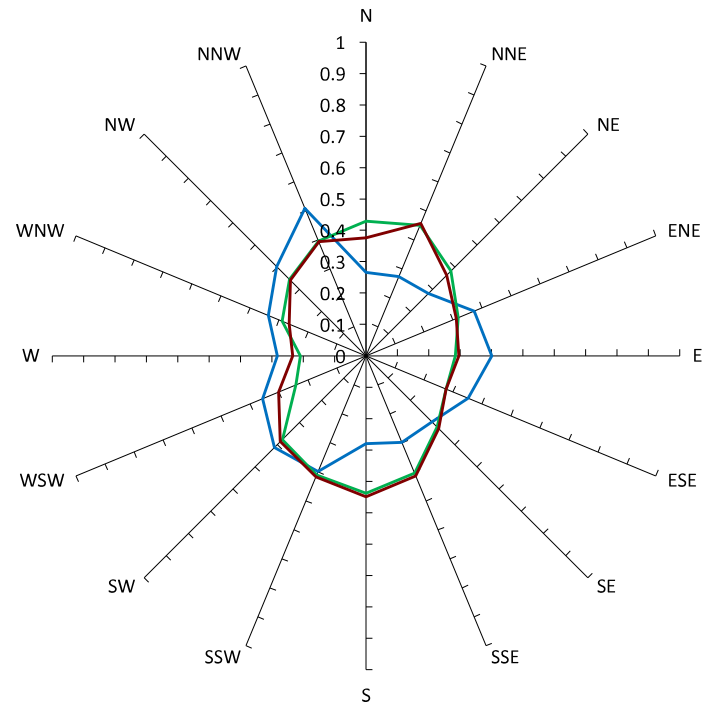
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.58	0.74%	4.54	< 0.001%	7.83
The Proposed Development with Existing Surrounds	< 0.01%	2.90	< 0.01%	3.74	< 0.001%	6.35
The Proposed Development with Future Surrounds	< 0.01%	2.87	< 0.01%	3.68	< 0.001%	5.97
The Proposed Development with Existing Surrounds and Mitigation						

Results for P11

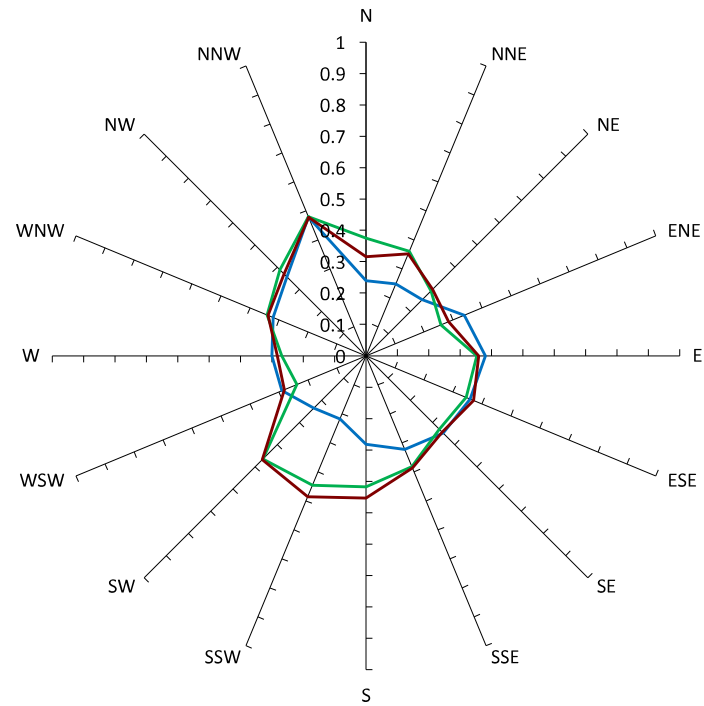
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.94	1.43%	4.93	< 0.001%	8.58
The Proposed Development with Existing Surrounds	< 0.01%	4.02	1.87%	5.28	< 0.001%	8.35
The Proposed Development with Future Surrounds	< 0.01%	4.08	2.25%	5.39	< 0.001%	8.48
The Proposed Development with Existing Surrounds and Mitigation						

Results for P12

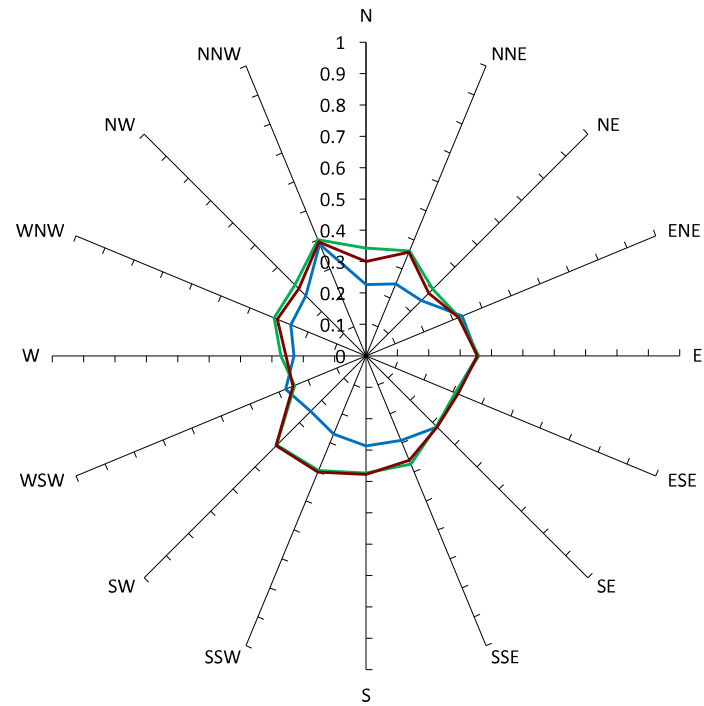
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.33	< 0.01%	4.23	< 0.001%	7.43
The Proposed Development with Existing Surrounds	< 0.01%	4.27	< 0.01%	5.42	< 0.001%	9.12
The Proposed Development with Future Surrounds	< 0.01%	4.47	< 0.01%	5.76	< 0.001%	9.45
The Proposed Development with Existing Surrounds and Mitigation						

Results for P13

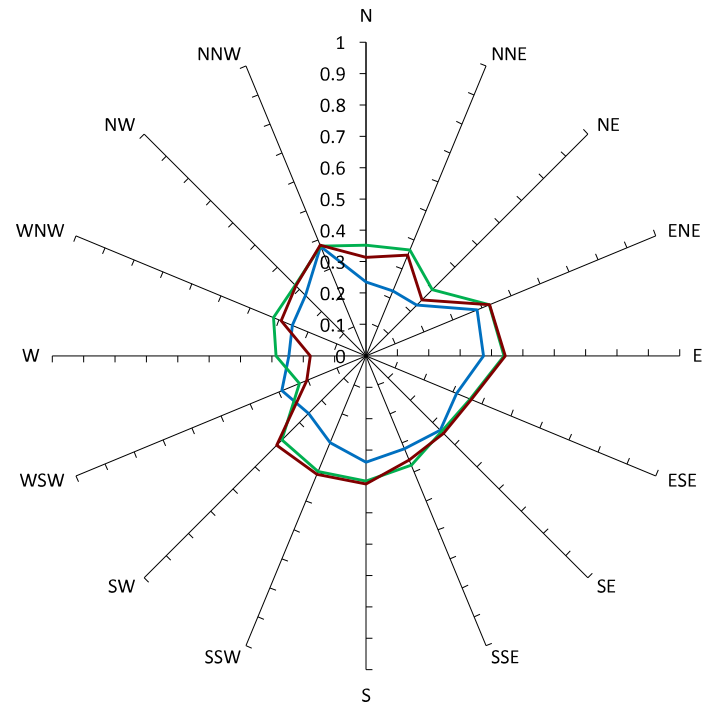
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	2.96	< 0.01%	3.89	< 0.001%	6.52
The Proposed Development with Existing Surrounds	< 0.01%	3.81	< 0.01%	4.89	< 0.001%	8.01
The Proposed Development with Future Surrounds	< 0.01%	3.81	< 0.01%	4.90	< 0.001%	8.04
The Proposed Development with Existing Surrounds and Mitigation						

Results for P14

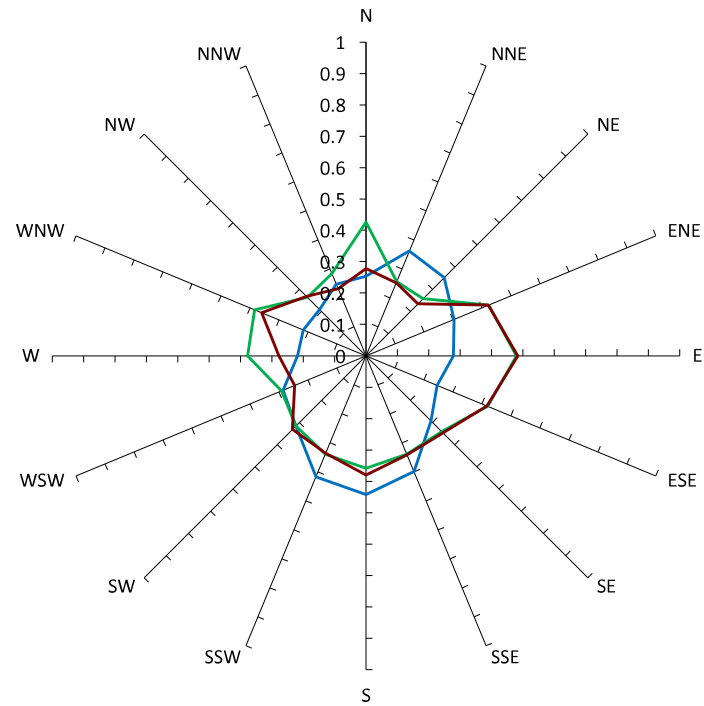
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.21	< 0.01%	4.32	< 0.001%	7.03
The Proposed Development with Existing Surrounds	< 0.01%	3.90	1.54%	5.13	< 0.001%	8.21
The Proposed Development with Future Surrounds	< 0.01%	3.97	1.72%	5.18	< 0.001%	8.38
The Proposed Development with Existing Surrounds and Mitigation						

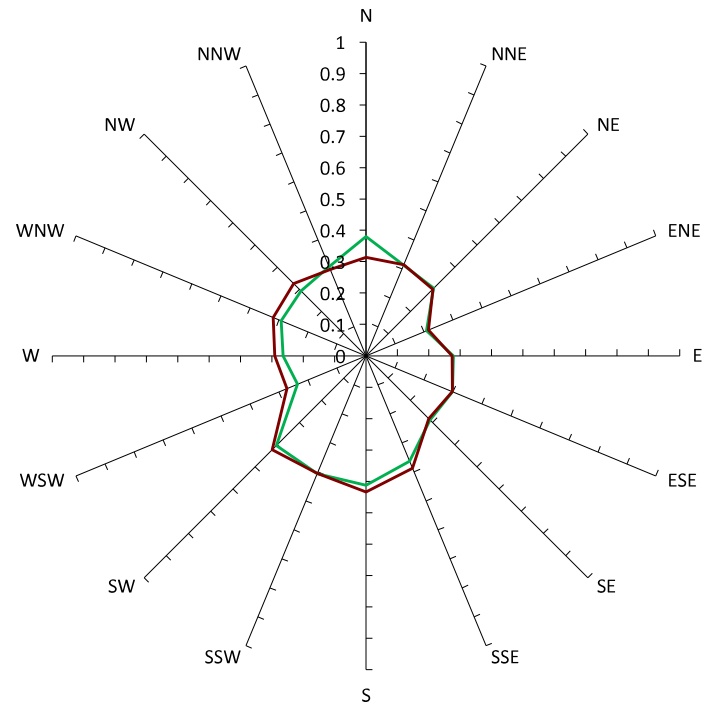
Results for P15

GEM Velocity Coefficients



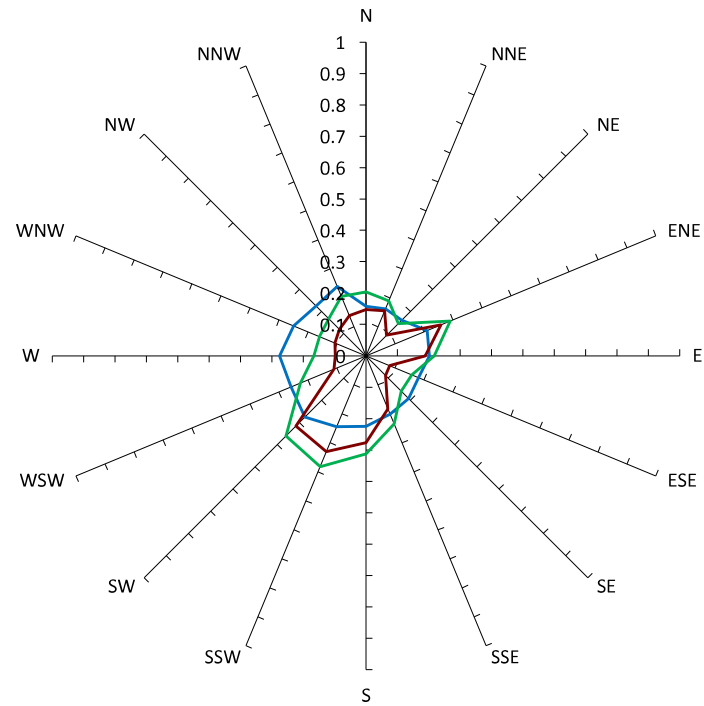
Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.90	< 0.01%	5.24	< 0.001%	8.17
The Proposed Development with Existing Surrounds	< 0.01%	3.90	< 0.01%	5.04	< 0.001%	8.43
The Proposed Development with Future Surrounds	< 0.01%	3.73	< 0.01%	4.89	< 0.001%	8.14
The Proposed Development with Existing Surrounds and Mitigation						

GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	< 0.01%	3.87	< 0.01%	5.05	< 0.001%	8.17
The Proposed Development with Future Surrounds	< 0.01%	4.00	< 0.01%	5.25	< 0.001%	8.46
The Proposed Development with Existing Surrounds and Mitigation						

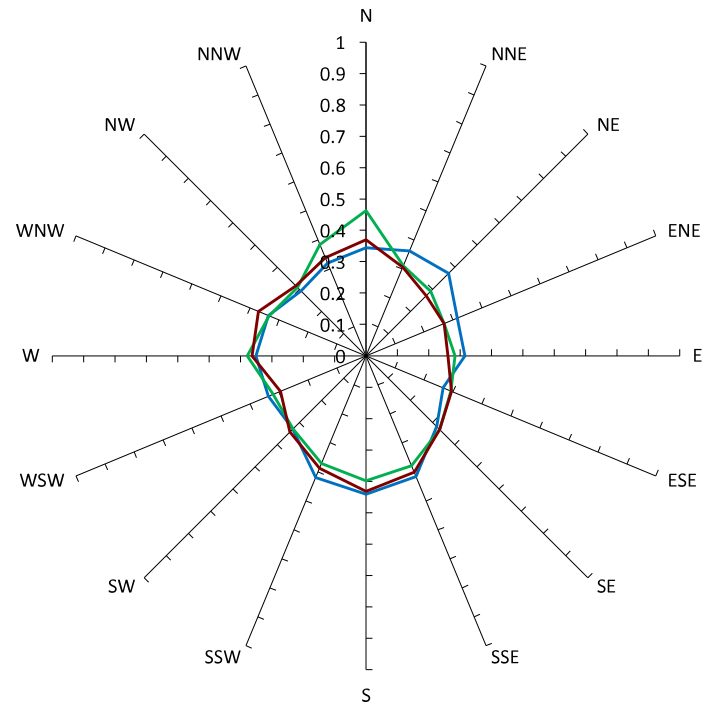
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	2.72	< 0.01%	3.40	< 0.001%	5.93
The Proposed Development with Existing Surrounds	< 0.01%	3.38	< 0.01%	4.29	< 0.001%	7.26
The Proposed Development with Future Surrounds	< 0.01%	2.94	< 0.01%	3.73	< 0.001%	6.32
The Proposed Development with Existing Surrounds and Mitigation						

Results for P18

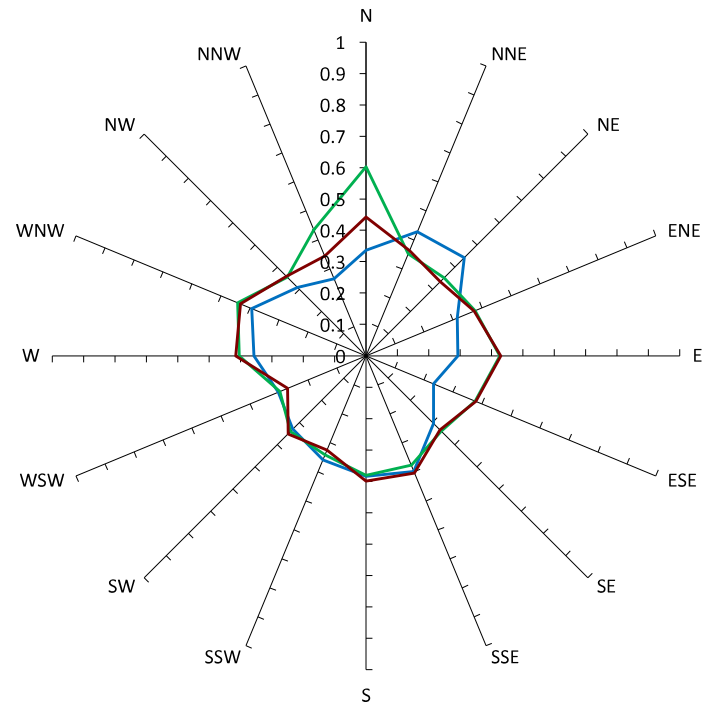
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.03	< 0.01%	5.38	< 0.001%	8.42
The Proposed Development with Existing Surrounds	< 0.01%	3.84	< 0.01%	5.04	< 0.001%	8.21
The Proposed Development with Future Surrounds	< 0.01%	3.95	< 0.01%	5.25	< 0.001%	8.24
The Proposed Development with Existing Surrounds and Mitigation						

Results for P19

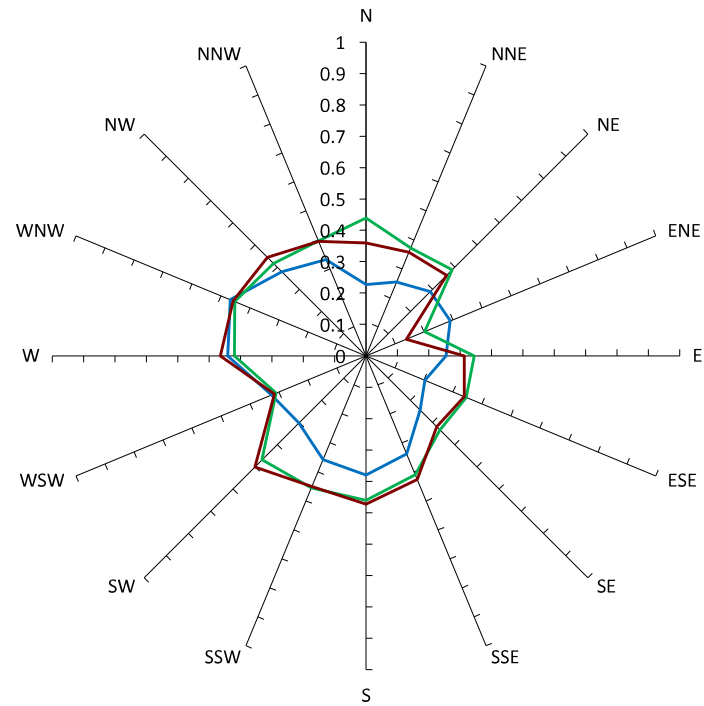
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.92	< 0.01%	5.00	< 0.001%	8.10
The Proposed Development with Existing Surrounds	< 0.01%	4.21	< 0.01%	5.30	< 0.001%	9.47
The Proposed Development with Future Surrounds	< 0.01%	4.19	< 0.01%	5.32	< 0.001%	8.81
The Proposed Development with Existing Surrounds and Mitigation						

Results for P20

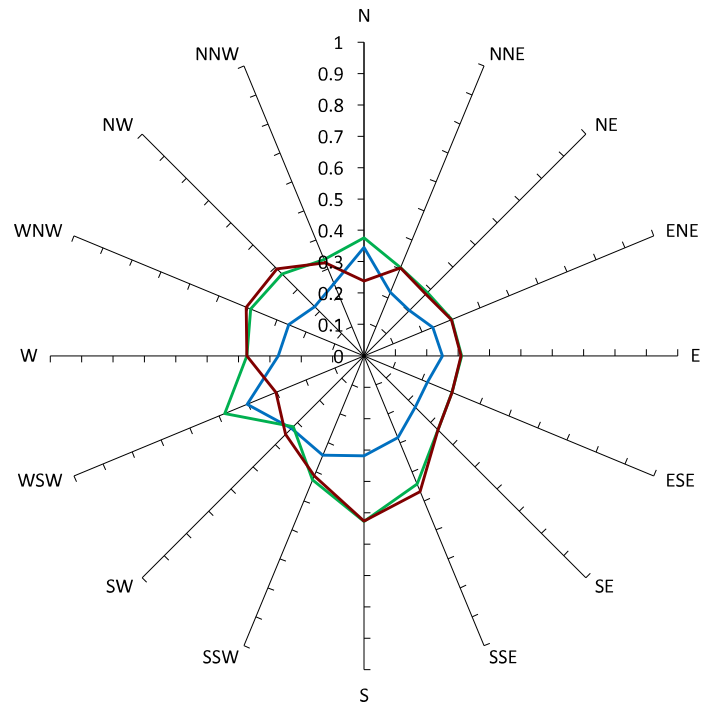
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.32	< 0.01%	5.29	< 0.001%	9.18
The Proposed Development with Existing Surrounds	< 0.01%	4.62	< 0.01%	5.91	< 0.001%	9.66
The Proposed Development with Future Surrounds	< 0.01%	4.82	0.68%	6.13	< 0.001%	10.18
The Proposed Development with Existing Surrounds and Mitigation						

Results for P21

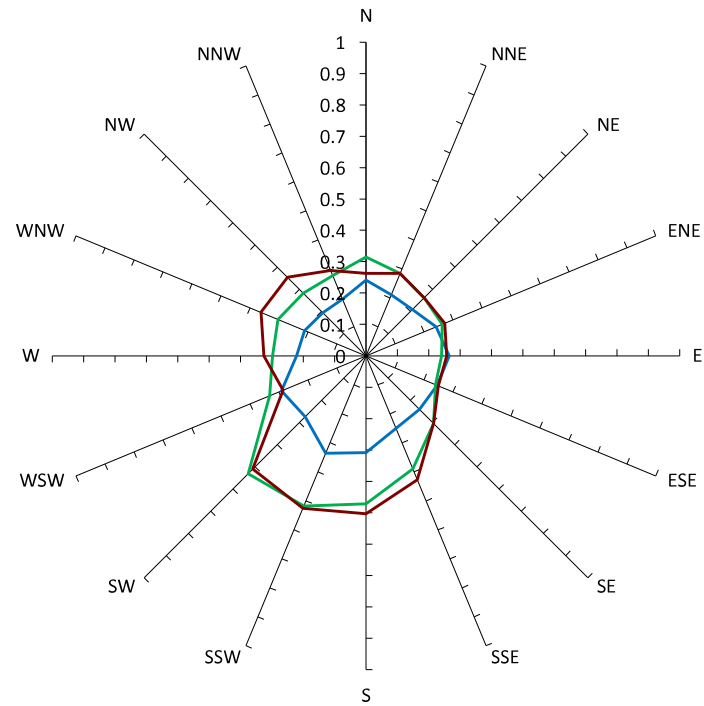
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.42	< 0.01%	4.36	< 0.001%	8.22
The Proposed Development with Existing Surrounds	< 0.01%	4.59	0.63%	6.20	< 0.001%	10.20
The Proposed Development with Future Surrounds	< 0.01%	4.48	< 0.01%	6.10	< 0.001%	9.47
The Proposed Development with Existing Surrounds and Mitigation						

Results for P22

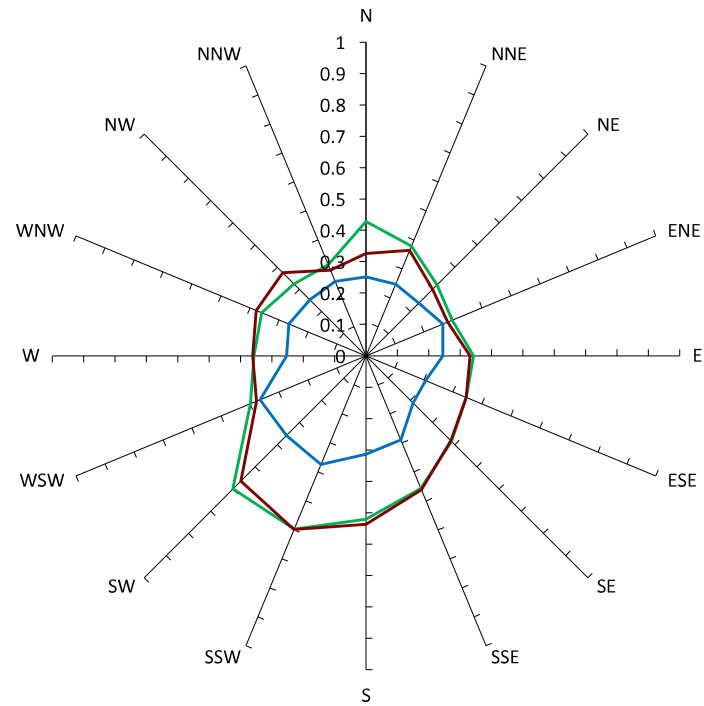
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
 The Existing Site with Existing Surrounds	< 0.01%	3.02	< 0.01%	3.95	< 0.001%	6.48
 The Proposed Development with Existing Surrounds	1.00%	4.80	6.13%	6.09	< 0.001%	10.35
 The Proposed Development with Future Surrounds	1.00%	4.84	7.59%	6.27	< 0.001%	10.26
 The Proposed Development with Existing Surrounds and Mitigation						

Results for P23

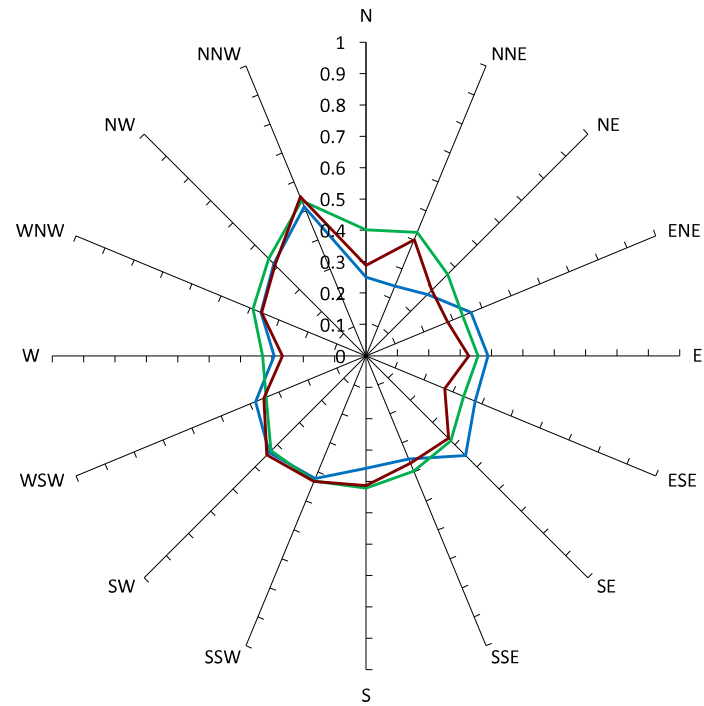
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.48	< 0.01%	4.44	< 0.001%	7.80
The Proposed Development with Existing Surrounds	< 0.01%	5.46	1.94%	6.93	< 0.001%	11.76
The Proposed Development with Future Surrounds	< 0.01%	5.38	1.85%	6.93	< 0.001%	11.44
The Proposed Development with Existing Surrounds and Mitigation						

Results for P24

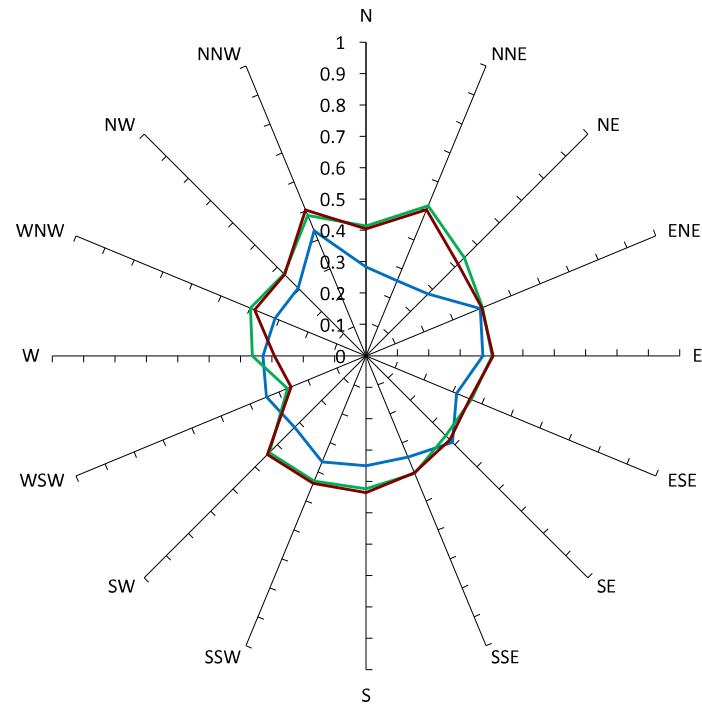
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.17	< 0.01%	5.26	< 0.001%	9.01
The Proposed Development with Existing Surrounds	< 0.01%	4.31	< 0.01%	5.50	< 0.001%	9.06
The Proposed Development with Future Surrounds	< 0.01%	4.25	< 0.01%	5.39	< 0.001%	9.14
The Proposed Development with Existing Surrounds and Mitigation						

Results for P25

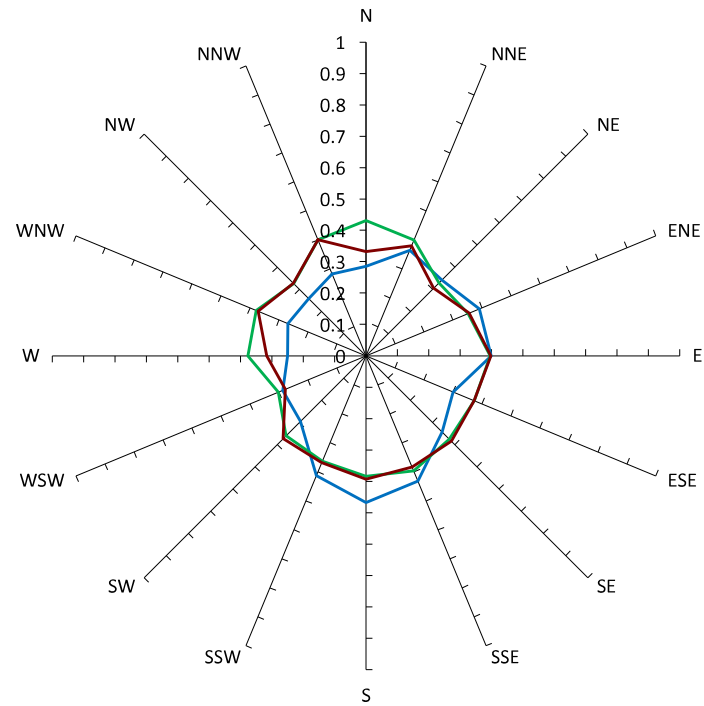
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.65	< 0.01%	4.79	< 0.001%	7.85
The Proposed Development with Existing Surrounds	< 0.01%	4.38	< 0.01%	5.57	< 0.001%	9.05
The Proposed Development with Future Surrounds	< 0.01%	4.37	< 0.01%	5.58	< 0.001%	9.09
The Proposed Development with Existing Surrounds and Mitigation						

Results for P26

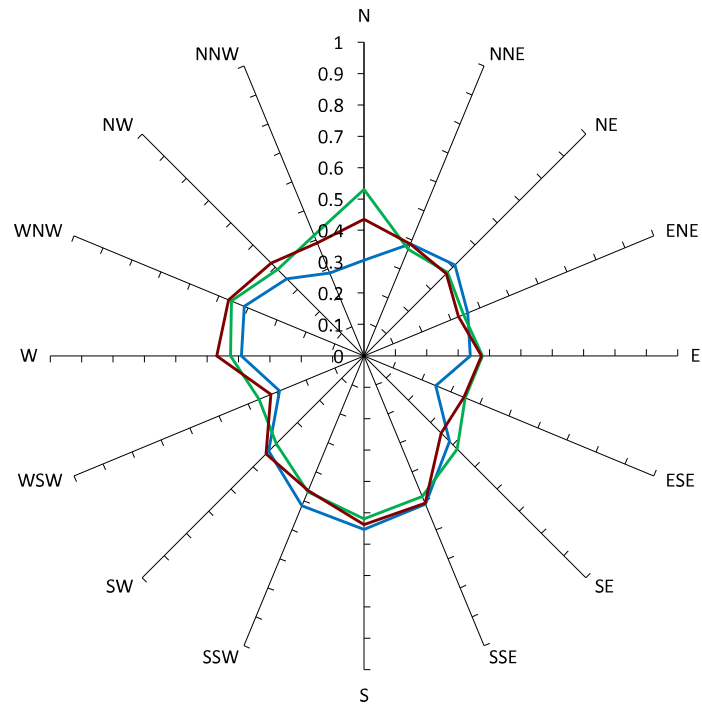
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.07	< 0.01%	5.51	< 0.001%	8.54
The Proposed Development with Existing Surrounds	< 0.01%	3.95	< 0.01%	5.11	< 0.001%	8.27
The Proposed Development with Future Surrounds	< 0.01%	3.86	< 0.01%	5.01	< 0.001%	7.99
The Proposed Development with Existing Surrounds and Mitigation						

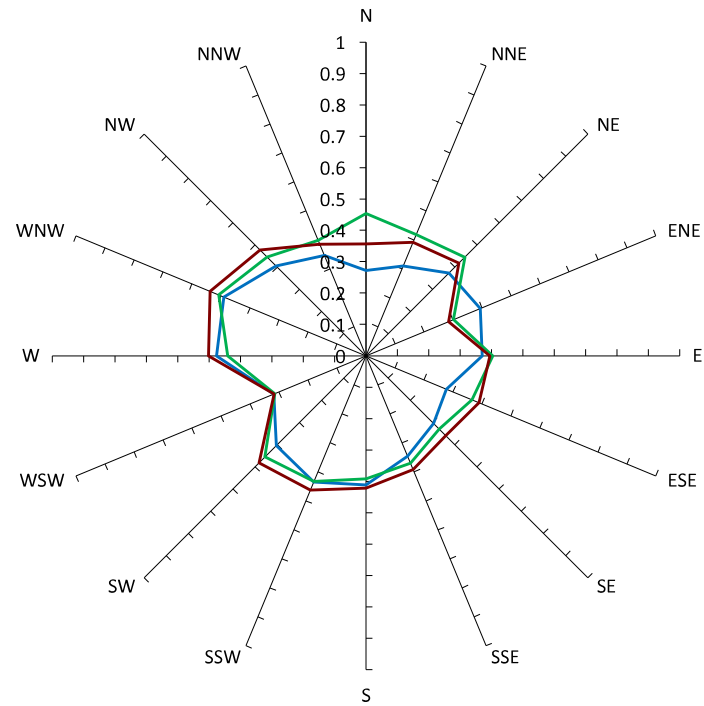
Results for P27

GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.92	1.01%	6.61	< 0.001%	10.28
The Proposed Development with Existing Surrounds	< 0.01%	4.77	0.70%	6.33	< 0.001%	9.99
The Proposed Development with Future Surrounds	< 0.01%	4.95	0.98%	6.55	< 0.001%	10.34
The Proposed Development with Existing Surrounds and Mitigation						

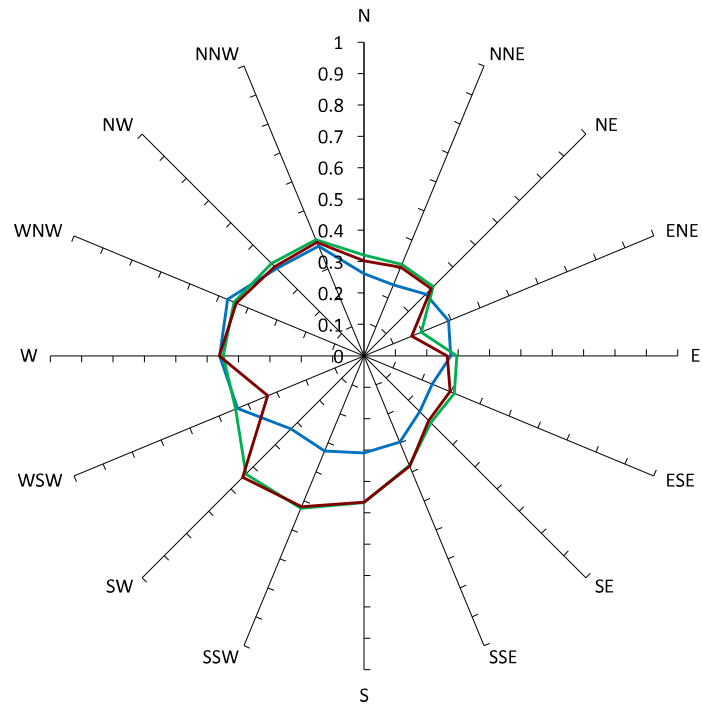
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.69	0.50%	5.83	< 0.001%	9.87
The Proposed Development with Existing Surrounds	< 0.01%	4.74	0.51%	5.80	< 0.001%	9.91
The Proposed Development with Future Surrounds	< 0.01%	5.09	0.95%	6.25	< 0.001%	10.71
The Proposed Development with Existing Surrounds and Mitigation						

Results for P29

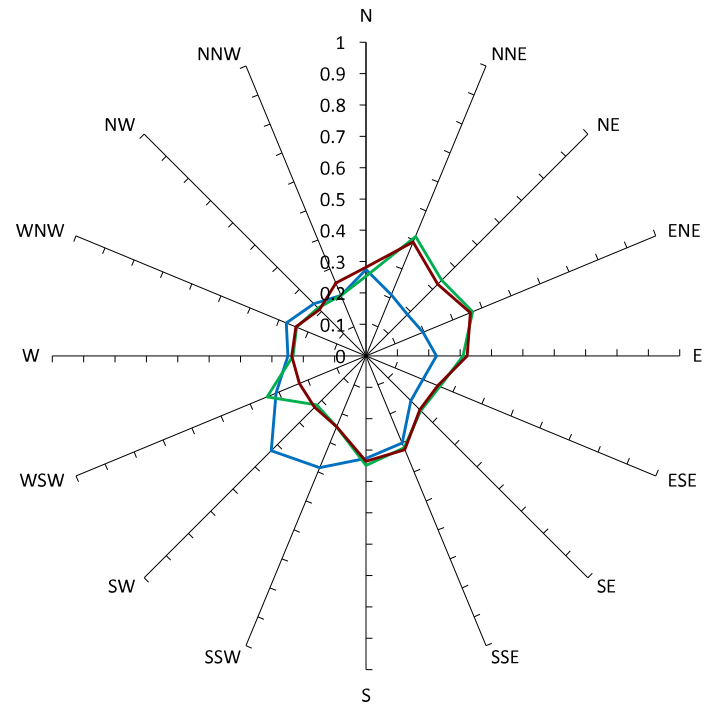
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.46	3.05%	5.43	< 0.001%	9.82
The Proposed Development with Existing Surrounds	1.28%	5.02	8.45%	6.40	< 0.001%	10.77
The Proposed Development with Future Surrounds	1.29%	5.02	8.08%	6.36	< 0.001%	10.76
The Proposed Development with Existing Surrounds and Mitigation						

Results for P30

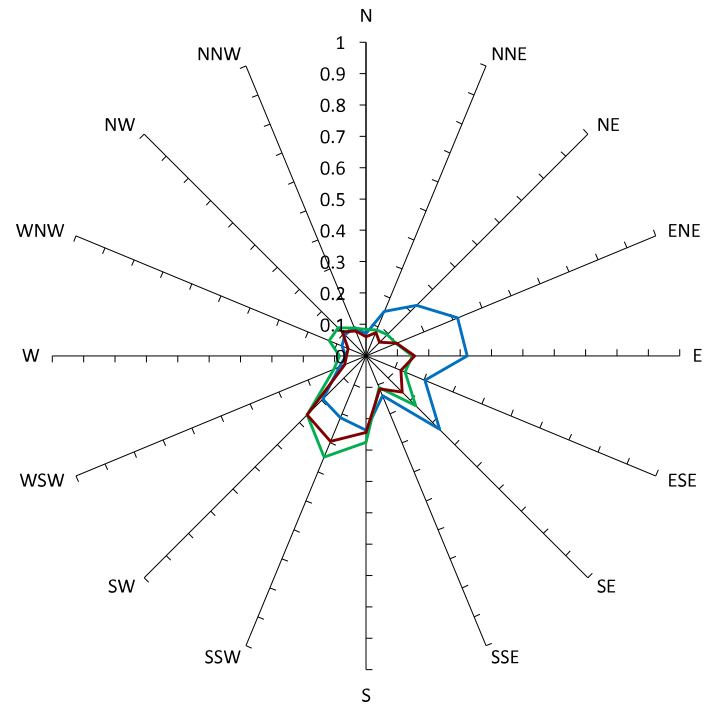
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.70	0.88%	4.60	< 0.001%	8.18
The Proposed Development with Existing Surrounds	< 0.01%	3.25	< 0.01%	4.28	< 0.001%	7.25
The Proposed Development with Future Surrounds	< 0.01%	3.08	< 0.01%	4.10	< 0.001%	6.56
The Proposed Development with Existing Surrounds and Mitigation						

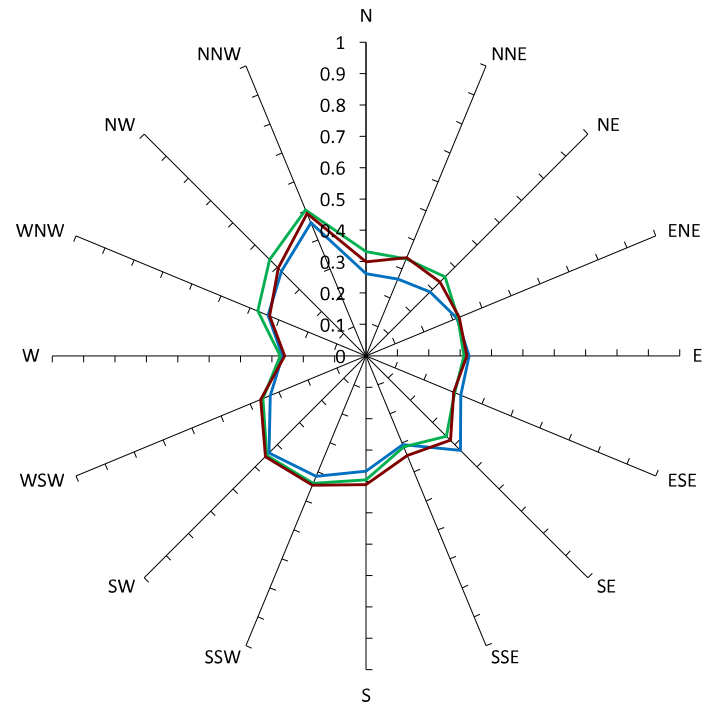
Results for P31

GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	2.38	< 0.01%	3.19	< 0.001%	5.64
The Proposed Development with Existing Surrounds	< 0.01%	2.92	< 0.01%	3.77	< 0.001%	6.28
The Proposed Development with Future Surrounds	< 0.01%	2.56	< 0.01%	3.27	< 0.001%	5.49
The Proposed Development with Existing Surrounds and Mitigation						

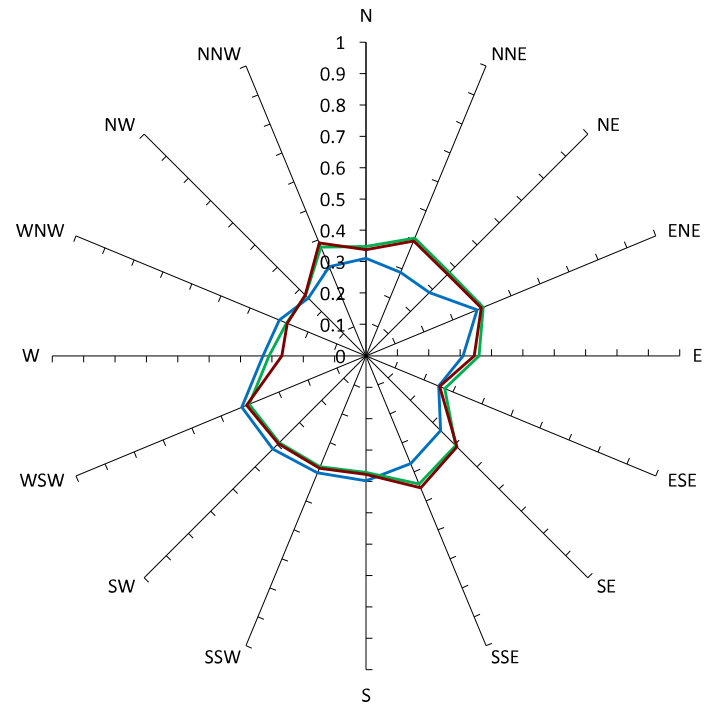
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.01	< 0.01%	5.05	< 0.001%	8.63
The Proposed Development with Existing Surrounds	< 0.01%	4.25	< 0.01%	5.33	< 0.001%	9.06
The Proposed Development with Future Surrounds	< 0.01%	4.25	< 0.01%	5.40	< 0.001%	9.10
The Proposed Development with Existing Surrounds and Mitigation						

Results for P33

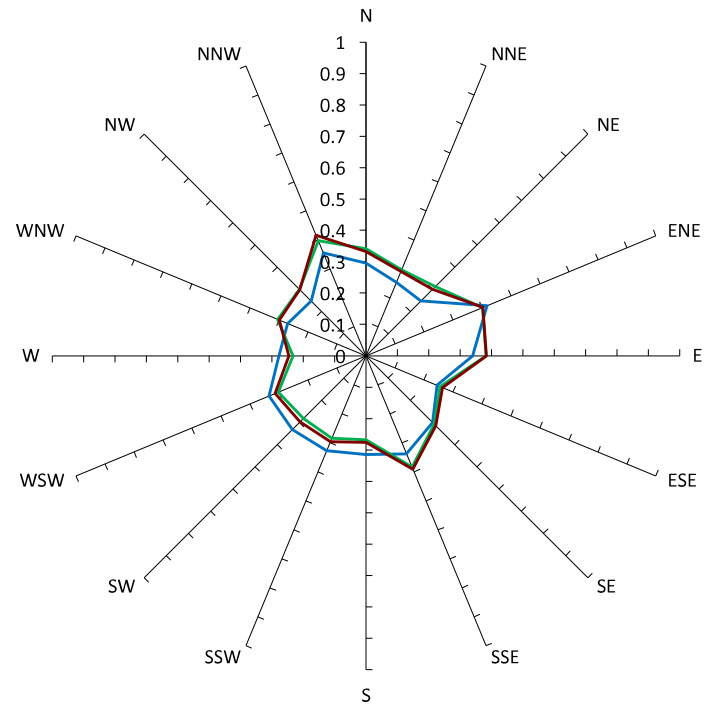
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.06	< 0.01%	5.24	< 0.001%	9.09
The Proposed Development with Existing Surrounds	< 0.01%	3.99	< 0.01%	5.20	< 0.001%	8.75
The Proposed Development with Future Surrounds	< 0.01%	4.03	< 0.01%	5.25	< 0.001%	8.90
The Proposed Development with Existing Surrounds and Mitigation						

Results for P34

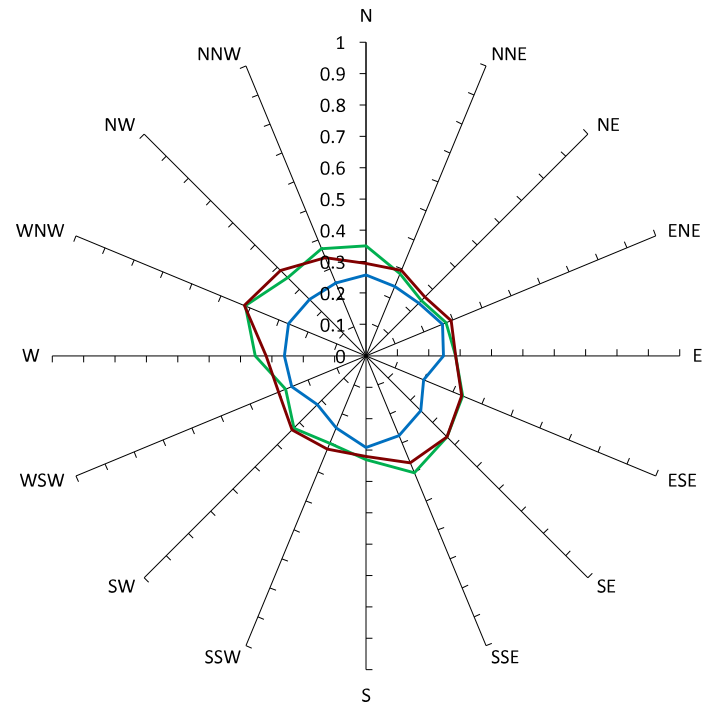
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.38	0.61%	4.49	< 0.001%	7.58
The Proposed Development with Existing Surrounds	< 0.01%	3.32	0.53%	4.40	< 0.001%	7.42
The Proposed Development with Future Surrounds	< 0.01%	3.38	0.60%	4.48	< 0.001%	7.54
The Proposed Development with Existing Surrounds and Mitigation						

Results for P35

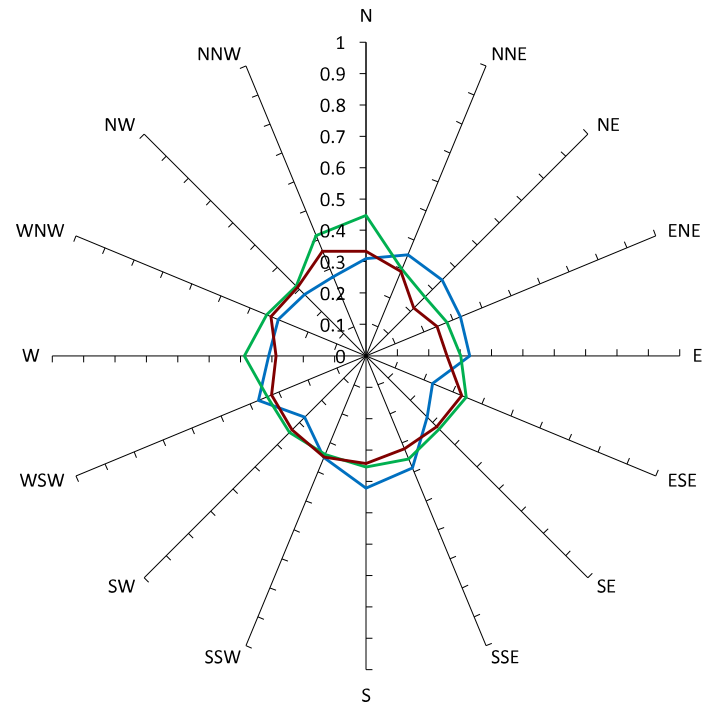
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	2.78	< 0.01%	3.65	< 0.001%	5.87
The Proposed Development with Existing Surrounds	< 0.01%	3.81	0.98%	4.76	< 0.001%	8.02
The Proposed Development with Future Surrounds	< 0.01%	3.79	0.81%	4.63	< 0.001%	7.92
The Proposed Development with Existing Surrounds and Mitigation						

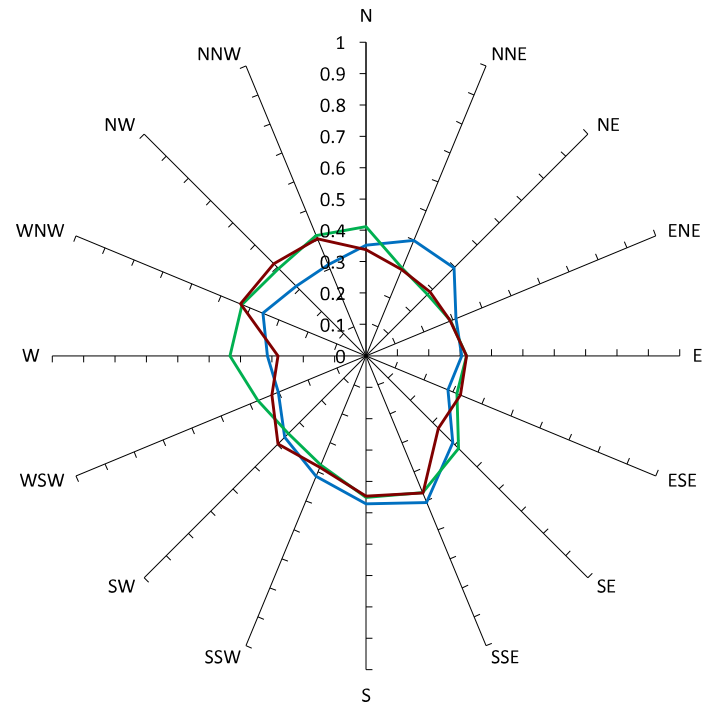
Results for P36

GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.73	< 0.01%	5.02	< 0.001%	8.09
The Proposed Development with Existing Surrounds	< 0.01%	3.80	< 0.01%	4.86	< 0.001%	8.23
The Proposed Development with Future Surrounds	< 0.01%	3.46	< 0.01%	4.47	< 0.001%	7.35
The Proposed Development with Existing Surrounds and Mitigation						

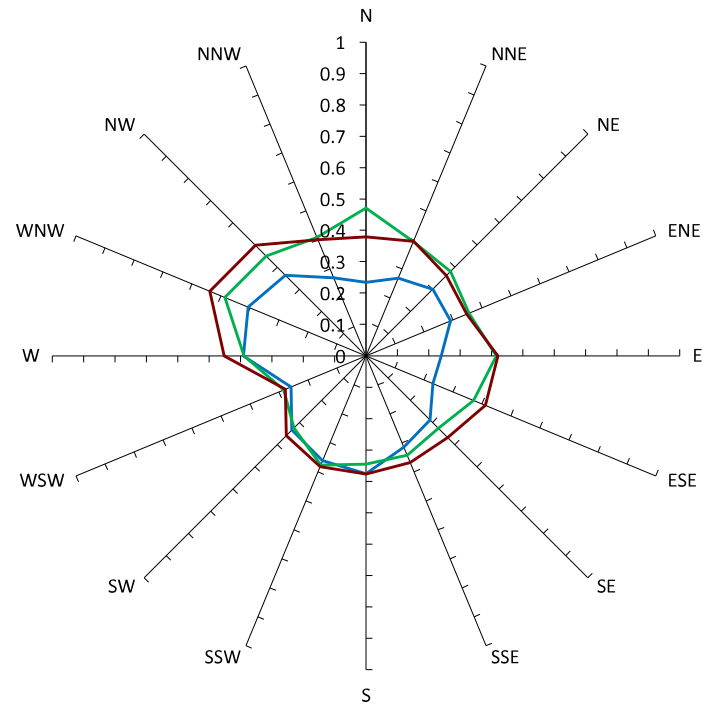
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.27	< 0.01%	5.75	< 0.001%	9.07
The Proposed Development with Existing Surrounds	< 0.01%	4.40	< 0.01%	5.75	< 0.001%	9.32
The Proposed Development with Future Surrounds	< 0.01%	4.27	< 0.01%	5.54	< 0.001%	8.93
The Proposed Development with Existing Surrounds and Mitigation						

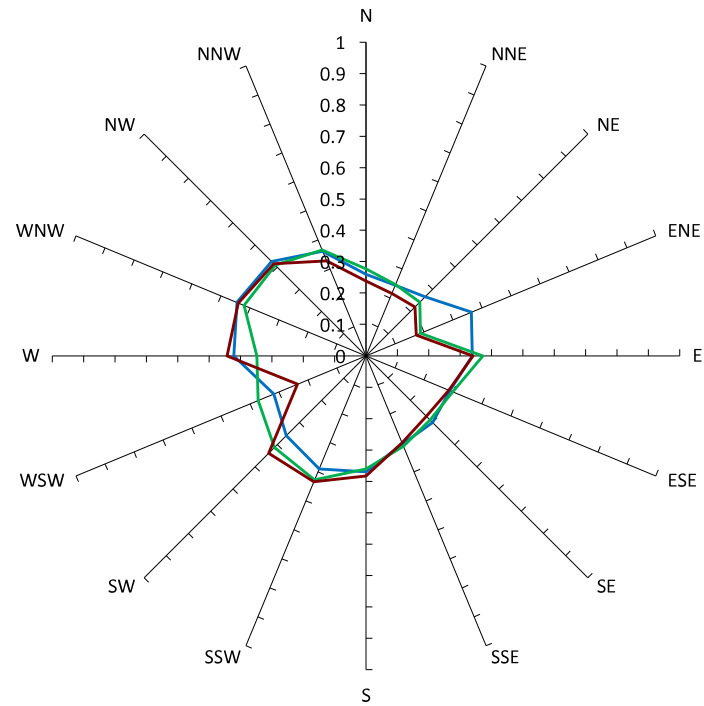
Results for P38

GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.91	< 0.01%	4.92	< 0.001%	8.19
The Proposed Development with Existing Surrounds	< 0.01%	4.38	< 0.01%	5.24	< 0.001%	9.16
The Proposed Development with Future Surrounds	< 0.01%	4.81	< 0.01%	5.70	< 0.001%	10.10
The Proposed Development with Existing Surrounds and Mitigation						

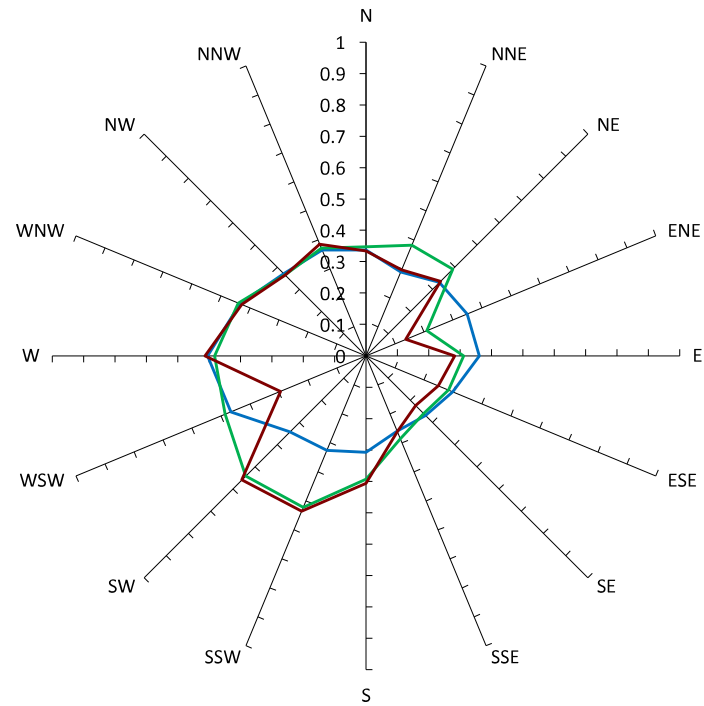
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.25	< 0.01%	5.26	< 0.001%	8.89
The Proposed Development with Existing Surrounds	< 0.01%	4.17	< 0.01%	5.22	< 0.001%	8.81
The Proposed Development with Future Surrounds	< 0.01%	4.44	< 0.01%	5.54	< 0.001%	9.38
The Proposed Development with Existing Surrounds and Mitigation						

Results for P40

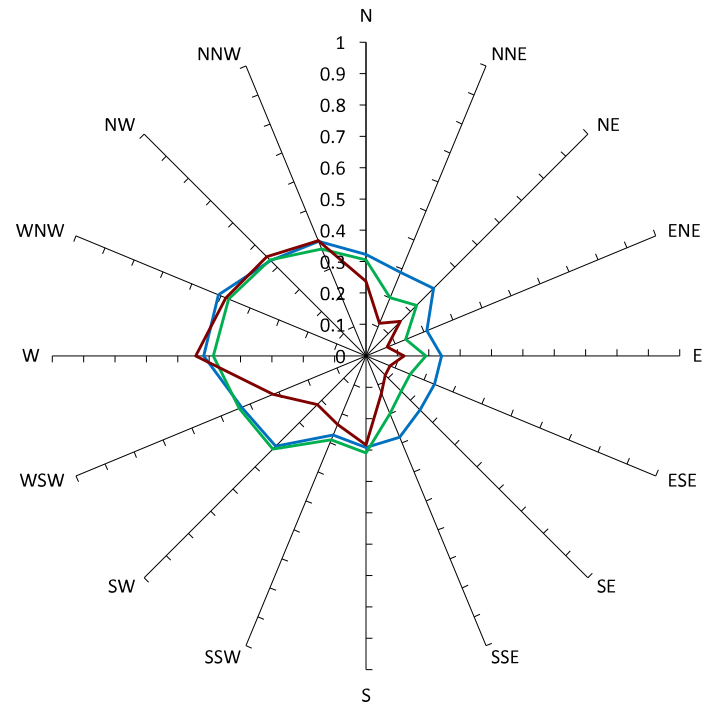
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.67	0.64%	5.72	< 0.001%	10.44
The Proposed Development with Existing Surrounds	< 0.01%	5.09	1.24%	6.42	< 0.001%	11.15
The Proposed Development with Future Surrounds	< 0.01%	5.18	1.30%	6.48	< 0.001%	11.18
The Proposed Development with Existing Surrounds and Mitigation						

Results for P41

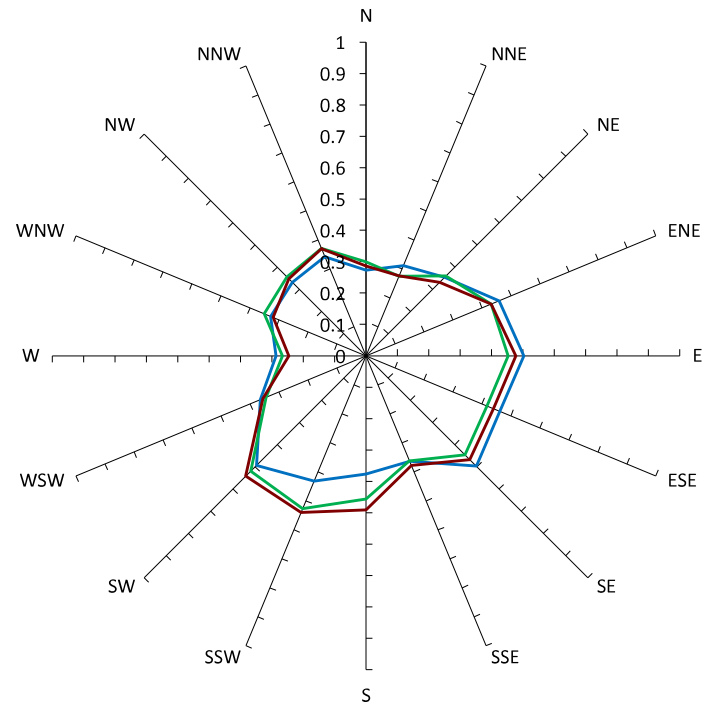
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	0.78%	4.90	5.11%	5.92	< 0.001%	10.61
The Proposed Development with Existing Surrounds	< 0.01%	4.66	4.02%	5.68	< 0.001%	10.18
The Proposed Development with Future Surrounds	0.83%	4.93	4.93%	5.88	< 0.001%	10.75
The Proposed Development with Existing Surrounds and Mitigation						

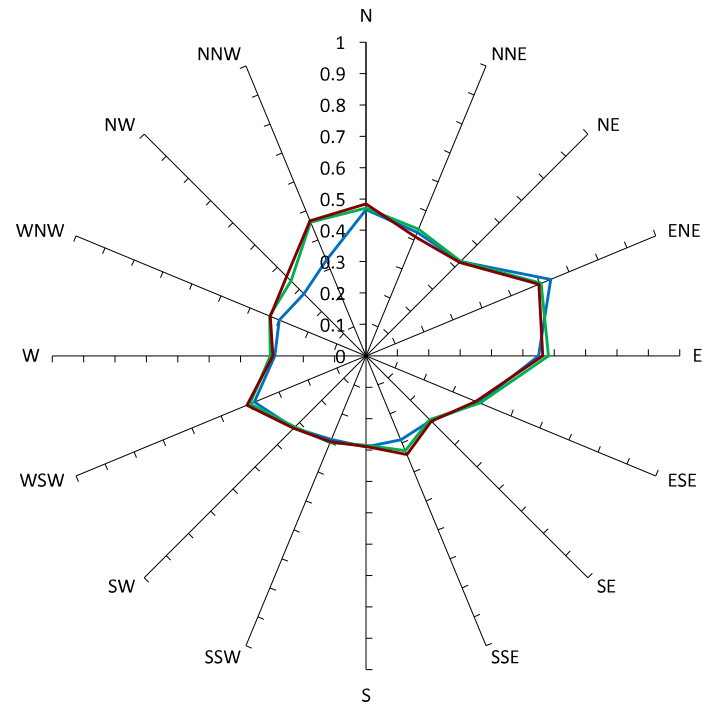
Results for P42

GEM Velocity Coefficients



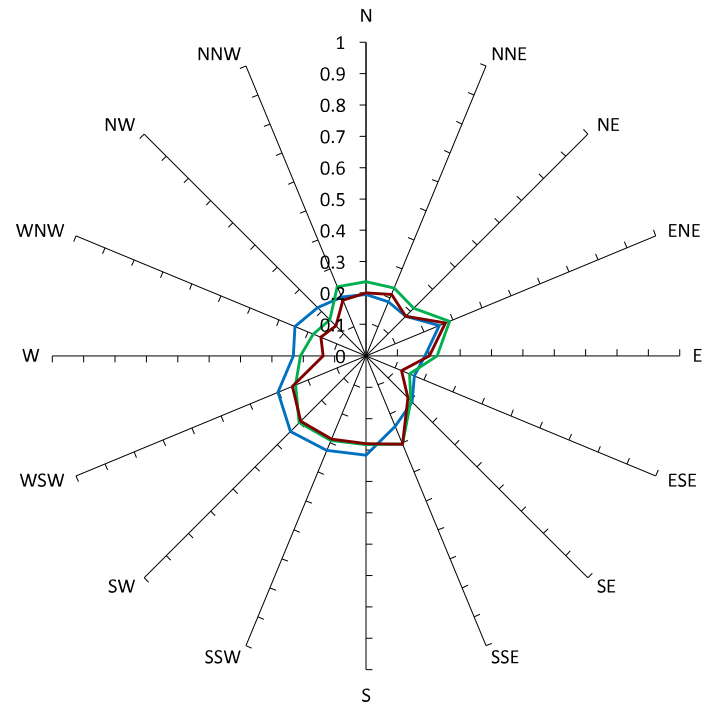
Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.42	< 0.01%	5.59	< 0.001%	9.68
The Proposed Development with Existing Surrounds	< 0.01%	4.82	0.72%	6.14	< 0.001%	10.28
The Proposed Development with Future Surrounds	< 0.01%	5.01	0.98%	6.39	< 0.001%	10.68
The Proposed Development with Existing Surrounds and Mitigation						

GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.14	0.77%	5.21	< 0.001%	10.76
The Proposed Development with Existing Surrounds	< 0.01%	4.24	0.67%	5.44	< 0.001%	10.48
The Proposed Development with Future Surrounds	< 0.01%	4.20	0.62%	5.41	< 0.001%	10.36
The Proposed Development with Existing Surrounds and Mitigation						

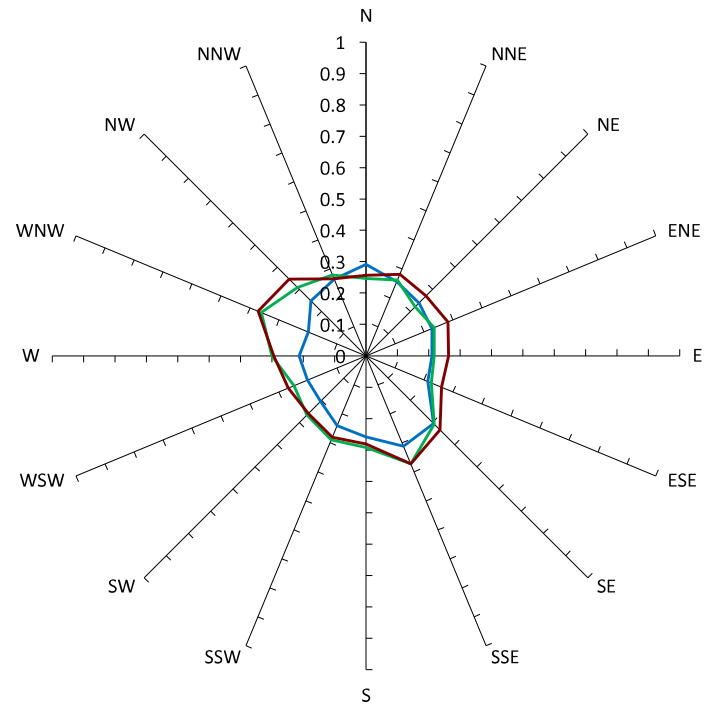
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.16	< 0.01%	4.05	< 0.001%	6.90
The Proposed Development with Existing Surrounds	< 0.01%	2.86	< 0.01%	3.73	< 0.001%	6.11
The Proposed Development with Future Surrounds	< 0.01%	2.81	< 0.01%	3.66	< 0.001%	6.04
The Proposed Development with Existing Surrounds and Mitigation						

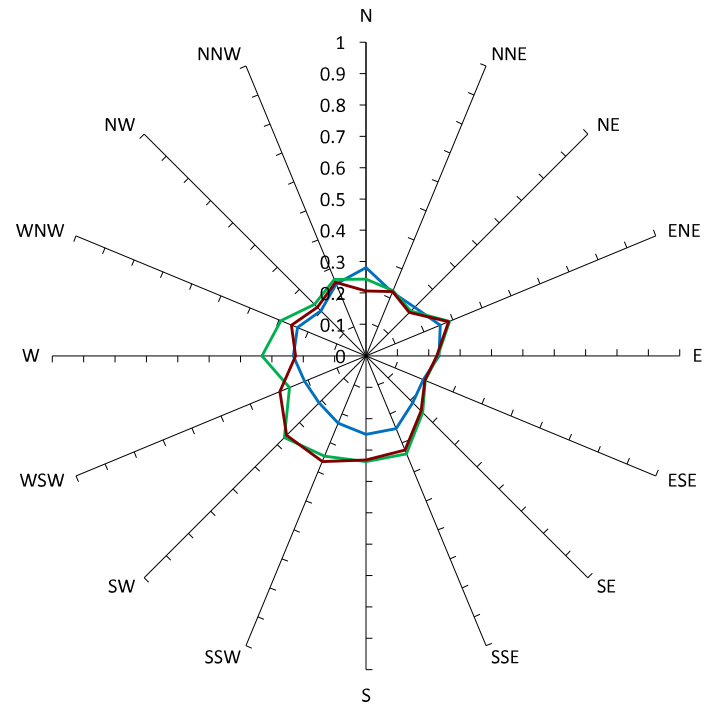
Results for P45

GEM Velocity Coefficients



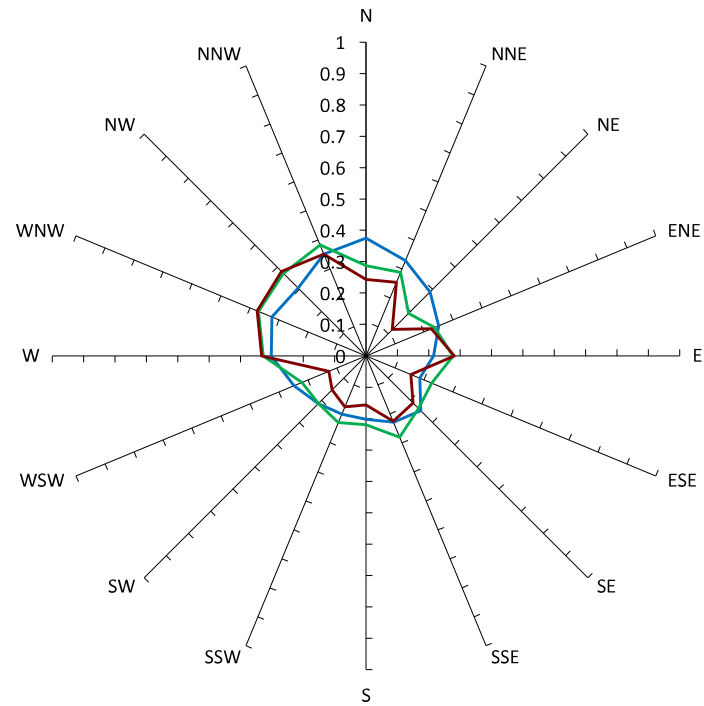
Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	2.57	< 0.01%	3.42	< 0.001%	5.56
The Proposed Development with Existing Surrounds	< 0.01%	3.32	< 0.01%	4.20	< 0.001%	7.02
The Proposed Development with Future Surrounds	< 0.01%	3.39	< 0.01%	4.23	< 0.001%	7.15
The Proposed Development with Existing Surrounds and Mitigation						

GEM Velocity Coefficients



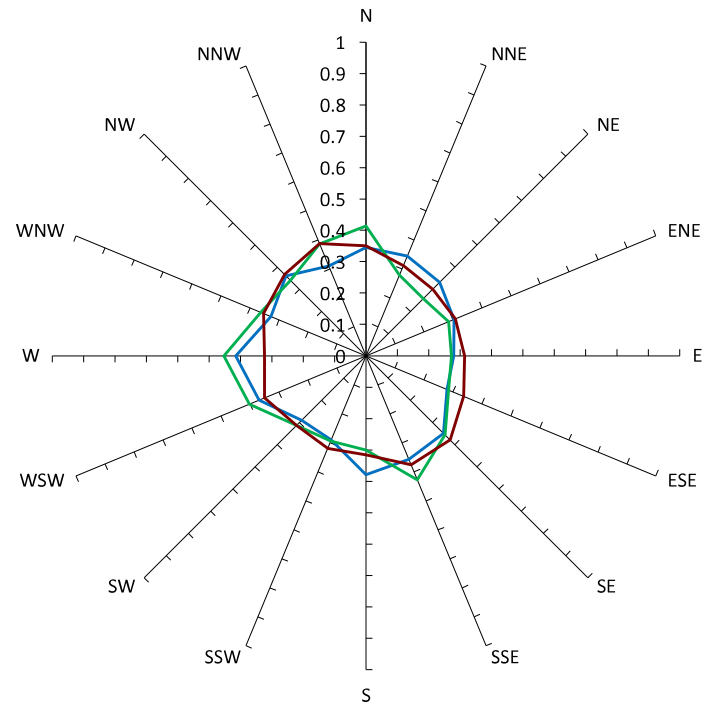
Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	2.48	< 0.01%	3.25	< 0.001%	5.25
The Proposed Development with Existing Surrounds	< 0.01%	3.48	0.54%	4.48	< 0.001%	7.41
The Proposed Development with Future Surrounds	< 0.01%	3.38	< 0.01%	4.37	< 0.001%	7.24
The Proposed Development with Existing Surrounds and Mitigation						

GEM Velocity Coefficients



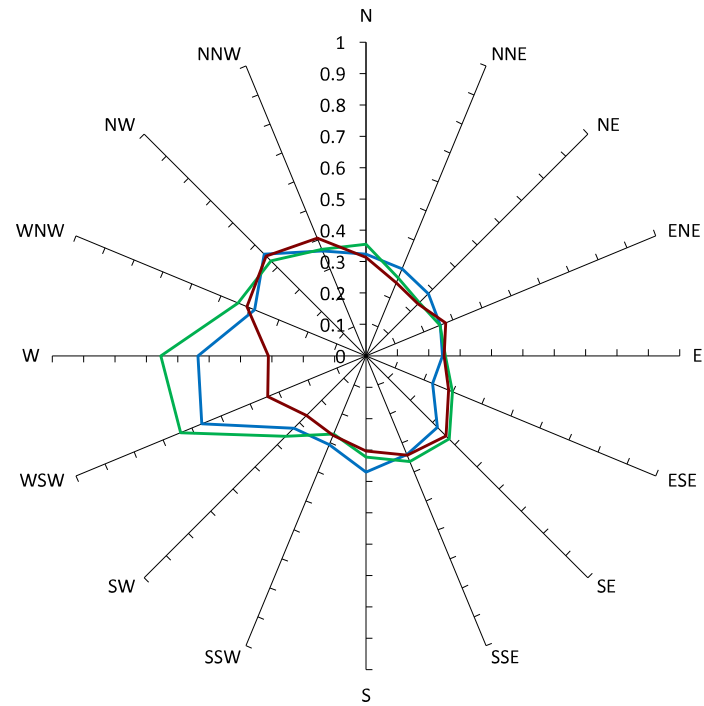
Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.06	< 0.01%	3.70	< 0.001%	6.62
The Proposed Development with Existing Surrounds	< 0.01%	3.39	< 0.01%	4.00	< 0.001%	7.18
The Proposed Development with Future Surrounds	< 0.01%	3.42	< 0.01%	3.95	< 0.001%	7.24
The Proposed Development with Existing Surrounds and Mitigation						

GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	3.91	< 0.01%	4.97	< 0.001%	8.52
The Proposed Development with Existing Surrounds	< 0.01%	4.19	< 0.01%	5.27	< 0.001%	9.29
The Proposed Development with Future Surrounds	< 0.01%	3.59	< 0.01%	4.59	< 0.001%	7.75
The Proposed Development with Existing Surrounds and Mitigation						

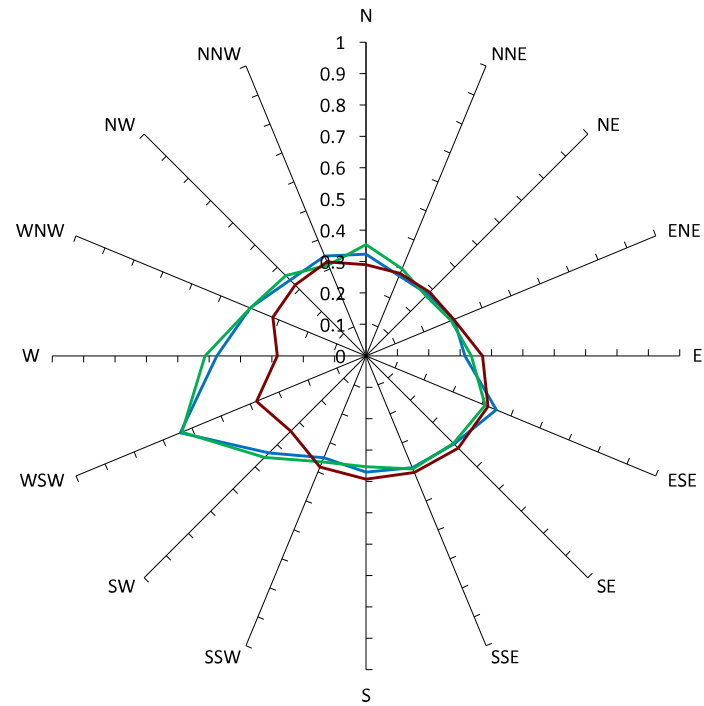
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	5.02	1.22%	6.15	< 0.001%	11.86
The Proposed Development with Existing Surrounds	< 0.01%	5.98	3.32%	7.27	< 0.001%	13.81
The Proposed Development with Future Surrounds	< 0.01%	3.83	< 0.01%	4.50	< 0.001%	8.10
The Proposed Development with Existing Surrounds and Mitigation						

Results for P50

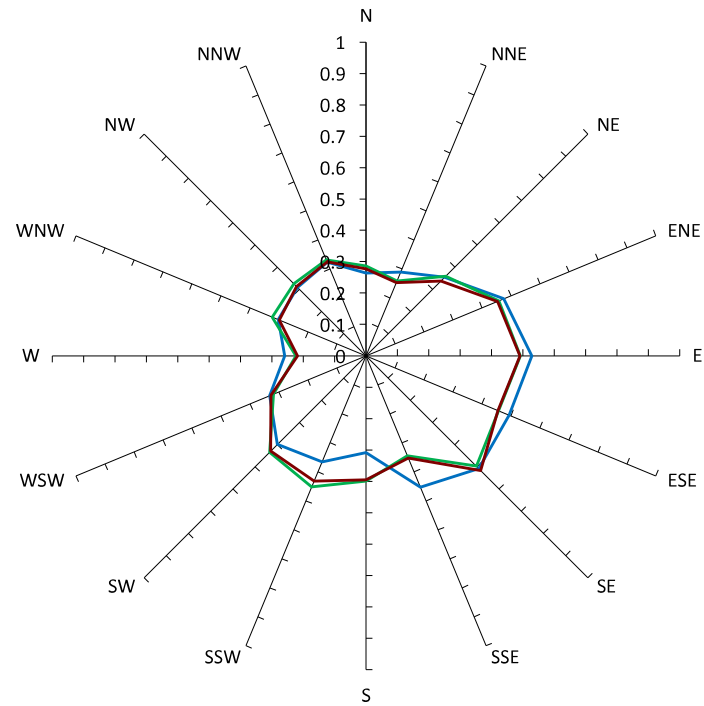
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	5.01	1.43%	6.18	< 0.001%	12.97
The Proposed Development with Existing Surrounds	< 0.01%	5.15	1.62%	6.37	< 0.001%	12.93
The Proposed Development with Future Surrounds	< 0.01%	3.81	< 0.01%	5.03	< 0.001%	8.22
The Proposed Development with Existing Surrounds and Mitigation						

Results for P51

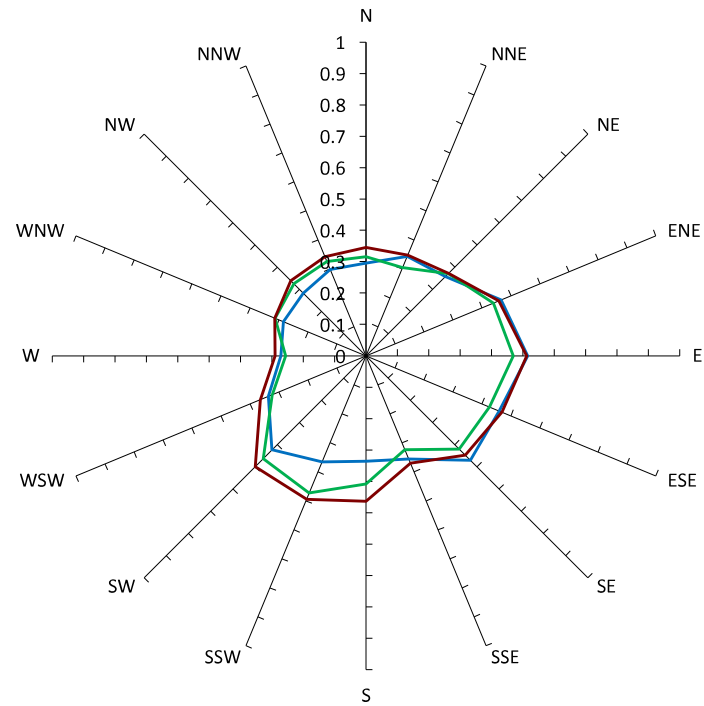
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.09	< 0.01%	5.40	< 0.001%	9.18
The Proposed Development with Existing Surrounds	< 0.01%	4.28	< 0.01%	5.54	< 0.001%	9.14
The Proposed Development with Future Surrounds	< 0.01%	4.20	< 0.01%	5.45	< 0.001%	9.04
The Proposed Development with Existing Surrounds and Mitigation						

Results for P52

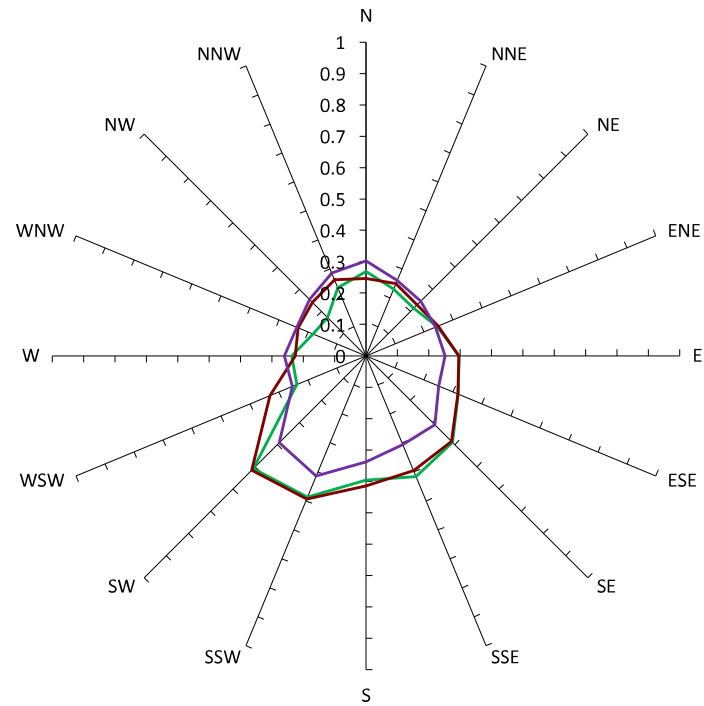
GEM Velocity Coefficients



Configuration	Summer Probability of Exceedance (%)	Summer Velocity to Cause (m/s)	Winter Probability of Exceedance (%)	Winter Velocity to Cause (m/s)	Annual Probability of Exceedance (%)	Annual Velocity to Cause (m/s)
The Existing Site with Existing Surrounds	< 0.01%	4.02	2.10%	5.19	< 0.001%	8.98
The Proposed Development with Existing Surrounds	< 0.01%	4.39	3.42%	5.61	< 0.001%	9.33
The Proposed Development with Future Surrounds	0.83%	4.71	5.87%	6.06	< 0.001%	10.00
The Proposed Development with Existing Surrounds and Mitigation						

Results for P53

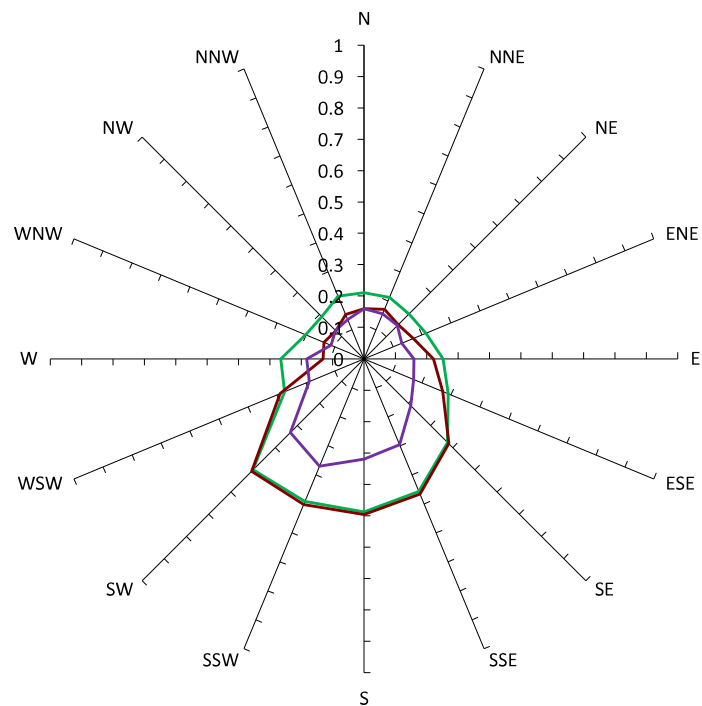
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	11.11%	4.49	27.87%	5.62	< 0.001%	9.80
The Proposed Development with Future Surrounds	11.87%	4.56	27.82%	5.71	< 0.001%	9.94
The Proposed Development with Existing Surrounds and Mitigation	2.98%	3.67	15.12%	4.68	< 0.001%	7.87

Results for P54

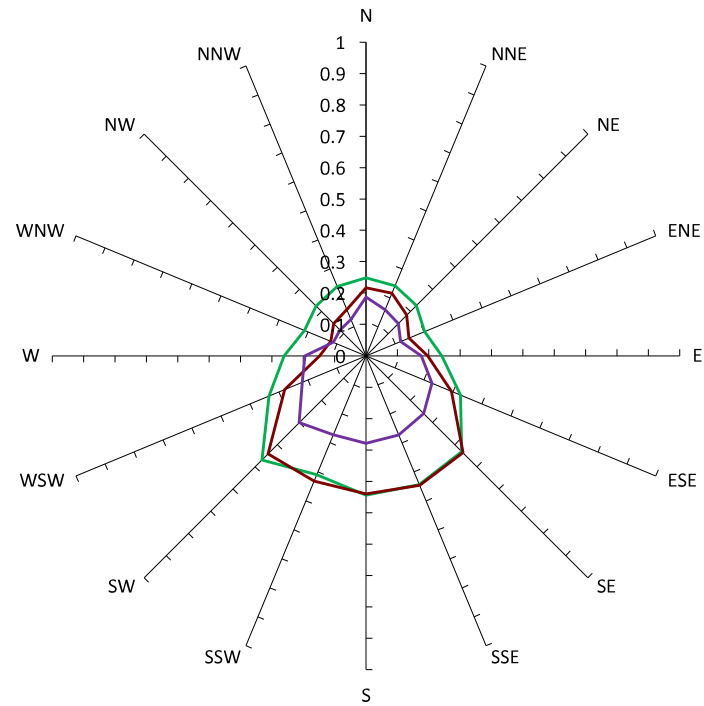
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	14.71%	4.65	30.51%	6.04	< 0.001%	9.92
The Proposed Development with Future Surrounds	16.12%	4.73	30.33%	6.15	< 0.001%	10.07
The Proposed Development with Existing Surrounds and Mitigation	1.10%	3.25	7.67%	4.20	< 0.001%	6.92

Results for P55

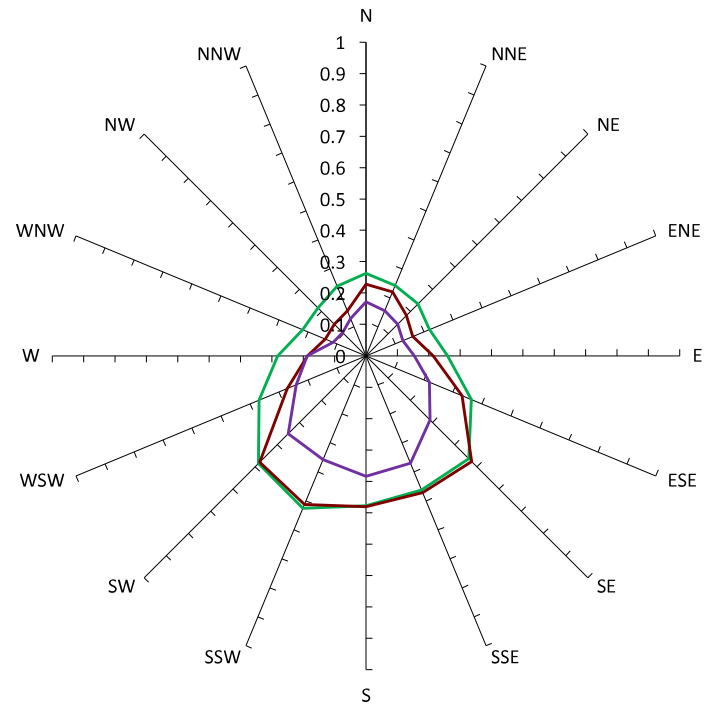
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	8.17%	4.24	29.24%	5.50	< 0.001%	9.16
The Proposed Development with Future Surrounds	7.47%	4.18	28.47%	5.47	< 0.001%	8.89
The Proposed Development with Existing Surrounds and Mitigation	< 0.01%	2.72	2.03%	3.51	< 0.001%	5.87

Results for P56

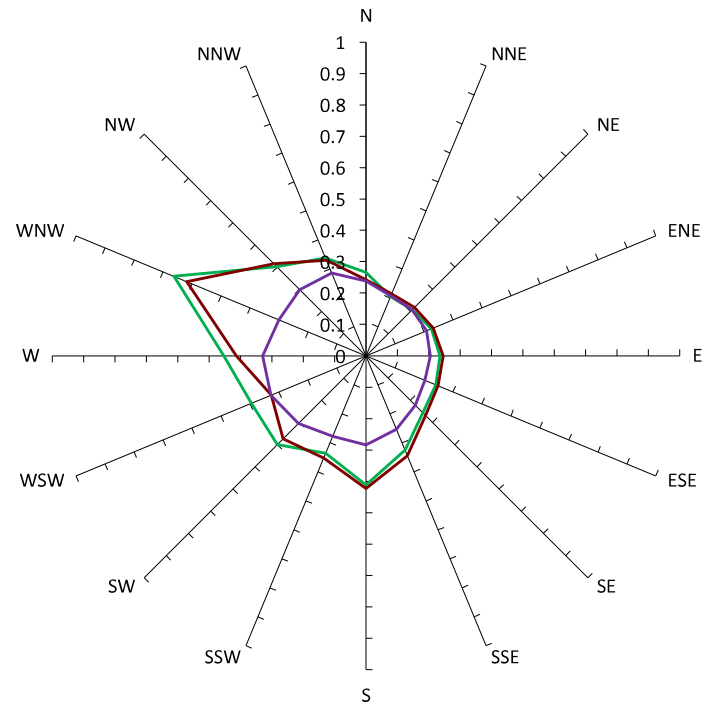
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	16.17%	4.74	32.62%	6.17	< 0.001%	10.05
The Proposed Development with Future Surrounds	15.22%	4.67	30.85%	6.09	< 0.001%	9.88
The Proposed Development with Existing Surrounds and Mitigation	1.82%	3.48	15.51%	4.62	< 0.001%	7.34

Results for P57

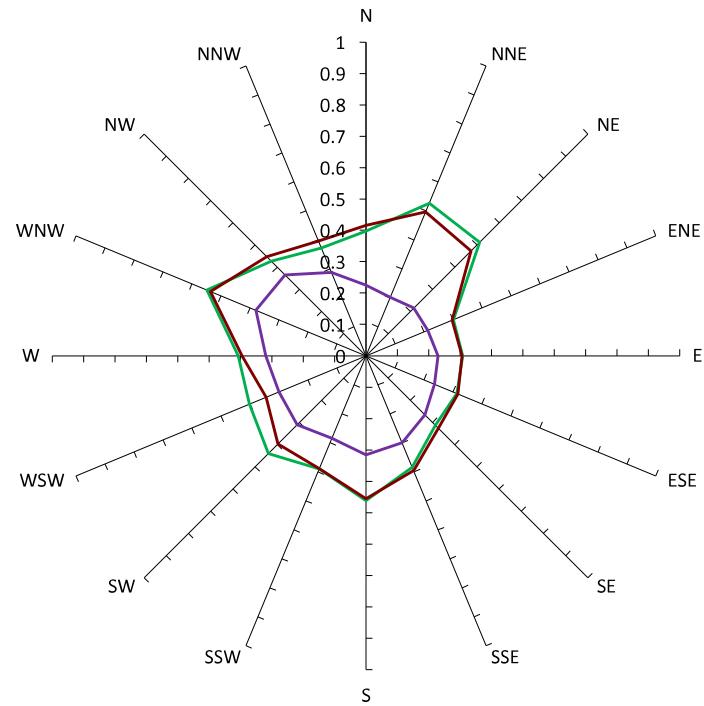
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	16.92%	5.59	25.46%	6.19	< 0.001%	11.94
The Proposed Development with Future Surrounds	13.71%	5.22	25.00%	5.84	< 0.001%	11.12
The Proposed Development with Existing Surrounds and Mitigation	0.80%	3.23	6.01%	4.06	< 0.001%	7.15

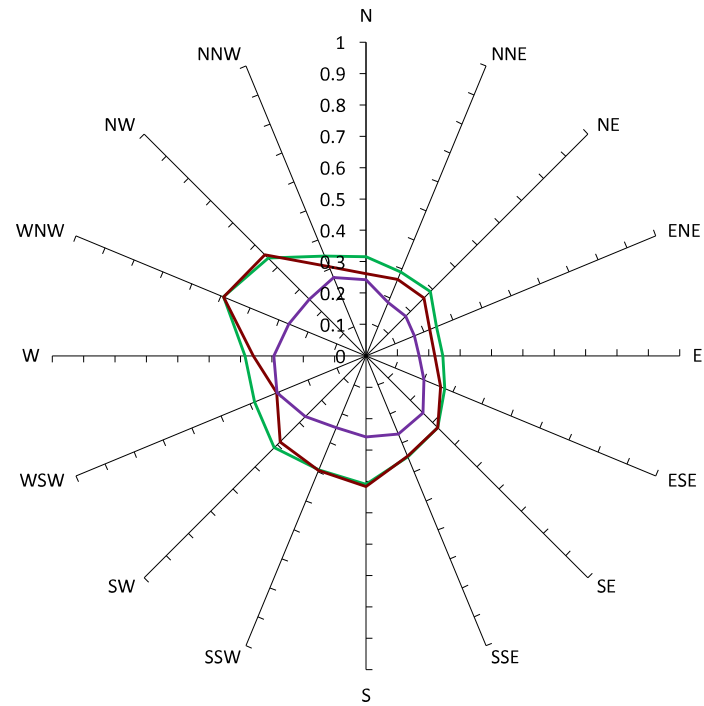
Results for P58

GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	0.94%	4.94	5.47%	5.99	< 0.001%	10.31
The Proposed Development with Future Surrounds	0.66%	4.79	4.41%	5.82	< 0.001%	9.93
The Proposed Development with Existing Surrounds and Mitigation	< 0.01%	3.49	< 0.01%	4.28	< 0.001%	7.36

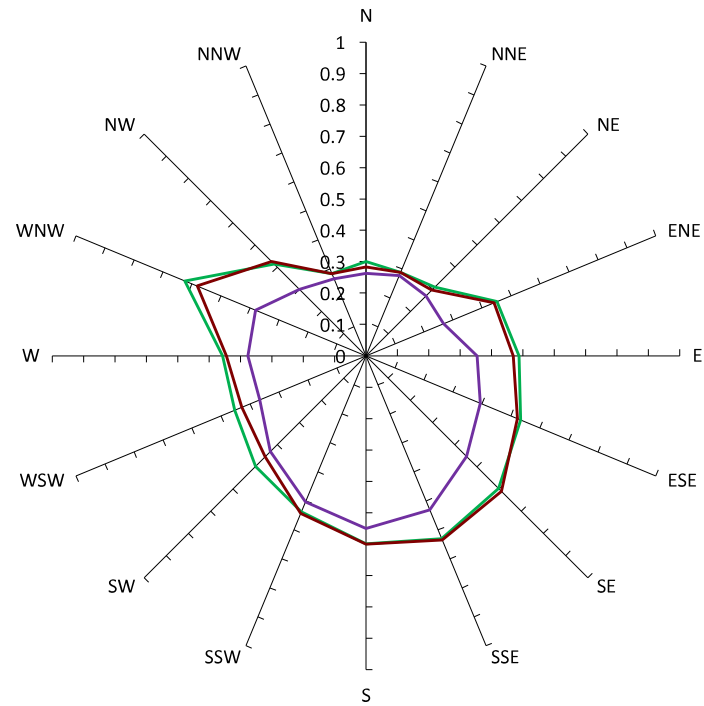
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	13.22%	4.47	29.13%	5.47	< 0.001%	9.41
The Proposed Development with Future Surrounds	12.01%	4.41	26.76%	5.37	< 0.001%	9.17
The Proposed Development with Existing Surrounds and Mitigation	< 0.01%	2.92	3.31%	3.70	< 0.001%	6.55

Results for P60

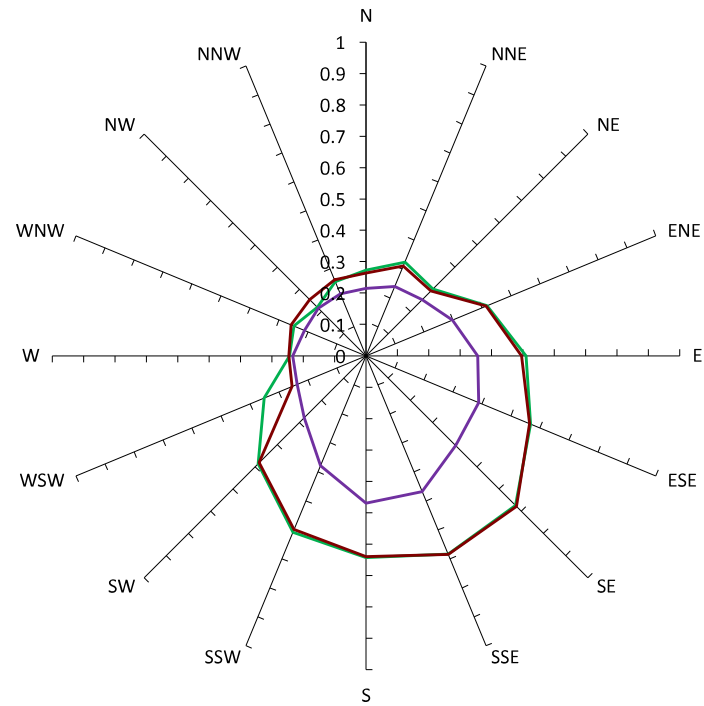
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	37.12%	5.85	45.70%	7.56	< 0.001%	12.20
The Proposed Development with Future Surrounds	34.62%	5.68	44.16%	7.48	< 0.001%	11.89
The Proposed Development with Existing Surrounds and Mitigation	20.32%	4.88	36.31%	6.59	< 0.001%	10.27

Results for P61

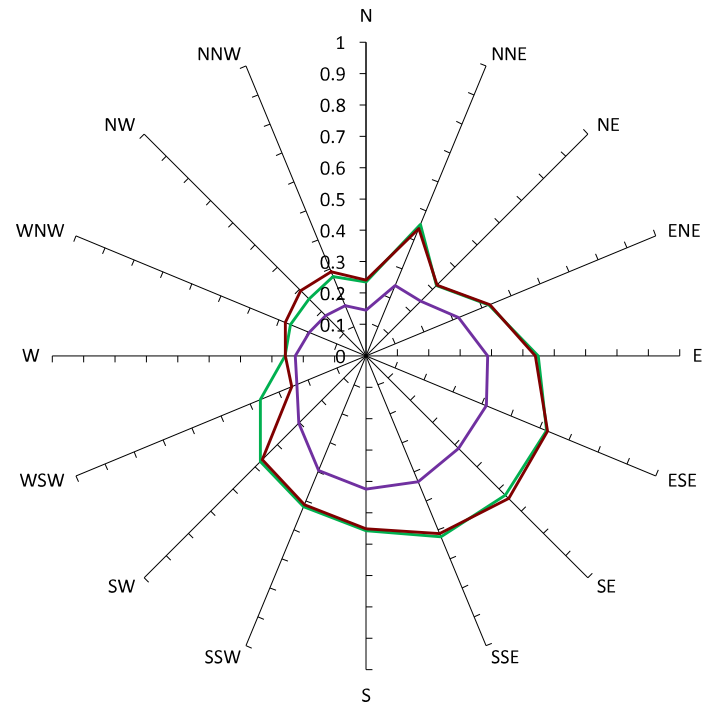
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	26.47%	5.86	39.28%	7.89	< 0.001%	12.46
The Proposed Development with Future Surrounds	25.84%	5.82	38.31%	7.84	< 0.001%	12.41
The Proposed Development with Existing Surrounds and Mitigation	5.66%	4.02	23.43%	5.50	< 0.001%	8.61

Results for P62

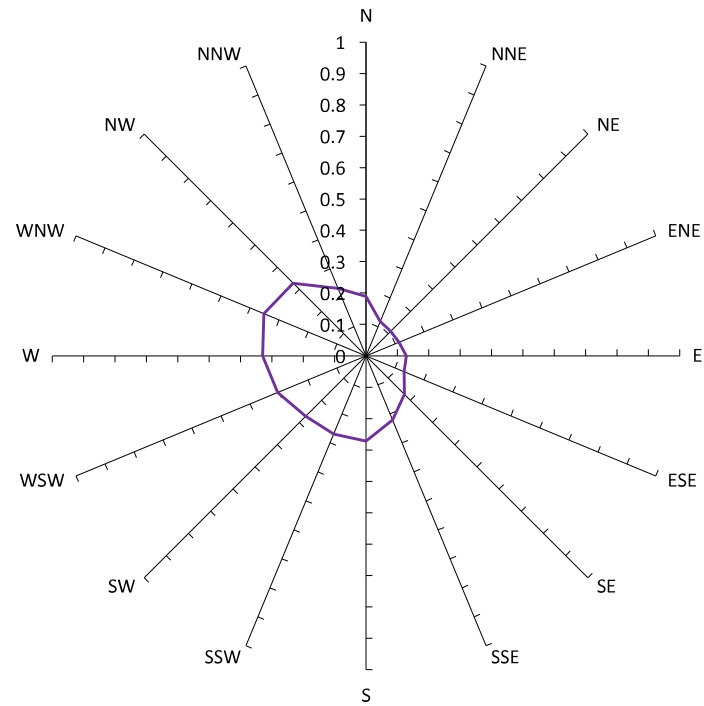
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds	26.23%	5.29	39.11%	7.06	< 0.001%	11.31
The Proposed Development with Future Surrounds	25.09%	5.22	37.96%	6.97	< 0.001%	11.20
The Proposed Development with Existing Surrounds and Mitigation	4.00%	3.84	24.24%	5.16	< 0.001%	8.09

Results for P63

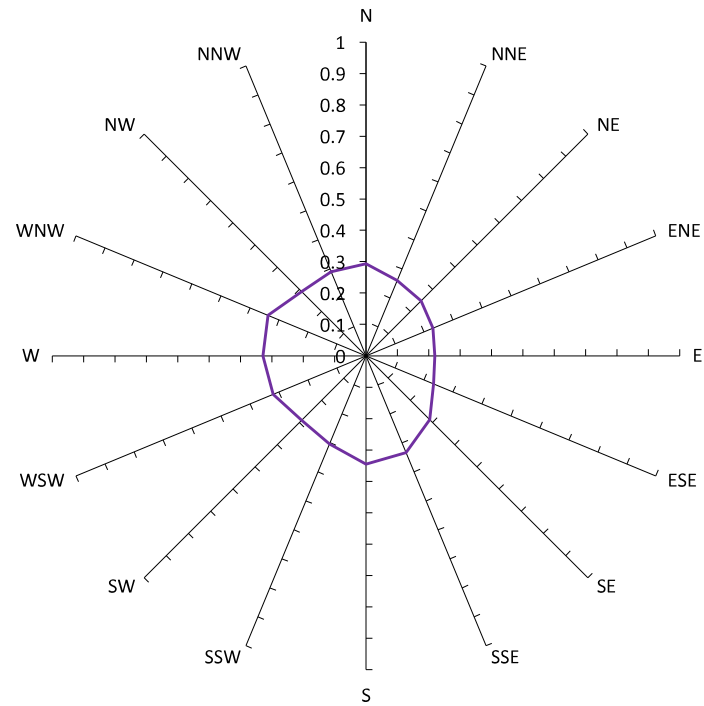
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds						
The Proposed Development with Future Surrounds						
The Proposed Development with Existing Surrounds and Mitigation	0.88%	3.30	5.75%	4.03	< 0.001%	7.10

Results for P64

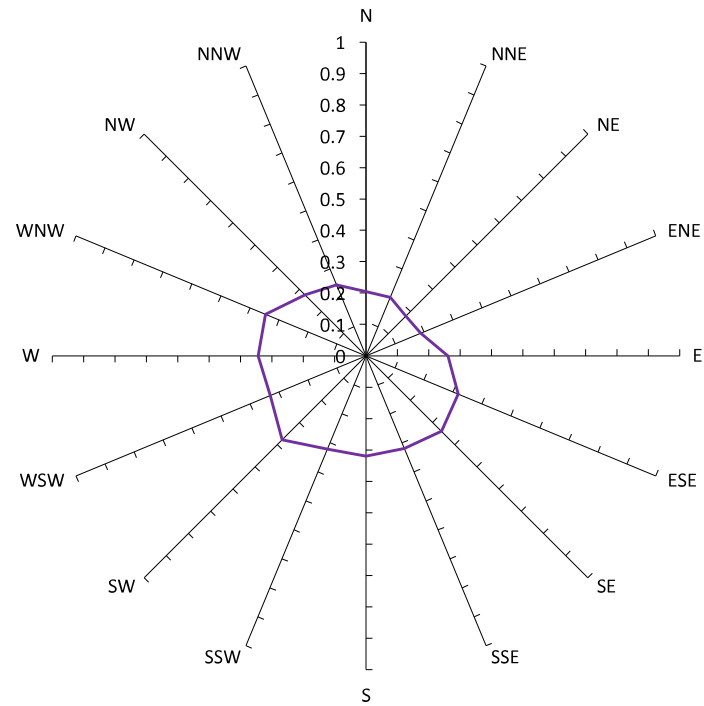
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds						
The Proposed Development with Future Surrounds						
The Proposed Development with Existing Surrounds and Mitigation	1.23%	3.40	10.78%	4.41	< 0.001%	7.26

Results for P65

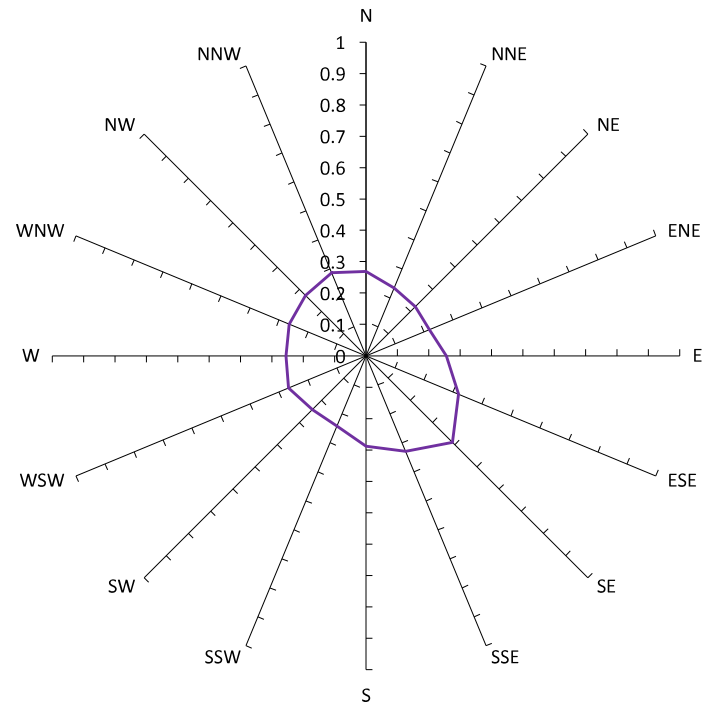
GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds						
The Proposed Development with Future Surrounds						
The Proposed Development with Existing Surrounds and Mitigation	2.17%	3.58	11.69%	4.51	< 0.001%	7.76

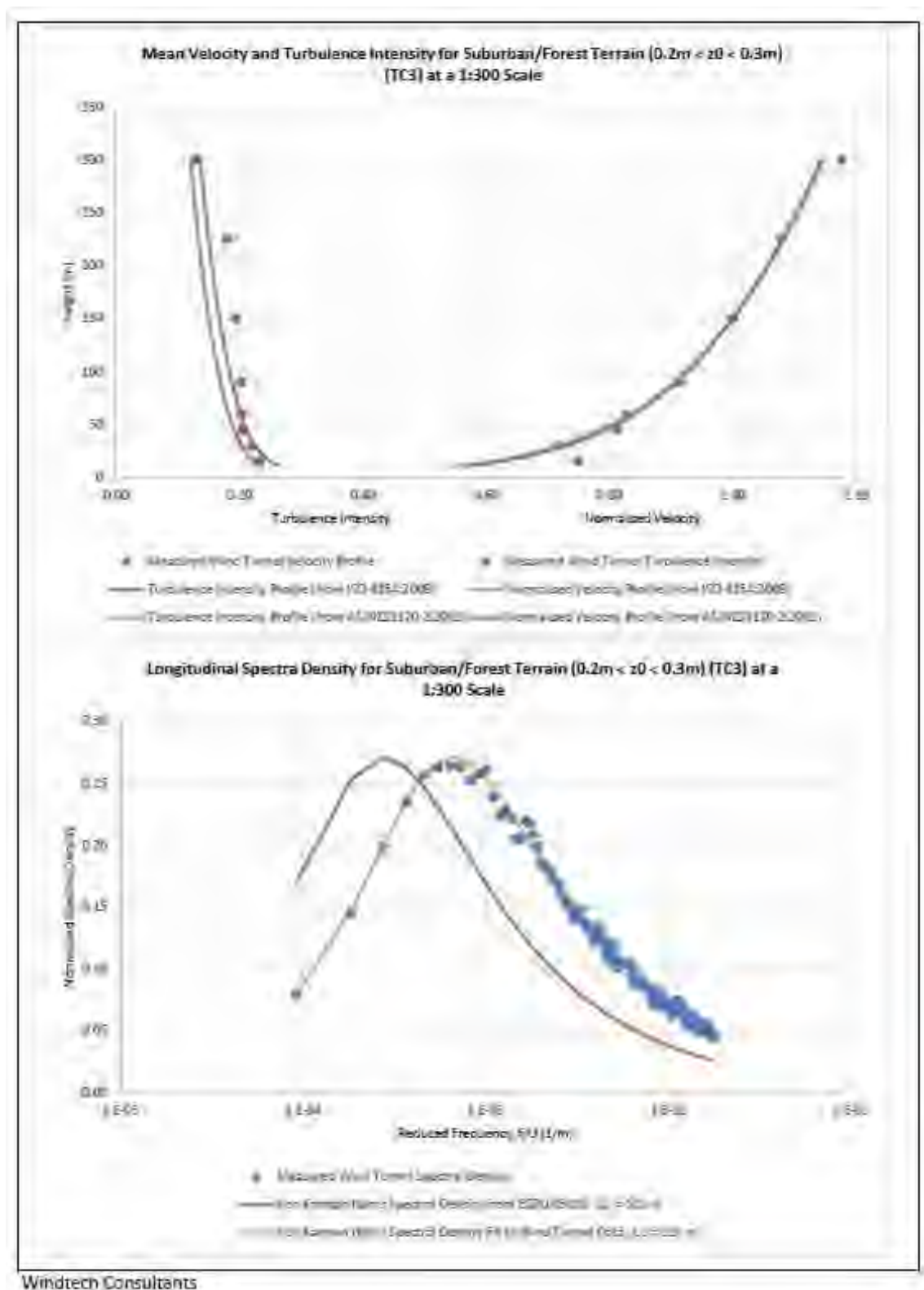
Results for P66

GEM Velocity Coefficients



Configuration	Summer	Summer	Winter	Winter	Annual	Annual
	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)	Probability of Exceedance (%)	Velocity to Cause (m/s)
The Existing Site with Existing Surrounds						
The Proposed Development with Existing Surrounds						
The Proposed Development with Future Surrounds						
The Proposed Development with Existing Surrounds and Mitigation	< 0.01%	2.89	4.02%	3.83	< 0.001%	6.33

APPENDIX D VELOCITY AND TURBULENCE INTENSITY PROFILES



APPENDIX E 3D RESULTS IMAGES – ELEVATED LEVELS

E.1 3D Study Points and Expected Intended Use

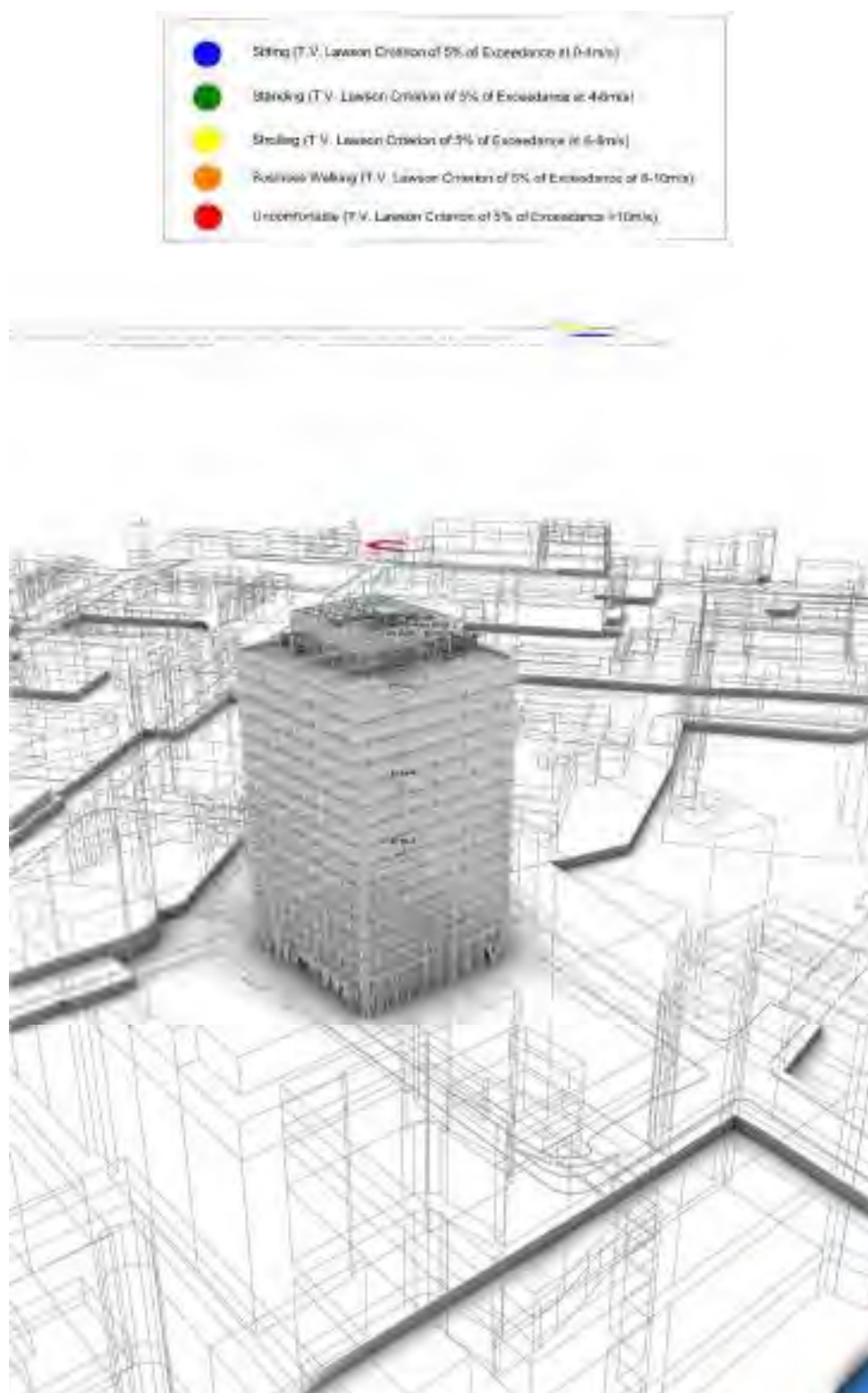


Figure E.1: Study Point Locations and Target Wind Speed Criteria – The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (North Aspect)



Figure E.2: Study Point Locations and Target Wind Speed Criteria – The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (East Aspect)



Figure E.3: Study Point Locations and Target Wind Speed Criteria – The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (South Aspect)



Figure E.4: Study Point Locations and Target Wind Speed Criteria – The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (West Aspect)

E.2 3D Annual Wind Safety Results

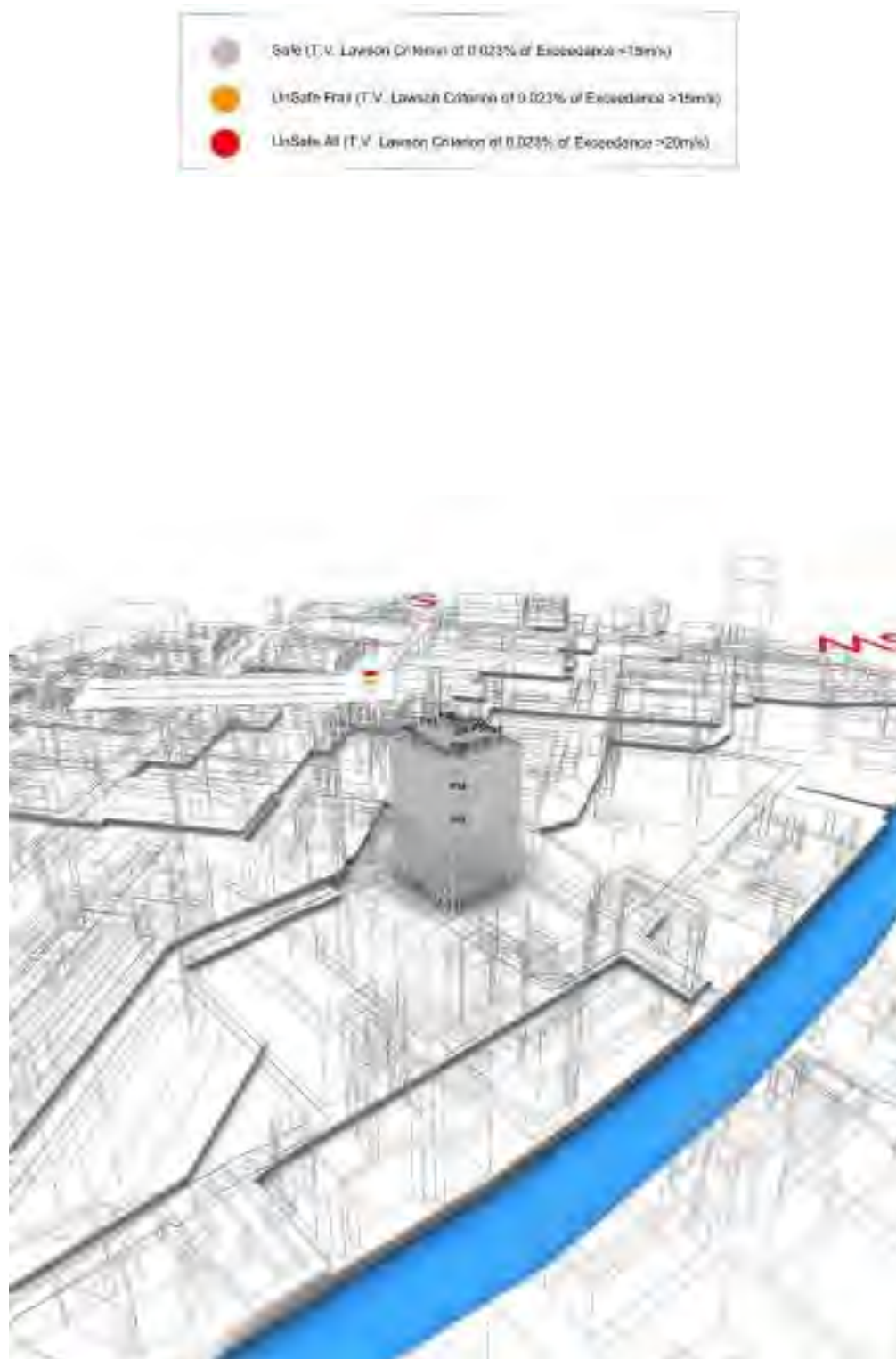


Figure E.5: The Proposed Development with Existing Surrounds: 3D Elevated Levels (North Aspect), Safety Results

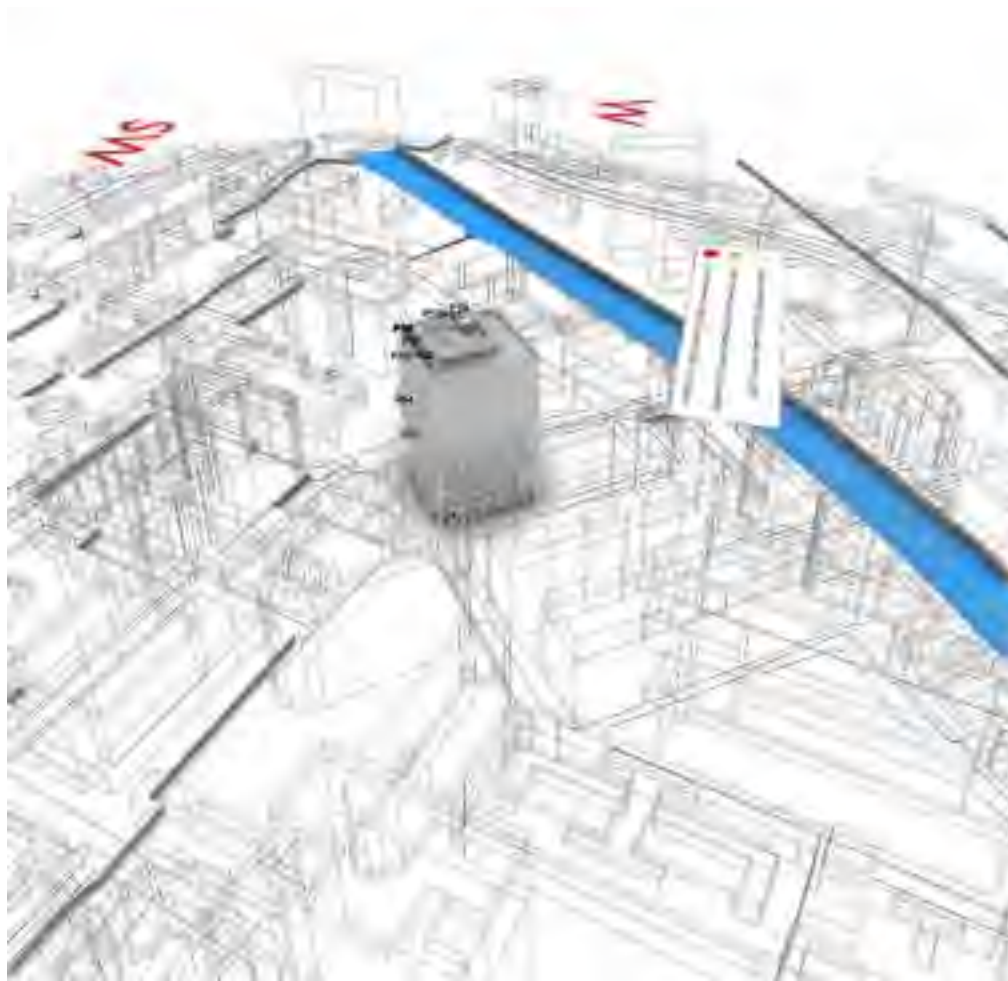


Figure E.6: The Proposed Development with Existing Surrounds: 3D Elevated Levels (East Aspect), Safety Results



Figure E.7: The Proposed Development with Existing Surrounds: 3D Elevated Levels (South Aspect), Safety Results



Figure E.8: The Proposed Development with Existing Surrounds: 3D Elevated Levels (West Aspect), Safety Results

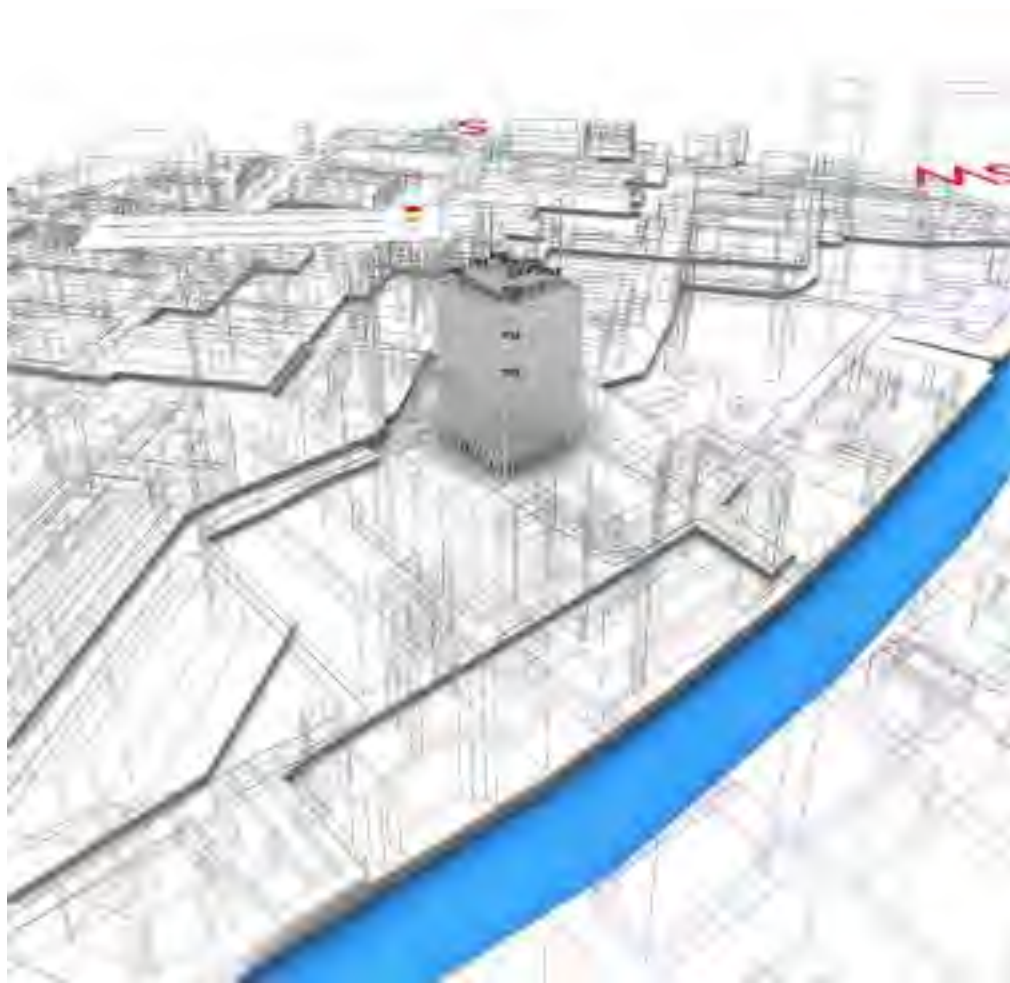


Figure E.9: The Proposed Development with Future Surrounds: 3D Elevated Levels (North Aspect), Safety Results

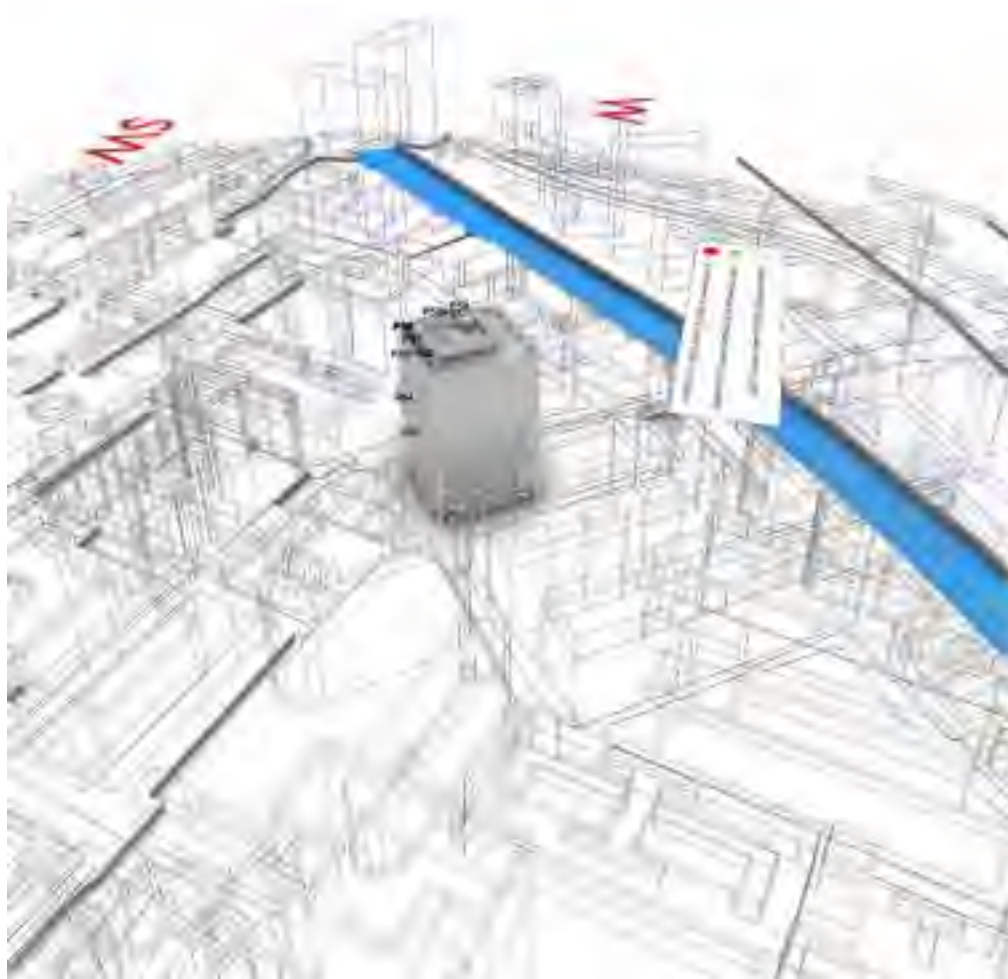


Figure E.10: The Proposed Development with Future Surrounds: 3D Elevated Levels (East Aspect), Safety Results

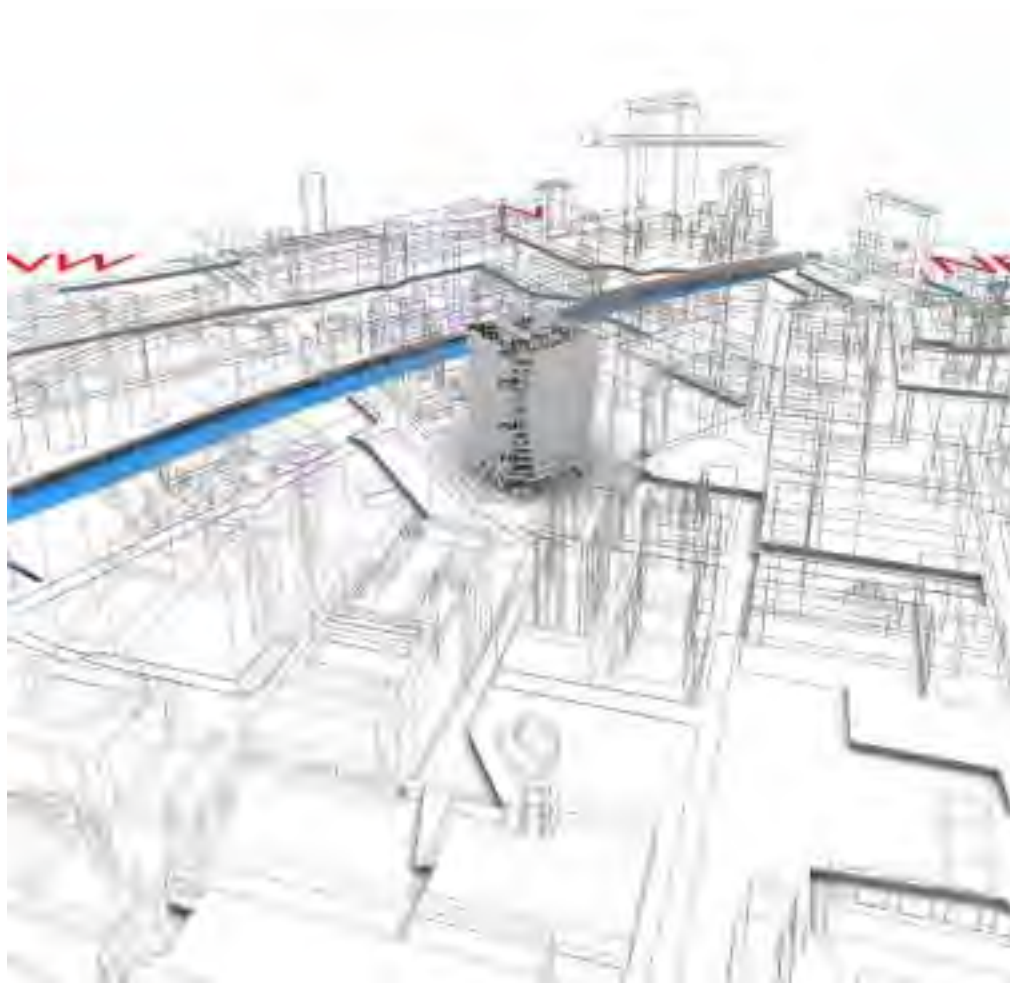


Figure E.11: The Proposed Development with Future Surrounds: 3D Elevated Levels (South Aspect), Safety Results



Figure E.12: The Proposed Development with Future Surrounds: 3D Elevated Levels (West Aspect), Safety Results



Figure E.13: The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (North Aspect), Safety Results



Figure E.14: The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (East Aspect), Safety Results

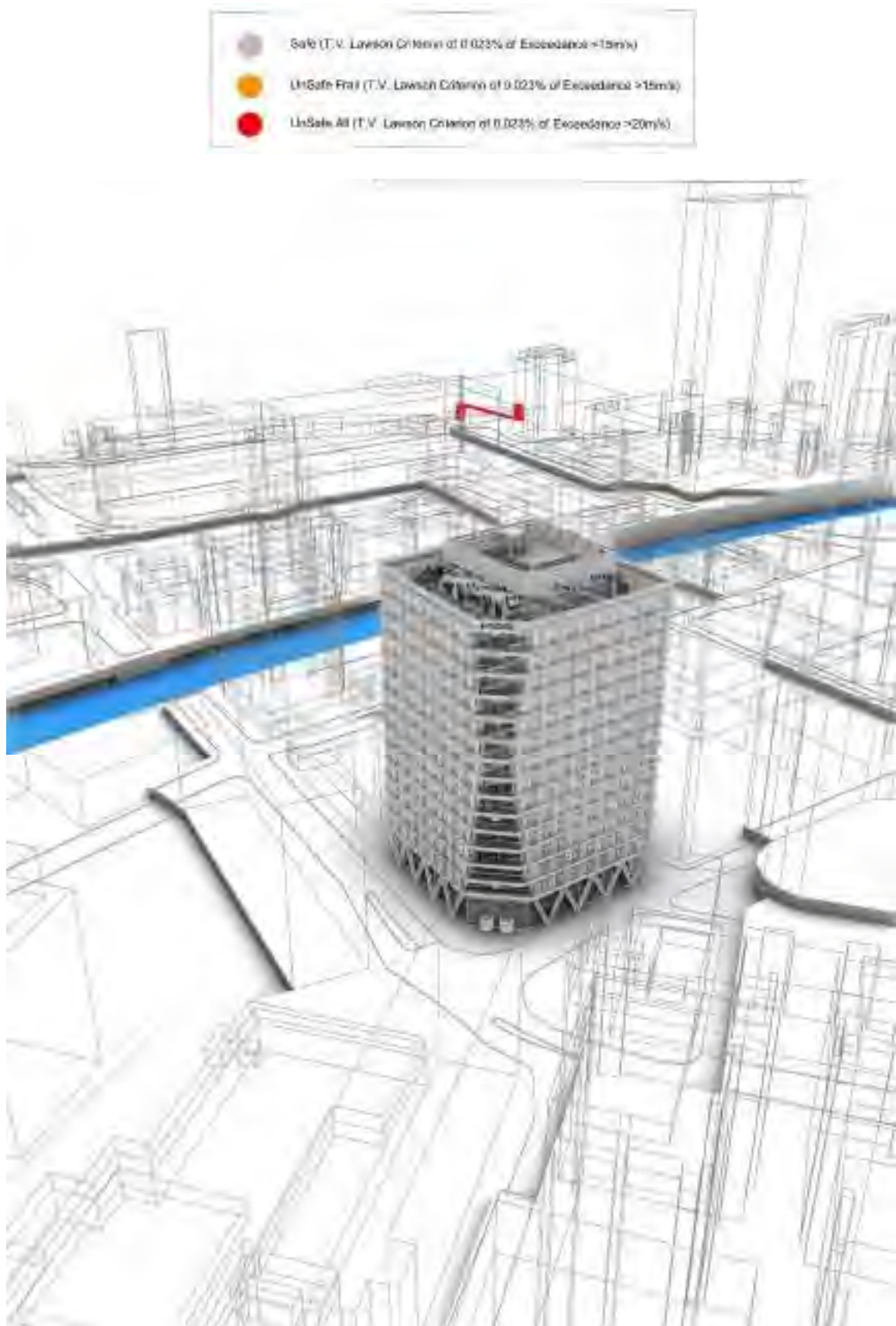


Figure E.15: The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (South Aspect), Safety Results



Figure E.16: The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (West Aspect), Safety Results

E.3 3D Summer Wind Comfort Results

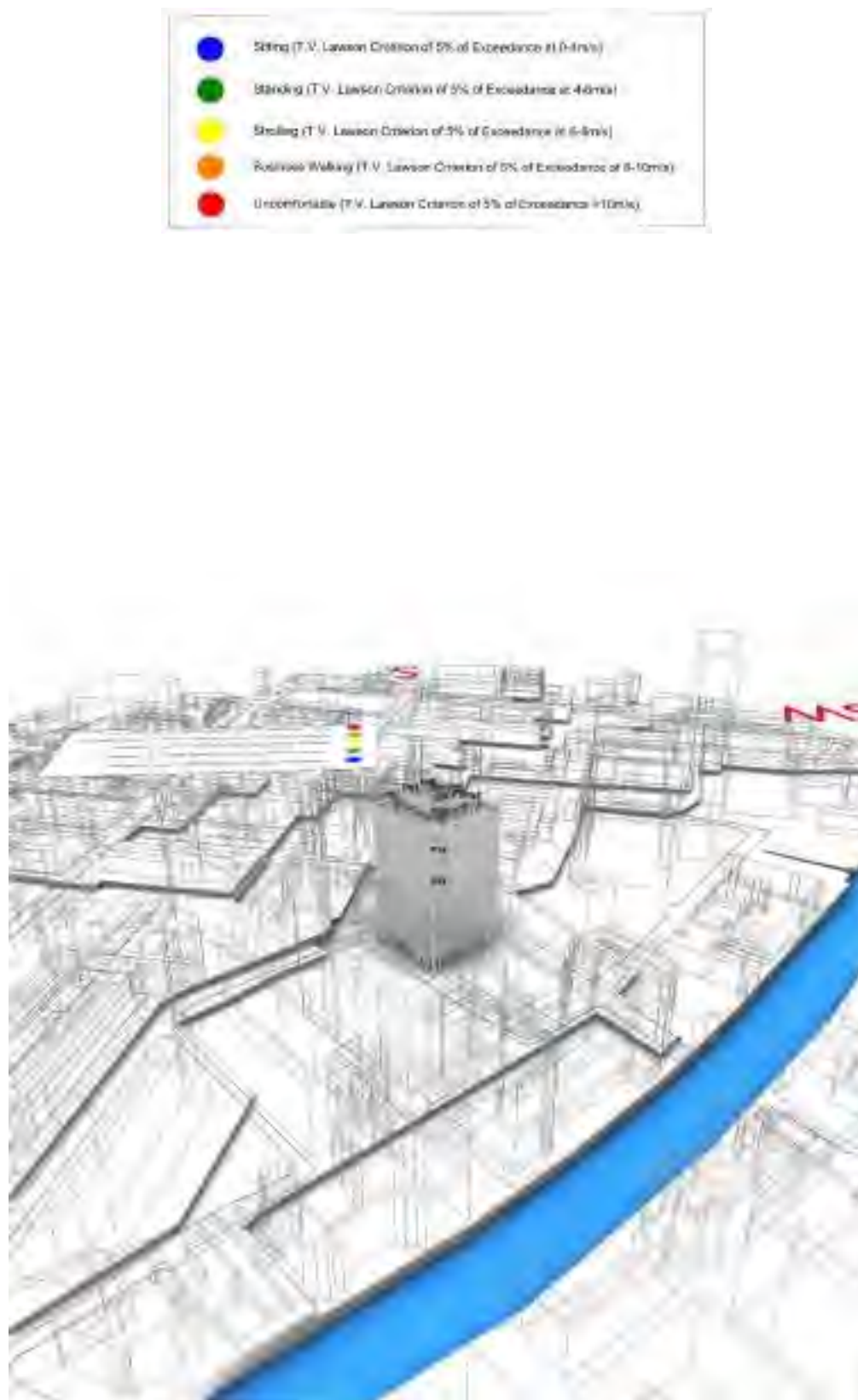


Figure E.17: The Proposed Development with Existing Surrounds: 3D Elevated Levels (North Aspect), Comfort Results, Summer Season

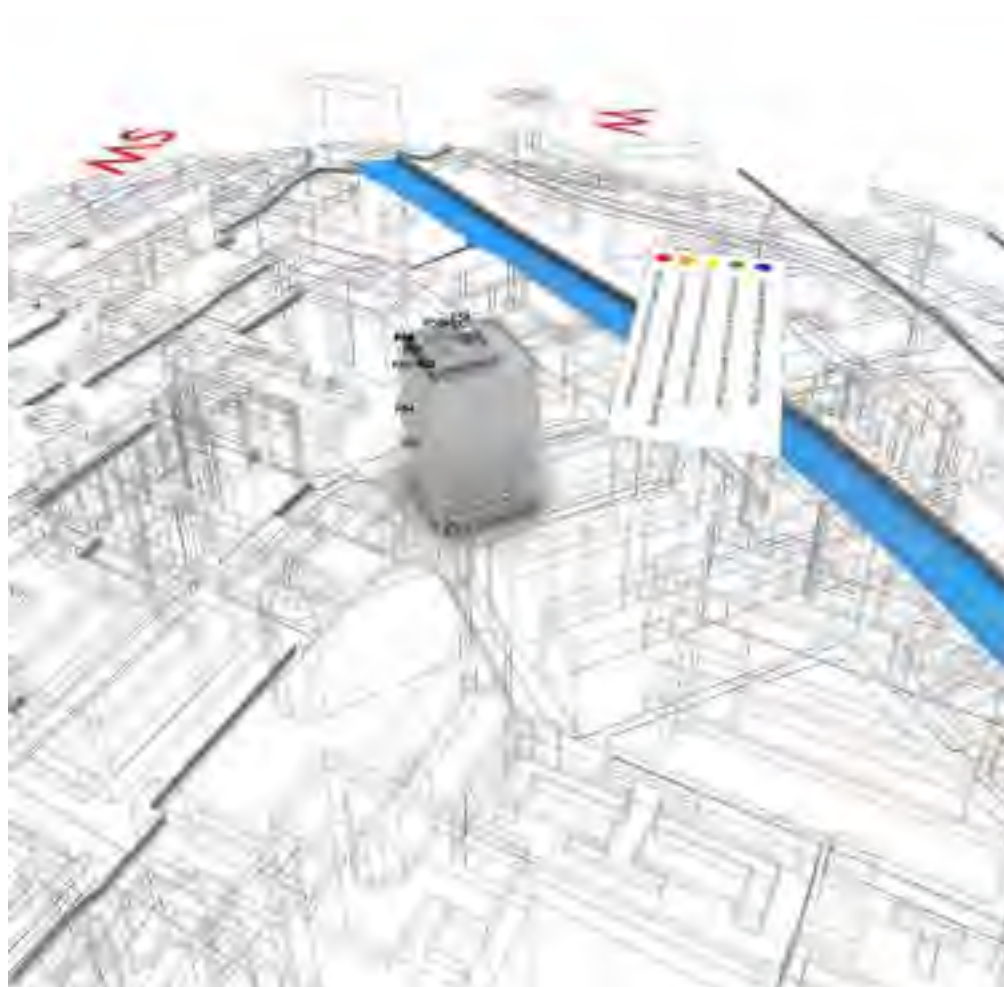
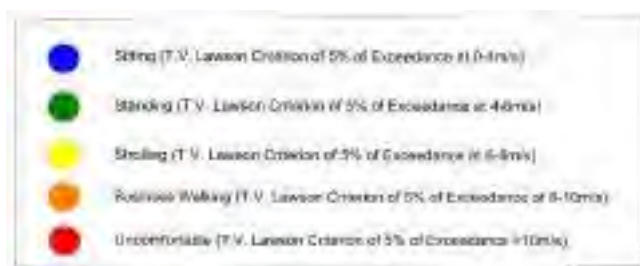


Figure E.18: The Proposed Development with Existing Surrounds: 3D Elevated Levels (East Aspect), Comfort Results, Summer Season

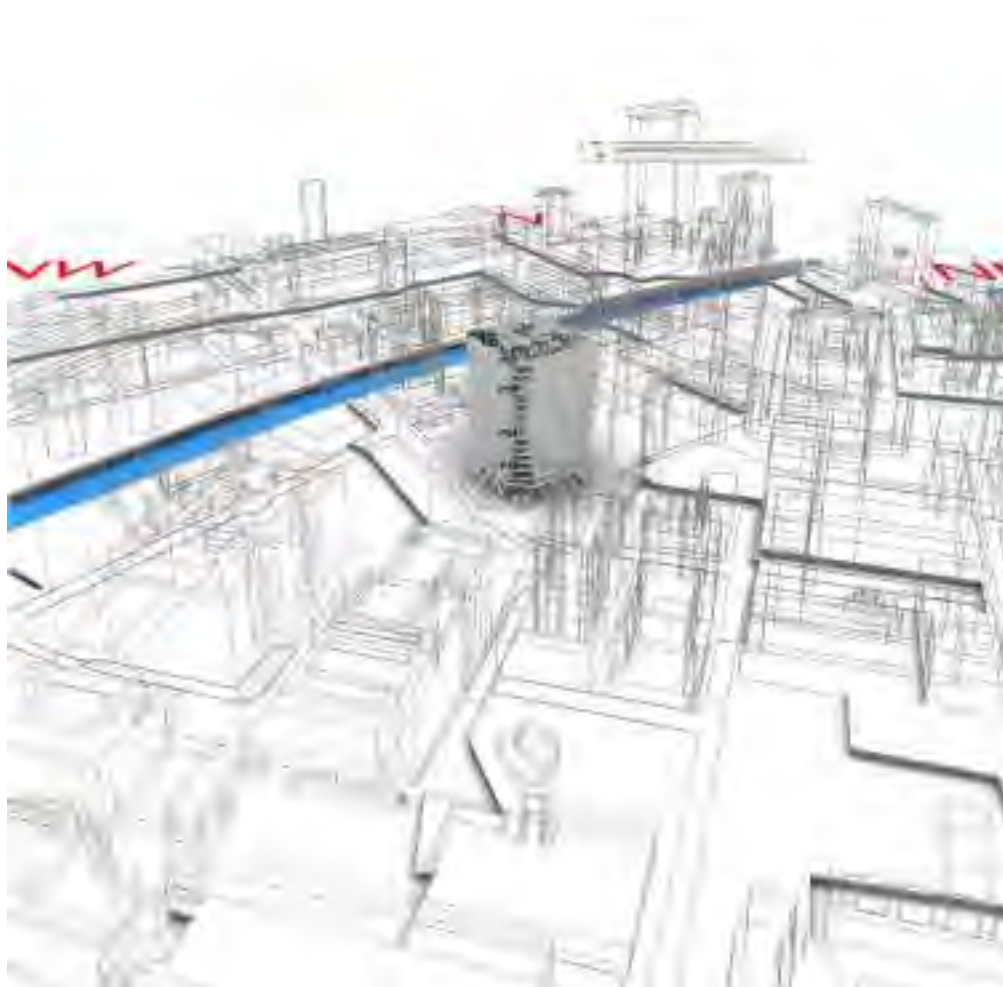
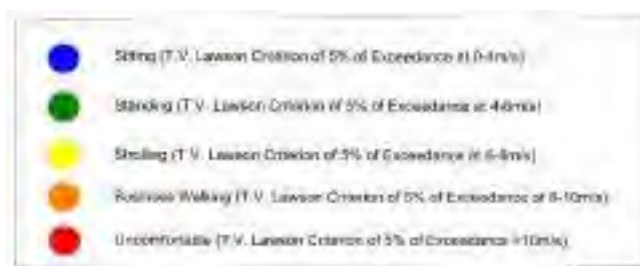


Figure E.19: The Proposed Development with Existing Surrounds: 3D Elevated Levels (South Aspect), Comfort Results, Summer Season



Figure E.20: The Proposed Development with Existing Surrounds: 3D Elevated Levels (West Aspect), Comfort Results, Summer Season



Figure E.21: The Proposed Development with Future Surrounds: 3D Elevated Levels (North Aspect), Comfort Results, Summer Season

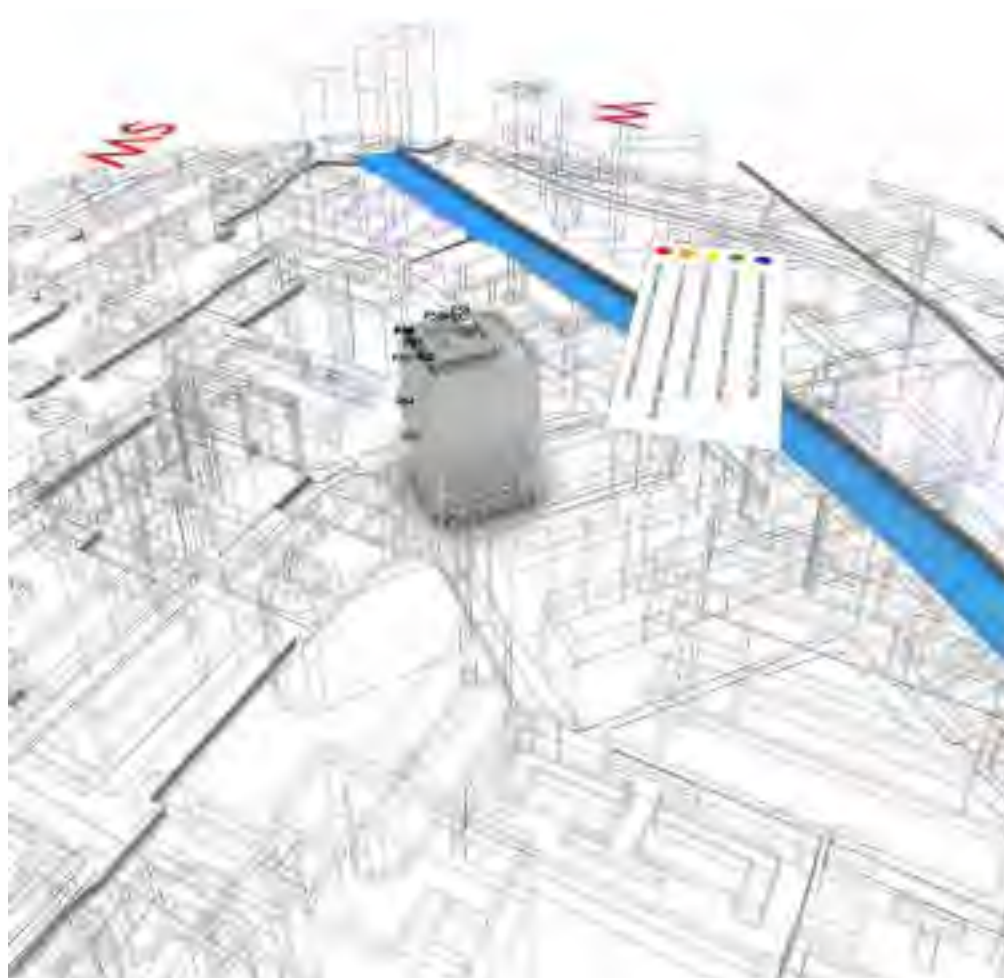


Figure E.22: The Proposed Development with Future Surrounds: 3D Elevated Levels (East Aspect), Comfort Results, Summer Season

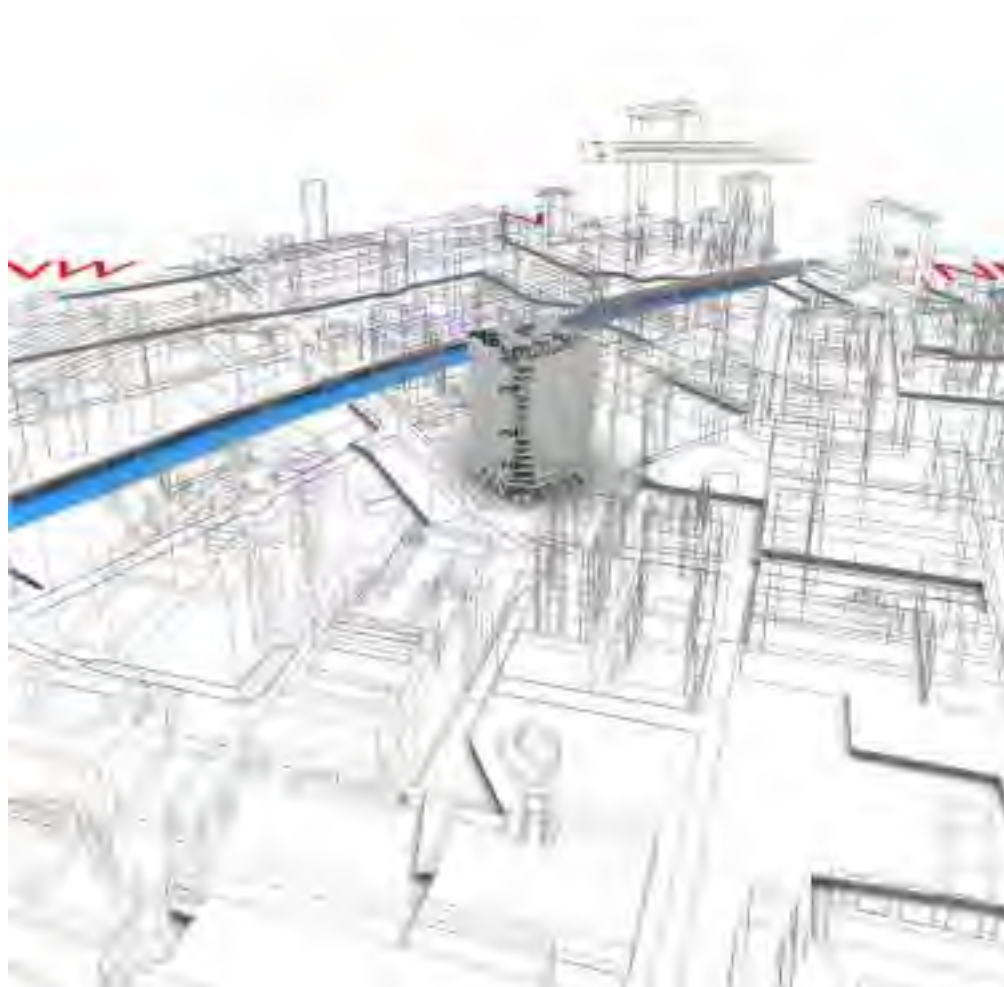
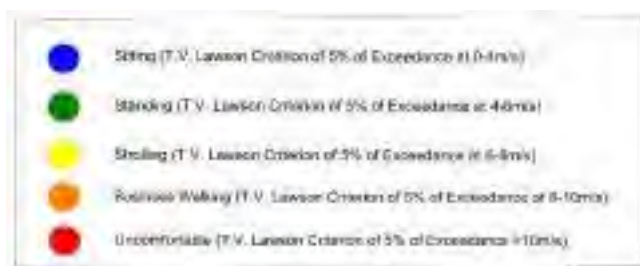


Figure E.23: The Proposed Development with Future Surrounds: 3D Elevated Levels (South Aspect), Comfort Results, Summer Season



Figure E.24: The Proposed Development with Future Surrounds: 3D Elevated Levels (West Aspect), Comfort Results, Summer Season



Figure E.25: The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (North Aspect), Comfort Results, Summer Season

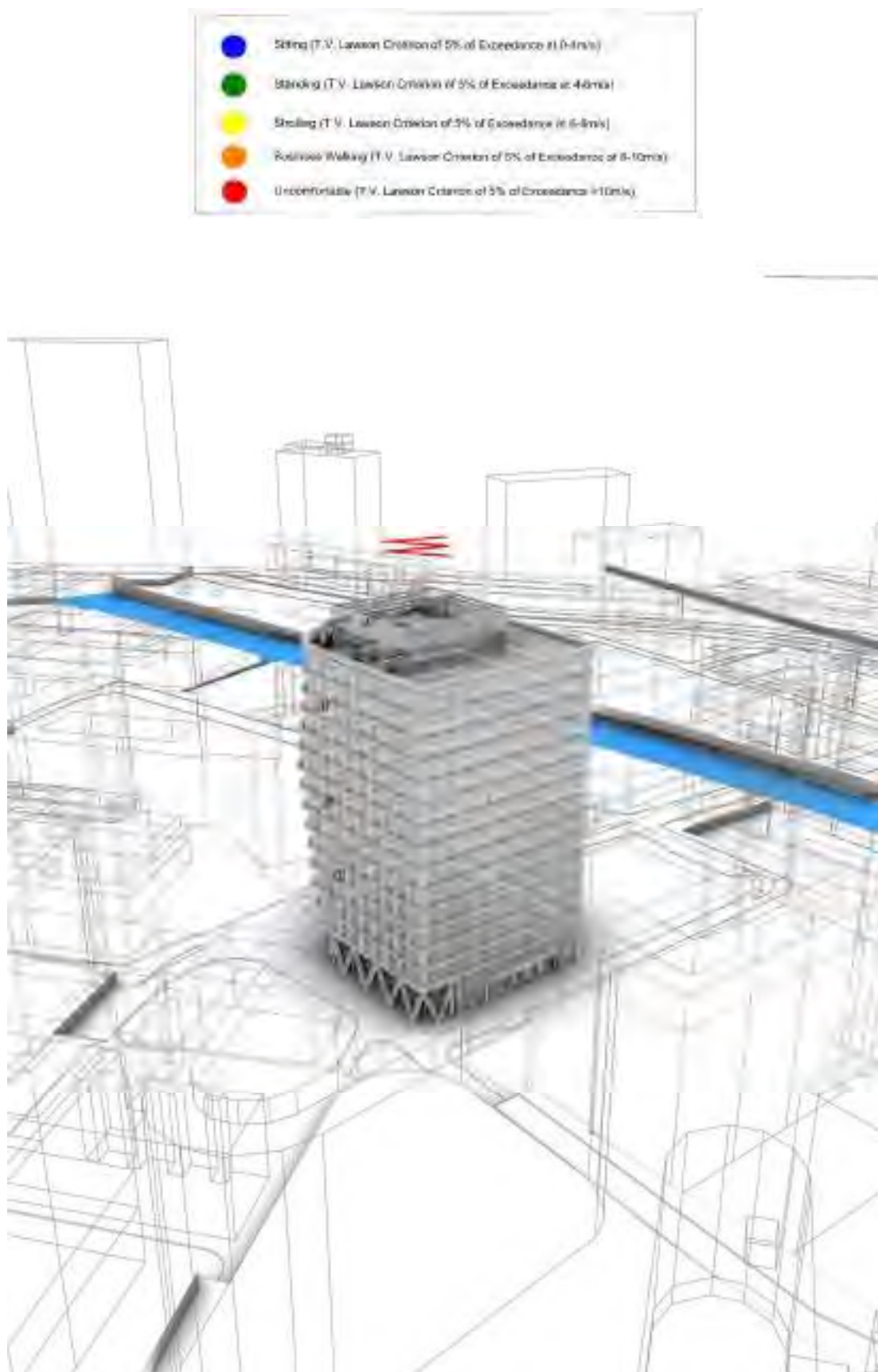


Figure E.26: The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (East Aspect), Comfort Results, Summer Season

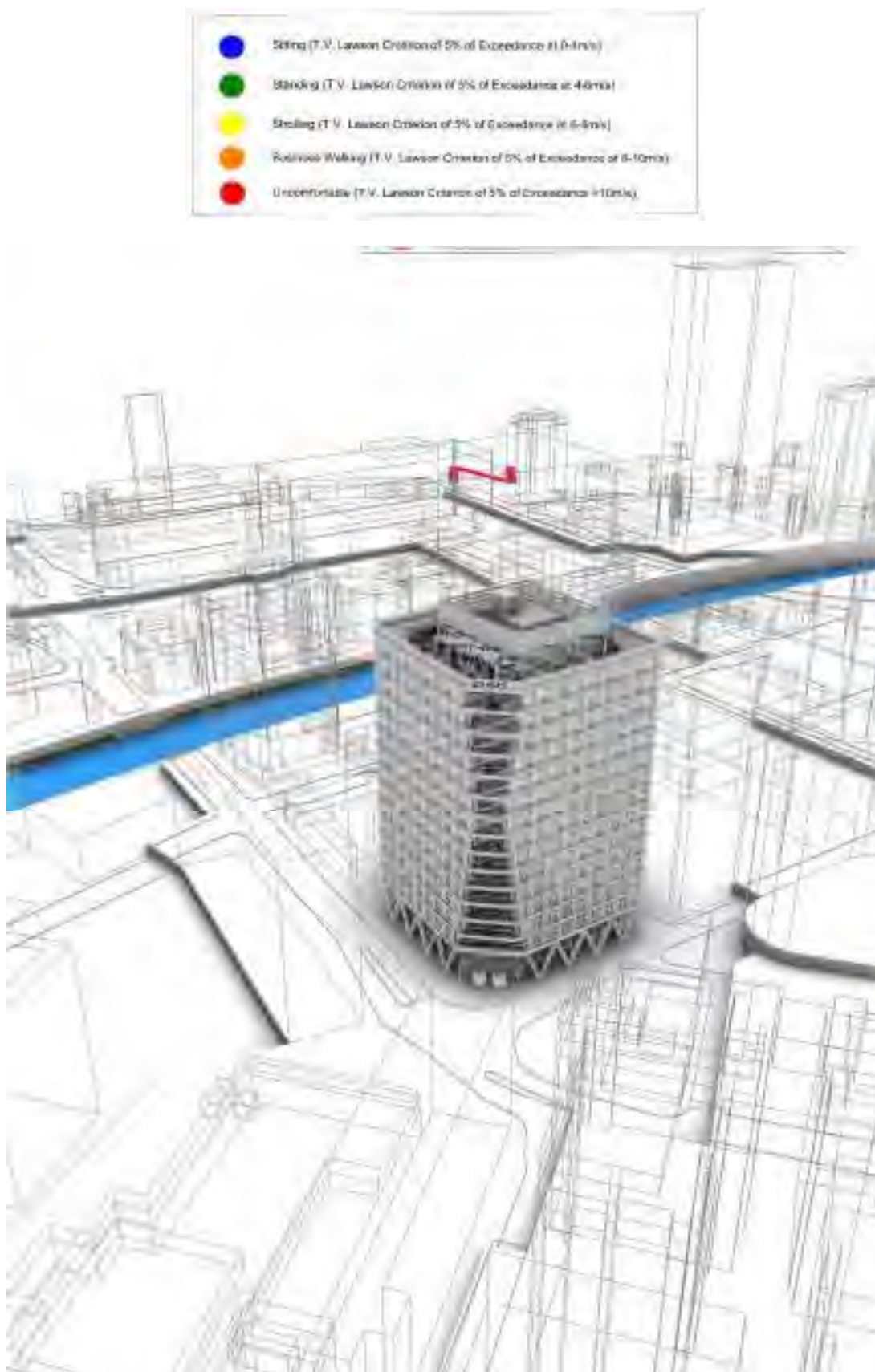


Figure E.27: The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (South Aspect), Comfort Results, Summer Season

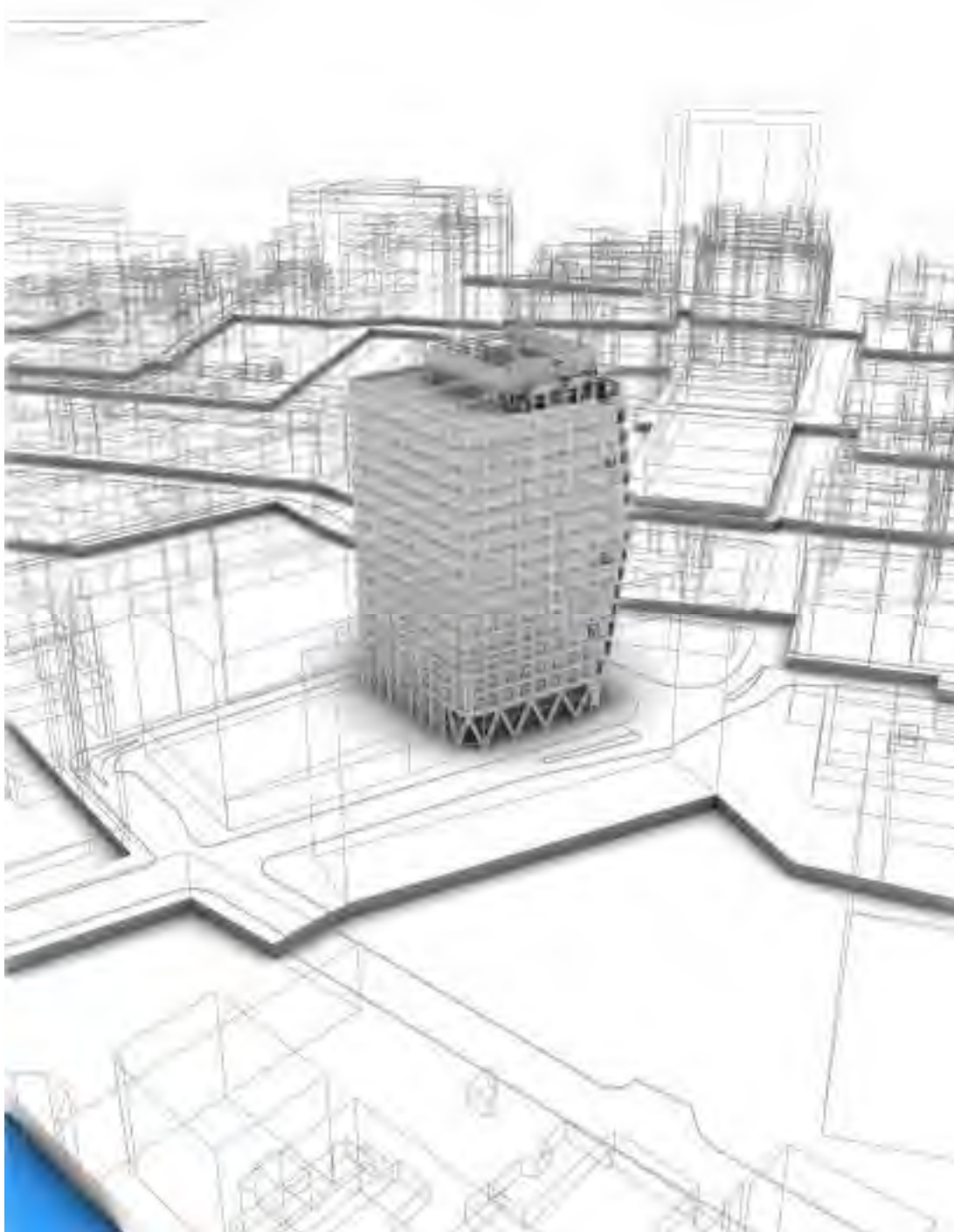
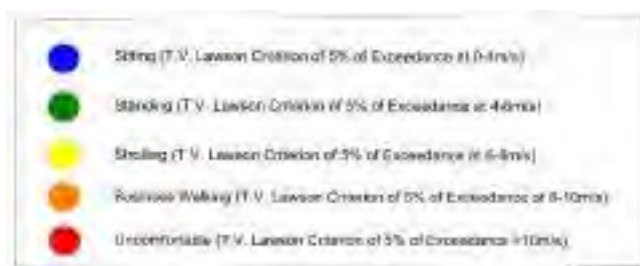


Figure E.28: The Proposed Development with Existing Surrounds and Mitigation: 3D Elevated Levels (West Aspect), Comfort Results, Summer Season

APPENDIX F OFF-SITE ENTRANCES



Figure F.1: The Off-Site Entrance at Point 22



Figure F.2: The Off-Site Entrance(s) at Point 29



Figure F.3: The Off-Site Entrance(s) at Point 31



Figure F.4: The Off-Site Entrance at Point 52