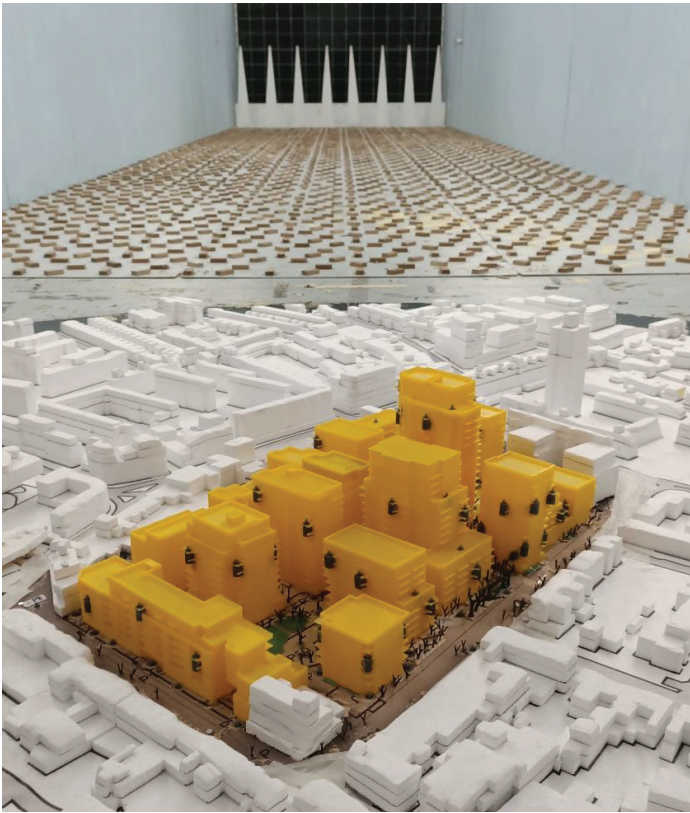


Appendix: Wind Microclimate

Annex 1: Wind Microclimate Assessment

Appendix: Wind Microclimate

Annex 1: Wind Microclimate Assessment



WIND MICROCLIMATE ASSESSMENT

AYLESHAM CENTRE, LONDON

WG609-01F03(REV0) – WE REPORT

MAY 30, 2024

Prepared for:

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DOCUMENT CONTROL

Date	Revision History	Issued Revision	Prepared By	Instructed By	Reviewed & Authorised By
May 31, 2024	Initial.	0	NO/ML	NO	NO/ML/EC

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EXECUTIVE SUMMARY

This report presents the findings of a wind microclimate assessment of the proposed Aylesham Centre development in London. 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 36 wind directions at 10-degree increments. Testing was carried out using a 1:400 detailed scale model of the development, which was fabricated based on the architectural drawings received on April 5th, 2024. The effects of nearby buildings and land topography have been accounted for using a proximity model, which represents an area with a radius of 500m.

Peak gust and mean wind speeds were measured at selected critical outdoor trafficable locations 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.

Four configurations were tested in the wind tunnel, which are as follows:

- CONFIGURATION 1: The Existing Site with Existing Surrounds (the Baseline Conditions)
- CONFIGURATION 2: Interim Phase of the Proposed Development with Existing Surrounds
- CONFIGURATION 3: Completed Proposed Development with Existing Surrounds; and
- CONFIGURATION 4: Completed Proposed Development with Existing Surrounds and Proposed Landscaping

The wind microclimate results when compared with the pedestrian comfort criteria are summarised as follows:

CONFIGURATION 1: THE EXISTING SITE WITH EXISTING SURROUNDS

SAFETY ASSESSMENT

- The existing site conditions are safe for pedestrian activities, including cyclist use throughout the year.

COMFORT ASSESSMENT

- The wind microclimate at the site and in the surrounds is suitable for intended pedestrian activities throughout the year.

CONFIGURATION 2: THE EXISTING SITE WITH INTERIM SURROUNDS

SAFETY ASSESSMENT

- The ground level wind conditions are safe for pedestrian and cyclist use throughout the year.
- At elevated levels the majority of locations, are safe for pedestrian use throughout the year.

- However, there are two locations that do exceed the safety criterion (Points P91 and 147)

COMFORT ASSESSMENT

- The wind microclimate outside all the entrances of the proposed development is suitable for ingress/egress throughout the year.
- During the summer season, the wind conditions at all the seating, outdoor amenity and play areas at the site within the surrounds are suitable for the intended use.
- Wind microclimate conditions at the podium locations (Points 75, 76, and 77) are suitable for the intended use during the summer season.
- The wind microclimate on the Podium/terraces (Points 20, 87, 88, 89, 90, 91, 92, 93, 98 and 117) exceed the comfort criterion for intended occupant use during the summer season. For these areas, additional mitigation measures (e.g. balustrades and/or soft landscaping) are recommended to provide further shelter for the intended occupant use.
- The wind microclimate conditions on balcony location Point 145 is suitable for intended occupant use during the summer season.
- The wind microclimate conditions on the balcony locations (Points 95, 96, 97, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 110, 111, 112, 114, 146, 147, 148, 149 and 150) exceed the comfort criterion for intended occupant use during the summer season.
- For these areas, additional mitigation measures (e.g. balustrades and/or side screening) are recommended to provide further shelter for the intended occupant use.
- The remaining locations within the site and surrounds are suitable for strolling throughout the year.

CONFIGURATION 3: THE EXISTING SITE WITH FUTURE SURROUNDS

SAFETY ASSESSMENT

- The ground level wind conditions are safe for pedestrian and cyclist use throughout the year.
- At elevated levels the majority of locations, are safe for pedestrian use throughout the year.
- However, there are three locations that do exceed the safety criterion (Points P20, P102 and 143).

COMFORT ASSESSMENT

- The wind microclimate outside all entrances except 1 location within the proposed development is suitable for ingress/egress throughout the year. Point 11 represents a very marginal exceedance and with the inclusion of the existing trees and landscaping within this area, it is anticipated this will be of no concern. Therefore, no mitigation is recommended.
- During the summer season, for most areas, the wind conditions are suitable for intended usage. However, there are outdoor café and seating areas where the wind conditions exceed the appropriate target activity of frequent sitting and occasional sitting (Points 48, 49, 57, 58, 66, 67 and 69).

- The wind microclimate on the Podium/terraces (Points 4, 5, 20, 84, 86, 87, 88, 89, 90, 91, 92, 93, 98, 117 and 128) exceed the comfort criterion for intended occupant use during the summer season. For these areas, additional mitigation measures (e.g. balustrades and/or soft landscaping) are recommended to provide further shelter for the intended occupant use.
- The wind microclimate conditions on the balcony locations (Points 121,124,125,126,133, 136, 140, 142, 144 and 145), is suitable for intended occupant use during the summer season.
- The wind microclimate conditions on the balcony locations (Points 94, 95, 96, 97, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 110, 111, 112, 113, 114, 115, 116, 119, 120, 122, 123, 127, 128, 129, 130, 131, 132, 134, 135, 137, 138, 139, 141, 143, 146, 147, 148, 149, 150) exceed the comfort criterion for intended occupant use during the summer season.
- The remaining locations within the site and surrounds are suitable for strolling throughout the year.

CONFIGURATION 4: THE PROPOSED SCHEME WITH EXISTING SURROUNDS

SAFETY ASSESSMENT

- The ground level wind conditions are safe for pedestrian and cyclist use throughout the year.
- At elevated levels, the majority of locations, are safe for pedestrian use throughout the year.
- However, two locations do exceed the safety criterion (Points P102 and 143).

COMFORT ASSESSMENT

- The wind microclimate outside all entrances except 2 locations within the proposed development is suitable for ingress/egress throughout the year. Points 38 and 53 represent a marginal exceedance and with the inclusion of further local landscaping within this area, it is anticipated this will be of no concern.
- During the summer season, for most areas, the wind conditions are suitable for intended usage. However, there are outdoor café and seating areas where the wind conditions exceed the appropriate target activity of frequent sitting and occasional sitting (Points 48, 49, 57, 58, 66 and 69).
- The wind microclimate on the Podium/terraces (Points 4, 5, 20, 84, 86, 87, 89, 90, 91, 98, 117 and 128) exceed the comfort criterion for intended occupant use during the summer season. For these areas, additional mitigation measures (e.g. balustrades and/or soft landscaping) are recommended to provide further shelter for the intended occupant use.
- The wind microclimate conditions on the balcony locations (Points 111, 114, 121,124, 126,128, 133, 136, 140, 142, 144, 145 and 147), is suitable for intended occupant use during the summer season.
- The wind microclimate conditions on the balcony locations (Points 94, 95, 96, 97, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 110, 112, 113, 115, 116, 119, 120, 122, 123, 125, 127, 129, 130, 131, 132, 134, 135, 137, 138, 139, 141, 143, 146, 148, 149, 150) exceed the comfort criterion for intended occupant use during the summer season.
- The remaining locations within the site and surrounds are suitable for strolling throughout the year.

SUMMARY AND RECOMMENDATIONS

Based on the currently tested configurations and mitigation measures included, there remain some areas of adverse wind safety and comfort conditions on-site. As such, additional onsite mitigation measures have been coordinated with the design team to provide suitable design where wind conditions in the remaining locations which are unsuitable for the intended use.

It is anticipated by the inclusion of these additional mitigation measures into the final design, all areas of the development will be safe and fit for intended usage.

It is recommended the efficacy of these measures is test prior to occupation with further wind tunnel or CFD testing.

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1 INTRODUCTION

A wind tunnel study has been undertaken to assess the wind microclimate 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 36 wind directions at 10-degree increments. The wind tunnel was configured to the appropriate boundary layer wind profile for each wind direction. Wind speeds were measured using pressure-based wind speed sensors, 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 1:400 scale model of the development and surroundings. The study model incorporates all necessary architectural features on the façade of the development to ensure an accurate wind flow is achieved around the model and was constructed using a Computer Aided Manufacturing (CAM) process to ensure that a high level of detail and accuracy is achieved. The study model was fabricated based on the architectural drawings received on April 5th, 2024. The effect of nearby buildings and land topography has been accounted for with a proximity model, which represents an area with a radius of 500m.

Four configurations were tested in the wind tunnel, which are as follows:

- CONFIGURATION 1: The Existing Site with Existing Surrounds (the Baseline Conditions)
- CONFIGURATION 2: Interim Phase of the Proposed Development with Existing Surrounds
- CONFIGURATION 3: Completed Proposed Development with Existing Surrounds; and
- CONFIGURATION 4: Completed Proposed Development with Existing Surrounds and Proposed Landscaping

Photographs of the wind tunnel model are presented in Figures 1. Plan views of the model are provided in Figures 2.



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



Figure 1b: Photograph of the Wind Tunnel Model: Interim Phase of the Proposed Development with Existing Surrounds (view from North)



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



Figure 2a: Plan View – (CONFIGURATION 1) The Existing Site with Existing Surrounds

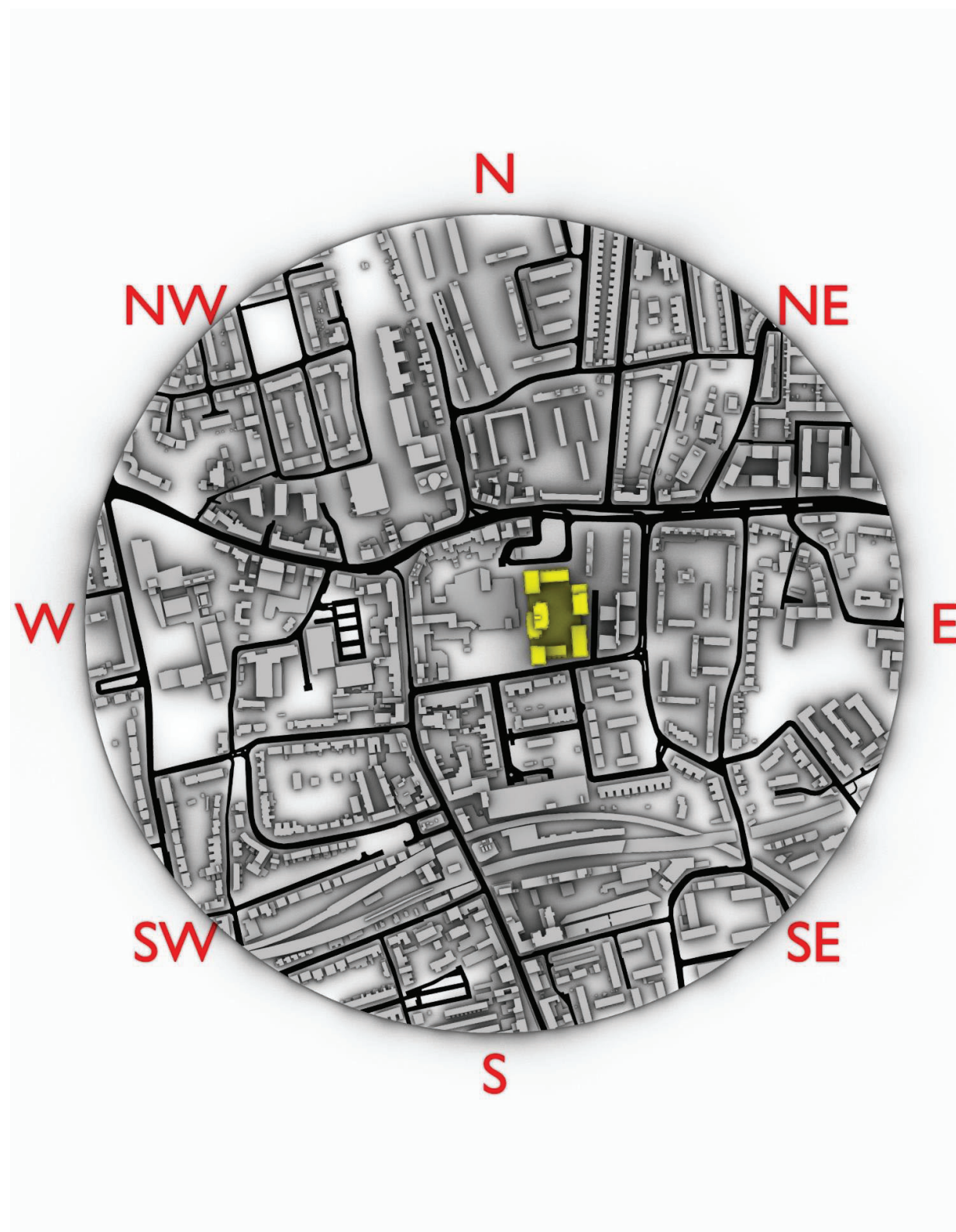


Figure 2b: Plan View – (CONFIGURATION 2) Interim Phase of the Proposed Development with Existing Surrounds



Figure 2c: Plan View – (CONFIGURATION 3) Completed Proposed Development with Existing Surrounds



Figure 2d: Plan View – (CONFIGURATION 4) Completed Proposed Development with Existing Surrounds and Proposed Landscaping

3 BOUNDARY LAYER WIND PROFILES AT THE SITE

The roughness of the surface of the earth has the effect of slowing down the wind near the ground. This effect is observed up to the boundary layer height, which can range between 500m to 3km above the earth's surface depending on the roughness of the surface (i.e.: 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 areas with many closely spaced mid-rise buildings.

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

The 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 Figures 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 the study reference height of 34.1m (which is approximately half the average height of the proposed development, since typically we are most interested in the wind effects at the ground plane). Details of the boundary layer wind profiles at the site are combined with the regional wind model (see Section 4) to determine the site wind speeds.

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

Wind Sector (degrees)	Terrain and Height Multiplier			Turbulence Intensity I_v	Equivalent Terrain Category (EN1991-1-4:2005 naming convention)
	$k_{tr,T=1hr}$ (hourly)	$k_{tr,T=10min}$ (10min)	$k_{tr,T=3s}$ (3sec)		
0	0.56	0.60	1.00	0.260	III.5
20	0.59	0.63	1.02	0.247	III
30	0.61	0.65	1.03	0.233	III
40	0.63	0.67	1.05	0.220	III
50	0.62	0.66	1.05	0.225	III
60	0.62	0.66	1.04	0.230	III
70	0.61	0.65	1.03	0.235	III
80	0.62	0.66	1.04	0.230	III
90	0.63	0.66	1.05	0.225	III
100	0.63	0.67	1.05	0.220	III
110	0.64	0.68	1.06	0.217	III
120	0.65	0.68	1.06	0.215	III
130	0.65	0.69	1.07	0.212	III
140	0.65	0.69	1.07	0.212	III
150	0.66	0.69	1.07	0.211	III
160	0.66	0.70	1.07	0.210	III
170	0.65	0.69	1.07	0.211	III
180	0.65	0.69	1.06	0.213	III
190	0.65	0.68	1.06	0.215	III
200	0.65	0.68	1.06	0.215	III
210	0.65	0.68	1.06	0.215	III
220	0.65	0.69	1.06	0.215	III
230	0.64	0.68	1.06	0.217	III
240	0.64	0.68	1.06	0.218	III
250	0.63	0.67	1.05	0.220	III
260	0.63	0.67	1.05	0.221	III
270	0.63	0.67	1.05	0.222	III
280	0.63	0.67	1.05	0.223	III
290	0.63	0.67	1.05	0.223	III
300	0.63	0.67	1.05	0.223	III
310	0.63	0.67	1.05	0.224	III
320	0.62	0.66	1.04	0.229	III

Wind Sector (degrees)	Terrain and Height Multiplier			Turbulence Intensity I_v	Equivalent Terrain Category (EN1991-1-4:2005 naming convention)
	$k_{tr,T=1hr}$ (hourly)	$k_{tr,T=10min}$ (10min)	$k_{tr,T=3s}$ (3sec)		
330	0.61	0.64	1.04	0.238	III
340	0.60	0.63	1.03	0.245	III
350	0.59	0.62	1.02	0.253	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 36 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 C of this report.

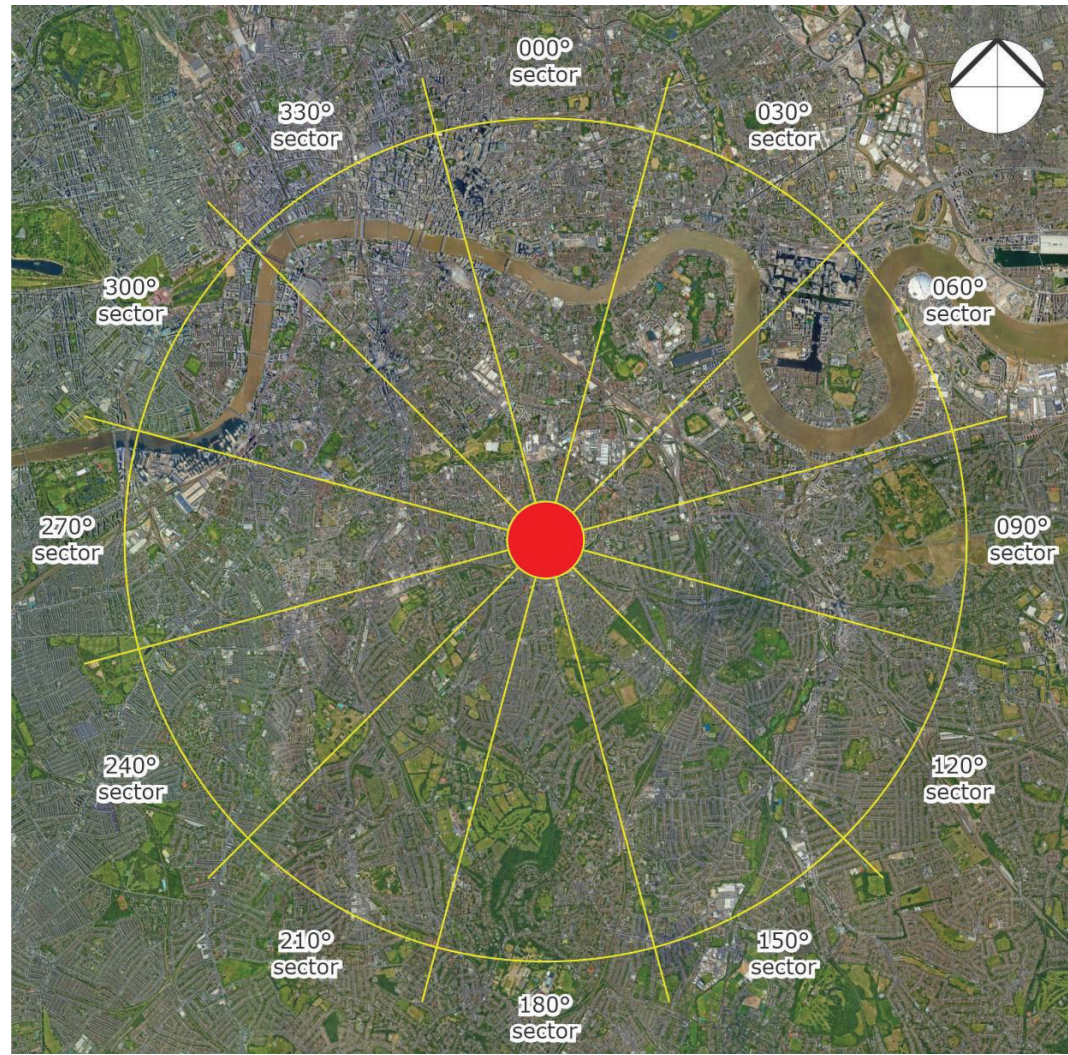


Figure 4a: Aerial Image of the Surrounding Terrain (radius of 5km from the edge of the proximity model)

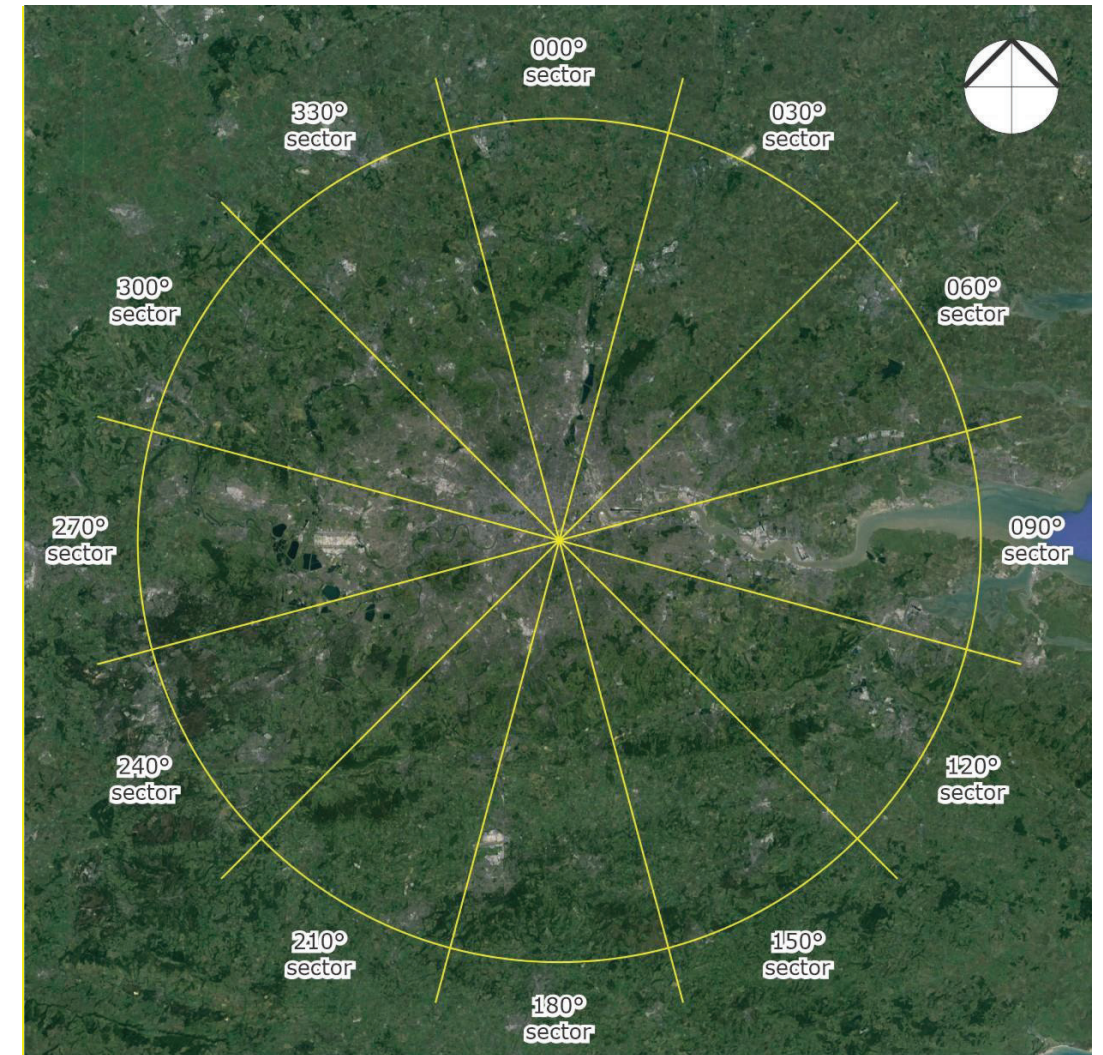


Figure 4b: Aerial Image of the Surrounding Terrain (radius of 50km)

REGIONAL WIND MODEL

The regional wind model used in this study was determined from an analysis of measured directional mean wind speeds obtained at meteorological stations located at Heathrow, Gatwick, and Stansted Airports. A total of 136 years of wind climate data has been collected from these stations 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 Figures 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-western quadrant.

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	5.9	5.6	5.5
NNE	6.2	5.6	5.6
NE	6.5	5.8	6.4
ENE	6.1	5.6	6.4
E	5.5	5.3	5.7
ESE	4.8	4.7	4.9
SE	4.6	4.1	4.8
SSE	5.1	4.0	5.9
S	6.9	5.7	8.0
SSW	8.3	7.5	9.3
SW	8.9	8.1	9.8
WSW	8.2	7.2	9.2
W	7.6	6.9	8.7
WNW	6.5	6.2	7.1
NW	6.0	5.8	6.3
NNW	5.8	5.4	5.7

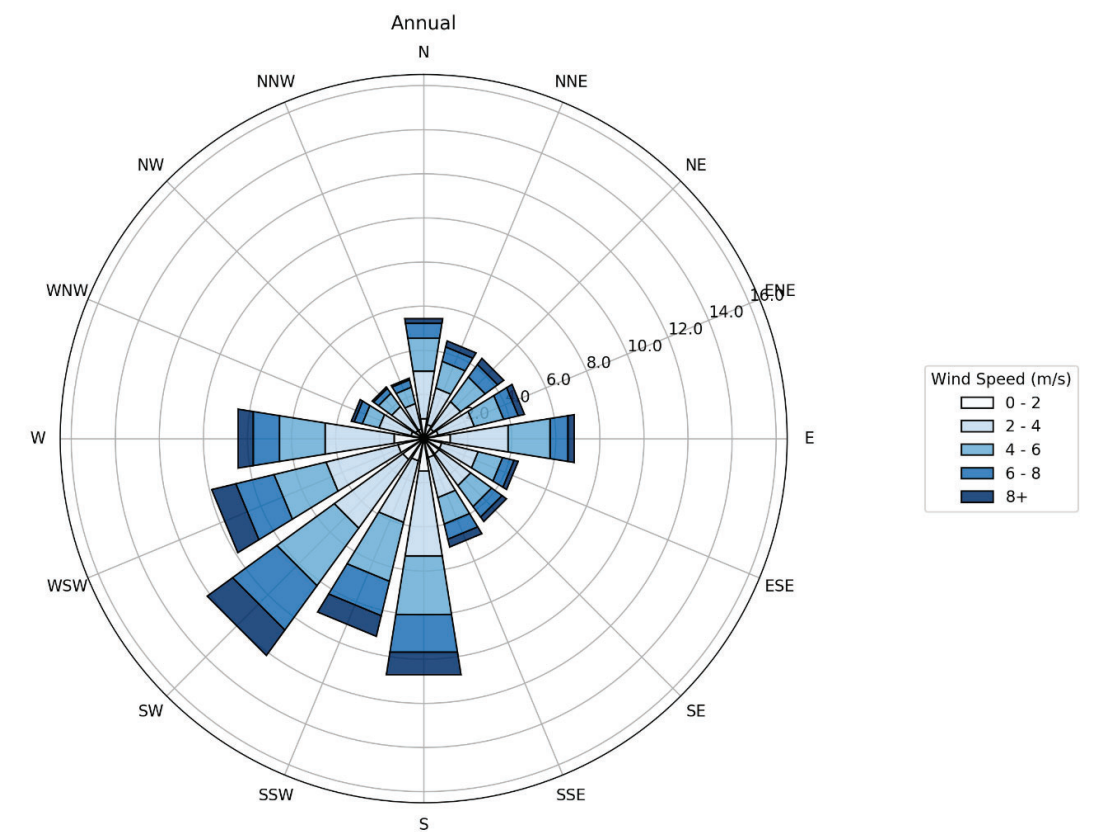


Figure 4a: Hourly Mean Wind Speeds (referenced to 10m height in standard open terrain) and Frequencies of Occurrence for London (all-year)

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 pressure-based wind speed sensors, positioned to monitor wind conditions at critical outdoor trafficable areas of the development. The reference mean free-stream wind speed measured in the wind tunnel, which is at a full-scale height of 200m and measured 3m upstream of the study model.

Measurements were acquired for 36 wind directions at 10-degree increments using a sample rate of 1,024Hz. The full methodology of determining the wind speed measurements at the site from pressure-based wind speed sensors is provided in Appendix B. Based on the results of the analysis of the boundary layer wind profiles at the site (see Section 3), and incorporating the regional wind model (see Section 4), the data sampling length of the wind tunnel test for each wind direction corresponds to a full-scale sample length ranging between 30 minutes and 1 hour. Research by A.W. Rofail and K.C.S. Kwok (1991) has shown that, in addition to the mean and standard deviation of the wind being stable for sample lengths of 15 minutes or more (full-scale), the peak value determined using the upcrossing method is stable for sample lengths of 30 minutes or more.

5.2 Wind Speed Criteria Used for This Study

For this study the measured wind conditions of the selected critical outdoor trafficable areas are compared against the City of London Lawson Criteria, which is referred to as the City Lawson Criteria. The criteria are described within the Birmingham Design Guide “Healthy Living and Working Places City Manual” and the “Wind Microclimate Guidelines for Developments in the City of London”. 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 0.022%. 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.

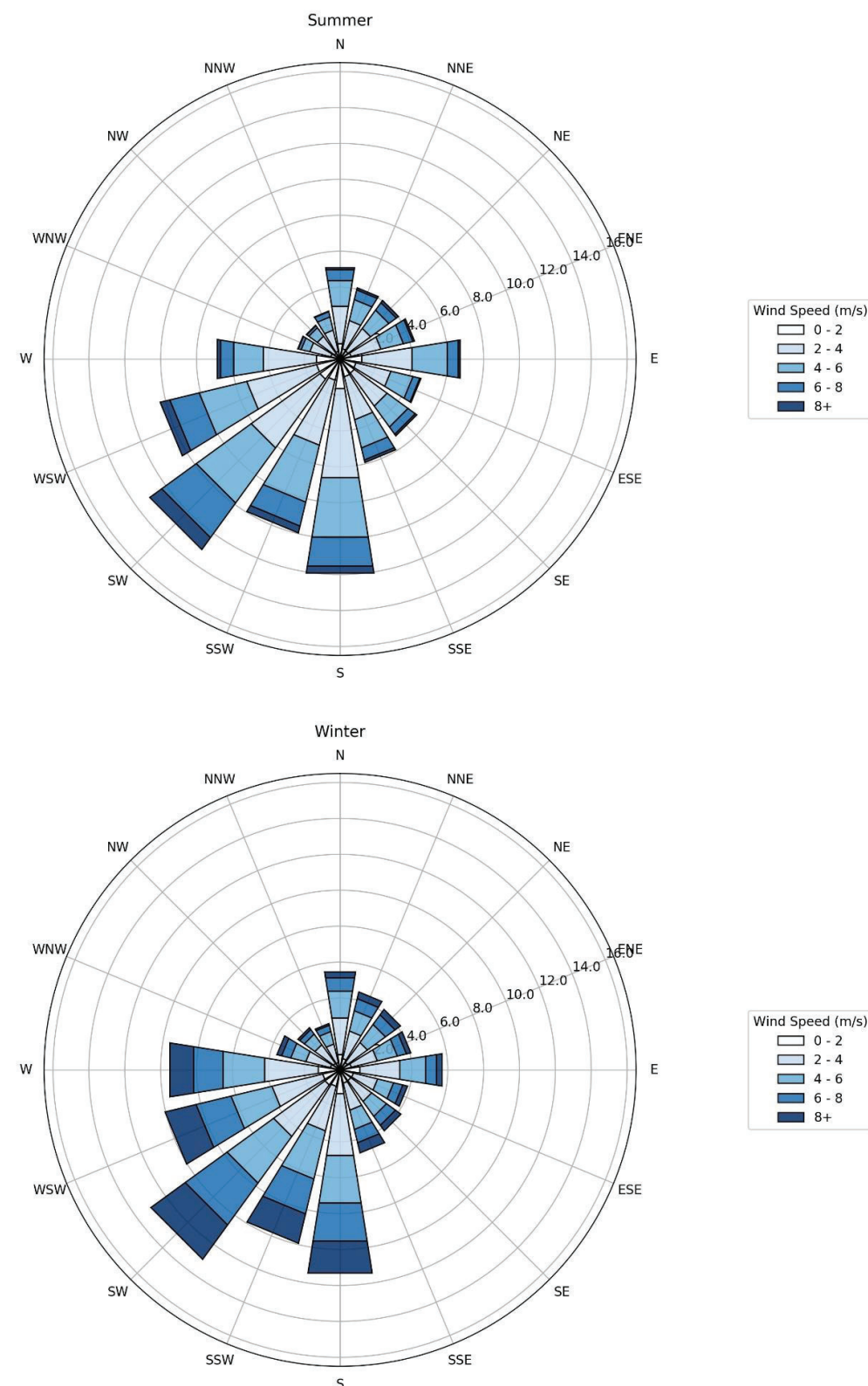


Figure 4b: Hourly Mean Wind Speeds (referenced to 10m height in standard open terrain) and Frequencies of Occurrence for London (summer top, winter bottom)

Table 3: City Lawson Criteria – Comfort

Classification	Activities	Mean and GEM Wind Speed (5% Exceedance) m/s
Frequent Sitting	Acceptable for frequent outdoor sitting use, e.g., restaurant, café.	2.5
Occasional Sitting	Acceptable for occasional outdoor seating, e.g., general public outdoor spaces, balconies and terraces intended for occasional use, etc.	4.0
Standing	Acceptable for entrances, bus stops, covered walkways, or passageways beneath buildings.	6.0
Walking	Acceptance for external pavements, walkways.	8.0
Uncomfortable	No comfortable for regular pedestrian access.	> 10.0

Table 4: City Lawson Criteria – Safety

Classification	Activities	Mean and GEM Wind Speed (0.022% Exceedance) m/s
Pedestrian Safety Limit	Presents a safety risk for pedestrians, especially to more vulnerable members of the public.	15

5.3 Layout of Study Points

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 5 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.

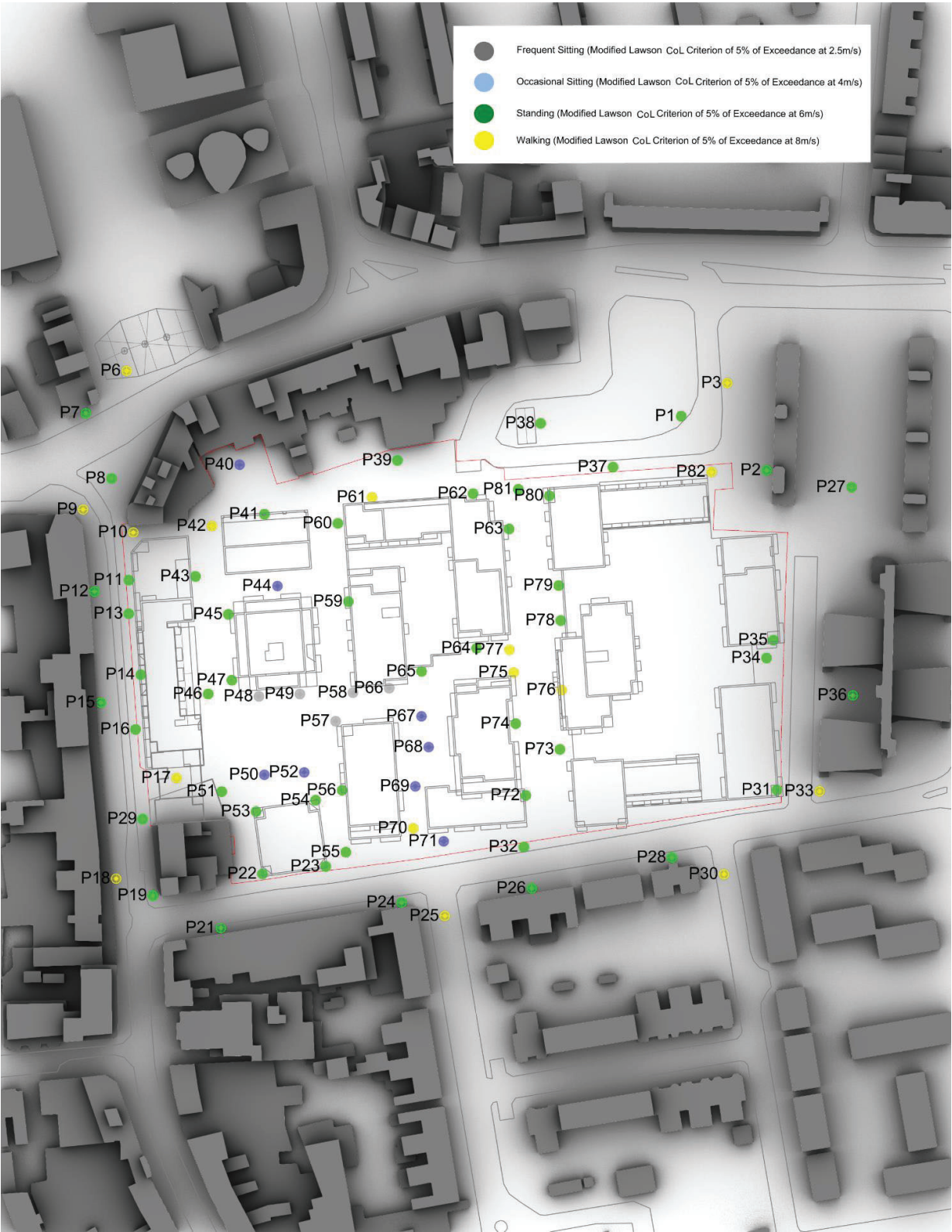


Figure 5a: Study Point Locations and Target Wind Speed Criteria – Completed Proposed Development with Existing Surrounds – Ground Level



Figure 5b: Study Point Locations and Target Wind Speed - Completed Proposed Development with Existing Surrounds – Elevated Amenity

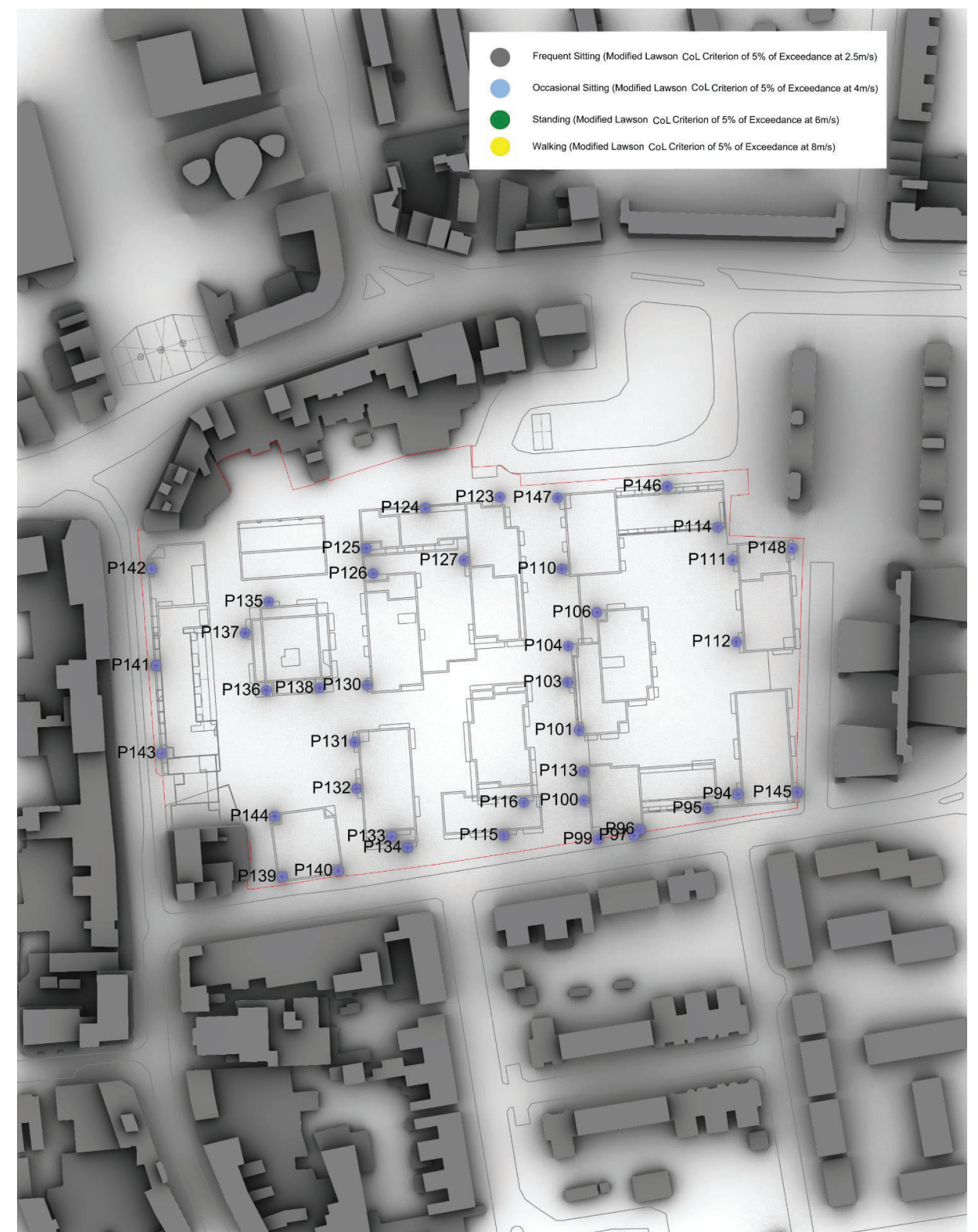


Figure 5c: Study Point Locations and Target Wind Speed Criteria - Completed Proposed Development with Existing Surrounds – Elevated Balcony Low

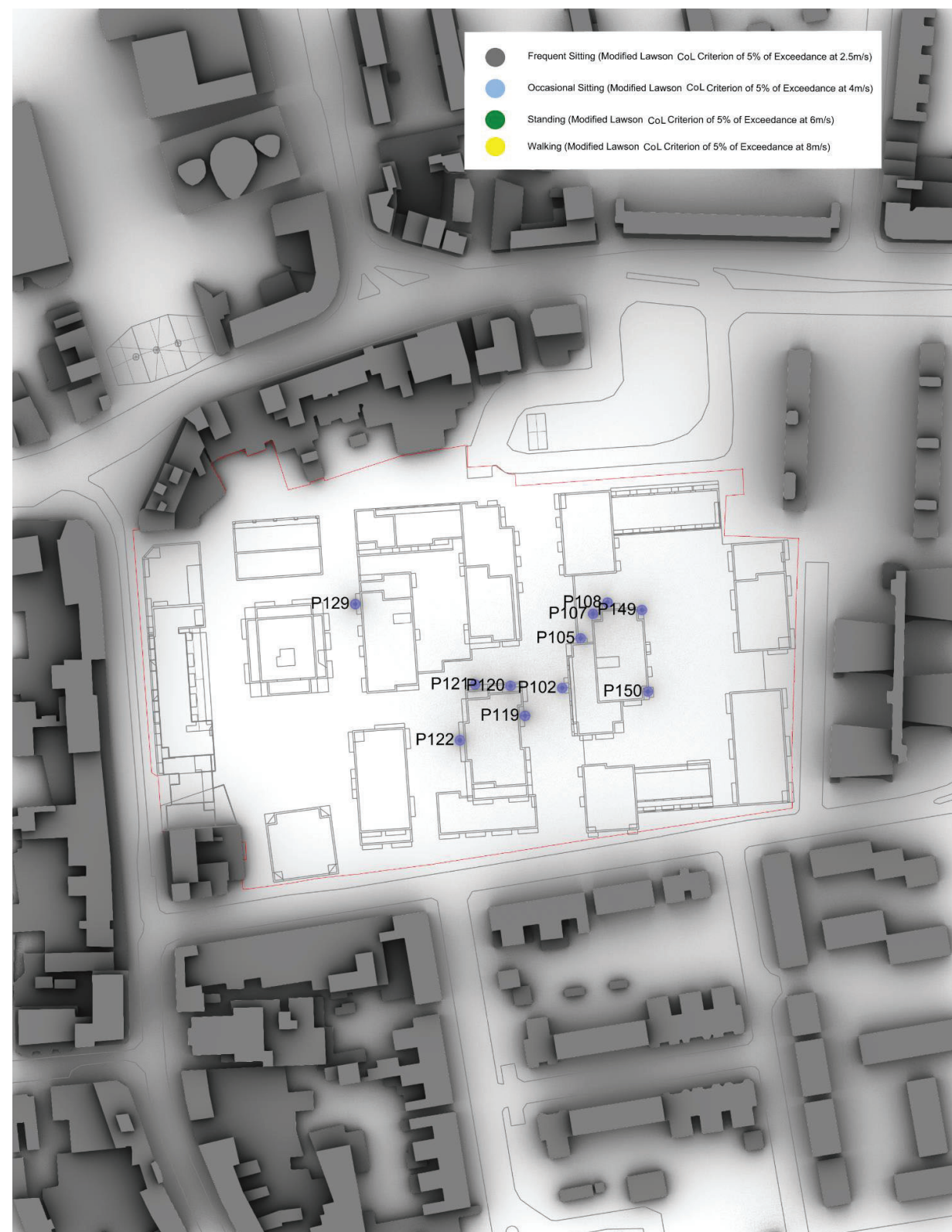


Figure 5d: Study Point Locations and Target Wind Speed Criteria - Completed Proposed Development with Existing Surrounds – Elevated Balcony Top



Figure 5e: Study Point Locations and Target Wind Speed Criteria - Completed Proposed Development with Existing Surrounds – Elevated Terraces Top

5.4 Tested Mitigation Measures

The tested landscaping and wind mitigation measures included during current wind tunnel testing for Configuration 4 are displayed in the following Figures 5f-5i.

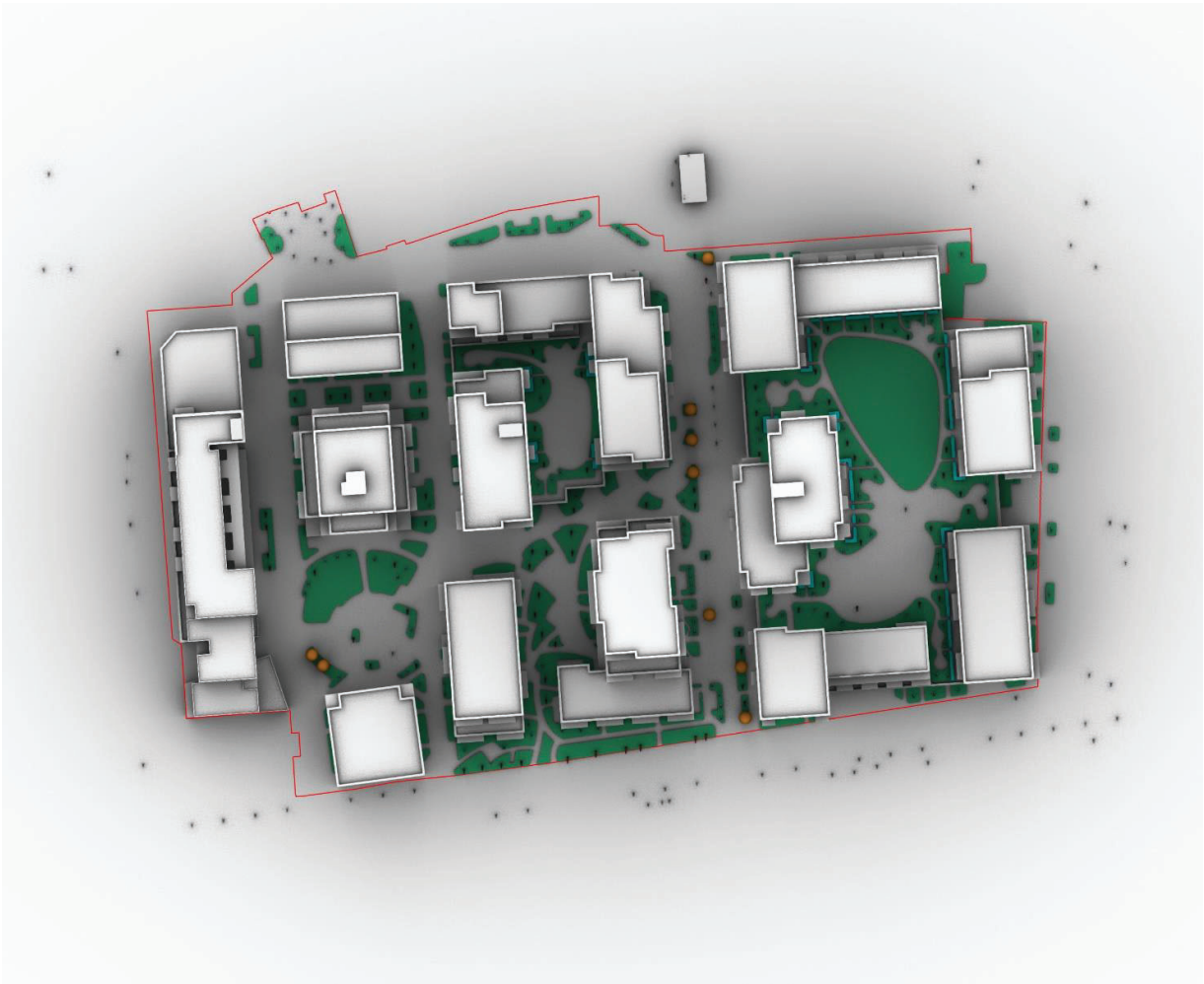
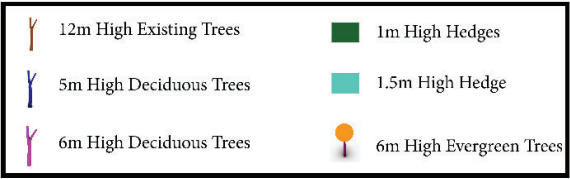
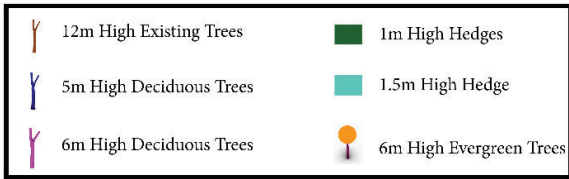


Figure 5f: Mitigation Measures Tested – (CONFIGURATION 4) Completed Proposed Development with Existing Surrounds and Proposed Landscaping - Plan View



Figure 5g: Mitigation Measures Tested – (CONFIGURATION 4) Completed Proposed Development with Existing Surrounds and Proposed Landscaping – 3D East Aspect

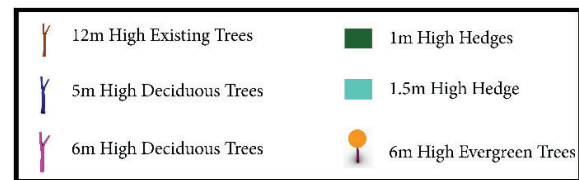


Figure 5h: Mitigation Measures Tested – (CONFIGURATION 4) Completed Proposed Development with Existing Surrounds and Proposed Landscaping – 3D West Aspect

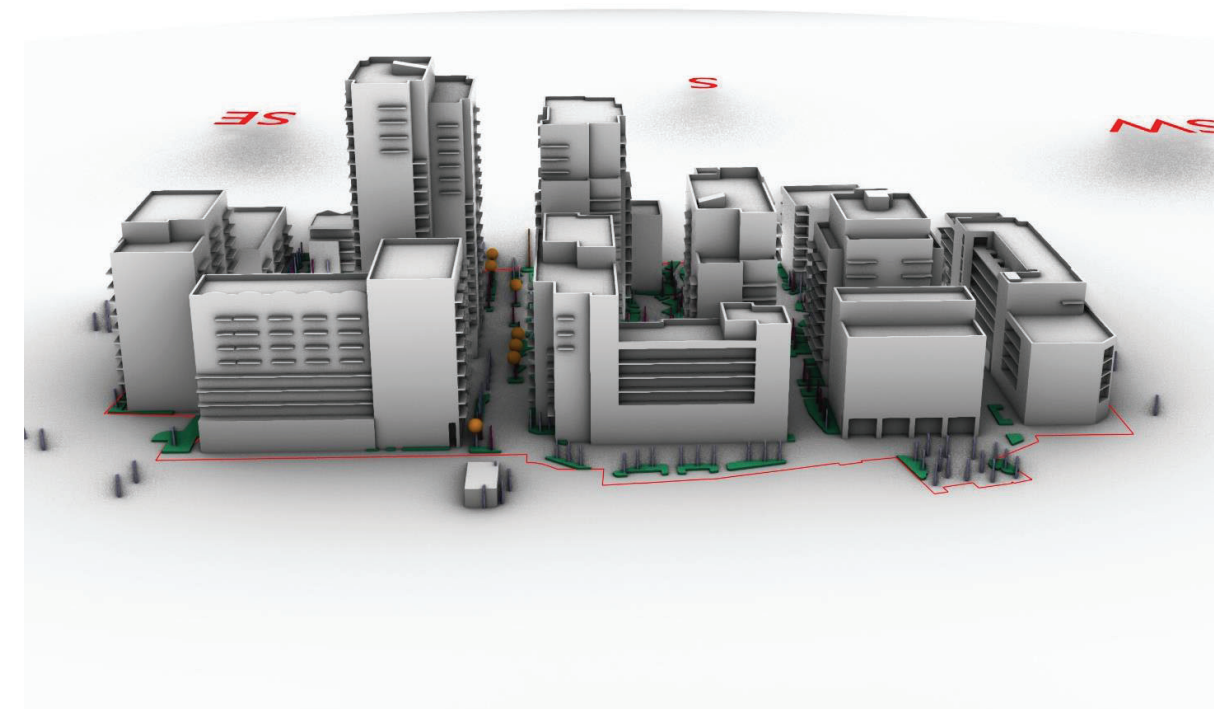


Figure 5i: Mitigation Measures Tested – (CONFIGURATION 4) Completed Proposed Development with Existing Surrounds and Proposed Landscaping – 3D North Aspect