

Appendix: Wind Microclimate

Annex 1: Pedestrian Level Wind Microclimate Assessment

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DRAFT REPORT



PEDESTRIAN LEVEL WIND MICROCLIMATE ASSESSMENT
BROAD STREET MALL

RWDI #1803396 – REV A
December 12th, 2018



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BROAD STREET MALL

READING, UK

PEDESTRIAN LEVEL WIND MICROCLIMATE ASSESSMENT

RWDI #1803396
DECEMBER 12, 2018

ON BEHALF OF

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VERSION HISTORY

RWDI Project #1803396 Broad Street Mall Reading, UK		
Report	Releases	Dated
Reports	Rev A	12 th December 2018
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1. EXECUTIVE SUMMARY

The objective of this study was to determine the ground level, Podium, and Terrace wind environment within and around the Proposed Development in Reading, UK.

This report presents a description of the methodology used and the results of three configurations tested in the wind tunnel, namely:

- Configuration 1: Existing site and Surrounding Buildings;
- Configuration 2: Proposed Development with Existing Surrounding Buildings; and
- Configuration 3: Proposed Development and Cumulative surrounding buildings.

All configurations include existing landscaping around the Proposed Development; to the South of Dusseldorf Way, and four trees to the North on Oxford Road.

The meteorological data for the Site indicate strong prevailing winds from the South-west quadrant throughout the year with secondary winds from the North-east direction which are more prevalent during the spring months.

The majority of locations in and around the Site in the baseline scenario (Configuration 1) have wind conditions suitable their intended use ranging from sitting to walking use during the windiest season. Three locations were unsuitable and there was one exceedance of the strong wind (safety) criteria.

With the Proposed Development in situ (Configuration 2), wind conditions range from suitable for sitting use to waking use during the windiest season. The majority of wind conditions on-site and off-site at ground level were suitable for the intended use, however the Podium and Terrace levels require mitigation: The following locations were too windy for their intended use;

- An entrance and thoroughfare on Queen's Walk;
- An Entrance to St Mary's Church;
- All Podium Locations; and
- All Terrace Locations.

There were three locations on Ground level, seven on Podium level, and one on Terrace level that had strong winds exceeding the safety threshold. These locations will all require mitigation.

Mitigation measures have been proposed and will be developed through an iterative wind tunnel test procedure to achieve a comfortable and safe wind microclimate. The following mitigation measures have been suggested;

- Introduction of canopies, approximately 2-3m deep above the Podium on Site A and Site B (the two taller Towers);
- Introduction of pergolas, shrubs, screens, and trellises (at least 2m height), to the Podium level of the Proposed Development;
- Addition of screens and dividers to Terrace level to achieve sitting conditions; and
- Screens, Planters, shrubs, and trees to be added to Queen's Walk.

With cumulative surrounding buildings in situ (Configuration 3) wind conditions are generally the same or calmer than (Configuration 2). The cumulative developments do not have a significant effect on the wind conditions on-site or in the surrounding area.

2. INTRODUCTION

RWDI was retained by Trium Environmental Consulting to conduct a pedestrian level wind microclimate assessment for the Broad Street Mall development proposals (referred to as the “Proposed Development” hereafter in this report) in Reading, UK. This report presents the background, objectives, results and discussion from RWDI’s assessment.

3. BACKGROUND AND APPROACH

Wind tunnel tests were conducted on a 1:300 scale model of the Proposed Development in Reading. The investigation quantifies the wind conditions within and around the Site, by comparing the measured wind speed and frequency of occurrence with the Criteria. Meteorological data for Reading has been analysed and adjusted to the Site conditions by modelling the effect of terrain roughness on the wind speeds approaching the Site.

Measurements were taken at up to 122 locations for 36 wind directions, in 10° increments. The measurements covered ground level locations along the building facades and at corners, near main entrances, on pedestrian routes within and around the Site, and on roof top terraces. Analysis was conducted on a seasonal basis but the report focuses on the windiest season results (i.e. winter) and those for the summer season, when pedestrian activity generally requires calmer conditions.

This report presents a description of the methodology used and the results of three configurations tested in the wind tunnel, namely:

- Configuration 1: Existing site and Surrounding Buildings;
- Configuration 2: Proposed Development with Existing Surrounding Buildings; and
- Configuration 3: Proposed Development and Cumulative surrounding buildings.

3.1 Site Description and Surroundings

The Proposed Development is located in Reading, around 500m to the South west of Reading Station with the site bounded by Oxford Road to the north, Dusseldorf Way and Hosier Street to the South, St Mary’s Butts to the East, and Queens Walk to the West. The OS Landranger reference grid for the Site is SU711734.

The site is currently occupied by Broad Street Mall to which three additional towers will be added, and the surrounding area comprises low- to medium-rise residential and commercial buildings. The surrounding area is characterised by ‘suburban’ terrain which results in a relatively turbulent wind environment with a lower mean wind speed (compared to an equivalent site in open terrain).

3.2 The Proposed Development

The Proposed Development retains the existing Broad Street Mall structure and adds three tall residential towers to be linked by a podium which will be used as outdoor amenity space. There are also a less substantial height increases to Quadrant house along the East of the site on St Mary’s Butts, and along the North of the site on Oxford Road.



Figure 1: Site Location with the approximate Site highlighted in yellow.

4. METHODOLOGY AND ASSESSMENT CRITERIA

Wind tunnel testing is the most well-established and robust means of assessing the pedestrian wind microclimate. It enables the wind conditions at the Site to be quantified and classified in accordance with the Criteria. To produce the results within the tunnel, two 1:300 scale models were constructed which included the existing buildings at the Site and the surrounding area within a 360 metre (m) radius of each model target (centre).

The basic methodology for quantifying the pedestrian level wind environment is outlined below:

1. Measure the wind speeds at pedestrian level in the wind tunnel relative to a reference wind speed;
2. Adjust standard meteorological data to account for conditions at the Site;
3. Combine these to obtain the expected frequency and magnitude of wind speeds at pedestrian level; and
4. Compare the results with the Criteria to ‘grade’ conditions around the Site.

4.1 Simulation of Atmospheric Winds

The wind is turbulent, or gusty, and this turbulence varies depending upon the Site. It is necessary to reflect these differences in the wind tunnel test. In addition, the atmospheric boundary layer is a shear flow which means that the mean wind speed increases with height. Modelling these effects is achieved by a combination of spires and floor roughness elements to create a naturally-grown boundary layer that is representative of urban or open country conditions, as appropriate. The detailed contoured proximity model around the Site is used to fine-tune the flow and create conditions similar to those expected at full scale (as shown in Figure 2).

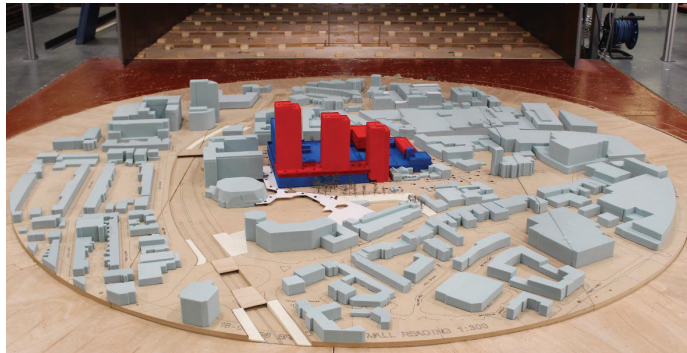


Figure 2: Image of the Proposed Development with Exiting Surrounding Buildings and Existing landscaping. (View in the wind tunnel from South)

4.2 Measurement Technique

Wind speed measurements were made using Irwin probes. For pedestrian comfort studies, both the mean wind speed and the peak wind speed are measured at selected locations at the Site and surrounding area to represent sensitive receptors, such as entrances, amenity areas and thoroughfares, at a scaled height of 1.5m above ground level. The typical equivalent full-scale time period for measuring the mean wind speed is around 90 minutes, whereas the peak wind speed is taken as the wind speed exceeded for 1% of the time.

Wind speed at each location was measured for 36 wind directions in 10° increments, with 0° representing wind blowing from the north and 90° wind blowing from the east.

4.3 Scaling

The length scale of the model was 1:300 and the velocity scale was approximately 1:2 for strong winds. Consequently, the time scale for the tests was 1:150, or in other words 1 second in the wind tunnel is equivalent to 150 seconds at full scale.

4.4 Meteorological Data

Approximately 30 years of meteorological data for Reading (represented by a dataset from Heathrow airport) was used in this report and is presented in Appendix B as wind roses by season. The radial axis indicates the directional distribution of winds. The seasons are defined as spring (March, April and May), summer (June, July and August), autumn (September, October and November) and winter (December, January and February).

The wind data derived from the meteorological station of Heathrow airport has been corrected to standard conditions of 10m above open flat level country terrain, over which pedestrian level wind speeds are greatest. The meteorological station data are then adjusted to site conditions by assessing the terrain in all directions around the Development. Pedestrian level wind speeds at open, flat, level country terrain are typically greater than at an inner city environment with low to medium rise buildings, due to the difference in boundary layer thickness for the vertical wind profile. Hence roughness lengths, a parameter for the wind profile equations that specifies the type of terrain, were estimated in all directions for appropriate upwind distances by use of virtual geographical software, and input into calculations for the wind profiles.

The meteorological data indicate that the prevailing wind direction throughout the year is from the south-west, which is a consistent feature of met stations in the South of the United Kingdom.

The combination of meteorological data and velocity ratios permits the percentage of time that wind speeds are exceeded on the site to be evaluated. The locations can then be assessed using the Criteria, as described below.

4.5 Pedestrian Comfort

The assessment of the wind conditions requires a standard against which the measurements can be compared. This report uses the Lawson Comfort Criteria, which have been established for over thirty years. The Criteria, which seek to define the reaction of an average pedestrian to the wind, are described in Table 1. If the measured wind conditions exceed the threshold wind speed for more than 5% of the time, then they are unacceptable for the stated pedestrian activity and the expectation is that there may be complaints of nuisance or people will not use the area for its intended purpose.

The Criteria sets out four pedestrian activities and reflect the fact that less active pursuits require more benign wind conditions. The four categories are sitting, standing, strolling and walking, in ascending order of activity level, with a fifth category for conditions that are uncomfortable for all uses. In other words, the wind conditions in an area for sitting need to be calmer than a location that people merely walk past.

The distinction between strolling and walking is that in the strolling scenario pedestrians are more likely to take on a leisurely pace, with the intention of taking time to move through the area, whereas in the walking scenario pedestrians are intending to move through the area quickly and are therefore expected to be more tolerant of stronger winds.

The Criteria are derived for open air conditions and assume that pedestrians will be suitably dressed for the season. Thermal comfort is discussed with reference to acceptable wind environments but not evaluated as part of the assessment.

The coloured key in Table 1 corresponds to the presentation of wind tunnel test results described later in this report.



Table 1: Lawson Comfort Criteria

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

4.6 Strong Winds

Lawson¹ also specified a lower limit strong wind threshold when winds exceed 15m/s for more than 2.2 hours of the year. Exceedance of this threshold may indicate a need for remedial measures or a careful assessment of the expected use of that location; e.g. is it reasonable to expect elderly or very young pedestrians to be present at the location on the windiest day of the year?

Wind speeds that exceed 20m/s for more than 2 hours of the year represent a safety issue for all members of the population, which would require mitigation to provide an appropriate wind environment.

Strong winds are generally associated with areas which would be classified as acceptable for walking or as uncomfortable. In a mixed-use urban development scheme, walking and uncomfortable conditions would not usually form part of the 'target' wind environment and would usually require mitigation due to pedestrian comfort considerations. This mitigation would also reduce the frequency of, or even eliminate, any strong winds.

5. RESULTS

5.1 Details of Analysis

To account for the difference in height and terrain roughness between meteorological conditions at the airports and the Site, it is necessary to apply adjustment factors to the wind tunnel velocity ratios. Adjustment factors (mean factors) were computed for wind directions from 0° through to 360°. The reference height in the wind tunnel was at the equivalent full-scale height of 120 metres. Table 2 presents the mean factors for the Site.

¹ Lawson T.V. (April 2001), Building Aerodynamics, Imperial College Press



Table 2: BREVe3 mean factors at 120m above ground level

Wind Direction	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
Mean Factor at 120 m	1.41	1.42	1.44	1.43	1.39	1.45	1.46	1.51	1.46	1.41	1.41	1.40

5.2 Desired Pedestrian Activity around the Development

Generally, for the Development, the target conditions are:

1. Strolling during the windiest season on pedestrian thoroughfares;
2. Standing conditions at main entrances, drop off areas or taxi ranks, and bus stops throughout the year; and
3. Sitting conditions at outdoor seating and amenity areas during the summer season when these areas are more likely to be frequently used by pedestrians.

The walking and uncomfortable classifications are usually avoided because of their association with occasional strong winds, unless they are on a minor pedestrian route or a route where pedestrian access could be controlled in the event of strong winds.

Achieving a sitting classification in the summer usually means that the same receptor would be acceptable for standing in the windiest season because winds are stronger at this time.

This is considered an acceptable occurrence for the majority of external amenity spaces because other factors such as air temperature and precipitation influence people's perceptions about the 'need' to use seating in the windiest season.

It should be noted that a mixture of sitting use and standing use is acceptable for larger amenity spaces, should designated seating not be located at the windier locations suitable for standing use. Furthermore, standing use conditions are also considered tolerable at private amenity areas (such as balconies) where the occupant has control over the use of the space.

5.3 Performance against the Lawson Criteria

The wind microclimate within and around the Site has been assessed and classified using the Lawson Criteria defined in Table 1. Expected usage of each location is shown in Table 2, below. Significant features of the proposed landscaping scheme required for suitable wind conditions are shown in Appendix A.

Table 2: Expected Receptor Usage

Receptor	Location	Receptor Reference (Probe Measurement Number)
On-Site		
Thoroughfares	Car Park	93, 94, 95, 96, 97, 98, 99, 100, 101
	Podium	102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116
	Site A Terrace	118
	Site B Terrace	120

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Entrances	Site C Terrace	122
	Queen's Walk	7, 15, 18
	Oxford Road	29, 31, 34, 38, 39
	St Mary's Butts	57
Thoroughfares	Off-Site	
	Queen's Walk	3, 4, 5, 6, 8, 9, 11, 14, 16, 17, 19
	Dusseldorf Way (South)	1, 2, 81, 83, 86, 87, 91, 91,
	Oxford Road	22, 23, 24, 25, 26, 35, 36, 37, 46, 47
	Broad Street	43, 44, 45
	St Mary's Butts	49, 51, 52, 53, 55, 56, 58, 59, 68, 69, 60, 61, 62, 63, 70, 72, 73, 66
	Hosier Street	73, 75, 76, 77, 78, 79, 80, 81, 82
Entrances	Queen's Court	10, 12
	Oxford Road	20, 21, 27
	St Mary's Church	67
Road	Oxford Road	24, 28, 30, 33
Roadways	St Mary's Butts	50, 54, 71
	Oxford Road	40, 41, 32
	St Mary's Butts	42, 48, 65

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114	S15	210	25.2
116	S15	290	4.8
120	S15	60	2.8
Configuration 3: Proposed Development and Cumulative Surrounding Buildings			
6	S15	210	4.6
74	S15	210	2.8
75	S15	210	2.7
102	S15	210	12.2
104	S15	210	20.8
105	S15	200	12.7
106	S15	210	9.0
110	S15	210	26.3
112	S15	200	8.1
114	S15	210	21.8
116	S15	280	4.7

5.4 Occurrence of Strong Winds

Strong winds exceeding 15m/s for more than 2.2 hours per year are listed below.

Table 3: Annual exceedance of strong winds

Location	Threshold Exceedance	Wind Direction	Hours per Annum
Configuration 1: Existing Site and Surrounding Buildings			
6	S15	200	3.3
Configuration 2: Proposed Development with Existing Surrounding Buildings			
6	S15	210	5.6
74	S15	200	8.9
77	S15	230	2.5
102	S15	210	14.1
104	S15	190	13.6
106	S15	210	10.3
110	S15	230	28.6
112	S15	200	9.2



6. CONCLUSIONS

1. Meteorological data for the Site indicate strong prevailing winds from the south-west quadrant throughout the year with secondary winds from the north-east direction which are more prevalent during the spring months.
2. The majority of locations in and around the Site in the baseline scenario (Configuration 1) have wind conditions suitable for their intended use. There is one strong wind safety exceedance at probe 6 on Queens Walk which will require mitigation. The following locations were unsuitable;
 - Thoroughfare on Queen's Walk (location 6)
 - An Entrance on Queen's Walk (location 7)
 - Ground level amenity space (location 74)
3. With the proposed development in Situ (Configuration 2), the majority of ground level locations are suitable for their intended use, however the balconies and terrace will require mitigation to be suitable for use, as will the following locations;
 - The entrance to St Mary's Church (location 67)
 - Thoroughfare and Entrance on Queen's Walk (location 6 and 7)
 - All Podium locations
 - All Terrace locations

Additionally, there were a number of safety exceedances (Table 3) which will require mitigation

4. With cumulative developments in situ (Configuration 3) wind conditions were generally the same or calmer than in Configuration 2 indicating the cumulative developments do not have a significant effect on the proposed development or surrounding area. Mitigation will be still be required in the same locations as in Configuration 2 to make all areas suitable for their intended use. There were a number of safety exceedances which will require mitigation as outlined in Table 3.
5. Existing Landscaping to the South of St Mary's Butts will be included in the wind tunnel model. It is expected this will make the entrance to St Mary's Church (location 67) suitable for use. Additionally this may mitigate safety exceedances at Ground Level amenity space (location 74), and ground level thoroughfare (location 77). If calmer winds are required, additional landscaping will be introduced and wind tunnel tested.
6. Mitigation measures proposed which will be wind tunnel tested, and incorporated into the design as appropriate include:
 - Canopies of at least 2-3m depth to be added to Site A and Site B (the two tallest towers) to mitigate against downwashing and corner accelerations. These may include porous baffles beneath the canopy to diffuse winds;
 - Pergolas added to the Podium level seating areas to make conditions suitable for seating;
 - Trellises added to the Podium level of at least 2m height and width in a scattered formation to mitigate against channelling;
 - Screens and dividers added to Terrace locations to make suitable for sitting conditions;
 - Screens, planters, and trees to be added to Queen's Walk to make the thoroughfare and entrance suitable for intended use (location 6 and 7), and



- Other elements including porous or solid screens (at least 2m height and width), planters or shrubs (at least 1.5m total height), trees (at least 3m total height) which can be incorporated into the landscaping plan as appropriate.

APPENDICES



APPENDIX A: WIND TUNNEL PHOTOS

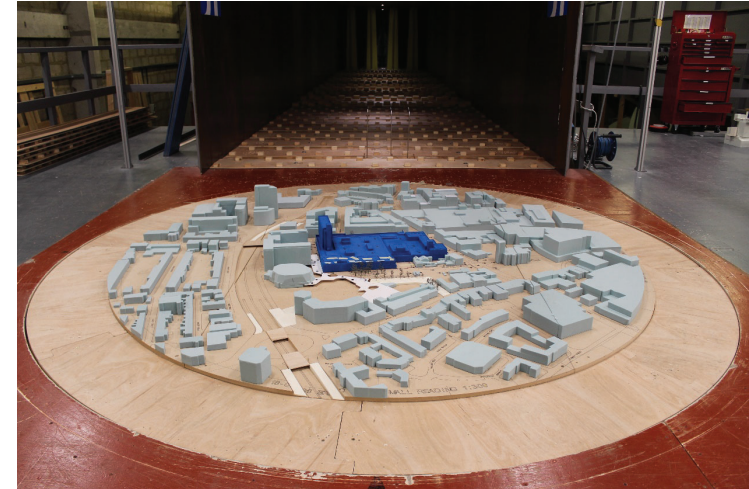


Figure 3: Existing Site and Surrounding Buildings (Configuration 1) – View in the Wind Tunnel (from the South)

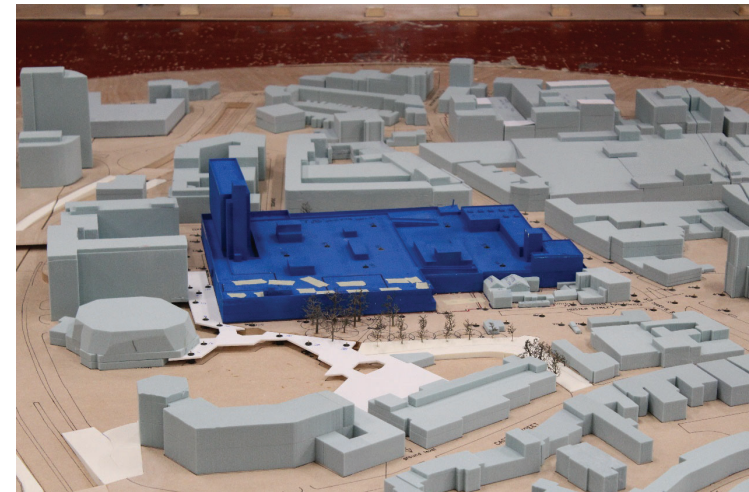


Figure 4: Existing Site and Surrounding Buildings (Configuration 1) – View in the Wind Tunnel (from the South)

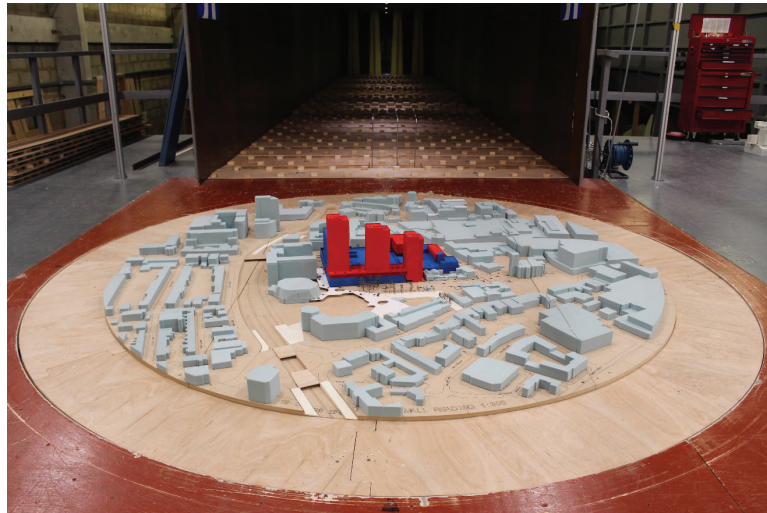


Figure 5: Proposed Development and Existing Surrounding Buildings (Configuration 2) – View in the Wind Tunnel (from the South)

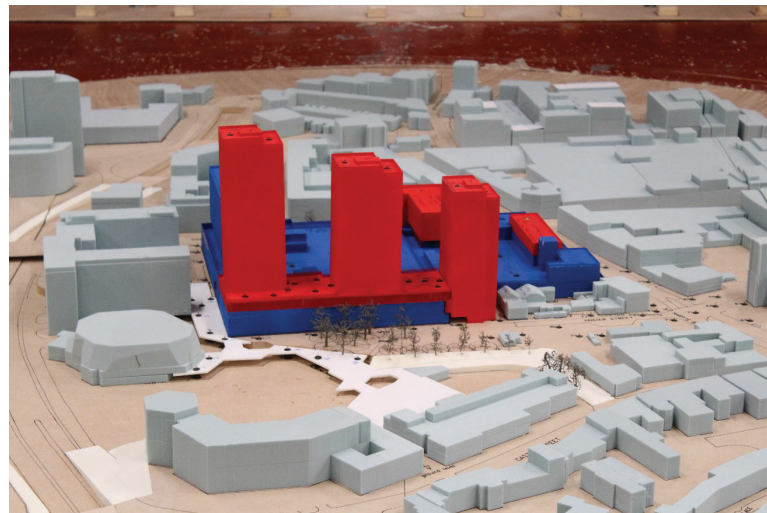


Figure 6: Proposed Development and Existing Surrounding Buildings (Configuration 2) – View in the Wind Tunnel (from the South)

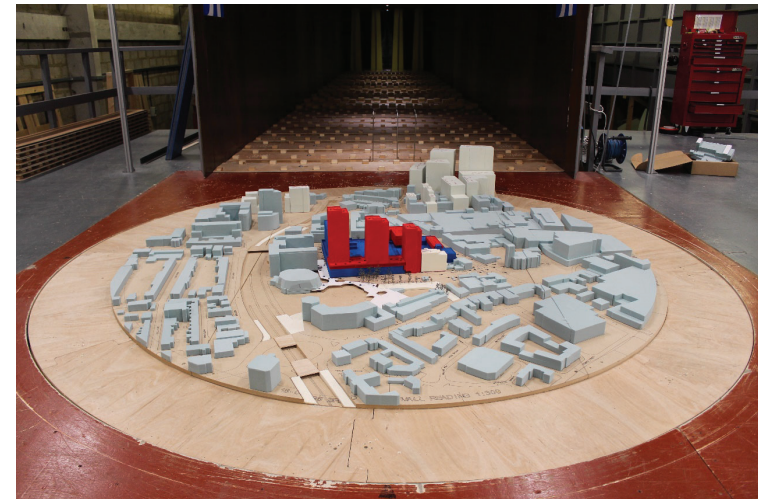


Figure 7: Proposed Development and Cumulative Surrounding Buildings (Configuration 3) – View in the Wind Tunnel (from the South)

APPENDIX B: METEOROLOGICAL DATA

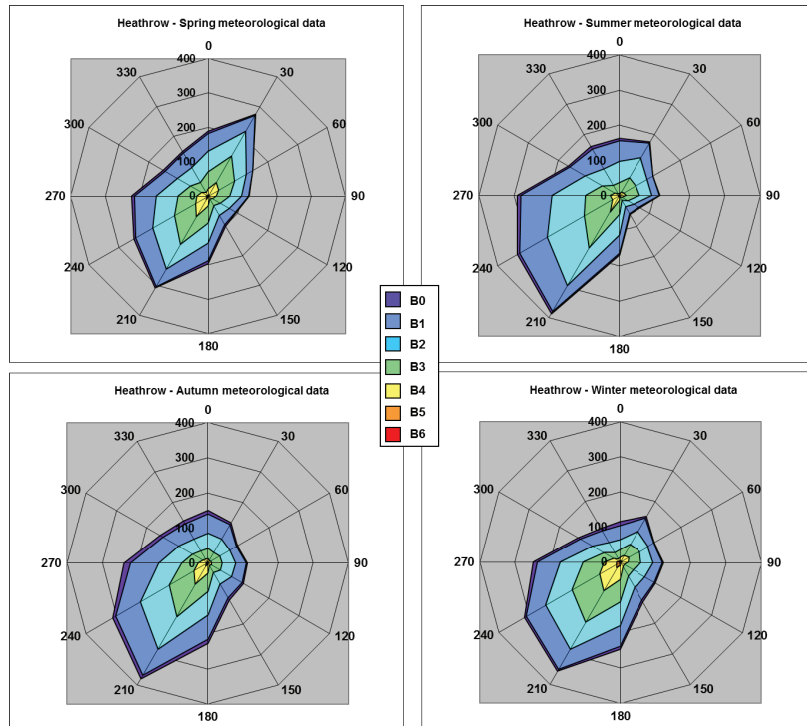


Figure 8: Seasonal wind roses from London Heathrow Airport (in Beaufort Force) - (Radial axis indicates the hours for which the stated Beaufort Range is exceeded)

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