APPENDIX 17.1
PEDESTRIAN LEVEL WIND MICROCLIMATE ASSESSMENT

FINAL REPORT

STAG BREWERY

LONDON, UK

PEDESTRIAN LEVEL WIND MICROCLIMATE ASSESSMENT

RWDI #2200369

4TH MARCH 2022

SUBMITTED TO

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VERSION HISTORY

RWDI Project #2200369	Stag Brewery London, UK	
Report	**Releases**	**Dated**
Reports	Rev A Final	31st January 2022 4th March 2022
Project Team	Hesham Ebrahim Jeniffer Lowther Stefan Astley	Project Engineer Project Engineer Project Manager

1 INTRODUCTION

RWDI was retained to conduct a pedestrian level wind microclimate (PLW) assessment for the Proposed Development in London, UK. This report presents the methodology employed by RWDI.

Wind tunnel tests were conducted on a 1:300 scale model of the Proposed Development (referred to as the "Proposed Development" in this report henceforth). The investigation quantifies the wind conditions within and around the Site through comparison of the measured wind velocity and frequency of occurrence with the Lawson Comfort Criteria. Meteorological data for London, UK has been combined, analysed and adjusted to the Site conditions by modelling the effect of upstream terrain roughness on the wind velocities approaching the Site.

Measurements were taken at up to 356 locations for 36 wind directions, in 10° increments. The measurements covered ground level locations along the building façades and at corners, near main entrances, on pedestrian routes within and around the Site, private balconies and terraces within the Site. The analyses were conducted on seasonal basis, however, the report focuses primarily on the windiest season (i.e. winter) and the summer season results, when pedestrian activity generally requires calmer conditions.

The following list details the configurations tested in the wind tunnel:

- Configuration 1: Existing Site with Existing Surrounding Buildings;
- Configuration 2: Proposed Development with Existing Surrounding Buildings; and
- Configuration 3: Proposed Development with Existing Surrounding Buildings and Proposed Landscaping.

2 METHODOLOGY AND ASSESSMENT CRITERIA

Wind tunnel testing is a well-established and robust technique to assess the pedestrian wind microclimate of the Proposed Development. It provides the means to quantify the wind conditions at the Site and for the measurements to be classified in accordance with the Lawson Comfort Criteria (outlined in Section 2.5). Wind tunnel investigations were conducted using a 1:300 scale model of the Proposed Development with existing and cumulative surrounding buildings and terrain covering a radius of 360m centred on the Site.

The basic methodology for quantifying the pedestrian level 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 velocities at pedestrian level; and
4. Compare the results with the Lawson Comfort Criteria to 'grade' conditions around the Site.

2.1 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 1).

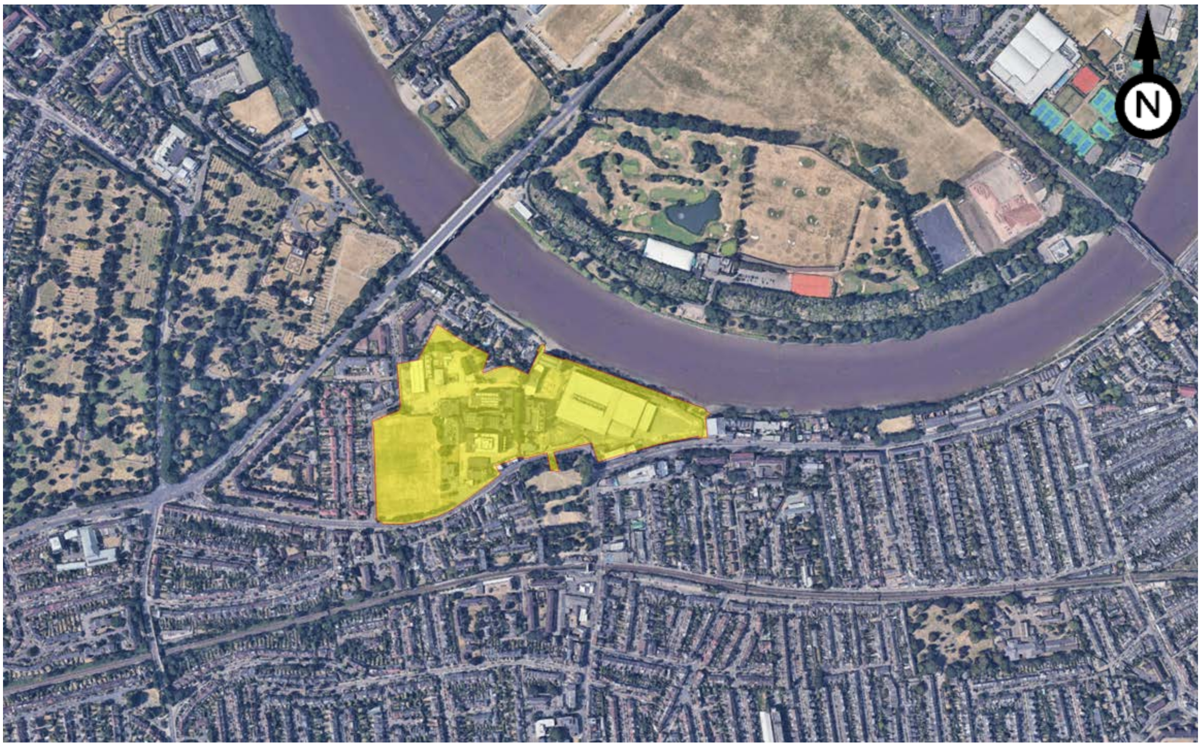

Figure 1: Aerial view of the existing Site (approximate extent of the Site highlighted in yellow)

2.2 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 each location 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 speeds at each location were measured for 36 wind directions in 10° intervals, with 0° representing a wind blowing from the north and 90° a wind blowing from the east.

2.3 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. The sampling frequency for the data acquisition equipment is therefore adjusted for the time scale.

2.4 Meteorological Data

Approximately thirty years' worth of data were obtained from the combined London airports and was categorised by season as demonstrated in Figure 2 as wind roses. The radial axis indicates the percentage hours per season that the wind speed exceeds the particular velocity range. 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 data has been corrected to standard conditions of 10m above open flat level country terrain, over which pedestrian level wind speeds are greatest. The data is then adjusted to the Site conditions using the methodology implemented in the BREVe3.2 software package. Low to medium rise inner city environments increase the turbulence within the atmospheric boundary layer which reduces the mean wind speed, requiring terrain roughness factors to be specified and applied to the meteorological data to account for the variations in terrain surrounding the Site.

The meteorological data indicates prevailing winds from the west throughout the year. There is a secondary peak from the south-east during the autumn and winter seasons.

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

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 0^0 through to 360°. The reference height in the wind tunnel was at the equivalent full-scale height of 120 metres. Table 1 presents the mean factors for the Site. To put these numbers into perspective, a higher mean factor for angles 0^0-30^0 means that the oncoming wind speeds are higher (likely due to having more open surrounds in these angles).

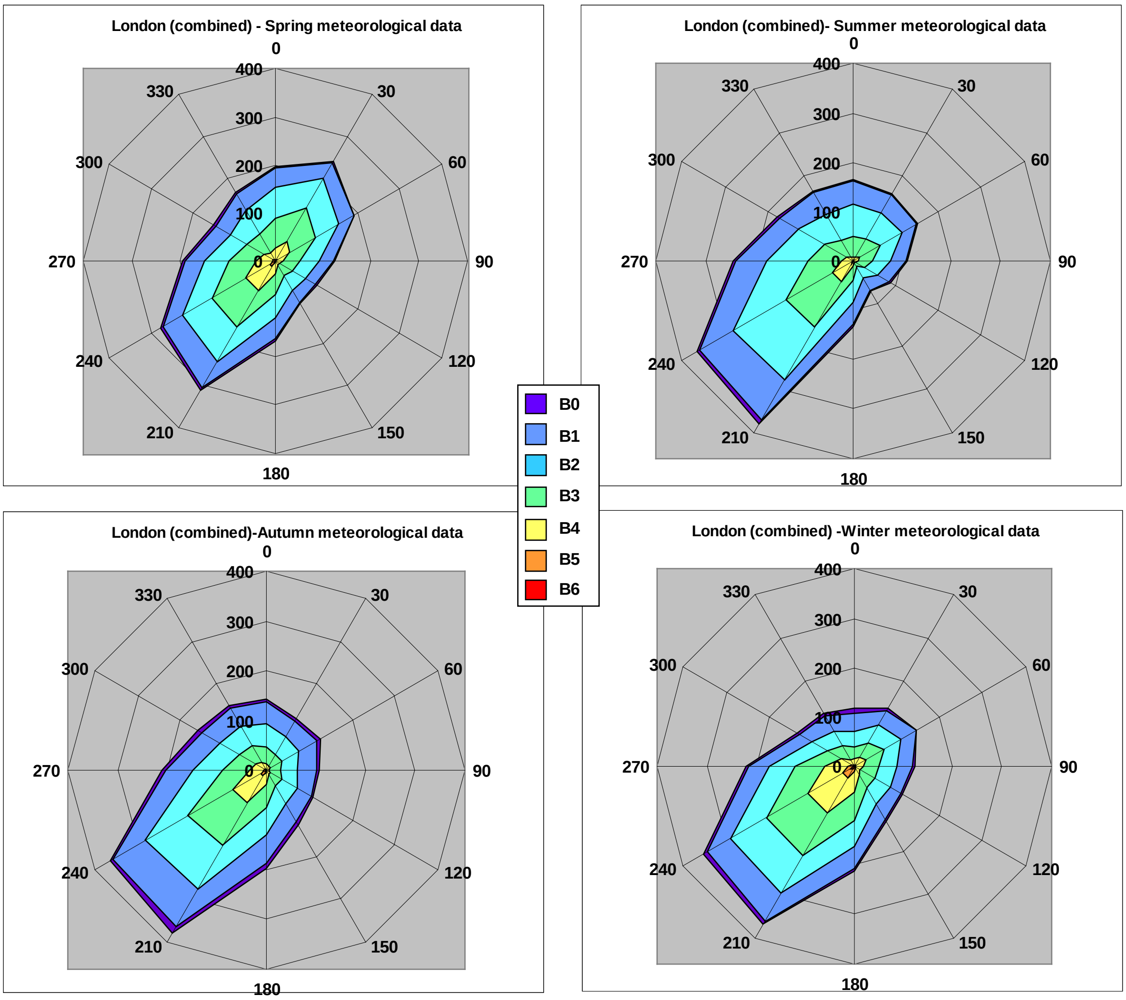

Figure 2: Figure 10: Seasonal wind roses for London (in Beaufort Force) (Radial axis indicates the hours for which the stated Beaufort Range is exceeded)

Table 1: ESDU 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	1.39	1.41	1.42	1.43	1.38	1.40	1.45	1.44	1.40	1.38	1.39	1.36

2.5 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[1] that have been established for over thirty years and have been widely used on building developments across the United Kingdom. The comfort criteria seek to define the reaction of an average pedestrian to the wind as described in Table 2. If the measured wind conditions exceed the threshold wind velocity for more than 5% of the time, then they are deemed unacceptable for the intended pedestrian activity. 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 categories are sitting, standing, strolling and walking, in ascending order of activity level, with a fifth category for conditions that are uncomfortable for all pedestrian 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.

The coloured key in Table 2 corresponds to the presentation of wind tunnel test results described in the results section of this report.

Table 2: Lawson Comfort Criteria

Key	Comfort Category	Threshold	Description
(light green)	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
(blue)	Standing	4-6 m/s	Gentle breezes acceptable for main building entrances, pick-up/drop-off points and bus stops
(yellow)	Strolling	6-8 m/s	Moderate breezes that would be appropriate for strolling along a city/town street, plaza or park
(magenta)	Walking	8-10 m/s	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering
(red)	Uncomfortable	>10 m/s	Winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended

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

2.6 Desired Pedestrian Activity around the Proposed Development

Generally, for a mixed-use development, the target conditions are:

- Strolling during the windiest season on pedestrian thoroughfares;
- Standing/entrance conditions at main entrances, drop off areas or taxi ranks, and bus stops throughout the year;
- Sitting conditions at outdoor seating during the summer season when these areas are more likely to be frequently used by pedestrians; and
- Sitting or standing use conditions during the summer season on balconies and private amenity spaces.

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 measurement location would be suitable for standing in the windiest season because winds are stronger during this period. 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 middle of winter.

For a large terrace space, a mix of standing and sitting wind conditions is acceptable provided that any desired seating areas are situated in areas having sitting wind conditions.

2.7 Strong Winds

In addition, the criteria stipulate two strong wind threshold limits; when winds exceed 15m/s or 20m/s for more than 0.025% of the time (approximately 2 hours of the year). The lower limit, 15m/s, if exceeded may require remedial measures depending on the sensitivity of the location i.e. is it reasonable to expect an elderly or very young pedestrian to be present at the location? Wind speeds that exceed the 20m/s threshold for more than approximately 2 hours per year would represent a safety risk for all members of the population and would therefore require mitigation to provide an appropriate wind environment.

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

Table 3 summarises the probe locations that wind conditions exceed the safety threshold.

Table 3: Annual Exceedance of Strong Winds

Location	Strong Wind Exceedance	Main Wind Direction	Hours per Annum
Configuration 1: Existing Site with Existing Surrounding Buildings			
No occurrences of strong winds within this Configuration.			
Configuration 2: Proposed Development with Existing Surrounding Buildings			
No occurrences of strong winds within this Configuration.			
Configuration 3: Proposed Development with Existing Surrounding Buildings and Proposed Landscaping			
No occurrences of strong winds within this Configuration.			

Table 5: Intended Usages at Each Probe Location

Usage	Location
Thoroughfares	1-72, 74-91, 93-117, 119-123, 128-132, 135-141, 147-154, 156-159, 164-165, 171-174, 176, 178-179, 181, 183, 185, 187, 189-196, 198-203, 207-208, 211-212, 214-216, 218-220, 222-224, 226-231, 233-236, 239-242, 244-246, 311-335
Entrances	73, 92, 118, 124-127, 133-134, 142-146, 155, 161, 163, 166, 175, 177, 180, 182, 188, 197, 204-206, 209, 213, 217, 221, 225, 232, 237-238, 243
Ground Level Amenity – Seating	160, 162, 167, 184, 186,
Above Ground Level Amenity	247-252, 254, 256, 258-260, 262-269, 271-278, 280-310, 351-356

APPENDIX A

APPENDIX A: WIND TUNNEL PHOTOS

Figure 3: Existing Site with Existing Surrounding Buildings (Configuration 1) – View of the Model (from the south)

Figure 4: Existing Site with Existing Surrounding Buildings (Configuration 1) – View of the Model (from the south)

Figure 5: The Development with Existing Surrounding Buildings (Configuration 2) – View of the Model (from the south)

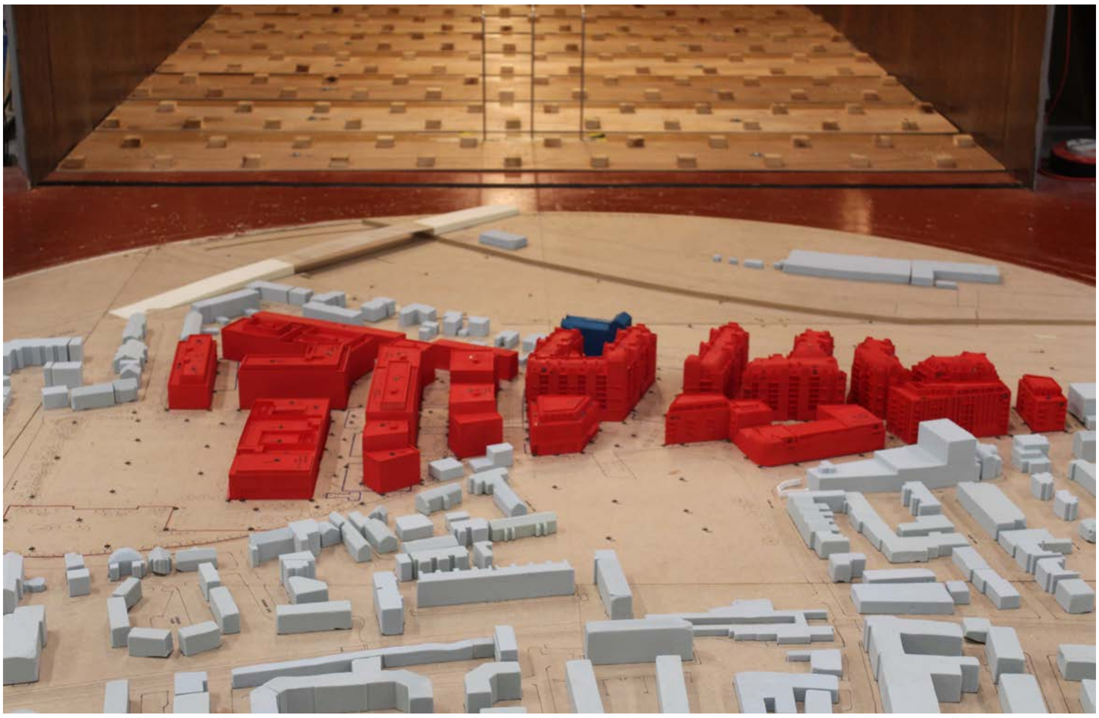

Figure 6: The Development with Existing Surrounding Buildings (Configuration 2) – View of the Model (from the south)

Figure 7: The Development with Existing Surrounding Buildings and Proposed Landscaping (Configuration 3) – View of the Model (from the south)

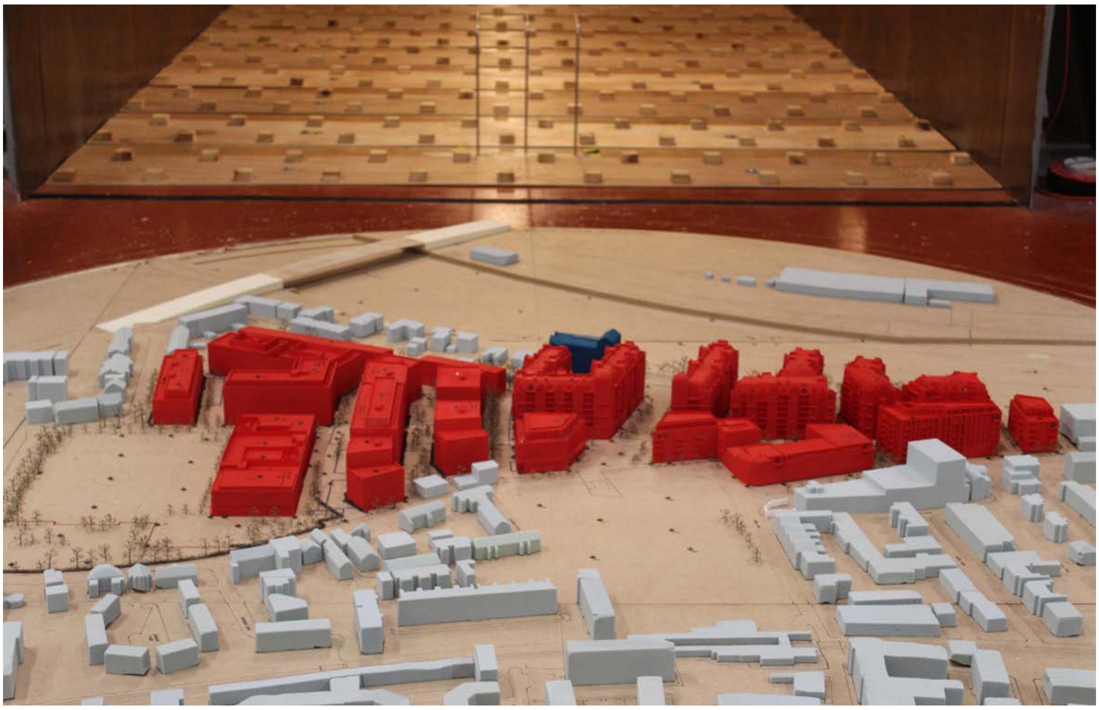

Figure 8: The Development with Existing Surrounding Buildings and Proposed Landscaping (Configuration 3) – View of the Model (from the south)