WIND MICROCLIMATE GUIDELINES
FOR DEVELOPMENTS IN THE CITY OF LONDON

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Contents

Introduction

This document provides general guidelines for wind microclimate studies required as part of the planning applications of new development proposals in the City of London (CoL).

Good wind microclimate conditions are necessary for creating outstanding public spaces in the City for all. Adverse wind effects can reduce the quality and usability of outdoor areas, and lead to safety concerns in extreme cases. These guidelines focus on the primary factors that affect the quality and consistency of wind microclimate studies.

Other factors such as temperature, sunlight, air quality and noise also have an influence on outdoor comfort, and some of these factors may be incorporated in a future edition of these guidelines.

The guidelines cannot cover every eventuality that may arise in such studies. Therefore, expert judgement from an experienced wind engineer will always be required in wind microclimate studies, particularly for issues that are not explicitly covered by these guidelines.

Developers are encouraged to address wind microclimate matters at an early stage before their designs are finalized. Using these guidelines, appointing experienced consultants, having dialogue with officers of the City and commissioning early-stage studies to quantify the wind microclimate conditions will help ensure good pedestrian comfort conditions around proposed development sites.

These guidelines may be updated from time to time, so users should check the City of London web site to ensure that the latest version of the guidelines are being used.

Wind studies may also be required for other purposes, such as obtaining loading conditions for the structure or for local fixings of facades and canopies. These issues are dealt with under the Building Regulations, and advice can be sought from the City's District Surveyor.

Recommended approach for wind microclimate studies

The table below outlines the general expectations for the types of wind microclimate studies required for various building heights.

This table is specifically tailored for building proposals in the City of London. This table may not be suitable in other parts of London or in other cities where the height of general surroundings is lower than the typical building stock in the city.

Also, this table may not cover all possible eventualities and cases. Developments that feature highly sensitive pedestrian activities or affect more vulnerable groups (e.g. transport hubs, hospitals, elderly people's homes, schools, nurseries, parks etc.) or those that are located near known windy or exposed areas (e.g. edge of Thames) may require more detailed checks. The wind consultant should use his/her judgement in consultation with the planning officers who have detailed local knowledge to determine whether the project they are working on has features that require extra care and attention.

Building Height	Recommended Approach to Wind Microclimate Studies
Similar or lower than the average height of surrounding buildings **Up to 25m in CoL**	Wind studies are not required, unless sensitive pedestrian activities are intended (e.g. around hospitals, transport hubs, etc.) or the project is located on an exposed location (e.g. edge of Thames, near a tall building)
Up to double the average height of surrounding buildings **25m to 50m in CoL**	Computational (CFD) Simulations **OR** Wind Tunnel Testing
Up to 4 times the average height of surrounding buildings **50m to 100m for CoL**	Computational (CFD) Simulations **AND** Wind Tunnel Testing
High-Rise **Above 100m**	**Early Stage Massing Optimization:** Wind Tunnel Testing OR Computational (CFD) Simulations **Detailed Design:** Wind Tunnel Testing **AND** Computational (CFD) Simulations to demonstrate the performance of the final building design

Where both wind tunnel and CFD are required, the two wind modelling approaches must be carried out by independent consultants.

Where there are differences between wind tunnel and CFD results, a report should be prepared to identify potential reasons for differences, sensitivity checks (e.g. grid sensitivity, surround extend sensitivity, turbulence generation in the wind tunnel, etc.) and a summary of the most representative set of wind conditions around the proposed scheme.

General technical requirements

The wind study should include the evaluation of pedestrian level wind conditions for following scenarios;

- Existing site,
- Proposed scheme with existing surroundings,
- Proposed scheme with planning consented schemes,
- Existing site with planning consented schemes, should the wind conditions for the previous case exceed the required Lawson comfort or safety categories,
- (If mitigation measures are required) the cases above with wind mitigation or improvement features,
- (If applicable or requested by CoL) proposed scheme with a likely future scenario, including buildings that may not be consented but are being designed at the time of planning submission. Discussion with planning officers can help identifying such future buildings.
- (If applicable or requested by CoL) the construction scenario with a demolished (vacant) site, especially if the existing building is taller than 40m in height.

When choosing the planning consented or future schemes for inclusion in the studies, the planning consultants should liaise with CoL, and use the following guidelines;

- Consented/future buildings that are immediately around the proposed development must be included, regardless of their height,
- Consented/future buildings that are taller than the average height of surrounding buildings and are within 300m of the site need to be included.

Information for consented buildings is publicly available at the CoL planning portal or could be requested from the relevant design team. CoL planning officers can provide guidance on future schemes and assist in obtaining information for such schemes (if any).

There are four key steps to a successful wind microclimate study;

1. Selecting appropriate wind statistics for the site (see Annex A for City of London wind statistics),
2. Determining the impact of the proposed development, through computational fluid dynamics (CFD) tools and/or wind tunnel testing, which provide a set of 'speed-up' ratios,
3. Combination of speed-up ratios with wind statistics to obtain comfort ratings,
4. Comparison of comfort ratings with intended pedestrian activities using the criteria provided in this guideline, as well as interpretation and presentation of results as covered separately in chapter 6.

Wind characteristics: statistical properties of wind climate are typically characterized by a Weibull probability density function. Annex A provides seasonal Weibull coefficients that can be used for projects in the heart of City of London (i.e. Terrain corrected for City of London). For projects on more exposed parts of the city – e.g. next to river Thames – an adjustment to these coefficients is required to take account of the site exposure, as described in Annex A. **These climate properties have been calibrated for City of London, and may not be appropriate for other parts of London or other cities.**

Number of wind directions: all wind studies should be carried out for 36 equally spaced wind directions.

Wind profile: the variation of mean and gust wind speed with height should be modelled based on the Harris and Deaves boundary layer models in UK National Annex to the Eurocode, also set out in ESDU 01008. Plots of simulated (wind tunnel or CFD) and targeted profile should be provided as part of the planning report.

Determination of speed-ups: computational fluid dynamics (CFD) tools or wind tunnel tests should be used to determine speed-up ratios for each individual wind direction. Speed-ups are defined as the ratio of local wind speed at pedestrian-level locations to the undisturbed reference wind speed. The pedestrian-level wind speeds should be measured at a height of 1.5m above the local ground level (or terrace/balcony level), and the reference wind speed should be determined at a height and location where the building models do not affect the reference speed measurement.

Measurement locations: critical pedestrian-level locations include building entrances, walkways, sitting areas, drop-off locations, bus stops, disabled parking bays, queuing areas, upper-level terraces, balconies, and other frequently used locations. Cycling paths and road crossings will also require measurements. The consultant should use expert judgement to ascertain the extent of the area to instrument and report.

Combination of speed-ups with wind statistics: using CFD or wind tunnel, a set of speed-ups will be determined for each wind direction simulated. These need to be combined with the Weibull probability distribution of the wind climate given in Annex A, to calculate the probability of exceedance of a given wind speed for each wind direction. Adding the probability of exceedance for all directions gives the total probability of exceedance of a given wind speed.

The estimation of comfort or safety speed usually requires a goal-seek calculation, where a certain wind speed is selected, the total probability of exceedance is calculated, and the wind speed is continually altered until the probability of exceedance reaches the desired exceedance value. Note that the CoL Lawson Criteria uses 5% exceedance for comfort and 0.022% Exceedance for safety limits, as described subsequently.

Above and below: **RWDI's wind testing tunnel (RWDI)**

Wind tunnel test requirements

Wind tunnel testing has been used to assess pedestrian microclimate conditions for the past several decades. However, significant variability in methodology can exist between different test facilities, and care should be taken to ensure the quality and consistency of wind tunnel tests.

Wind tunnel models should accurately represent the three-dimensional geometry of the proposed development. It is noted that building features that project more than 0.5m near pedestrian areas can affect the localized wind conditions, and must therefore be modelled for the proposed building and existing buildings immediately around the site. Also, building geometry near entrances and key pedestrian areas could affect the results and must be included in the models.

It is prudent to ignore landscape features in the baseline wind studies, especially when the landscape elements are smaller than 8m in height. Larger mature trees can be included, but limited published guidance exists for modelling such landscape features, so care should be taken to provide appropriately conservative interpretation of their impacts.

The wind tunnel models should represent all surrounding buildings that are within 400m from the centre of the site. Other taller buildings outside of this zone that could have an influence on wind conditions within the project site – based on the expert opinion of the wind consultant – should be included for wind directions where they are upwind of the project site.

The overall blockage in the wind tunnel (percent of tunnel area occupied by models) should be kept below 5% for closed-circuit wind tunnels and 8% for open-jet or blockage tolerant wind tunnels (in accordance of published wind tunnel testing guidelines such as ASCE SEI and AWES QAM).

The instrumentation used in the wind tunnel should be capable of capturing both the mean (typically 10-15 minute averaged) and gust speeds, with gust values divided by 1.85 To make them comparable to mean values (also referred to as gust equivalent mean value). Instrumentation should not be blocked or impeded by the models.

Care should be taken to ensure that in areas with significant localized variation of wind speed (e.g. near corners) that there are sufficient number of probes to be able to capture the windiest conditions. This typically requires 3 probes at each corner of the proposed development, in areas of increased windiness, and increased probe densities in passageways, between closely spaced buildings, and near key pedestrian areas. Furthermore, probes should be placed on the roadways surrounding the site, to capture possible impacts on cyclists.

Probes should also be placed in areas away from the site where cumulative effects of a cluster of tall buildings could lead to adverse wind conditions. The wind consultant should be aware of the wind conditions expected around other cumulative or existing high-rise buildings, by reviewing the publicly available planning reports on the City of London planning portal.

CFD requirements

Computational fluid dynamics (CFD) tools can create high quality output that provide a good understanding of fundamental flow features. However, significant variability in methodology can exist between different CFD methods and care should be taken to ensure that appropriate modelling approaches are used.

The CFD models must include a detailed three-dimensional representation of the proposed development. It is noted that building features that project more than 0.5m near pedestrian areas can affect the localized wind conditions, and must therefore be modelled for the proposed building and existing buildings immediately around the site. Also, building geometry near entrances and key pedestrian areas could affect the results and must be included in the models.

It is prudent to ignore landscape features in the baseline wind studies, especially when the landscape elements are smaller than 8m in height. Large mature trees can be included, but limited published guidance exists for modelling such landscape features, so care should be taken to provide appropriately conservative interpretation of their impacts.

Maximum cell sizes near critical locations (e.g. entrances, corners, etc.) must be 0.3m or smaller. It is also expected that sufficient cells are used between buildings with a minimum of 10 across a street canyon. However, the cell size of buildings away from the target can be larger to allow for modelling efficiency.

The CFD models should represent all surrounding buildings that are within 400m from the centre of the site. Other taller buildings outside of this zone that could have an influence on wind conditions within the project site – based on the expert opinion of the wind consultant - should be included for wind directions where they are upwind of the project site.

The models must contain at least 3 prism layers below 1.5m height, to capture near-ground effects.

The standard k-epsilon model, or 0 or 1 equation models, should be avoided. The realisable k-epsilon model is currently a robust industry standard, and other turbulence models - such as k-omega SST - can be used if the user can demonstrate that the mesh is suitable for that model.

CFD analysis should report conditions in areas away from the site where cumulative effects of a cluster of tall buildings could lead to adverse wind conditions. The wind consultant should be aware of the wind conditions expected around other cumulative or existing high-rise buildings, by reviewing the publicly available planning reports on the City of London planning portal.

Using wind tunnel and CFD in combination

On some projects wind tunnel testing and CFD are both required for a more comprehensive evaluation. In these situations, two aspects need to be considered;

It is possible to use the two tools to get a more comprehensive understanding of wind effects around a site. For example, CFD results can guide the placement of wind tunnel probes, or highlight the mechanisms of the fundamental wind patterns which can then be further studied in the wind tunnel. Similarly, the transient data collection provided by the wind tunnel tests may identify areas of high turbulence (gusts) which could inform the type of detail of CFD modelling.

Where there are differences between wind tunnel and CFD results, an experienced wind engineer should carry out sensitivity checks (e.g. grid sensitivity, surround extend sensitivity, turbulence generation in the wind tunnel, etc.) To better understand the likely reasons for the differences and summarize the most representative set of wind conditions around the proposed scheme.

Presentation of results and reporting

Wind comfort criteria: a modified version of the Lawson LDDC criteria referred to as the City Lawson Criteria - is to be used for all wind studies as summarized table below;

Category	Mean and GEM wind speed (5% exceedance)	Description
Frequent Sitting	2.5m/s	Acceptable for frequent outdoor sitting use, e.g. restaurant, café.
Occasional Sitting	4m/s	Acceptable for occasional outdoor seating, e.g. general public outdoor spaces, balconies and terraces intended for occasional use, etc.
Standing	6m/s	Acceptable for entrances, bus stops, covered walkways or passageways beneath buildings.
Walking	8m/s	Acceptable for external pavements, walkways.
Uncomfortable	>8m/s	Not comfortable for regular pedestrian access.

The table above deviates from the original Lawson LDDC Criteria in a couple of areas,

- The 'Frequent Sitting' category is based on City of London's desire to create more active public spaces with amenable cafés/restaurant sitting areas in the future.
- The 'Uncomfortable' category is based on experience that Lawson business walking conditions often lead to complaints in the City of London. Therefore, this category is now re-named as 'uncomfortable'. This category is only suitable for areas that are not expected to receive regular public footfall, like service areas, back-of-house areas, etc.
- Discussions with City of London planning officers about the categorisation of sensitive areas would be highly recommended.

Wind safety criteria: a separate safety criteria is to be applied to ascertain the safety risks to pedestrians and cyclists as follows;

Category	Mean and GEM wind speed from any wind direction (0.022% exceedance)	Description
Pedestrian Safety Limit	15m/s	Presents a safety risk for pedestrians, especially to more vulnerable members of the public.

The criteria do not cover wind effects on other activities such as recreation (e.g. sailing) or impact on specific vehicles. More research needs to be conducted to expand the applicability of the criteria for such cases.

Seasonal results: a 'worst season' scenario should be presented, where the worst comfort conditions at each location are provided regardless of the season. Separately a summer season (June-July-August) results should be presented, for areas that are to be used mainly in warmer months of the year. Other seasonal results can be provided at the discretion of the wind consultant.

Safety conditions should be reported annually.

Presentation of results: the comfort conditions should be presented using a colour-coded diagram using the colour coding below. Wind safety results can be overlaid on top of the comfort results, such that any red zone indicates unacceptable or unsafe condition. Alternatively, a separate plot showing the safety conditions can be provided, in addition to the comfort plot.

Comfort Category	Colour
Frequent Sitting	Grey
Occasional Sitting	Blue
Standing	Green
Walking	Yellow
Uncomfortable and/or Unsafe	Red

Acceptability of wind conditions: a detailed review of the intended pedestrian activities around the site should be carried out, and graphically presented and described in the planning submission. This should include the expected pedestrian activities around the proposed development, as well as the pedestrian activities experienced or proposed around existing buildings in the area. The review should take in to account of groups who are more vulnerable to wind conditions such as wheelchair users, people with ambulant mobility impairment, people who are blind, partially sighted or have sensory/neurological processing difficulties, elderly people, pregnant women and young children. If the conditions at any location exceed the levels required for the intended pedestrian activities - or are unsafe - because of the impact of the proposed development, mitigation measures will be required.

Existing wind problems: if the existing site or the consented schemes give rise to exceedances of the comfort or safety criteria for the intended pedestrian uses, this should be clearly demonstrated by testing these configurations (i.e. without proposed scheme). The proposed development should not increase the comfort or safety conditions beyond the levels observed for these scenarios.

Presentation of the test configurations: the report should contain detailed photographs or images of the 3D CFD or wind tunnel used in the analysis. This is expected to include;

- Far-field views of the entire model from north, south, east and west as a minimum,
- Plan view of the entire model,
- Close-up images of the proposed scheme and surrounding buildings within 1 block away from the site,
- Close-up views of key pedestrian areas, such as entrances, key pedestrian walkways, outdoor seating areas, etc.,
- Other building details or appendages that are relevant for wind conditions.

Presentation of mitigation measures: the following details of each mitigation measure or improvement feature should be provided;

- Plan showing the location of each mitigation measure, with each measure given an identifier number,
- Images of each mitigation measure as tested in the wind tunnel or CFD model (preferably accompanied by an architectural diagram/interpretation),
- Table containing the size (height, width, depth), porosity and other relevant aerodynamic parameters (e.g. tree trunk and crown heights).

These requirements apply even if the design feature is not materially categorized as a mitigation measure, but helps to improve the wind conditions. It is intended that all features that improve the wind conditions become an intrinsic part of the building design and are fully implemented on-site.

Significance criteria: it is noted that environmental impact assessments (EIA) require a description of the significance of wind effects at a particular location. This section is intended to provide consistency in these significance descriptors.

Whether a condition is significant or not depends on whether the condition requires mitigation. The tables in the following sections also include a column that defines if mitigation measures are necessary.

The significance of on-site measurement locations are defined by comparing the wind comfort/safety levels with the intended pedestrian activity at each location, using the table opposite;

On-site Receptors

Significance	Trigger	Mitigation required?
Major Adverse	Conditions are 'unsafe'.	Yes
Moderate Adverse	Conditions are 'unsuitable' (in terms of comfort) for the intended pedestrian use.	Yes
Negligible	Conditions are 'suitable' for the intended pedestrian use.	No
Moderate Beneficial	Conditions are calmer than required for the intended pedestrian use (by at least one comfort category).	No

The significance of off-site measurement locations are defined not only by comparing the wind comfort levels with the intended pedestrian activity, but also by comparing the conditions to those experienced prior to the introduction of the proposed development (baseline), using the table below;

Off-site Receptors

Significance	Trigger	Mitigation required?
Major Adverse	Conditions that were 'safe' in the baseline scenario become 'unsafe' as a result of the Proposed Development. OR Conditions that were 'suitable' in terms of comfort in the baseline scenario become 'unsuitable' as a result of the Proposed Development. OR Conditions that were 'unsafe' in the baseline scenario are made worse as a result of the Proposed Development.	Yes
Moderate Adverse	Conditions that were 'suitable' in terms of comfort in the baseline scenario are made windier (by at least one comfort category) as a result of the Proposed Development, but remain 'suitable' for the intended pedestrian activity.	No
Negligible	Conditions remain the same as in the baseline scenario.	No
Major Beneficial	Conditions that were 'unsafe' in the baseline scenario become 'safe' as a result of the Proposed Development.	No
Moderate Beneficial	Conditions that were 'unsuitable' in terms of comfort in the baseline scenario become 'suitable' as a result of the Proposed Development. OR Conditions that were 'unsafe' in the baseline scenario are made better as a result of the Proposed Development (but not so as to make them 'safe').	No

Cyclist comfort

Background: cycling is an increasingly important way of moving around and through the city and is proactively promoted by the city. As a result, ensuring comfort and safety for those cycling is a priority for the city. Wind effects can have a major impact on cycling comfort and safety. In extreme cases, particularly the cross-winds can destabilize or push the cyclist into the path of vehicles. With increasing number of cyclists in the City of London this is an important consideration.

There are other factors that influence the stability of a cyclist, such as weight, side area, proximity to other vehicles/cyclists, speed of travel and the ability/experience of the rider. It is also likely that most cyclists will take some precautions on windy days. However, it is not possible to statistically quantify many of these parameters.

But it is possible to use local wind speed, wind direction and gust duration to make informed decisions on cyclist safety.

Cyclist safety criterion: the LDDC Lawson Criteria notes that the 15m/s safety criteria (from any wind direction exceeded at least once a year) is applicable for cyclists but does not provide a detailed description of how such wind conditions affect riders.

CoL wishes to provide a higher degree of comfort and safety for the increasing number of cyclists on the roads. This section of the guideline builds upon the Lawson criteria to provide a more robust assessment, particularly focussing on the cross-wind gust effects.

CoL wishes to ensure that design teams carefully consider the impact of a local wind conditions on cyclists. The following key considerations are recommended;

The wind consultants should ensure that adequate number of instruments or data collection points are placed along the main roadways, cycle paths and road/pedestrian crossings. For wind tunnel studies this will typically involve one probe at least every 40m on cycling paths immediately around the proposed development.

Areas where the wind speeds rapidly change along a cyclist path (e.g. cyclist travels from a sheltered zone to a wind zone in a short space) can cause distress for cyclists. Therefore, it is expected that wind consultants will focus their attention to such zones – typically near building corners – by increasing the density of measurements and modelling detail in these areas.

The gustiness of local wind conditions also influences cyclist safety and comfort. It is expected that wind tunnel and CFD studies will be carefully interpreted to assess gust effects on all cycling paths.

If the Lawson safety limit is exceeded at any cycling location, appropriate mitigation measures will need to be implemented to improve the conditions.

It is noted that these simplified guidelines do not take account of rider speed, effective angle of wind direction and other important parameters. In the future editions of these guidelines it is hoped that a more comprehensive cyclist safety limit can be defined.

It is also noted that the above limits only apply to commuter cyclists, and not for special cycling events (such as races) where the speed of riders may be a much more significant factor.

Annex A: Wind climate properties

Introduction

The parameters in the tables below should be used to generate a statistical model of the wind frequency (by speed and direction) for the City of London. Please note that these parameters have been scaled specifically to account for the terrain around the City of London, and are not valid for use in other areas.

Usage

Parameters c and k are the scale and shape factors respectively for use in calculating a Weibull probability distribution. Parameter p is the probability that wind will approach from a given direction. These parameters can be used in combination with the measured local wind speeds from a wind tunnel test or CFD simulation to determine the probability of exceeding a given wind speed at a given measurement location during a given season.

Probability of exceedance at a given location (for comparison against the CoL Lawson Criteria) is calculated as follows. For each measurement location:

1. Measure the local wind speed for each wind angle using wind tunnel testing or CFD simulation, and express this speed as a ratio over the wind speed at a known reference height upwind of the site;

Note: the reference height should ideally be greater than 100m above the ground, and should be sufficiently far upwind so as not to be directly influenced by the modelled surrounding buildings.

2. Multiply the wind speed ratio by the factor in table 1 corresponding to the chosen reference height.

Note: the probability distributions have been scaled to reference height of 120m above ground, hence the factor in table 1 for 120m is equal to 1.

Note: for reference heights not specified in table 1, you may interpolate between the specified values.

3. Multiply the factored wind speed ratio for each angle by the corresponding parameter c in table 2. Repeat for each season and annually.

4. For each angle, calculate the probability of exceedance of each threshold in the criteria (using the parameters for each season for comfort, and using the annual parameters for the safety threshold) using the following formula:

$$f_{(x)} = p \cdot e^{-\left(\frac{x}{c}\right)^k}$$

and sum across all angles to arrive at the total probability of exceedance for that season.

Note: alternatively, you may choose to calculate the wind speed x exceeded for 5% and 0.022% of the time. In this case please note that the wind speed should be calculated for a total probability across all wind angles, and not for individual angles. This would likely require a “goal seek” or “solver”-type method, depending on how and in what programming language the calculation is implemented.

5. Compare the seasonal results against the comfort criteria to determine the suitability of the location in terms of comfort, and the annual result against the safety criterion to determine whether the location is safe or not.

Note: if both mean and gust-equivalent mean velocities have been measured (as in the methodology for wind tunnel testing, set out in the main document), then this process should be repeated for both sets of velocities. The worse category of the two assessments should be taken to determine comfort and safety.

Background

These probability distributions have been developed based on historical wind data from London Heathrow Airport (LHR) and London City Airport (LCY). The data range from LHR covers the period from 1973 to 2017, and the data from LYC covers the period from 1988 to 2017. Both data sets have been checked for data quality, with erroneous data points being removed from the set prior to fitting a Weibull distribution curve.

Data from each airport has been corrected to “open country” conditions at 10m height, to account for the effects of nearby terrain, using the methodology set out in ESDU 01008. The terrain-corrected data has subsequently been scaled again to represent specific terrain conditions in and around the City of London (again using the methodology set out in ESDU 01008).

Reference height [m]	Scale factor
100	0.96
120	1.00
160	1.07
200	1.13
250	1.19
300	1.24
450	1.37
600	1.48

Table 1: Reference height scale factors

Table 2: Weibull parameters (*c* scaled to reference height of 120m above ground)

36 Wind directions (10° increments)

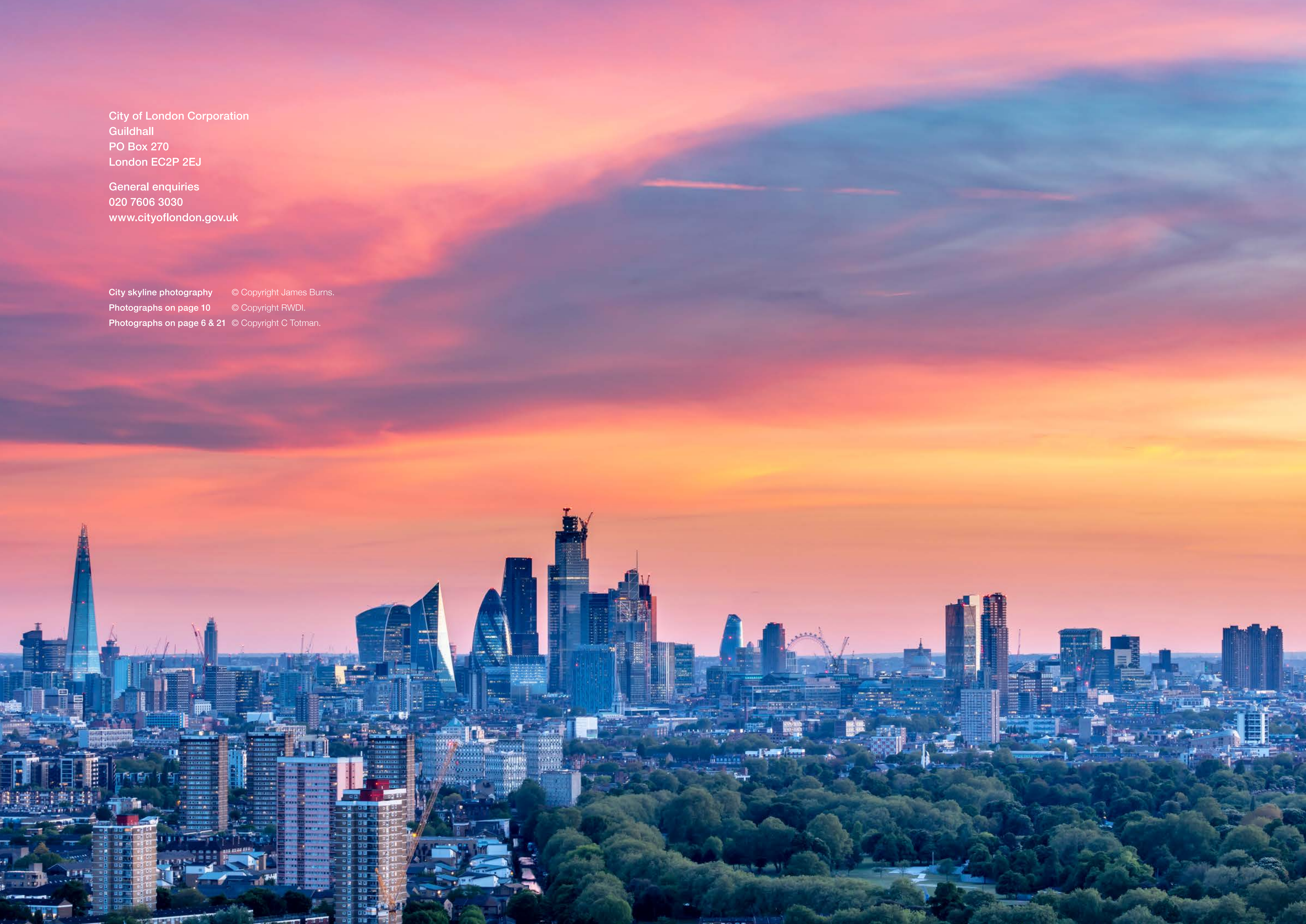
Season	Annual											
Direction	0	10	20	30	40	50	60	70	80	90	100	110
p	0.021	0.020	0.024	0.026	0.023	0.021	0.020	0.020	0.021	0.028	0.021	0.015
c [ms^{-1}]	4.63	5.06	5.40	5.65	5.85	6.07	6.29	6.45	6.77	6.66	6.38	5.71
k	1.70	1.80	1.87	1.92	1.99	2.07	2.08	2.06	2.09	2.16	2.20	2.18
Direction	120	130	140	150	160	170	180	190	200	210	220	230
p	0.013	0.013	0.013	0.014	0.015	0.020	0.025	0.033	0.041	0.056	0.057	0.053
c [ms^{-1}]	5.36	5.26	5.21	5.27	5.50	5.72	5.98	6.34	6.67	6.89	6.91	7.03
k	2.11	2.08	2.03	1.92	1.83	1.79	1.81	1.87	1.92	1.96	1.99	2.04
Direction	240	250	260	270	280	290	300	310	320	330	340	350
p	0.055	0.058	0.044	0.043	0.034	0.030	0.025	0.023	0.020	0.020	0.018	0.020
c [ms^{-1}]	7.06	6.90	6.58	6.02	5.67	5.37	5.13	5.02	4.86	4.79	4.72	4.64
k	2.01	1.88	1.78	1.64	1.58	1.57	1.63	1.69	1.73	1.70	1.65	1.64

Season	Spring											
Direction	0	10	20	30	40	50	60	70	80	90	100	110
p	0.024	0.026	0.035	0.038	0.034	0.030	0.028	0.027	0.028	0.033	0.022	0.014
c [ms^{2}]	5.02	5.47	5.94	6.24	6.46	6.62	6.79	6.84	7.08	6.94	6.65	6.00
k	1.83	1.92	2.01	2.06	2.14	2.20	2.23	2.21	2.22	2.28	2.30	2.25
Direction	120	130	140	150	160	170	180	190	200	210	220	230
p	0.011	0.012	0.012	0.013	0.014	0.019	0.024	0.030	0.037	0.048	0.046	0.041
c [ms^{-1}]	5.63	5.53	5.48	5.44	5.55	5.80	6.01	6.28	6.65	6.92	6.92	6.98
k	2.15	2.13	2.14	2.03	1.93	1.89	1.91	1.96	2.02	2.05	2.04	2.06
Direction	240	250	260	270	280	290	300	310	320	330	340	350
p	0.041	0.049	0.040	0.039	0.030	0.027	0.023	0.022	0.020	0.020	0.020	0.022
c [ms^{-1}]	7.08	7.19	6.97	6.52	6.20	5.89	5.50	5.23	5.00	4.97	5.04	5.02
k	2.09	2.04	1.90	1.78	1.69	1.64	1.66	1.71	1.77	1.78	1.82	1.82

Season	Summer											
Direction	0	10	20	30	40	50	60	70	80	90	100	110
p	0.020	0.018	0.020	0.022	0.020	0.017	0.016	0.015	0.019	0.028	0.021	0.014
c [ms^{-1}]	4.42	4.85	5.16	5.41	5.60	5.81	5.90	6.05	6.57	6.76	6.66	5.94
k	1.98	2.08	2.18	2.21	2.21	2.19	2.14	2.17	2.28	2.38	2.40	2.34
Direction	120	130	140	150	160	170	180	190	200	210	220	230
p	0.010	0.009	0.008	0.010	0.011	0.015	0.021	0.029	0.041	0.063	0.064	0.056
c [ms^{-1}]	5.44	5.18	4.96	4.94	5.08	5.22	5.41	5.74	6.15	6.47	6.49	6.51
k	2.21	2.10	2.10	2.06	2.04	2.05	2.13	2.24	2.30	2.26	2.24	2.25
Direction	240	250	260	270	280	290	300	310	320	330	340	350
p	0.059	0.064	0.050	0.050	0.039	0.033	0.029	0.025	0.023	0.022	0.019	0.019
c [ms^{-1}]	6.55	6.54	6.34	6.02	5.67	5.37	5.08	4.86	4.64	4.49	4.42	4.38
k	2.23	2.20	2.15	2.10	2.07	2.00	1.92	1.90	1.93	1.97	1.96	1.95

Season	Autumn											
Direction	0	10	20	30	40	50	60	70	80	90	100	110
p	0.021	0.020	0.020	0.020	0.017	0.016	0.017	0.018	0.019	0.027	0.021	0.017
c [ms^{-1}]	4.42	4.79	4.90	4.86	4.87	5.07	5.39	5.76	6.20	6.18	5.96	5.43
k	1.67	1.75	1.74	1.78	1.86	1.98	2.02	2.04	2.08	2.15	2.14	2.08
Direction	120	130	140	150	160	170	180	190	200	210	220	230
p	0.016	0.017	0.016	0.018	0.019	0.023	0.028	0.035	0.043	0.058	0.059	0.055
c [ms^{-1}]	5.25	5.24	5.17	5.13	5.30	5.43	5.66	6.00	6.33	6.48	6.49	6.72
k	2.02	2.07	2.10	1.98	1.89	1.85	1.86	1.87	1.91	1.94	1.99	2.03
Direction	240	250	260	270	280	290	300	310	320	330	340	350
p	0.056	0.057	0.040	0.039	0.033	0.030	0.026	0.024	0.020	0.019	0.017	0.021
c [ms^{-1}]	6.88	6.75	6.26	5.82	5.51	5.16	4.87	4.76	4.74	4.73	4.60	4.46
k	2.03	1.93	1.79	1.68	1.66	1.64	1.67	1.68	1.70	1.69	1.63	1.63

Season	Winter											
Direction	0	10	20	30	40	50	60	70	80	90	100	110
p	0.018	0.018	0.022	0.023	0.021	0.020	0.020	0.019	0.019	0.023	0.019	0.014
c [ms^{-1}]	4.50	4.82	5.07	5.45	5.82	6.20	6.60	6.76	6.89	6.56	6.20	5.44
k	1.51	1.62	1.68	1.77	1.91	2.04	2.07	1.98	1.93	1.97	2.07	2.15
Direction	120	130	140	150	160	170	180	190	200	210	220	230
p	0.013	0.014	0.014	0.015	0.017	0.023	0.028	0.037	0.044	0.057	0.060	0.059
c [ms^{-1}]	5.06	5.00	5.11	5.49	6.01	6.27	6.60	7.04	7.32	7.53	7.52	7.65
k	2.11	2.04	1.91	1.83	1.82	1.78	1.80	1.86	1.90	1.95	1.99	2.05
Direction	240	250	260	270	280	290	300	310	320	330	340	350
p	0.062	0.065	0.045	0.042	0.035	0.029	0.023	0.020	0.017	0.016	0.015	0.017
c [ms^{-1}]	7.77	7.67	7.21	6.71	6.29	5.89	5.53	5.34	5.08	4.98	4.79	4.55
k	2.05	1.93	1.78	1.67	1.63	1.61	1.62	1.65	1.64	1.58	1.49	1.44



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