FINAL REPORT

GREAT GEORGE STREET

LIVERPOOL, UK

PEDESTRIAN LEVEL WIND DESK-BASED ASSESSMENT

RWDI #1803827 - REV A

NOVEMBER 20TH, 2019

SUBMITTED TO

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VERSION HISTORY

RWDI Project #1803827	Great George Street Liverpool, UK		
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K. Jayyaratnam	Rev A	21/09/2018	D. Hackett
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1 EXECUTIVE SUMMARY

This is a qualitative assessment of the likely wind conditions around the proposed Great George Street development in Liverpool, UK. The report outlines the overall methodology and the use of the Lawson Comfort Criteria to describe the expected on-Site wind conditions. The assessment is based upon analysis of meteorological conditions for Liverpool, adjusted to the Site, and a review of the scheme drawings in the context of the meteorological data.

The Site description is used mainly to identify building massing and features that are pertinent to the wind microclimate on Site. The expected main flow interactions around the Site are then described and categorised in terms of the Lawson Comfort Criteria, used for around thirty years throughout the UK in assessments of this kind.

The meteorological data for the Site indicates prevailing winds predominantly from the west with secondary winds in the spring and summer from the north-west and in autumn and winter from the south-east. Winds from other directions do occur, and are considered within the assessment; however, their impact on the overall wind microclimate conditions tend to be low, due to being relatively infrequent (compared to the prevailing directions).

There are several areas where wind mitigation measures are required, as summarized below, but the conditions elsewhere are expected to be generally suitable for their intended uses.

The majority of thoroughfare areas are expected to be suitable for the intended use; however, the narrow spaces between Phase 1 and Block 2A and between Blocks 2B and 3A are expected to have windier than required conditions and occasional strong winds exceeding the 15m/s safety threshold. These areas would require mitigation. Several entrances to the Proposed Development are suitable for the intended use; however, entrances to Block 2A and the majority of entrances to Phase 3 will require localised mitigation.

The landscaped terrace of Phase 2 and the private gardens of Phase 3 will require mitigation, in order to create suitable conditions for an amenity space. Additionally, dependant on seating arrangements within the public square of Phase 3, localised measures may be required. Balconies are recommended to be situated away from building corners and inset from the façade; if alternative balcony designs/locations are desired, mitigation measures will likely be required. Furthermore, if roof terraces are accessible to occupant/public, mitigation measures will be required.

Example mitigation measures have been discussed within this report and with the implementation of these measures, it is expected that wind condition in and around the Proposed Development would be suitable for the intended uses.

2 INTRODUCTION

RWDI was retained by Great George Street Developments Ltd to conduct a desk-based assessment of the proposed Great George Street development (hereafter referred to as the 'Proposed Development'), in Liverpool. This report presents the background, objectives, results and recommendations from RWDI's assessment. A summary of the overall recommendations from the study are presented in Section 8, "Concluding Remarks".

3 SITE DESCRIPTION

3.1 Site and Surroundings

The Site is located in to the west of Great George Street and is bounded by Cookson Street, Upper Pitt Street, Duncan Street and Upper Fredrick Street to the east.

The existing site comprises a vacant brownfield site. The site is generally surrounded by low level residential and warehouse in all directions with Liverpool Cathedral located to approximately 200m to the east of the site. It is expected that the oncoming winds have a relatively high mean windspeed with lower turbulence (i.e. less 'gusty') compared to a more urban upwind terrain and comparatively a lower mean wind speed than a site surrounded by open terrain.

The Ordnance Survey Landranger reference for the Site is SJ351893. Figure 1a below, shows an aerial view of the Site and surroundings.

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

3.2 The Proposed Development

The Proposed Development, consisted of two phases, namely Phases 2 and 3. The Proposed Development will be residential led and will be a maximum of 18 storeys in height. The scheme consists of several blocks, varying in height.

Phase 2 consists of three blocks (2A-2C), two which are connected via a podium and Phase 3 consists of four separate blocks (3A-3D). The orientation of the Blocks is expected to shelter some areas and create localised areas of high wind speeds where they align with the prevailing wind directions. Blocks 2A and 2C are expected to have protruding balconies; balconies of this design are more exposed to the oncoming winds.

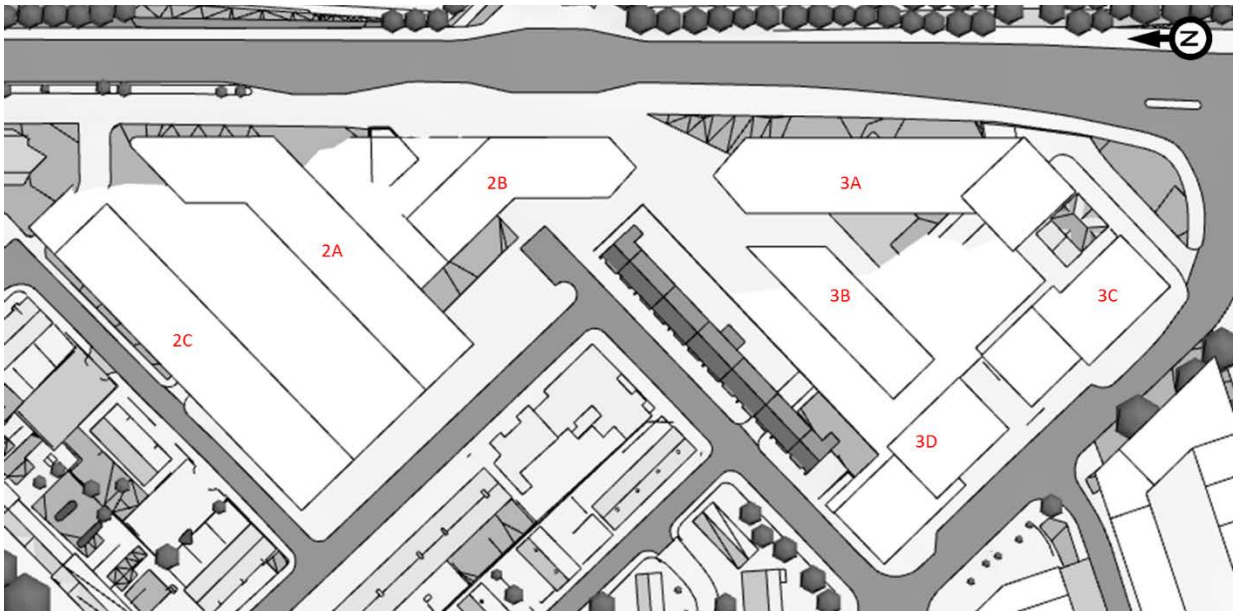


Figure 1b: Plan view of the Proposed Development

4 METHODOLOGY AND ASSESSMENT CRITERIA

Knowledge of the prevailing wind direction focuses attention on the likely impact of these winds on the Site except where the proposed building massing / layout indicates that winds from other directions are likely to be important.

4.1 General Meteorological Data

Approximately 30 years of meteorological data derived from the meteorological station at Liverpool John Lennon Airport is presented as wind roses by season (Figure 2). 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 meteorological station data is then adjusted to the Site conditions using the methodology implemented in the BREVe3 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 indicate that the prevailing wind direction is from the north-west during the spring and summer seasons and from the south-east during the autumn and winter seasons. Winds from the west are the strongest throughout the year, while winds from the north and north-east are infrequent.

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.

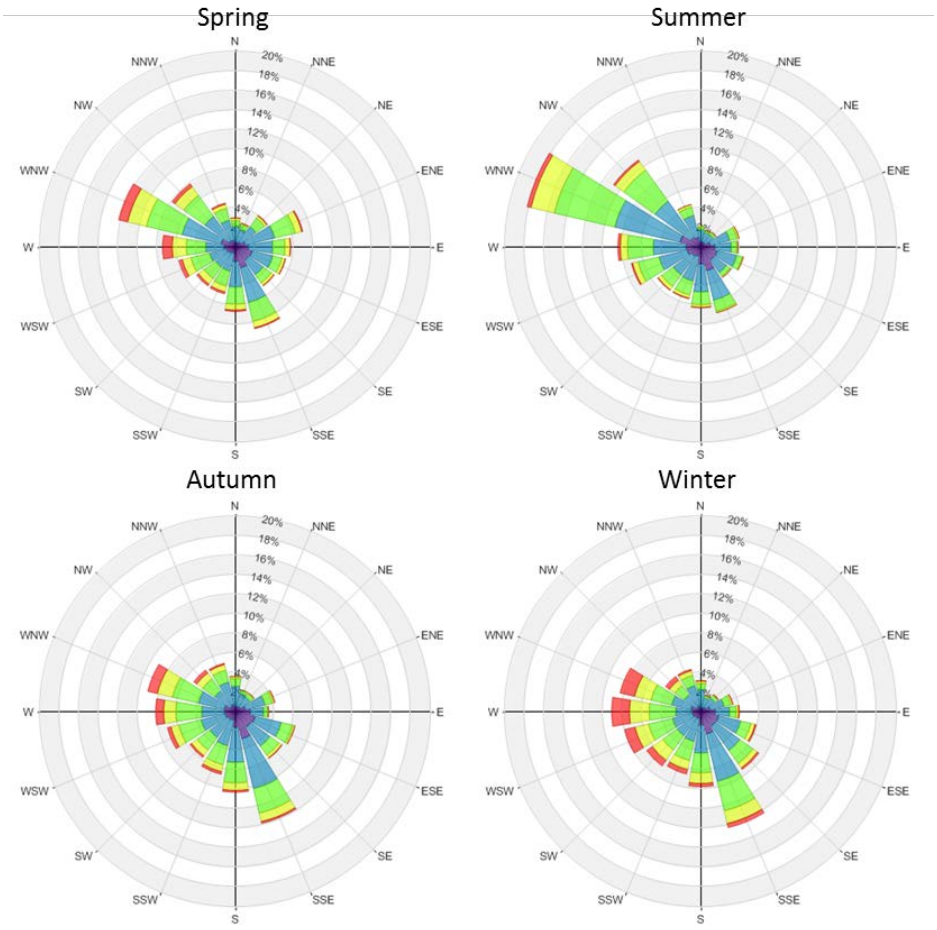


Figure 2: Seasonal wind roses for Liverpool (Radial axis indicates the percentage time for which the stated velocity range is exceeded)

4.2 Terrain Roughness

Another consideration is the terrain roughness in each wind direction because wide, open spaces permit the wind to flow smoothly at ground level generating conditions similar to those of open countryside even within a built-up area. An assessment of the terrain roughness for the Site was conducted using the BREVe3.2 software.

Table 1 presents the 'mean factors' for the Site where the mean factor represents the ratio of wind speed on site, at the stated reference height, as a fraction of the wind speed in open, flat countryside at a height of 2m and 10m. The table shows that the terrain is fairly consistent towards the north, east and south with a more open terrain to the south-west and west in relation to its effect on wind speed.

Table 1: BREVe3 mean factors at 2m and 10m above ground level

Wind Direction (N°)	0	30	60	90	120	150	180	210	240	270	300	330
Mean Factor at 2m	0.43	0.43	0.43	0.43	0.43	0.44	0.43	0.84	0.88	0.45	0.46	0.46
Mean Factor at 10m	0.79	0.79	0.80	0.79	0.79	0.82	0.70	1.05	1.10	0.83	0.86	0.85

4.3 Comfort Criteria

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 2. 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 set 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 more 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 windier conditions.

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 2 corresponds to the presentation of wind tunnel test results described later in this report.

The Lawson Criteria set out five pedestrian activities and reflect the fact that less active pursuits require calmer wind conditions. In ascending order of activity level, the categories are:

- Sitting;
- Standing;
- Strolling;
- Walking; and
- Uncomfortable.

Table 2: 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

Generally, the target conditions are:

Strolling use during the windiest season on pedestrian thoroughfares (with walking conditions potentially being tolerated in areas where pedestrians would not linger);

Standing conditions at entrances, drop off areas or taxi ranks, and bus stops throughout the year; and

Sitting use conditions at outdoor seating and amenity areas during the summer season when these areas are more likely to be frequently used by pedestrians. It is noted that in large mixed-use amenity spaces a mixture of sitting use and standing / entrance use can be considered acceptable as users can choose to sit in 'calmer' areas, with 'windier' areas acceptable for more active pursuits.

The wind conditions in an area for sitting need to be calmer than a location that people merely walk past and this is reflected in the Comfort Criteria. The Criteria are derived for open air conditions and assume that pedestrians will be suitably dressed for the season. The criteria address the force of the wind on a person, or activity, they do not take account of thermal factors.

4.4 Strong Winds

Lawson[1] also specified a lower limit strong wind threshold when winds exceed 15m/s for more than 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 safety issue for all members of the population, which would require mitigation to provide an appropriate wind environment.

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

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.

4.5 Typical Wind – Building Interactions

The wind conditions at the Proposed Development are expected to be due to either one, or a combination of, three generalised flow behaviours.

Down-washing (Figure 3a) of the wind occurs when a building is taller than its surrounding buildings. The taller scheme forces high level winds to ground level where they create locally high wind speeds in the pedestrian realm.

Channelling (Figure 3b) of the wind occurs between buildings of similar height when in close proximity to each other. Windy conditions occur at pedestrian level since the flow accelerated as it is "squeezed" between the buildings.

Corner acceleration (Figure 3c) around building corners may occur due to the difference in pressure on the upwind and downwind façades (low pressure zones on the leeward side and zones of higher pressure on the windward side of the building). This effect is particularly pronounced around sharp corners which create localised windy areas in the vicinity of the corner where the flow is accelerated around the building.

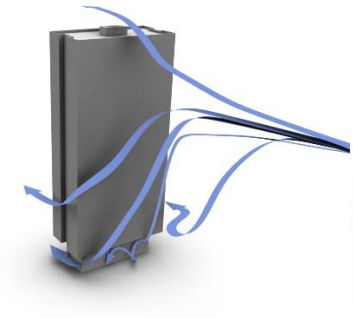


Figure 3a: Down-washing

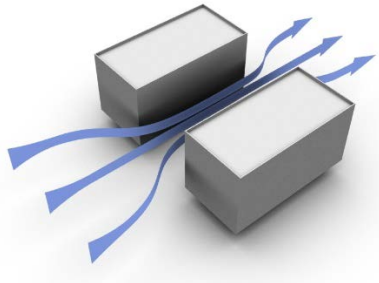


Figure 3b: Channelling

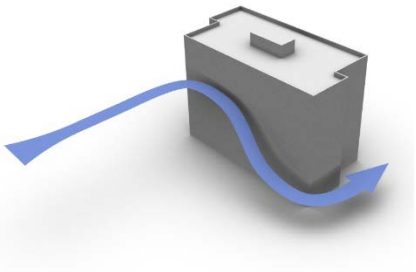


Figure 3c: Corner acceleration

5 BASELINE CONDITIONS

Often a new development will alter the pedestrian activity (i.e. intended use) on site. Occasionally, although wind conditions may not change after the Proposed Development is completed (e.g. stay suitable for strolling), mitigation would still be required if, on the new development, the location of interest is intended for a critical activity (e.g. a main entrance) for which the wind condition would be unsuitable. Assessment in terms of the desired pedestrian activity on, or around, a site takes into consideration any change of use and this is where the comfort criteria are particularly helpful.

5.1 Pedestrian Comfort

Based on the terrain roughness analysis presented in section 3.2, the baseline conditions at 2m above ground level at an idealised "empty" Site would be acceptable for strolling use in the windiest season and standing use in summer.

The Site is currently occupied by low-rise residential/warehouse buildings and open fields. As the surrounding area is relatively low-rise, winds are expected to flow unimpeded towards the site, resulting in a generally high mean wind speed.

Wind conditions around the existing Site are expected to be classified as suitable for strolling use during the windiest season and therefore expected to be suitable for the intended thoroughfare use.

5.2 Strong Winds

Strong winds in excess of 15m/s are not expected to occur at the existing Site for more than 2 hours per year.

6 WIND CONDITIONS AROUND THE PROPOSED DEVELOPMENT

Wind conditions suitable for strolling use or calmer are desirable on main thoroughfares during the windiest season for a residential development in an urban area. Standing use wind conditions or calmer are generally required at entrances throughout the year. Amenity spaces require sitting use conditions (or a mixture of sitting and standing use conditions in larger areas) during the summer season.

Occurrences of strong winds in excess of 15m/s are expected to be limited when wind conditions meet the above criteria and are suitable for pedestrian comfort.

The assessment made below is based on a worst-case assessment of the expected wind conditions at the Site. This worst-case assessment assumes no landscaping to be present.

6.1 Pedestrian Comfort

Lawson comfort plots are appended to the end of this report presenting the expected wind conditions for ground level during the windiest season (Figure 6) and the summer season (Figure 7). During the windiest season, wind conditions would be expected to range from being suitable for strolling to walking use, windier than conditions expected in the existing scenario. During the summer season, when wind comfort conditions are generally one category calmer than the windiest season, wind conditions are expected range from suitable for sitting to strolling use. The expected wind microclimate is discussed below.

6.1.1 Thoroughfares (Figure 6)

As shown in Figure 5, wind conditions at ground level during the windiest season are expected to be suitable for standing to walking use. Walking use wind conditions are expected in the narrow spaces between Phase 1 and Block 2A and between Blocks 2B and 3A. As this narrowing is aligned with the prevailing westerly wind direction, there is expected to be channelling effects in these spaces which will result in locally high wind speeds. These two areas **will require mitigation** to reduce wind speeds to a strolling or calmer classification.

All other ground level areas, during the windiest season, are expected to have strolling or standing wind conditions; these wind conditions are suitable for thoroughfare use.

During the summer season, wind conditions are expected to be one category calmer and range from suitable for sitting to strolling use.

6.1.2 Entrances (Figure 6)

During the windiest season, all entrances would require a standing or calmer wind condition. The exception to this would be infrequently used entrances such as bin/cycle stores, fire exits, maintenance entrances etc. Entrances to the Proposed Development are shown in Figure 4.

Figure 4: Entrance locations

For Phase 2, the majority of entrances along the eastern façade of Block 2C and both the western and eastern facades of Block 2A are expected to be suitable for their intended use with standing wind conditions. Furthermore, due to the beneficial design of the overhanging balconies along the western façade of Block 2C, which effectively creates a recessed entrance to these residential units, it is expected that these entrances would have the required standing wind condition.

For Phase 3, entrances along the eastern façade of Block 3B are also expected to have the required standing wind condition.

The entrances marked in red in Figure 4 are expected to be windier than required and **will require mitigation.**

6.1.3 Amenity Spaces (Figure 7)

There are no ground level amenity spaces; however, all podium level spaces will be used for amenity purposes. The residential courtyard and public space (east of Block 2A) of Phase 2 are expected to have the desired sitting wind conditions during the summer season. The public square of Phase 3 is expected to have a mix of sitting and standing wind condition. These wind conditions are suitable for a large mixed-use amenity space provided that fixed seating areas are situated in areas with sitting wind conditions. if seating is desired in areas with standing wind conditions, **mitigation will be required.**

Both the landscaped terrace of Phase 2 and the private garden of Phase 3 are expected to have standing wind conditions and therefore if fixed seating is desired in these areas, **mitigation will be required.**

It is expected there will be balconies on some of the Proposed Development Blocks. It is recommended that balconies are inset (i.e. in line with the façade) as they will only be exposed to the wind from one side. Protruding balconies are more exposed to the wind due to the design and therefore will be susceptible to higher wind speeds. Furthermore, it is recommended that balconies are not situated at building corners where locally high wind speeds will be expected due to the acceleration of wind around the corner. **Mitigation will be required** for protruding and corner balconies.

All roof terraces are expected to have windier than desired conditions due to the insignificant shelter provided by the relatively low-rise surrounding buildings. As such, if roof terraces will be accessible to occupants/public, and used for amenity purposes, **mitigation will be required.**

6.2 Strong Winds

Instances of winds exceeding 15m/s for more than 0.025% of the time (approximately two hours per year) are often associated with areas with wind conditions suitable for walking use or, less frequently, strolling use. It is expected that there will be strong wind exceeding this threshold in the narrow spaces between Blocks Phase 1 and Block 2A and between Blocks 2B and 3A. **Mitigation will be required** in these areas to eliminate these expected strong wind exceedances.

7 MITIGATION MEASURES

Due to the orientation and location of the Proposed Development, with low-rise surrounding buildings providing insignificant shelter, there are several areas in and around the site which will require mitigation. Measures are summarised in the table below with examples measures and their locations in Figure 5a for both comfort and safety exceedances.

Label in Fig 5a	Area	Aerodynamic cause	Potential Mitigation Measures
A	Thoroughfares (between Phase 1 and Block 2A and between Block 2B and 3A)	• Channelling	• Trees (evergreen if possible) ~ minimum of 3m high when planted • Shrubs in planters – minimum of 1.5m high • Staggered porous screen – minimum of 2m high
B	Entrances (around Block 2B and Phase 3)	• Corner acceleration • Exposure to oncoming winds	• Solid screening either side – 2m high and 1.5m wide • Planting either side – 2m high when planted • Recessing entrance – minimum depth of 1.5m
C	Amenity spaces (landscaped terrace of Phase 2 and private gardens of Phase 3)	• Corner acceleration • Down-washing	• General landscaping – ranging from 1m – 3m high when planted • Localised landscaping around seating (shrubs in planters or screening) – 1 to 1.5m in height
D	Amenity spaces (public square)	• Down-washing	• Localised landscaping around seating (shrubs in planters or screening) – 1 to 1.5m in height when planted
-	Balconies (protruding)	• Exposure	• Solid balustrade – 1.5m high
-	Balconies (corner)	• Exposure	• Solid balustrade – 1.5-2m high • Solid side screen on corner edge – 2m high
-	Roof terraces	• Exposure	• General landscaping (shrubs in planters, trees etc.) – ranging from 1m - 3m high when planted • Solid balustrade – 1.5m high • Staggered screens (porous/solid/artwork) – 1m to 2m high

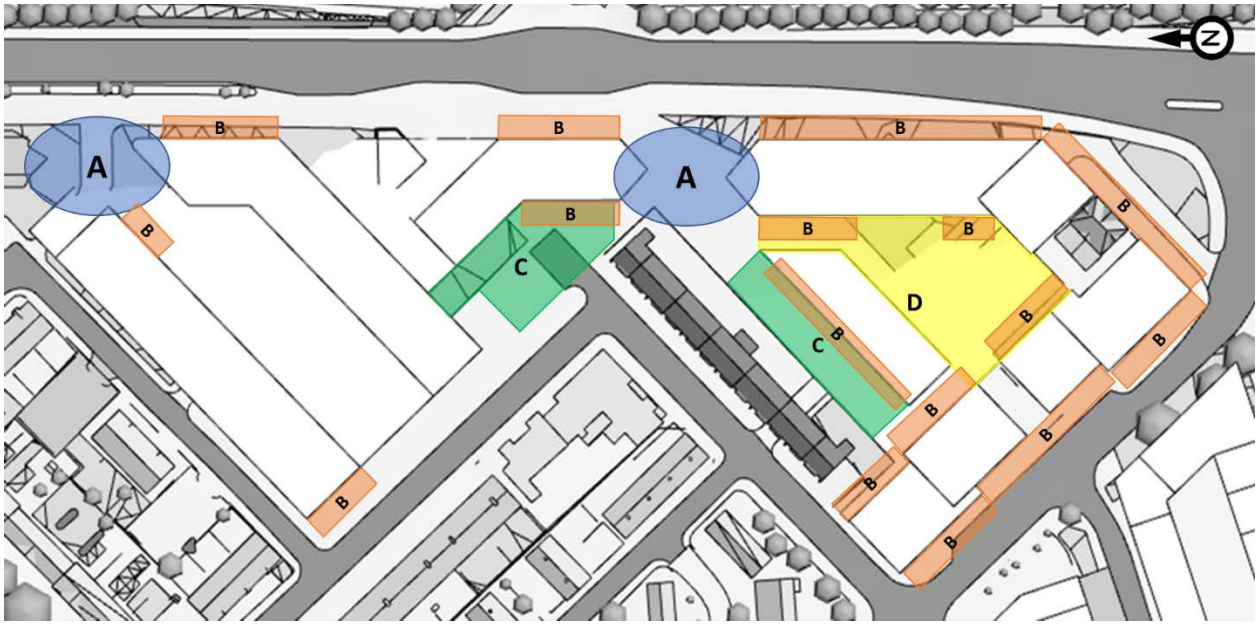


Figure 5a: Areas requiring mitigation measures

Figure 5b: Examples of mitigation measures (thoroughfares – top row, entrances – middle row, amenity spaces – bottom row)

8 CONCLUDING REMARKS

In conclusion:

1. The meteorological data for the Site indicates prevailing winds from the west throughout the year with north-westerly wind during spring and summer and south-easterly winds during the autumn and winter.

2. For the existing site, the wind microclimate at ground level is expected to be acceptable for the current, predominately thoroughfare, use during the windiest season.

3. The orientation and height of the Proposed Development results in windier conditions with its completion. There are two areas at ground level which will be too windy for thoroughfare use and have occasional strong wind winds exceeding the safety threshold and therefore **will require mitigation**. Furthermore, a number of entrance to Phase 2 and 3 are expected to **require mitigation.**

4. During the summer season, wind conditions are generally one category calmer. The courtyard amenity space of Phase 3 is expected to be suitable for the intended use. Similarly, the public square of Phase 3 is expected to be suitable for the intended amenity use provided seating allocations are situated where sitting wind conditions are expected. **Localised mitigation will be required** if seating is provided in areas with standing wind conditions. the landscaped terrace of Phase 2 and the private gardens of Phase 3 **will require mitigation.**

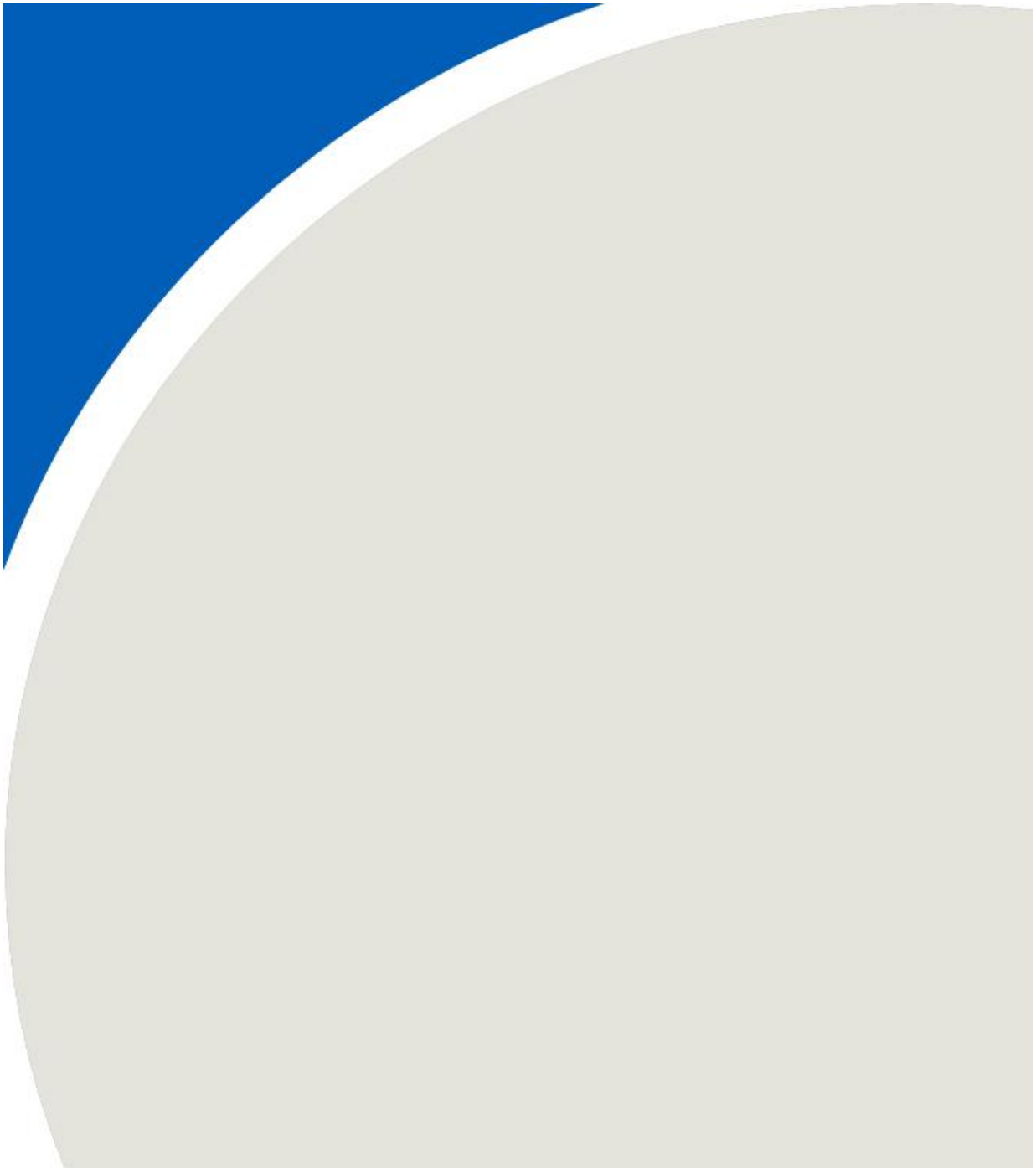
5. Balcony locations are not finalised at this stage of the design; however, it is recommended they are inset from the façade and located away from building corners. Suitable mitigation measures have been suggested if protruding balconies/corner balconies are desired. Additionally, mitigation measures have been discussed for all roof terraces, if accessible and desired for amenity use.

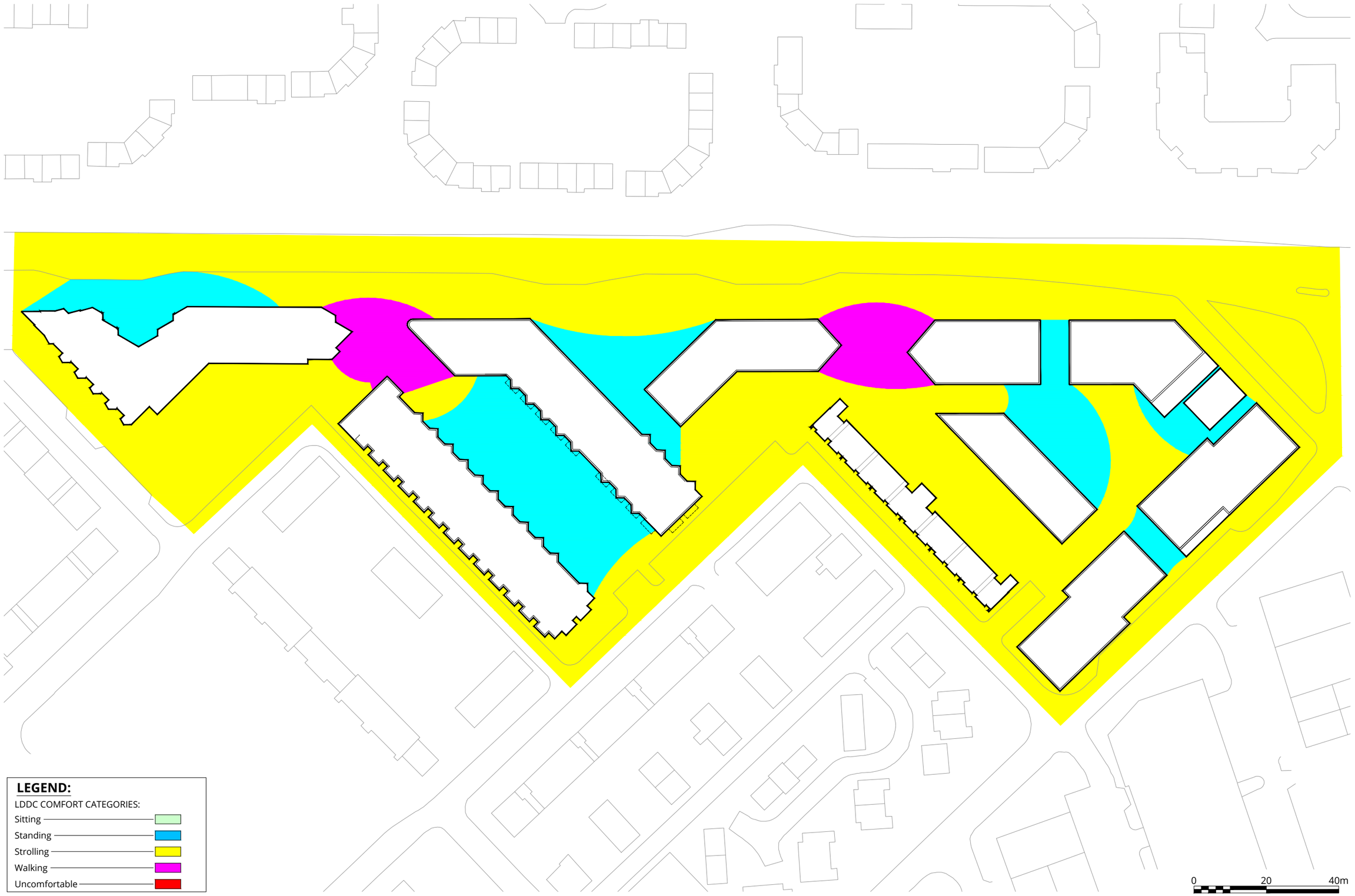
6. Overall, wind conditions around the Site are expected to be suitable for their intended use, with localised areas of windier than desired conditions. Mitigation measures have been suggested within this report which are expected to reduce wind speeds in these highlighted areas. We would be happy to discuss the results of the wind assessment in more detail and mitigation options through a conference call.

9 REFERENCES

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

FIGURES





Desk Study - Upper Ground Floor

Proposed Development with Existing Surrounding Buildings

Windiest Season

Great George Street, Liverpool (U.K.)

True North

Project #1803827

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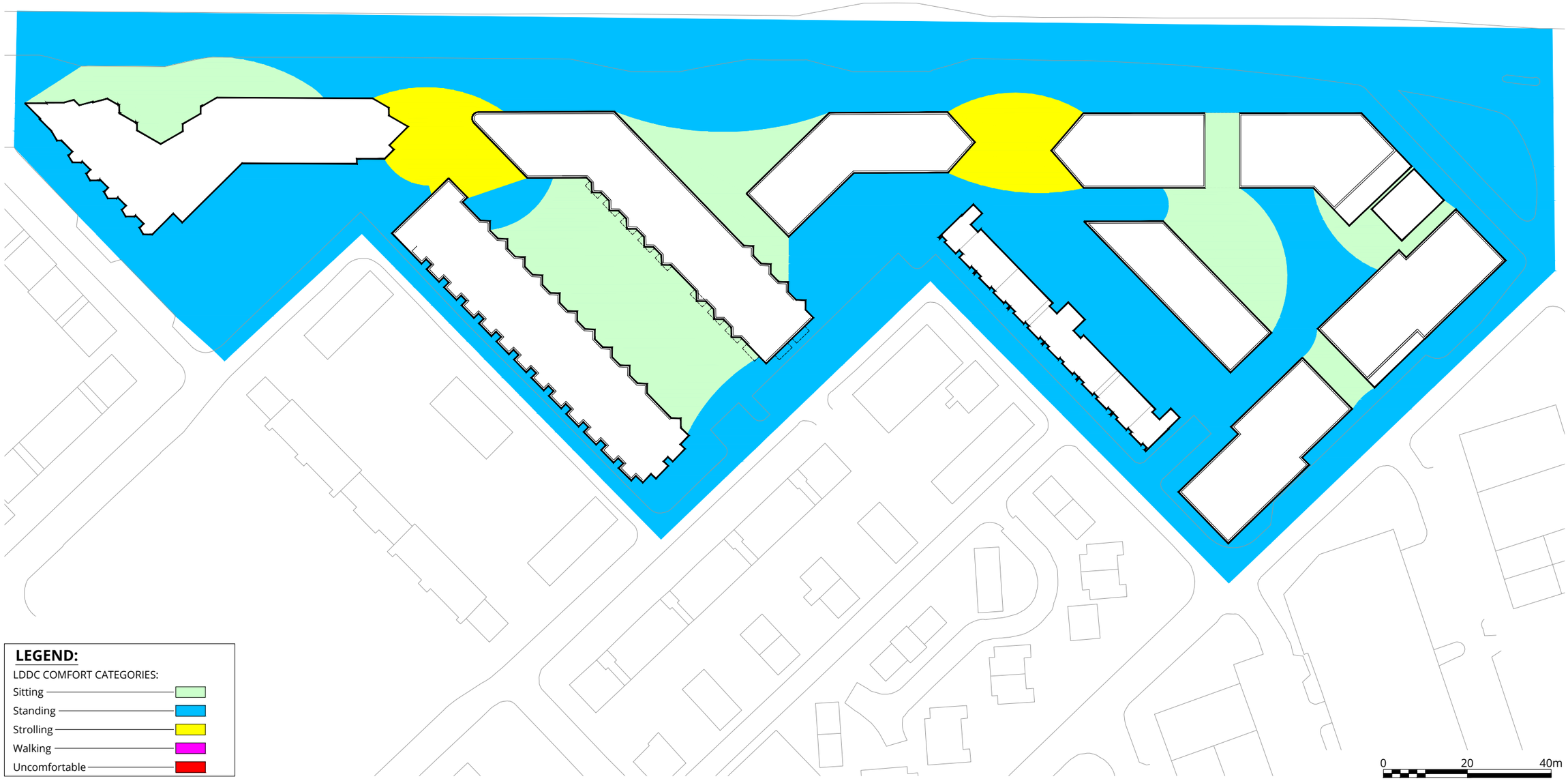
Approx. Scale @A3: 1:1000

Date Revised: Sept. 12, 2018



Desk Study - Upper Ground Floor

Proposed Development with Existing Surrounding Buildings
Summer Season

Great George Street, Liverpool (U.K.)

True North

Project #1803827

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Date Revised:	Sept. 12, 2018		