Viadux

For

Salboy Central Limited

Wind Microclimate Report

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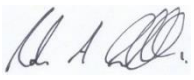
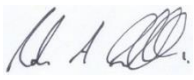
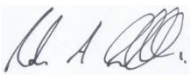
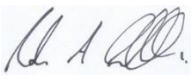
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Executive Summary

Background

A study has been carried out by Architectural Aerodynamics Ltd. (ArcAero) to assess the wind microclimate for the proposed Viadux development in Manchester, UK.

The study has adopted wind tunnel testing to predict the strength of winds. Then using the industry standard Lawson criteria, it has established the suitability of wind conditions and the impact on the surrounding area, following the introduction of the proposed development.

Conclusions

The following conclusions have been drawn:

- Following the introduction of the proposed development with wind mitigation measures, wind conditions in / around the immediate vicinity of the proposed development meet the criteria for pedestrian safety and are largely suitable for use in terms of comfort.
- An exception occurs on Great Bridgewater Street (location 96) where the wind conditions exceed the wind safety criteria following the introduction of Plot 2a and Plot 2b of the proposed development. Initial solutions were examined in the wind tunnel, before being further developed and explored in greater detail via CFD. CFD results show that these mitigation concepts are effective in reducing wind speeds in both of these locations, indicating that while these are not yet finalised components of the design, they do represent concepts that are likely to form part of an eventual solution.

1 Introduction

A microclimate is defined as the distinctive climate of a small-scale area. The weather variables in a microclimate, such as wind, may be different to the conditions prevailing over the area as a whole. Wind microclimate assessments consider the wind conditions that would result upon the introduction of a new development into an existing space.

Such assessments predict the proportion of time an area will experience wind speeds in excess of threshold values associated with safe and comfortable use by pedestrians and occupants once the development is introduced. It can therefore be shown within the various parts of a new proposal and neighbouring properties whether wind conditions are suitable or unsuitable, and whether design adjustment or mitigation measures are required. It is for this purpose that wind microclimate assessments are undertaken.

This report summarises the results of wind tunnel studies commissioned by Salboy Central Limited, to assess the wind microclimate for the proposed Viadux development in Manchester, UK.

2 The Proposed Development

2.1 Site Location and Surrounding Area

The Viadux development is bounded by the Hilton Hotel (Beetham Tower) to the west, Great Bridgwater Street to the north, Lower Mosley Street to the east and Trafford Street, Deansgate-Castlefield Metrolink Station and Deansgate Locks to the south.

At present the area immediately surrounding the proposed development principally comprises medium to high-rise buildings. Further afield, the wider surrounding area largely consists of a mixture of low, medium and high-rise buildings.

2.2 Proposed Development

The Proposed Development will be delivered across two plots comprising the following principal uses:

- Plot A: a hotel with residential apartments above.
- Plot B: affordable homes.

Together with these principal uses, the Proposed Development comprises residential amenities; secure cycle parking; public realm improvements and new green landscaping; and associated works to the public highway.

Plot 2a is located immediately east of the recently completed Phase 1 building, on land partially comprising the grade II listed Castlefield Viaduct. This plot will deliver a 76-storey mixed use tower comprising a hotel (Use Class C1) with associated bar and restaurant and residential units above comprising 1, 2 and 3 bed, and penthouse apartments (Use Class C3) with associated residential amenity spaces. Secure cycle spaces, serving this and the Phase 1 building, are provided at the ground floor level. At viaduct level, a redesigned service yard for the conference centre is enclosed by a new podium structure with residents' external amenity space above. A section of the Great Bridgewater Street bridge (deck) is removed to bring light into the street below.

Plot 2b, located at the western-most section of the Site between the viaduct and Beetham Tower, consists of a 23-storey residential building accommodating affordable 1-, 2- and 3-bed apartments (Use Class C3), secure cycle parking spaces, flexible commercial units (Use Class E) opening onto the viaduct, and public realm enhancements on Great Bridgewater Street.

Following the introduction of Plot 2a & Plot 2b, recreational space is substantially provided by the shared podium terrace between Phases 1 and Plot 2a. This features a substantially open general amenity space with various benches for more short-term sitting. There are also numbers of areas, primarily around the base of Plot 2a, where tables and chairs are provided.

Wind tunnel testing has been carried out based on an earlier iteration of the proposed development. The overall scale massing, pedestrian uses, and resulting conditions are

materially the same in the vast majority of areas. CFD modelling has been carried out separately to verify this and to validate the similarity of the resulting wind microclimate.

2.3 Drawing Information Describing the Proposed Development

Assessment models for wind tunnel testing have been constructed on the basis of the following drawings received from SimpsonHaugh on 19th October 2023:

- 10448_Viadux Phase 2a 2b and 3.dwg

The existing surrounding area was based upon information supplied by Ordnance Survey details for the area. Cumulative surrounds were based upon the information contained within the Manchester City Council planning portal.

2.4 Landscaping Proposals

The wind microclimate has been assessed for the proposed development with initial landscaping proposals and surrounding landscaping, before subsequently being assessed with additional wind mitigation measures (summarised in section 2.5).

Landscaping proposals are summarised herein as follows:

- Ground level & Level 01 (VIA-PLA-XX-XX-M2-L-0001.dwg) received on 24th October 2023, presented in Figure 2.1
- Level 03 Viadux residential podium (2843-PLA-XX-02-DR-L-0003.dwg) received on 25th November 2023, presented in Figure 2.2

2.5 Wind Mitigation Measures

The proposed development has been assessed with and without embedded wind mitigation measures.

These are:

- At ground level, presented in Figure 2.3
  - 7.5m tall wall & 50% porous gate
  - 2.0m wall & 50% porous gate
- At Level 01 as presented in Figure 2.4
  - 50% Porous Screen - 1.8m (L) X 3.1m (H)
  - 50% Porous Screen - dimension presented in Figure 2.4
- Level 3 Podium as presented in Figure 2.5
  - Updated Level 03 landscaping plan, indicating planter preventing pedestrian access

The additional wind mind mitigation measures which were assessed separately via CFD only are as below:

- Glazed canopy structure at the northern edge of level 01;

2.6 Surrounding Contexts

A number of cumulative schemes have been considered in the assessment. These schemes are presented in tabular format in Table 2-1.

Table 2-1 – Cumulative Schemes

Development Name	Planning Reference
One City Road	128002/FO/2020
One Medlock Street	135419/FO/2022
10-12 Whitworth Street (Vision)	111003/FO/2016/C1
Plot 10a, First Street	136043/FO/2023
Park Place (Plot G, Great Jackson Street)	129273/FO/2021
Bridgewater House Great Jackson Street	134694/FO/2022
Great Northern Warehouse	135565/FO/2022
Student Castle	121252/FO/2018
Great Jackson Street - Crown Street Plot D (The Lighthouse)	137227/FO/2023
Great Jackson Street Plot C and E (The Green)	137226/FO/2023
Apex Tower	133172/FO/2022

A cumulative scheme has recently been approved and was not considered in the assessment as below:

Table 2-2 - Cumulative Scheme that was not considered

Development Name	Planning Reference
Hotspur House	138805/FO/2023

Hotspur House is located a considerable distance (320m) from the site and it is located on a non-prevailing wind sector. This cumulative scheme is expected not to materially impact the wind conditions within and around the proposed development, nor will the proposed development materially affect conditions around Hotspur House.

3 Assessment Methodology

3.1 Overview

Wind tunnel modelling was undertaken in the Imperial College 10x5 atmospheric boundary layer wind tunnel in London. Full details of the wind tunnel testing conducted for the study are presented in Appendix A of this report. Additionally, CFD modelling has also been undertaken as part of initial assessments of the scheme, and more recently, to explore the effectiveness of wind mitigation measures. Full details of the CFD methodology employed are presented in Appendix D.

Modelling via wind tunnel testing has derived mean and gust equivalent mean wind speeds, in accordance with best industry practice. In doing so 16 wind directions were assessed, in 22.5° increments.

The industry standard criteria for wind microclimate assessments, the LDDC variant of the Lawson criteria (1), has been employed for the study.

3.2 Wind Climate Analysis

Wind microclimate studies require that meteorological data is transposed from a nearby weather station with sufficient wind data to produce accurate wind frequency statistics. The current study uses data from Manchester Airport.

Full details of the wind climate relevant to the site, the wind properties approaching the site and the modelling of those wind properties in the wind tunnel models are provided in Appendix B of this report. All analysis of wind data and the atmospheric boundary layer has employed the methods of ESDU item 01008 (2), in accordance with best industry practice.

3.3 Assessment Scenarios

The wind tunnel model covered a radius of 600 metres from the site. All features which are likely to impact the wind flow within the study area have been replicated. The model was reviewed and approved by the design team prior to the study. The assessment considered a full range of directions in 22.5° intervals, and considered the following configurations:

1. Scenario 1: (Existing Baseline) - Site as is today i.e. Phase 1 tower as built with the various amendments, Phase 1 tower as built with the various amendments, Plots 2a and 2b in their existing use (which originally formed part of the Beetham Tower consent) is vacant.
2. Scenario 1b: (Cumulative Baseline) - Site as is today i.e. Phase 1 tower as built with the various amendments, noting that the office scheme which forms part of Phase 1 consent is not built out and Plot 2b (which originally formed part of the Beetham Tower consent) is vacant, with cumulative surroundings.
3. Scenario 2 - Viadux Plot 2a & Plot 2b, existing surrounding conditions
4. Scenario 2a - Viadux Plot 2a & Plot 2b, cumulative surrounding conditions

5. Scenario 2 - (Viadux Plot 2a & Plot 2b, existing surrounding conditions) with mitigation measures
6. Scenario 2a - (Viadux Plot 2a & Plot 2b, cumulative surrounding conditions) with mitigation measures

Details of the tunnel and model used for the wind tunnel study are presented in Appendix A of this report.

3.4 The LDDC Lawson Criteria

The industry standard criteria for wind microclimate assessments are commonly referred to in the UK as the Lawson criteria after one of their main authors. As with most other leading practitioners, ArcAero use the 'LDDC' variant of the Lawson Criteria (London Docklands Development Corporation (1)).

The LDDC variant applies a single percentage probability of exceedance of a range of wind speeds and associates different wind speeds to different types of usage. This offers a relatively simple and practical manner for the assessment of wind comfort and safety.

3.4.1 Safety

A wind speed of 15 m/s occurring once per year is rated as unsuitable, in terms of safety, with the potential to de-stabilise the less able members of the public including the elderly, cyclists and children.

3.4.2 Comfort

The LDDC variant of the Lawson criteria (1) prescribes that wind conditions are suitable for a given activity when the threshold is exceeded no more than 5% of the time. The value of 5% has been established as giving a reasonable allowance for extreme and relatively infrequent winds that are tolerable within each category.

Where certain activities are year-round, such as walking, entrance use or for waiting areas, comfort ratings are required to be met in all seasons. For more seasonal activities, such as outdoor recreation or for sitting spaces, the assessment focuses on relevant seasons where the expectation will exist for conditions to be suitable. The LDDC comfort threshold wind speed values are presented in Table 3-1.

Table 3-1 – LDDC Wind Comfort Thresholds

Threshold Wind Speed [m/s]	Comfort Rating / Activity	
4	C4	Long-term sitting
6	C3	Short-term sitting / standing
8	C2	Strolling
10	C1	Walking
> 10	C0	Uncomfortable

3.5 Pedestrian / Occupant Uses

In using the Lawson criteria to consider the suitability of spaces, in terms of comfort, it is necessary to identify the anticipated usage of the various areas and assign that usage to an assessment receptor. Each measurement location is assigned a pedestrian / occupant use, for each assessment scenario. This is presented in in Appendix C.

4 Results: Basic Assessment Scenarios, Wind Tunnel

4.1 Scenario 1: Existing Baseline

The results for the existing baseline are presented graphically within Figure 4.1 and Figure 4.2 for worst-seasonal and summer conditions respectively.

4.1.1 Safety

There are several areas within the site and immediate surrounds which exceed the wind criteria for safety:

- West & northwest of Beetham Tower (locations 68 & 72)
- Great Bridgewater Street (location 92)
- Viaduct level, south-west of Viadux Phase 1 corner (location 119)

Elsewhere, all locations within the Site and immediate surrounds meet the safety criteria.

4.1.2 Comfort

Overall, existing wind conditions are expected to be suitable for existing uses. This includes thoroughfares which are substantially suitable for strolling or better, entrances and the Metrolink Station that are suitable for short-term standing / sitting, and the outdoor seating areas within the Deansgate Locks area.

Where the comfort criteria are not entirely met:

- Wind conditions at the southwest corner of the Phase 1 tower (location 119) marginally exceed the comfort criteria, being suitable for strolling approximately 93% of the time in the winter.
- Conditions for outdoor seating at the east end of the canal (location 12) also marginally exceed comfort criteria, being suitable for long-term sitting approximately 93% of the time in summer.
- Wind conditions at the street level entrance to Phase 1 (location 90) modestly exceed comfort criteria, being suitable for short-term standing / sitting approximately 93% of the time in winter.

4.2 Scenario 1b: Cumulative Baseline

The results for the cumulative baseline are presented graphically within Figure 4.3 and Figure 4.4 for worst-seasonal and summer conditions respectively.

4.2.1 Safety

There are several areas within the site and immediate surrounds which fail to meet the wind criteria for safety within the cumulative baseline scenario:

- Viaduct level 01, south-west corner of Viadux phase 1 (location 119)

- Great Bridgewater Street (locations 90, 91, 92)
- Watson Street (locations 125, 126 & 127)

Elsewhere, all locations within the site and immediate surrounds meet the safety criteria.

4.2.2 Comfort

4.2.2.1 Thoroughfares & Cycleways

In general, wind conditions within the site are suitable for strolling or better in the worst-season, and are thus suitable for thoroughfare and cycleway use.

Some areas within the site are somewhat windy for comfortable thoroughfare or cycleway use, particularly in the winter months, in the areas below:

- Great Bridgewater Street (locations 90, 91 & 92) suitable for strolling approximately 93% of the time at worst.
- Viadux podium (location 119) suitable for strolling approximately 92% of the time at worst.

4.2.2.2 Entrances

Within this cumulative baseline scenario, wind conditions at the street level entrances to Phase 1 (locations 87 & 90) exceed comfort criteria, being suitable for short-term standing 94% and 88% of the time in winter. Other entrances are suitable for the intended use.

4.2.2.3 Surrounding Area

Within the wider surrounding area, for the cumulative baseline scenario, wind conditions are generally suitable for existing and planned pedestrian uses, including the use of thoroughfares, cycleways and entrances, the Metrolink platform waiting area and the canalside outdoor seating venues.

Exceptions are predicted to exist within Watson Street (locations 125, 126) suitable for fast walking in winter (suitable for strolling 92% of the time in winter).

4.3 Scenario 2: Existing Baseline + Viadux Plot 2a & Viadux Plot 2b

The results for Plot 2a & Plot 2b are presented graphically within Figure 4.5 and Figure 4.6 for worst-seasonal and summer conditions respectively.

4.3.1 Safety

Upon the introduction of Plot 2a & Plot 2b, the safety criteria are substantially met throughout the study area. Exceedances occur in the following areas:

- Viadux level 03 residential podium (location 204, 221, 222)
- Between Plot 2b and Beetham Tower (location 55)
- Great Bridgewater Street (locations 96)
- Northwest of Hilton Manchester Deansgate (location 72)

The wind safety exceedance to the west of Beetham Tower (location 72) is present within the Existing Baseline (scenario 1) and is not introduced by the proposed development.

4.3.2 Comfort

4.3.2.1 Thoroughfares & Cycleways

With the introduction of Plot 2a & Plot 2b, wind conditions at a majority of areas within the site are suitable for comfortable thoroughfare or cycleway use, being suitable for strolling or better throughout the year.

Wind conditions at Viaduct level 01, at the corner of Plot 2b (location 81), marginally exceed comfort criteria, being suitable for strolling 94% of the time in winter.

4.3.2.2 Entrances

Upon the introduction of Plot 2a & Plot 2b, entrances within the site are generally suitable for short-term standing / sitting or better. Exceptions occur:

- At the back-of-house entrance to Plot 2b (location 55) which exceeds the wind comfort criteria, being suitable only for thoroughfares in winter, thus being too windy for comfortable ingress / egress.
- At the entrance to Phase 01 from the residential podium. Conditions at this entrance (location 230) marginally exceed the criteria for an entrance, being suitable for short-term standing / sitting approximately 94% in winter.

4.3.2.3 Level 03 Terrace

Upon the introduction of Plot 2a & Plot 2b, wind conditions on the Level 03 terrace are reasonable, being broadly suitable for short-term standing / sitting in summer, and suitable for long-term standing / sitting at a majority of the seating locations shown around the perimeter of Plot 2b.

Two main windier areas exist, with one at the southern edge of the terrace (locations 221, 222) and the other more centrally located (location 204). These areas, suitable for strolling in summer, would ideally be calmer, and should benefit from additional sheltering mechanisms. Such mechanisms would additionally be welcome for the wider terrace, in order to maximise the proportion of the area that is suitable for at least short-term standing / sitting during spring and autumn. In these seasons, windier conditions, suitable for strolling, occur in a majority of the central space (locations 201, 202, 203, 204, 205, 210, 211, 217, 221, 222, 223).

4.3.2.4 Surrounding Area

Upon the introduction of Plot 2a & Plot 2b, wind conditions for the canal side outdoor seating are generally suitable for long-term sitting in summer, with the exception of the eastern end of the canalside by Axis Tower. Conditions at this location (location 12) are similar to conditions within the existing baseline scenario.

Elsewhere, wind conditions within the surrounding area are substantially acceptable following the introduction of Plot 2a & Plot 2b. Conditions for the tram station platform (location 6) fall

very marginally shy of being suitable for 95% of the time during winter, but not to an extent that would be noticeable.

4.4 Scenario 2a: Existing Baseline + Viadux Plot 2a & Viadux Plot 2b + Cumulative

The results for the Plot 2a & Plot 2b within cumulative surrounds are presented graphically within Figure 4.7 and Figure 4.8 for worst-seasonal and summer conditions respectively.

4.4.1 Safety

Following the introduction of Plot 2a & Plot 2b within cumulative surrounds, the safety criteria are met in a majority of areas within the site and surrounding area.

There are areas where exceedances of the safety criteria occur. These are:

- Viaduct Level 03, Viadux Residential Podium (location 204, 221, 222).
- Great Bridgewater Street (locations 96)
- Watson Street (locations 125 & 126), though this area is improved relative to the cumulative baseline scenario (scenario 1b).

4.4.2 Comfort

4.4.2.1 Thoroughfares & Cycleways

Following the introduction of Plot 2a & Plot 2b within cumulative surrounds, conditions are generally comfortable for thoroughfare and cycleway use within the site.

An exception to this occurs in Great Bridgewater Street, in the vicinity of the crossing point (location 96), where conditions are marginally too windy for strolling in winter. While this would ideally be entirely suitable for strolling, this is a minor exceedance (predicted to be suitable for strolling approximately 94% of the time in winter) and is likely to be tolerable for pedestrians, while conditions in the cycle lane (which is beside the pavement) should be calmer, and acceptable.

4.4.2.2 Entrances

Upon the introduction of Plot 2a & Plot 2b within cumulative surrounds, entrances within the site are generally suitable for short-term standing / sitting or better. Exceptions occur:

- At the back-of-house entrance to Plot 2b (location 55), which exceeds conditions for short-term standing in winter (suitable 92% of the time).
- At the street level entrances to Phase 1 (location 90), which modestly exceeds the criteria for short-term standing, being suitable 92% of the time in winter.

4.4.2.3 Level 03 Terrace

Upon the introduction of Plot 2a & Plot 2b in cumulative surrounds, wind conditions on the Level 03 terrace are reasonable (as they are in existing surrounds (scenario 2) with which the environment is similar), being broadly suitable for short-term standing / sitting in summer, and suitable for long-term standing / sitting at a majority of the seating locations shown around the perimeter of Plot 2b.

Two main windier areas also exist within this scenario, again at the southern edge of the terrace (locations 221, 222) and more centrally located (location 204). These areas, suitable for strolling in summer, would ideally be calmer, and should benefit from additional sheltering mechanisms. Such mechanisms would additionally be welcome for the wider terrace, in order to maximise the proportion of the area that is suitable for at least short-term standing / sitting during spring and autumn. In these seasons, for this scenario, windier conditions, suitable for strolling, occur in a majority of the central space (locations 202, 203, 204, 205, 210, 211).

4.4.2.4 Surrounding Area

Wind conditions within the surrounding area are substantially acceptable following the introduction of Plot 2a & Plot 2b. Exceptions are as follows:

- Watson Street (locations 125, 126) marginally exceeds strolling conditions and falls into the fast-walking classification, being suitable for strolling 93% in winter. With the introduction of Plot 2a & Plot 2b, wind conditions in this area improve marginally, relative to the cumulative baseline scenario (scenario 1b).
- On the tram station platform (location 44) where conditions are suitable for short-term standing / sitting 94% of the time in spring, thus marginally exceeding the ideal threshold.

4.5 Scenario 2: Existing Baseline + Viadux Plot 2a & Viadux Plot 2b with Mitigation Measures

The results for the scenario 2 with mitigation measures are presented graphically within Figure 4.9 and Figure 4.10 for worst-seasonal and summer conditions respectively.

4.5.1 Safety

With the introduction of mitigation measures, all locations within the site and surrounds satisfy the safety criteria with two exceptions, as follows:

- To the west of Beetham Tower (location 72) – this exceedance is present within the Existing Baseline (scenario 1) and is not introduced by the proposed development.
- Within Great Bridgewater Street (location 96).

4.5.2 Comfort

4.5.2.1 Thoroughfares & Cycleways

With the introduction of Plot 2a & Plot 2b with mitigation measures, all thoroughfares and cycleways within the site are now suitable for at least strolling throughout the year, and are thus acceptable.

4.5.2.2 Entrances

Upon the introduction of Plot 2a & Plot 2b with mitigation measures, conditions at all entrances within the site are suitable for short-term standing / sitting or better, and thus for comfortable pedestrian ingress / egress.

4.5.2.3 *Level 03 Terrace*

Upon the introduction of mitigation measures, all parts of the Level 03 terrace are generally suitable for short-term standing / sitting or better during summer and autumn. A marginally windier location exists near the centre of the terrace (location 217), but this area is nevertheless suitable for short-term standing for approximately 94% of the time in summer.

Furthermore, the seating areas around the perimeter of Plot 2a are all suitable for long-term sitting in summer, while a majority are also suitable in spring (with the exception of the western portion of the northern façade, location 214), and slightly less so during autumn (along the southern façade, locations 225 & 226).

4.5.2.4 *Surrounding Area*

Wind mitigation measures typically have a localised effect, and having been introduced within the proposed development, wind conditions within the wider surrounding area are materially the same as they are in scenario 2. Specifically, therefore, wind conditions for the canalside outdoor seating are generally suitable for long-term sitting in summer, and where not are similar to conditions within the existing baseline scenario. Elsewhere, conditions within the surrounding area are substantially acceptable.

4.6 Scenario 2a: Existing Baseline + Viadux Plot 2a & Viadux Plot 2b + cumulative with Mitigation Measures

The results for the scenario 2a with mitigation measures are presented graphically within Figure 4.11 and Figure 4.12 for worst-seasonal and summer conditions respectively.

4.6.1 Safety

With the introduction of mitigation measures, all locations within the Site and surrounding area meet the safety criteria except for the following areas:

- Within Great Bridgewater Street (locations 90, 96)
- Within Watson Street (locations 125 and 126).

4.6.2 Comfort

4.6.2.1 *Thoroughfares & Cycleways*

With the introduction of the Plot 2a & Plot 2b within cumulative surrounds with mitigation measures; thoroughfares and cycleways within the site are substantially suitable for at least strolling throughout the year, and are thus acceptable.

An exception persists in Great Bridgewater Street (location 96) where conditions are suitable for fast walking in winter. This is a marginal exceedance, suitable for strolling from spring to autumn and meeting the strolling threshold wind speed approximately 94% of the time in winter. This area will primarily be used as a crossing point, for which conditions are likely to be tolerable, in terms of comfort.

4.6.2.2 Entrances

Upon the introduction of Plot 2a & Plot 2b within cumulative surrounds and with mitigation measures, wind conditions at all entrances within the site are generally suitable for short-term standing / sitting or better, and thus for pedestrian ingress / egress.

4.6.2.3 Level 03 Terrace

Upon the introduction of Plot 2a & Plot 2b within cumulative surrounds and with mitigation measures, all parts of the Level 03 terrace are suitable for short-term standing / sitting or better during summer and autumn. A slightly windier region exists within the northern part of the terrace (locations 210, 211) during spring. Nevertheless, the short-term standing / sitting threshold wind speed is met between 92% and 95% of the time during spring in this area, meaning this would be characterised as a relatively modest springtime exceedance.

Importantly, with the introduction of mitigation measures, the seating areas around the perimeter of Plot 2a are all suitable for long-term sitting in from spring to autumn.

4.6.2.4 Surrounding Area

Wind conditions within the surrounding area are substantially acceptable following the introduction of Plot 2a & Plot 2b. Exceptions are as follows:

- Watson Street (locations 125, 126) marginally exceeds strolling conditions and falls into the fast-walking classification, being suitable for strolling 93% in winter.
- On the tram station platform (location 44) where conditions are suitable for short-term standing / sitting 93% of the time in spring, thus marginally exceeding the ideal threshold.

5 Results: Level 01 Mitigation Concepts, CFD

5.1 Overview: WT Results

In the cumulative surrounding context, wind tunnel testing predicts that a moderate safety exceedance is introduced within Great Bridgewater Street (location 96) upon the introduction of Plot 2a and Plot 2b of the proposed development. This exceedance is driven by the presence of the proposed development.

Simultaneously, a region of modest safety exceedance is identified within Watson Street (locations 125, 126). While present, the exceedances in this area differ in nature, by virtue of the fact that (a) they are present within scenario 1b (cumulative baseline) and are therefore not driven by Plot 2a and Plot 2b of the proposed development, and (b) with the introduction of Plot 2a and Plot 2b of the proposed development, the magnitude of exceedance is notably reduced, relative to the magnitude predicted for the cumulative baseline scenario.

In short, therefore, wind tunnel testing predicts that Plot 2a and Plot 2b introduce a safety exceedance in Great Bridgewater Street, while alleviating a safety exceedance within Watson Street. The Great Bridgewater Street exceedance is also present for the existing surrounding context, but in this scenario, it is smaller in magnitude and the cumulative surrounding context therefore represents the worst-case scenario.

Initial solutions targeted to address the Great Bridgewater Street area were explored in the wind tunnel. These were relatively simple in nature, comprising a simple vertical screen around the northern edge of Level 01 (viaduct level). The effect of canopies in the same vicinity was also explored. While a final solution was not found within the wind tunnel testing campaign, the concepts did show good promise and demonstrated the potential to form part of an effective solution. Once the wind tunnel test was completed, these possible solutions were then explored in greater detail via a number of CFD simulations.

5.2 Mitigation Concepts

A number of solution concepts have now been examined in greater detail via CFD. Two of the most effective to date, labelled Options 8^{+} and 8^{++} are presented within Figure 5.1, both of which include:

- glazed vertical screens with connected roof structure at the northern edge of level 01
- wind baffles and soft landscaping at level 01
- wind baffles attached to Plot 2b.

These concepts seek to disrupt:

- the passage of wind between Phase 1 and Plot 2b
- wind spilling beneath Plot 2b
- Wind being drawn down the northwest facing façade of Plot 2b

5.3 Results

CFD results, in the form of contours of annual safety exceedance, are presented in Figure 5.2 for Options 8^{+} and 8^{++}.

The CFD results suggest that these solution concepts are effective in improving wind conditions, within Great Bridgewater Street, and also within Watson Street.

Additionally, these results show that these mitigation mechanisms are effective in reducing wind speeds in both of these locations, indicating that while these are not yet finalised components of the design, they do represent concepts that are likely to form part of an eventual solution.

6 Conclusions

The following conclusions have been drawn:

- Following the introduction of the proposed development with wind mitigation measures, wind conditions in / around the immediate vicinity of the proposed development meet the criteria for pedestrian safety and are largely suitable for use in terms of comfort.
- An exception occurs on Great Bridgewater Street (location 96) where the wind conditions exceed the wind safety criteria following the introduction of Plot 2a and Plot 2b of the proposed development. Initial solutions were examined in the wind tunnel, before being further development and explored in greater detail via CFD. CFD results show that these mitigation concepts are effective in reducing wind speeds in both of these locations, indicating that while these are not yet finalised components of the design, they do represent concepts that are likely to form part of an eventual solution.

7 References

1. **Lawson, T.V.** *The determination of the wind environment of a building complex before construction.* Bristol : University of Bristol, Department of Aeronautical Engineering, 1990.

2. **ESDU (Engineering Science Data Unit).** *Item 01008. Computer Program for wind speeds and turbulence properties: flat or hilly sites in terrain with roughness.* 2001.

3. **F, Menter.** *Zonal Two Equation k-ω Turbulence Models for Aerodynamic Flows.* 1993. AIAA Paper 93-2906.

4. **F, Menter.** *Turbulence Modelling for Engineering Flows.* s.l. : ANSYS Inc., 2011.

5. **Richards, P.J. and Hoxey, R.P.** *Appropriate boundary conditions for computational wind engineering models using the k-ε turbulence model.* s.l. : Journal of Wind Engineering and Industrial Aerodynamics, 1993. vol. 46 & 47, pg. 145 - 153.

6. **Quality Assurance Manual - Wind Engineering Studies of Buildings. 2001. AWES-QAM-1-2001.**

7. The American Society of Civil Engineers (ASCE) Manual of Practice No.67 for Wind Tunnel Studies. ASCE SEI 49/12.

8 Figures

Figure 2.1 - Ground Level & Level 01 (Initial Landscaping Proposals)

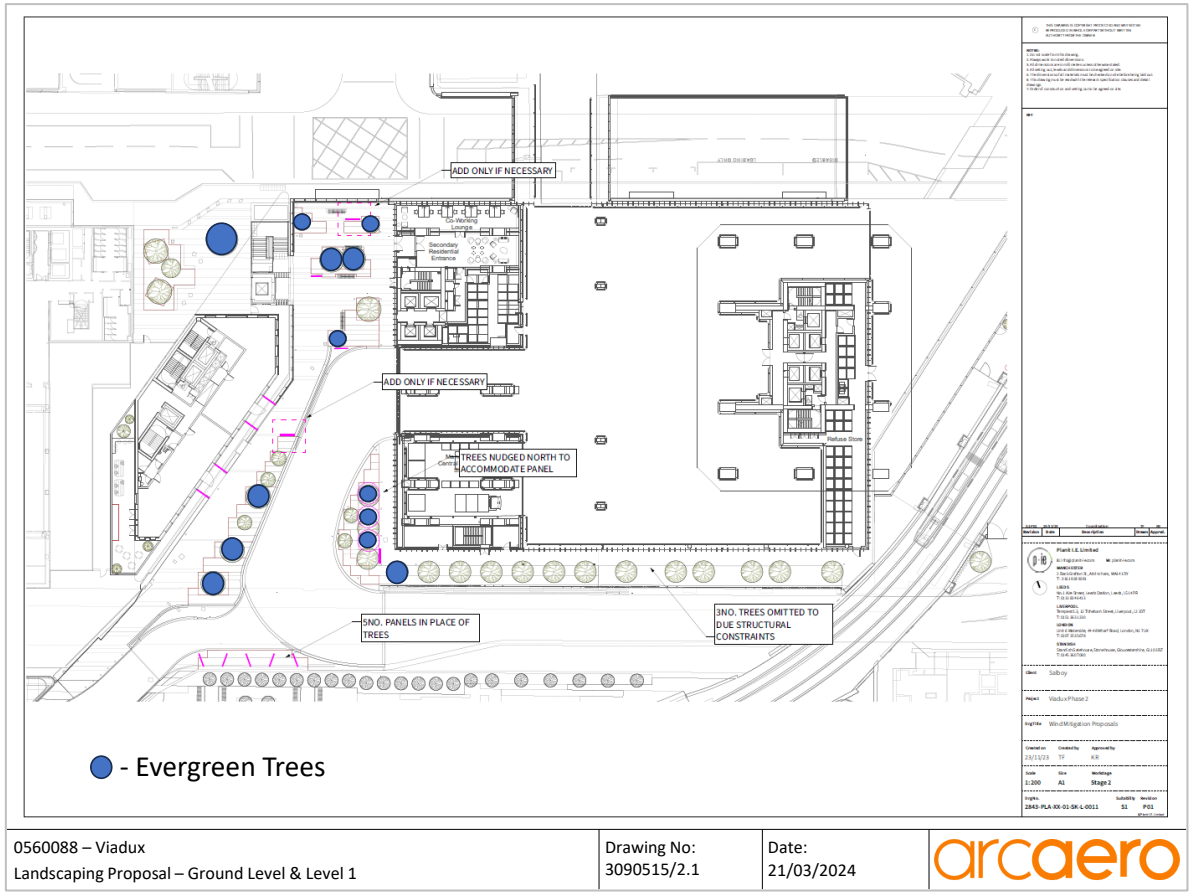
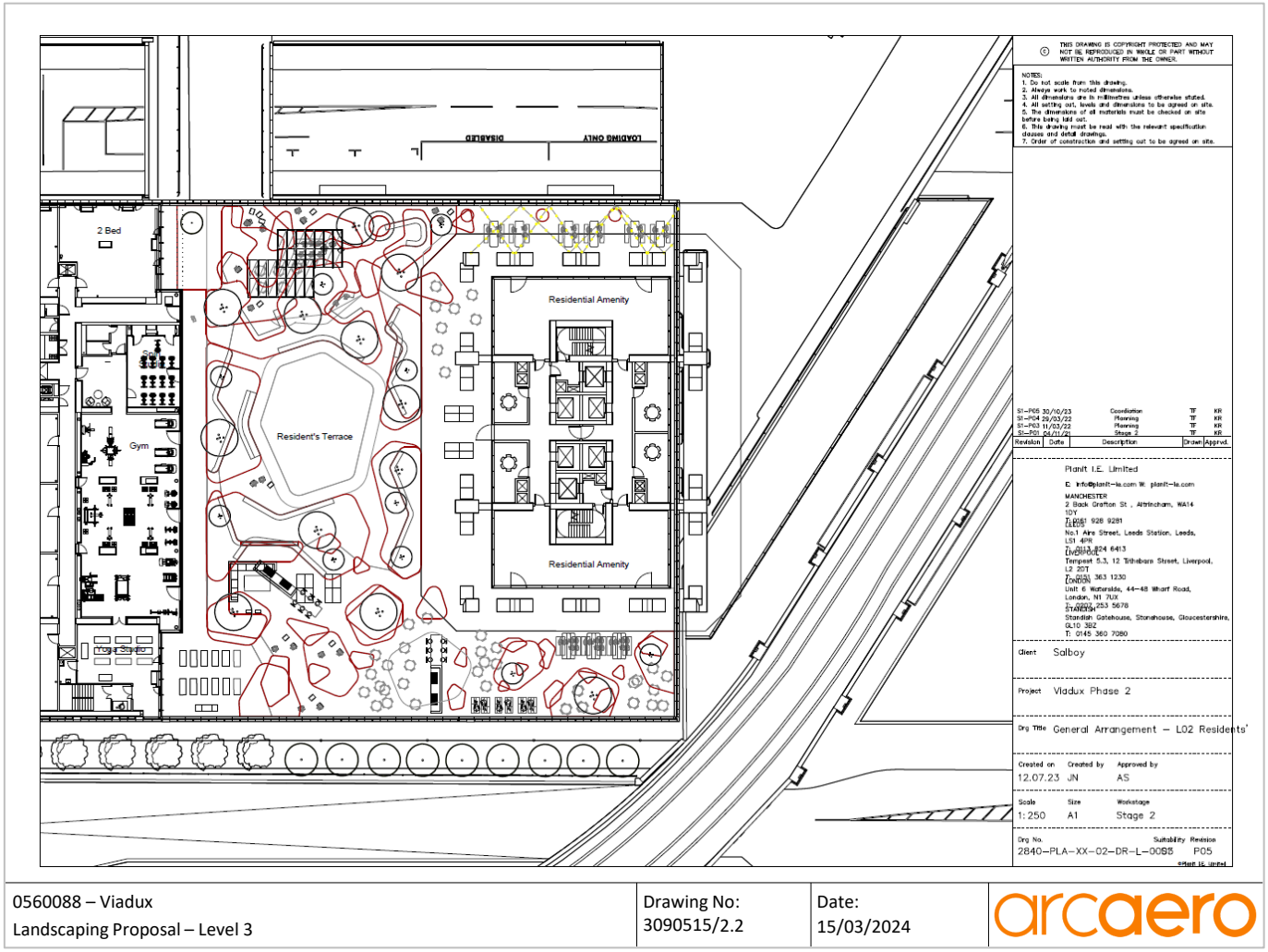
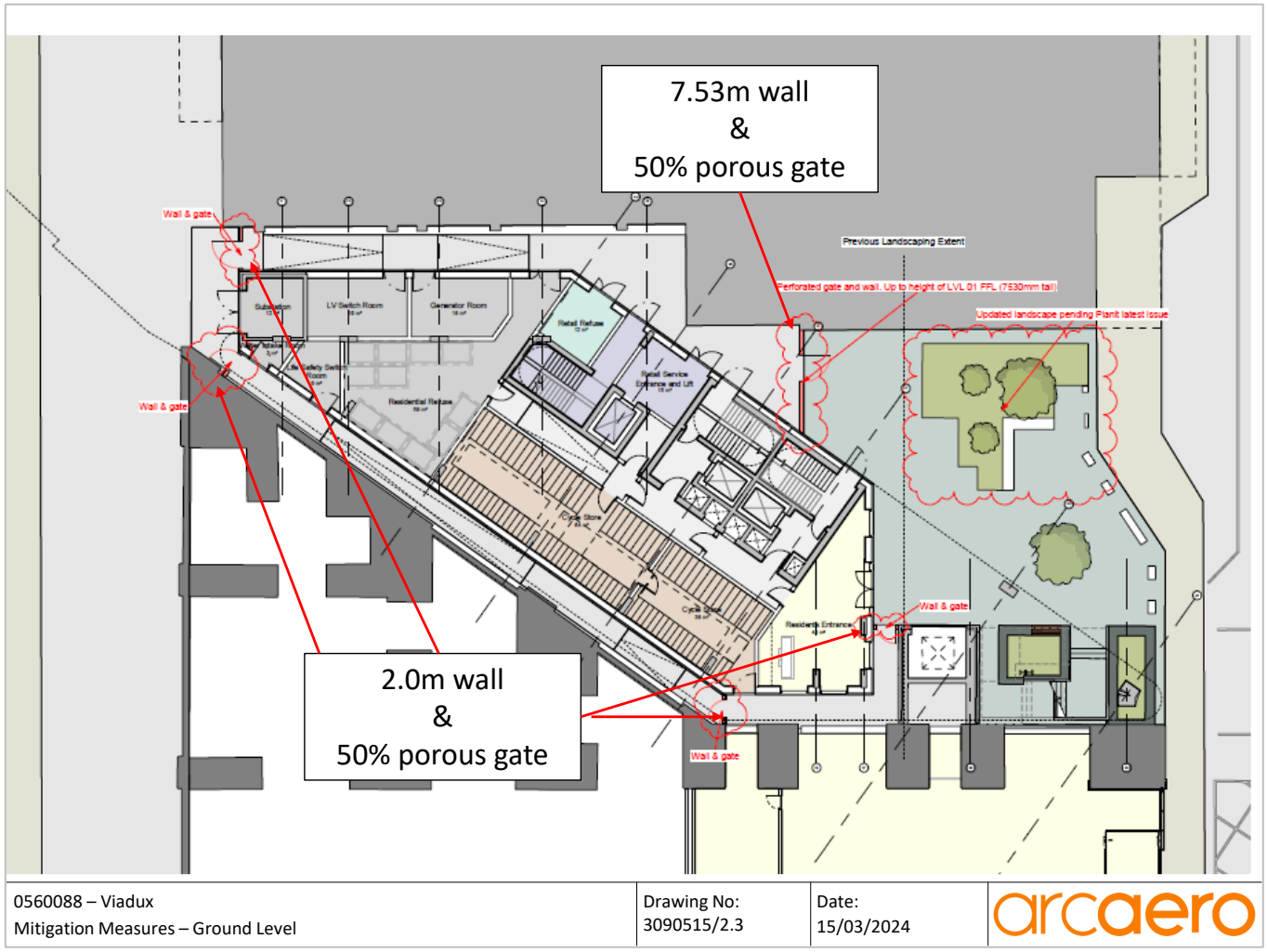


Figure 2.2 – Level 3, Viadux residential podium (Initial Landscaping Proposal)



0560088 – Viadux Landscaping Proposal – Level 3	Drawing No: 3090515/2.2	Date: 15/03/2024	arcaero

Figure 2.3 – Mitigation measures (1)



0560088 – Viadux Mitigation Measures – Ground Level	Drawing No: 3090515/2.3	Date: 15/03/2024	arcaero

Figure 2.4 – Mitigation measures (2)

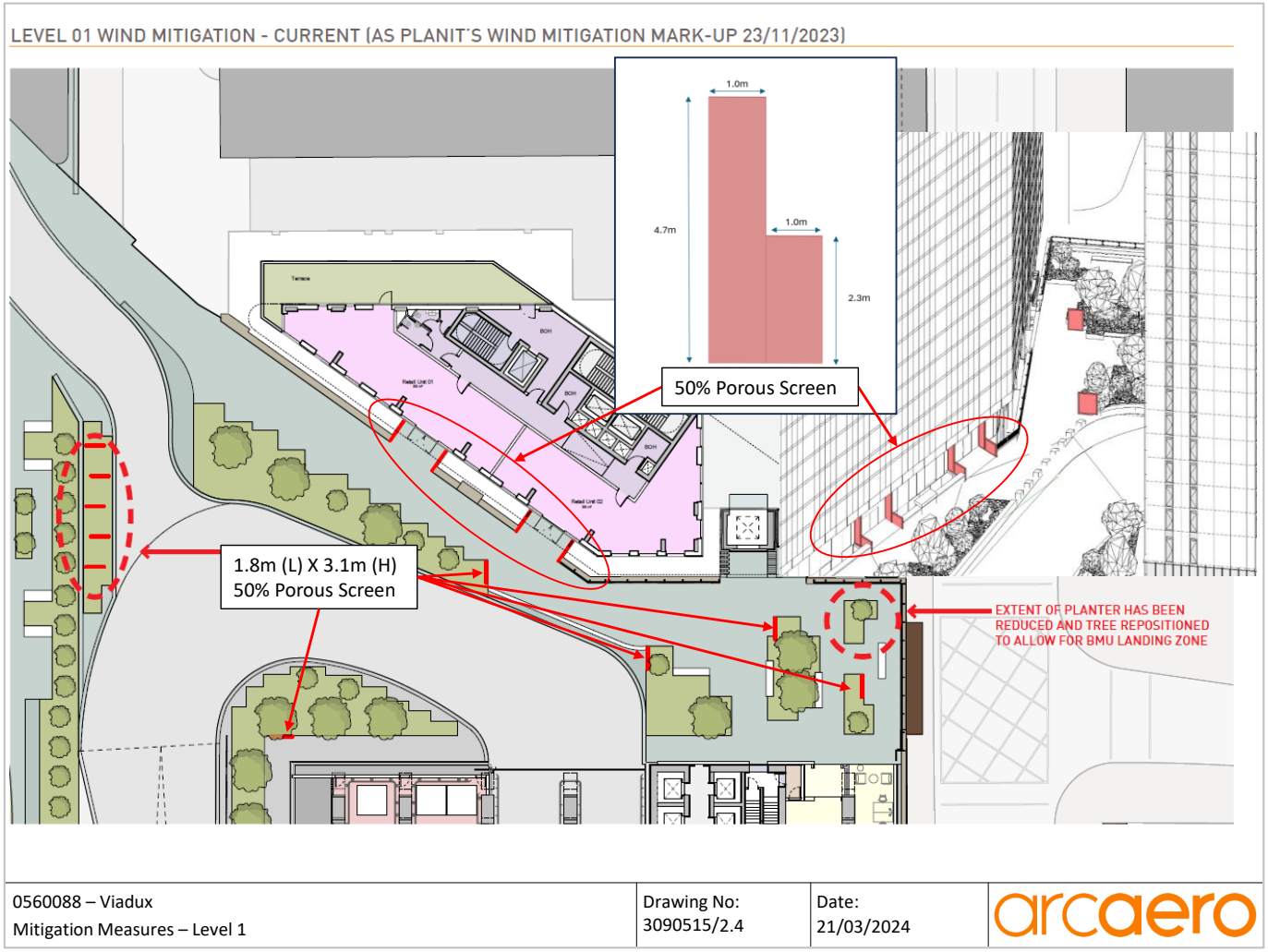
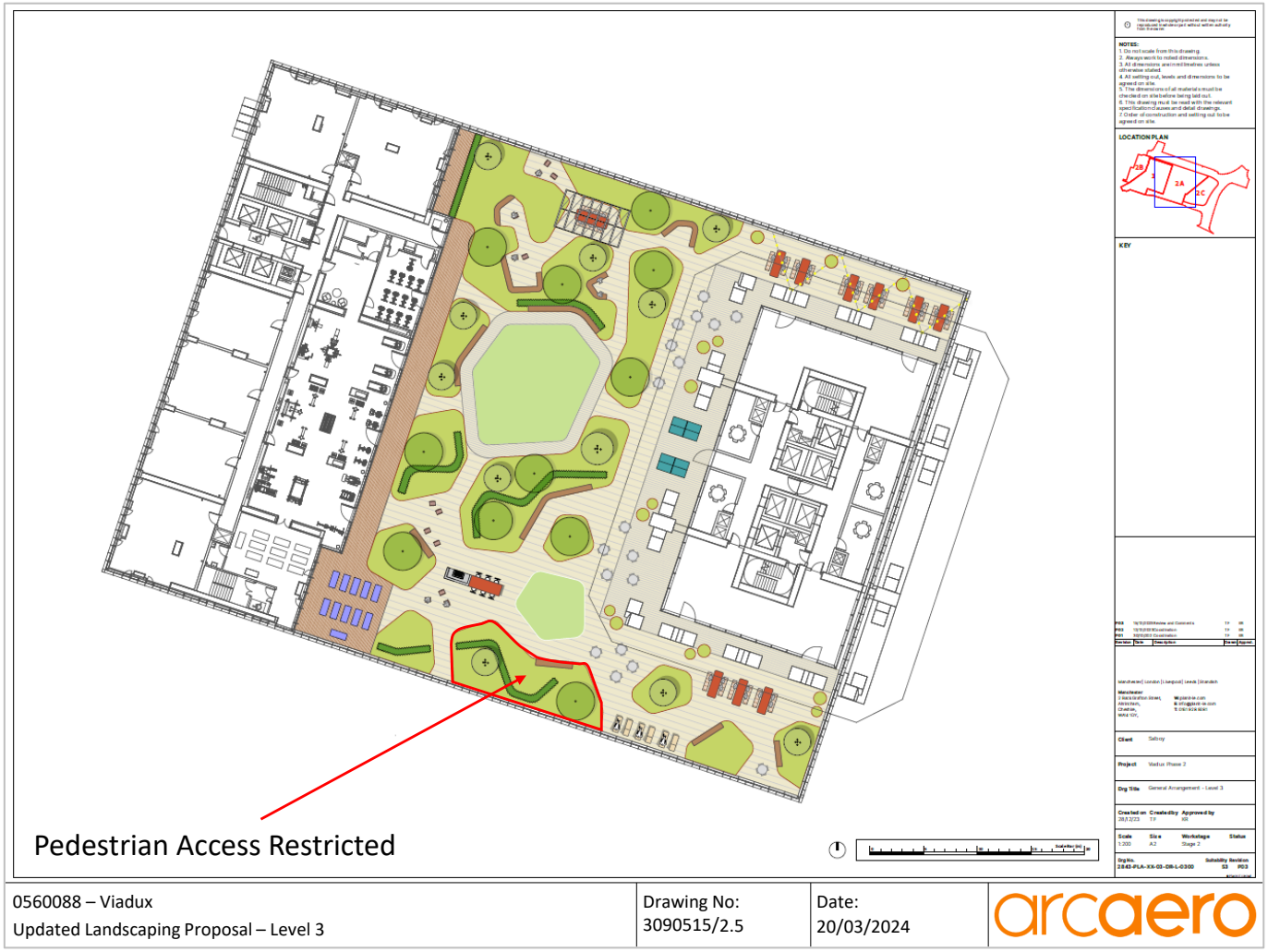


Figure 2.5 – Mitigation measures (3)



0560088 – Viadux Updated Landscaping Proposal – Level 3	Drawing No: 3090515/2.5	Date: 20/03/2024	arcaero

Figure 4.1 - Pedestrian wind conditions, Scenario 1 - Baseline, 'worst' season

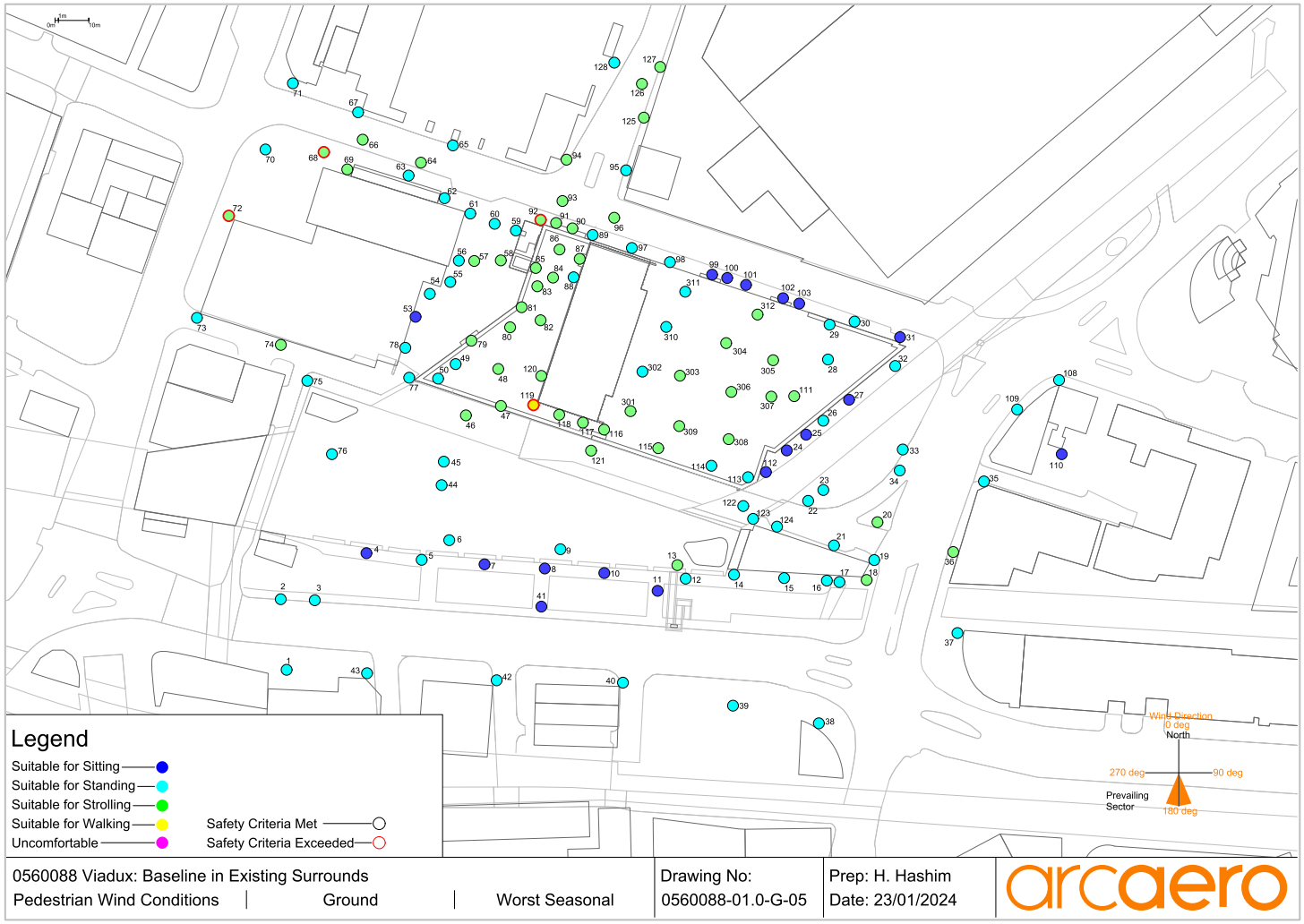


Figure 4.2 - Pedestrian wind conditions, Scenario 1 - Baseline, summer

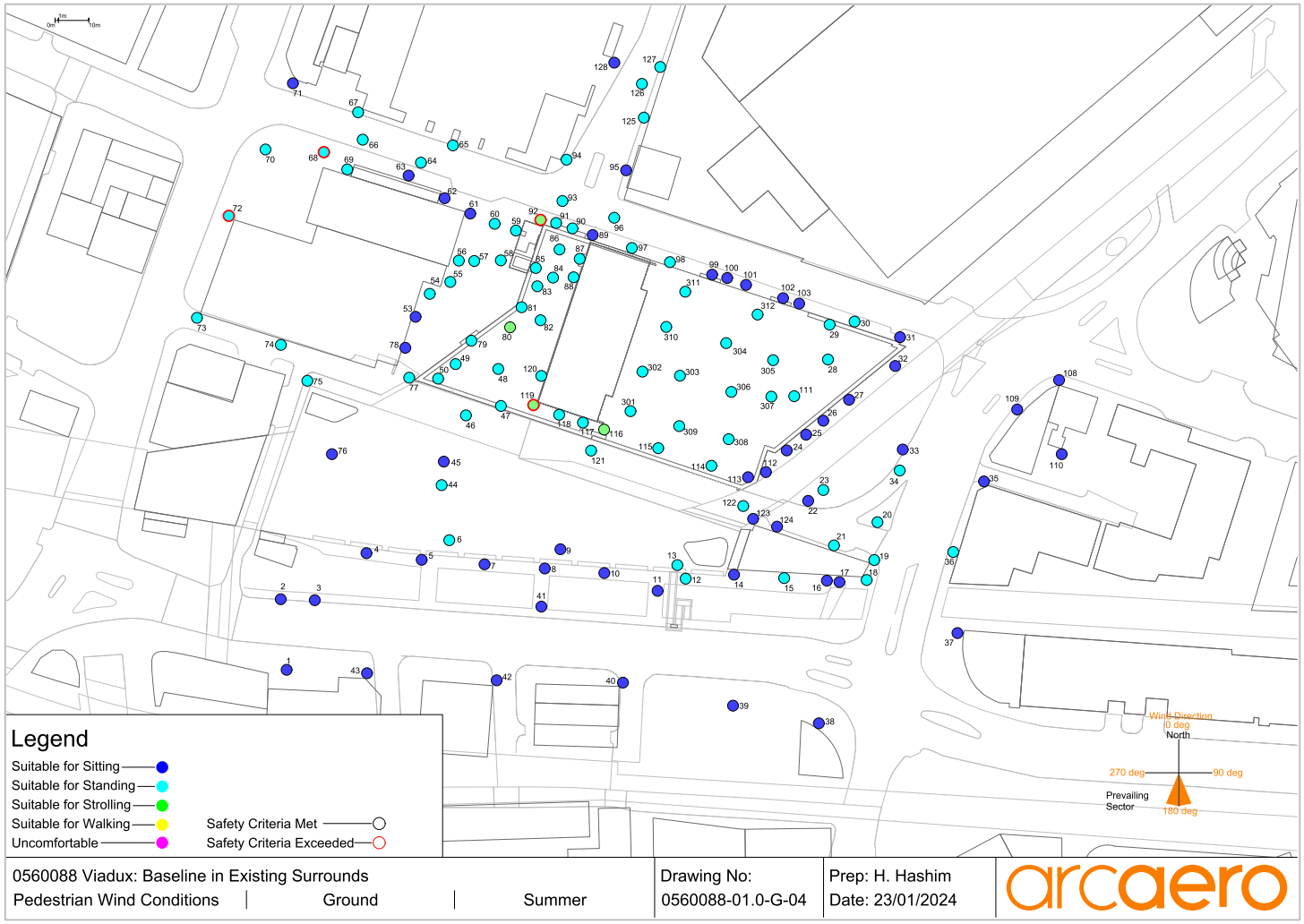


Figure 4.3 - Pedestrian wind conditions, Scenario 1b – Cumulative Baseline, 'worst' season

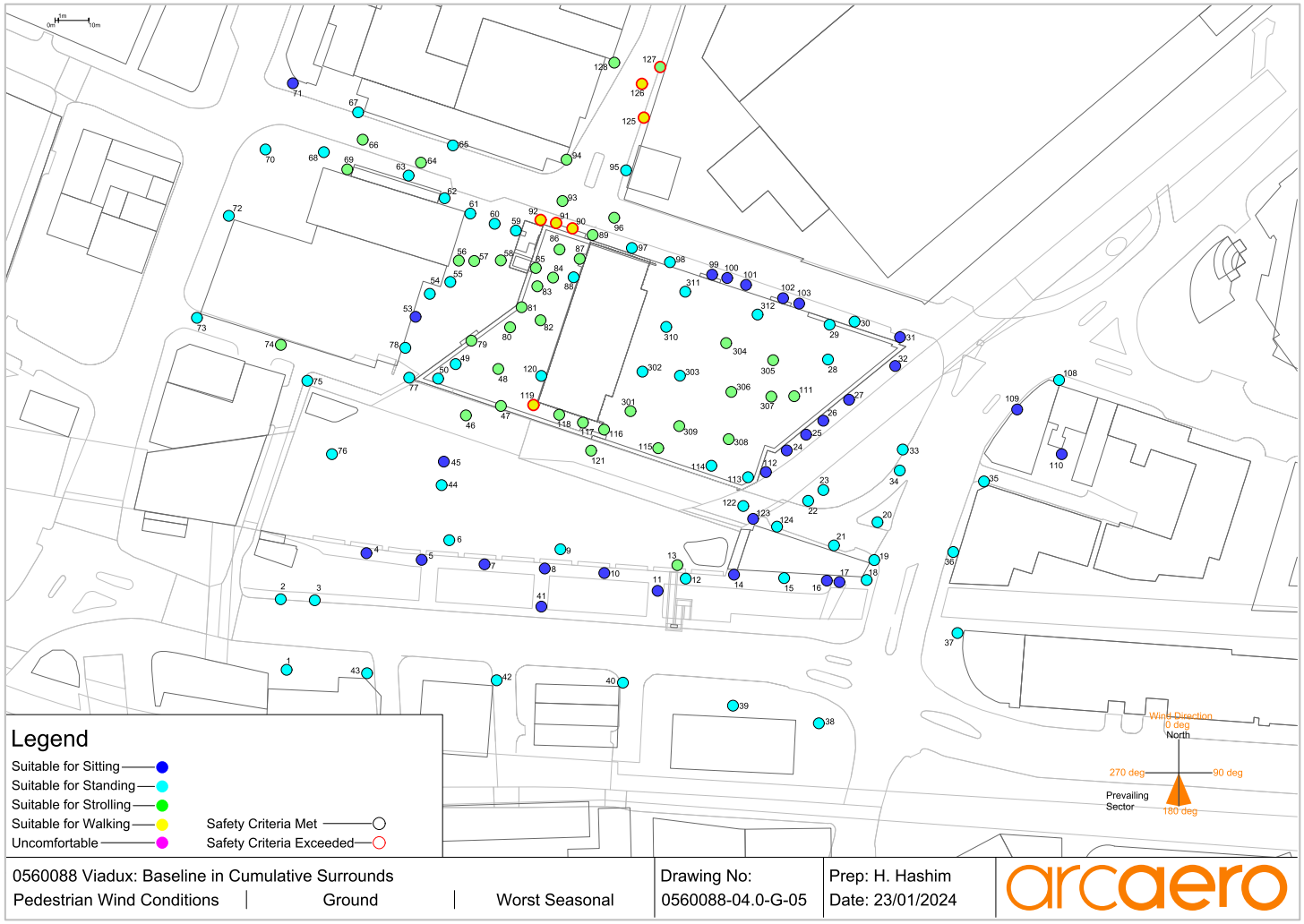


Figure 4.4 - Pedestrian wind conditions, Scenario 1b – Cumulative Baseline, summer

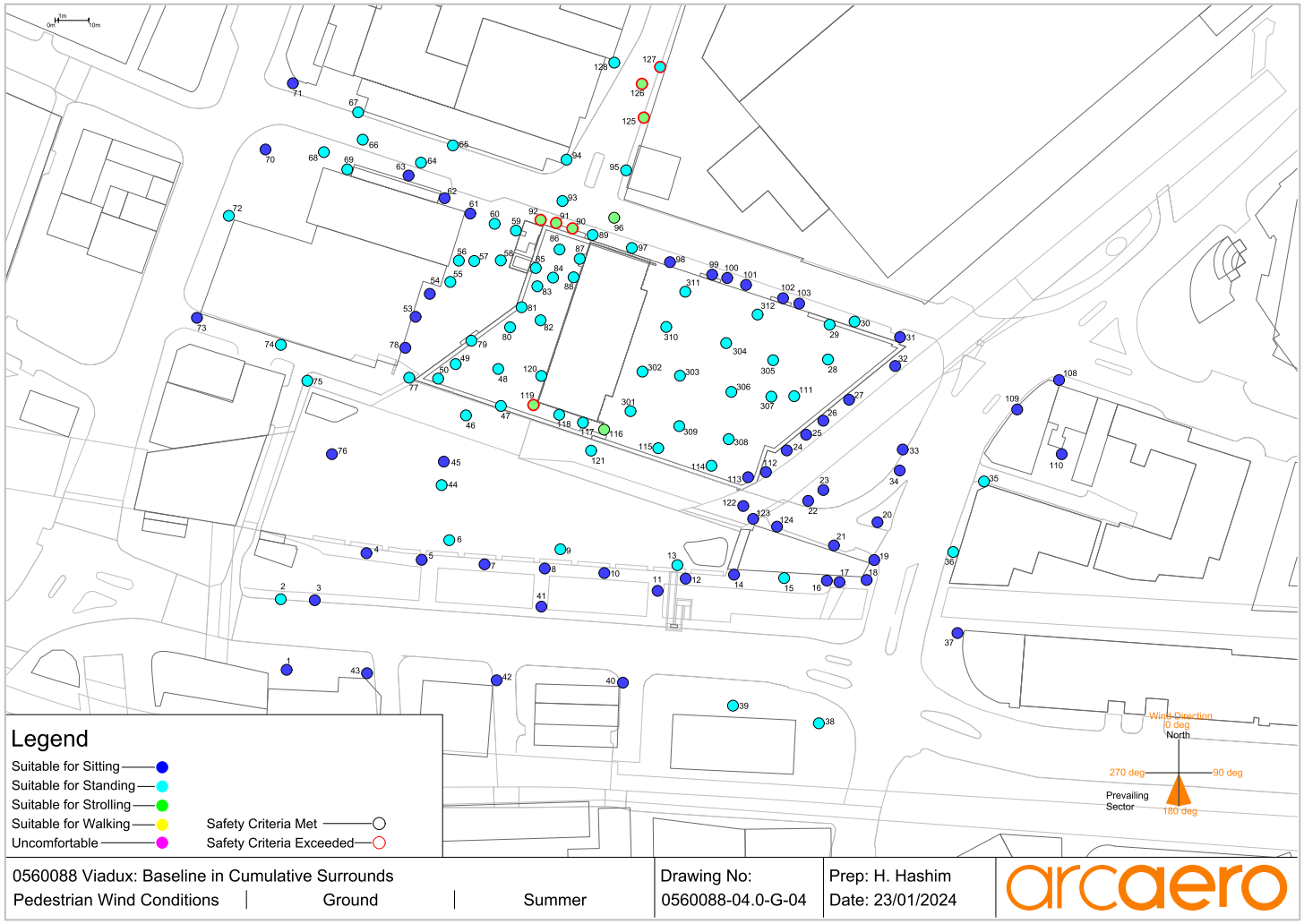


Figure 4.5 - Pedestrian wind conditions, Scenario 2: Existing Baseline with Viadux Plot 2a & Plot 2b, 'worst' season

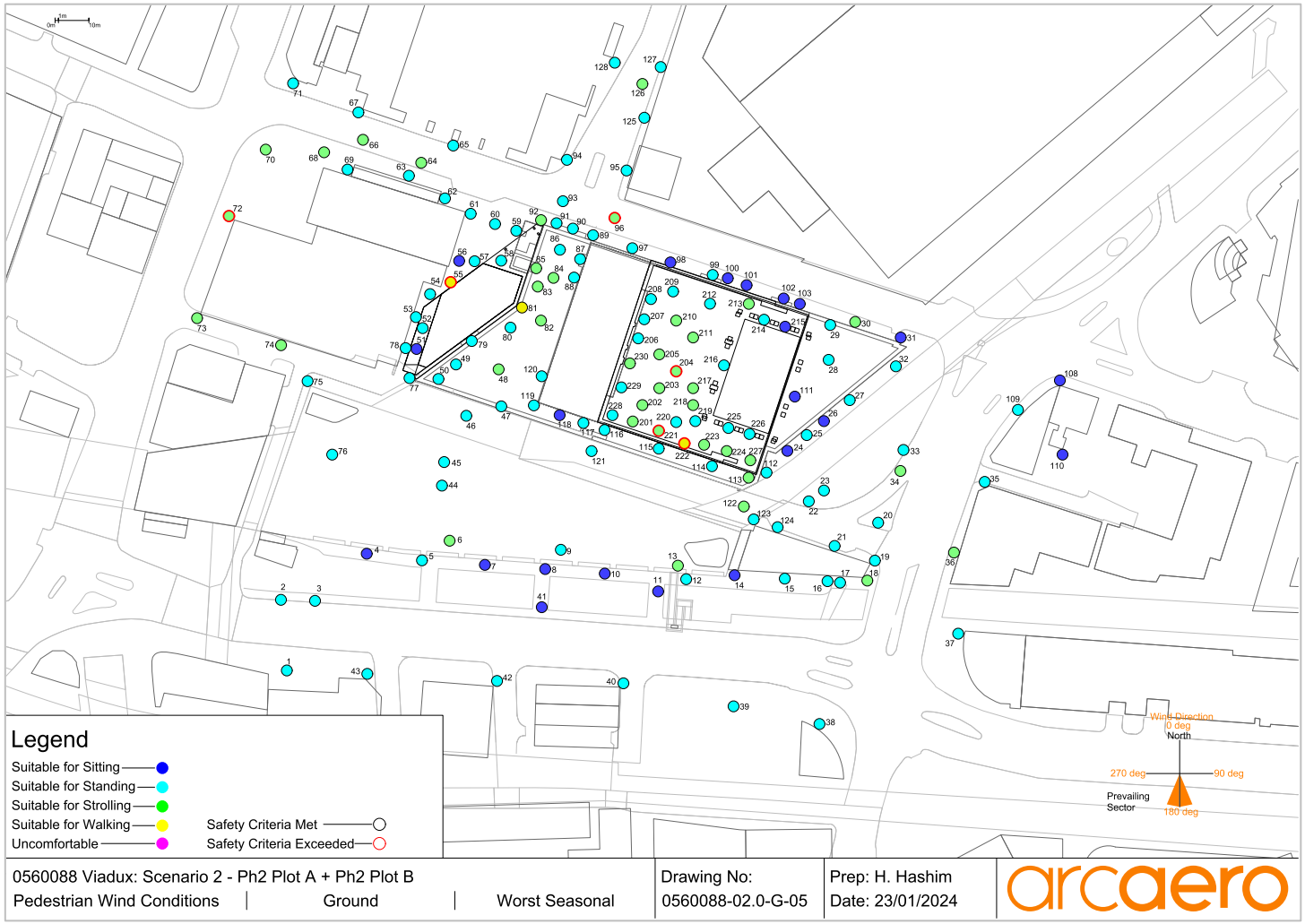


Figure 4.6 - Pedestrian wind conditions, Scenario 2: Existing Baseline with Viadux Plot 2a & Plot 2b, summer

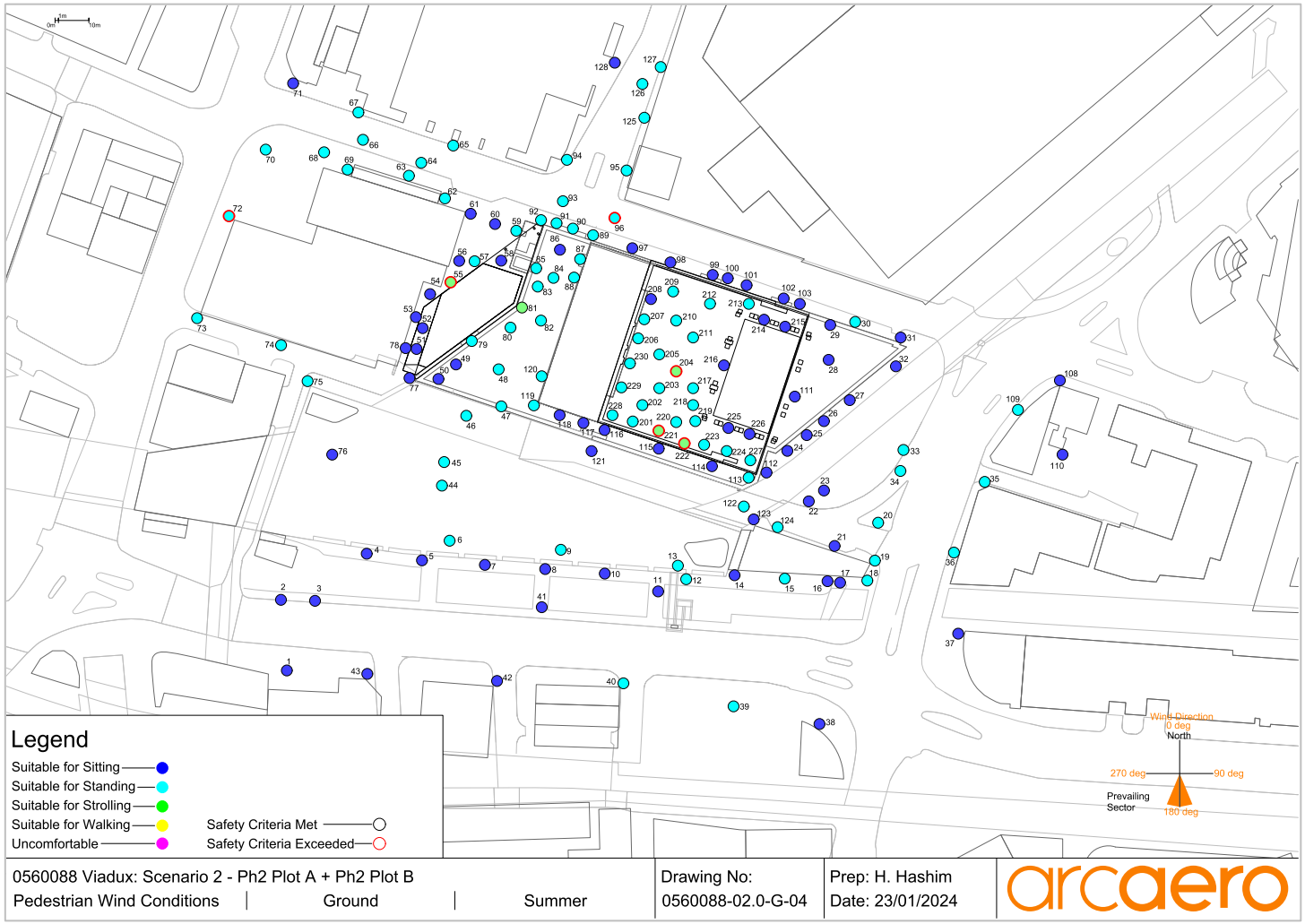


Figure 4.7 - Pedestrian wind conditions, Scenario 2a: Existing Baseline with Viadux Plot 2a & Plot 2b within cumulative surrounds, 'worst' season

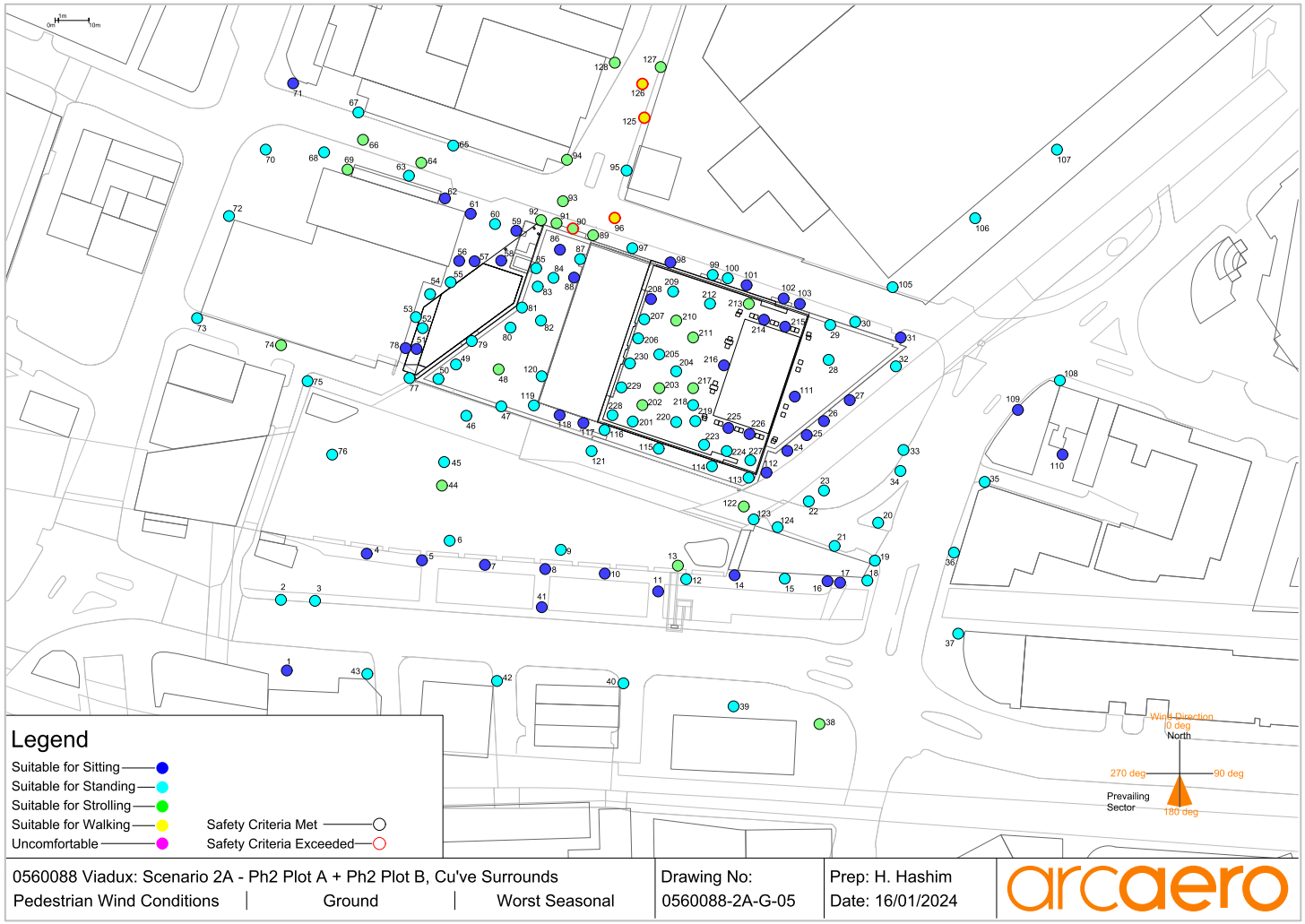


Figure 4.8 - Pedestrian wind conditions, Scenario 2a: Existing Baseline with Viadux Plot 2a & Plot 2b within cumulative surrounds, summer

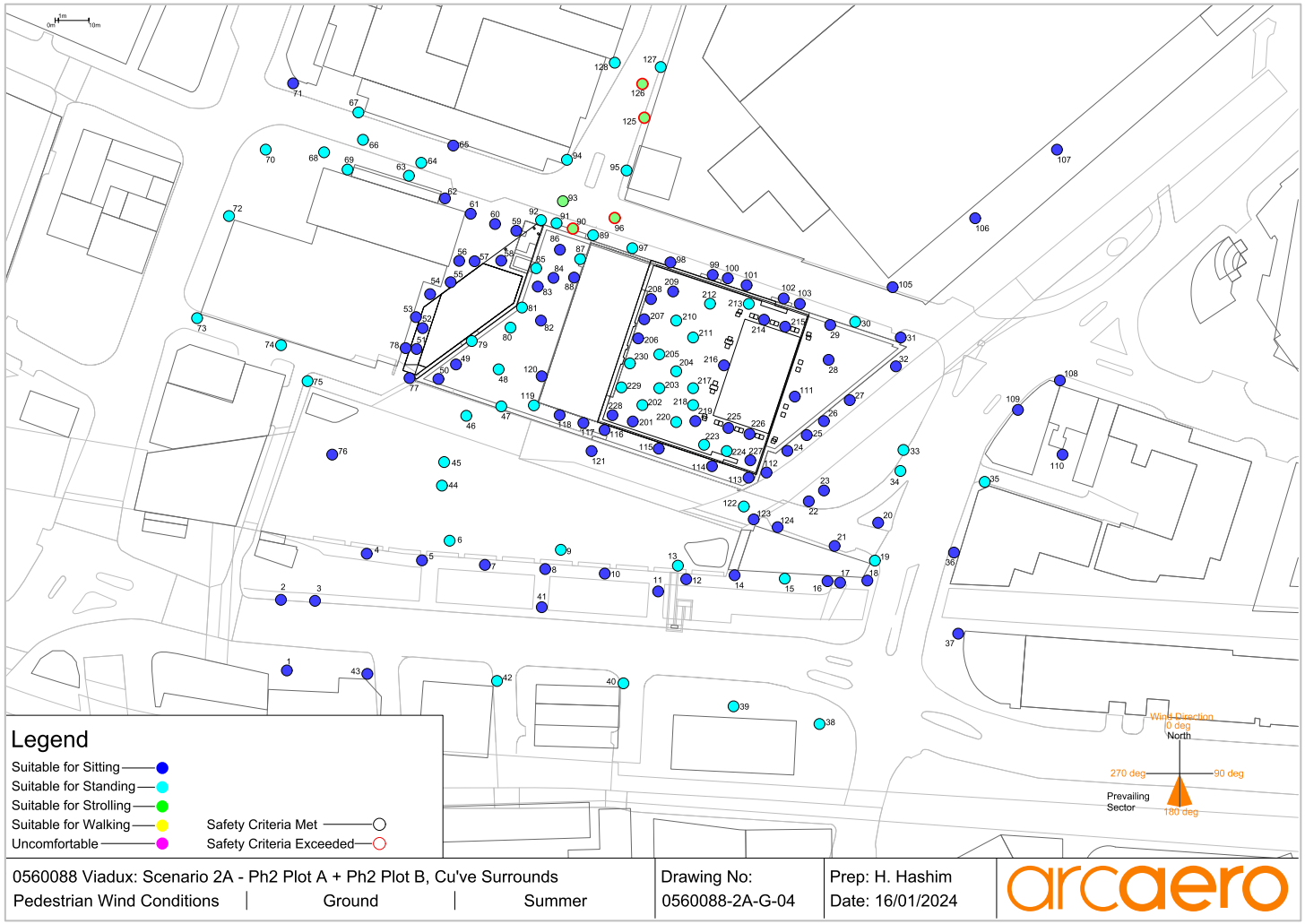


Figure 4.9 - Pedestrian wind conditions, Scenario 2: Existing Baseline with Viadux Plot 2a & Plot 2b with mitigation measures, 'worst' season

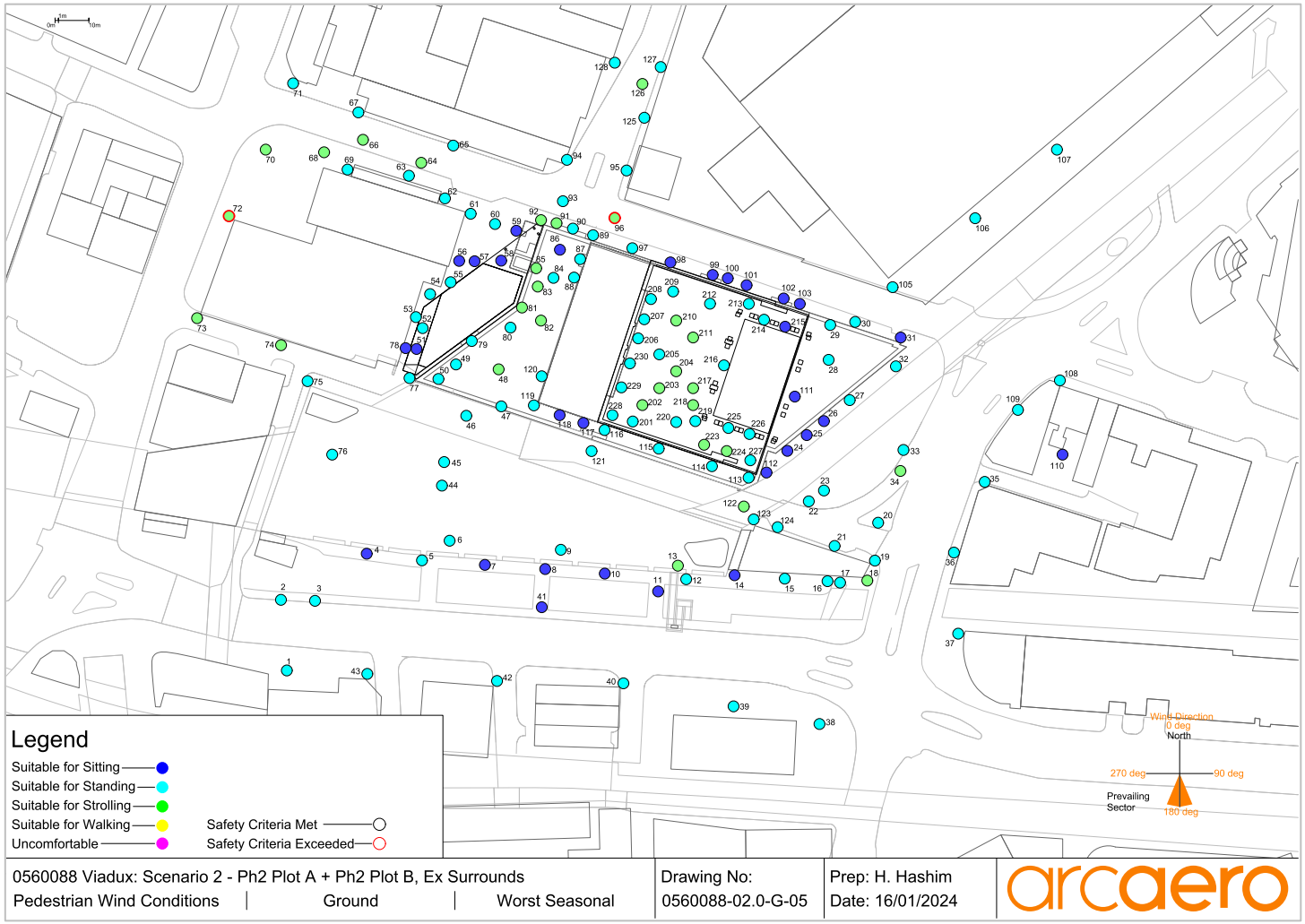


Figure 4.10 - Pedestrian wind conditions, Scenario 2: Existing Baseline with Viadux Plot 2a & Plot 2b with mitigation measures, summer

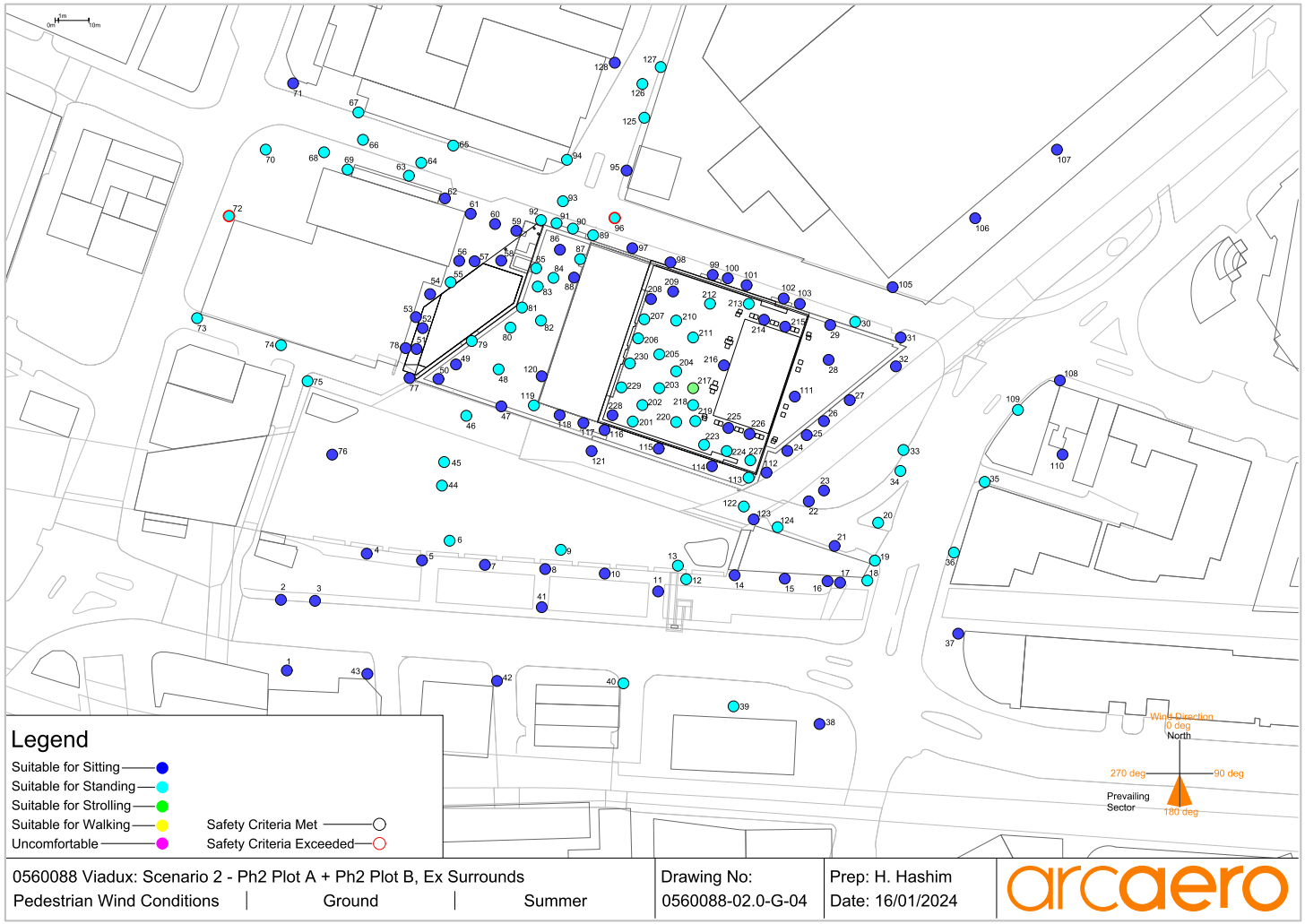


Figure 4.11 - Pedestrian wind conditions, Scenario 2a: Existing Baseline with Viadux Plot 2a & Plot 2b within cumulative surrounds with mitigation measures, 'worst' season

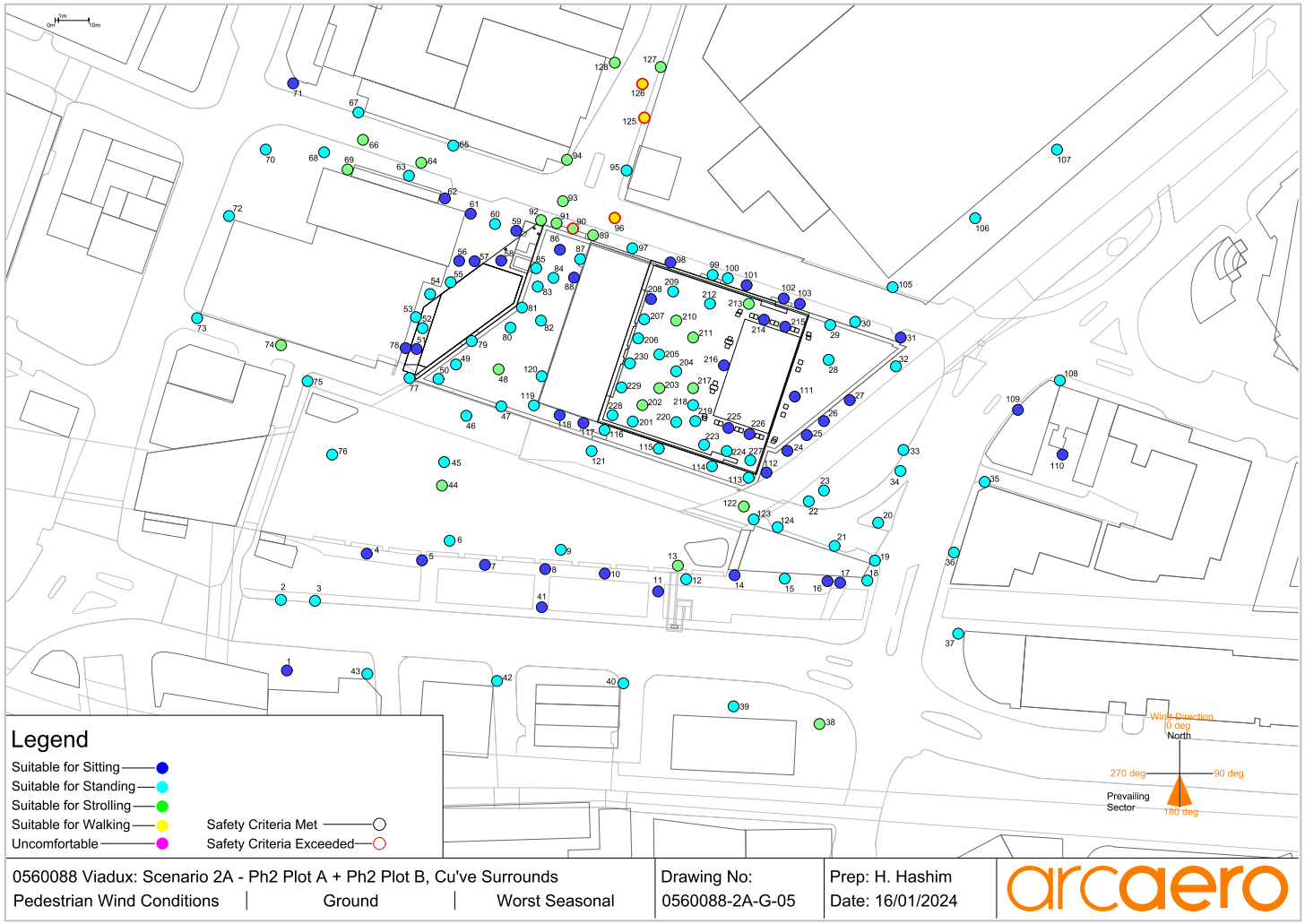


Figure 4.12 - Pedestrian wind conditions, Scenario 2a: Existing Baseline with Viadux Plot 2a & Plot 2b within cumulative surrounds with mitigation measures, summer

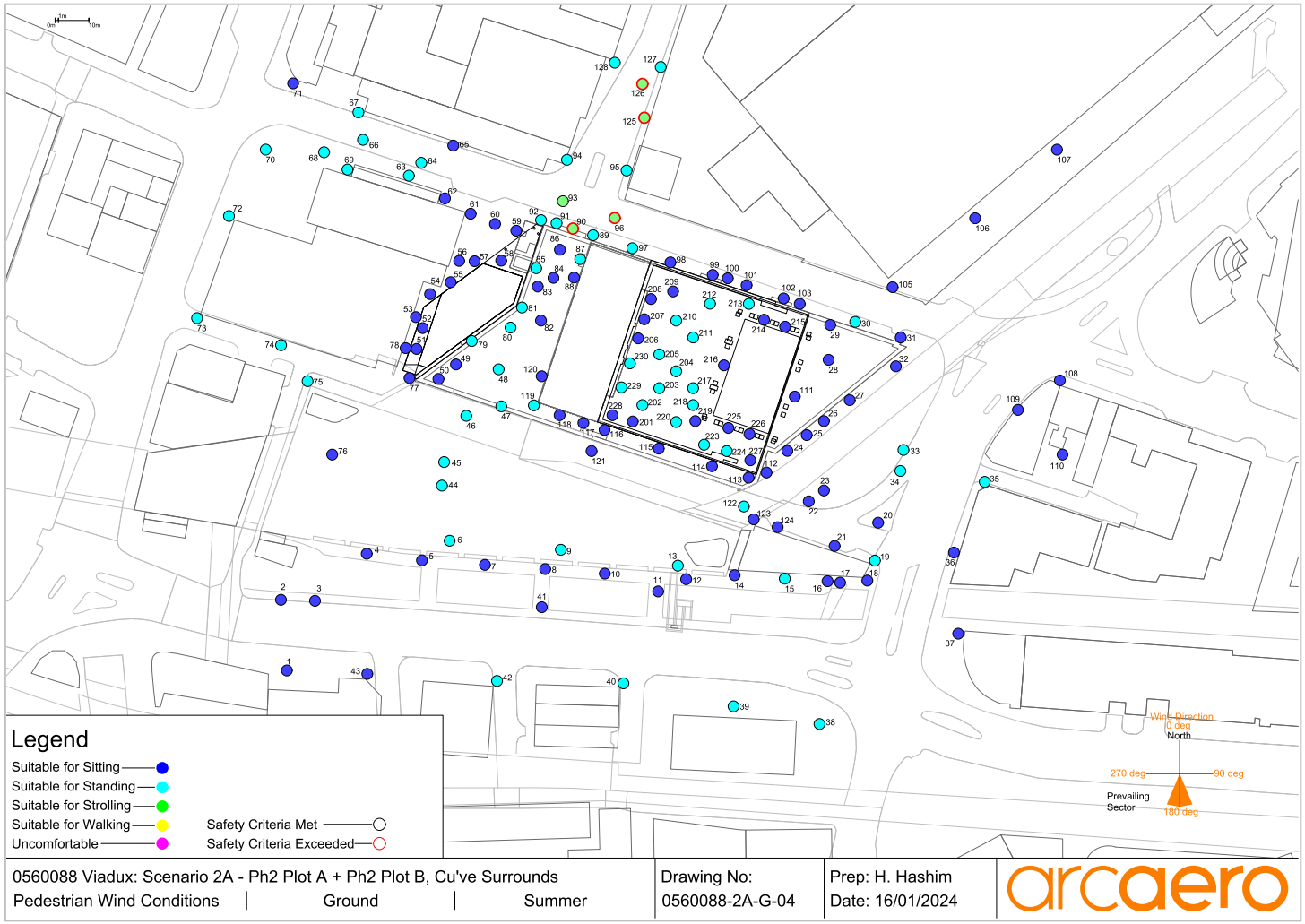


Figure 5.1 - Improvised mitigation measures, Op8+ and Op8++



Figure 5.2 – Pedestrian wind conditions, Improvised solutions (Op8+ & Op8++), annual safety



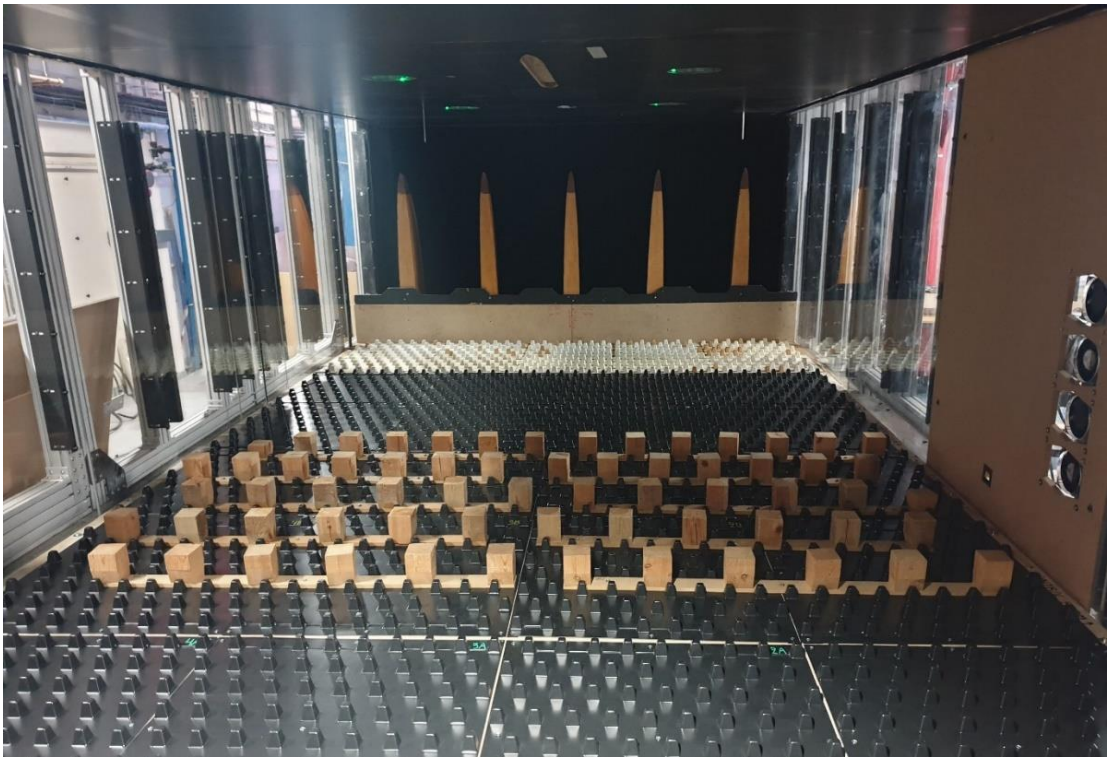
Appendix A Wind Tunnel and Model

A.1 Atmospheric Boundary Layer Modelling

The study was conducted at the Imperial College 10’ x 5’ wind tunnel in London. This closed-loop facility provides a 20-metre-long boundary layer test section and a 3.0 metre x 1.5 metre test section. The wind speed operating range is 0-40 m/s.

‘Roughness blocks’, a 2D fence and 3D posts were used to replicate the boundary layer. These elements are presented Figure A.1.

Figure A.1 - Boundary layer creation, Imperial College, London.



A.2 Wind Tunnel Models

A 1:400 scale wind tunnel was constructed from materials such as dense foam, wood and plastic. The wind microclimate was assessed at approximately 160 locations.

Photos of the wind tunnel model are presented as follows:

- Figure A.2 and Figure A.3: Scenario 1 (Baseline)
- Figure A.4 and Figure A.5: Scenario 1b (Cumulative Baseline)
- Figure A.6 and Figure A.7: Scenario 2 (Existing Baseline with Viadux Plot 2a & Plot 2b)
- Figure A.8 and Figure A.9: Scenario 2a (Existing Baseline with Viadux Plot 2a & Plot 2b) within cumulative surrounds
- Figure A.10 and Figure A.11: close-ups of completed development

Figure A.2 – Scenario 1: Baseline conditions, looking north.

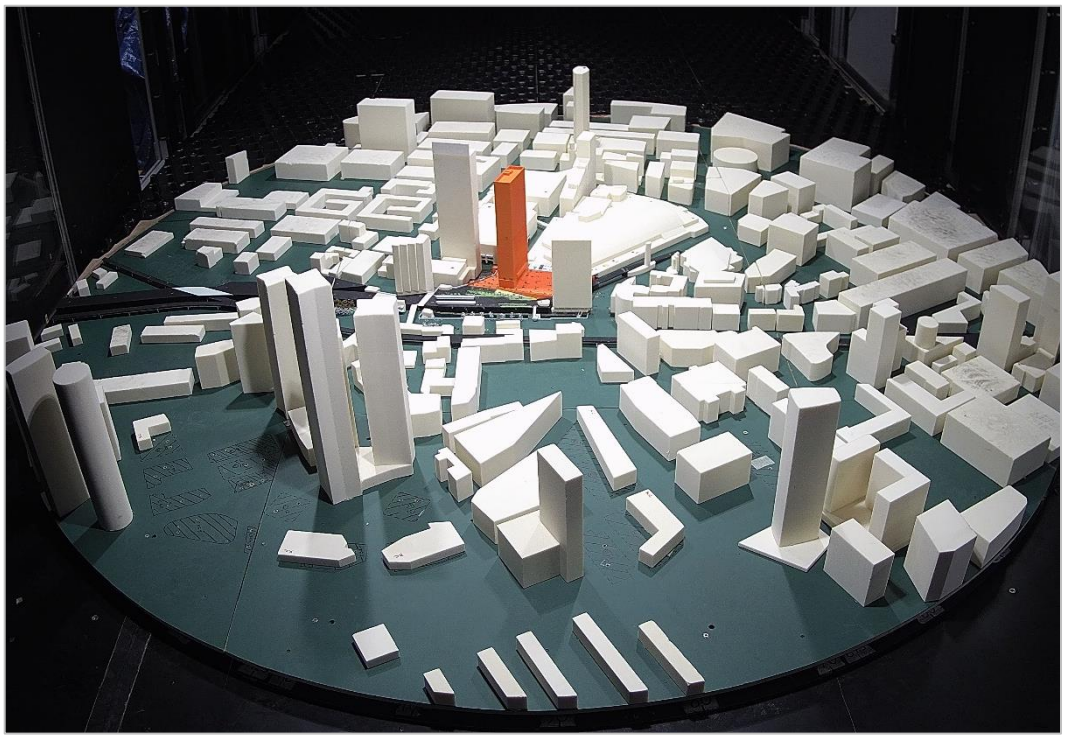


Figure A.3 - Scenario 1 : Baseline conditions, looking south.

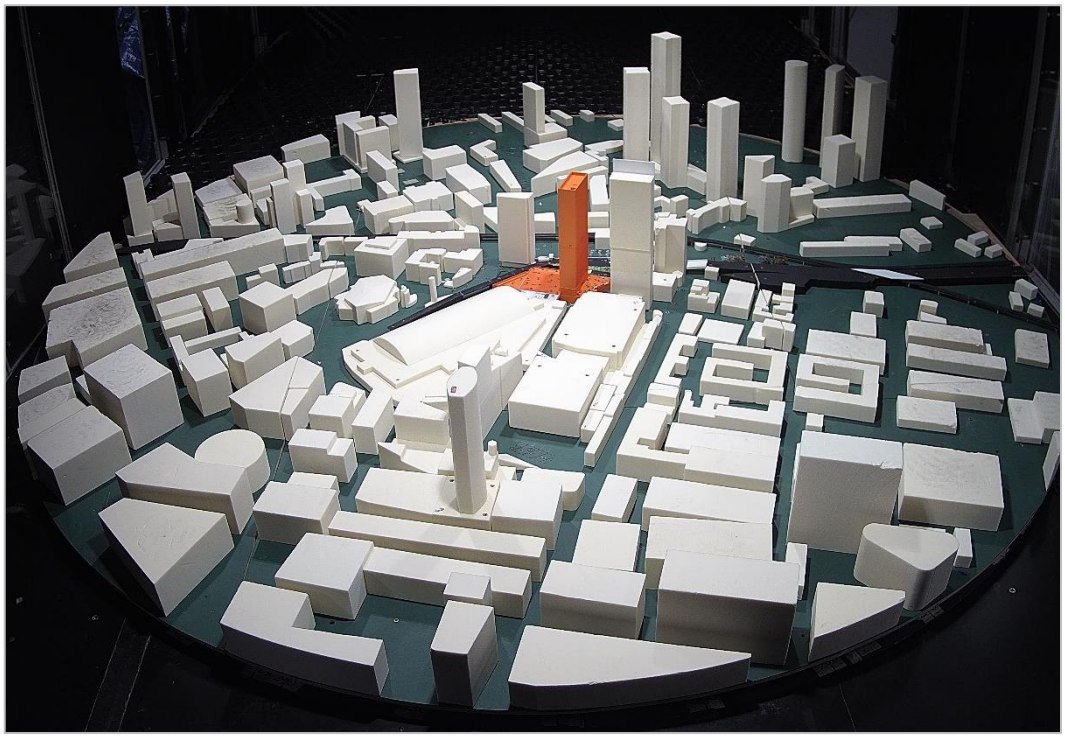


Figure A.4 – Scenario 1b (Cumulative Baseline), looking north.



Figure A.5 – Scenario 1b (Cumulative Baseline), looking south.



Figure A.6 – Scenario 2 (Existing Baseline with Viadux Plot 2a & 2b), looking north.

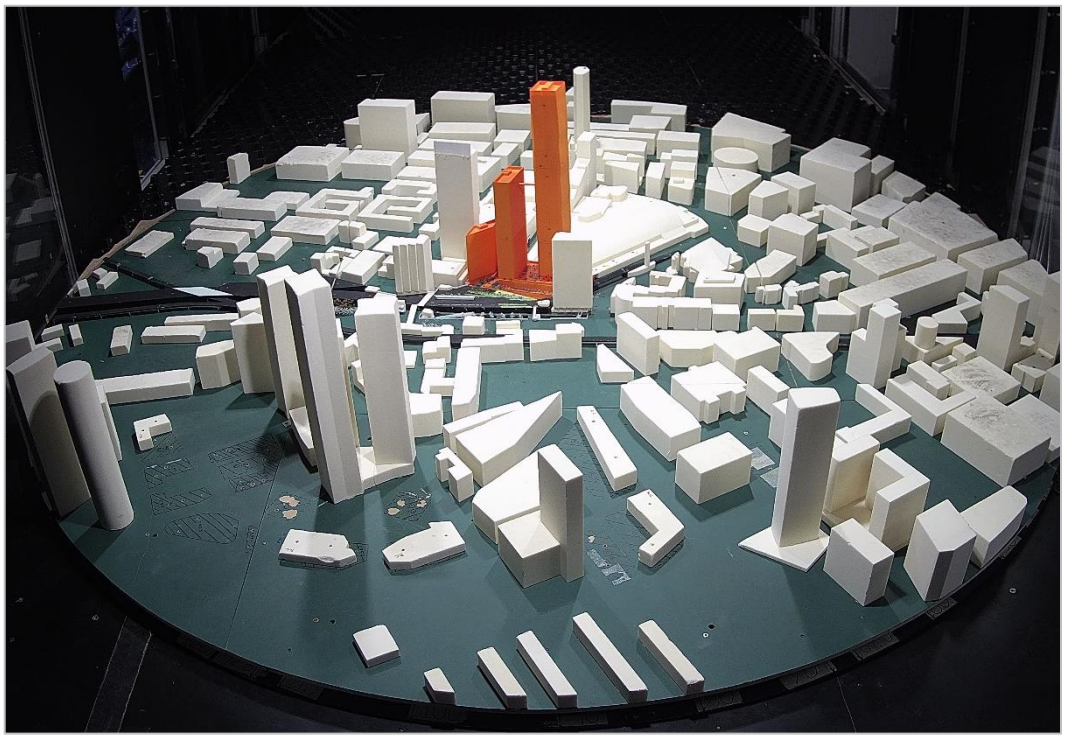


Figure A.7 – Scenario 2 (Existing Baseline with Viadux Plot 2a & 2b), looking south.

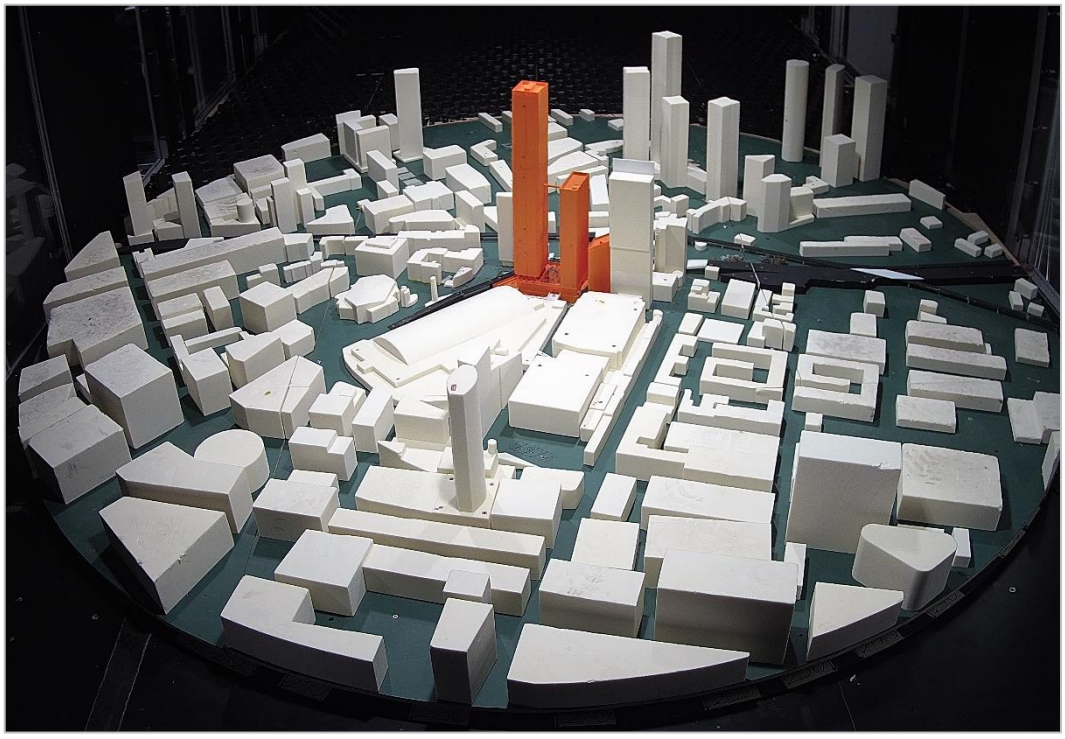


Figure A.8 – Scenario 2a (Existing Baseline with Viadux Plot 2a & 2b) within cumulative surrounds, looking north.



Figure A.9 – Scenario 2a (Existing Baseline with Viadux Plot 2a & 2b) within cumulative surrounds, looking south.

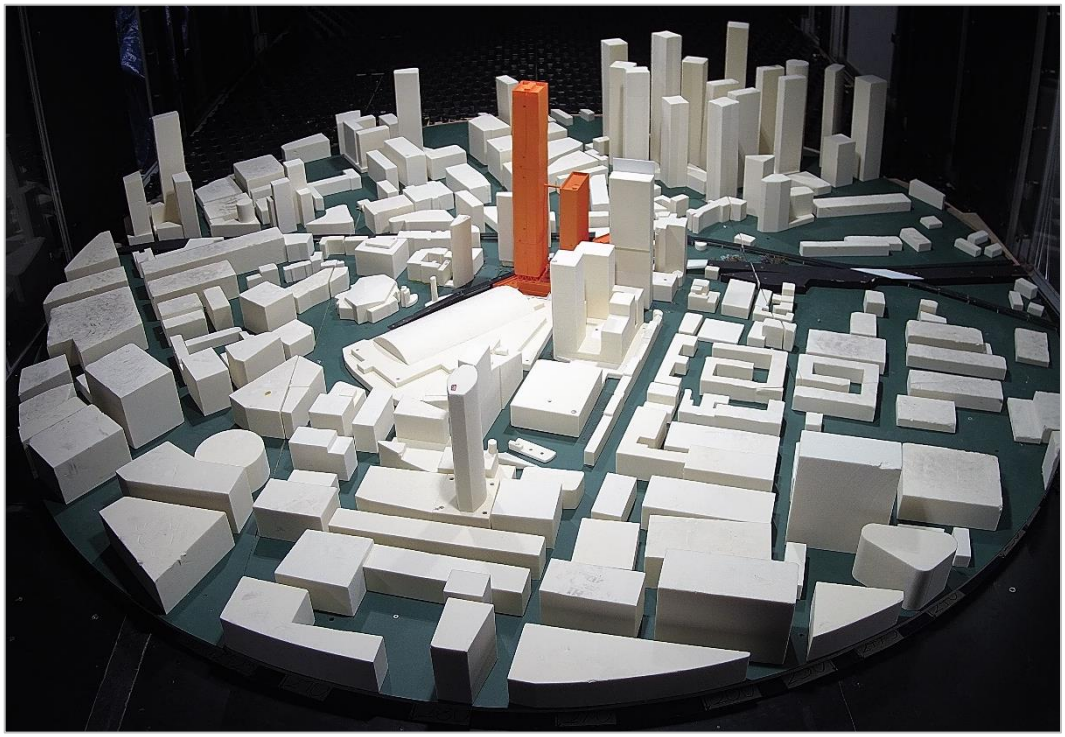


Figure A.10 – Close-up of the proposed development, viewed from southwest.

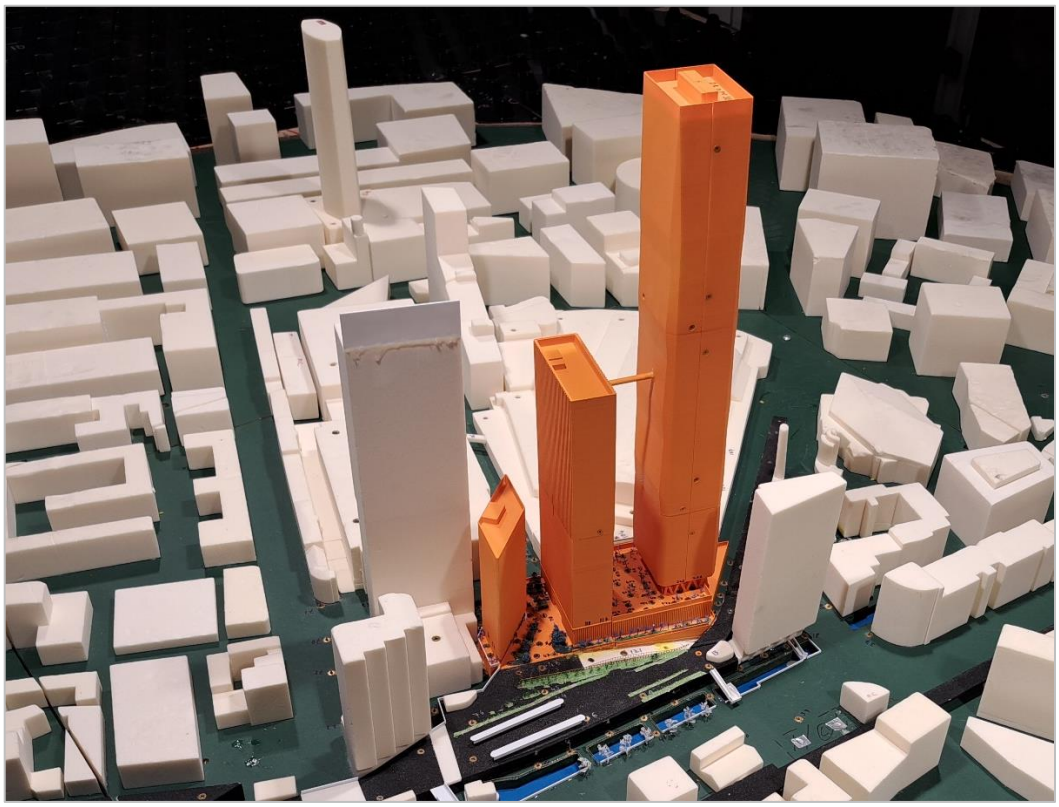
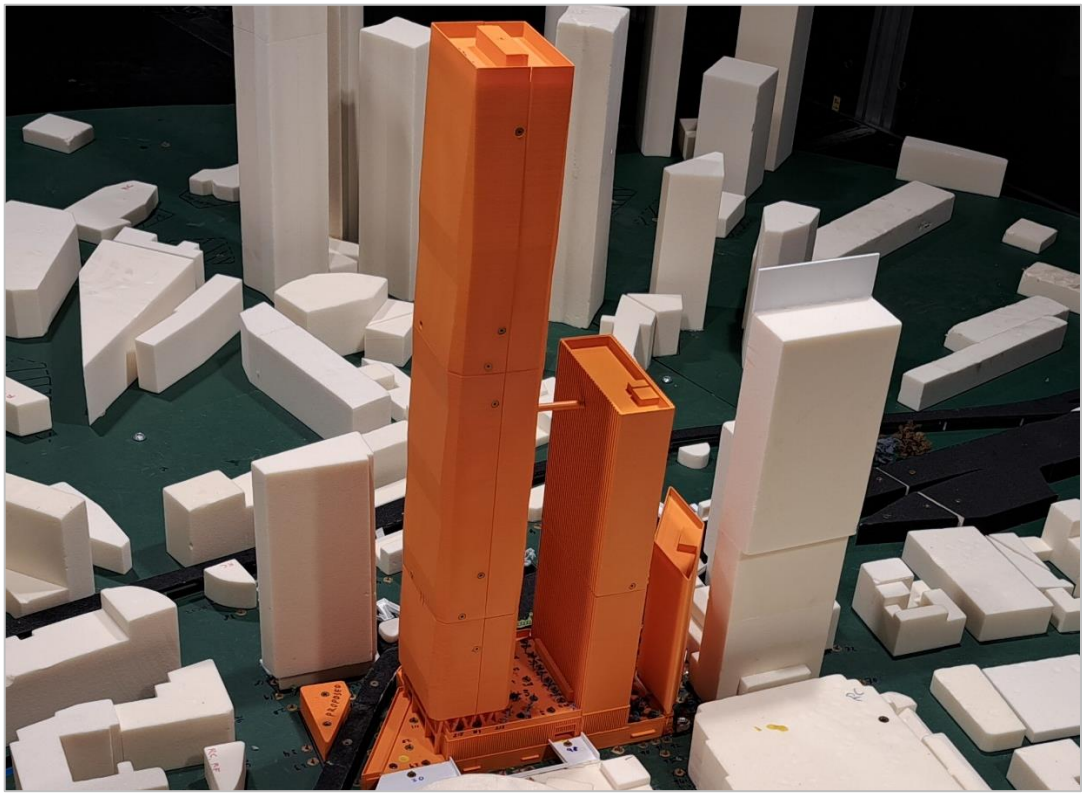


Figure A.11 – Close-up of the proposed development, viewed from northeast.



A.3 Data Acquisition

Wind speed measurements were made using 'Irwin probes', capable of measuring fluctuating pressure differences that are calibrated against wind speed. A system of probes running simultaneously was used to obtain results from approximately 160 locations at a height corresponding to 1.5m at full scale.

Data was recorded for a sufficient length of time to determine the mean and 3-second gust wind speeds.

The gust wind speed is translated to an equivalent mean wind speed, the Gust Equivalent Mean or GEM, according to the following equation:

$$U_{GEM} = \frac{U_{GUST}}{1.85}$$

The results at each location were combined with wind statistics transposed to the site to assess the exceedance of threshold wind speeds that relate to comfort and safety in accordance with the Lawson criteria.

Appendix B Wind Climate Analysis

B.1 Wind Frequency Data, Manchester Airport

Wind microclimate studies require that wind speed data obtained from a measurement station be transposed to the site of interest. The current study employs wind data from Manchester Airport.

The wind speed history has been reformatted into the number of observations of mean-hourly wind speeds within each of several wind speed ranges, for each wind direction and for each month of the year. To facilitate the transposition of the wind data, the months are grouped into the seasons and a Weibull distribution is fitted to the wind speed distribution for each wind direction, for each season.

From the Weibull cumulative distribution, the probability that, for a given wind direction, a wind speed, V, will be exceeded is given by:

$$P(>V) = e^{-(\frac{V}{c})^k}$$

where *c* is the dispersion parameter and *k* is the shape parameter.

To these parameters is further added the probability, p, of each wind direction occurring. Thus, for each month of the year the probability that a specified wind speed is exceeded for a specified wind direction may be calculated.

The resulting weather centre wind data is transposed to a standard reference terrain category, 'open country terrain', at sea-level, accounting for upwind terrain, topography and altitude for the weather centre. The open country wind data is then transposed to the reference height at the site of the proposed development, accounting for upwind terrain, topography and altitude for the target site.

For the transposition of wind speed data from the weather station to open country, and from open country to the site, the methods set out in ESDU item 01008 (2) (the industry standard) have been employed.

The resulting annual and seasonal directional and wind speed probability distributions at the reference height of 240m, at the proposed site, are given in Figures B.2 to B.6, respectively.

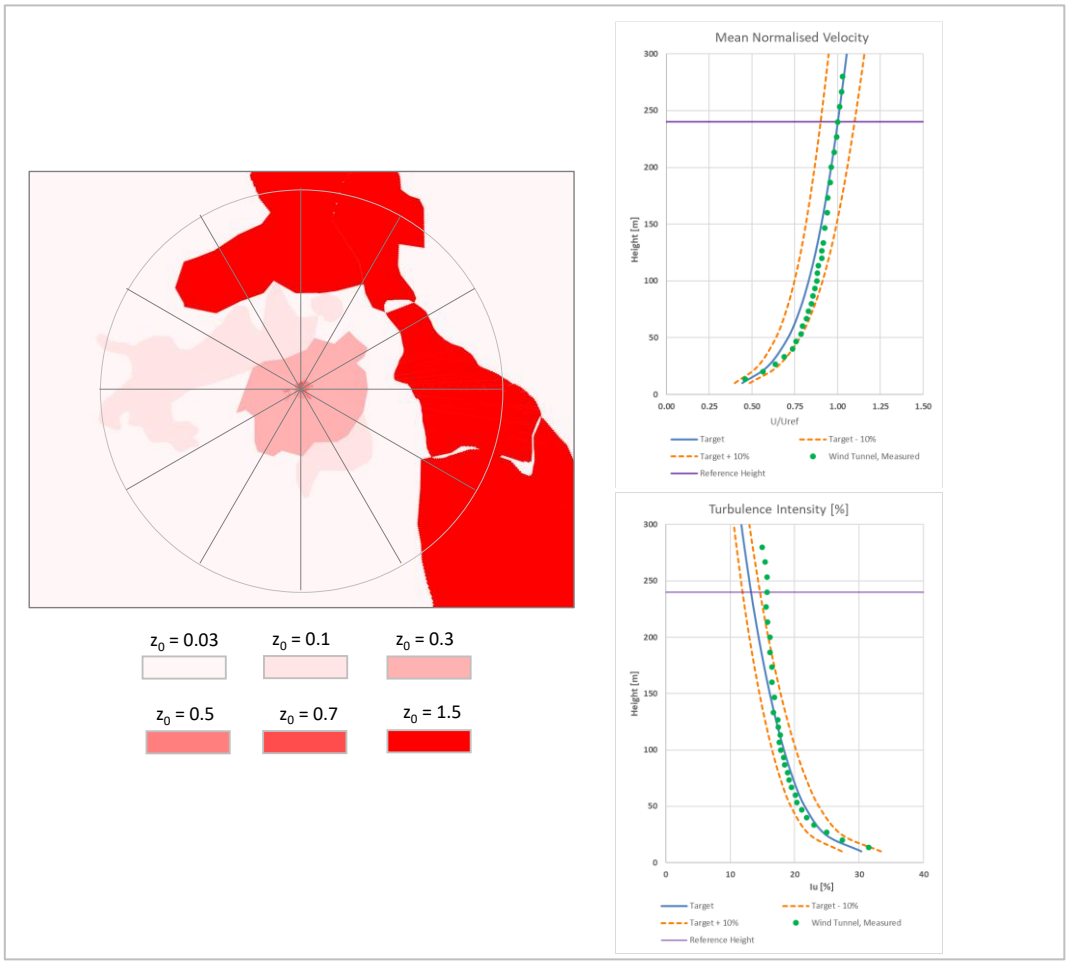
B.2 Wind Properties at the Site

A detailed analysis, based on the widely accepted Deaves and Harris model of the atmospheric boundary layer (ABL), as defined in ESDU Item 01008 (2), has been carried out to determine the wind properties at the site. From this analysis a representative profile was defined as a target for the ABL simulation in the wind tunnel.

Upon conducting the ESDU analysis, one wind profile was replicated in the wind tunnel to adequately account for wind blowing from all angles.

ArcAero's terrain analysis and resulting mean wind speed and turbulence intensity profiles are presented within Figure A.1.

Figure A.1 – Target mean wind speed and turbulence intensity profiles and wind tunnel profile



B.3 Wind Frequency Data

Wind microclimate studies require that meteorological data is transposed from a nearby weather station with sufficient wind data to produce accurate wind frequency statistics. The current study uses data from Manchester Airport. The cumulative wind speed probability distributions, transposed to building height at site are provided in Figure B.2 to Figure B.6.

Figure B.2 – Cumulative wind speed probability distribution at site, annual

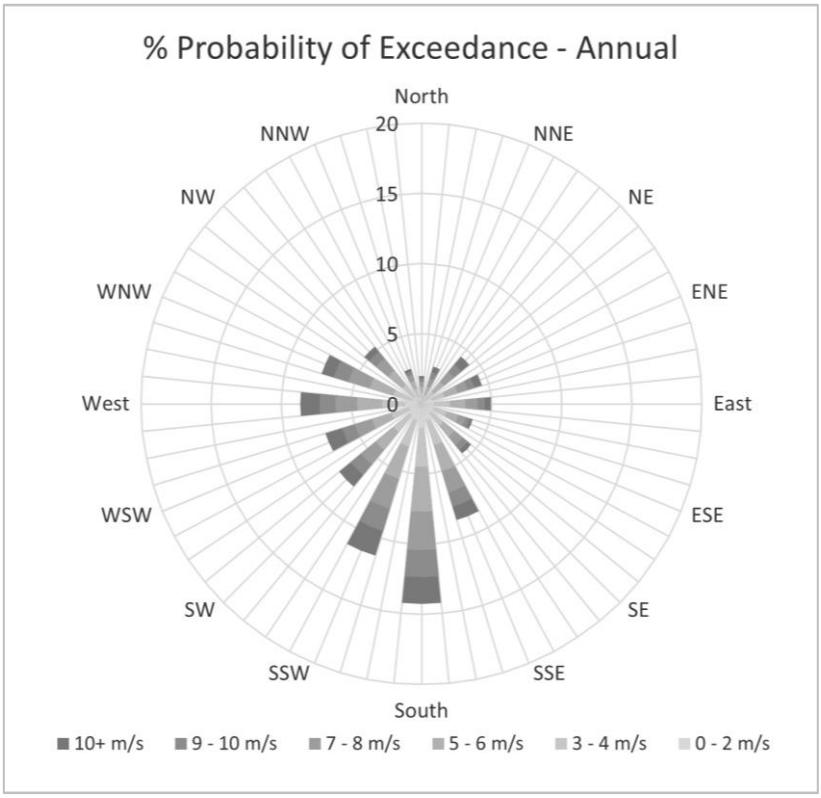


Figure B.3 – Cumulative wind speed probability distribution at site, spring

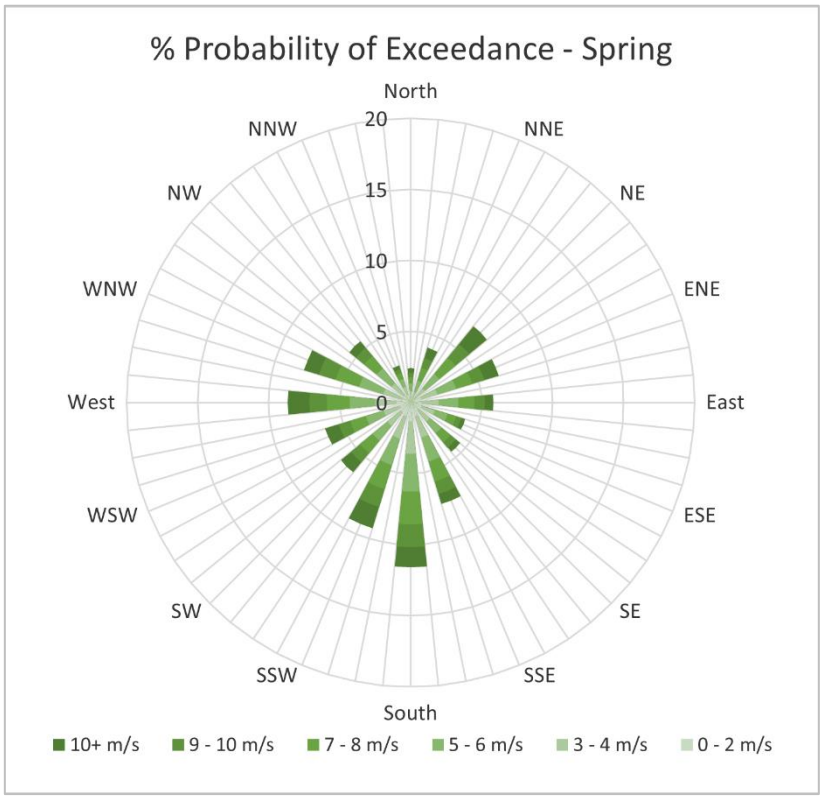


Figure B.4 – Cumulative wind speed probability distribution at site, summer

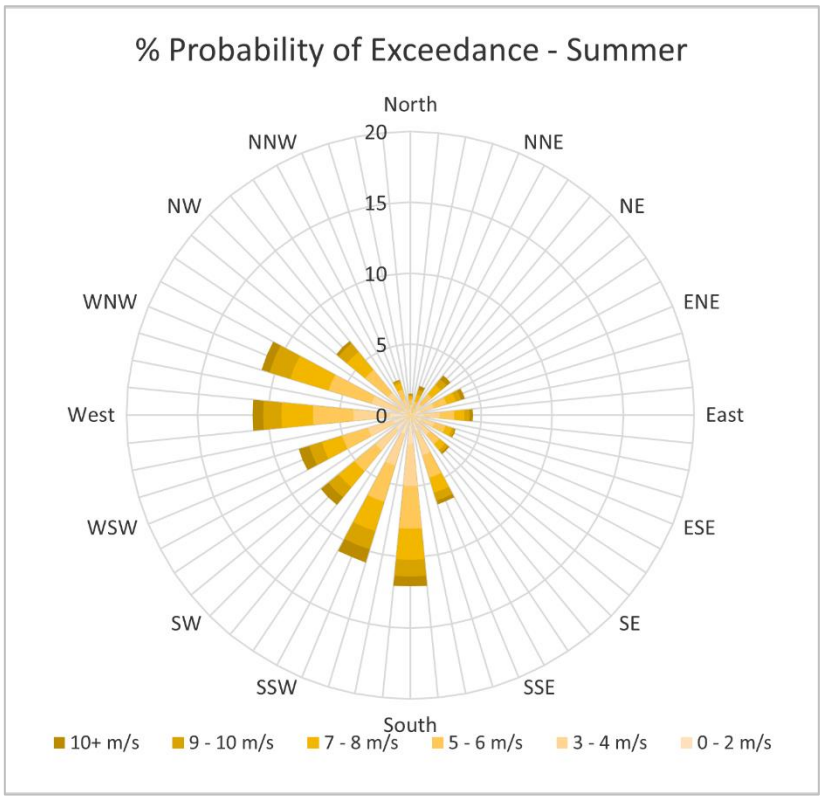


Figure B.5 – Cumulative wind speed probability distribution at site, autumn

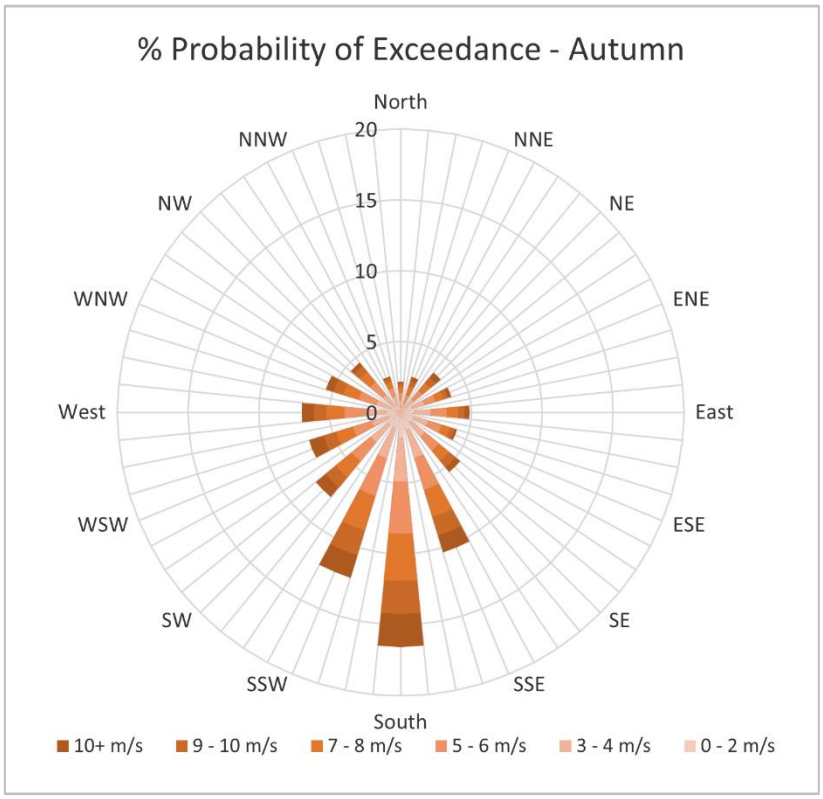
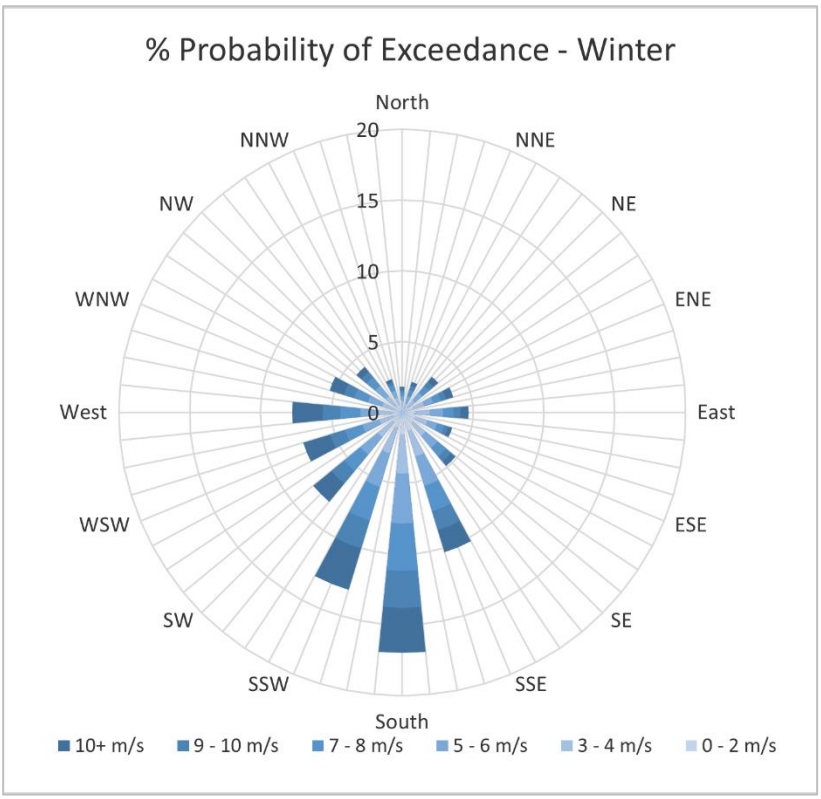


Figure B.6 – Cumulative wind speed probability distribution at site, winter



Appendix C Pedestrian / Occupant Uses

Figure C.1 - Pedestrian uses: Baseline in Existing Surrounds

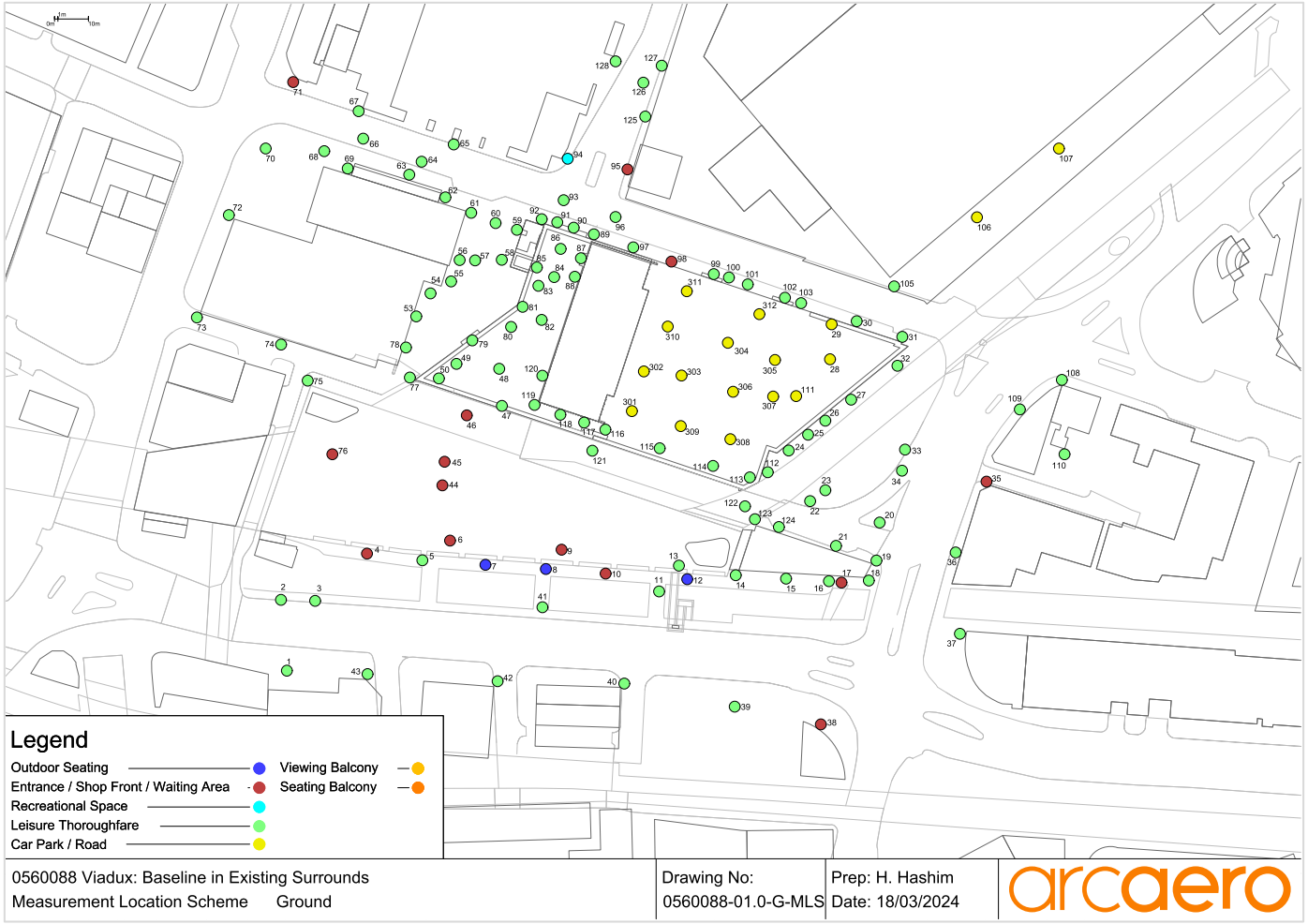


Figure C.2 - Pedestrian uses: Alternative Baseline in Existing Surrounds

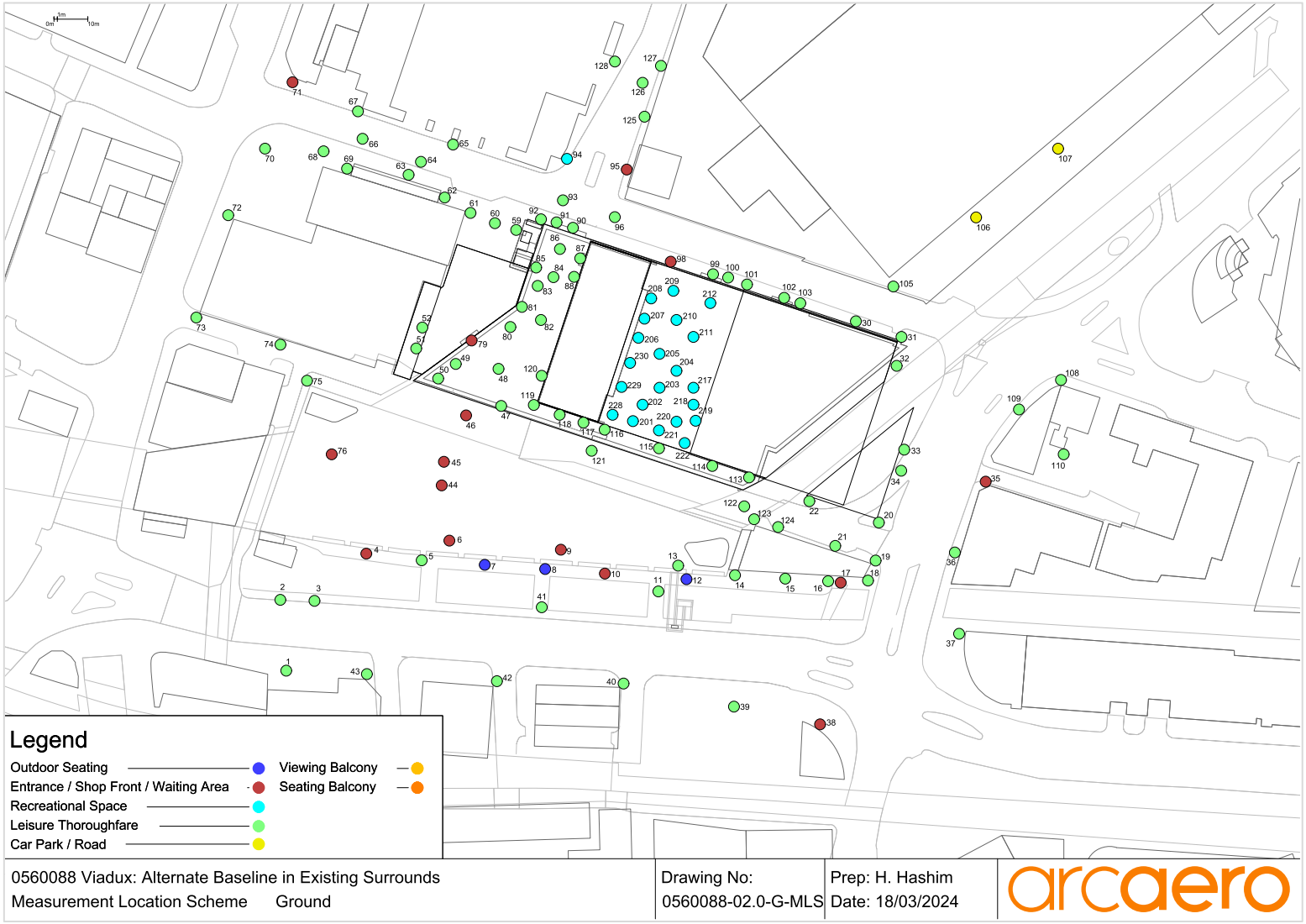


Figure C.3 - Pedestrian uses: Baseline in Cumulative Surrounds

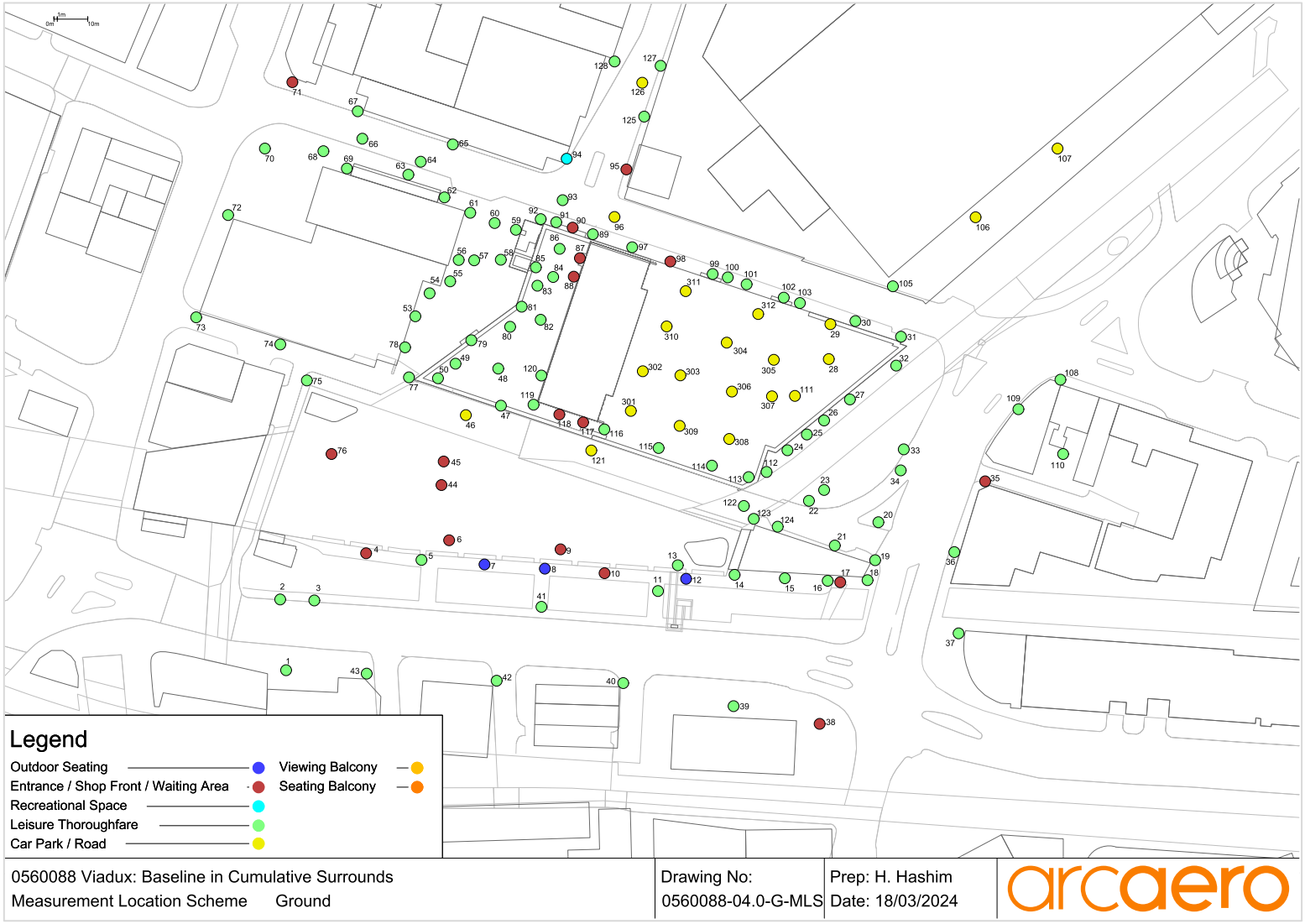
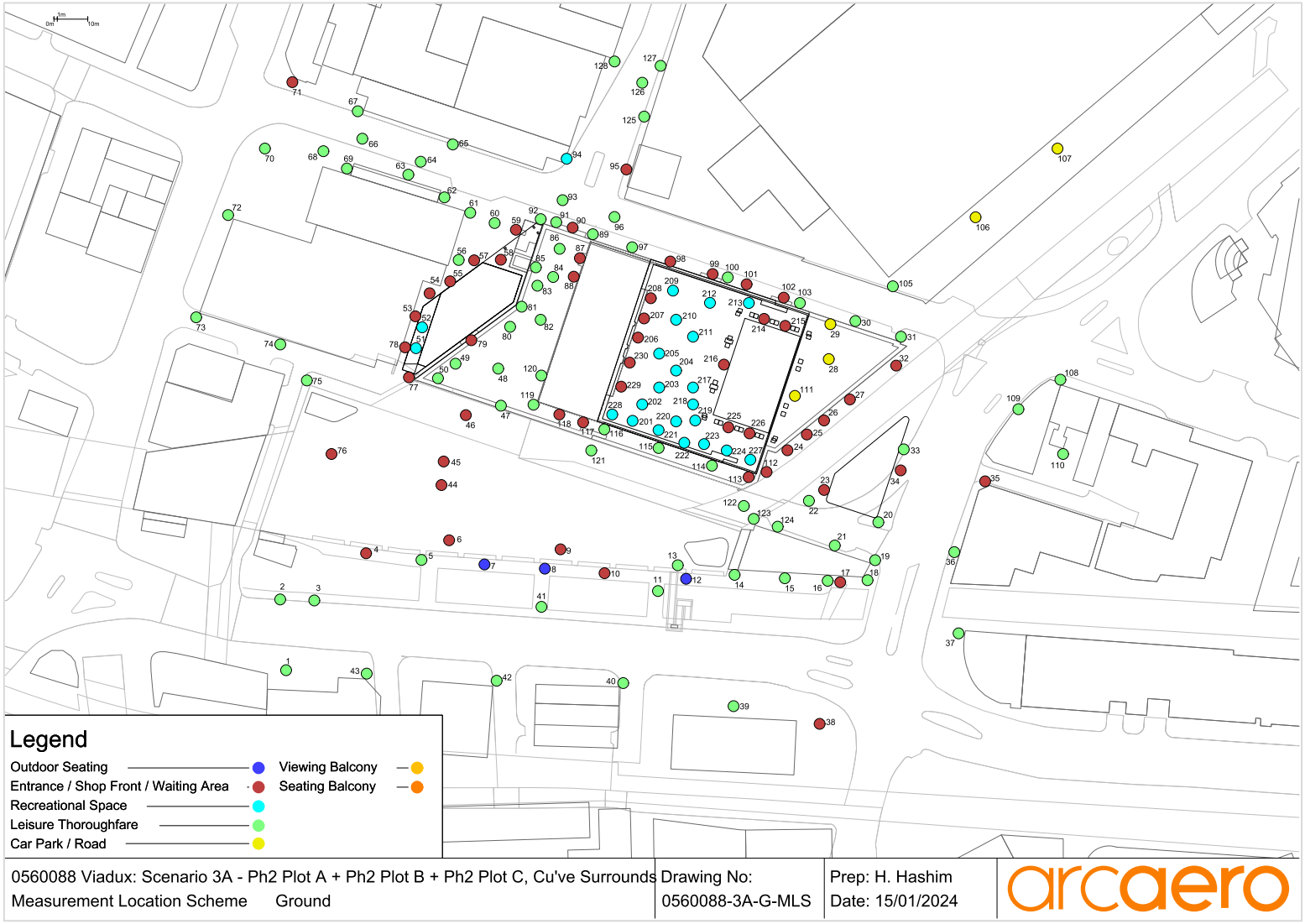


Figure C.4 - Pedestrian uses: Proposed Development



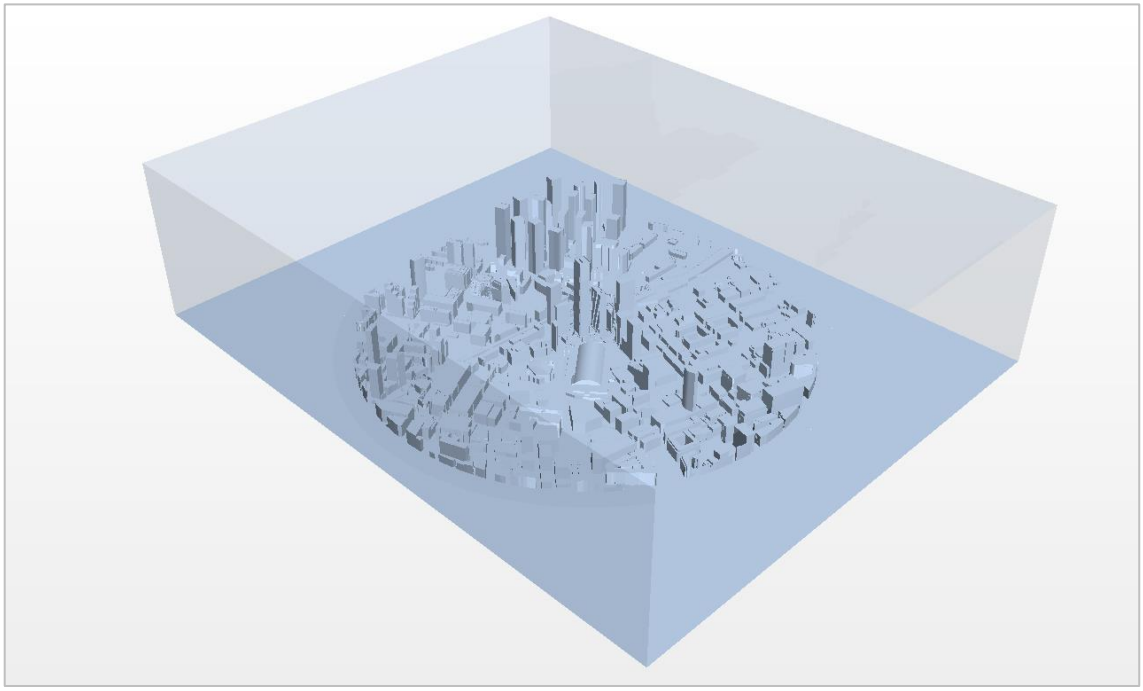
Appendix D CFD Modelling

D.1 Spatial discretization

The computational domain was discretised using polyhedral cells for the core mesh, and low aspect-ratio prism cells adjacent to walls and the ground. Computational meshes were constructed for each of the three different study configurations.

The computational domain includes the proposed development site, with surrounding buildings and topographical features within a 600m radius represented explicitly. The full computational domain extends to 1500m in the along-wind direction, 1100m in the across-wind direction, and 450m vertically.

The proposed development and immediate vicinity were meshed down to a cell size of 0.2m in order to capture the detailed geometric features and resulting flow artefacts. The pedestrian ground level surfaces were meshed with a prism layer mesh of 5 layers, which, in the vicinity of the building rise up to a total height of 1.5m above the ground.



D.2 Solution Method

The modelling of an incompressible fluid flow was completed with combinations of semi-implicit method for pressure-linked equations (SIMPLE) algorithms. The resulting flow turbulent features were modelled with introduction of the Shear Stress Transport (SST) k-ω turbulence model. This model was suggested by Menter (3) and is based on a two-equation eddy-viscosity approach, where the SST model formulation combines the use of a k-ω in the inner parts of the boundary layer, but also switches to a k-ε behaviour in the free-stream regions of the solutions. Further details for the selected turbulence model are provided in the work of Menter (4).

D.3 Initial and Boundary Conditions

The atmospheric boundary layer flow was simulated by implementing a logarithmic velocity profile model presented by Richards and Hoxey (5), with the following main assumptions:

- The vertical velocity component at the domain boundary is negligible
- The pressure gradient and shear stress are constant

The model implies the following equation for the mean inlet velocity at the CFD domain:

$$U(z) = \frac{U^*}{\kappa} \cdot ln\left(\frac{z + z_0}{z_0}\right)$$

where:

- κ - is the von Karman's constant
- z - is the distance from the ground surface in vertical direction
- z_o - is the ground surface roughness length in meters

The friction velocity U* is calculated by the following equations:

$$U^* = \kappa \cdot \frac{U_{ref}}{ln\left(\frac{z_{ref} + z_0}{z_0}\right)}$$

where:

- z_{ref} – is the reference height in metres
- U_{ref} - is the reference velocity in m/s measured at z_{ref}

The turbulent velocity fluctuations at the domain inlet are induced by the constant shear stress with height, maintained by the turbulent kinetic energy k equation below:

$$k(z) = \frac{(U^*)^2}{\sqrt{C_\mu}}$$

where:

- Cμ = 0.03 - is a k-ε turbulence model constant

All surface boundary conditions were modelled as smooth walls with a no-slip condition. A no-slip wall boundary condition with a varying roughness length height based on the terrain analysis for the site was applied on the ground surface outside the explicit surrounds area of the domain.

D.4 Gust Equivalent Mean Calculation

The gusts in the wind flow is a major component that may lead to additional danger and discomfort to that caused by the mean wind flow. Thus, the gust wind speed is accounted by a calculation of the equivalent mean wind speed, considering the standard deviation of the mean wind speed, in particular the turbulent kinetic energy, k:

$$\sigma = \sqrt{(k * 2/3)}$$

The GEM is them calculated as:

$$U_{GEM} = \frac{U_{Mean} + 3.5\sigma}{k_g}$$

Where gust factor, k_g= 1.85

The final speedup used in the Lawson criteria is the worst case from U_{GEM} and U_{Mean}.