metec
CONSULTING ENGINEERS

WIND MICROCLIMATE ASSESSMENT

for the

KNOCKACARRA DISTRICT CENTRE

at

RAHOON,
CO. GALWAY

for

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CONTENTS

EXECUTIVE SUMMARY

METEC Consulting Engineers have been instructed by our client, Glenveagh Living Limited, to carry out a pedestrian level wind microclimate assessment for the proposed development at Knocknacarra District Centre, Rahoon, Co. Galway

The pedestrian level wind microclimate assessment conclusions are sumarised as:

- Pedestrian comfort was achieved in all areas of the site of the site designated for thoroughfare and recreation in both the summer and the worst-case winter seasons;
- The majority of the site had no issues with pedestrian distress/safety:
    - No areas of the site were rated as 'Unsuitable for Able-bodied';
    - Two small areas of the site, south of Block E, and between Blocks E and F, were rated as 'Unsuitable for General Public' which includes vulnerable pedestrians such as the elderly and the young. The landscape masterplan proposes planting in this area which will help to mitigate the higher wind speeds. Evergreen planting at various heights is recommended including mature trees, hedges and bushes.
- All recreational and outdoor sitting areas around Block A, Block B, Block C, and Block D, together with podium level between Block E and Block F are expected to be comfortable and safe for their proposed use.

With the introduction of the proposed landscape masterplan, it is expected that all pedestrian spaces will have improved comfort levels and will be safe for their purpose of use.

The balcony wind microclimate assessment conclusions are sumarised as:

- The majority of the balconies were rated as suitable for 'Long-term sitting' in both summer and winter seasons.
- In summer, all balconies were rated as suitable for 'Long-term sitting' or 'Standing' except the top two balconies on the southeast corner of Block E which were rated as suitable for 'Strolling'.
- In winter, all balconies were rated between suitable for 'Long-term sitting' to 'Strolling' except the top two balconies on the southeast corner of Block E which were rated as suitable for 'Walking'.
- Some of the high-level balconies exceed the pedestrian distress criteria on the southwest corner and east side of Block B, and the southeast and northwest corner of Block E. Mitigation is recommended for these balconies. For example, high-level screens on one side of these balconies, and railings

with low porosity (i.e. a free area of less than <=50%), would reduce wind speeds significantly.

- With introduction of the proposed porous balustrades, significant improvements of the wind microclimate conditions within the private balconies are expected.

1.0 INTRODUCTION

METEC Consulting Engineers have been instructed by our client, Glenveagh Living Limited, to carry out a pedestrian level wind microclimate assessment for the proposed development at Knocknacarra District Centre, Rahoon, Co. Galway. The methodology used in the study is presented in Section 2 Study Methodology with further details in Appendix C CFD Modelling Methodology. Section 3 Results of the Assessment gives results of Pedestrian Comfort and Pedestrian Distress. Pedestrian level wind speed plots are given in Appendix B Additional Wind Data.

A summary of the assessment and findings are presented in Section 4 Summary.

2.0 STUDY METHODOLOGY

2.1 LAWSON PEDESTRIAN COMFORT AND DISTRESS CRITERIA

This study uses the Lawson Pedestrian Comfort and Pedestrian Distress [1] criteria to assess the wind microclimate at pedestrian level for the proposed development at Knocknacarra District Centre, Rahoon, Co. Galway.

The pedestrian comfort criteria given in Table 2.1.1 quantify a person's comfort or discomfort due to the wind based on their activity. The criteria give an hourly average wind speed threshold that must not be exceeded for more than 5% of the assessment period. In this study, assessments covering the summer, winter, autumn and spring periods, plus a whole year were undertaken. The report provides results of the summer assessment and the winter (worst-case seasonal) assessment.

Comfort Rating	Threshold Speed	Exceedance Time
Uncomfortable	10 m/s	> 5 %
Business walking	10 m/s	<= 5%
Strolling	8 m/s	<= 5%
Standing	6 m/s	<= 5%
Long-term sitting	4 m/s	<= 5%

Table 2.1.1: Lawson Pedestrian Comfort Criteria

Table 2.1.2 gives the recommended target pedestrian comfort designation for a variety of public area usage patterns.

Usage	Description	Target
Outdoor seating	For long periods of sitting such as for an outdoor café / bar	'Long-term sitting' in summer
Entrances, waiting areas, shop fronts	For pedestrian ingress / egress at a building entrance / window shopping, or short periods of sitting or standing such as at a bus stop, taxi rank, meeting point, etc.	'Standing' in all seasons
Recreational spaces	For outdoor leisure uses such as a park, children's play area, etc.	'Strolling' from spring through autumn
Leisure Thoroughfare	For access to and passage through the development and surrounding area	'Strolling' in all seasons
Pedestrian Transit (A-B)	For access to and passage through the development and surrounding area	'Business walking' in all seasons

Table 2.1.2: Recommended Target Comfort Rating for Different Public Space Usage

The pedestrian distress criteria given in Table 2.1.3 quantify a person's distress and/or safety due to the wind. Application of the pedestrian distress analysis seeks to identify areas where a pedestrian may find walking difficult, or could even stumble or fall. The criteria give a wind speed threshold that must not be exceeded for more than once during the assessment period which is taken as 2 hours (or more), based on an exceedance probability of 0.025% [1]

Distress Rating	Threshold Speed
Unsuitable for General Public (this covers vulnerable pedestrians, e.g. the elderly and children, also included are cyclists)	15 m/s
Unsuitable for Able-Bodied	20 m/s

Table 2.1.3: Lawson Pedestrian Distress Criteria

2.2 ACCOUNTING FOR THE EFFECT OF GUSTS

Pedestrian comfort and pedestrian distress are not only affected by the mean wind velocity but also by shorter timescale wind gusts due to the turbulent nature of wind. Therefore, in this study wind gust speed is accounted for by calculating the equivalent mean wind speed, considering the standard deviation of the mean wind speed, in particular the turbulent kinetic energy, k:

$$\sigma_U = \sqrt{k * {}^2/_3}$$

Based on the work of Melbourne [4], the peak gust wind speed is derived as:

$$\ddot{U} = U_{MEAN} + 3.5\sigma_U$$

And the Gust Equivalent Mean (GEM) is derived as:

$$U_{GEM} = \ddot{U}/1.85$$

The pedestrian wind speed is defined as:

$$\max(U_{MEAN}, U_{GEM})$$

2.3 MODEL GEOMETRY

Figure 2.3.1 shows the CFD model geometry used in the study. The geometry of the surroundings and terrain were built from aerial photographs taken in 2018 using photogrammetry techniques to digitise points that define the geometry over which a surface mesh was generated. Further details of the CFD geometry, mesh and solution method are given in Appendix C: CFD Modelling Methodology.

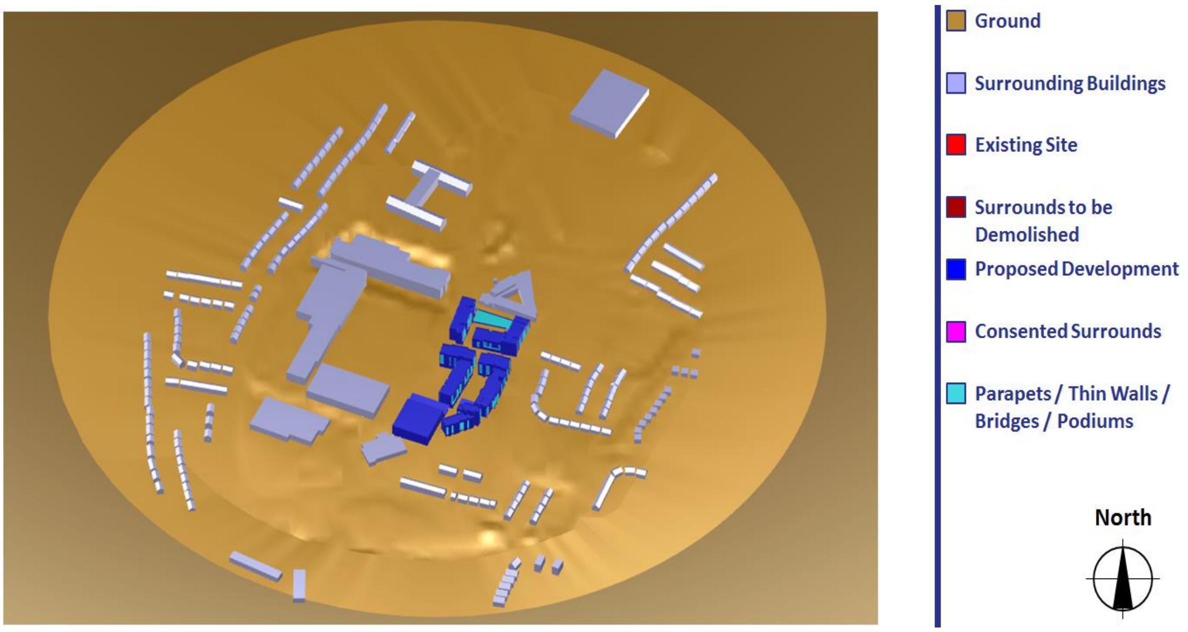

Figure 2.3.1: CFD Model Geometry

2.4 SITE AND SURROUNDINGS

An aerial view of the proposed Strategic Housing Development at Knocknacarra District Centre, Rahoon, Co. Galway and surrounding terrain can be seen in Figure 2.4.1.

The site, located in Rahoon, Galway, is surrounded by low-rise residential housing and retail store buildings.

Figure 2.4.1: Site Location

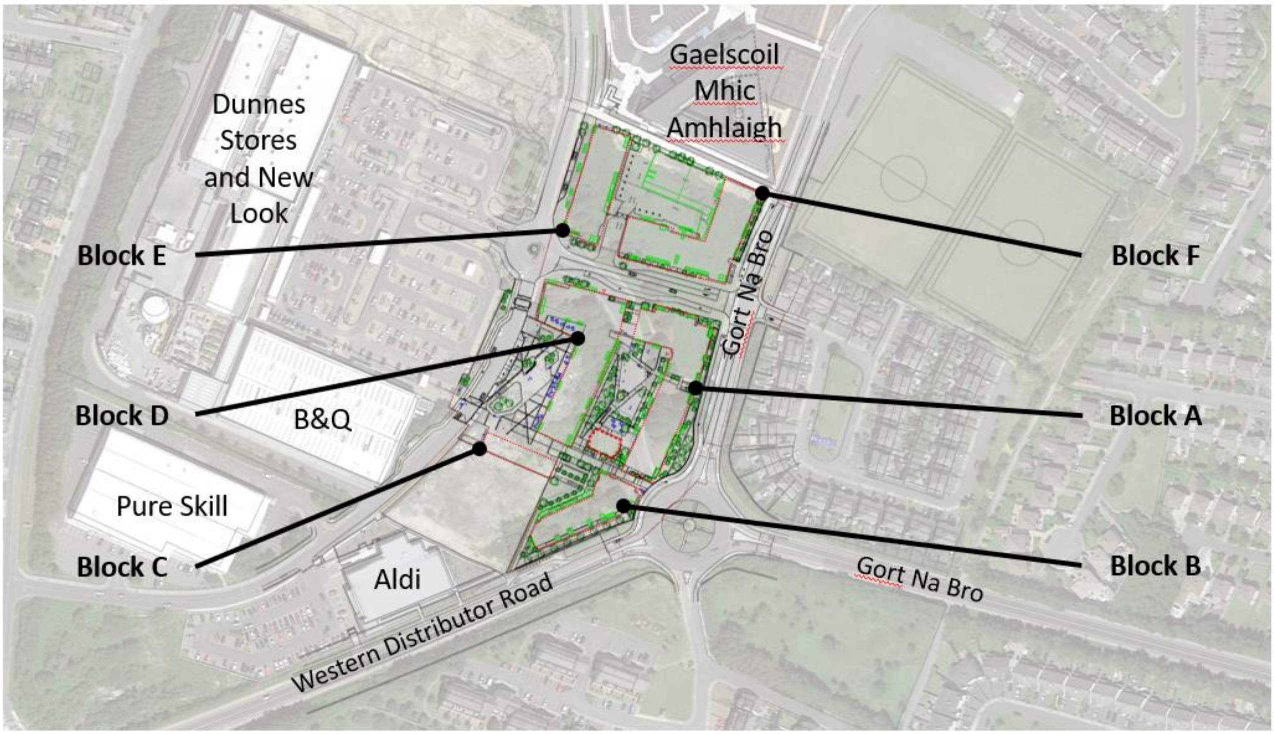

Figure 2.4.2: Site Layout Plan

Figure 2.4.2 shows the site layout plan for the proposed Strategic Housing Development at Knocknacarra District Centre, Rahoon, Co. Galway.

2.5 SITE WIND MICROCLIMATE ASSESSMENT

Figure 2.5.1 and Figure 2.5.2 show wind roses for the proposed development at Knocknacarra District Centre site at the reference height of 20m for the summer and winter periods. Additionally, annual, spring and autumn period wind roses are shown in Appendix B Additional Wind Data.

The wind roses were calculated using wind data from Shannon Airport[1] between January 1999 and December 2018 adjusted for the site location based on terrain analysis using the EDSU methodology [6].

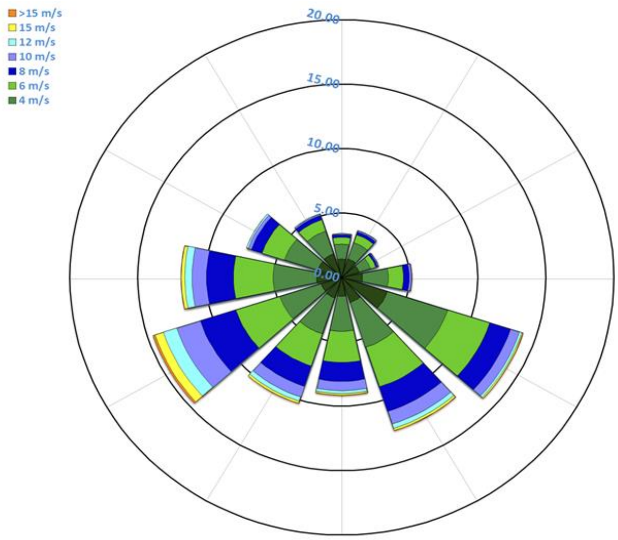

Figure 2.5.1: Winter Period Wind Rose at Reference Height for the site

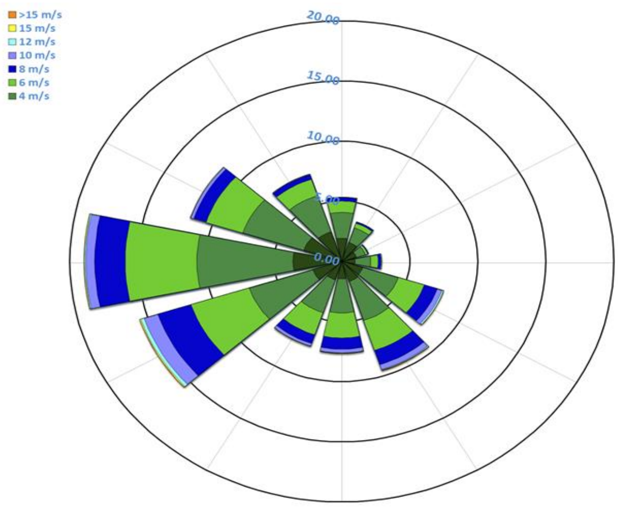

Figure 2.5.2: Summer Period Wind Rose at Reference Height for the site

[1] The weather data available from the station at Shannon airport was more detailed (in length and frequency) than that available from the weather station at Galway Airport.

3.0 RESULTS OF THE ASSESSMENT

The main body of the report contains results for Pedestrian Comfort and Pedestrian Distress. Additionally, plots of velocity ratio for each of the 12 wind directions modelled are provided in Appendix A Velocity Ratio.

3.1 PEDESTRIAN COMFORT

Figure 3.1.1 shows a plot of Pedestrian Comfort rating at 1.5m above ground level for the worst seasonal conditions, which at this site occurs during winter. Figure 3.1.2 shows a plot of Pedestrian Comfort for the summer period.

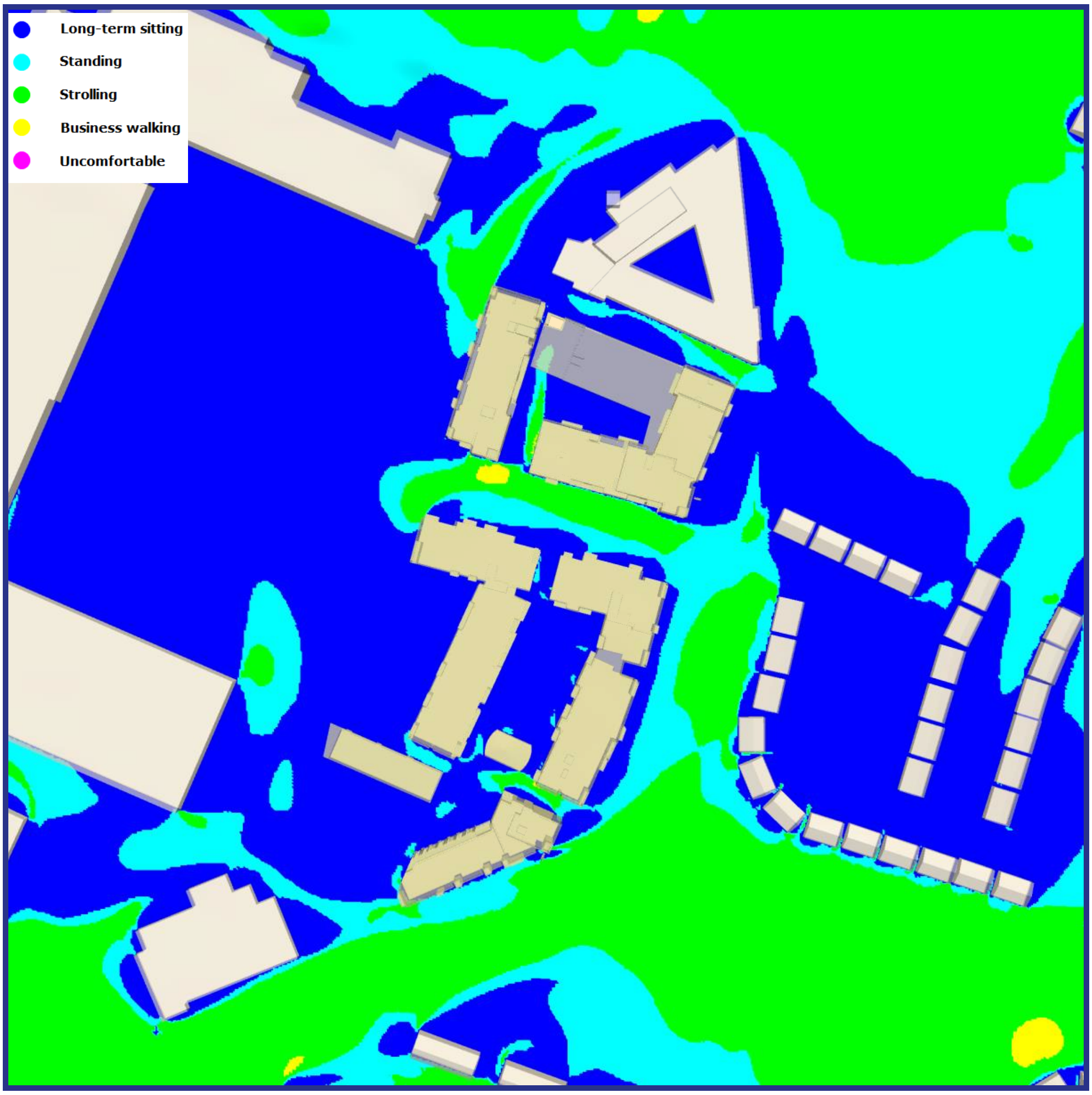

Figure 3.1.1: Pedestrian Comfort Rating for Worst Seasonal Conditions (Winter)

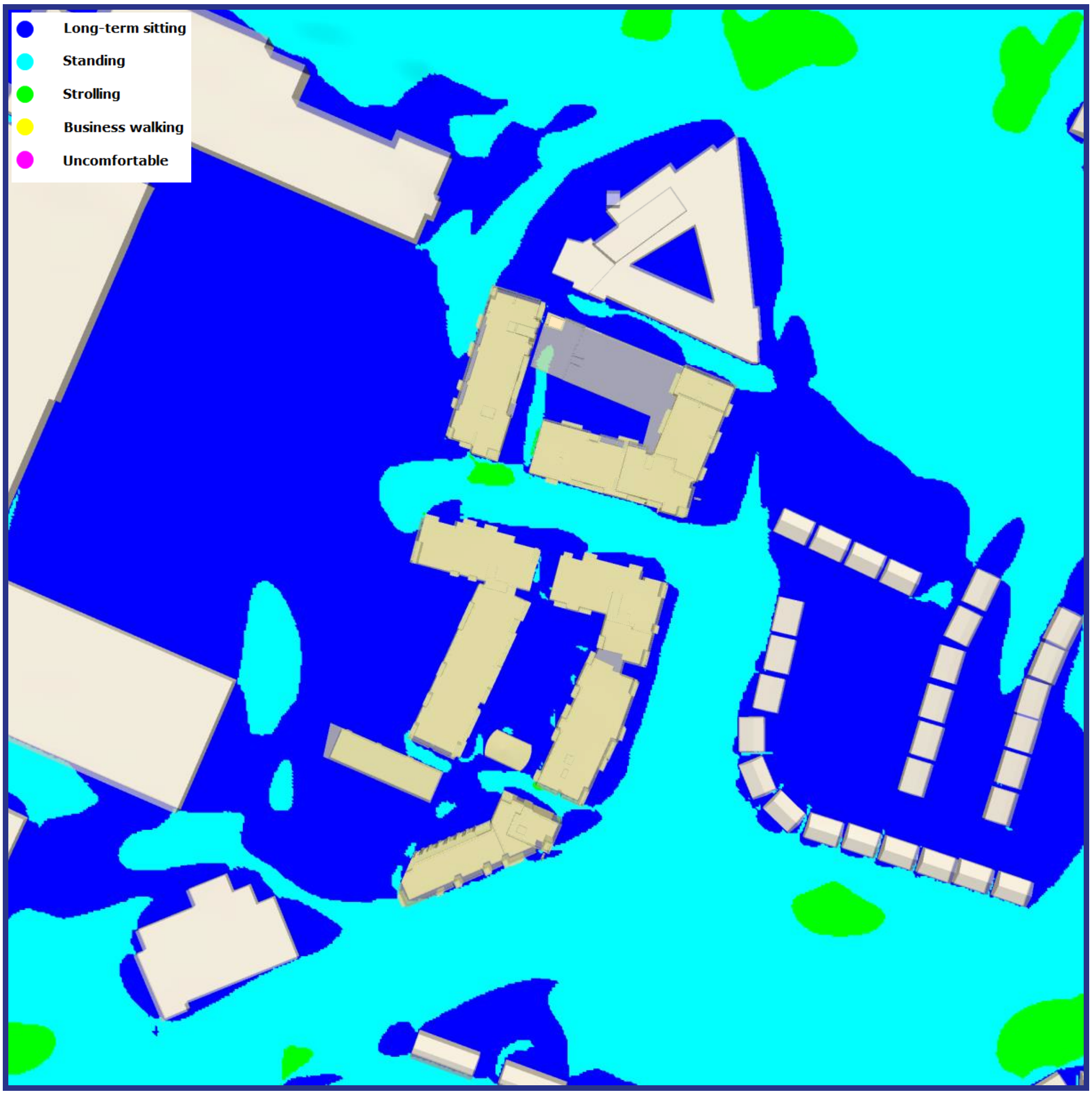

Figure 3.1.2: Pedestrian Comfort Rating for Summer Period

3.2 PEDESTRIAN DISTRESS

Figure 3.2.1 shows a plot of Pedestrian Distress Rating at 1.5m above ground level, where the Lawson Pedestrian Distress Criteria are exceeded for 2 hours (or more) per year, based on an exceedance probability for the annual assessment period of 0.025% [1].

Figure 3.2.1: Pedestrian Distress Rating

Note: The General Public Distress Rating covers vulnerable pedestrians, e.g. the elderly and children, also included are cyclists.

3.3 BALCONY ASSESSMENT

Figure 3.3.1 and Figure 3.3.2 show a plot of Pedestrian Comfort rating for each balcony for the worst seasonal (winter) conditions. Figure 3.3.3 and Figure 3.3.4 show a plot of Pedestrian Comfort for the summer period.

Figure 3.3.5 and Figure 3.3.6 shows Pedestrian Distress plotted for the balconies.

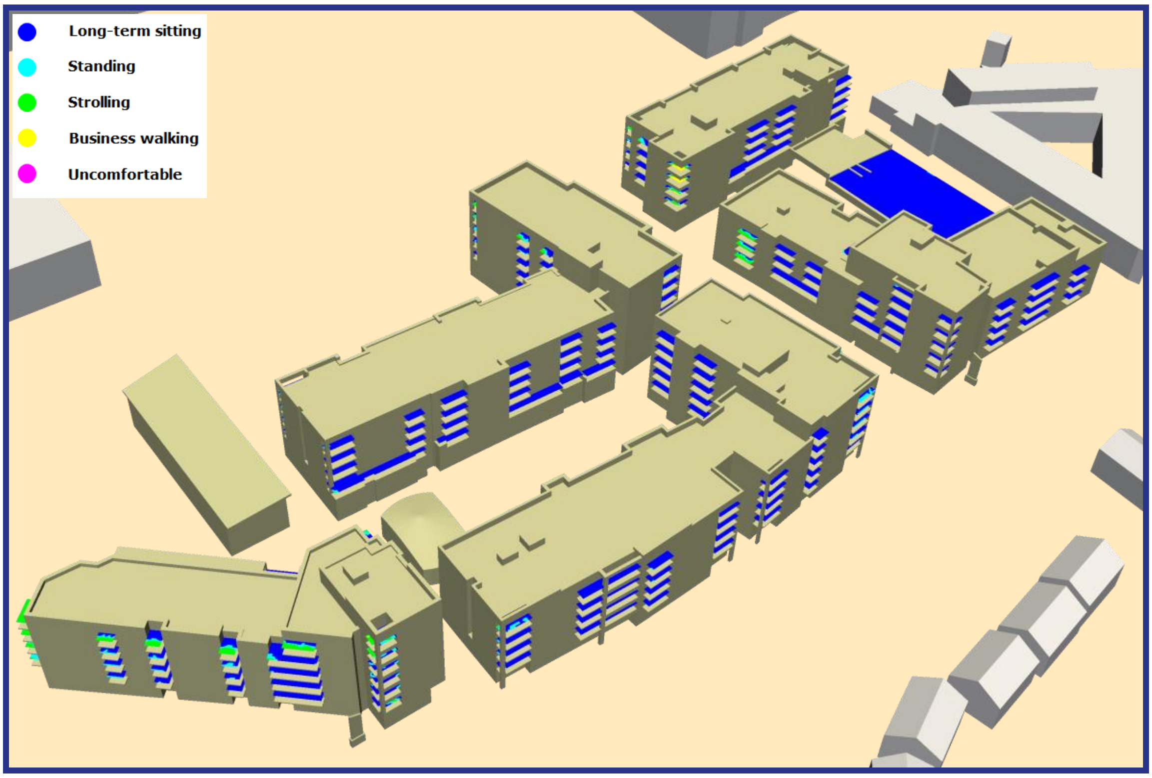

Figure 3.3.1: Winter Pedestrian Comfort rating of the balconies, view from south

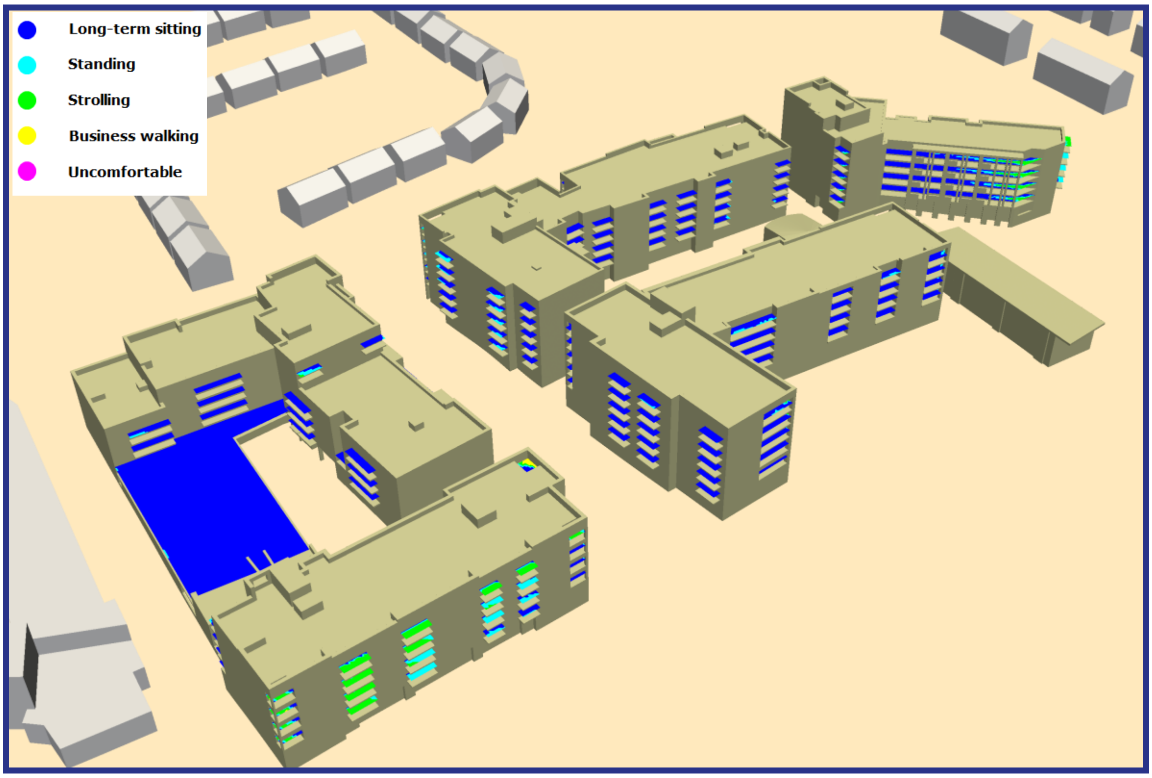

Figure 3.3.2: Winter Pedestrian Comfort rating of the balconies, view from north

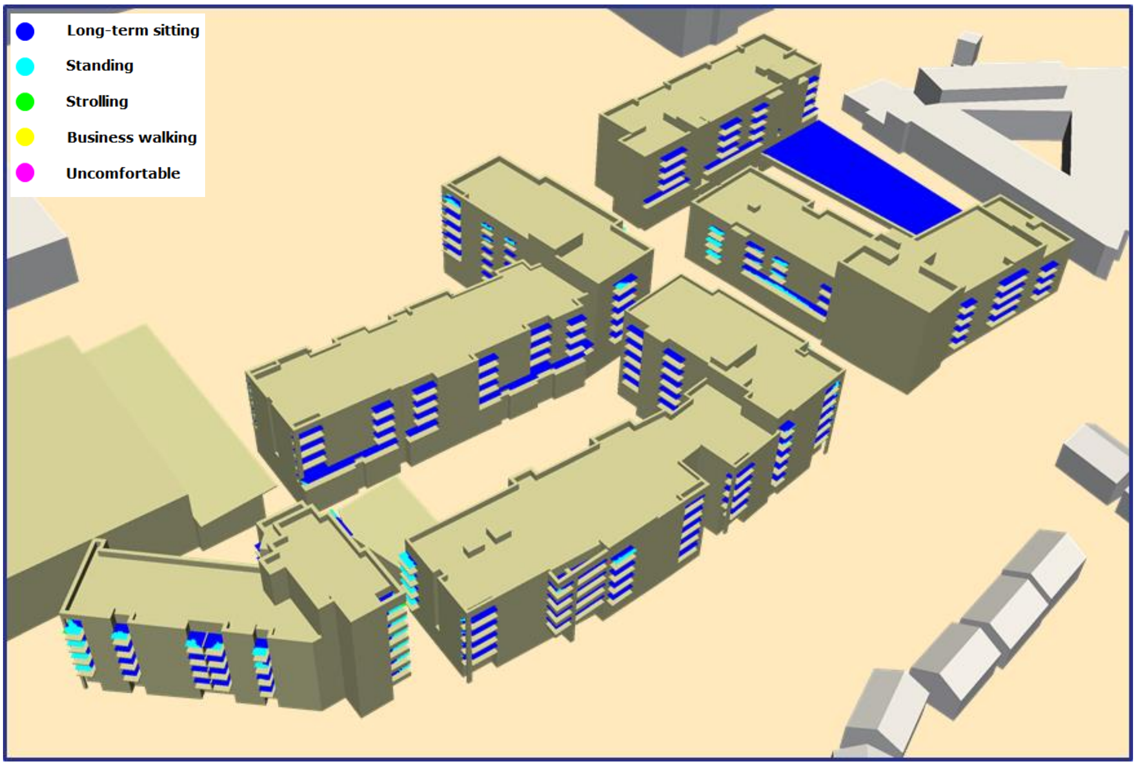

Figure 3.3.3: Summer Pedestrian Comfort rating of the balconies, view from south

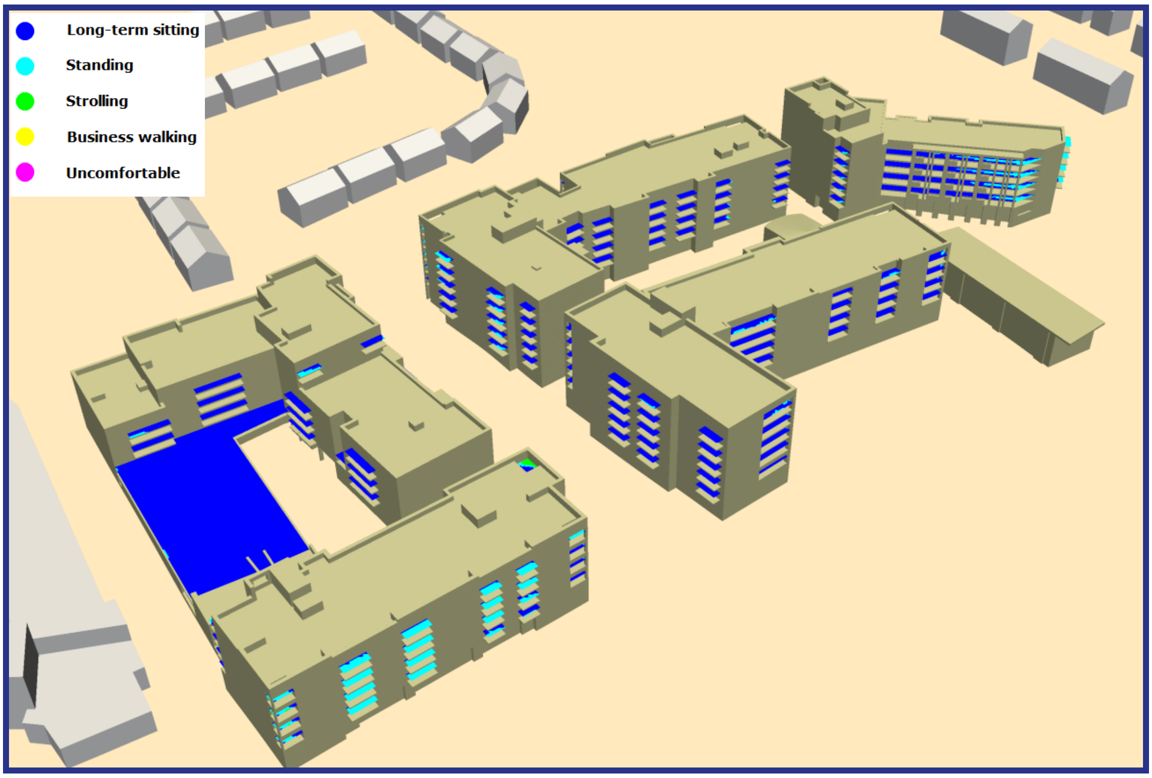

Figure 3.3.4: Summer Pedestrian Comfort rating of the balconies, view from north

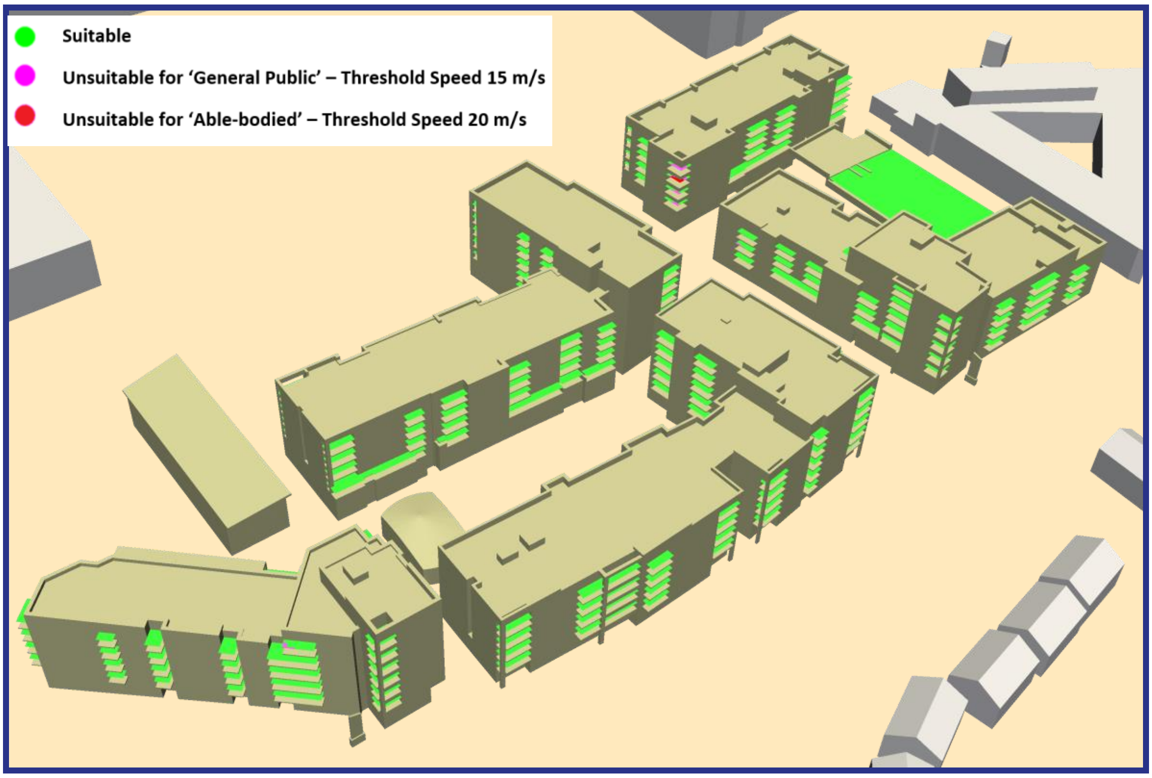

Figure 3.3.5: Pedestrian Distress rating of the balconies, view from south

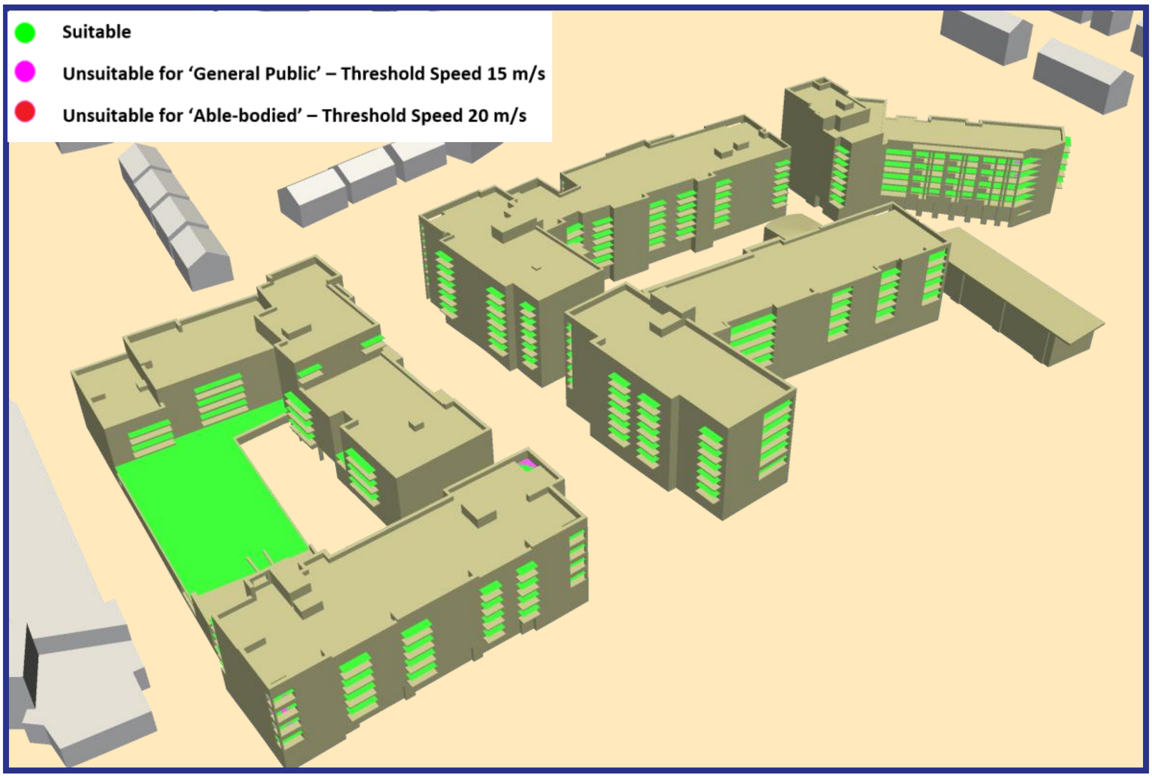

Figure 3.3.6: Pedestrian Distress rating of the balconies, view from north

4.0 SUMMARY

4.1 PEDESTRIAN COMFORT

The wind microclimate assessment for the proposed development identified the following regarding pedestrian comfort.

- Pedestrian comfort was achieved in all areas of the site designated for thoroughfare and recreation in both the summer and the worst-case winter season;
- There were no areas of the site that were rated as 'Uncomfortable';
- In summer, the majority of the site was rated as suitable for 'Long-term sitting' or for 'Standing';
- In winter, the majority of the site was rated between 'Long-term sitting' and 'Strolling';
- Two small areas of the site, south of Block E and between Blocks E and F were subject to higher wind speeds. Here, wind speeds were rated as suitable for 'Strolling' in summer and as suitable for 'Business walking' in winter;
- All recreational and outdoor sitting areas around Block A, Block B, Block C, and Block D, together with podium level between Block E and Block F are expected to be comfortable and safe for their proposed use.

With the introduction of the proposed landscape masterplan, it is expected that all pedestrian spaces outlined above will have a further improvement to pedestrian comfort levels, and to be suitable for their purpose of use.

4.2 PEDESTRIAN DISTRESS

With regards to pedestrian distress, the assessments key findings were as follows.

- No areas of the site exceed the Lawson distress threshold for able-bodied pedestrians;
- Two small areas of the site, south of Block E, and between Blocks E and F, had wind speeds that exceeded 15m/s and was therefore rated as 'Unsuitable for General Public' (a rating that includes vulnerable pedestrian such as the elderly and young). The landscape masterplan proposes planting in the area south of Block E which will help to mitigate the higher wind speeds in this area. Evergreen planting at various heights is recommended, including mature trees, hedges and bushes.

However, with the introduction of the proposed landscape masterplan, it is expected all pedestrian spaces outlined above to be safe for their purpose of use.

4.4 BALCONIES

Though they are intended for analysis of public spaces rather than balconies, here we apply pedestrian comfort and distress criteria to quantify the wind conditions experienced on the balconies of the proposed development. The balconies were modelled as open, i.e. without railings. Therefore, the results presented will tend to overestimate the wind speeds on the balconies.

Balcony Comfort

The wind microclimate assessment for the proposed development identified the following regarding comfort on balconies.

- In summer, the balconies were rated as suitable for 'Long-term sitting' or 'Standing'. The pedestrian comfort category of 'Standing' means a public space is suitable for short-term sitting.
- In winter, the balconies were rated between 'Long-term sitting' and 'Strolling'. The 'Strolling' rating also allows for short-term sitting and standing, but on a less frequent basis.
- The majority of the balconies were rated as suitable for 'Long-term sitting' in both summer and winter seasons. These balconies would have significant periods during the year where they would be inviting spaces. Less favourably rated balconies would still be suitable for short-term sitting and standing, and of course on calmer days, would still be suitable for long-term sitting.

Balcony Distress

The wind microclimate assessment for the proposed development identified the following regarding distress/safety on balconies.

- The majority of the balconies had no distress/safety issues.
- Some of the high-level balconies exceed the pedestrian distress criteria on the southwest corner and east side of Block B, and the southeast and northwest corner of Block E. These balconies should have mitigation applied, e.g.:
  - A railing with a low porosity (free area of less than 50%);
  - High level screens on one side.
- With introduction of the proposed porous balustrades, significant improvements of the wind microclimate conditions within the private balconies are expected.

APPENDIX A – VELOCITY RATIO

Figure A1 to Figure A12 show contour plots of velocity magnitude ratio in and around the proposed redevelopment site for each of the 12 wind directions modelled. The velocity magnitude is calculated by dividing the local air speed by the reference air speed: the wind speed at 20m above ground level at the start of the explicitly modelled inner area of the domain as calculated by terrain and wind profile analysis using the EDSU methodology [6].

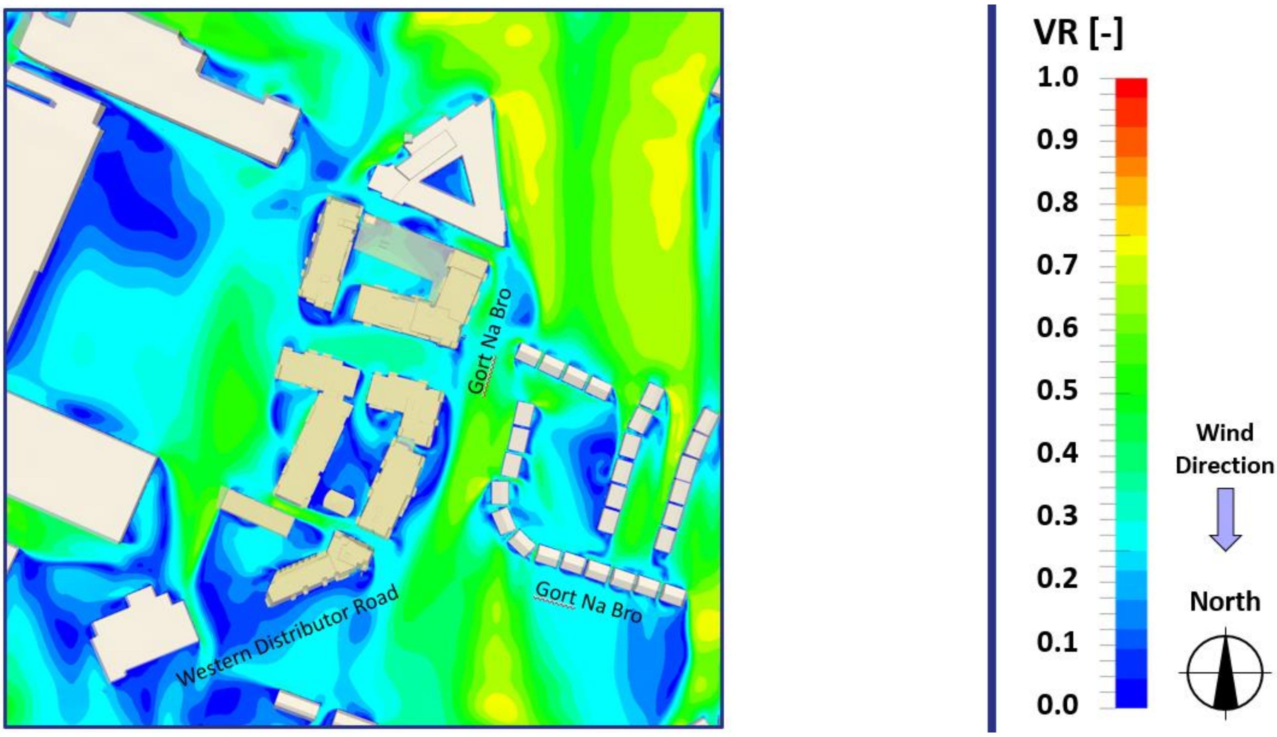

Figure A1: Velocity Ratio, Wind Direction of 0 Degrees (Northerly)

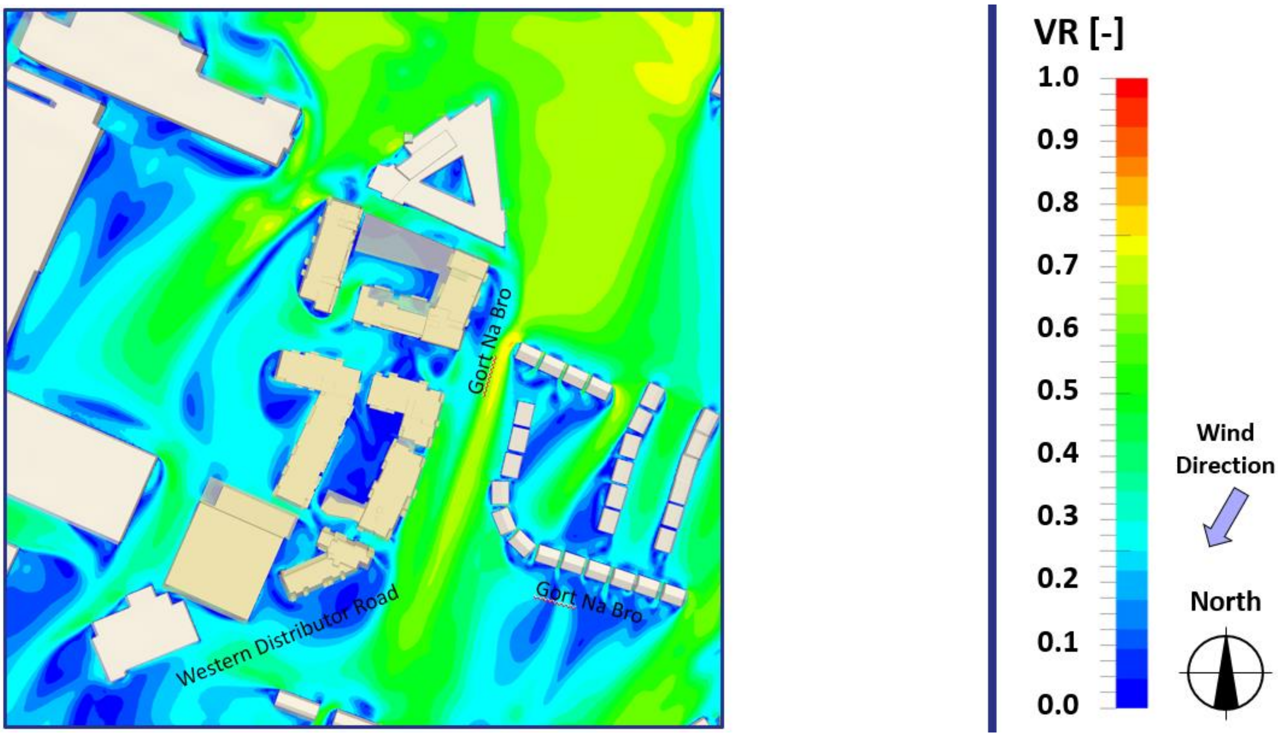

Figure A2: Velocity Ratio, Wind Direction of 30 Degrees

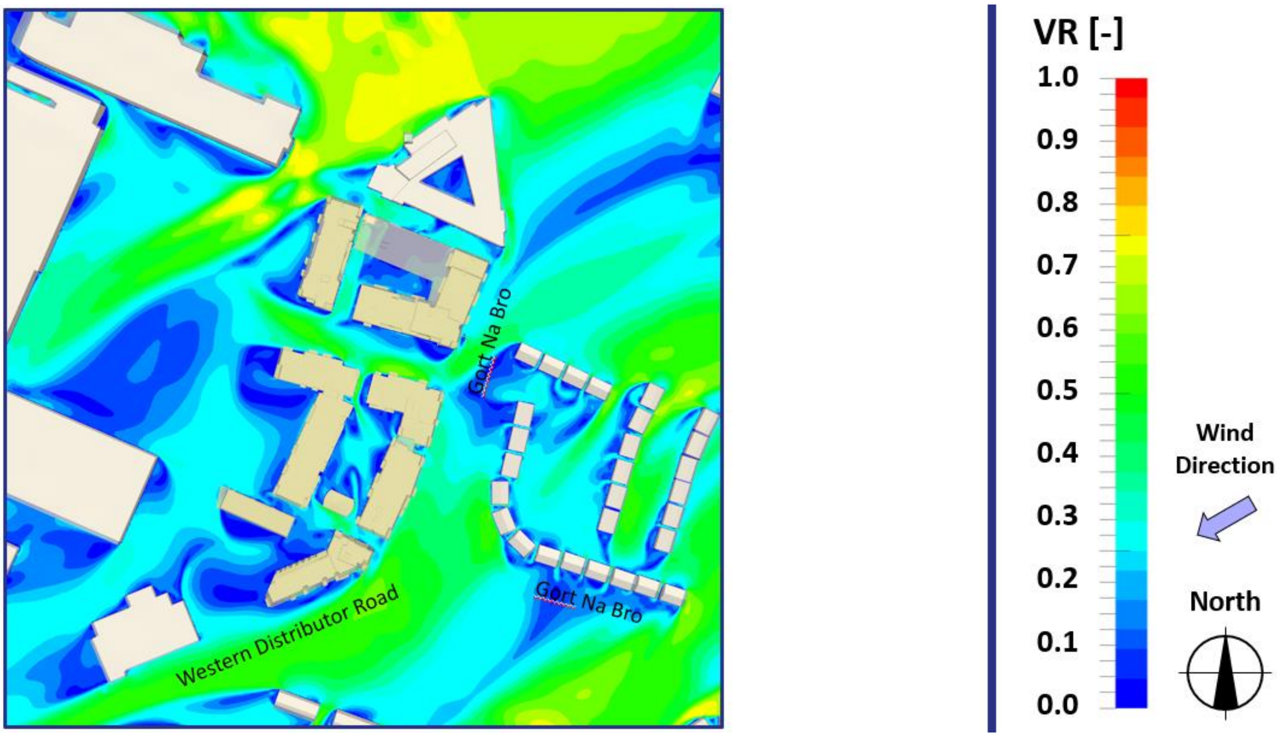

Figure A3: Velocity Ratio, Wind Direction of 60 Degrees

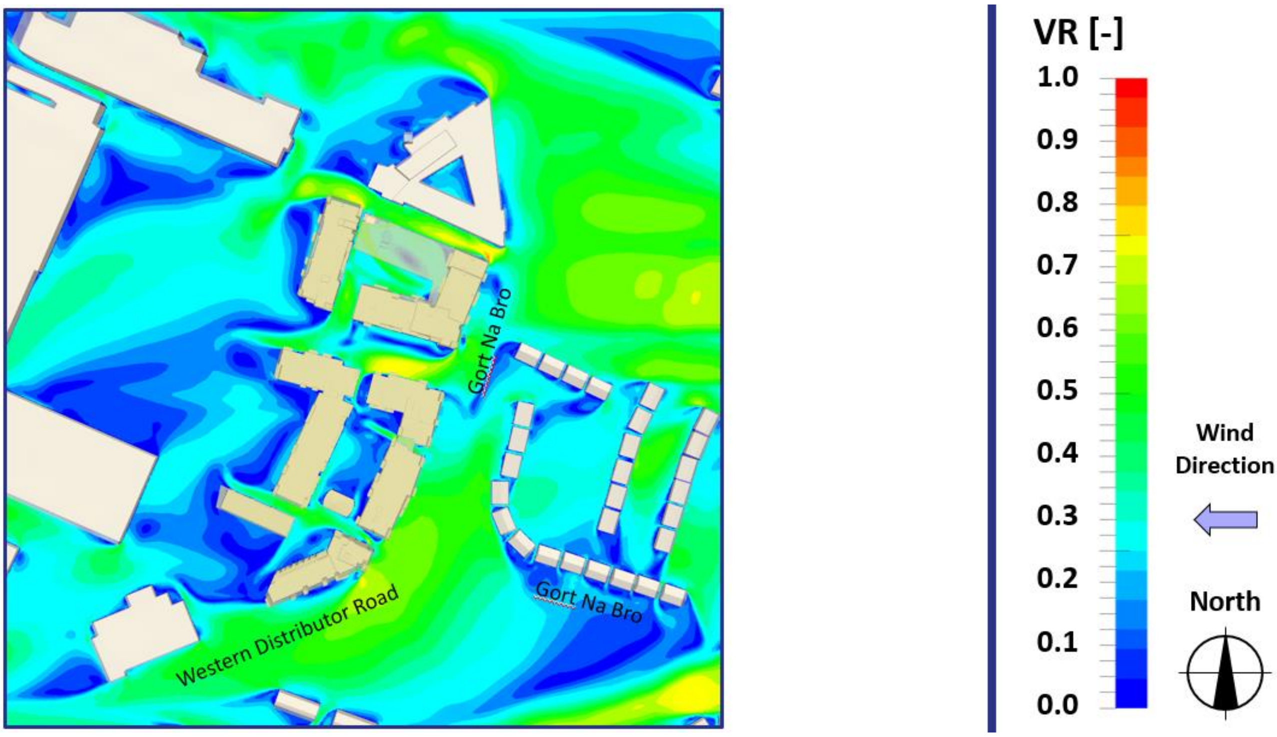

Figure A4: Velocity Ratio, Wind Direction of 90 Degrees (Easterly)

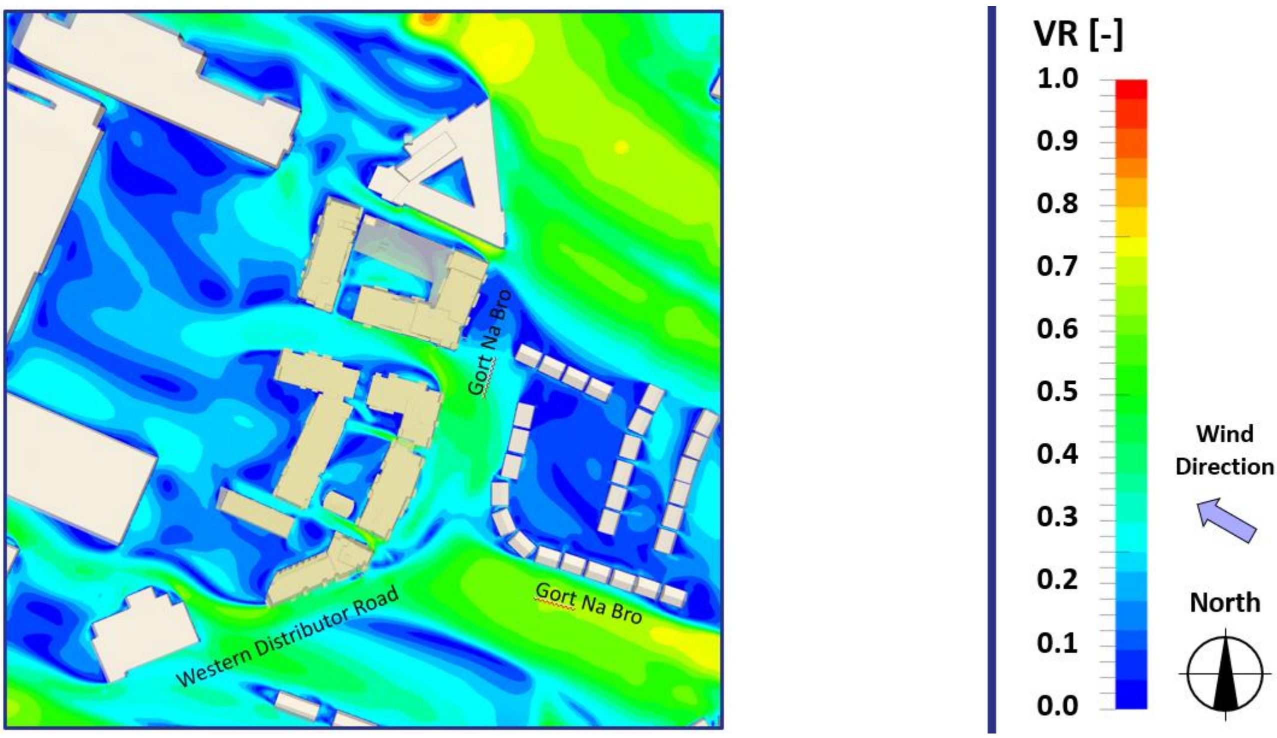

Figure A5: Velocity Ratio, Wind Direction of 120 Degrees

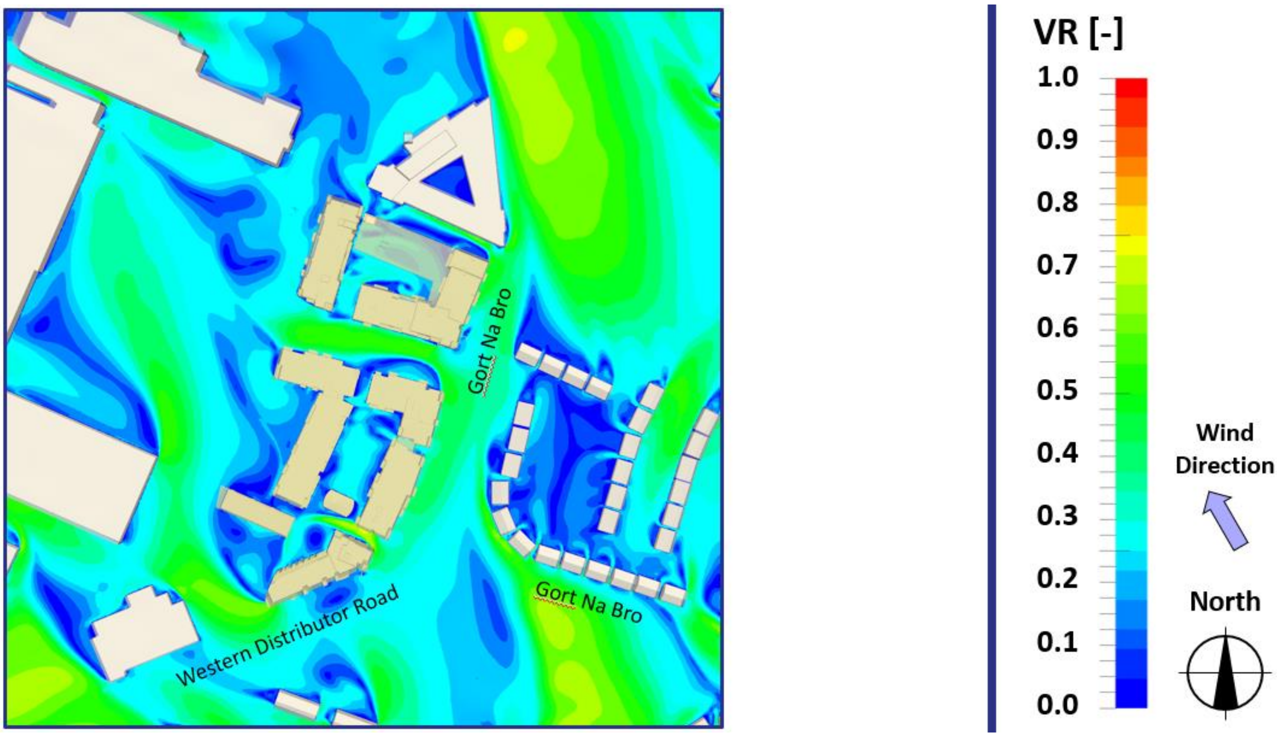

Figure A6: Velocity Ratio, Wind Direction of 150 Degrees

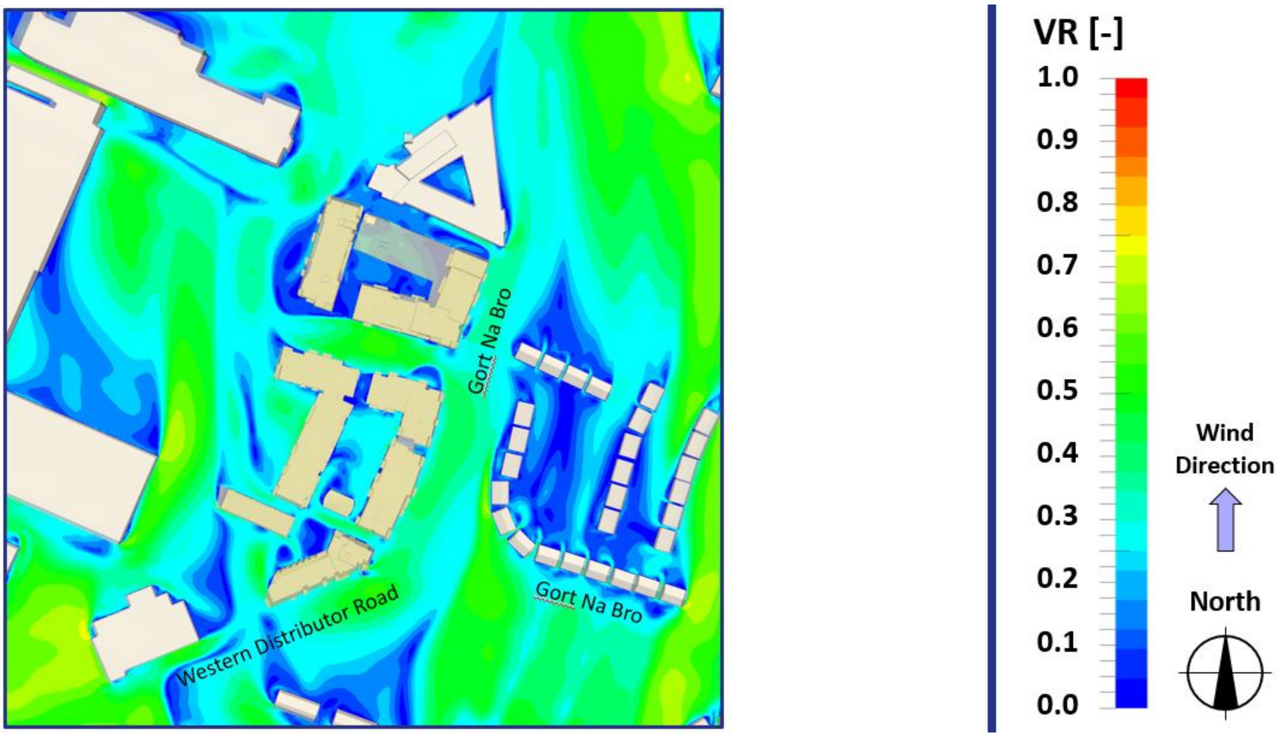

Figure A7: Velocity Ratio, Wind Direction of 180 Degrees (Southerly)

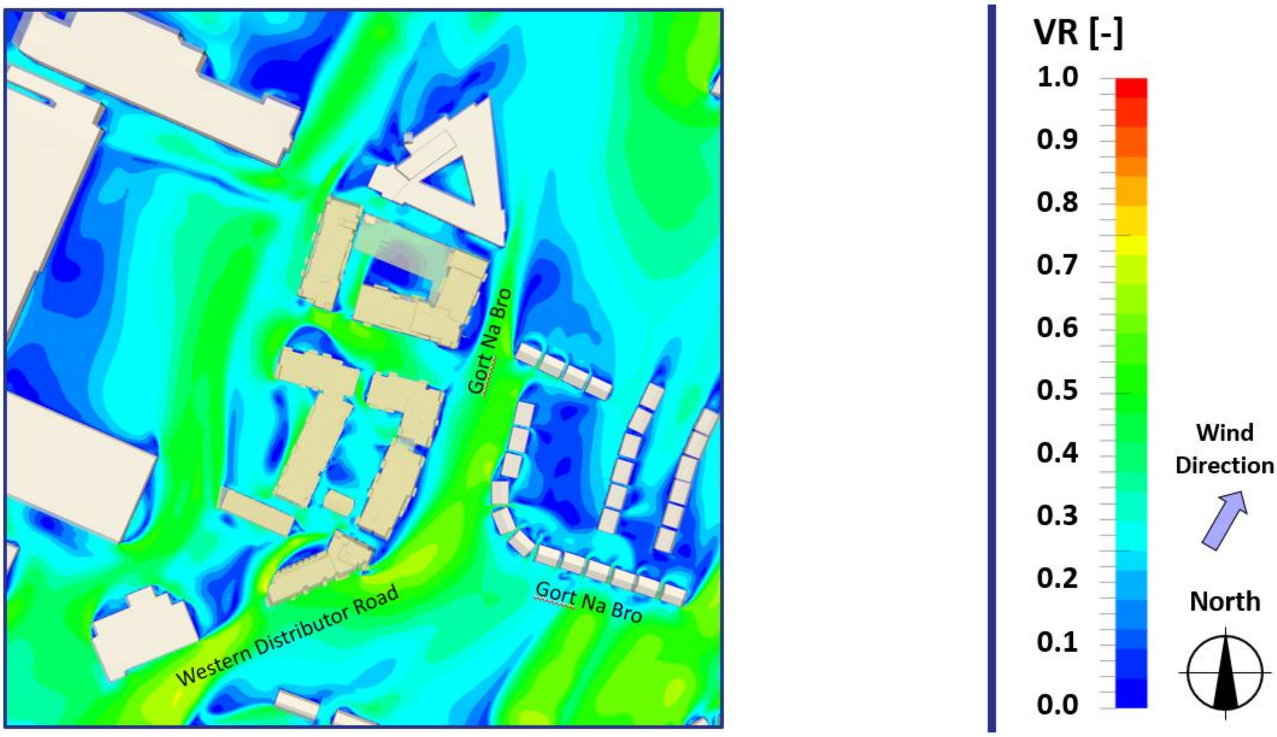

Figure A8: Velocity Ratio, Wind Direction of 210 Degrees

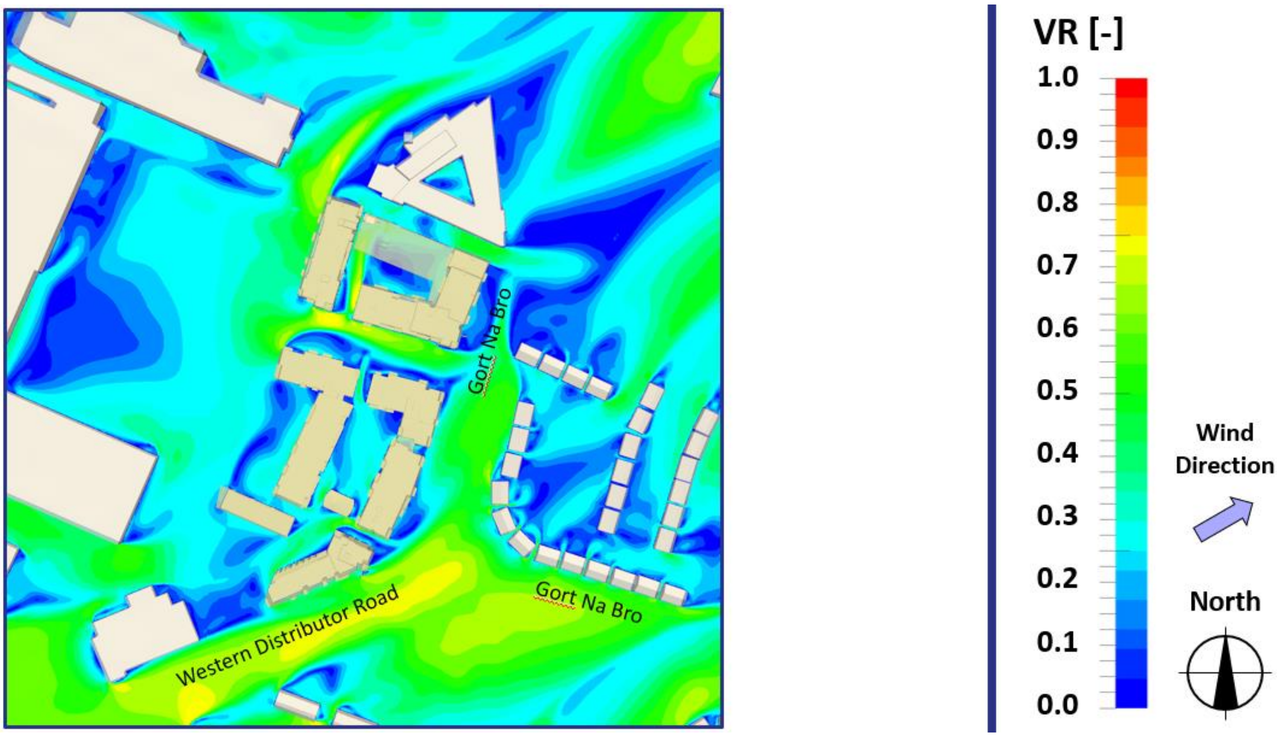

Figure A9: Velocity Ratio, Wind Direction of 240 Degrees

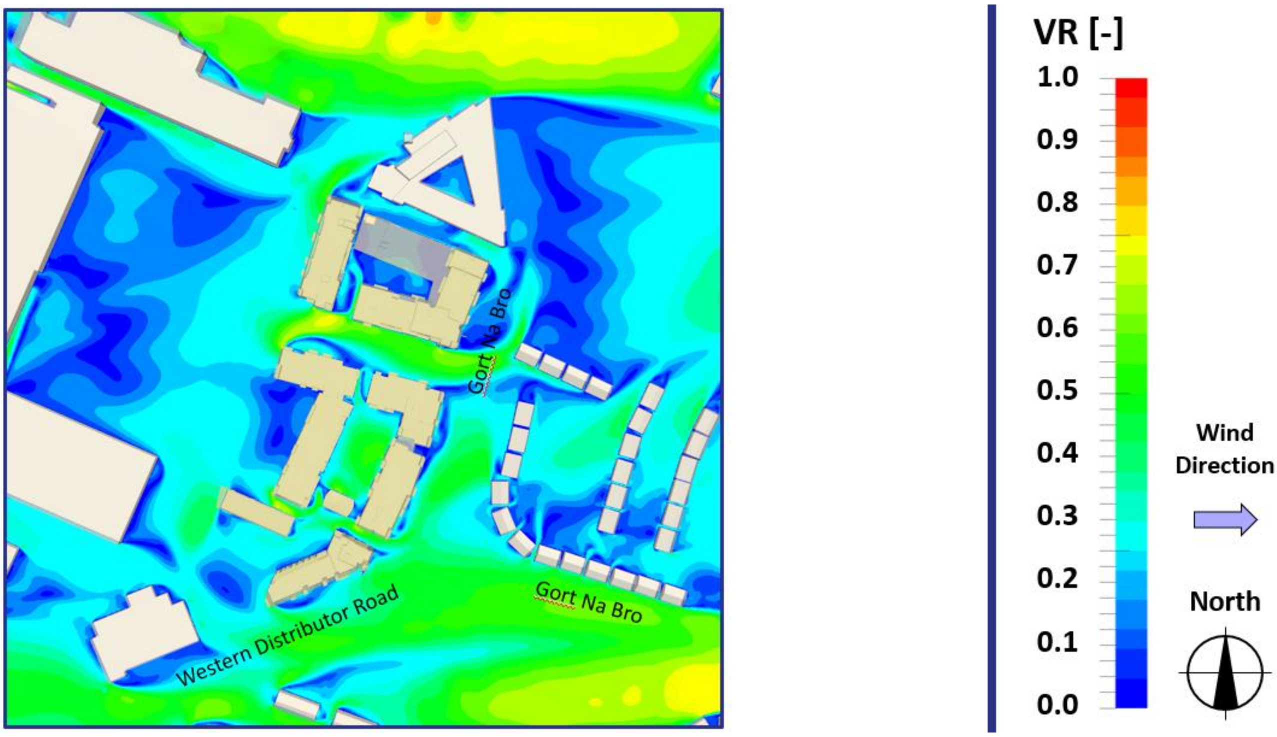

Figure A10: Velocity Ratio, Wind Direction of 270 Degrees (Westerly)

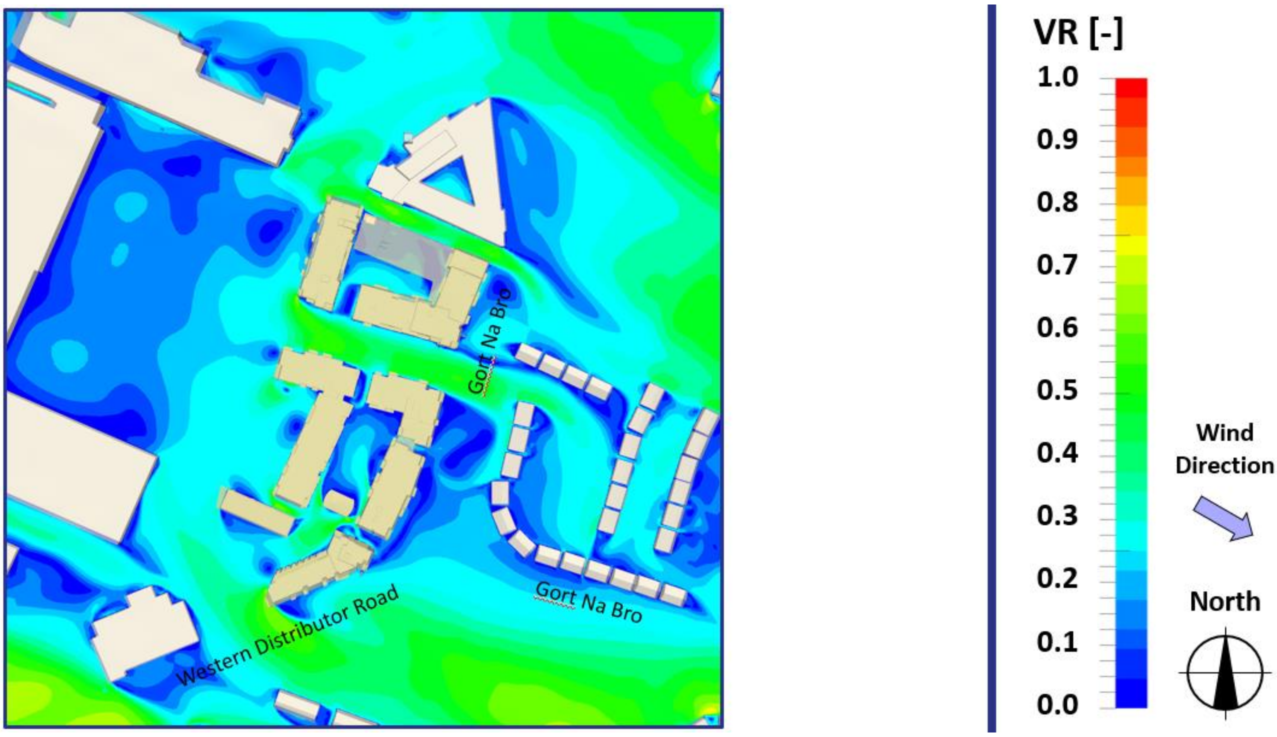

Figure A11: Velocity Ratio, Wind Direction of 300 Degrees

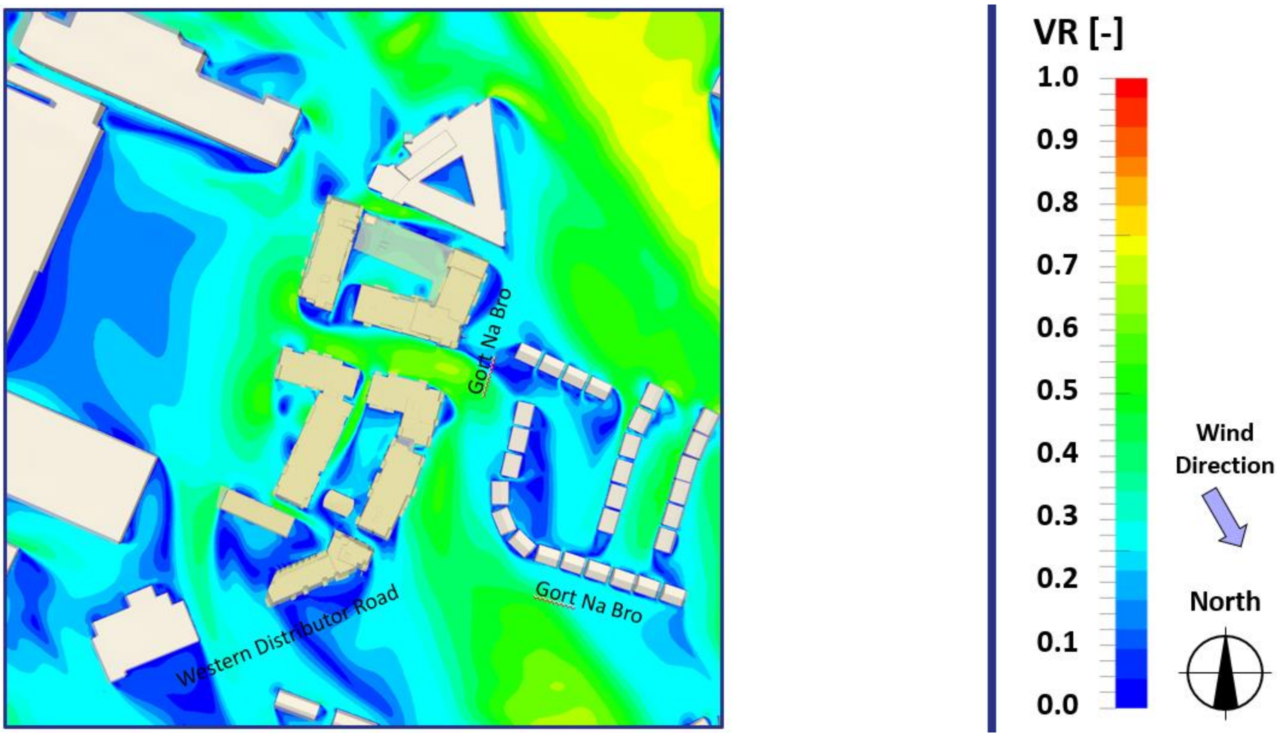

Figure A12: Velocity Ratio, Wind Direction of 330 Degrees

APPENDIX B – ADDITIONAL WIND DATA

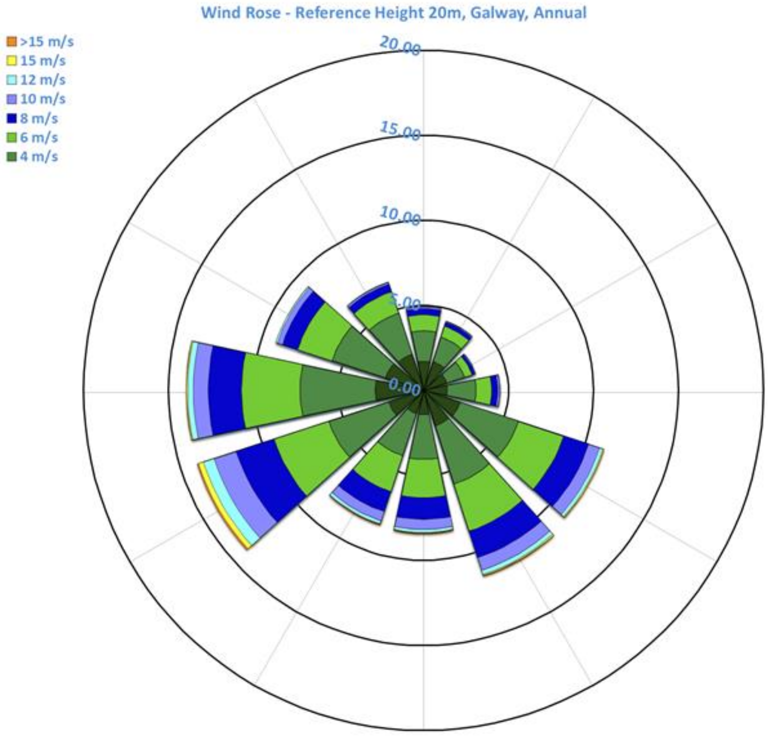

Figure B1: Annual Wind Rose at Reference Height for the Proposed site

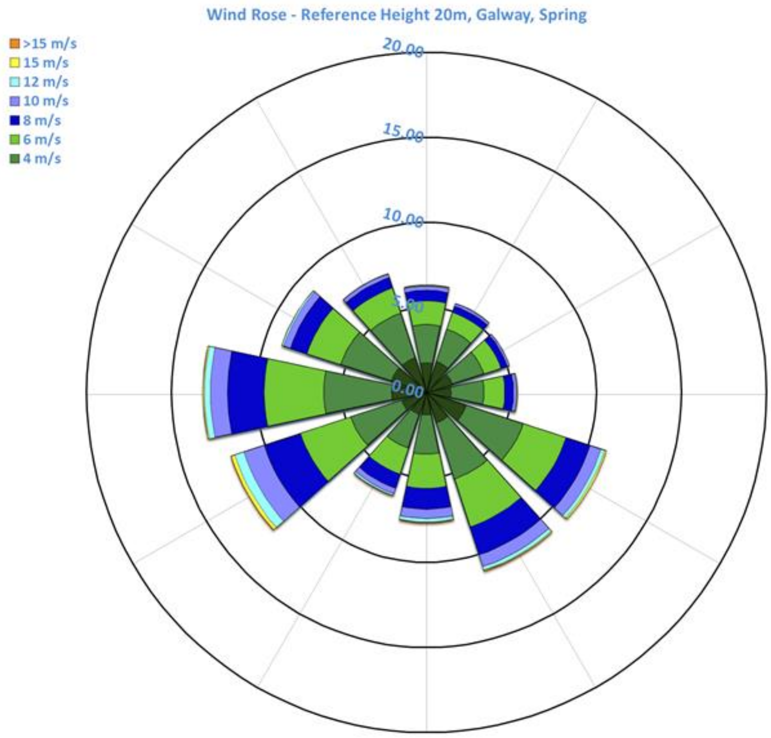

Figure B2: Spring Period Wind Rose at Reference Height for the Proposed site

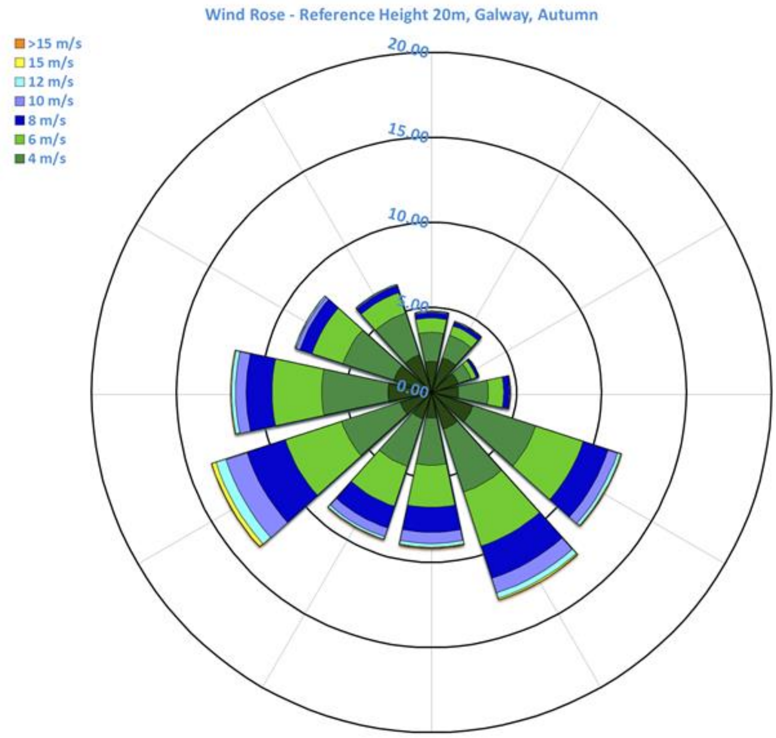

Figure B3: Autumn Period Wind Rose at Reference Height for the Proposed site

APPENDIX C – CFD MODELLING METHODOLOGY

GENERAL:

The multi-purpose CFD software OpenFoam® (www.openfoam.com, version 2.0) was used for the wind environment simulations. A total of 12 steady state atmospheric boundary layer simulations were completed for the assessment, covering 360 degrees of approaching winds, with a wind sector increment of 30 degrees.

SPATIAL DISCRETIZATION:

The spatial discretization of the 3D model was completed with snappyHexMesh utility, part of the CFD code OpenFoam®. Computational meshes, consisting of approximately 12 million hexahedral and polyhedral elements, were constructed for one site configuration: the proposed development within the existing surrounds

The generated numerical grids are shown in Figure C1 and Figure C2. The computational domain included the proposed development site, the surrounding buildings and terrain explicitly modelled to approximately 500 m from the development, 1000 m in radius ground surface and the outer boundaries (side and upper at 1000 m height from the ground).

The base cell size in the numerical grid was defined to 25.0 m. The refinement level increased to 0.1 m in the zone closest to the proposed site, in order to capture the detailed geometrical features. Additionally, 5 prism surface layers were introduced to all pedestrian ground level surfaces, with the first layer height of approximately 0.15 m.

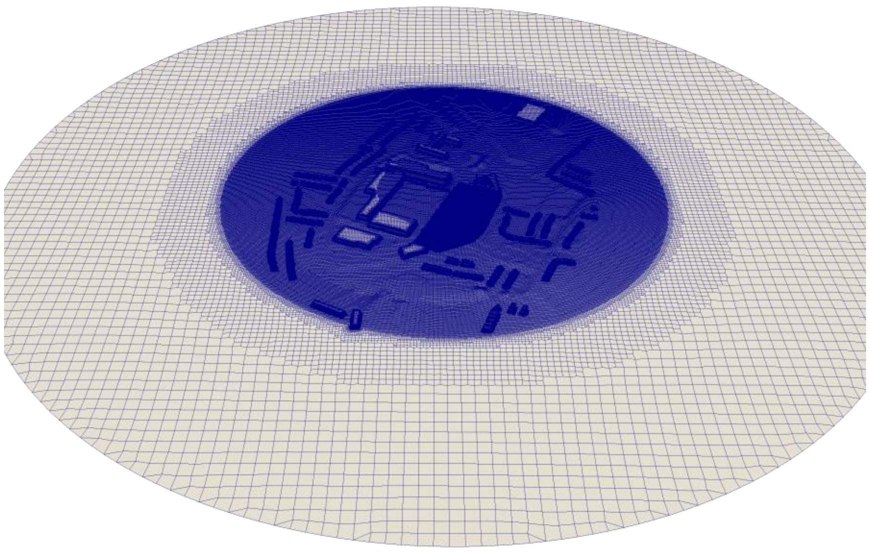

Figure C1: Spatial Discretization

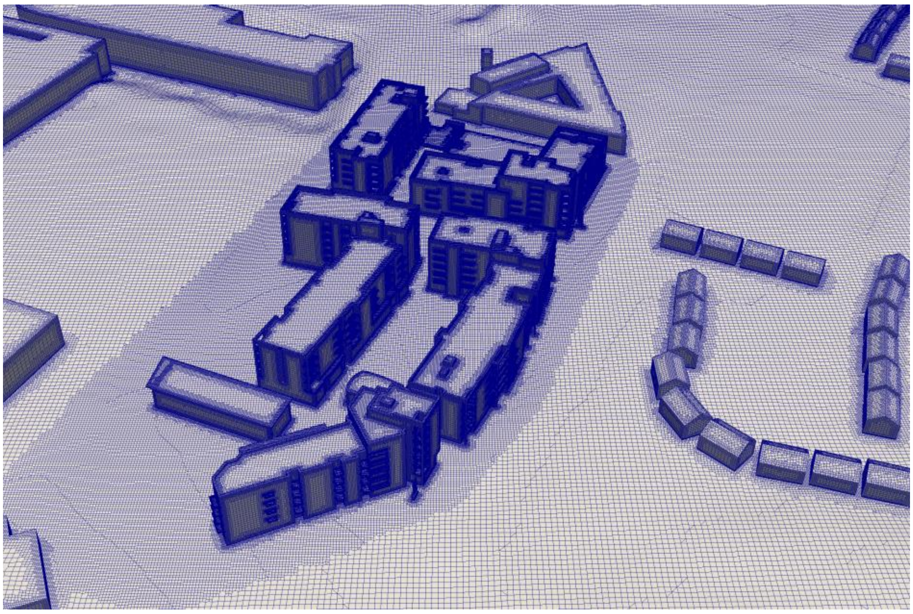

Figure C2: Spatial Discretization, Close-up View of Buildings in Proposed Development

SOLUTION METHOD:

The RANS (Reynolds-averaged Navier–Stokes) CFD simulations were performed using the simpleFoam solver. The modelling of an incompressible fluid flow was completed using the semi-implicit method for pressure-linked equations (SIMPLE) algorithms. The resulted flow turbulent features were modelled using the Shear Stress Transport (SST) k-ω turbulence model. This model by Menter [2] 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 [3].

BOUNDARY CONDITIONS:

The atmospheric boundary layer flow was simulated by implementing a logarithmic velocity profile model presented by Richards and Hoxey [4], 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:

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

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:

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

where:

z_{ref} – is the reference height in meters;

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:

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

where:

$C_\mu = 0.09$ - is the usual k-ε turbulence model constant.

Within the inner region of the domain (i.e. where the development, surrounding buildings and terrain were modelled) all surface boundary conditions were modelled as smooth walls with a no-slip condition. On the surface representing the ground in the outer region of the domain (i.e. the region without explicitly modelled building geometry) a no-slip wall boundary condition with a varying roughness length based on the terrain analysis for that region was applied.

REFERENCES

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

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