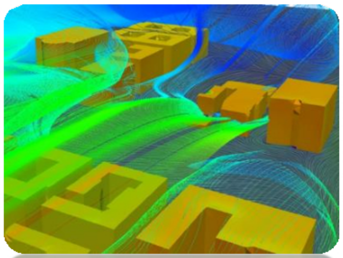 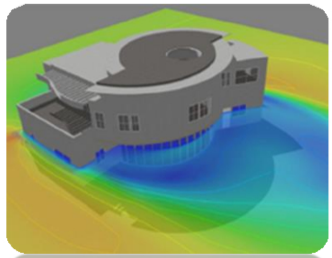 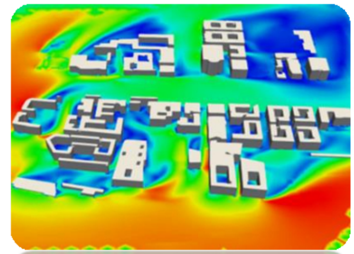

WIND AND MICROCLIMATE MODELLING

PROJECT SHORELINE GA1

Baldoyle, Co. Dublin

Prepared by: B-Fluid Ltd.| Buildings Fluid Dynamics Consultants

For: Richmond Homes

B-Fluid
Buildings Fluid Dynamics

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<tr><th colspan="3">Document Reference</th></tr>
<tr><td>Project Name</td><td colspan="2">WIND AND MICROCLIMATE MODELLING
Project Shoreline GA1
Baldoyle, Co.Dublin</td></tr>
<tr><td>Project Ref.</td><td colspan="2">W_2009160</td></tr>
<tr><td>Site location</td><td colspan="2">Baldoyle, Co. Dublin</td></tr>
<tr><td>CFD Study by</td><td colspan="2">B-Fluid Ltd.</td></tr>
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CEng MIEI, PhD. Mech Eng., MEng. Aerospace Eng.</td></tr>
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B-Fluid | Wind Modelling

Contents

1. INTRODUCTION

This report is completed by Dr. Cristina Paduano, Dr. Eleonora Neri and Dr. Arman Safdari.

Dr. Cristina Paduano is a Chartered Engineer (CEng) and member of Engineers Ireland who specialises in computational fluid dynamics applications for urban environment and the construction industry with over 15 years of experience. She holds a PhD in Mechanical Engineering from Trinity College Dublin, with M.Eng and B.Eng in Aerospace Engineering.

Dr. Eleonora Neri is a Chartered Engineer (CEng) and member of Engineers Ireland who specialises in computational fluid dynamics applications for the urban environment and in wind tunnel measurements for the aerospace industry. She holds a PhD in Aeroacoustics from Trinity College Dublin, a M.Sc. and B.Sc. in Aeronautical Engineering.

Dr. Arman Safdari is a CFD Modelling Engineer who specialises in computational fluid dynamics applications. He is an expert in airflow modelling, heat and mass transfer and multi-phase flow simulations. He holds a PhD in Mechanical Engineering from Pusan National University, a M.Sc. and B.Sc. in Mechanical Engineering.

This report assesses the impact of the proposed Strategic Housing Development (SHD) (referred to as "the proposed Project") on the wind conditions and microclimate affecting activities in areas within and surrounding the development. The Site of the proposed Project is located at Baldoyle-Stapolin Growth Area 1 (GA1), Baldoyle, Dublin 13. Figure 1.1 shows a view of the proposed project.

The development will consist of alterations to the permitted development, as permitted under FCC Reg. Ref. 16A/0412, ABP Reg. Ref. ABP-248970 (as amended by F20A/0258 and F21A/0046) of 544 no. residential units (385 no. apartments and 159 no. houses), retail and a crèche, to the development of 882 no. new residential dwellings (747 no. apartments, 135 no. houses), residential tenant amenity, retail, crèche, parking, and public realm, over a total site area of c. 9.1 ha, and site development area of c. 8.89 ha. Landscaping will include extensive communal amenity areas, and significant public open space provision.

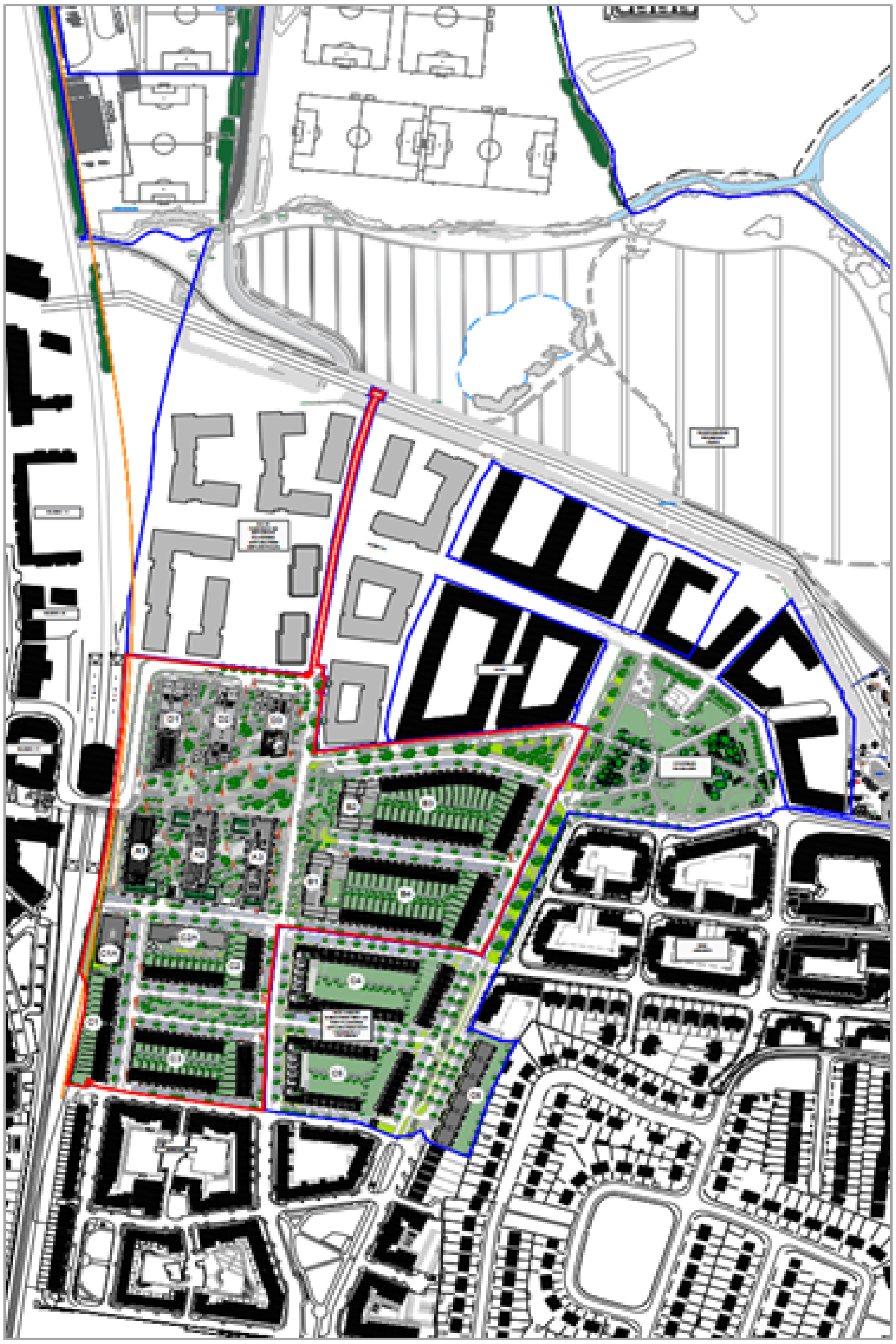


Figure 1.1: The Proposed Project

Wind and Micro-climate study identifies the possible wind patterns around the existing environment and proposed development, under mean and peak wind conditions typically occurring in Dublin. For this project the wind assessment has considered the proposed development in the existing environment including the GA2 development (which has been permitted) and Clongriffin developments (existing and permitted but not built) as shown in Figure 1.2, and furthermore, the proposed development in a cumulative scenario where a potential GA3 is included as shown in Figure 1.3. The Figures 1.4 and 1.5 show isometric views of GA1 proposed blocks.

Figure 1.2: Project Shoreline GA1 Development Site - Existing Scenario (with GA2 permitted and Clongriffin developments (existing and permitted but not built))

Figure 1.3: Project Shoreline GA1 Development Site - Cumulative Scenario (with GA2 permitted,and Clongriffin developments (existing and permitted but not built) and GA3 potential phase)

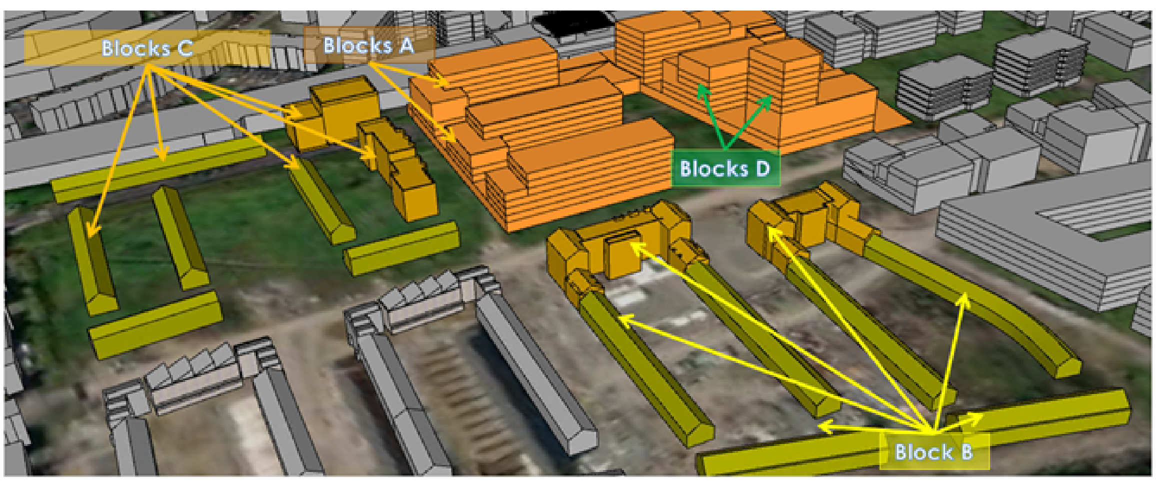


Figure 1.4: Shoreline GA1 Development Blocks

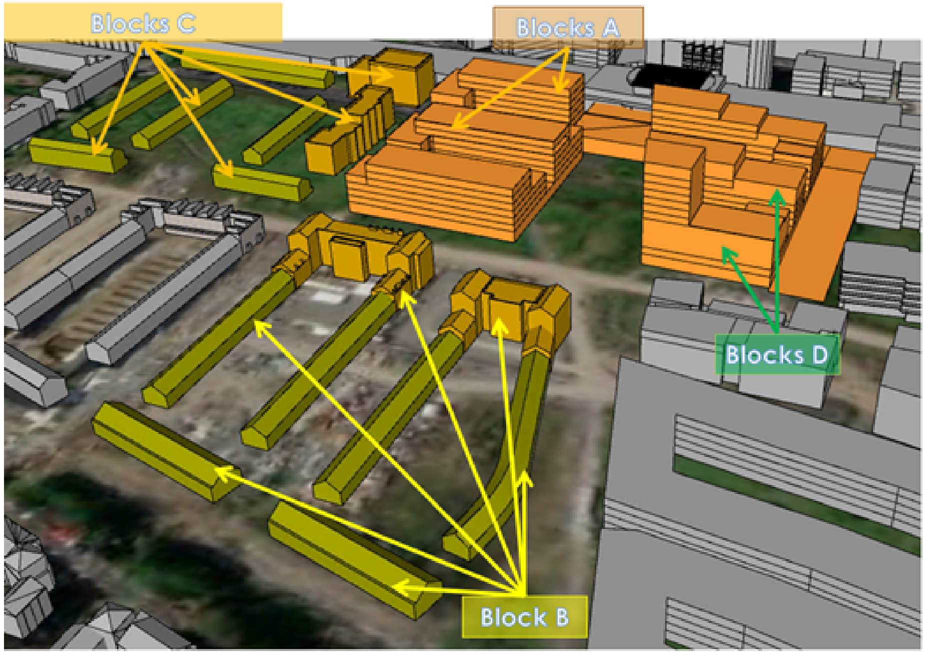


Figure 1.5: Shoreline GA1 Development Blocks

This assessment is performed through Advanced Computational Fluid Dynamics (CFD) which is a numerical method used to simulate wind conditions and its impact on the development and to identify areas of concern in terms of downwash/funneling/downdraft/critical flow accelerations that may likely occur. The Advanced CFD numerical algorithms applied here are solved using high speed supercomputing computer clusters.

These results are utilized by Richmond Homes design team to configure the optimal layout for the proposed Strategic Housing Development (SHD) (referred to as "the proposed Project") for the aim of achieving a high-quality environment for the scope of use intended of each areas/building (i.e. comfortable and pleasant for potential pedestrian) and not to introduce any critical wind impact on the surrounding areas and on the existing buildings.

The next sections describes in details the wind and microclimate modelling performed, it's methodology and assumptions which B-Fluid Ltd. has adopted for this study, together with impacts of the proposed development on the existing environment.

Objective Of Wind And Microclimate Modelling

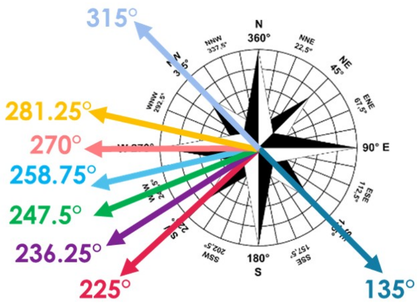
CFD wind modelling is adopted to identify areas of concern in terms of critical flows and areas where pedestrian safety and comfort could be compromised. Pedestrian Wind Comfort and Safety Studies are conducted to predict, assess and, where necessary, mitigate the impact of the residential development on pedestrian level wind conditions. The objective is to maintain comfortable and safe pedestrian level wind conditions that are appropriate for the season and the intended use of pedestrian areas. Pedestrian areas include side-walks, street frontages, pathways, building entrance areas, open spaces, amenity areas, outdoor sitting areas, and accessible roof top areas among others.

For this purpose, 18 different wind scenarios and directions have been modelled as shown in Table 1.1 in order to take into consideration all the different relevant wind directions. In particular, a total of 18 compass directions on the wind rose are selected. For each direction, the reference wind speed is set to the 5% exceedance wind speed for that direction, i.e. the wind speed that is exceeded for over 5% of the time whenever that wind direction occurs.

DUBLIN WIND SCENARIOS AND DIRECTIONS		
Velocity (m/s)	Direction (deg)	Frequency
5.601	225	11.233
4.626	135	6.849
5.847	236.25	6.792
6.049	258.75	6.747
6.034	247.5	6.689
5.888	270	5.662
4.994	315	4.338
5.503	281.25	3.904
4.974	292.5	3.436
5.357	213.75	3.288
4.736	123.75	3.105
4.406	146.25	2.751
5.101	303.75	2.648
5.246	112.5	2.500
4.121	157.5	2.386
4.581	101.25	2.340
4.169	45	2.180
3.558	90	2.135

Table 1.1: Summary of The 18 Wind Scenarios Modelled for Project Shoreline GA1 Development

This modelling study focuses on reporting 8 worst case and most relevant wind speeds, which are the speeds and directions showing the most critical wind speeds relevant to the development. The 8 modelled scenarios reported in this study are presented in Figure 1.6.



Velocity (m/s)	Direction (°)	Frequency
5.601	225	11.233
4.626	135	6.849
5.847	236.25	6.792
6.049	258.75	6.747
6.034	247.5	6.689
5.888	270	5.662
4.994	315	4.338
5.503	281.25	3.904

Figure 1.6: Summary of 8 Wind Scenarios Reported

National Policy

According to the 'Urban Development and Building Heights, Guidelines for Planning Authorities (Government of Ireland, December 2018)' document, specific impact assessment of the micro-climatic effects should be performed for 'buildings taller than prevailing building heights in urban areas'. (In the same guidance, standard buildings height is considered 6-8 storeys. Above this height, buildings are considered 'taller' for Dublin standards.) Usually, the recommended approach to wind microclimate studies is based on the building height, as presented in Figure 2.5 and prescribed by the Wind Microclimate Guidelines for Developments in the City of London (August 2019). Good wind microclimate conditions are necessary for creating outstanding public spaces. Adverse wind effects can reduce the quality and usability of outdoor areas, and lead to safety concerns in extreme cases. Usually, the recommended approach to wind microclimate studies is based on the building height, as presented in Figure 1.7.

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

Figure 1.7: Recommended Approach to Wind Microclimate Studies based on Building Height, as prescribed by the Wind Microclimate Guidelines for Developments in the City of London (August 2019)

Computational fluid dynamics (CFD) tools can create high quality output that provide a good understanding of fundamental flow features. The CFD models must include a detailed three-dimensional representation of the proposed development.

Maximum cell sizes near critical locations (e.g. entrances, corners, etc.) must be 0.3m or smaller. Sufficient cells should be also used between buildings with a minimum of 10 across a street canyon. However, the cell size of buildings away from the target can be larger to allow for modelling efficiency. The CFD models should represent all surrounding buildings that are within 400m from the centre of the site. Other taller buildings outside of this zone that could have an influence on wind conditions within the project site should be included for wind directions where they are upwind of the project site. The models must contain at least 3 prism layers below 1.5m height, to capture near-ground effects.

CFD analysis also reports conditions in areas away from the site where cumulative effects of a cluster of tall buildings could lead to adverse wind conditions.

2. ASSESSMENT METHODOLOGY

2.1 STUDY METHODOLOGY

Acceptance Criteria

Pedestrian Comfort Pedestrian Wind Comfort is measured in function of the frequency of wind speed threshold exceeded based on the pedestrian activity. The assessment of pedestrian level wind conditions requires a standard against which measured or expected wind velocities can be compared.

Only gust winds are considered in the safety criterion. These are usually rare events, but deserve special attention in city planning and building design due to their potential impact on pedestrian safety. Gusts cause the majority of cases of annoyance and distress and are assessed in addition to average wind speeds. Gust speeds should be divided by 1.85 and these "gust equivalent mean" (GEM) speeds are compared to the same criteria as for the mean hourly wind speeds. This avoids the need for different criteria for mean and gust wind speeds.

The following criteria are widely accepted by municipal authorities as well as the international building design and city planning community:

- DISCOMFORT CRITERIA: Relates to the activity of the individual.
  Onset of discomfort:
  - Depends on the activity in which the individual is engaged and is defined in terms of a mean hourly wind speed (or GEM) which is exceeded for 5% of the time.

- DISTRESS CRITERIA: Relates to the physical well-being of the individual.
  Onset of distress:
  - 'Frail Person Or Cyclist': equivalent to an hourly mean speed of 15 m/s and a gust speed of 28 m/s (62 mph) to be exceeded less often than once a year. This is intended to identify wind conditions which less able individuals or cyclists may find physically difficult. Conditions in excess of this limit may be acceptable for optional routes and routes which less physically able individuals are unlikely to use.
  - 'General Public': A mean speed of 20 m/s and a gust speed of 37 m/s (83 mph) to be exceeded less often than once a year. Beyond this gust speed, aerodynamic forces approach body weight and it rapidly becomes impossible for anyone to remain standing. Where wind speeds exceed these values, pedestrian access should be discouraged.

The above criteria set out six pedestrian activities and notes that calm activity requires calm wind conditions, which are summarised by the Lawson scale, shown in Figure 2.1. The Lawson scale assesses pedestrian wind comfort in absolute terms and defines the reaction of an average person to the wind. Each wind type is associated to a number, corresponding to the Beaufort scale, which is represented in Figure 2.2. The Beaufort scale is an empirical measure that relates wind speed to observed conditions at sea or on land. A 20% exceedance is used in these criteria to determine the comfort category, which suggests that wind speeds would be comfortable for the corresponding activity at least 80% of the time or four out of five days.

These criteria for wind forces represent average wind tolerances. They are subjective and variable depending on thermal conditions, age, health, clothing, etc. which can all affect a person's perception of a local microclimate. Moreover, pedestrian activity alters between winter and summer months. The criteria assume that people will be suitably dressed for the time of year and individual activity. It is reasonable to assume, for instance, that areas designated for outdoor seating will not be used on the windiest days of the year.

Weather data measured are used to calculate how often a given wind speed will occur each year over a specified area. Pedestrian comfort criteria are assessed at 1.5m above ground level. Unless in extremely unusual circumstances, velocities at pedestrian level increase as you go higher from ground level.

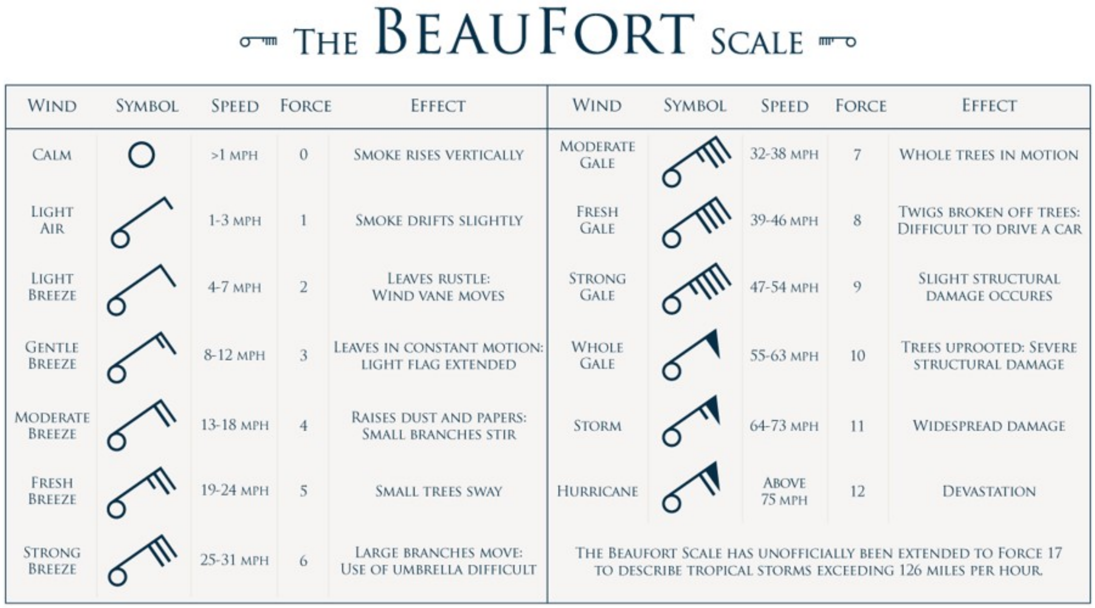
A breach of the distress criteria requires a consideration of:

- whether the location is on a major route through the complex,
- whether there are suitable alternate routes which are not distressful.

If the predicted wind conditions exceed the threshold, then conditions are unacceptable for the type of pedestrian activity and mitigation measure should be implemented into the design.

Beaufort Scale	Wind Type	Mean Hourly Wind Speed (m/s)		Acceptance Level Based on Activity–Lawson Criteria			
				Sitting	Standing/ Entrances	Leisure Walking	Business Walking
0-1	Light Air	0 – 1.55	COMFORT				
2	Light Breeze	1.55 - 3.35					
3	Gentle Breeze	3.35 - 5.45					
4	Moderate	5.45 - 7.95					
5	Fresh Breeze	7.95 - 10.75					
6	Strong Breeze	10.75 - 13.85					
7	Near Gale	13.85 - 17.15					
8	Gale	17.15 - 20.75	DISTRESS				
9	Strong Gale	20.75 - 24.45					
Legend	Acceptable / Tolerable	Not acceptable / Dangerous					

Figure 2.1: Lawson Scale



THE BEAUFORT SCALE

Wind	Symbol	Speed	Force	Effect
Calm		>1 mph	0	Smoke rises vertically
Light Air		1-3 mph	1	Smoke drifts slightly
Light Breeze		4-7 mph	2	Leaves rustle: Wind vane moves
Gentle Breeze		8-12 mph	3	Leaves in constant motion: Light flag extended
Moderate Breeze		13-18 mph	4	Raises dust and papers: Small branches stir
Fresh Breeze		19-24 mph	5	Small trees sway
Strong Breeze		25-31 mph	6	Large branches move: Use of umbrella difficult
Moderate Gale		32-38 mph	7	Whole trees in motion
Fresh Gale		39-46 mph	8	Twigs broken off trees: Difficult to drive a car
Strong Gale		47-54 mph	9	Slight structural damage occures
Whole Gale		55-63 mph	10	Trees uprooted: Severe structural damage
Storm		64-73 mph	11	Widespread damage
Hurricane		Above 75 mph	12	Devastation

The Beaufort Scale has unofficially been extended to Force 17 to describe tropical storms exceeding 126 miles per hour.

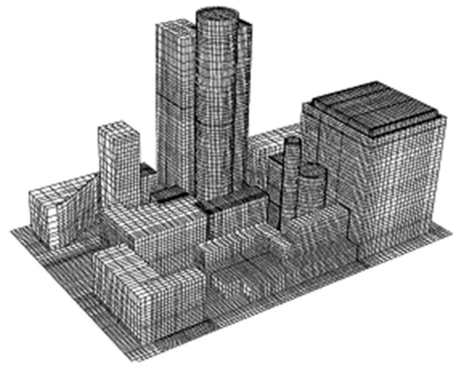
Figure 2.2: BeaufortScale

CFD Modelling Method

Computational Fluid Dynamics (CFD) is a numerical technique used to simulate fluid flow, heat and mass transfer, chemical reaction and combustion, multiphase flow, and other phenomena related to fluid flows. CFD modelling includes three main stage: pre-processing, simulation and post-processing as described in Figure 2.3. The Navier-Stokes equations, used within CFD analysis, are based entirely on the application of fundamental laws of physics and therefore produce extremely accurate results provided that the scenario modelled is a good representation of reality.

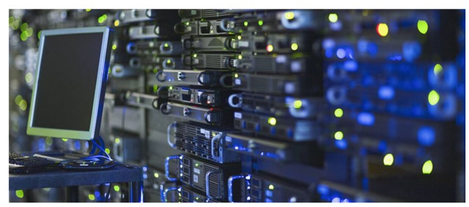
PRE-PROCESSING

This is the construction of a representative geometric model to be utilized within a flow domain of interest and the subsequent division of this domain into small control volumes (cells), a process often called "meshing." After setting up the model and mesh, the model is completed by setting appropriate boundary and initial conditions.



SIMULATION

The equations governing the behaviour of fluid particles (Navier-Stokes equations) are solved iteratively over each control volume within the computational domain, until the results change no more; i.e. a converged solution is reached. In a transient simulation this process is repeated and convergence verified at each time step, whereas in a steady-state simulation, this is only done at one time step, since it is assumed conditions do not vary over time. The field solutions of pressure, velocity, air temperature, and other properties are obtained for each control volume, at cell centre, nodal point, or face centre in order to render the flow field.



POST-PROCESSIONG

This is the plotting and viewing of the predicted flow field from the CFD model simulations at selected locations, surfaces, or planes of interest.

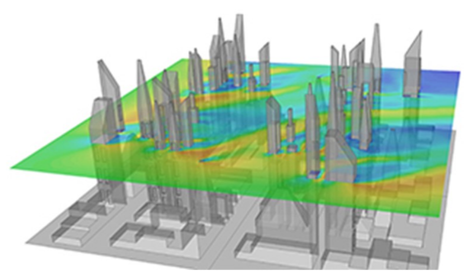


Figure 2.3: CFD Modelling Process Explanation

OpenFOAM Numerical Solver Details

This report employs OpenFoam Code, which is based on a volume averaging method of discretization and uses the post-processing visualisation toolkit Paraview version 5.5. OpenFoam is a CFD software code released and developed primarily by OpenCFD Ltd, since 2004. It has a large user base across most areas of engineering and science, from both commercial and academic organisations.

OpenFOAM CFD code has capabilities of utilizing a Reynolds Averaged Navier-Stokes (RANS) approach, Unsteady Reynolds Averaged Navier-Stokes (URANS) approach, Detached Eddy Simulation (DES) approach, Large Eddy Simulation (LES) approach or the Direct Numerical Simulation (DNS) approach, which are all used to solve anything from complex fluid flows involving chemical reactions, turbulence and heat transfer, to acoustics, solid mechanics and electromagnetics. Quality assurance is based on rigorous testing. The process of code evaluation, verification and validation includes several hundred daily unit tests, a medium-sized test battery run on a weekly basis, and large industry-based test battery run prior to new version releases. Tests are designed to assess regression behaviour, memory usage, code performance and scalability.

The OpenFOAM solver algorithm directly solves the mass and momentum equations for the large eddies that comprise most of the fluid's energy. By solving the large eddies directly no error is introduced into the calculation.

To reduce computational time and associated costs the small eddies within the flow have been solved using the widely used and recognised Smagorinsky Sub-Grid Scale (SGS) model. The small eddies only comprise a small proportion of the fluids energy therefore the errors introduced through the modelling of this component are minimal.

The error introduced by modelling the small eddies can be considered of an acceptable level. Computational time will be reduced by modelling the small eddies (compared to directly solving).

3. RECEIVING ENVIRONMENT

3.1 THE EXISTING RECEIVING ENVIRONMENT ASSESSMENT

In this chapter, wind impact has been assessed on the existing receiving environment considered as the existing buildings (including the GA2 development (which has been permitted) and Clongriffin developments (existing and permitted but not built) as shown in Figure 3.1). Also, the topography of the site prior to construction of the proposed development. A statistical analysis of 30 years historical weather wind data has been carried out to assess the most critical wind speeds, directions and frequency of occurrence of the same. The aim of this assessment has been to identify the wind microclimate of the area that may cause critical conditions for pedestrians comfort criteria.

Figure 3.1: Project Shoreline GA1 Development Site - Existing Scenario (with GA2 permitted and Clongriffin developments (existing and permitted but not built))

Site Location And Surrounding Area

The Site of the proposed Project is located in Baldoyle-Stapolin Growth Area 1 (GA1), Baldoyle, Dublin 13, c. 10km north-east of the City centre. While the Site is on the edge of the urban extent of Dublin City it is within the administrative area of Fingal County Council. The area forms part of the Northern Fringe lands which span Dublin City and Fingal Council areas. The proposed Project is framed within the context of national, regional and local planning policy.

The Existing Environment site is shown in Figure 3.2. The area considered for the existing environment and proposed development assessment comprises a 2km^2 area around the Project Shoreline GA1 Development as represented in Figure 3.3.

Figure 3.2: Project Shoreline GA1 Development Site Location and Existing Environment

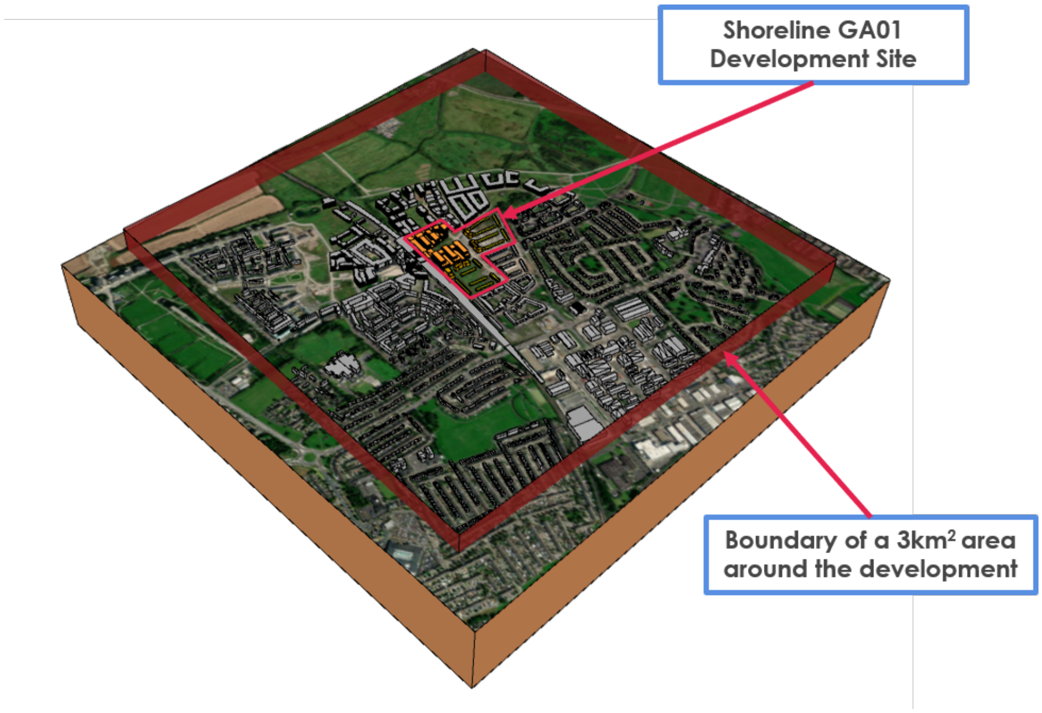


Figure 3.3: Extents of Analysed Existing Environment Around Project Shoreline GA1 Development

Topography And Built In Environment

Figure 3.4 shows an aerial photograph of the terrain surrounding the construction site at Project Shoreline GA1 Development.

The Site of the proposed Project is located in Baldoyle-Stapolin Growth Area 1 (GA1), Baldoyle, Dublin 13., c. 10km, north-east from Dublin City Centre and it is 6km east of Dublin Airport and c. 1.5km from Baldoyle village.

The area surrounding the Site can be characterised as urban environment. Some shelter effect can be expected for wind approaching from directions within this sector. All the wind directions considered for this study are in this connection “urban winds” and no distinction will be made between them.

Figure 3.4: Built-in Environment around Construction Site at the Proposed Project (Site Location in Red)

Wind And Microclimate Conditions

This analysis considers the existing environment being exposed to typical wind conditions of the site. The buildings are oriented as shown in the previous sections. The wind profile is built using the annual average of meteorology data collected at Dublin Airport Weather Station. Figures 3.5 and 3.6 shows on the map the position of Project Shoreline GA1 Development and the position of Dublin Airport.

Figure 3.5: Map Showing the Position of the Proposed Project and Dublin Airport

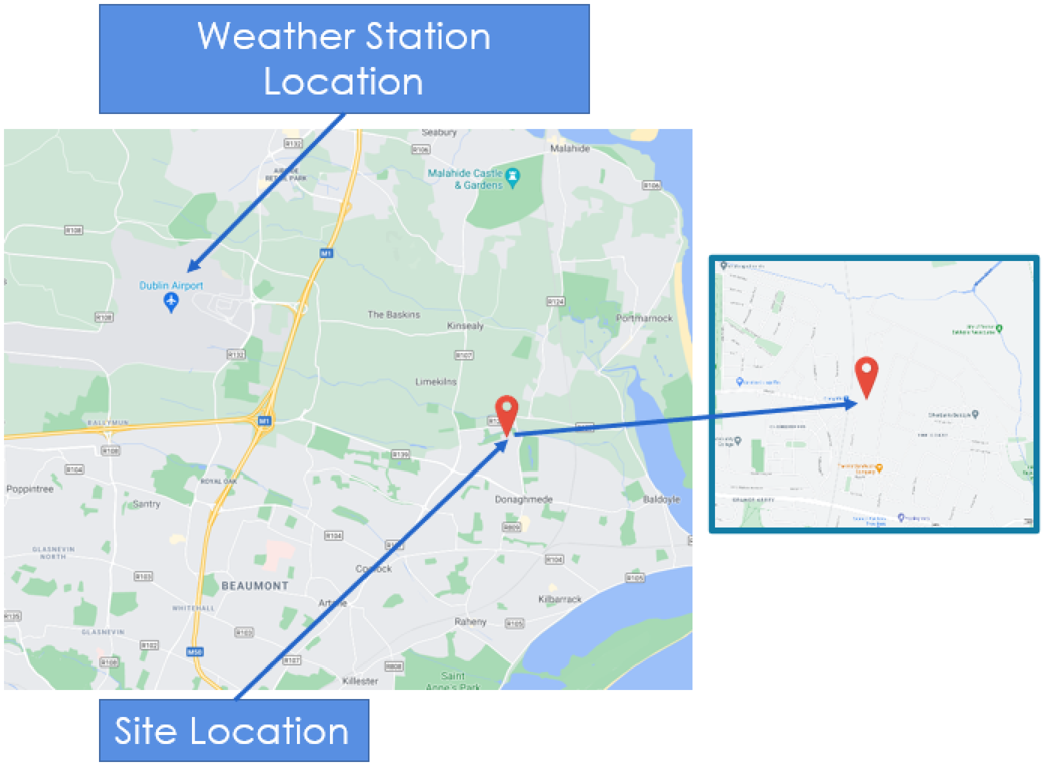


Figure 3.6: Map Showing the Position of the Proposed Project and Dublin Airport

Regarding the transferability of the available wind climate data, the following considerations have been made:

- **Terrain**: The meteorological station is located in the flat open terrain of the airport, whereas the development site is located in urban area with dense built-in structure with buildings of at least 15m height in average.

- **Mean Wind Speeds**: Due to the different terrain environment, the ground-near wind speeds (at pedestrian level) will be lower at the construction site compared to the meteorological station at the airport.

- **Wind Directions**: The landscape around the development site can in principle be characterized as flat terrain. Isolated elevations in the near area of the development should have no influence on the wind speed and wind directions. With respect to the general wind climate no significant influence is expected. Based on the above considerations it can be concluded that the data from the meteorological station at Dublin Airport are applicable for the desktop assessment of the wind comfort at the development site.

Wind Conditions

The assessment of the wind comfort conditions at the new development will be based on the dominating wind directions throughout a year (annual wind statistic).

As stated above, the local wind climate is determined from historical meteorological data recorded at Dublin Airport. Two different data sets are analyzed for this assessment as follows:

- The meteorological data associated with the maximum daily wind speeds recorded over a 30 year period between 1985 and 2020 and,
- The mean hourly wind speeds recorded over a 10 year period between 2005 and 2020. The data is recorded at a weather station at the airport, which is located 10m above ground or 71mOD.

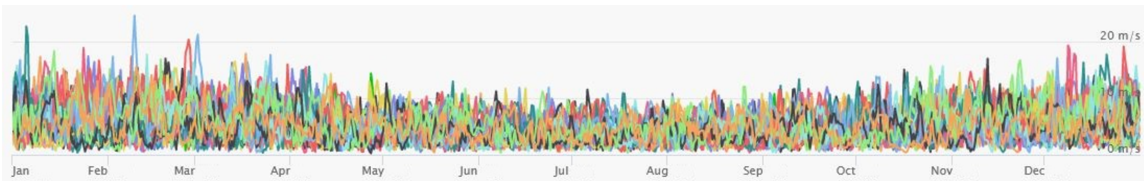


Figure 3.7: Local Wind Speed (10m) - 1985-2020

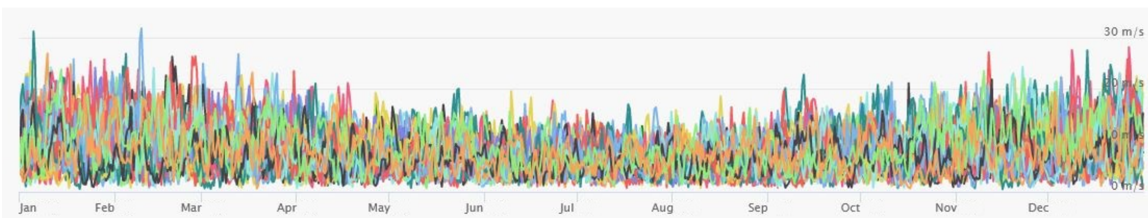


Figure 3.8: Local Wind Gust (10m) - 1985-2020

Figure 3.9, presenting the wind speed diagram for Dublin, shows the days per month, during which the wind reaches a certain speed. In Figure 3.10, the wind rose for Dublin shows how many hours per year the wind blows from the indicated direction, confirming how the predominant directions are WSW, W, and SW.

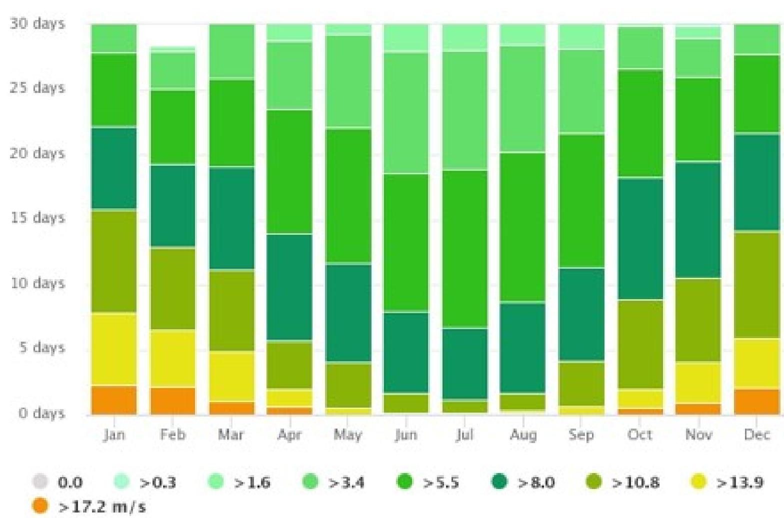


Figure 3.9: Dublin Wind Speed Diagram

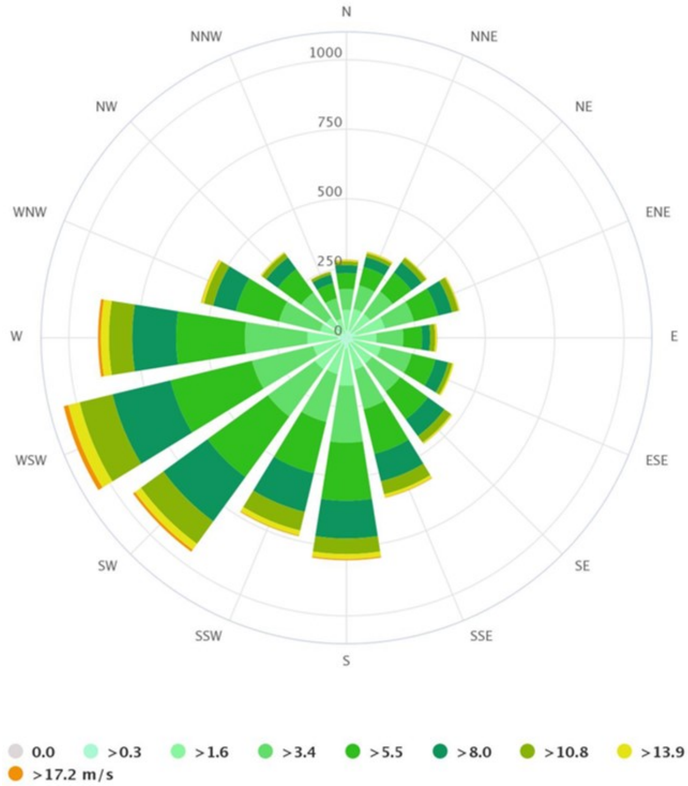


Figure 3.10: Dublin Wind Rose

Based on the criterion of occurrence frequency the main wind directions are presented in Figure 3.11 and listed below in descending order of dominance:

1. South-West with most frequent wind speeds around 6m/s (all year).
2. South-East
3. West-South-West.

The analysis will mainly focus on the large sector of prevailing wind directions of winds from above. Other wind directions will be discussed if deemed necessary for the study.

Velocity (m/s)	Direction (°)	Frequency
5.601	225	11.233
4.626	135	6.849
5.847	236.25	6.792
6.049	258.75	6.747
6.034	247.5	6.689
5.888	270	5.662
4.994	315	4.338
5.503	281.25	3.904
4.974	292.5	3.436
5.357	213.75	3.288
4.736	123.75	3.105
4.406	146.25	2.751
5.101	303.75	2.648
5.246	112.5	2.500
4.121	157.5	2.386
4.581	101.25	2.340
4.169	45	2.180
3.558	90	2.135
4.801	202.5	2.021
3.689	78.75	1.963
3.627	168.75	1.495
4.285	67.5	1.370
4.863	56.25	1.279
4.042	191.25	1.199
4.630	326.25	1.164
3.844	11.25	1.142
4.418	337.5	1.062
4.787	348.75	0.982
4.006	22.5	0.959
3.555	180	0.879
4.059	33.75	0.845
0.700	0	0.011
Selected Conditions : 32	Total Coverage : 95.35 %	

Figure 3.11: Main Wind Directions Occurrence Frequency

Mean And Maximum Wind Conditions

Examination of the daily wind data reveals that the wind predominantly blows from West and Southwest directions, however, there is a secondary wind from the Southeast. It is apparent that winds from other directions are rare. Maximum daily wind speeds of nearly 30 m/s were recorded in the past 30 years, however, the maximum daily winds are commonly found between 6 m/s and 15 m/s. the strongest winds arise from the West and South-West.

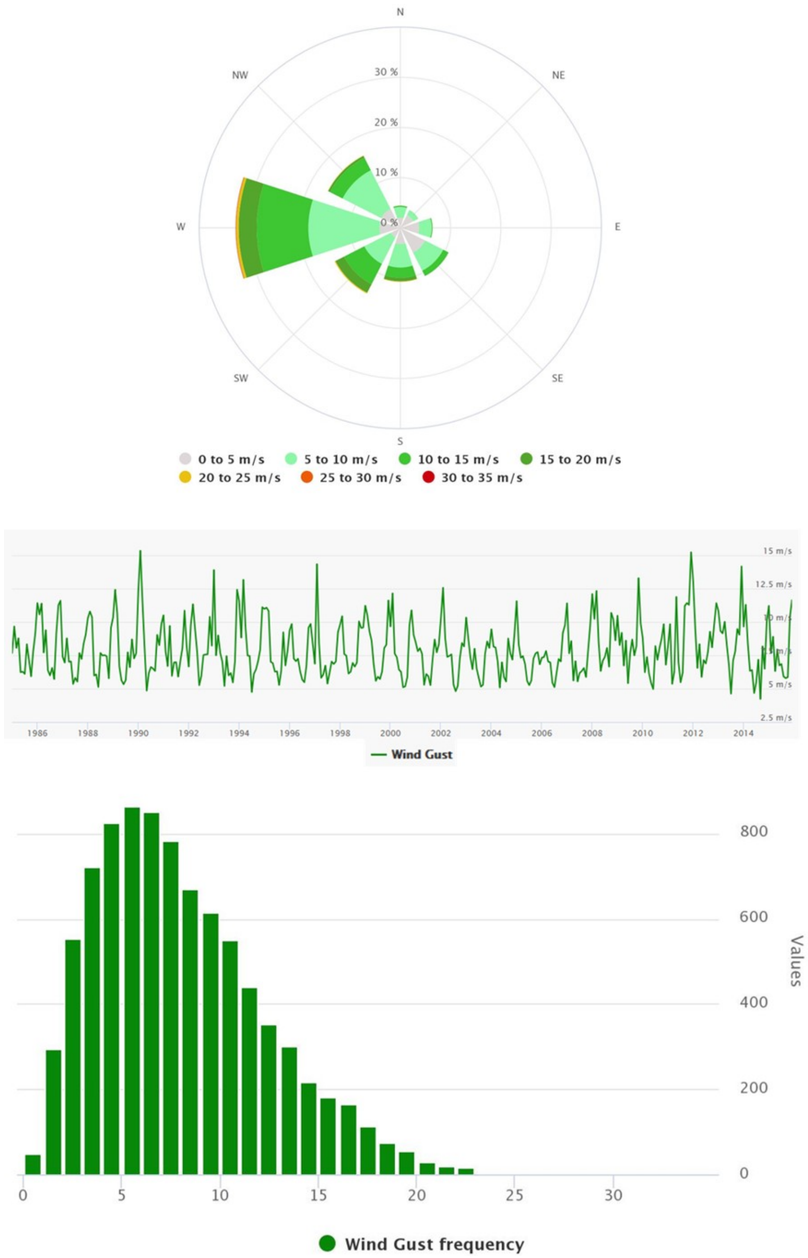


Figure 3.12: Maximum Wind Conditions

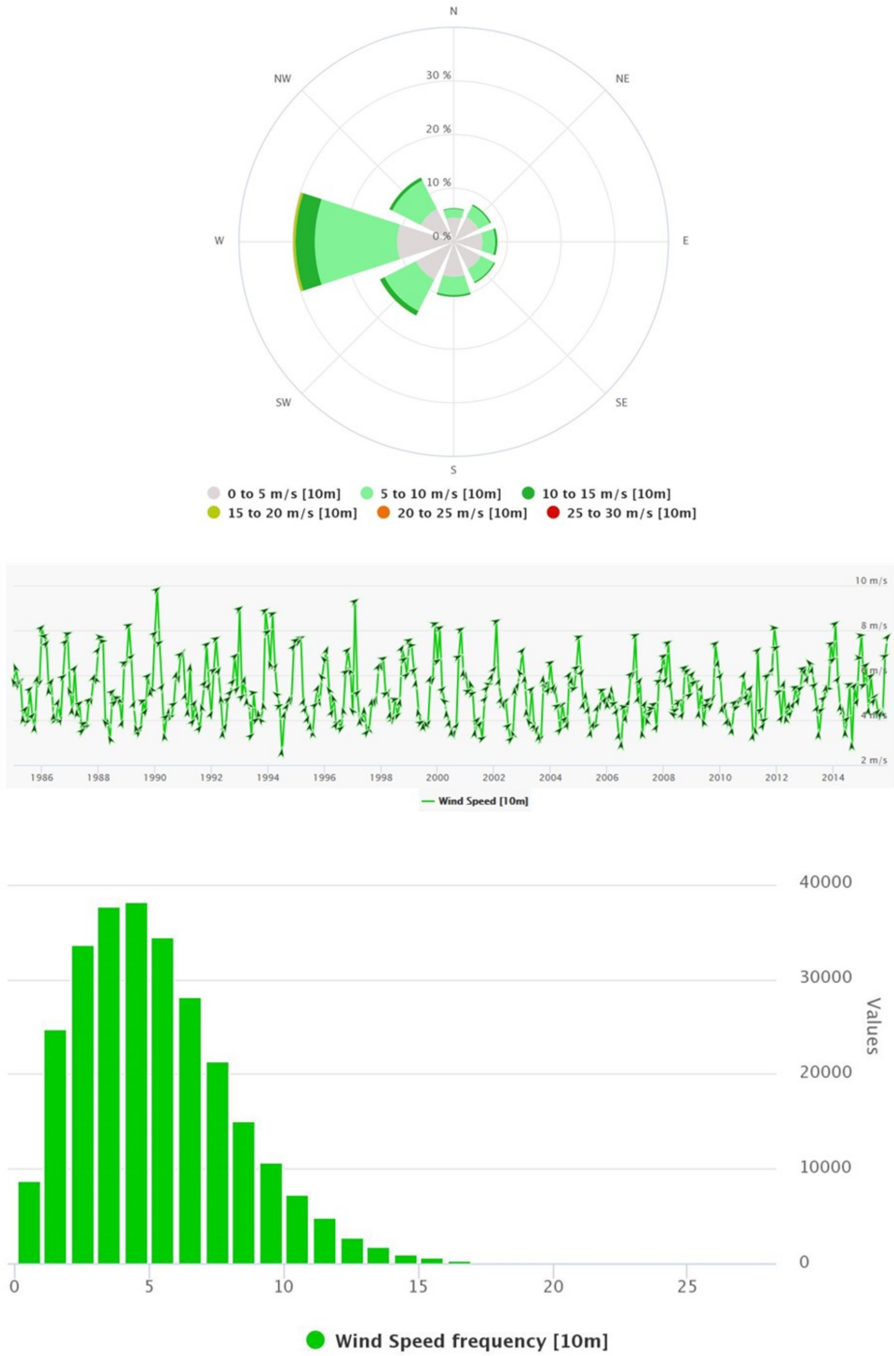


Figure 3.13: Mean Wind Conditions

Comparison with the on-site weather station

The wind profile built using the data from Dublin Airport, is also compared with the one obtained using the data collected on-site in the period 14th Dec 2018 – 10 Jan 2019 (28 days).

Figure 3.14 shows B-Fluid weather station.

Figure 3.14: B-Fluid On-site Weather Station

Figures 3.15 and 3.16 respectively show wind speed and gust and wind direction recorded by the on-site weather station during the 28 days.

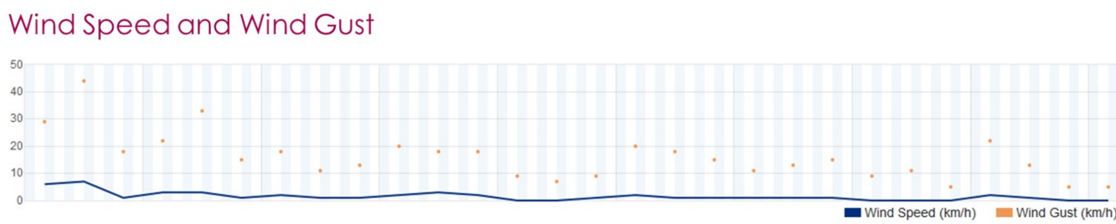


Figure 3.15: Wind speed and Wind Gust recorded by B-Fluid On-site Weather Station

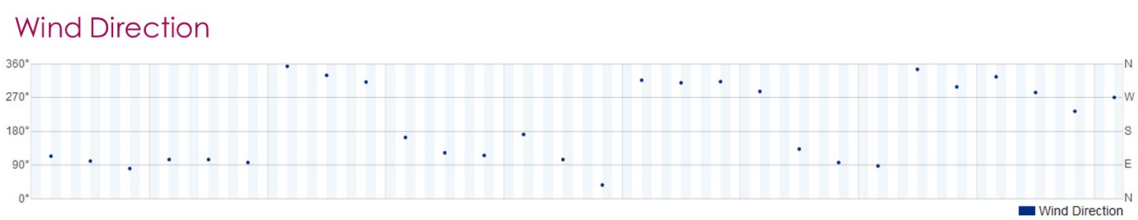


Figure 3.16: Wind direction recorded by B-Fluid On-site Weather Station

As it is possible to assess from the comparison between on-site and airport measurements, presented in Figure 3.17 and 3.18, the wind speed daily mean and the wind gust daily mean recorded on site follow the same pattern as the one recorded at Dublin Airport. However, the wind speed levels and the gust wind speed levels registered on-site are quite lower. This is due to the fact that the site is located in the urban environment thus much more shielded if compared with Dublin Airport. This confirms that using wind data from Dublin Airport ensures a conservative analysis of the wind impact on Shoreline GA1 Project despite its location not far from the coast.

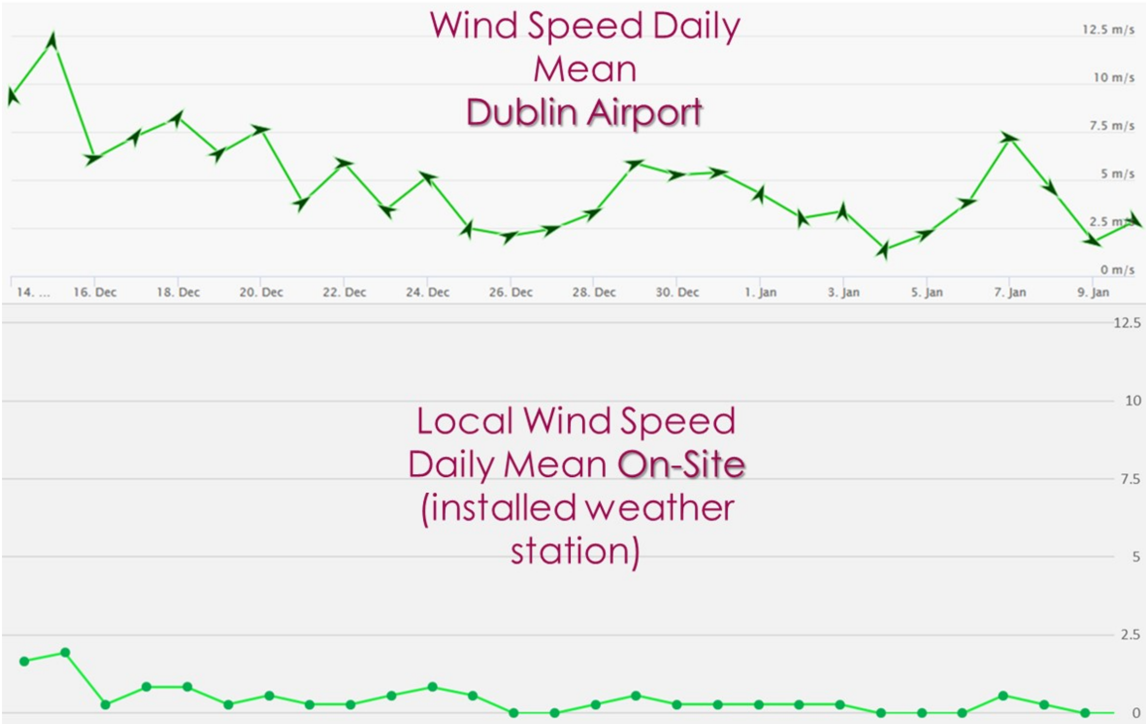


Figure 3.17: Wind Speed Daily Mean Comparison

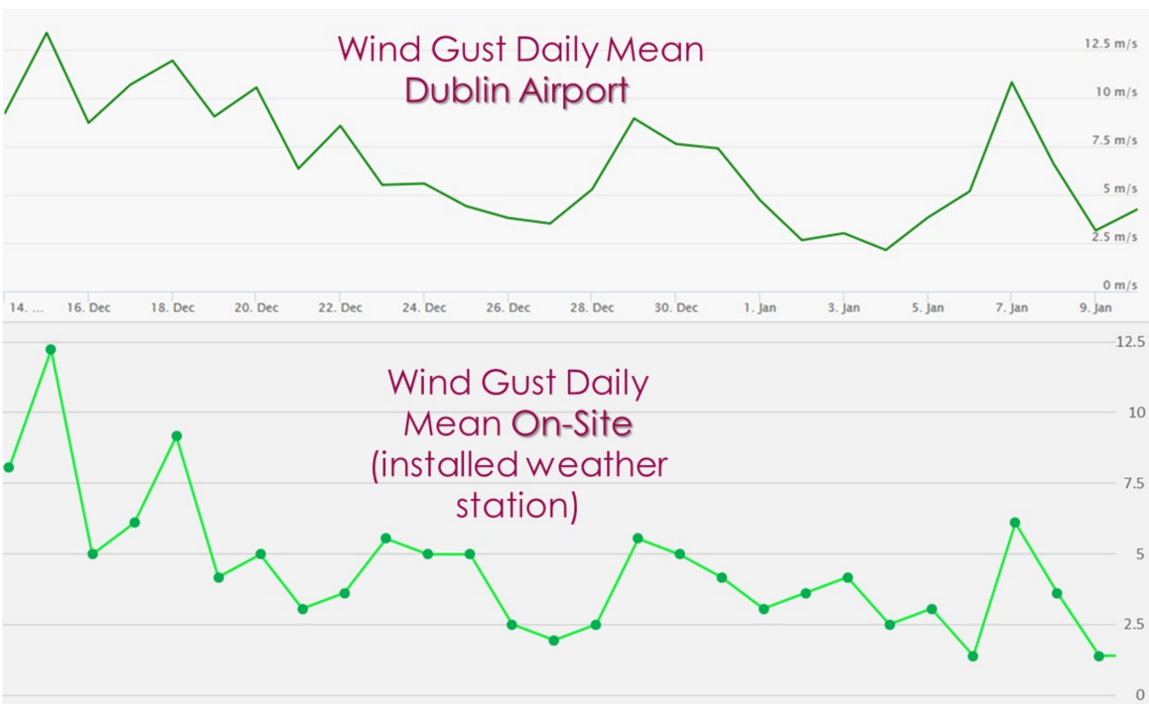


Figure 3.18: Wind Gust Daily Mean Comparison

Open Area Functions

The assessment of pedestrian wind comfort in urban areas focuses on activities people are likely to perform in the open space between buildings, which are in turn related to a specific function. For example the activity sitting a longer period of time is typically associated with the location of a street café or similar. Such combinations of activity and area can be grouped in four main categories:

A	Sitting for a long period of time; laying steady position; pedestrian sitting; *Terrace; street café or restaurant; open field theatre; pool*
B	Pedestrian standing; standing/sitting over a short period of time; short steady positions; *Public park; playing field; shopping street; mall*
C	Pedestrian walking; leisurely walking; normal walking; ramble; stroll *Walkway; building entrance; shopping street; mall*
D	Objective business walking; brisk or fast walking *Car park; avenue; sidewalk; belvedere*

Figure 3.19: Main Categories for Pedestrian Activities

Baseline Environment Summary

The wind desktop study of the existing receiving environment showed that:

- The wind profile was built using the annual average of meteorology data collected at Dublin Airport Weather Station. In particular, the local wind climate was determined from historical meteorological data recorded 10 m above ground level at Dublin Airport. 18 different scenarios were selected in order to take into consideration all the different relevant wind directions. In particular, a total of 18 compass directions on the wind rose are selected. For each direction, the reference wind speed is set to the 5% exceedance wind speed for that direction, i.e. the wind speed that is exceeded for over 5% of the time whenever that wind direction occurs.

- The wind profile built using the data from Dublin Airport, is also compared with the one obtained using the data collected on-site. Except few differences, both the wind speed daily mean and the wind gust daily mean recorded on-site follow the same patterns as the ones recorded at Dublin Airport. The speed levels registered on-site are in few cases slightly lower. This is due to the fact that, despite its vicinity to the coast, the Site is located close to the urban environment thus much more shielded if compared with Dublin Airport. This confirms the fact that using wind data from Dublin Airport still ensures a conservative analysis of the wind impact on the proposed Project.

- The prevailing wind directions for the site are identified in the West, West South-West and South-East with magnitude of approximately 6m/s.

4. CHARACTERISTICS OF THE PROPOSED DEVELOPMENT

4.1 DESCRIPTION OF PROPOSED DEVELOPMENT

The development will consist of alterations to the permitted development, as permitted under FCC Reg. Ref. 16A/0412, ABP Reg. Ref. ABP-248970 (as amended by F20A/0258 and F21A/0046) of 544 no. residential units (385 no. apartments and 159 no. houses), retail and a crèche, to the development of 882 no. new residential dwellings (747 no. apartments, 135 no. houses), residential tenant amenity, retail, crèche, parking, and public realm, over a total site area of c. 9.1 ha, and site development area of c. 8.89 ha. Landscaping will include extensive communal amenity areas, and significant public open space provision.

Full details on the background, Site history and the proposed Project is provided in Chapter 5 of the EIAR report (Description of the Proposed Project).

The images in Figures 4.1 to 4.5 show the development masterplan, scale, massing and elevations.

Figure 4.1: Project Shoreline GA1 Masterplan in the red line boundary

Figure 4.2: Project Shoreline GA1 development site (CFD modelled)

Figure 4.3: Project Shoreline GA1 development site (CFD modelled)

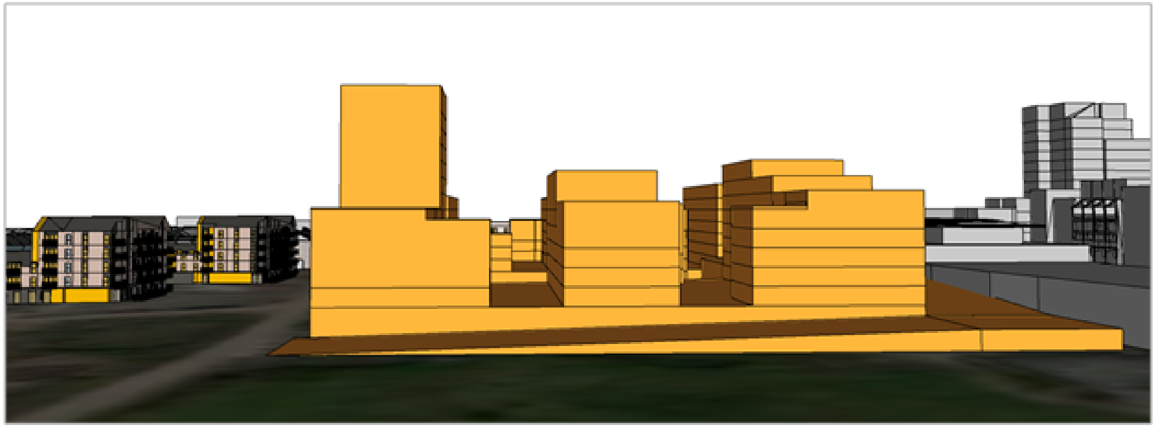


Figure 4.4: Project Shoreline GA1 - Elevation Layout Block D

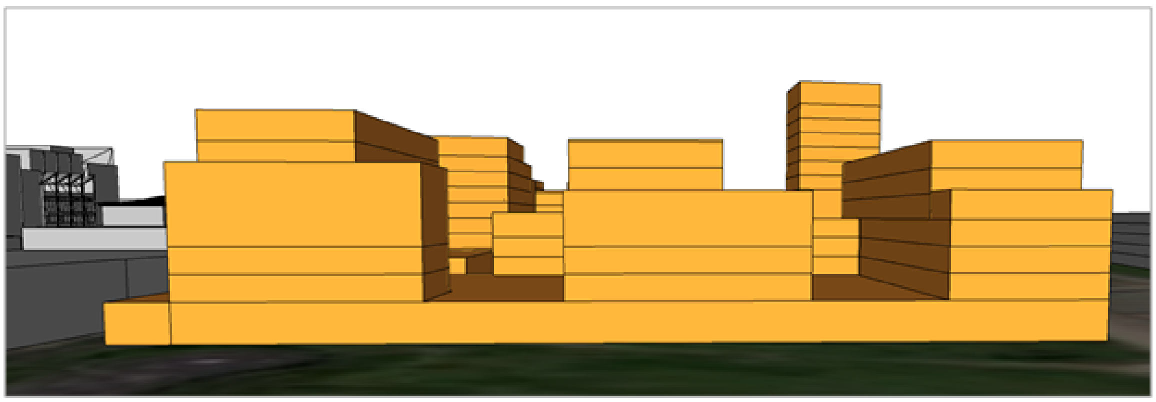


Figure 4.5: Project Shoreline GA1 - Elevation Layout Block A

5. POTENTIAL IMPACT OF PROPOSED DEVELOPMENT

Construction Phase

The effects on wind microclimate at the Site during the construction phase have been assessed using professional judgement. As construction of the Proposed Development progresses the wind conditions at the Site would gradually adjust to those of the completed development, and mitigation measures would need to be implemented before completion and operation.

Operational Phase

The construction of the development can potentially calm the existing wind condition in the area by providing further "urban context" to the existing topography, however, some areas can become more critical from a wind acceleration and re-circulation point of view and phenomena such as downwash, funnelling and downdraft can be experienced as well. The development, in principle, offer more drag to the incoming wind profile as detailed in the session that follow (see "Planetary boundary layer and terrain roughness"). Consequently, the wind at lower level can reduce and modify its flow path directions. However, zones of re-circulations caused by the re-direction of the wind can also been expected, especially in the West South West direction where some funnelling can potentially occur. The potential impact of the development on the local wind microclimate have been quantify through the modelling of different wind scenarios and where areas of criticism have been detected, appropriate mitigation has been implemented and modelled to verify the reduction of the criticism and the suitability of the specific area to the designated pedestrian activity.

Cumulative Qualitative Assessment

In order to conduct the wind comfort assessment, Figures 5.1 and 5.2 show the orientation of the development. It should be kept in mind that this analysis is only indicative and based on experience and fundamental fluid mechanical principles.

In general, this qualitative assessment is more conservative than the quantitative assessment resulting from the more detailed CFD analysis.

As presented in previous Sections, the site is receiving a predominant wind from South-West, which correspond to the dominant wind direction in Dublin. For this reason the qualitative assessment is performed for this condition.

Figure 5.1: Orientation of the Shoreline GA1 Proposed development within the red line

Figure 5.2: Orientation of the proposed GA1 development in colour, existing buildings (including permitted Clongriffin developments, but not built) in grey – Proposed GA2 in purple (permitted) and GA3 potential future planning proposal.

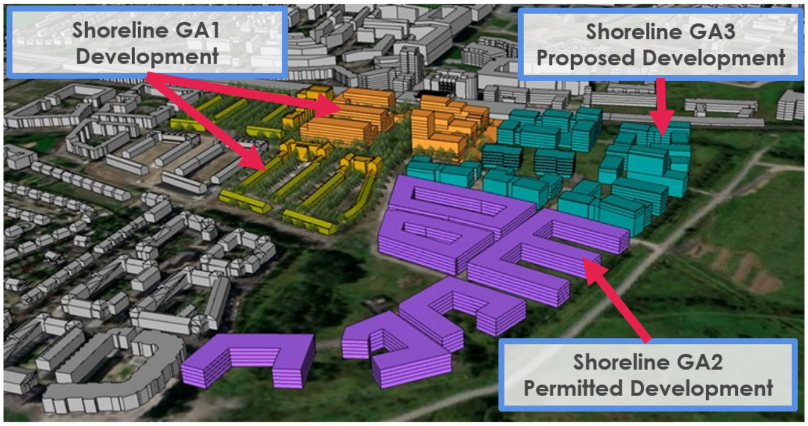


Figure 5.3: Orientation of the proposed GA1 development in colour, existing buildings (including permitted Clongriffin developments, but not built) in grey – Proposed GA02 in purple (permitted) and GA03 potential future planning proposal.

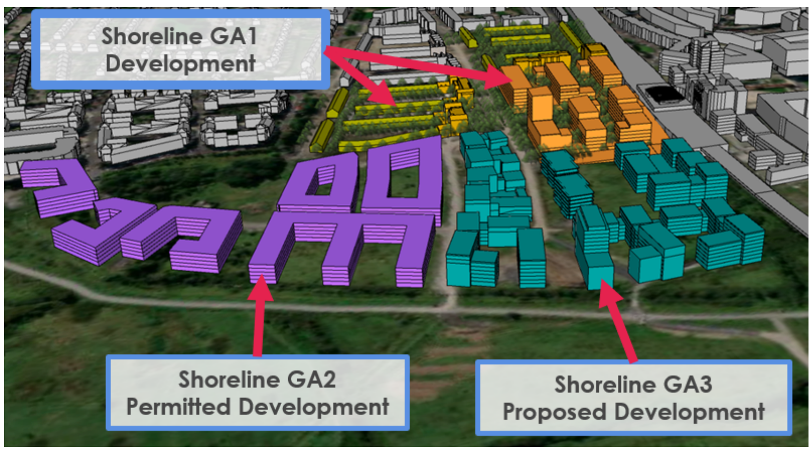


Figure 5.4: Orientation of the proposed GA1 development in colour, existing buildings (including permitted Clongriffin developments, but not built) in grey – Proposed GA02 in purple (permitted) and GA3 potential future planning proposal.

POTENTIAL DOWNDRAFT EFFECT

The building heights varies across the site, this can create phenomena of downdraft in some areas. This can be seen when the leeward face of a low building faces the windward face of a tall building, it causes an increase in the downward flow of wind on the windward face of the tall building.

POTENTIAL FUNNELLING EFFECT

The buildings location appear to converge on the central area of “Ireland Eye Avenue”, this distribution is likely to create phenomena of funnelling/wind canyon causing acceleration of wind speeds. The intensity of this acceleration is influenced by the building heights, size of the facades, building separation distance and building orientation.

POTENTIAL DOWNWASH EFFECT

There is an intention of constructing tall buildings within the development. In this case, if the height ratio between the proposed tall buildings and their surrounding is increased significantly, a Downwash effect will be likely to occur. The tall buildings tends to deflect the wind downwards, causing accelerated wind speeds at pedestrian level and around the windward corners of the buildings.

Planetary Boundary Layer And Terrain roughness

Due to aerodynamic drag, there is a wind gradient in the wind flow just a few hundred meters above the Earth's surface – "the surface layer of the planetary boundary layer".

Wind speed increases with increasing height above the ground, starting from zero, due to the no-slip condition. In particular, the wind velocity profile is parabolic. Flow near the surface encounters obstacles that reduce the wind speed, and introduce random vertical and horizontal velocity components. This turbulence causes vertical mixing between the air moving horizontally at one level, and the air at those levels immediately above and below it. For this reason, the velocity profile is given by a fluctuating velocity along a mean velocity value. Figure 5.5 shows the wind velocity profile, as described above.

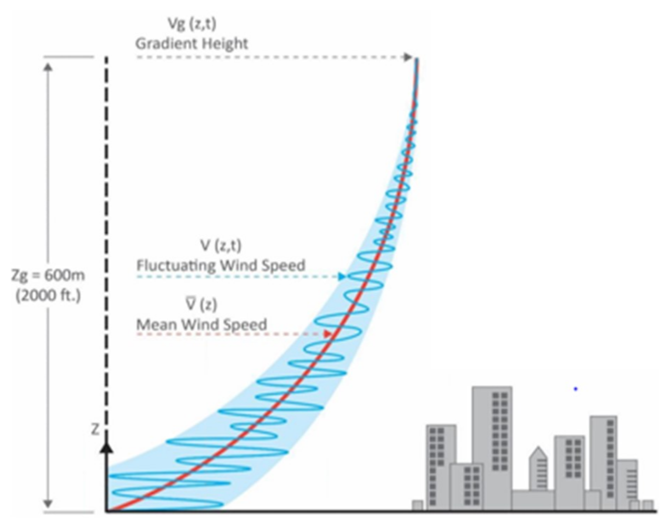


Figure 5.5: Wind Velocity Profile

Two effects influence the shape of the wind speed profile:

- Contours of the terrain: a rising terrain such as an escarpment will produce a fuller profile at the top of the slope compared with the profile of the wind approaching the slope.
- Aerodynamic 'roughness' of the upstream terrain: natural roughness in the form of woods or man-made roughness in the form of buildings. Obstructions near the ground create turbulence and friction, lowering the average wind speed. The higher the obstructions, the greater the turbulence and the lower the wind speed. As a general rule, wind speed increases with height.

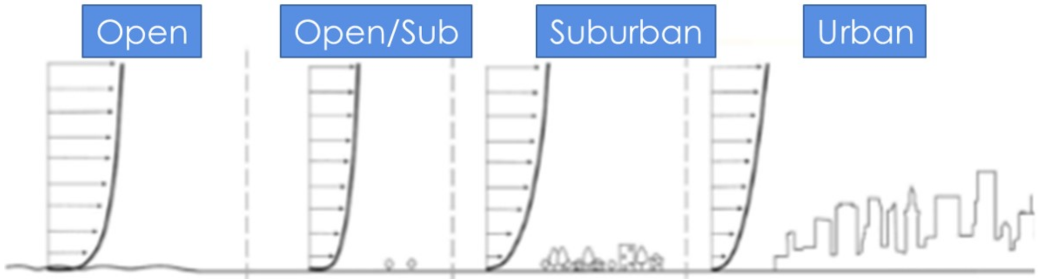


Figure 5.6: Wind Velocity Profile for different terrains

In order to assess the wind conditions in a particular area, it is important to know (Figure 5.7):

- Weather conditions in the area
- Location and orientation of the site
- Buildings distribution in the area
- Flow patterns at the building

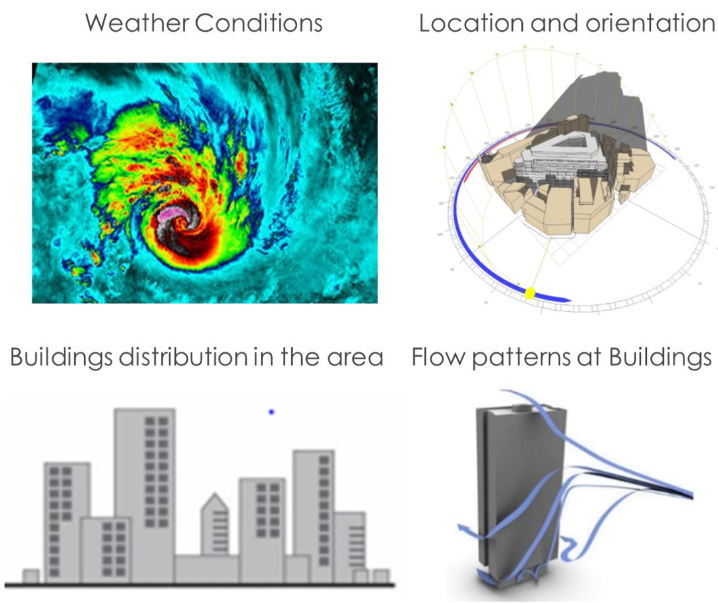


Figure 5.7: Parameters to know for Wind Conditions Assessment

Moreover, it is important to understand key flow features (Figure 5.8):

- Broad Building Face creates “DOWNWASH”
- Low Building Upwind Increases Wind Effects
- Gaps Between Buildings Increases Wind Velocity
- Low Building Upwind Increases Wind Effects

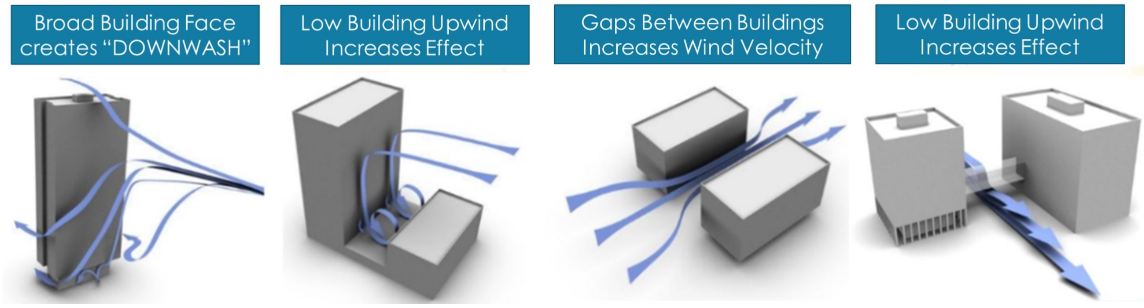


Figure 5.8: Parameters to know for Wind Conditions Assessment

6. MITIGATION MEASURES

6.1 MITIGATION MEASURES

6.1.1 Construction Phase

The effects on wind microclimate at the Site during the construction phase have been assessed using professional judgement.

As construction of the Proposed Development progresses the wind conditions at the Site would gradually adjust to those of the completed development, and mitigation measures would need to be implemented before completion and operation.

6.1.2 Operational Phase

As stated above, if the wind conditions exceed the threshold, these conditions become unacceptable for favourable pedestrian activities and mitigation measure should be accounted for.

Mitigation measures include:

- **Landscaping** : the use vegetation to protect buildings from wind

- **Sculptural screening**(solid or porous): to either deflect the wind or bleed the wind by removing its energy.

- **Canopies and Wind gutters** : horizontal canopies are used to deflect the wind and redirect the wind around the building and above the canopy.

In particular, it is possible to summarise the different flow features and the corresponding mitigation option as follows (Figures 6.1 and 6.2):

- **Downwash Effects**: when wind hits the windward face of a tall building, the building tends to deflect the wind downwards, causing accelerated wind speeds at pedestrian level and around the windward corners of the building. This can occur when Tall and wide building facades face the prevailing winds.

- **Downdraft Effects**: When the leeward face of a low building faces the windward face of a tall building, it causes an increase in the downward flow of wind on the windward face of the tall building. This results in accelerated winds at pedestrian level in the space between the two buildings and around the windward corners of the tall building.

  Example of Typical Mitigation Options:
  - To mitigate unwanted wind effects it is recommended to introduce a base building or podium with a step back, and setting back a tower relative to the base building, the downward wind flow can be deflected, resulting in reduced wind speed at pedestrian level.
  - Landscaping the base building roof and tower step back, wind speeds at grade can be further reduced, and wind conditions on the base building roof can improve.

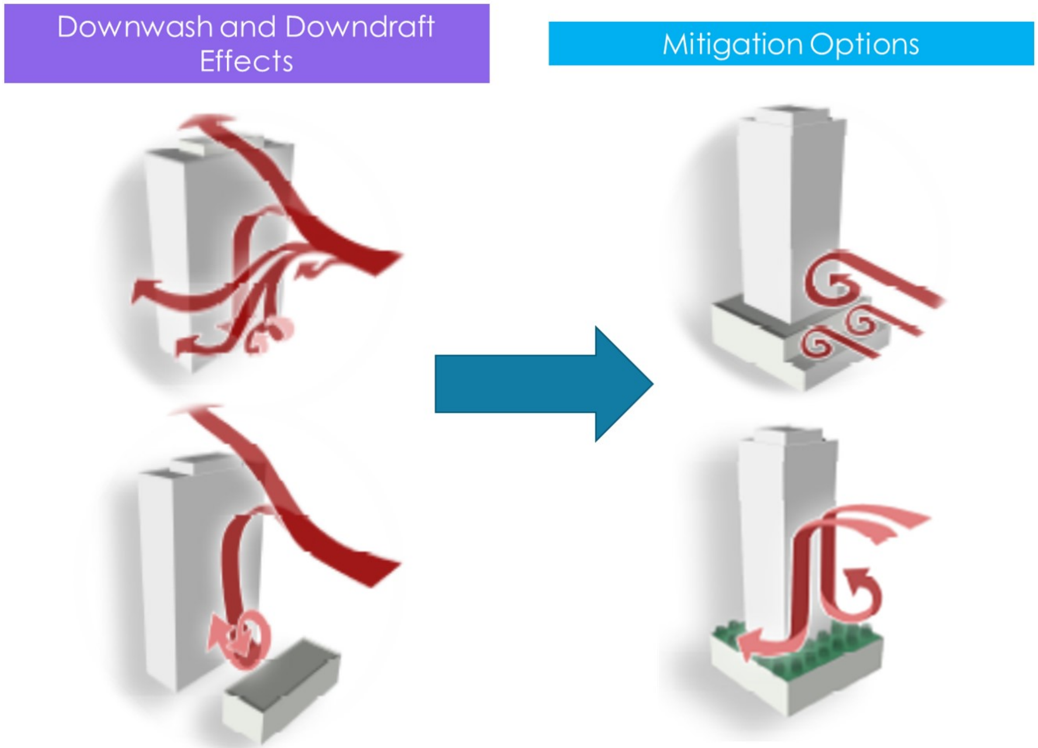


Figure 6.1: Mitigation Measures for Downwash and Downdraft Effects

- **Funneling Effects**: Wind speed is accelerated when wind is funneled between two buildings. This is referred to as the "wind canyon effect". The intensity of the acceleration is influenced by the building heights, size of the facades, building separation distance and building orientation. Similar effect can be noticed when a bridge is connecting two buildings, the wind passing below the bridge is accelerated, therefore pedestrians can experience high uncomfortable velocities of wind .

  Example of Typical Mitigation Options:
  - A horizontal canopy on the windward face of a base building can improve pedestrian level wind conditions. Parapet walls around a canopy can make the canopy more effective.
  - Sloped canopies only provide partial deflection of downward wind flow.
  - A colonnade on the windward face of the base building provides the pedestrian with a calm area where to walk while being protected or a breeze walking space outside the colonnade zone.

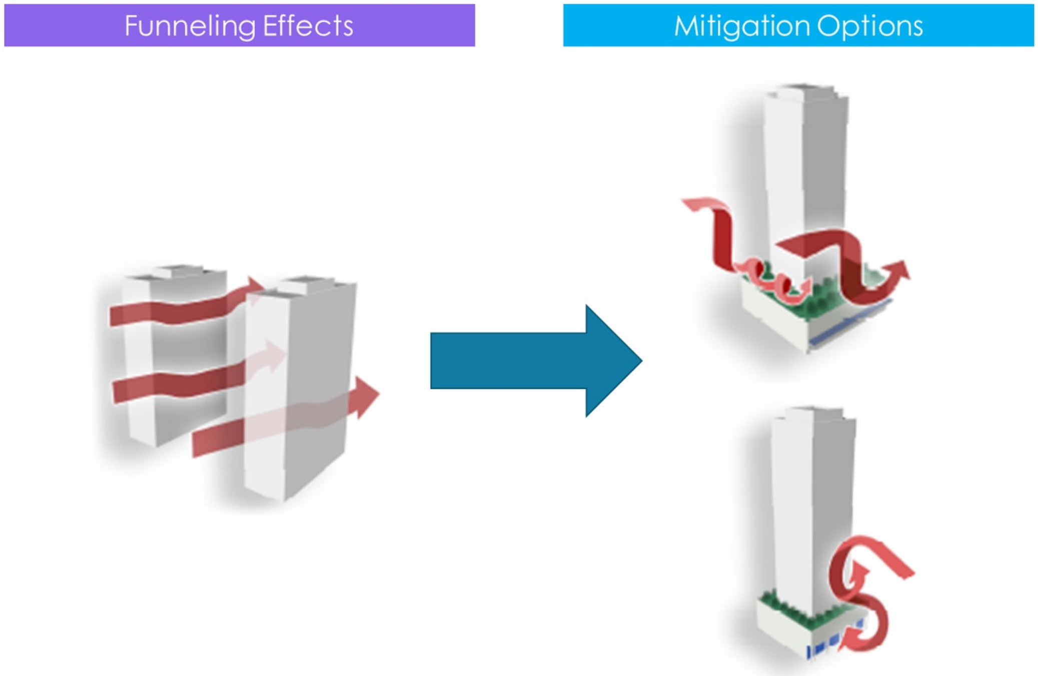


Figure 6.2: Mitigation Measures for Funnelling Effects

The mitigation measures utilized for the proposed Project is landscaping using tree plantings, which creates a reduced vorticity, making it possible to reduce incoming velocities, thus reducing wind impacts on the buildings, public spaces or pedestrian paths. Small particles randomly distributed within an area are normally used in numerical modelling to model trees, as shown in Figures 6.3 and 6.4. These introduce a pressure drop in the model and therefore causes the wind to reduce its speed when passing through the trees, as expected in reality. The CFD plot shown in Figure 6.5 demonstrates this effect. Trees are introduced into the model as porous mediums, this to reproduce the velocity modifications and pressure drop that vegetation will create on the incoming air flows. These porous mediums are illustrated in the form of 3D boxes in geometry as shown in Figure 6.12.

Figure 6.6 shows a plan view of the mitigation measures that will be implemented as agreed with BSLArch (Project Landscape Architects) around the proposed Project. Figures 6.7 and 6.8 show the CFD modelling of the trees. Figure 6.9 shows in detail the mitigation measures implemented around Block A1, A2 and A3. Figures 6.10 and 6.11 respectively show in detail the mitigation measures implemented as linear parks in the proposed Project.

Landscape Trees Modelling (Using Porous Media)

Through CFD Modelling, it is possible to implement the effects of landscaping trees on the wind flowing through an urban environment. Urban landscape managers, local councils and architects can now observe and assess the effects of landscaping trees in their urban landscape models. The landscape trees are simulated as comprising effects of porous zones within the urban environments. This is an essential tool for accurately assessing the actual wind speed and pattern at a pedestrian level when landscape is available. Figures 6.3 to Figure 6.5 show the modelling approach of utilizing porous media within the CFD numeric code to implement the effect of landscape within Shoreline GA1 - Baldoyle, Dublin 13.

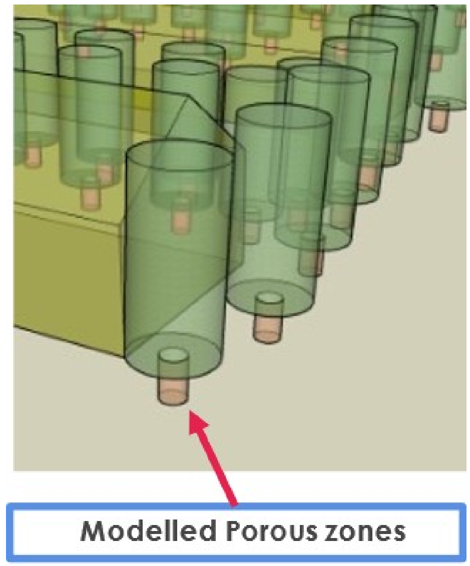


Figure 6.3: CFD Modelleling of a tree

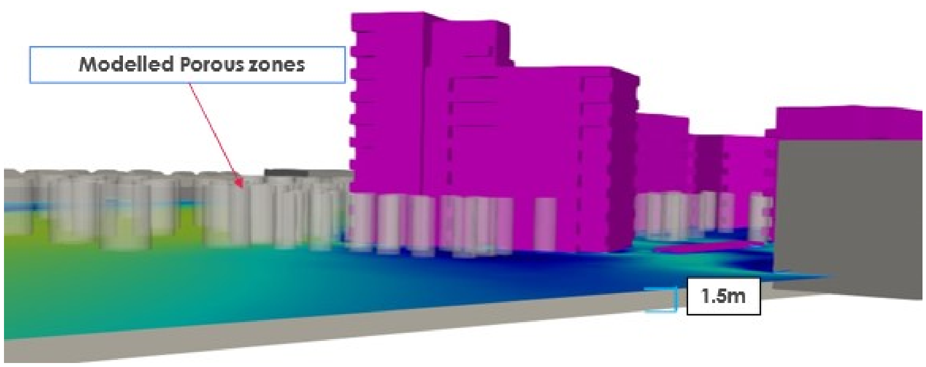


Figure 6.4: CFD Modelleling of a tree

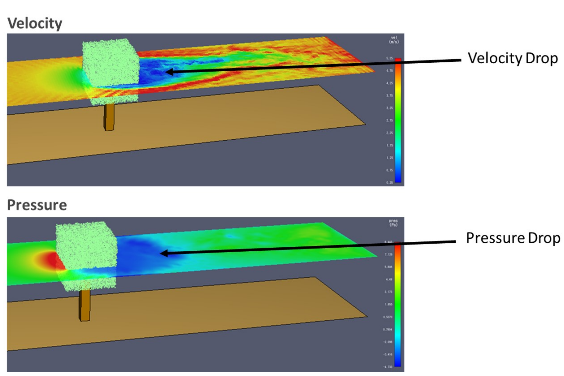


Figure 6.5: Generic Result of Wind Impacting on a Tree

Figure 6.6: Plan View of the Mitigation Measures that will be implemented around the Project Shoreline GA1 Development

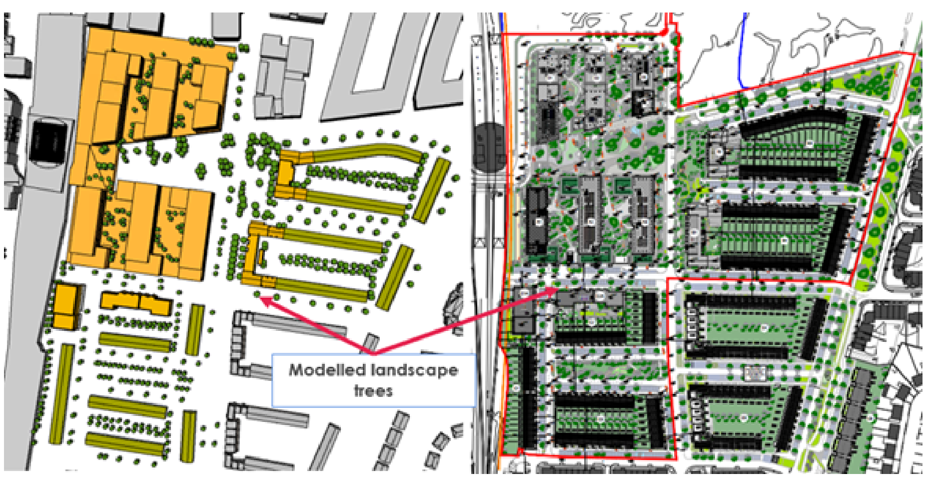


Figure 6.7: CFD Modelleling of a tree

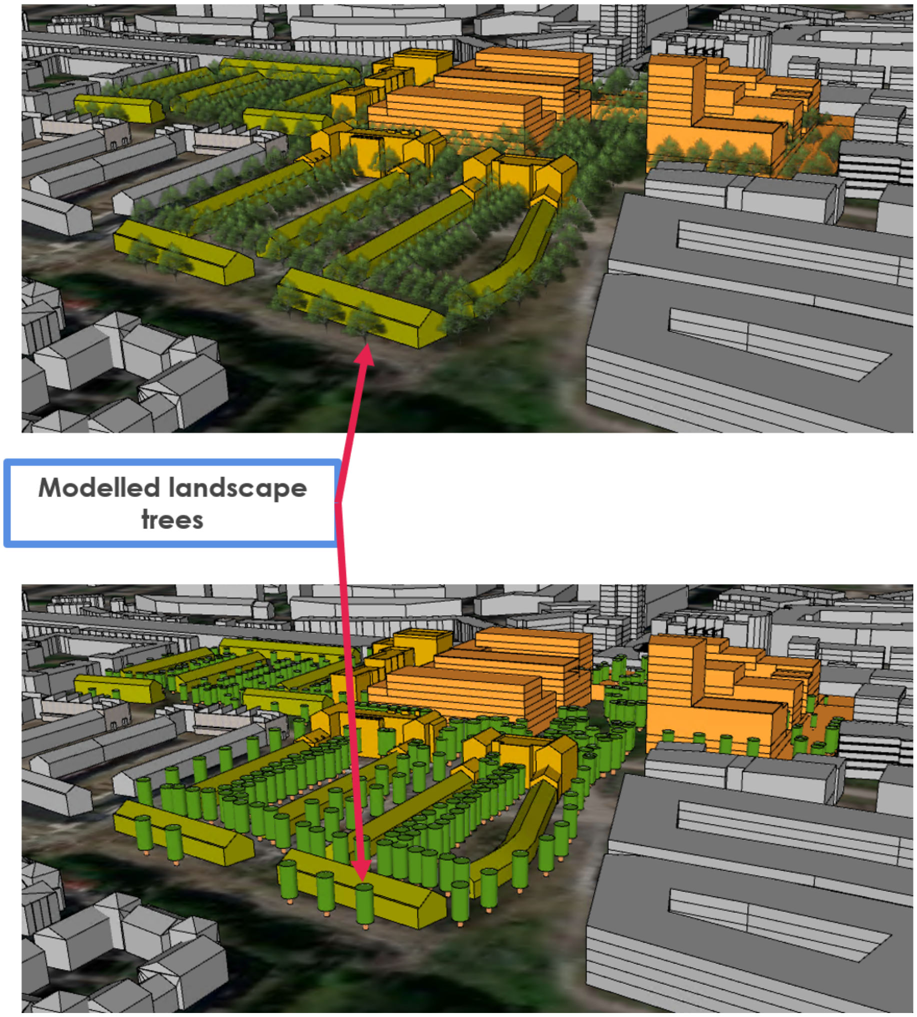


Figure 6.8: CFD Modelleling of a tree

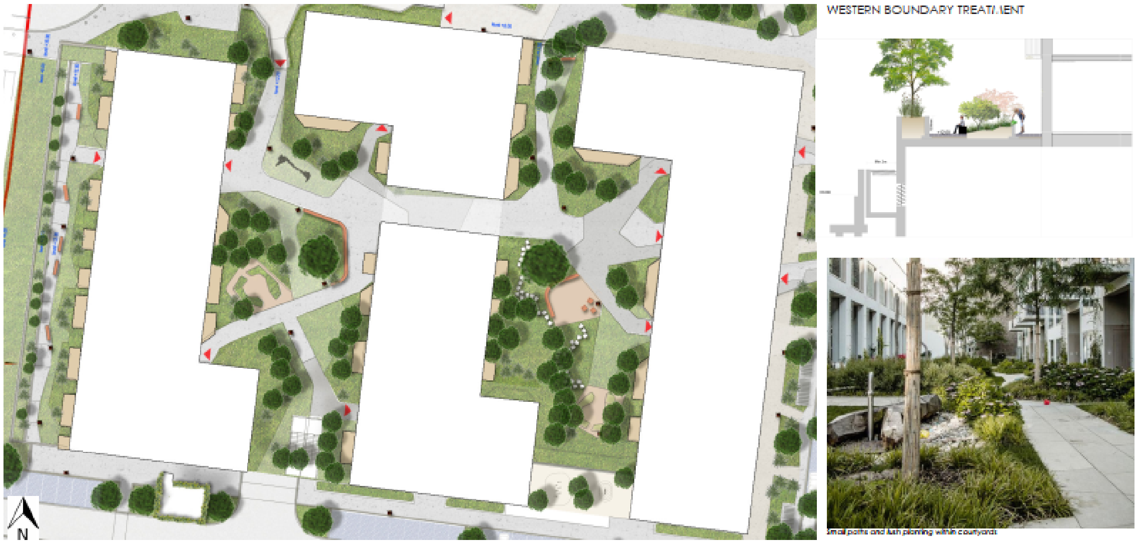


Figure 6.9: Mitigation Measures that will be implemented around Block A1, A2 and A3.

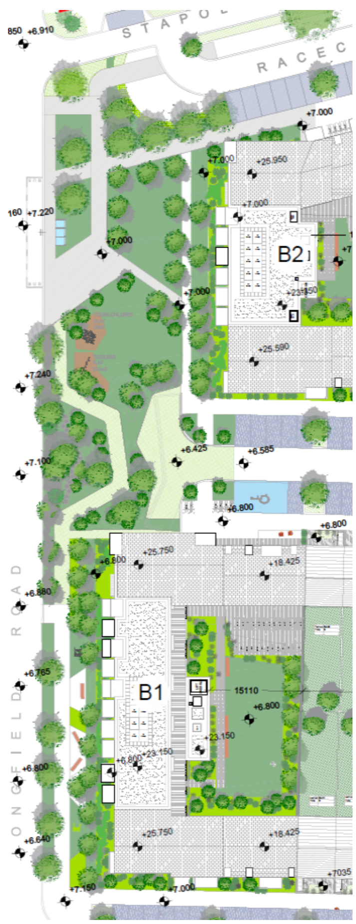
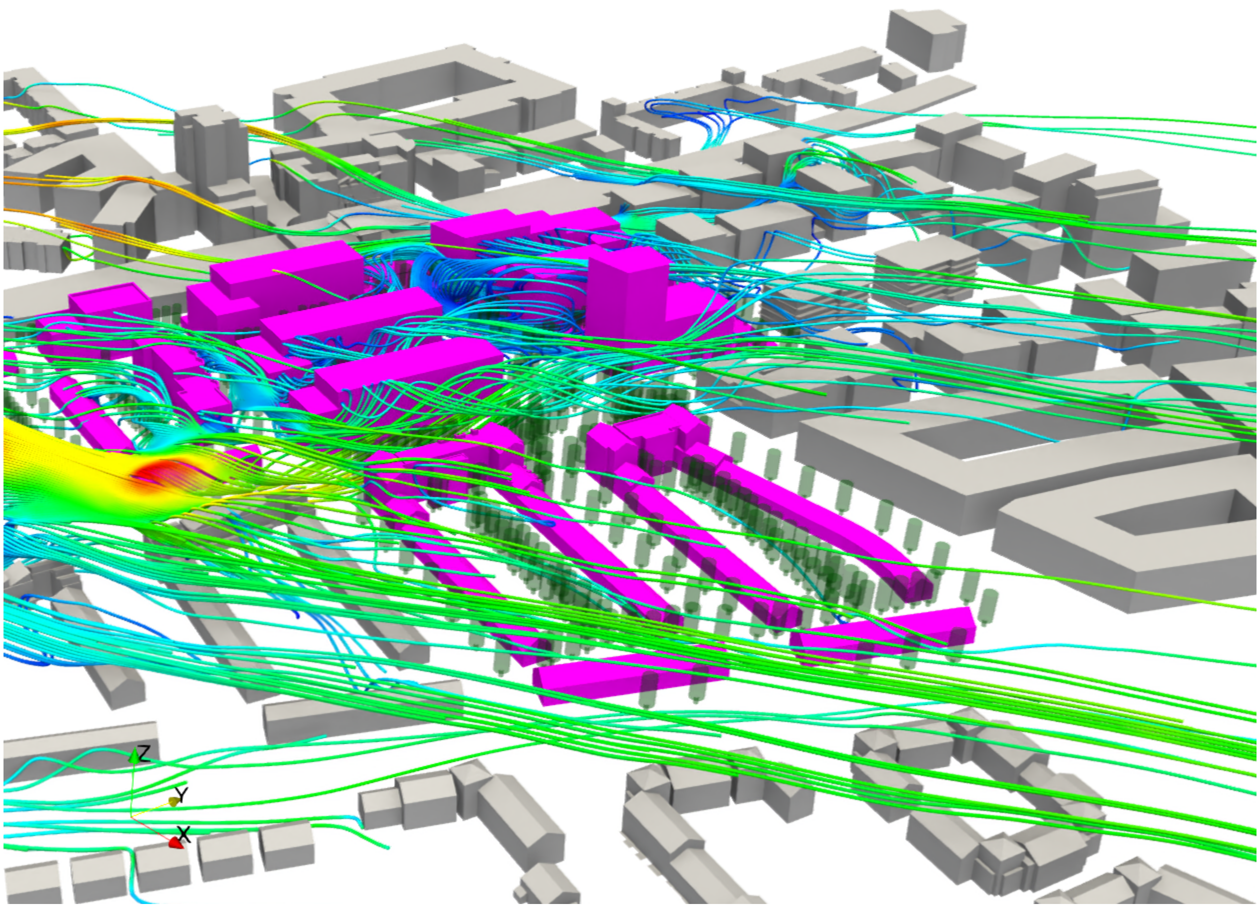


Figure 6.10: Mitigation Measures - linear park 1

Figure 6.11: Mitigation Measures - linear park 2

Figure 6.12: Mitigation Measures in CFD model

7. PREDICTED IMPACT OF THE PROPOSED DEVELOPMENT



This section assessed the potential impact of the proposed development on the already existing environment, and the suitability of the proposed development to create and maintain a suitable and comfortable environment for different pedestrian activities.

CFD Model Details Of The Proposed Development

This subsection describes all features included in the geometrical and physical representation of the proposed Project CFD model. Any object which may have significant impact on wind movement and circulation are represented within the model. To be accurate, the structural layout of the building being modelled should include only the obstacles, blockages, openings and closures which can impact the wind around the building. It is important to remember that a CFD simulation approximates reality, so providing more details of the geometry within the model will not necessarily increase the understanding of the bulk flows in the real environment.

Modelled Geometry

The proposed Project Model is shown in Figures 7.1 and 7.2. The modelled layout and dimensions of the surrounding environment are outlined in the table below (Table 7.1).

In order to represent reality and consider the actual wind impacting on the site, the modelled area for the wind modelling study comprises a wider urban area of $2km^2$ around the Project Shoreline GA1 Development, as shown.

	MODELLED CFD ENVIRONMENT DIMENSIONS		
	Width	Length	Height
CFD Mesh Domain	1500m approx	1500m approx	200m approx

Table 7.1: Modelled Environment Dimensions

Figure 7.1: Project Shoreline GA1 Development - Extents of Modelled Area

Figure 7.2: Project Shoreline GA1 Development

Boundary Conditions

A rectangular computational domain was used for the analysis. The wind directions were altered without changing the computational mesh. For each simulation scenario, an initial wind velocity was set according to the statistical weather data collected in order to consider the worst case scenario. Building surfaces within the model are specified as 'no slip' boundary conditions. This condition ensures that flow moving parallel to a surface is brought to rest at the point where it meets the surface. Air flow inlet boundaries possess the 'Inlet' wind profile velocity patch boundary condition with its appropriate inflow turbulence intensity and dissipation rates. Air exits the domain at the 'pressure outlet' boundary condition.

The wind velocity data provided by the historical data collection and by the local data measuring are used in the formula below for the logarithmic wind profile to specify the wind velocity profile (wind velocity at different heights) to be applied within the CFD model:

$$v_2 = v_1 \cdot \frac{ln\frac{h_2}{z_0}}{ln\frac{h_1}{z_0}} \tag{7.1}$$

where:

- v_1 = wind speed measured at the reference height h_1
- h_1 = reference height to measure v_1
- h_2 = height of the wind speed v_2 calculated for the wind profile
- z_0 = 0.4 [m] roughness length selected (see table in Figure 7.3 below)

Roughness Classes and Lengths

Roughness class	Roughness length z_0	Land cover types
0	0.0002 m	Water surfaces: seas and Lakes
0.5	0.0024 m	Open terrain with smooth surface, e.g. concrete, airport runways, mown grass etc.
1	0.03 m	Open agricultural land without fences and hedges; maybe some far apart buildings and very gentle hills
1.5	0.055 m	Agricultural land with a few buildings and 8 m high hedges seperated by more than 1 km
2	0.1 m	Agricultural land with a few buildings and 8 m high hedges seperated by approx. 500 m
2.5	0.2 m	Agricultural land with many trees, bushes and plants, or 8 m high hedges seperated by approx. 250 m
3	0.4 m	Towns, villages, agricultural land with many or high hedges, forests and very rough and uneven terrain
3.5	0.6 m	Large towns with high buildings
4	1.6 m	Large cities with high buildings and skyscrapers

Figure 7.3: Roughness length and class to be used for the logarithmic wind profile

The wind profile used in the model has been calculated using the formula above and is represented in Figure 7.4.

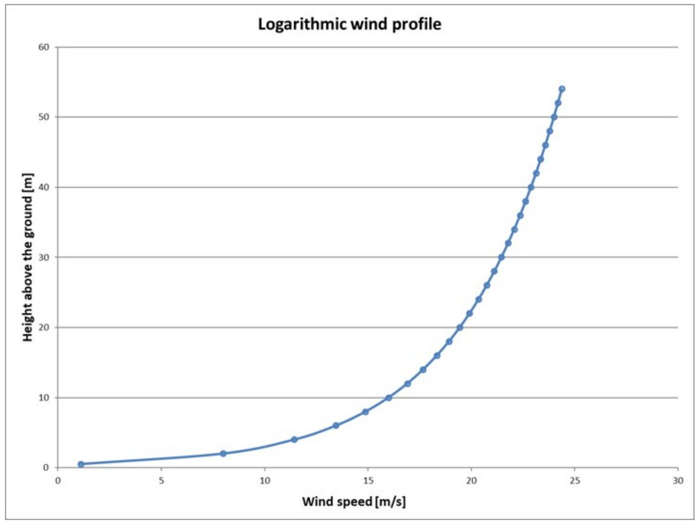


Figure 7.4: Wind profile used in the model

Computational Mesh

The level of accuracy of the CFD results are determined by the level of refinement of the computational mesh. A mesh independent analysis is carried out prior to detailed simulation for final results. Details of parameters utilized for air and the computational mesh are presented in Table 7.2, while an example of the utilized computational mesh grid is as shown in Figures 7.5 and 7.7.

The grid follows the principles of the 'Finite Volume Method', which implies that the solution of the model equations is calculated at discrete points (nodes) on a three-dimensional grid, which includes all the flow volume of interest. The mathematical solution for the flow is calculated at the center of each of these cells and then an interpolation function is used by the software to provide the results in the entire domain.

AIR AND COMPUTATIONAL MESH PARAMETERS	
Air Density ρ	$1.2kg/m^3$
Ambient Temperature (T)	$288K(approx.15C^{\circ})$
Mesh cell sizes	Approx. 0.1m - 0.5m At Development Building Approx. 0.5m - 1.5m At Environment Buildings Approx. 2m - 5m Elsewhere
Background cell size ratio	1:1:1 (dx:dy:dz)
Total mesh size	Approx. cells number = 15 million

Table 7.2: Air and Computational Mesh Paramenters

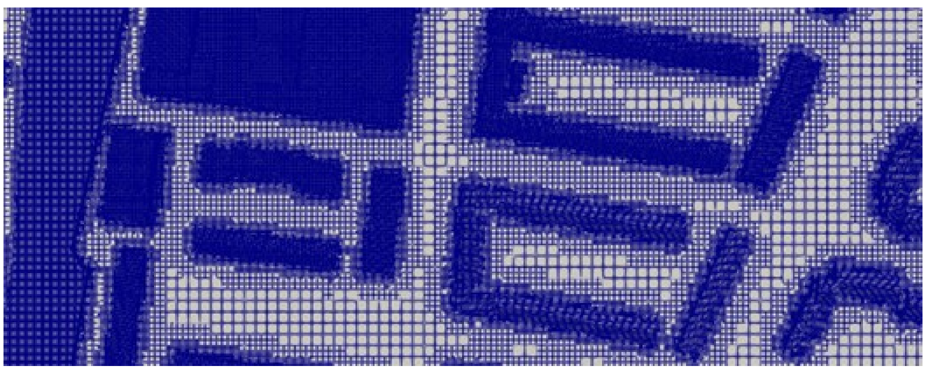


Figure 7.5: Proposed Project Domain - Computational Mesh Utilized

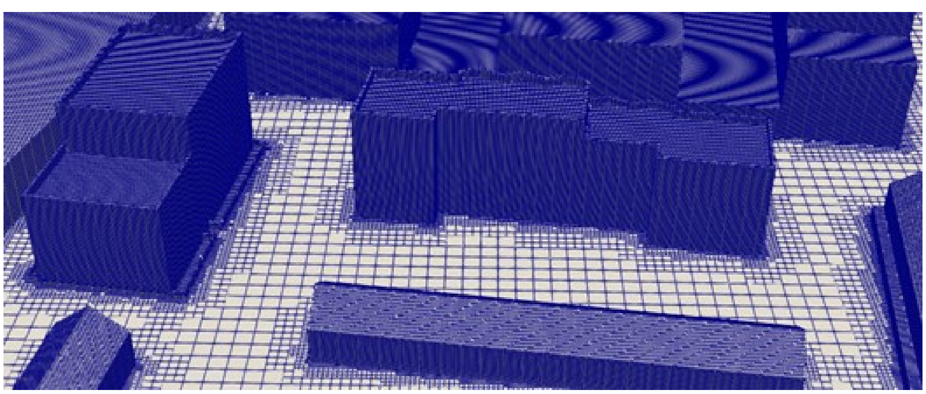


Figure 7.6: Proposed Project - Computational Mesh Utilized

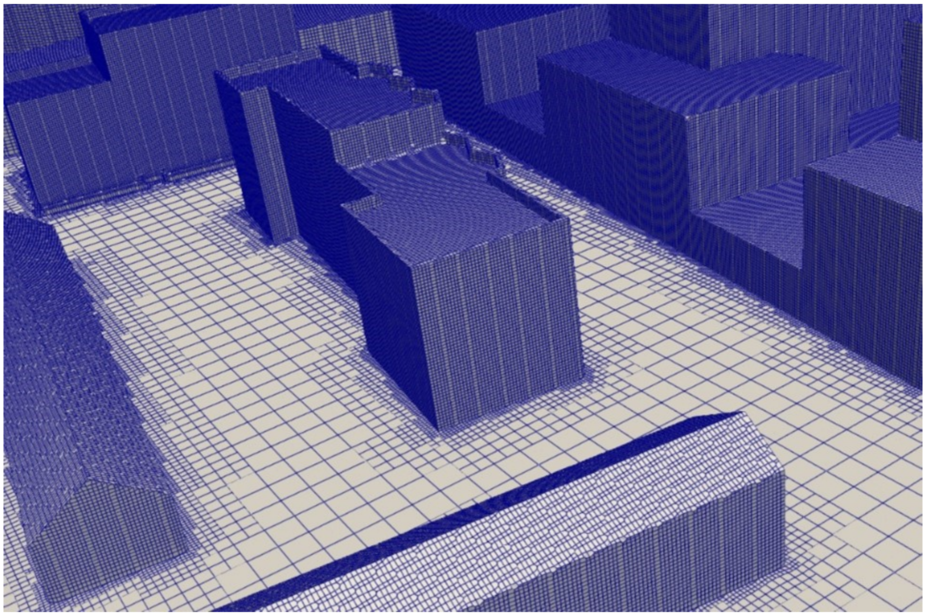


Figure 7.7: Proposed Project - Computational Mesh Utilized

7.0.1 Construction Phase

The possible effects on wind micro-climate at the site during the construction phase of Project Shoreline GA1 Development has not been directly assessed but was evaluated based on professional judgement. Statistical Dublin historical wind data have been used to carry out this analysis based on the fact that the dominant wind direction is from South-West.

As the finalization of the development proceeds, the wind setting at the site would progressively conform to those of the completed development. It is possible that in the final stages of construction, implementation of the mitigation measures would be needed in areas that are expected to be windier than others should in case some areas of the site are expected to be functional before the construction is finalized.

Due to the fact that windier conditions are acceptable within a construction area (not accessible to the public), and the proposed Project would not be the reason for critical wind conditions on-site (and are slightly calmer when the proposed Project is in situ), the impacts evaluated on-site are considered to be insignificant. Thus, the predicted impacts during Construction Phase are identified as not significant or imperceptible.

In summary, as construction of the proposed Project progresses, the wind conditions at the Site would gradually adjust to those of the completed development. During the Construction Phase, predicted impacts are classified as negligible.

7.0.2 Operational Phase

This section shows CFD results of wind and microclimate assessment carried out considering the ”Operational Phase” of the proposed Project. In this case the assessment has considered the impact of wind on the existing area including the proposed Project. For this scenario, the proposed Project has been simulated. Wind simulations have been carried out on all the various directions for which the development could show critical areas in terms of pedestrian comfort and safety. For this, the Lawson and Distress Maps have been presented to identify the suitability of each areas to its prescribed level of usage and activity. The results present parameters outlined within the acceptance criteria previously described.

A summary of CFD model input data used in this project is given in the table shown in Figure 7.8.

Parameter	CARMANHALL ROAD DEVELOPMENT MODEL
Environment Conditions	
Ambient pressure	101325 Pa
Wind profile	Logarithmic atmospheric profile
Ambient temperature	15 ºC
Analysis type	Steady state (LES)
Computational Details	
Total cells used	> 20,000,000
Mesh size	< 0.2 m
Turbulence treatment	K-epsilon turbulence model
Convergence Criteria	$< 10^{-6}$
Boundary Conditions	
CFD Domain Inlet	Wind Velocity inlet
CFD Domain Outlet	Pressure Outlet condition (zero pressure)
Carmanhall Road Buildings	Zero velocity gradient (No-slip condition)

Figure 7.8: Summary of CFD Model Input Data

It is also of interest at this point to underline once more the objectives of simulations performed. In particular:

- Pedestrian Wind Comfort and Safety Studies are conducted to predict, assess and, where necessary, mitigate the impact of the development on pedestrian level wind conditions.

- To assess comfortable and safe pedestrian level wind conditions that are appropriate for the intended use of pedestrian areas. Pedestrian areas include sidewalks and street frontages, pathways, building entrance areas, open spaces, public spaces, amenity areas, outdoor sitting areas, etc.

Results of simulations carried out are detailed in the following sections. These results present parameters as outlined in the acceptance criteria section described previously for Project Shoreline GA1 development. Results of wind flow speeds are collected throughout the simulation and analysed based on the Lawson Discomfort Criteria.

Figure 7.9 shows a 3D example of wind speed results collected at 1.5m height above ground floor level of the development. Red colors generally indicate critical values while blue colors indicate tenable conditions.

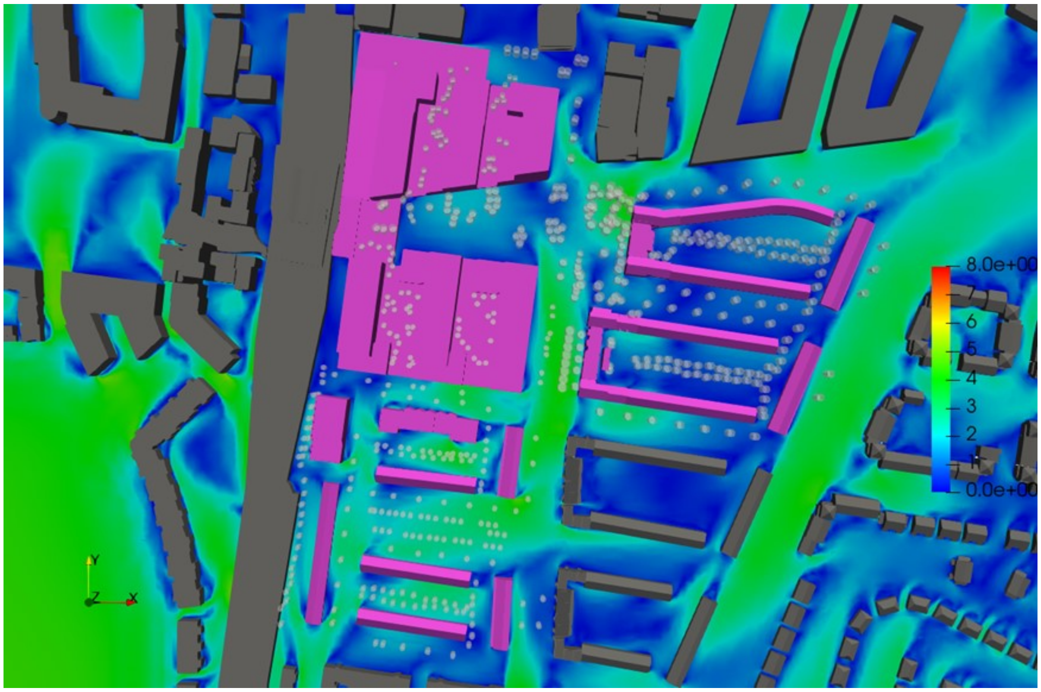


Figure 7.9: An example of Wind Flow Results Collected At 1.5m Height Above Ground Floor

7.0.3 Shoreline GA1 with permitted Shoreline GA2 (Existing Scenario)

This section assessed the potential impact of the proposed development on the already existing environment, also considering future buildings that have been granted planning permission but that are not built yet, and the suitability of the proposed development to create and maintain a suitable and comfortable environment for different pedestrian activities.

Shoreline GA1 Development and adjacent buildings Model (including permitted GA2 and Clongriffin developments (existing and permitted but not built)) are shown in Figures 7.10 (top views).

Figure 7.10: Top View - Shoreline GA1 Development, Permitted Shoreline GA2 Development and Clongriffin developments (existing and permitted but not built) - Extents of Modelled Area

Flow Velocity Results - Ground Floor Level

Results of wind speeds and their circulations around the proposed Project at pedestrian level of 1.5m above the development ground are presented for all the simulated wind directions in the following figures, in order to assess wind flows at ground floor level of the proposed Project.

Higher velocities are experienced around the buildings for certain wind directions. In particular, some recirculation effects are expected near the corners of the units, on the main road on the South and South-East side of the proposed GA1 development and on the main road across the development. Courtyards, parks and squares seem to be well shielded. However, some recirculation effect have been found for certain wind directions.

Figures from 7.11 to 7.30 present views of the flow velocity results for the entire domain for the dominant wind direction (225°).

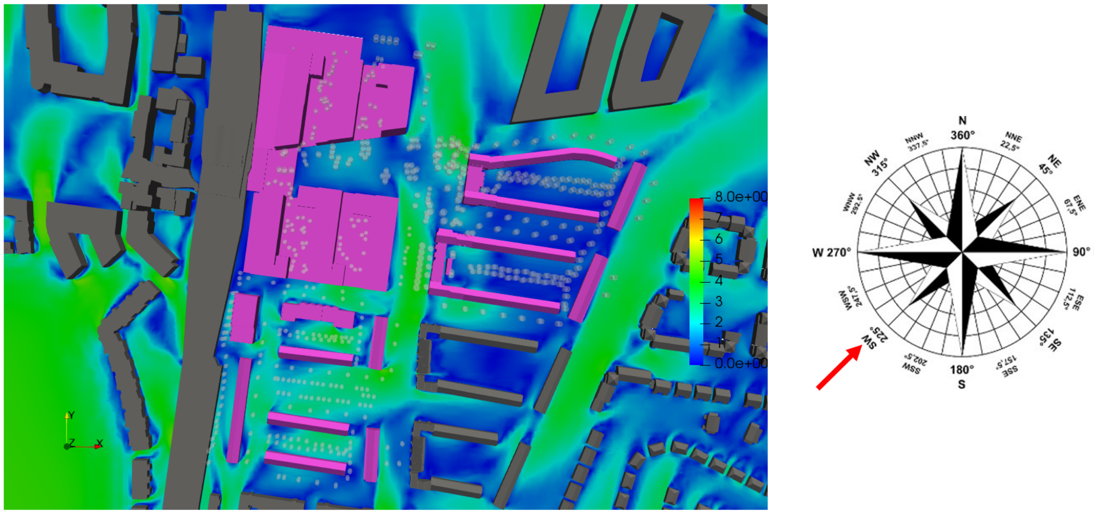


Figure 7.11: Wind Speed Results at 1.5m above Ground - Top View: 225°

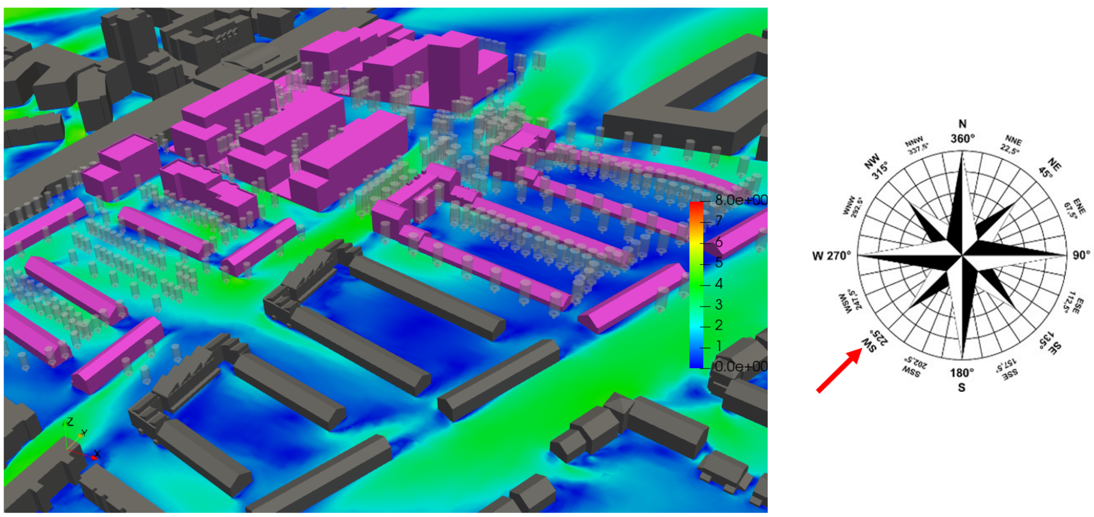


Figure 7.12: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 225°

Figures from 7.13 to 7.33 present views of the flow velocity results for the entire domain for the dominant wind direction (135°).

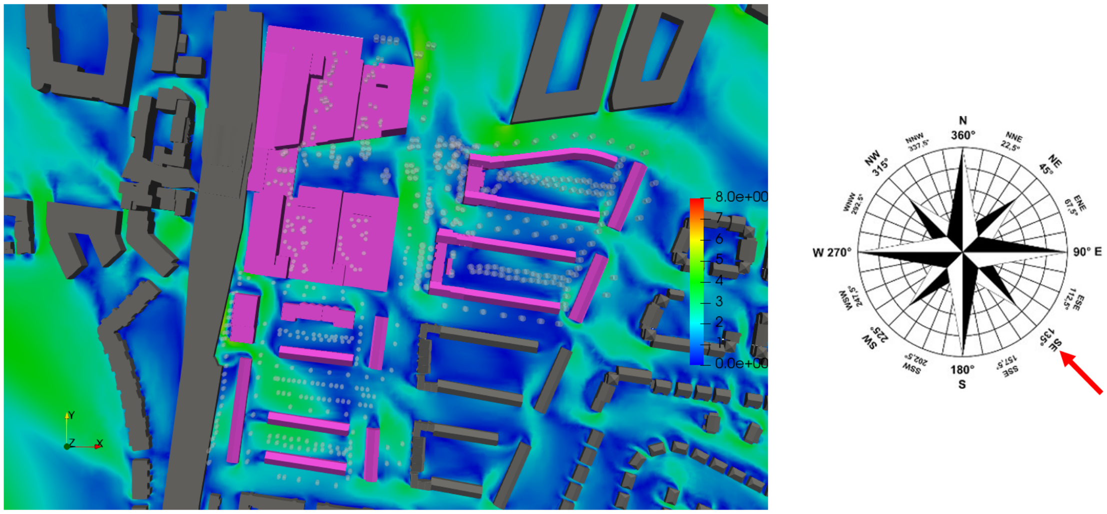


Figure 7.13: Wind Speed Results at 1.5m above Ground - Top View: 135°

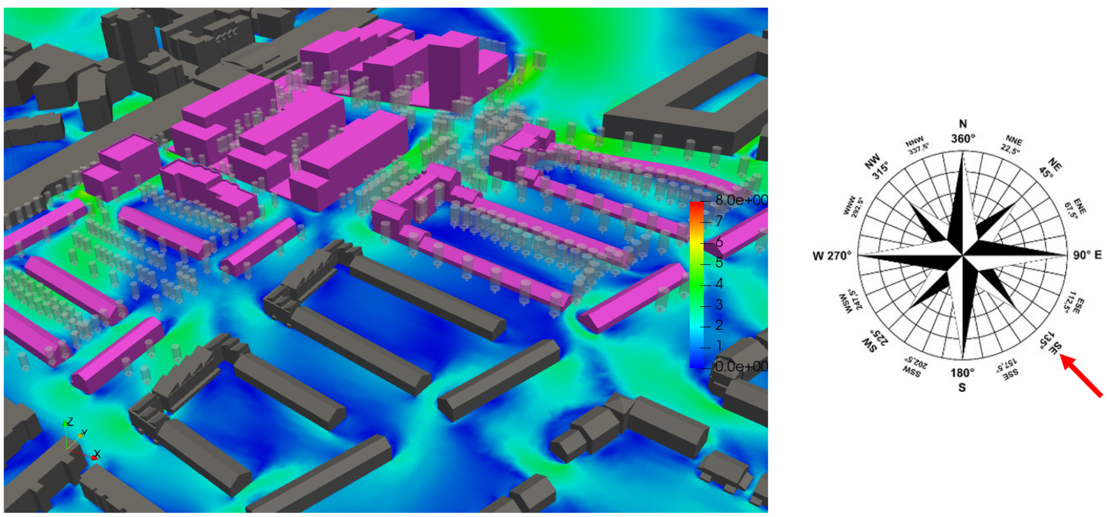


Figure 7.14: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 135°

Figures from 7.15 to 7.36 present views of the flow velocity results for the entire domain for the dominant wind direction (236°).

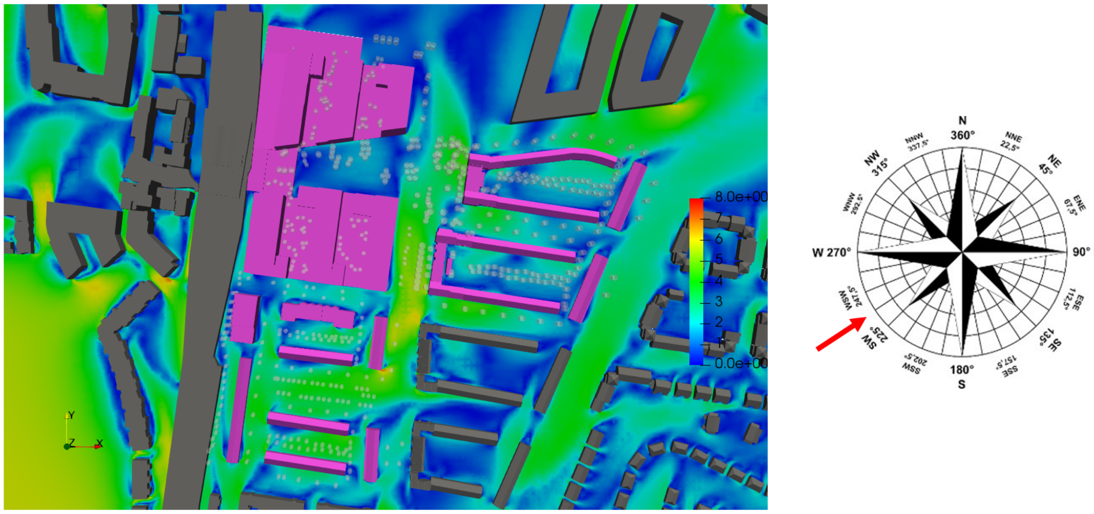


Figure 7.15: Wind Speed Results at 1.5m above Ground - Top View: 236°

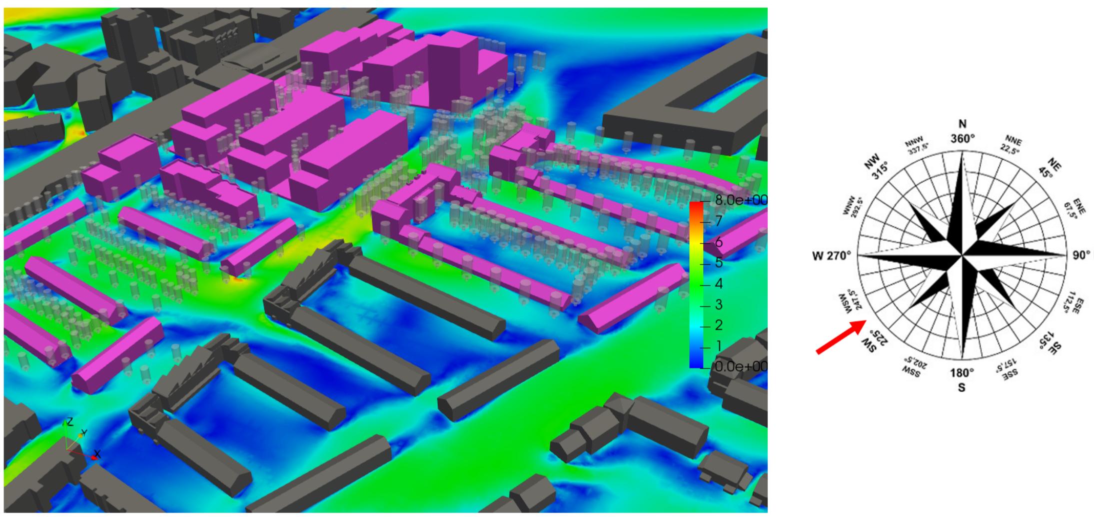


Figure 7.16: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 236°

Figures from 7.17 to 7.39 present views of the flow velocity results for the entire domain for the dominant wind direction (258°).

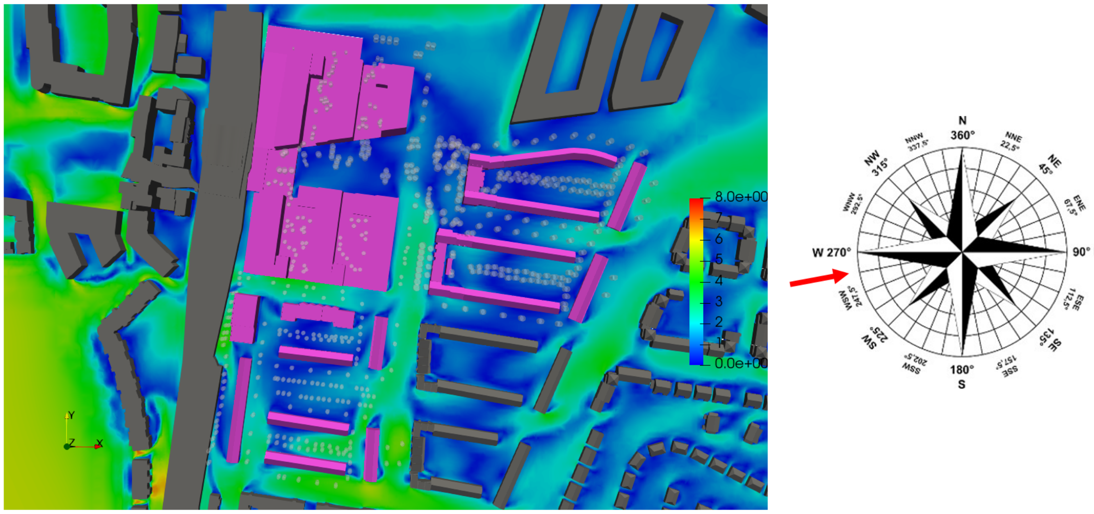


Figure 7.17: Wind Speed Results at 1.5m above Ground - Top View: 258°

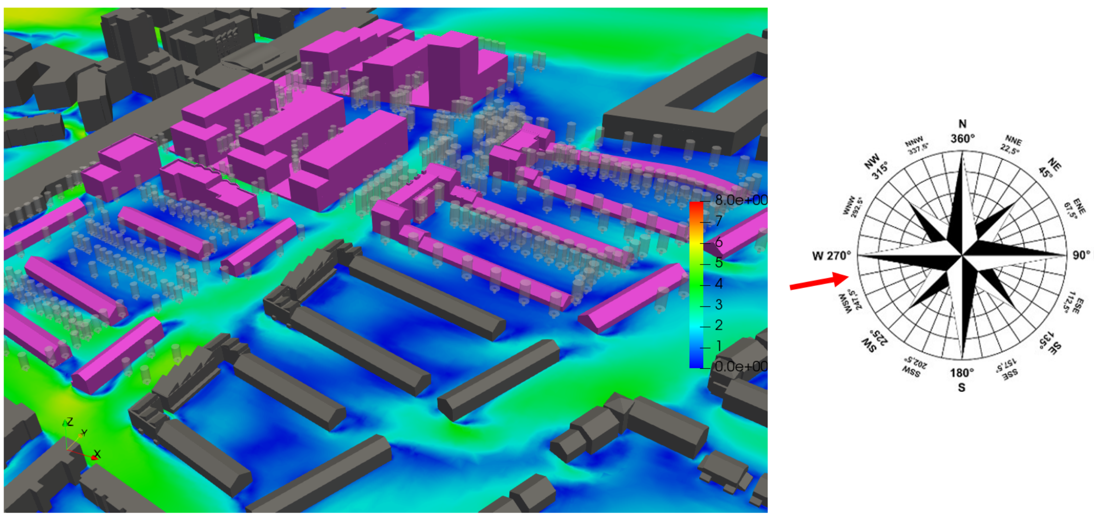


Figure 7.18: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 258°

Figures from 7.19 to 7.42 present views of the flow velocity results for the entire domain for the dominant wind direction (247°).

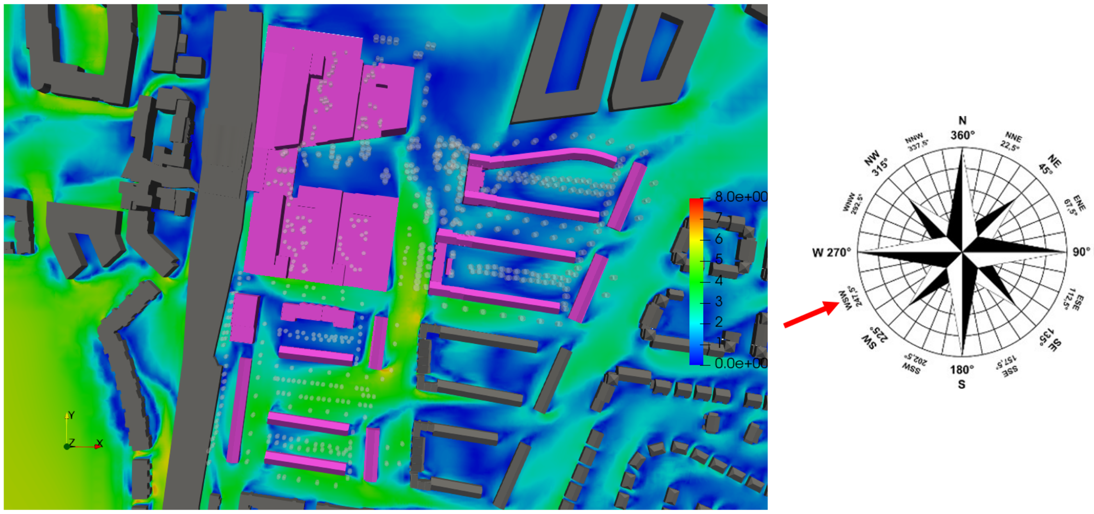


Figure 7.19: Wind Speed Results at 1.5m above Ground - Top View: 247°

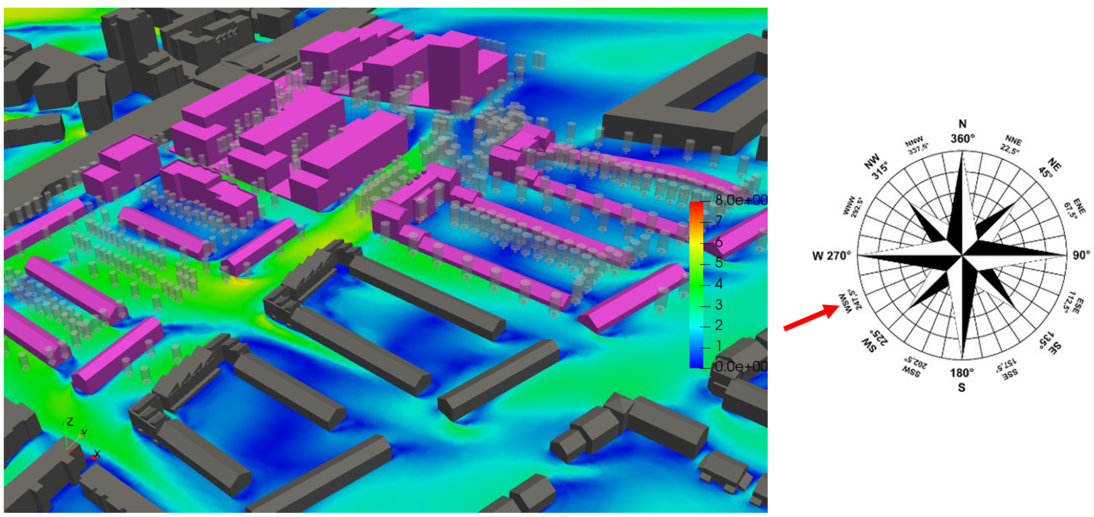


Figure 7.20: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 247°

Figures from 7.21 to 7.45 present views of the flow velocity results for the entire domain for the dominant wind direction (270°).

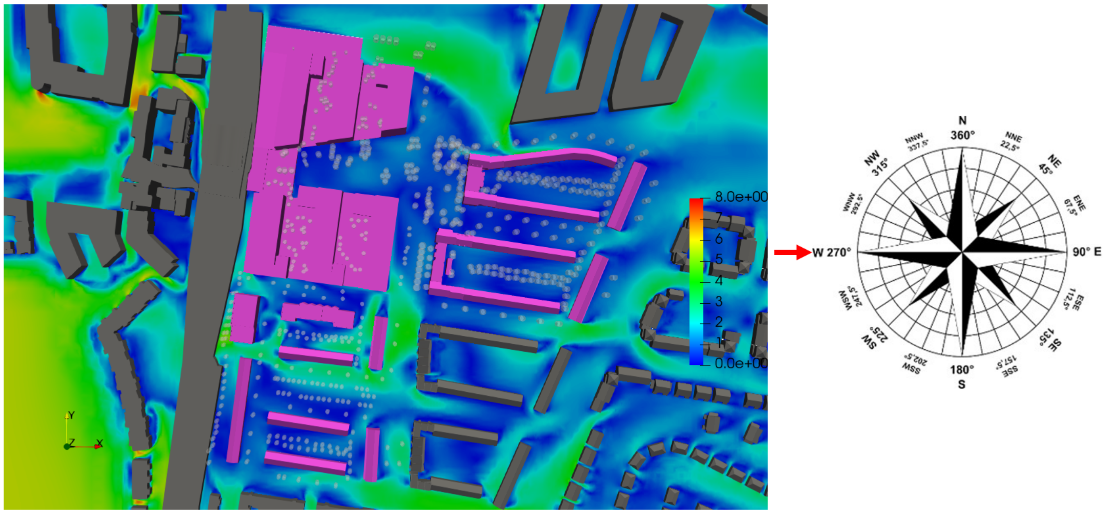


Figure 7.21: Wind Speed Results at 1.5m above Ground - Top View: 270°

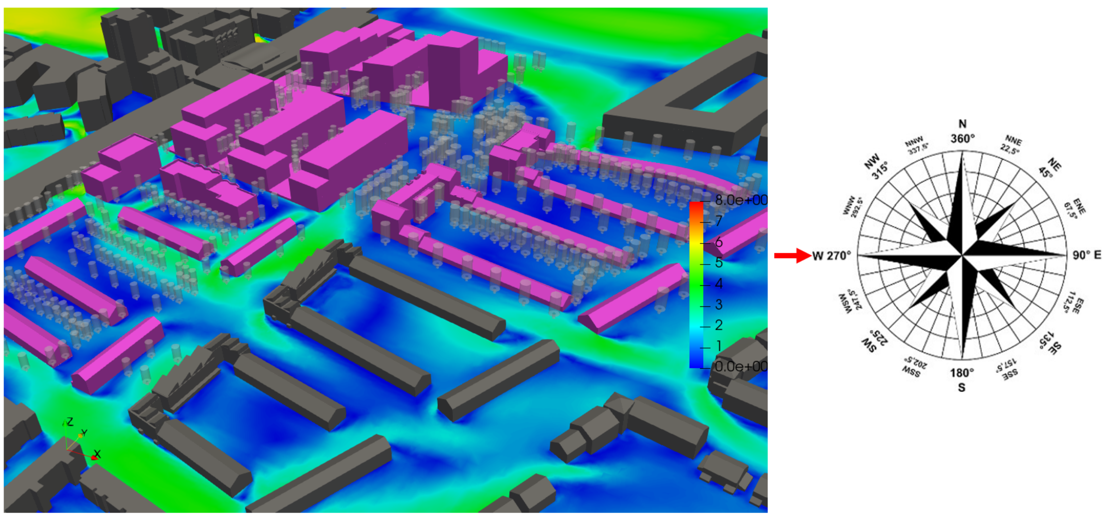


Figure 7.22: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 270°

Figures from 7.23 to 7.48 present views of the flow velocity results for the entire domain for the dominant wind direction (315°).

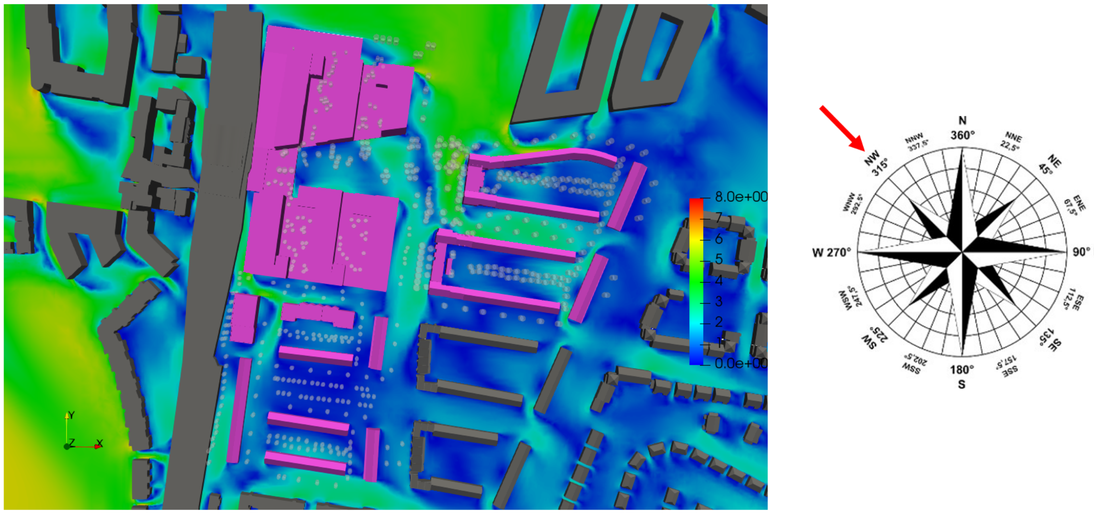


Figure 7.23: Wind Speed Results at 1.5m above Ground - Top View: 315°

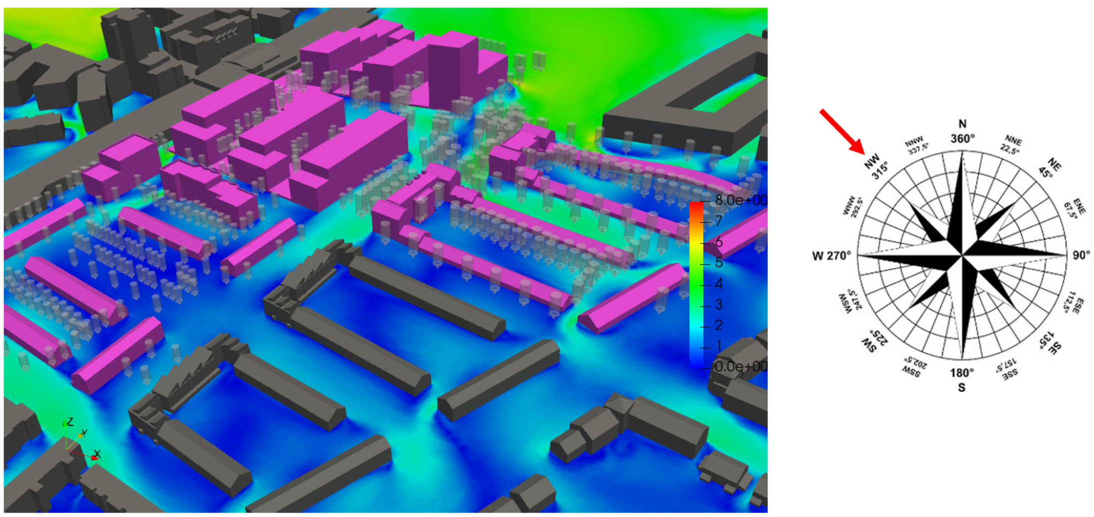


Figure 7.24: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 315°

Figures from 7.25 to 7.51 present views of the flow velocity results for the entire domain for the dominant wind direction (281°).

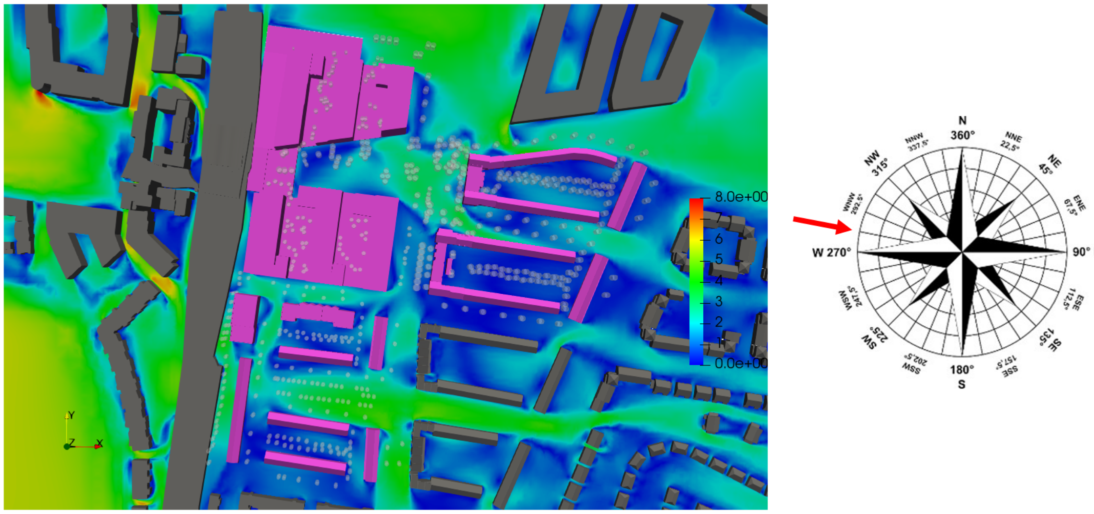


Figure 7.25: Wind Speed Results at 1.5m above Ground - Top View: 281°

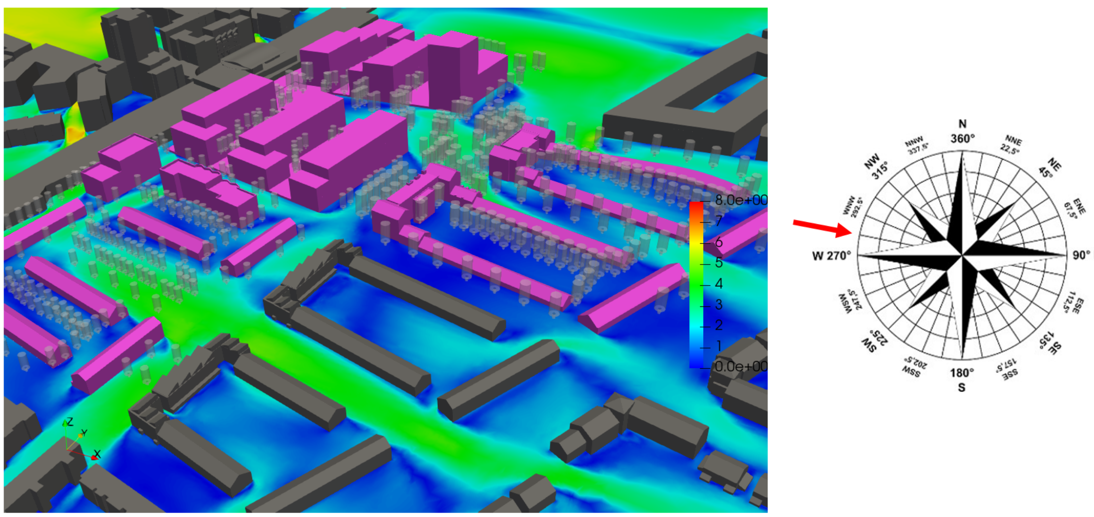


Figure 7.26: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 281°

7.0.4 Shoreline GA1 with permitted Shoreline GA2 and Proposed Shoreline GA3 (Cumulative Scenario)

This section assessed the potential impact of the proposed development on the already existing environment, also considering Shoreline GA2 buildings, that have been granted planning permission (but that are not built yet), Clongriffin developments (existing and permitted but not built) and Shoreline GA3 Development (that will be potentially constructed in the future).

Shoreline GA1 Development and adjacent buildings Model (including GA2, Clongriffin and GA3) are shown in Figures 7.10 (top views).

Figure 7.27: Top View - Shoreline GA1 Development, Permitted Shoreline GA2 Development, Clongriffin developments (existing and permitted but not built) and Proposed Shoreline GA3 Development - Extents of Modelled Area

Flow Velocity Results - Ground Floor Level

As shown in the previous sections for the existing scenario, also for the cumulative one, results of wind speeds and their circulations around the proposed Project at pedestrian level of 1.5m above the development ground are presented for all the simulated wind directions.

In general the introduction of the potential GA3 developments is improving the wind impact onn the north east side, however some higher velocities are still experienced around the buildings of GA1 due to south west wind directions. In particular, some recirculation effects are expected near the corners of the blocks, on the main road on the east side of the proposed Project and on the main road across the development, as well as near the train station, especially when the wind is blowing from south-west and west-south-west. The implementation of tree landscaping is still effective in mitigating the wind similarly to what was seen in the existing scenario analysed. Courtyards, parks and squares seem to be well shielded. However, some recirculation effect have been still found for certain wind directions but their impact is negligible.

Figures from 7.28 to 7.30 present views of the flow velocity results for the entire domain for the dominant wind direction (225°).

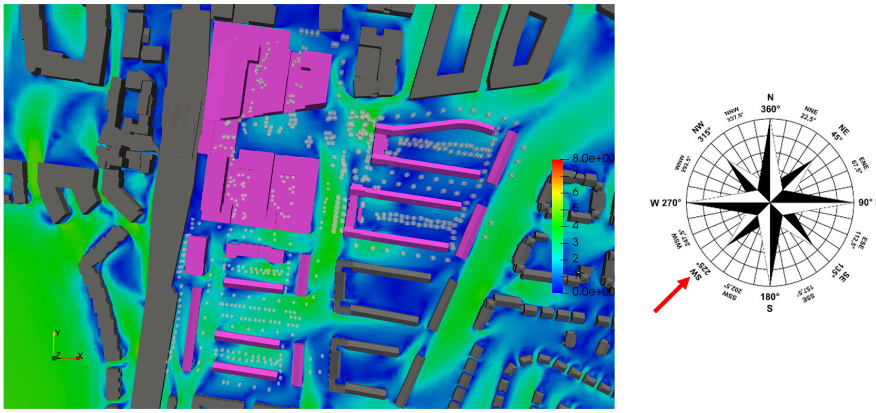


Figure 7.28: Wind Speed Results at 1.5m above Ground - Cumulative Scenario - Top View: 225°

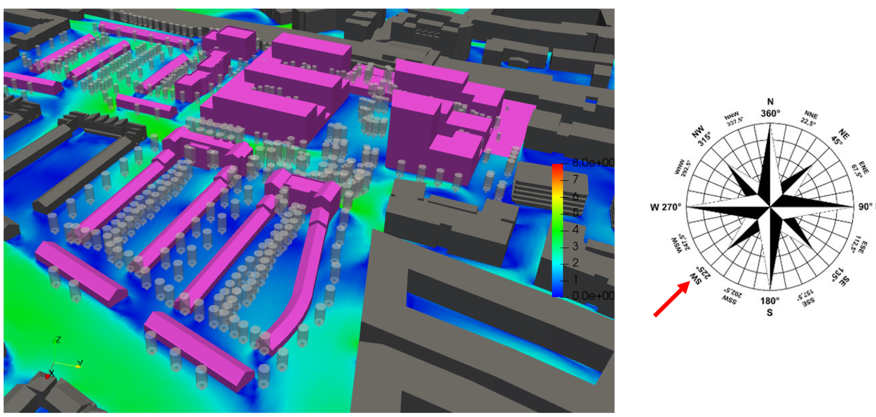


Figure 7.29: Wind Speed Results at 1.5m Above Ground - Cumulative Scenario - 3D View: 225°

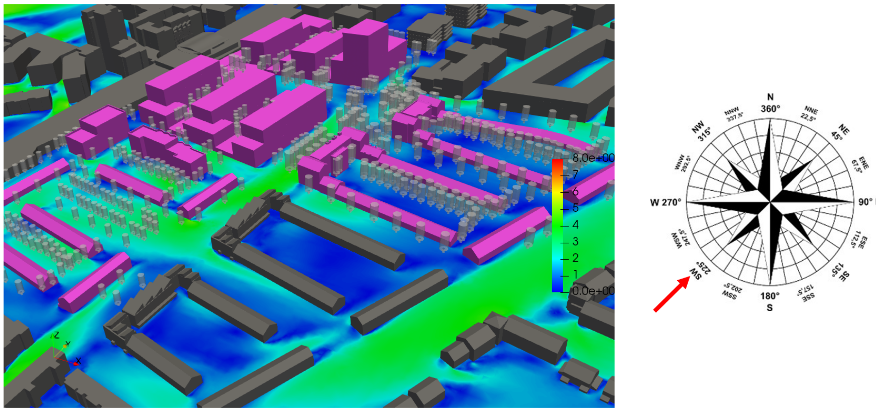


Figure 7.30: Wind Speed Results at 1.5m Above Development Ground Floor - Cumulative Scenario - 3D View - Wind Direction: 225°

Figures from 7.31 to 7.33 present views of the flow velocity results for the entire domain for the dominant wind direction (135°).

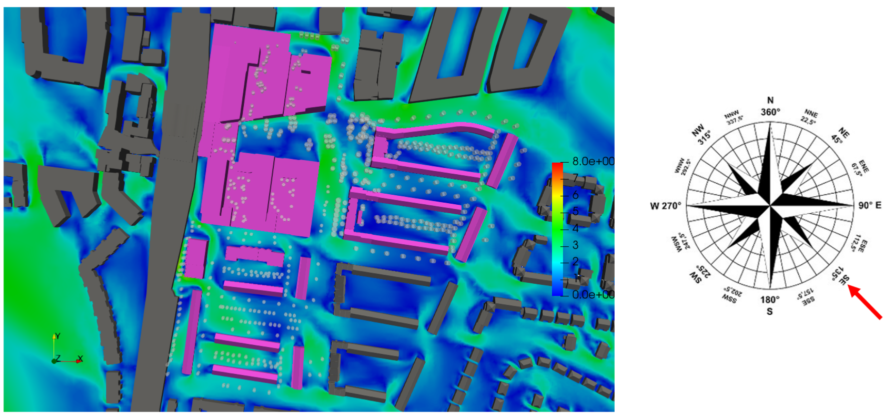


Figure 7.31: Wind Speed Results at 1.5m above Ground - Cumulative Scenario - Top View: 135°

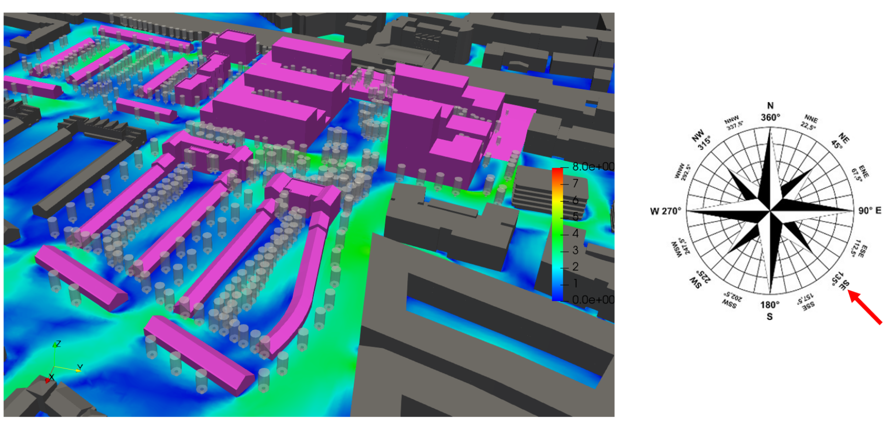


Figure 7.32: Wind Speed Results at 1.5m Above Ground - Cumulative Scenario - 3D View: 135°

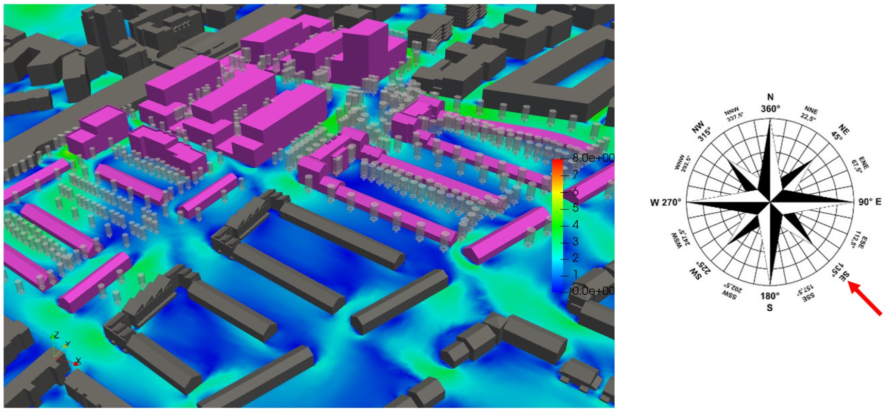


Figure 7.33: Wind Speed Results at 1.5m Above Development Ground Floor - Cumulative Scenario - 3D View - Wind Direction: 135°

Figures from 7.34 to 7.36 present views of the flow velocity results for the entire domain for the dominant wind direction (236°).

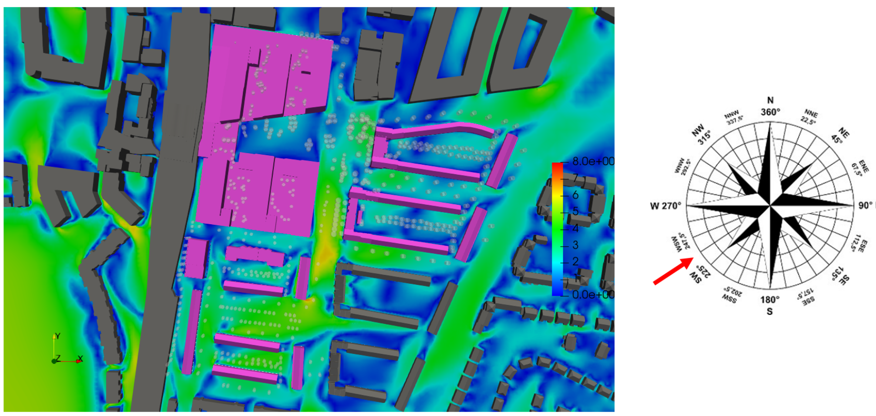


Figure 7.34: Wind Speed Results at 1.5m above Ground - Cumulative Scenario - Top View: 236°

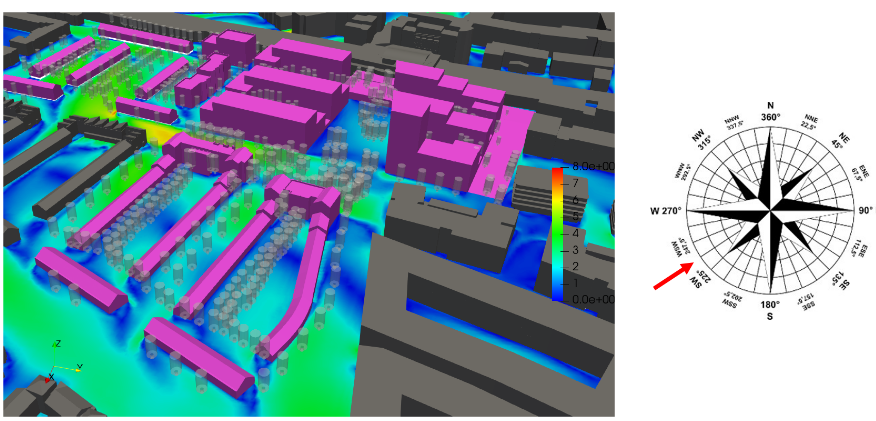


Figure 7.35: Wind Speed Results at 1.5m Above Ground - Cumulative Scenario - 3D View: 236°

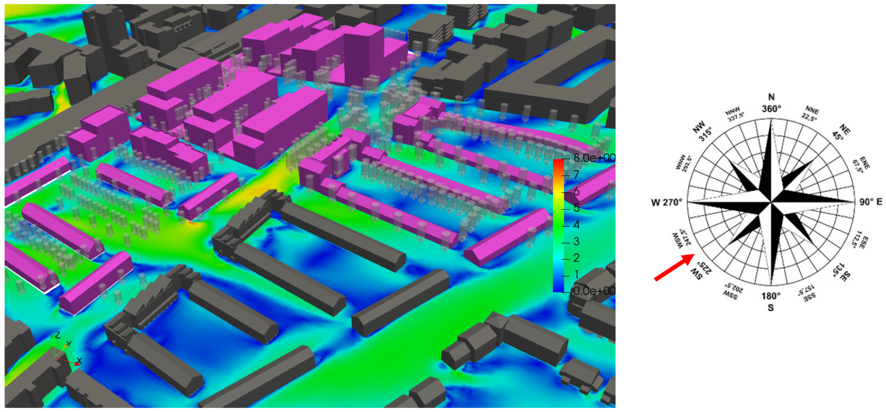


Figure 7.36: Wind Speed Results at 1.5m Above Development Ground Floor - Cumulative Scenario - 3D View - Wind Direction: 236°

Figures from 7.37 to 7.39 present views of the flow velocity results for the entire domain for the dominant wind direction (258°).

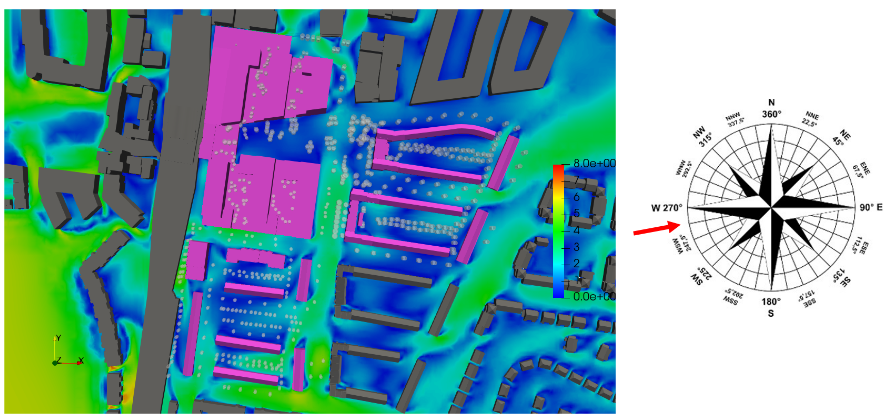


Figure 7.37: Wind Speed Results at 1.5m above Ground - Cumulative Scenario - Top View: 258°

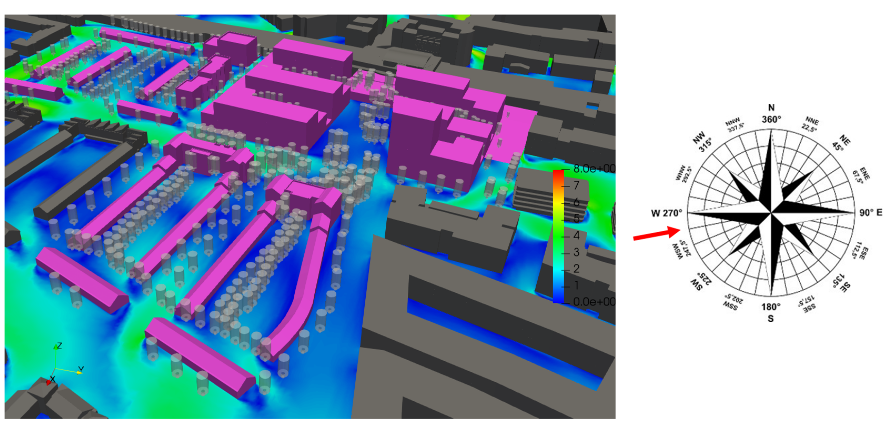


Figure 7.38: Wind Speed Results at 1.5m Above Ground - Cumulative Scenario - 3D View: 258°

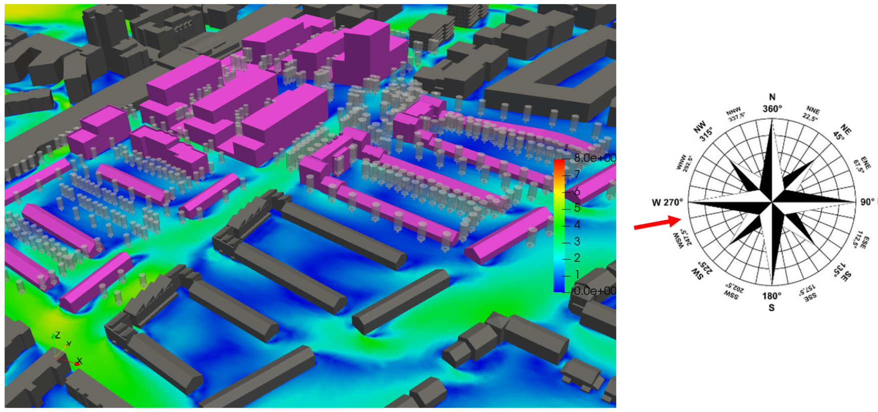


Figure 7.39: Wind Speed Results at 1.5m Above Development Ground Floor - Cumulative Scenario - 3D View - Wind Direction: 258°

Figures from 7.40 to 7.42 present views of the flow velocity results for the entire domain for the dominant wind direction (247°).

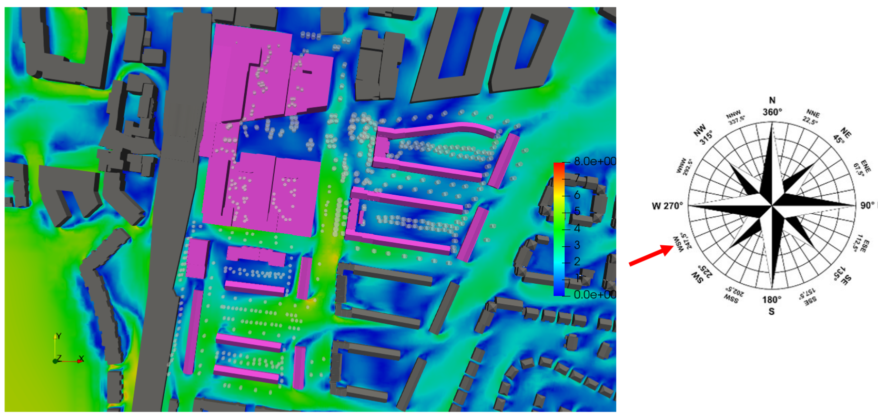


Figure 7.40: Wind Speed Results at 1.5m above Ground - Cumulative Scenario - Top View: 247°

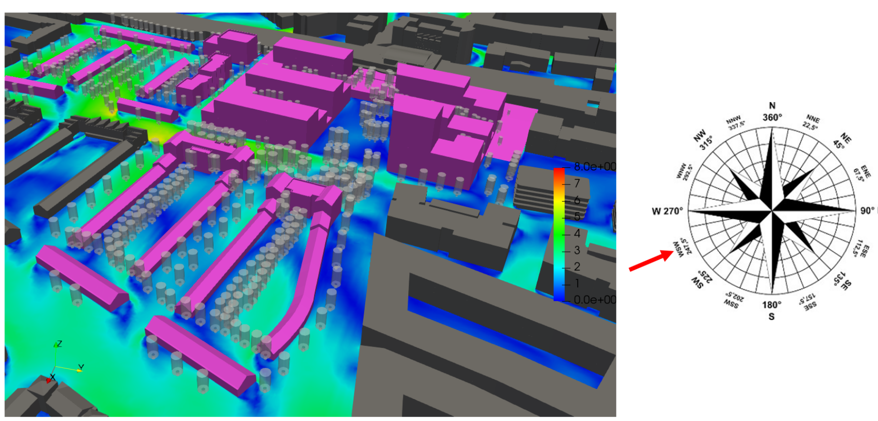


Figure 7.41: Wind Speed Results at 1.5m Above Ground - Cumulative Scenario - 3D View: 247°

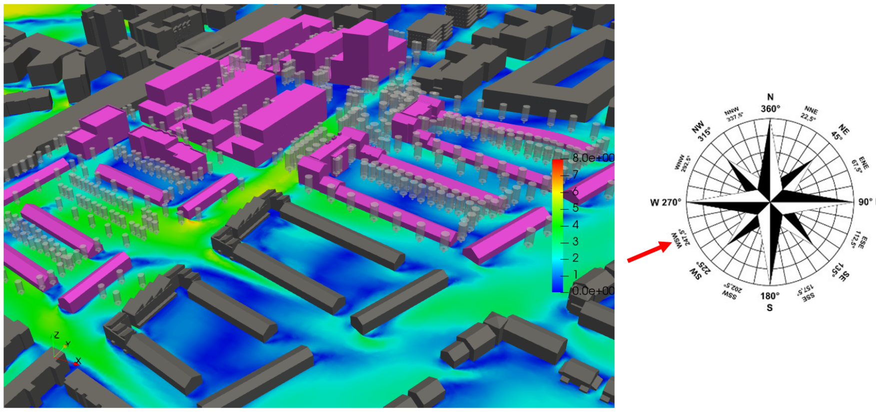


Figure 7.42: Wind Speed Results at 1.5m Above Development Ground Floor - Cumulative Scenario - 3D View - Wind Direction: 247°

Figures from 7.43 to 7.45 present views of the flow velocity results for the entire domain for the dominant wind direction (270°).

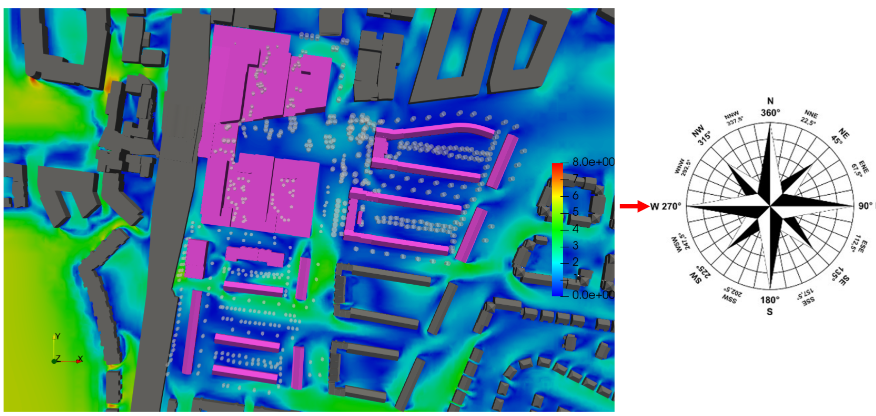


Figure 7.43: Wind Speed Results at 1.5m above Ground - Cumulative Scenario - Top View: 270°

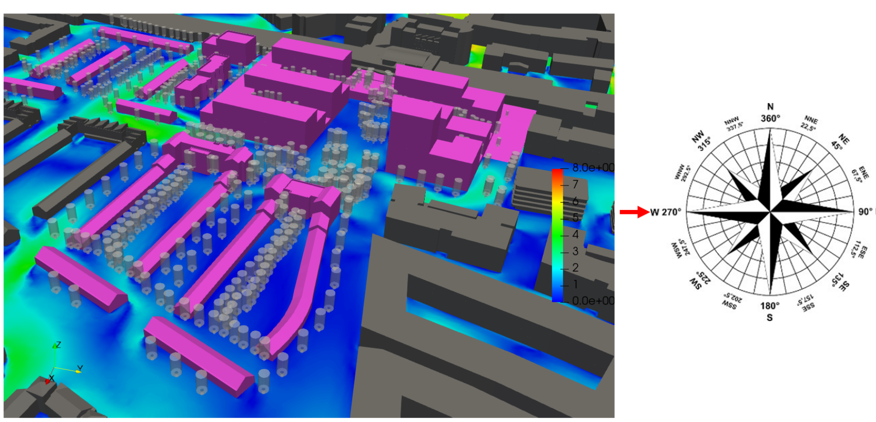


Figure 7.44: Wind Speed Results at 1.5m Above Ground - Cumulative Scenario - 3D View: 270°

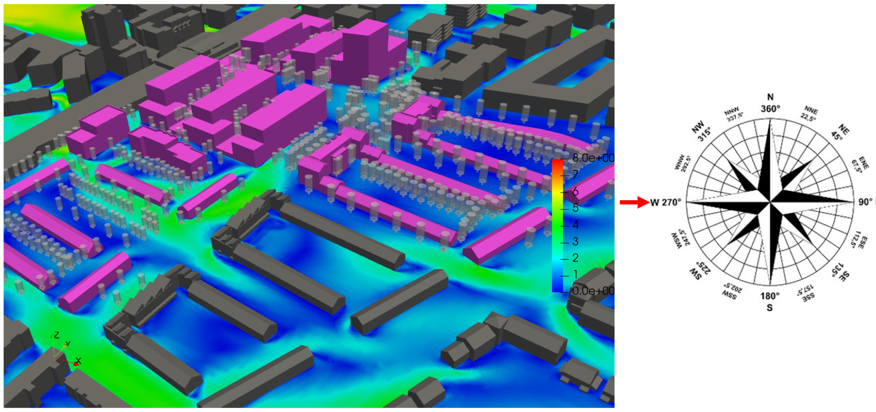


Figure 7.45: Wind Speed Results at 1.5m Above Development Ground Floor - Cumulative Scenario - 3D View - Wind Direction: 270°

Figures from 7.46 to 7.48 present views of the flow velocity results for the entire domain for the dominant wind direction (315°).

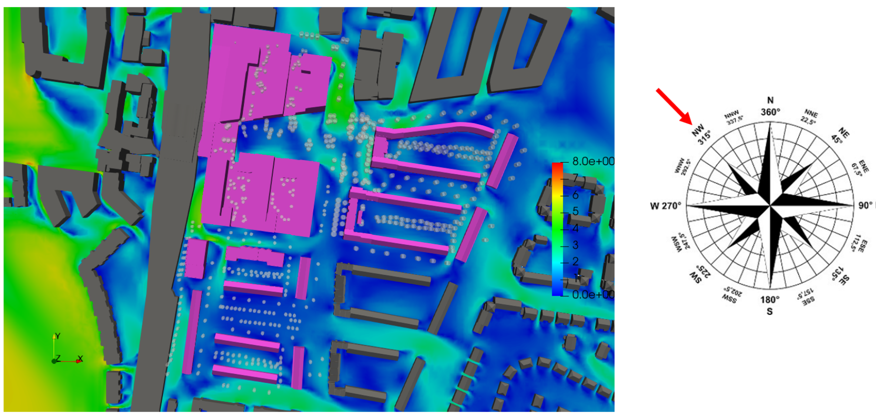


Figure 7.46: Wind Speed Results at 1.5m above Ground - Cumulative Scenario - Top View: 315°

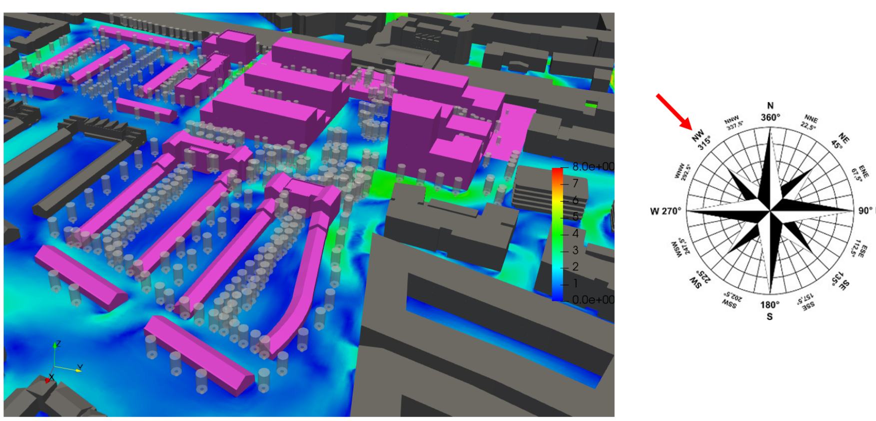


Figure 7.47: Wind Speed Results at 1.5m Above Ground - Cumulative Scenario - 3D View: 315°

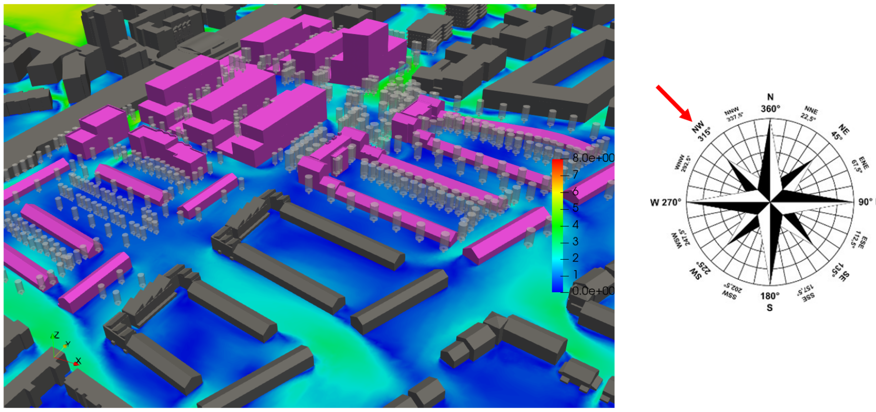


Figure 7.48: Wind Speed Results at 1.5m Above Development Ground Floor - Cumulative Scenario - 3D View - Wind Direction: 315°

Figures from 7.49 to 7.51 present views of the flow velocity results for the entire domain for the dominant wind direction (281°).

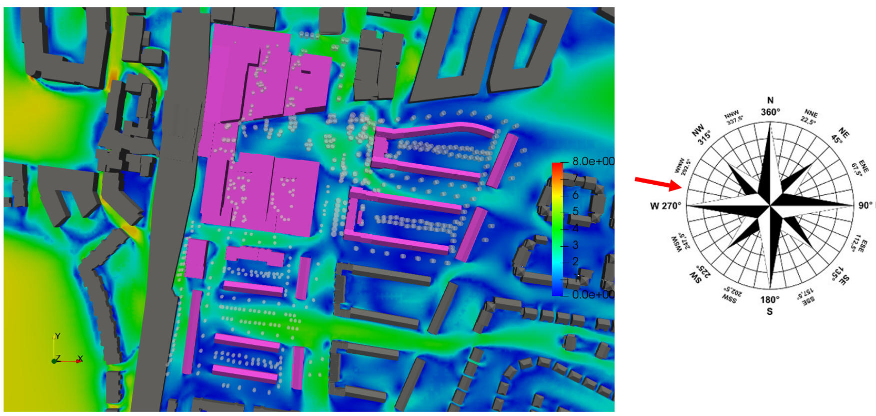


Figure 7.49: Wind Speed Results at 1.5m above Ground - Cumulative Scenario - Top View: 281°

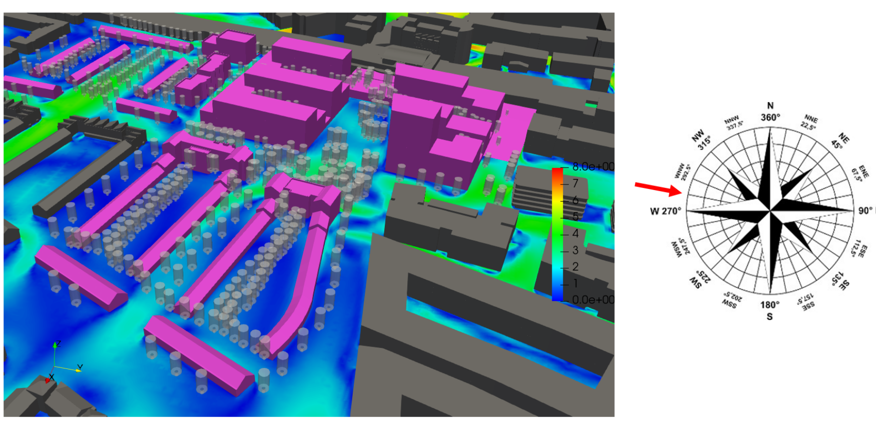


Figure 7.50: Wind Speed Results at 1.5m Above Ground - Cumulative Scenario - 3D View: 281°

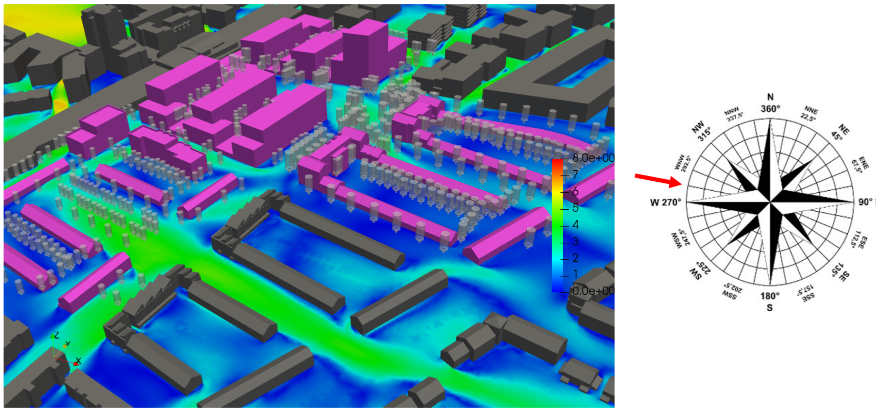


Figure 7.51: Wind Speed Results at 1.5m Above Development Ground Floor - Cumulative Scenario - 3D View - Wind Direction: 281°

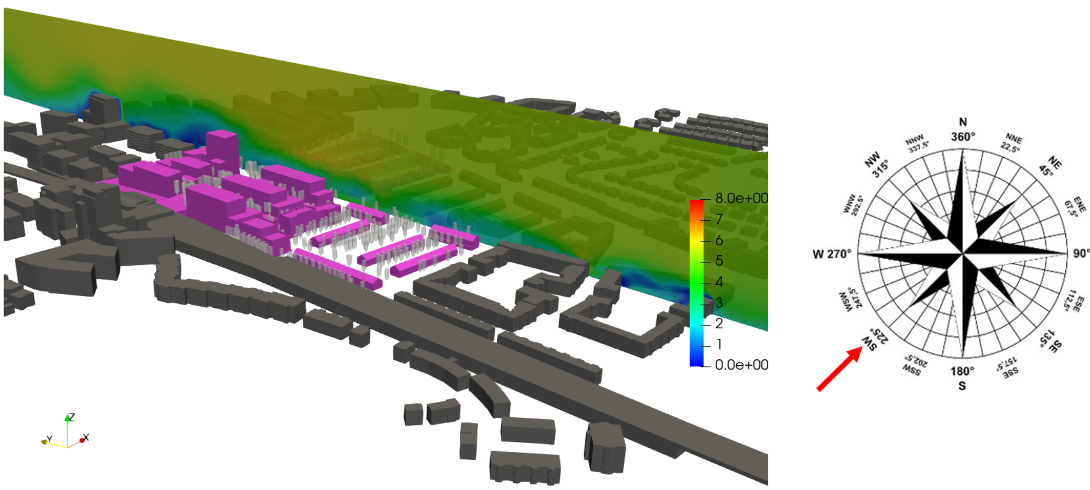


Figure 7.52: Wind Speed Results (Vertical Slice) - Cumulative Scenario - 3D View: 225°

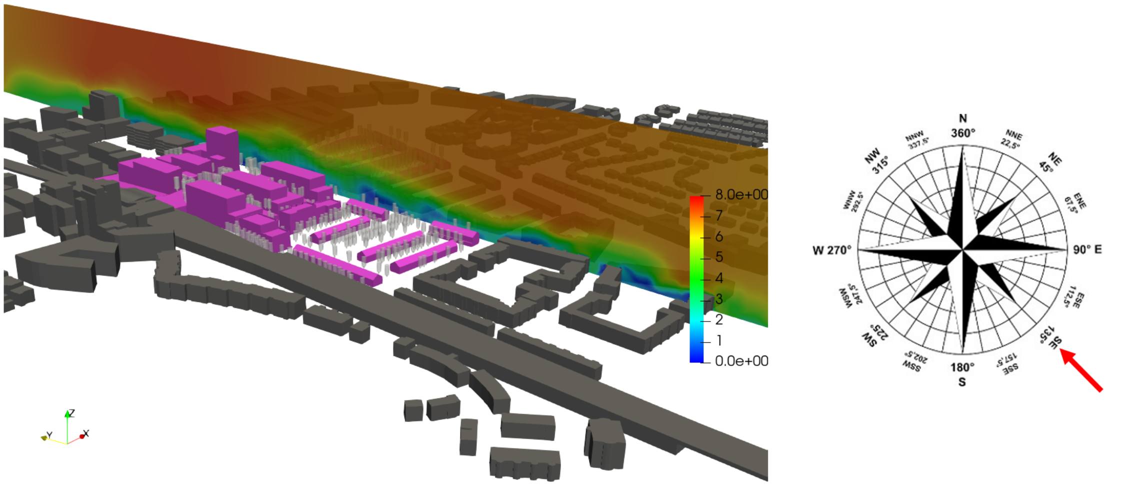


Figure 7.53: Wind Speed Results (Vertical Slice) - Cumulative Scenario - 3D View: 135°

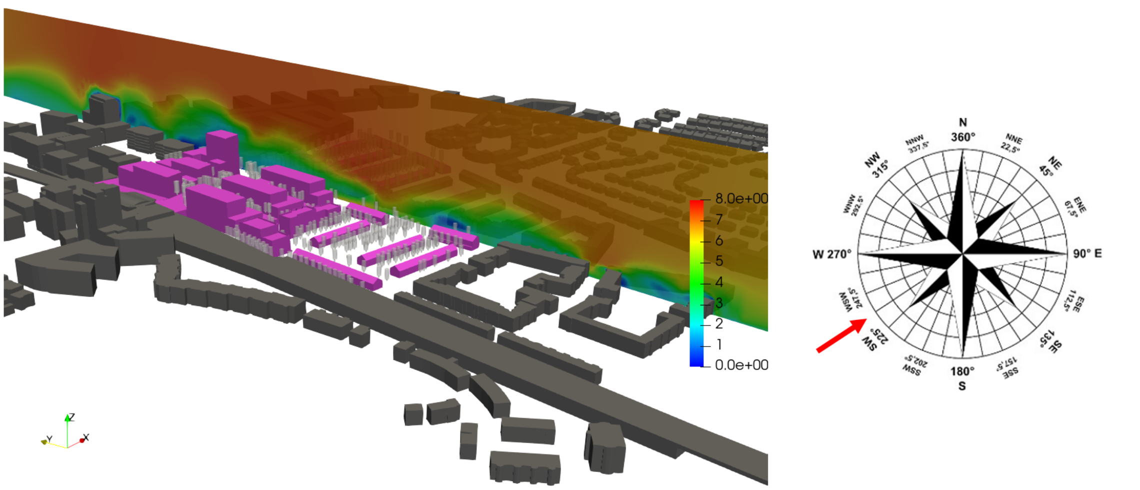


Figure 7.54: Wind Speed Results (Vertical Slice) - Cumulative Scenario - 3D View: 236°

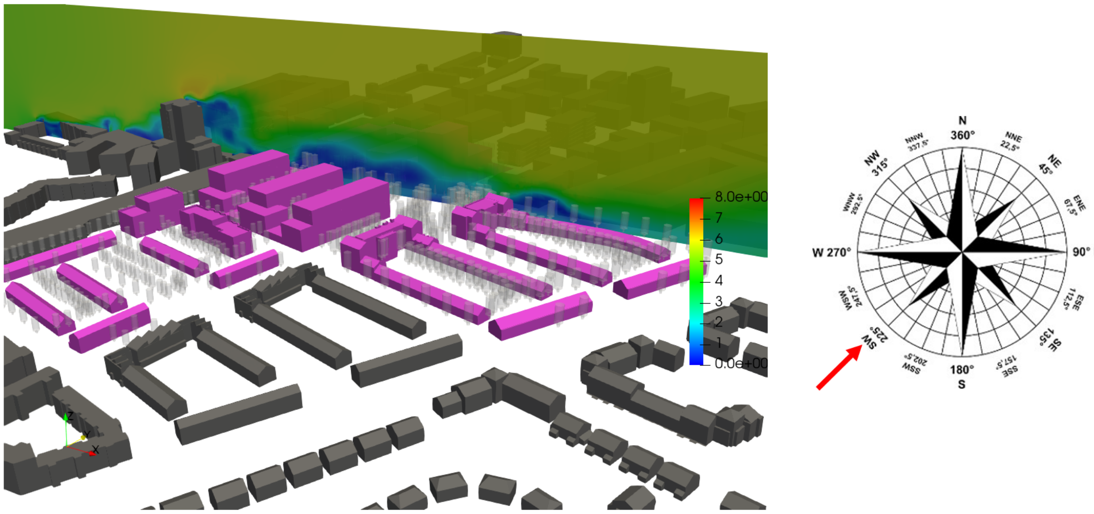


Figure 7.55: Wind Speed Results (Vertical Slice) - Cumulative Scenario - 3D View: 225°

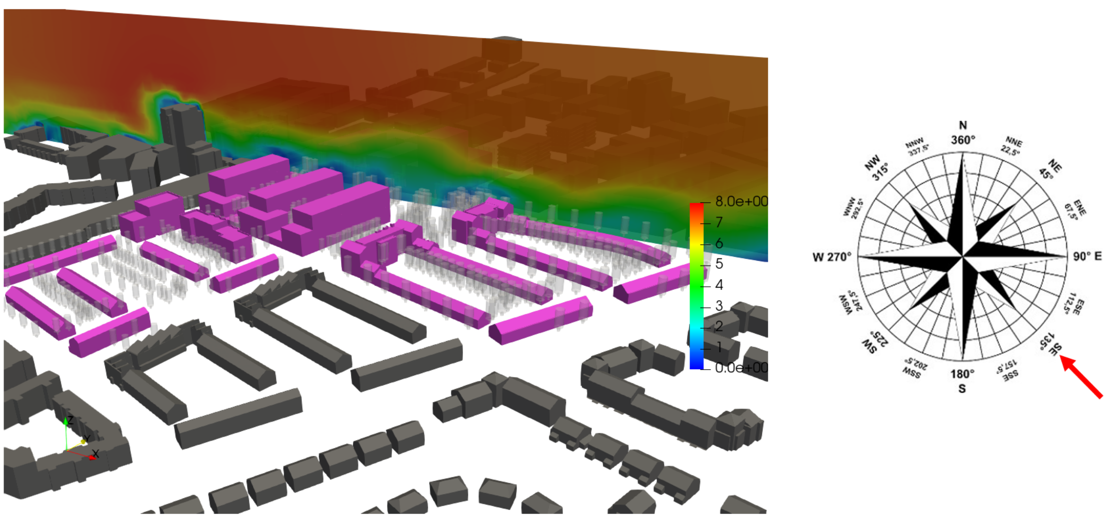


Figure 7.56: Wind Speed Results (Vertical Slice) - Cumulative Scenario - 3D View: 135°

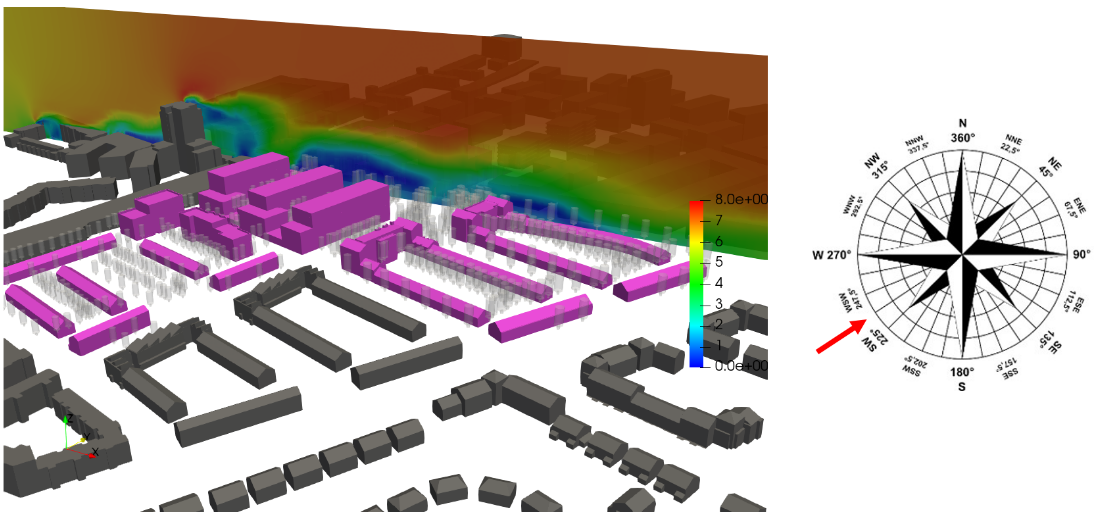


Figure 7.57: Wind Speed Results (Vertical Slice) - Cumulative Scenario - 3D View: 236°

Mitigation Measures in CFD model

As discussed in the previous chapter, porous mediums are used to model trees and wind mitigation measures to reproduce the velocity modifications and pressure drop that vegetation will create on the incoming air flows. These regions are defined within the simulation and located to represent the landscaping design as developed by BSLArch (shown in Figure 7.58).

Figure 7.58: Mitigation Measures in CFD model

Results of wind speeds and their circulations around the proposed development at pedestrian level of 1.5m above the development ground are presented for the 236° wind direction in Figures 7.59 to 7.62, in order to assess wind flows at ground floor level of the proposed Project when mitigation measures with tree landscaping are implemented.

Results comparing the unmitigated case with the mitigated case, show that the mitigation measures in place significantly reduce the velocities around the proposed Project. The recirculation and funnelling effects highlighted in the previous sections have been successfully reduced or eliminated.

Some slightly higher velocities are still found for some wind directions around some of the corners of the buildings and on the west side of the development. However, these velocities are below critical values.

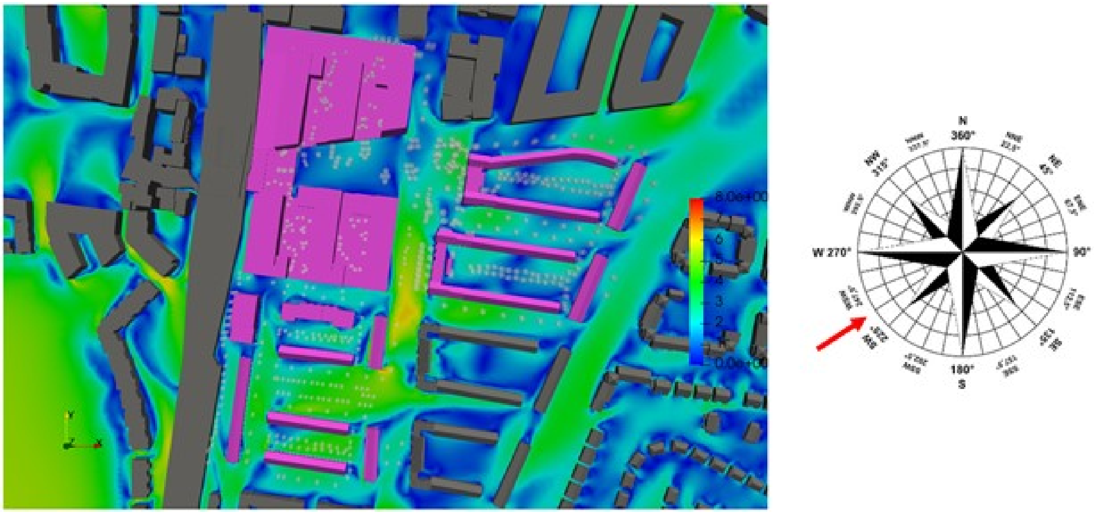


Figure 7.59: Wind Speed Results at 1.5m Above Development Ground - Mitigation Measures - Top View: 236°

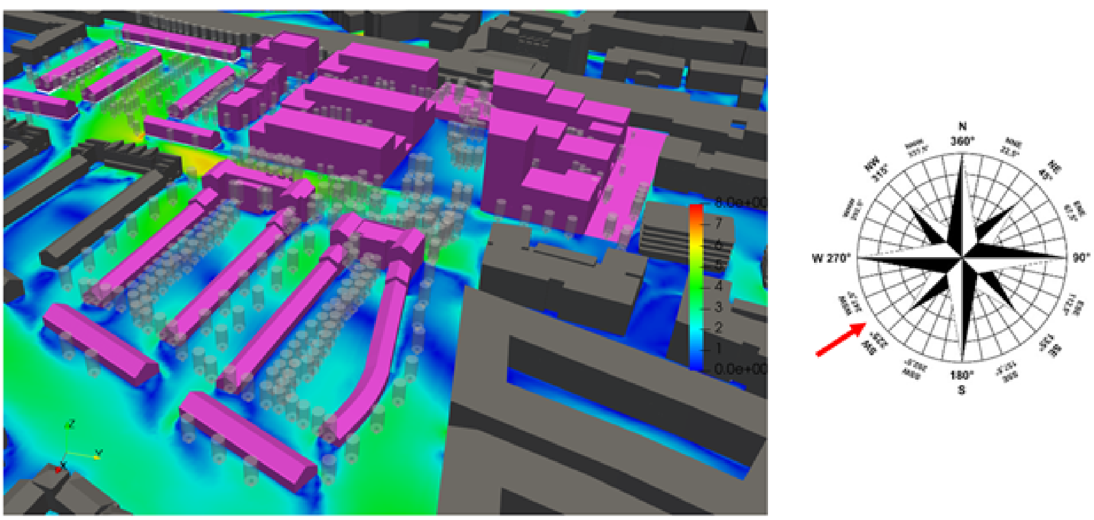


Figure 7.60: Wind Speed Results at 1.5m Above Development Ground - Mitigation Measures - 3D View: 236°

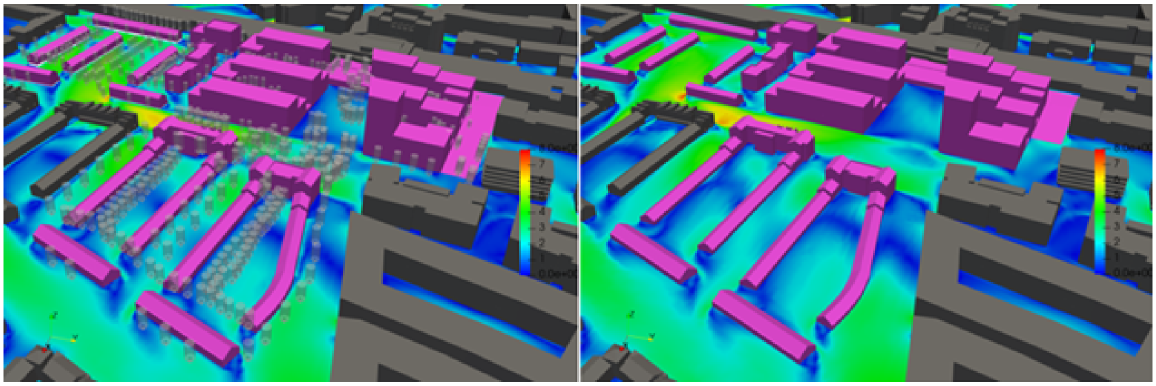


Figure 7.61: Wind Speed Results around the Development at 1.5m Above Development Ground - Comparison between not mitigated case (left) and mitigated case (right): 236° - Top View

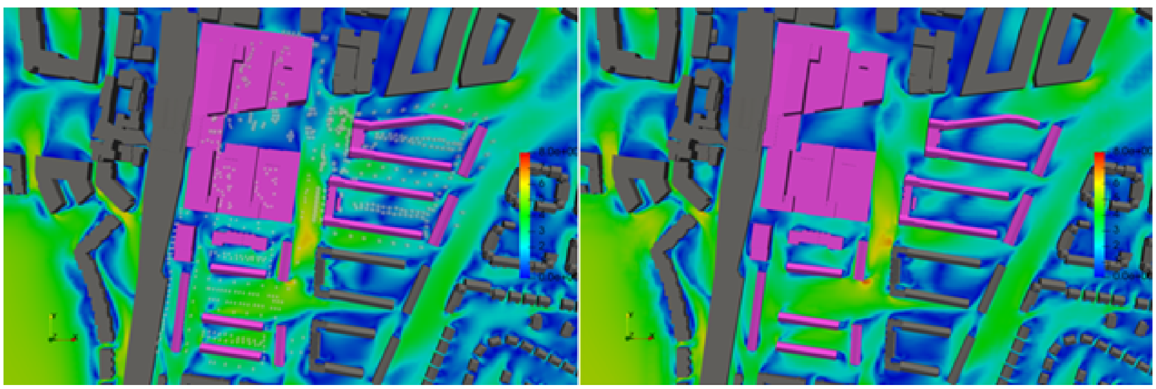


Figure 7.62: Wind Speed Results around the Development at 1.5m Above Development Ground - Comparison between not mitigated case (left) and mitigated case (right): 236° - 3D view

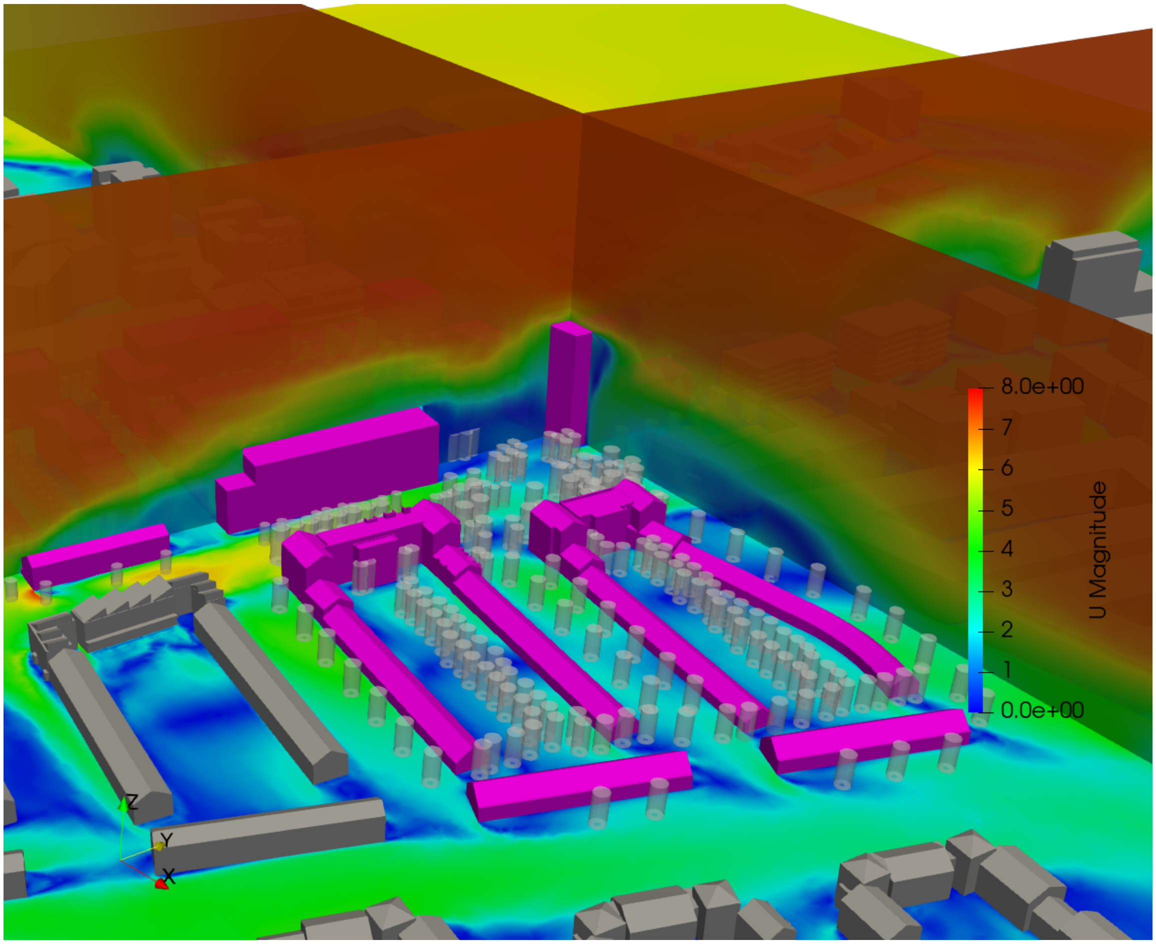


Figure 7.63: Wind Speed Results around the development near Block D3 (the tallest building in the development site): 236° - Cumulative Scenario -3D view

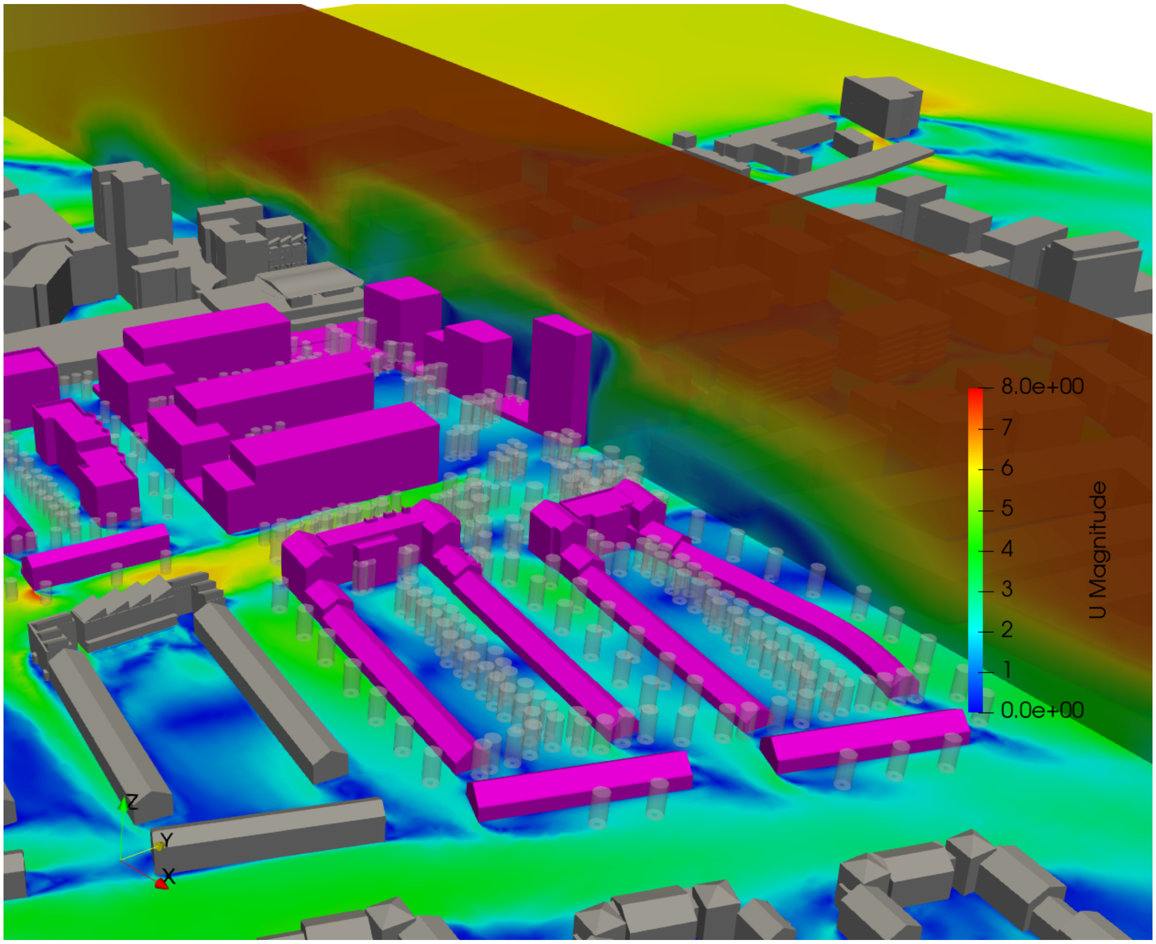


Figure 7.64: Wind Speed Results around the development near Block D3 (the tallest building in the development site): 236° - Cumulative Scenario - 3D view

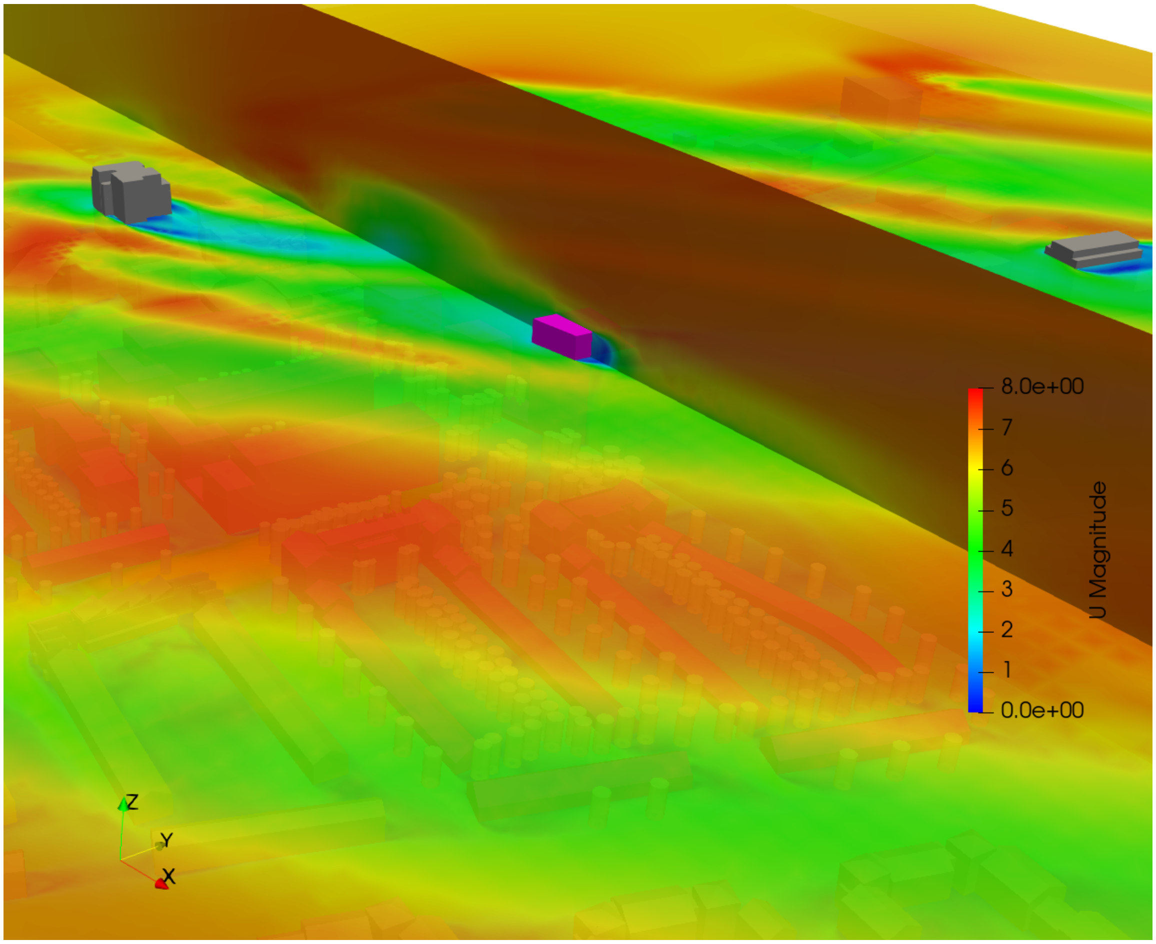


Figure 7.65: Wind Speed Results around the development near Block D3 (the tallest building in the development site): 236° - Cumulative Scenario - 3D view

7.0.5 Predicted Impact of the proposed development summary

The existing environment and proposed Project Shoreline GA1 Development would receive prevailing winds from South-West. As discussed in the previous sections and demonstrated through this assessment of CFD modelling, all adverse wind impacts has been considered and shows to be suitable to its intended use.

The existing site cumulative assessment has accounted for the modelling and simulation of all the topography and existing developments in the surrounding as the presence of adjacent buildings dictates how the wind will approach the proposed development.

From the wind modelling results, Project Shoreline GA1 Development will introduce no negative wind effect on adjacent, nearby or future phases developments within its vicinity. Wind modelling of future phases around this development will need to be performed for all future phase developments.

7.0.6 Risks to Human Health

This subsection aims to identify areas of Project Shoreline GA1 Development where the pedestrian safety and comfort could be compromised (in accordance with the Lawson Acceptance Criteria previously described). Pedestrian comfort criteria are assessed at 1.5m above ground level level.

Discomfort Criteria

Figures 7.67 and 7.68 combines all the above directions together and show the Lawson comfort categories over the ground floor area around Project Shoreline GA1 Development (including permitted GA2 and Clongriffin developments (existing and permitted but not built)). Figures 7.69 and 7.70 illustrate the Lawson comfort map obtained at 1.5m above the ground around the development (including permitted GA2, Clongriffin developments (existing and permitted but not built) and proposed GA3). The scale used is set out in Figure 7.66.

For the Lawson discomfort criteria, the onset of discomfort depends on the activity in which the individual is engaged and it is defined in terms of a mean hourly wind speed (or GEM) which is exceeded for 5% of the time. Depending on the wind direction, the suitability of the different areas can be assessed using the maps. It can be seen that the wind conditions range from "suitable for long term sitting" to "suitable for walking and strolling" and really rarely are only suitable for "business walking" or "unacceptable for pedestrian comfort".

The results shown in the map show that there are no critical area which are unacceptable for pedestrian comfort. Thus, the discomfort criteria is satisfied for all the different cases and in all directions and the are all around the development seems to be always suitable for long term sitting.

All the courtyards, parks and squares are always suitable for long term sitting, short term sitting, standing, walking and strolling activities.

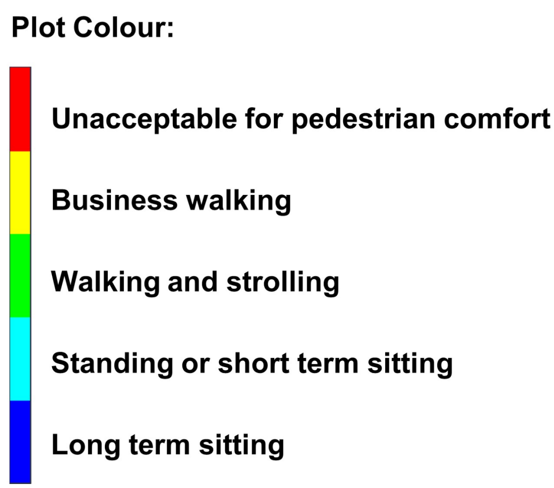


Figure 7.66: Lawson Comfort Categories

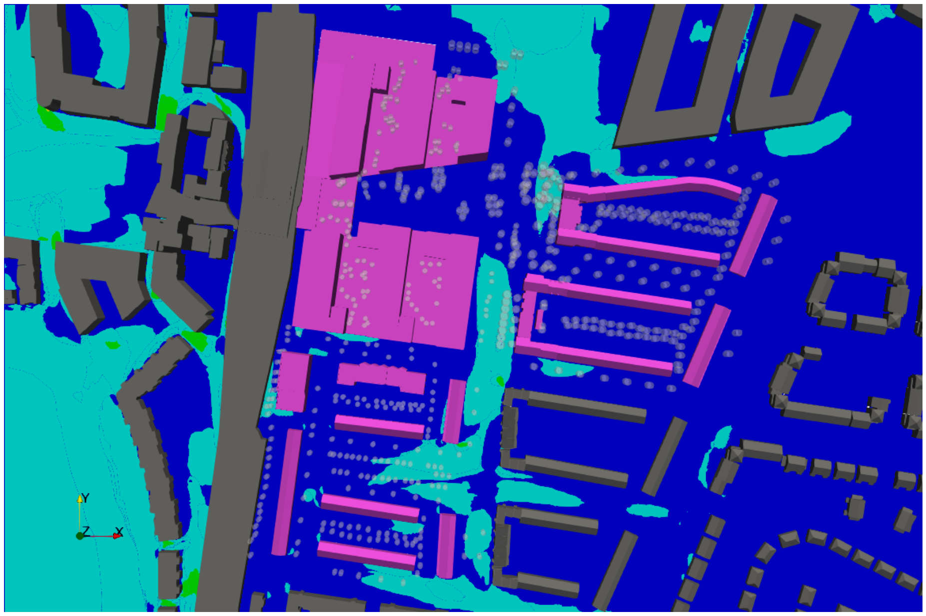


Figure 7.67: Ground Floor - Lawson Discomfort Map - Existing Scenario

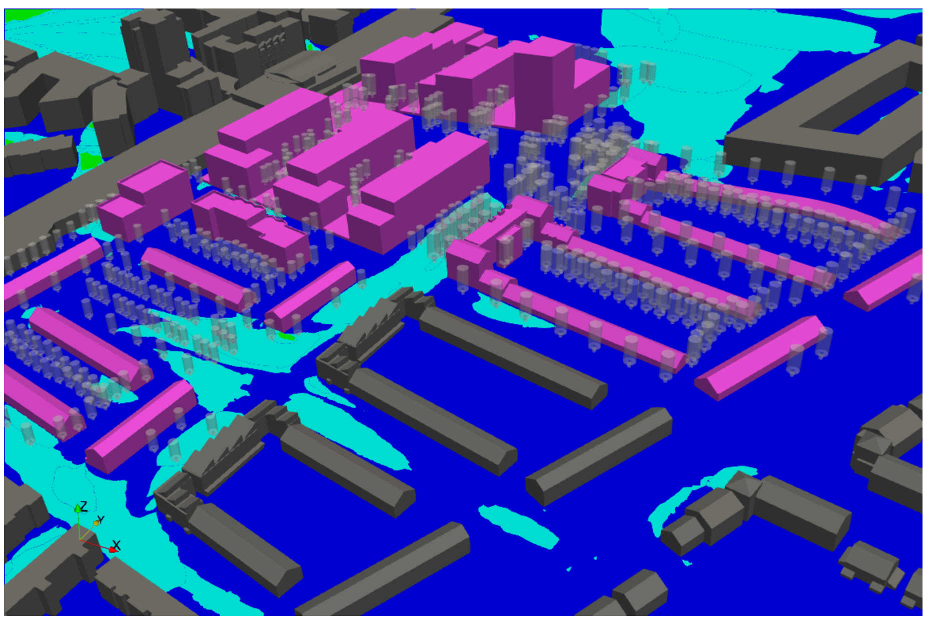


Figure 7.68: Ground Floor - Lawson Discomfort Map - Existing Scenario

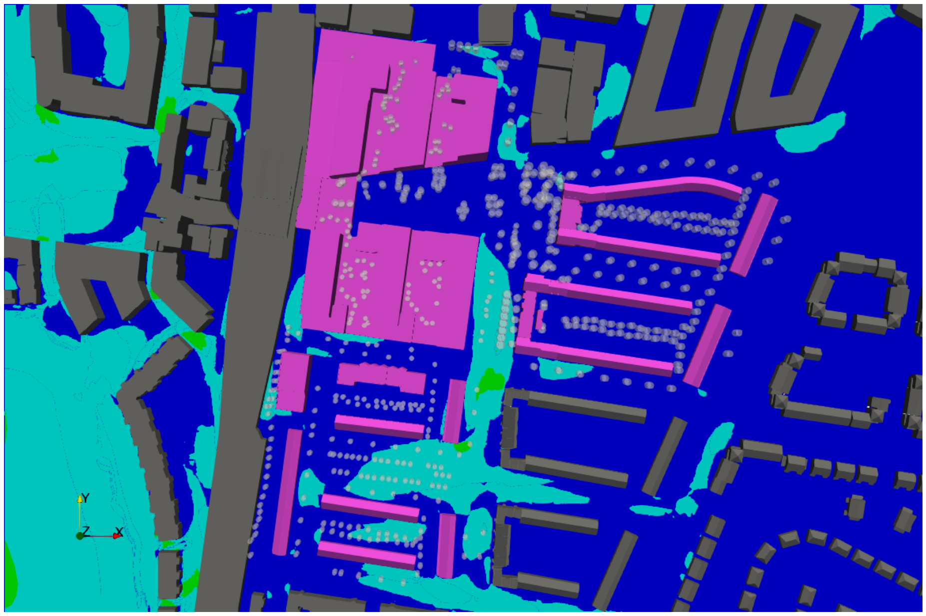


Figure 7.69: Ground Floor - Lawson Discomfort Map - Cumulative Scenario

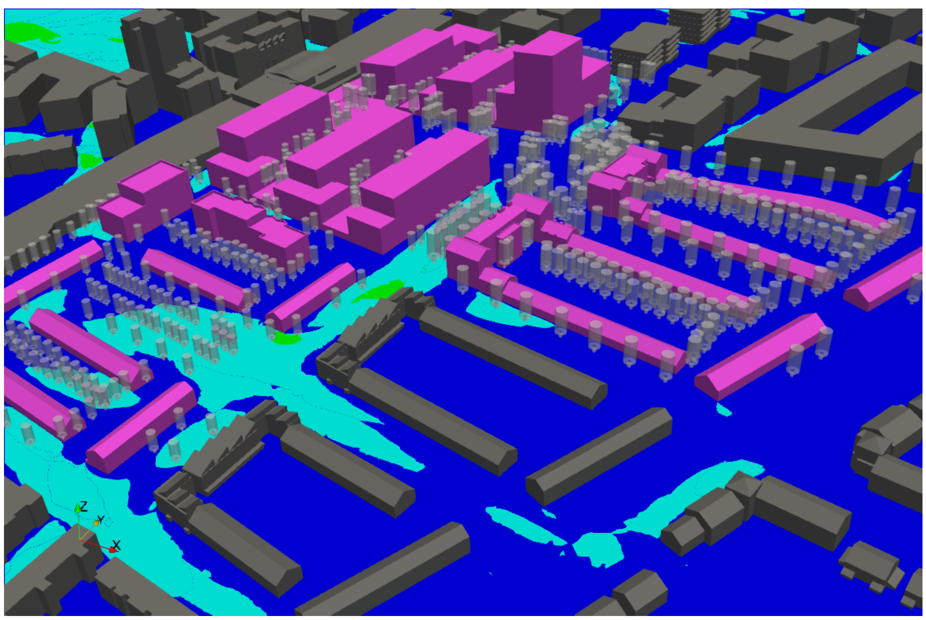


Figure 7.70: Ground Floor - Lawson Discomfort Map - Cumulative Scenario

Distress Criteria

In addition to the criteria for "discomfort" the Lawson method presents criteria for "distress". The discomfort criteria focus on wind conditions which may be encountered for hundreds of hours per year. The distress criteria require higher wind speeds to be met, but focus on two hours per year. These are rare wind conditions but with the potential for injury rather than inconvenience.

Figure 7.71 shows the hourly wind gust rose for Dublin, from 1985 to 2020. This will be necessary to assess how many hours per year on average the velocity exceed the threshold values.

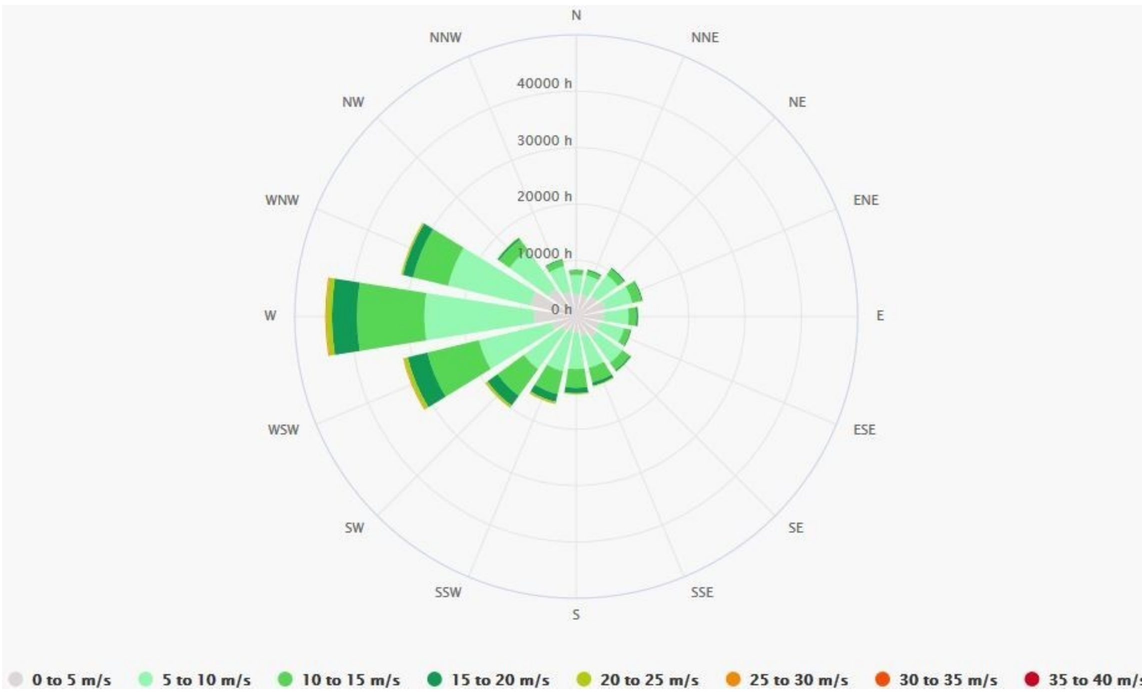


Figure 7.71: Hourly Dublin Wind Gust Rose

The criteria for distress for a frail person or cyclist is 15m/s wind occurring for more than two hours per year. Limiting the results from the above wind rose to the only values above 15m/s (as reported in Figures 7.72 and 7.73 respectively as cumulative hours and cumulative percentage), it is possible to see how many hours in 30 years the gust velocity of 15m/s is exceed at pedestrian level in each direction.

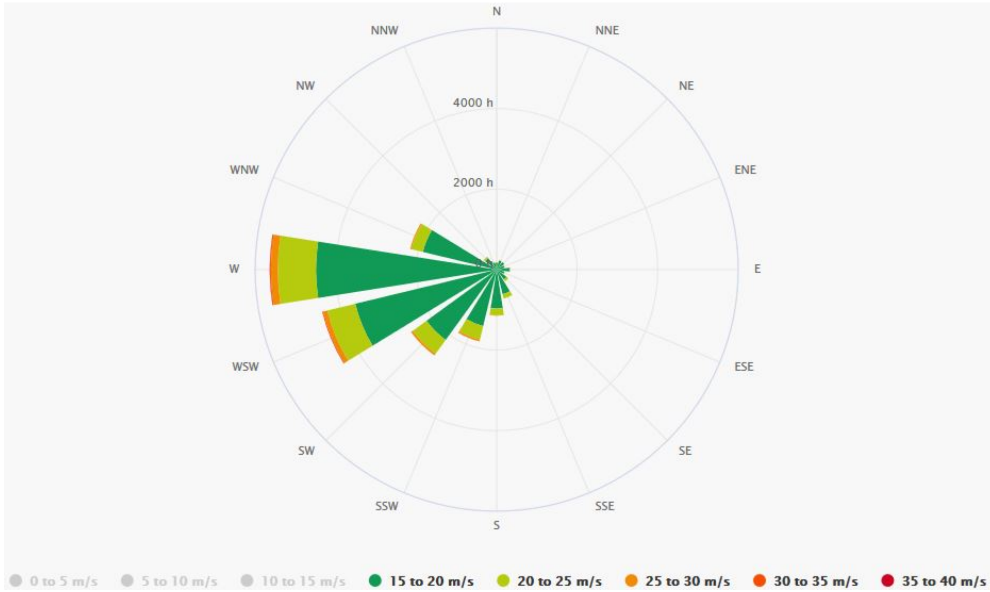


Figure 7.72: Hourly Dublin Wind Gust Rose - Cumulative hours when the velocity is above 15m/s

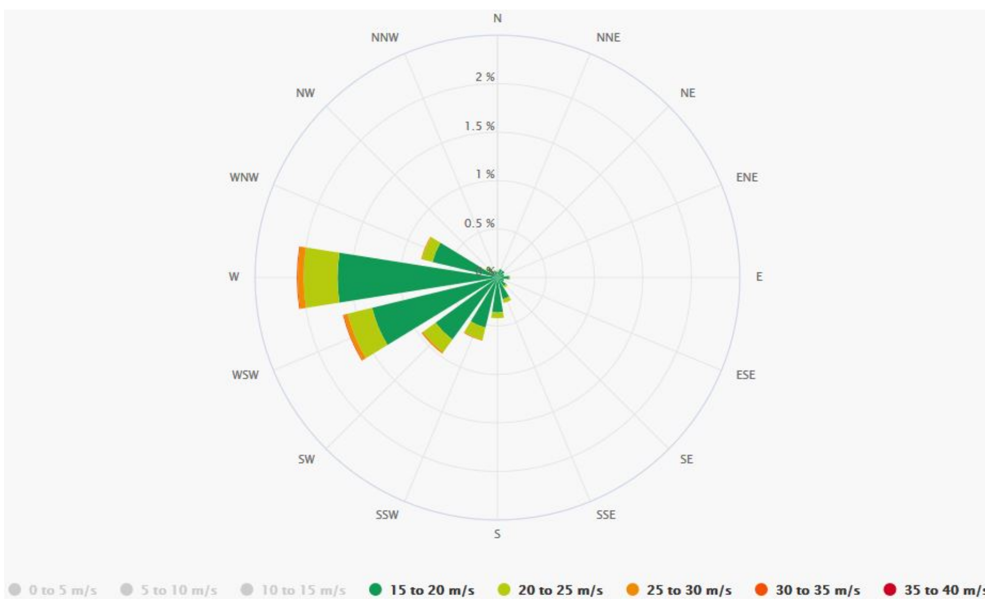


Figure 7.73: Hourly Dublin Wind Gust Rose - Cumulative percentage of time when the velocity is above 15m/s

A total of 2 hours per years corresponds to 0.02% in one year, which means 0.6% in 30 years. Looking at the wind roses above, it is possible to notice that a velocity of 15m/s was reached in Dublin only for the following directions (in increasing order of percentage) over the years 1985-2020:

1. West 270°
2. West-South-West 247.5°

3. South-West 225°

For this reason, it is of interest to show the distress results for these directions. Figures 7.75 and 7.76 show the areas where the measured velocity is above 15 m/s for existing and cumulative scenarios, respectively. Figure 7.74 shows the scale used in this case. Results show that there are not critical areas where the velocity increases above 15 m/s for both scenarios.

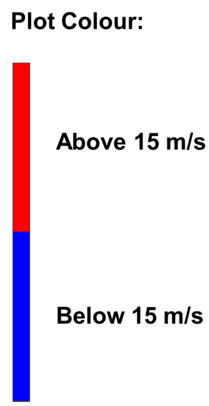


Figure 7.74: Lawson Distress Categories - Frail Person or Cyclist

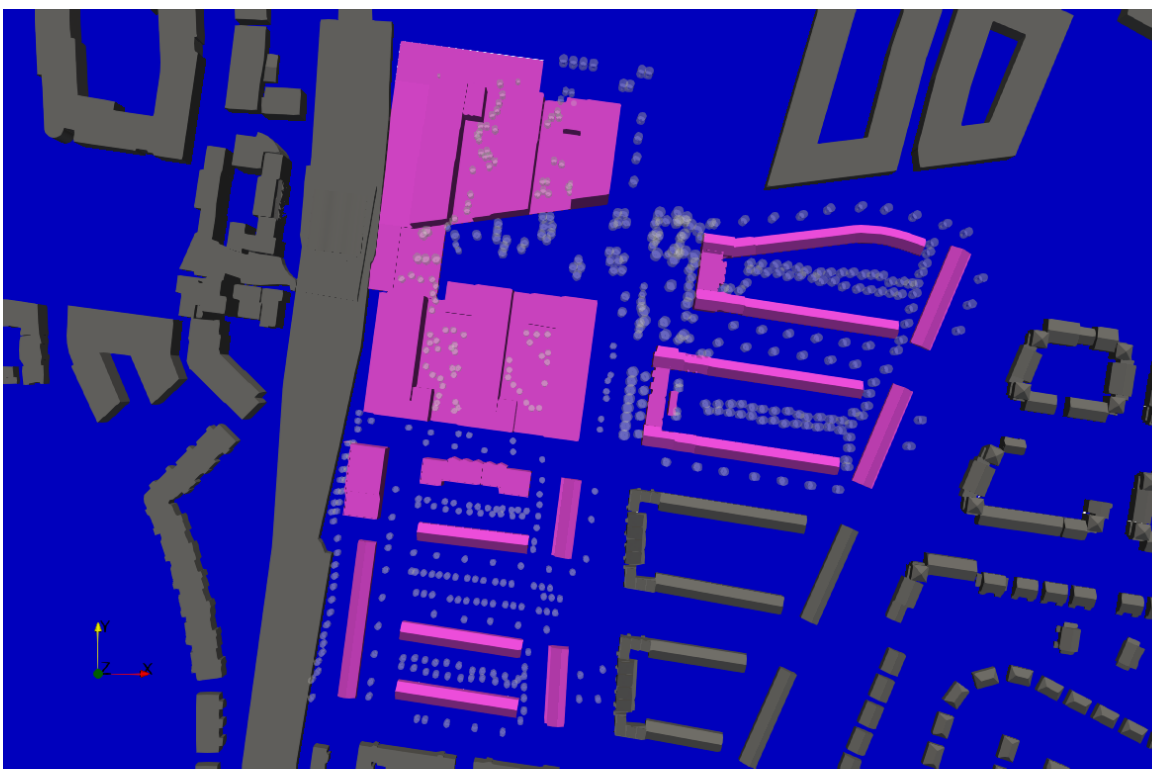


Figure 7.75: Lawson Distress Map - Frail Person or Cyclist - Existing Scenario

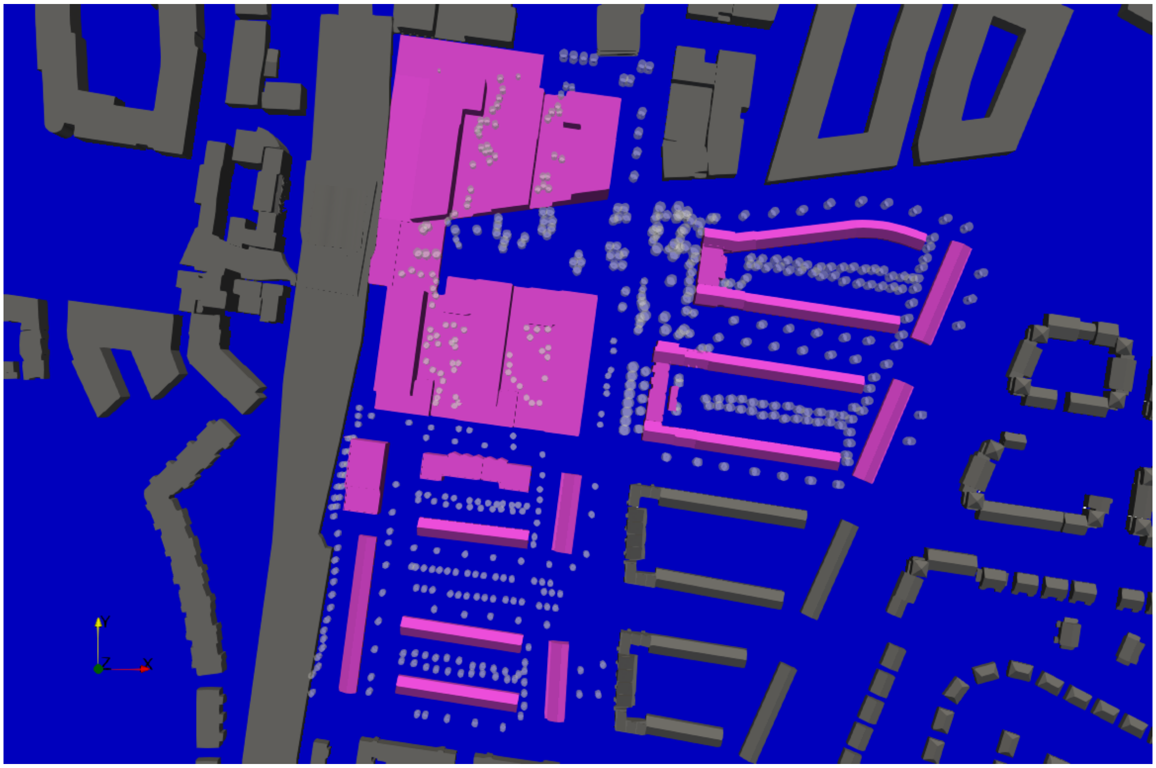


Figure 7.76: Lawson Distress Map - Frail Person or Cyclist - Cumulative Scenario

The criteria for distress for a member of the general population is 20m/s wind occurring for more than two hours per year. Limiting the results from the above wind rose to the only values above 20m/s (as reported in Figures 7.77 and 7.78 respectively as cumulative hours and cumulative percentage), it is possible to see how many hours in 30 years the gust velocity of 20m/s is exceed at pedestrian level in each direction.

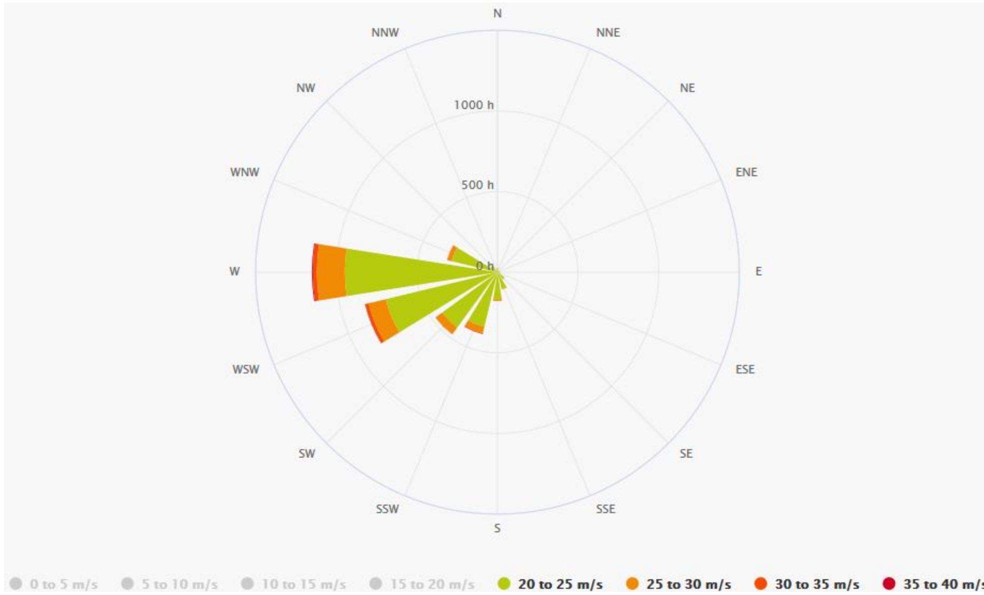


Figure 7.77: Hourly Dublin Wind Gust Rose - Cumulative hours when the velocity is above 20m/s

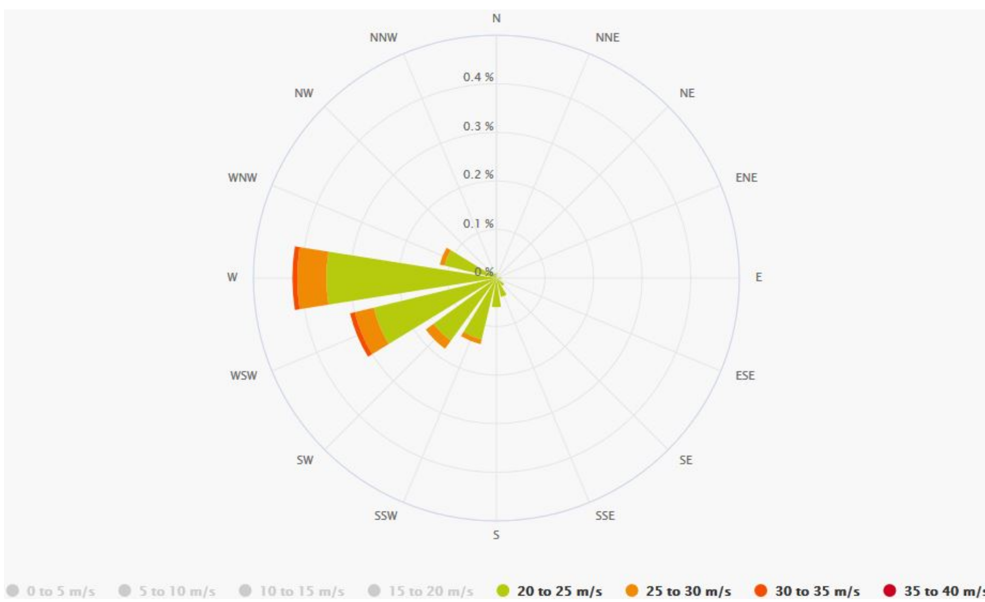


Figure 7.78: Hourly Dublin Wind Gust Rose - Cumulative percentage of time when the velocity is above 20m/s

A total of 2 hours per years corresponds to 0.02% in one year, which means 0.6% in 30 years. Looking at the wind roses above, it is possible to notice that a velocity of 20m/s was never reached in Dublin over the years 1985-2020. For this reason, it is not of interest to show the distress results for any of the wind directions and the criteria is always satisfied.

Summary of Analysis of the Proposed Development

From the simulation results the following observations are pointed out:

- The proposed Project Shoreline GA1 Development will produce a quality environment that is attractive and comfortable for pedestrians at ground floor both when assessed within the existing environment (including the permitted GA2 and Clongriffin developments (existing and permitted but not built)) both when the potential development GA3 was included. In the cumulative scenario, in particular, the area on the north of the site is further shielded providing some extra protection from those wind directions also for the proposed GA1.

- Areas around the development where velocities can be higher have been identified near the corners of the blocks, on the main road across the development. However, these were mitigated using tree landscaping, with particulate attention to the corners of the blocks.

- Funnelling effects are experienced on some of the main roads around the development and on the roads in-between some of the blocks. These have been mitigated using tree landscaping, It must be noted that the roads are not used as sitting areas therefore higher flow velocities can be accepted.These effects can be seen as being further reduced during the cumulative assessment.

- Parks and squares are well shielded from the various wind directions and well implemented with tree landscaping.

- The mitigation measures in place significantly reduce the velocities around the proposed Project for both scenarios. The recirculation and funnelling effects highlighted in the initial scheme have been successfully reduced or eliminated during the design re-iteration. Some slightly higher velocities are still found for some wind directions around some of the corners of the buildings and on the south side of the proposed Project. However, these velocities are below critical values.

- The proposed Project does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings when analysed in the existing environment and also including the cumulative scenario.

- The pedestrian comfort assessment, performed at Ground Floor level according to the Lawson criteria, identified the areas that are suitable for the different pedestrian activities in order to guarantee pedestrian comfort. The area all around the development seems to be suitable for every activity, including long term sitting. Also the courtyards, parks and squares are always suitable for long term sitting, short term sitting, standing, walking and strolling activities. Moreover, in terms of distress, no critical conditions were found for “Frail persons or cyclists” and ”General Public” in the surrounding of the development.

8. MONITORING

8.0.1 Construction Phase

There is no particular requirement to monitor wind impact during construction phase as the designated amenity areas will not be in use during this phase of the project.

8.0.2 Operational Phase

During the development operational phase, it has been designed to conform to acceptable Lawson Criteria for Comfort and Distress in accordance with the Wind Beaufort Scale.

9. REINSTATEMENT

9.1 REINSTATEMENT

9.1.1 Construction Phase

Not applicable.

9.1.2 Operational Phase

Not applicable.

10. DIFFICULTIES ENCOUNTERED

10.1 DIFFICULTIES ENCOUNTERED IN COMPILING

No difficulties were encountered during the assessment of wind and microclimate impacts on Project Shoreline GA1 Development or its existing environments.

11. CONCLUSIONS

11.1 CONCLUSIONS and COMMENTS ON MICROCLIMATE STUDY

This report presents the CFD modelling assumptions and results of Wind and Microclimate Modelling of the proposed Project located at Baldoyle-Stapolin Growth Area 1 (GA1), Baldoyle, Dublin 13.

Results of this are utilized by the design team to configure the optimal layout for Project Shoreline GA1 Development for the aim of achieving a high-quality environment for the scope of use intended for each areas/building (i.e. comfortable and pleasant for potential pedestrian) and not to introduce any critical wind impact on the surrounding areas and on the existing buildings (in accordance with the Lawson Acceptance Criteria).

- The wind profile was built using the annual average of meteorology data collected at Dublin Airport Weather Station. In particular, the local wind climate was determined from historical meteorological data recorded 10 m above ground level at Dublin Airport. 18 different scenarios were selected in order to take into consideration all the different relevant wind directions. In particular, a total of 18 compass directions on the wind rose are selected. For each direction, the reference wind speed is set to the 5% exceedance wind speed for that direction, i.e. the wind speed that is exceeded for over 5% of the time whenever that wind direction occurs.

- The wind profile built using the data from Dublin Airport, is also compared with the one obtained using the data collected on-site. Except few differences, both the wind speed daily mean and the wind gust daily mean recorded on site follow the same patterns as the ones recorded at Dublin Airport. The speed levels registered on-site are in few cases slightly lower. This is due to the fact that, despite its vicinity to the coast, the site is located close to the urban environment thus much more shielded if compared with Dublin Airport. This confirms the fact that using wind data from Dublin Airport still ensures a conservative analysis of the wind impact on the development.

- The prevailing wind directions for the site are identified in the West, West South-West and South-East with magnitude of approximately 6m/s.

- The proposed development has been assessed considering permitted GA2 and Clongriffin developments (existing and permitted but not built) as part of the existing environment and including proposed GA3 for cumulative scenario.

- The proposed Project Shoreline GA1 Development will produce a quality environment that is attractive and comfortable for pedestrians at ground floor both when assessed within the existing environment (including the permitted GA2 and Clongriffin developments (existing and permitted but not built)) both when the potential development GA3 was included. In the cumulative scenario, in particular, the area on the north of the site is further shielded providing some extra protection from those wind directions also for the proposed GA1.

- Areas around the development where velocities can be higher have been identified near the corners of the blocks, on the main road across the development. However, these were mitigated using tree landscaping, with particulate attention to the corners of the blocks.

- Funnelling effects are experienced on some of the main roads around the development and on the roads in-between some of the blocks. These have been mitigated using tree landscaping, It must be noted that the roads are not used as sitting areas therefore higher flow velocities can be accepted.These effects can be seen as being further reduced during the cumulative assessment.

- Parks and squares are well shielded from the various wind directions and well implemented with tree landscaping.

- The mitigation measures in place significantly reduce the velocities around the proposed Project for both scenarios. The recirculation and funnelling effects highlighted in the initial scheme have been successfully reduced or eliminated during the design re-iteration. Some slightly higher velocities are still found for some wind directions around some of the corners of the buildings and on the south side of the proposed Project. However, these velocities are below critical values.

- The proposed Project does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings when analysed in the existing environment and also including the cumulative scenario.

- The pedestrian comfort assessment, performed at Ground Floor level according to the Lawson criteria, identified the areas that are suitable for the different pedestrian activities in order to guarantee pedestrian comfort. The area all around the development seems to be suitable for every activity, including long term sitting. Also the courtyards, parks and squares are always suitable for long term sitting, short term sitting, standing, walking and strolling activities. Moreover, in terms of distress, no critical conditions were found for "Frail persons or cyclists" and "General Public" in the surrounding of the development.

- During the proposed Project Construction Phase the predicted impacts are classified as negligible.

Therefore, the CFD study carried out has shown that under the assumed wind conditions typically occurring within Dublin for the past 30 years:

- **The development is designed to be a high-quality environment for the scope of use intended of each areas/building (i.e. comfortable and pleasant for potential pedestrian), and,**
- **The development does not introduce any critical impact on the surrounding buildings, or nearby adjacent roads.**

12. REFERENCES

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