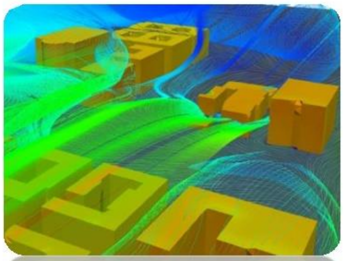
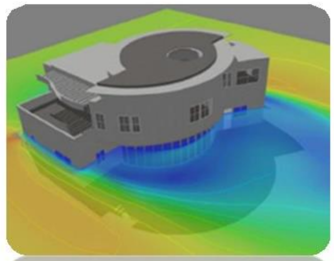
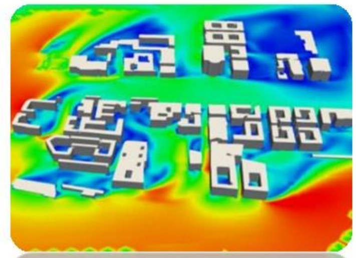

WIND MICROCLIMATE MODELLING

Coastal Quarter SHD 2

Bray, Co. Dublin and Co. Wicklow

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

For: Shankill Property Investments Limited

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Buildings Fluid Dynamics

<table>
<tr><th colspan="3">Document Reference</th></tr>
<tr><td>Project Name</td><td colspan="2">WIND MICROCLIMATE MODELLING
Coastal Quarter SHD 2</td></tr>
<tr><td>Project Ref.</td><td colspan="2">W_2209359</td></tr>
<tr><td>Site location</td><td colspan="2">Former Bray Golf Club lands, off Ravenswell Road and Dublin Road, Bray</td></tr>
<tr><td>CFD Study by</td><td colspan="2">B-Fluid Ltd.</td></tr>
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CFD Modelling Specialist
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Mech Eng. PhD, M.Sc, B.Eng</td><td>Dr. Arman Safdari
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<tr><td>Report issued on</td><td colspan="2">September 7, 2022</td></tr>
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Contents

1. EXECUTIVE SUMMARY

B-Fluid Limited has been commissioned by 'Shankill Property Investments Limited' to carry out a Wind Microclimate Modelling Study for the Coastal Quarter - Strategic Housing Development at the Former Bray Golf Club lands, off Ravenswell Road and Dublin Road, Bray, Co. Dublin and Co. Wicklow, as part of the supporting documents required for the planning application for the proposed development. The proposed masterplan residential development is located on the northern side of Bray town centre. The overall masterplan is 44 acres (17.8 hectares (ha)) in size and will be developed in two key phases, namely:

- Phase 1 - Coastal Quarter; and,
- Phase 2 - River Quarter.

This study is for the development of the Phase 1 - Coastal Quarter (hereafter referred to as 'the proposed development' or 'the site'), via the Strategic Housing Development (SHD) planning process.

Phase 1 of the Coastal Quarter - Strategic Housing Development Masterplan consists of the Coastal Quarter, and is located within Wicklow County and Dún Laoghaire - Rathdown County jurisdictions.

The site is generally bounded to the north by the existing public open space at Valley Park and existing housing estate at Corke Abbey, to the east by the Irish Rail Dublin-Rosslare main rail line, to the south and south west by the River Dargle and the Phase 2 development lands, and to the west by the existing Ravenswell schools campus.

The applicant intends to apply to An Bord Pleanála for permission for a Strategic Housing Development (SHD) comprising 586 no. residential units in a mix of apartments, duplexes and houses. In addition, a childcare facility, café, retail unit and 1 no. commercial unit (incorporating a gym and a juice bar) are proposed along with all associated and ancillary development and infrastructural works, hard and soft landscaping, open spaces, boundary treatment works, ancillary car and bicycle parking spaces at surface, undercroft and basement levels. The proposed houses and duplexes range in height from 2 – 3 storeys with the proposed 4 no. apartment blocks ranging in height from 3 – 12 storeys. Block A will accommodate 162 no. Build-to-Rent (BTR) units. It is proposed that 274 no. units will be located within the administrative area of Dun Laoghaire-Rathdown County Council and 312 no. units will be located within the administrative area of Wicklow County Council. The childcare facility, retail, café and commercial unit will all be located in the administrative area of Wicklow County Council.

Planning permission was granted on part of the subject site for 234 no. residential units, a childcare facility, café and retail unit subject to compliance with the terms of conditions attached to reference ABP-311181-21. The current proposed development includes the development as previously permitted under ABP-311181-21 including minor revisions chiefly addressing conditions and new proposals for Blocks A and B which were previously refused.

Figure 1.1 shows a view the site boundary in the redline.

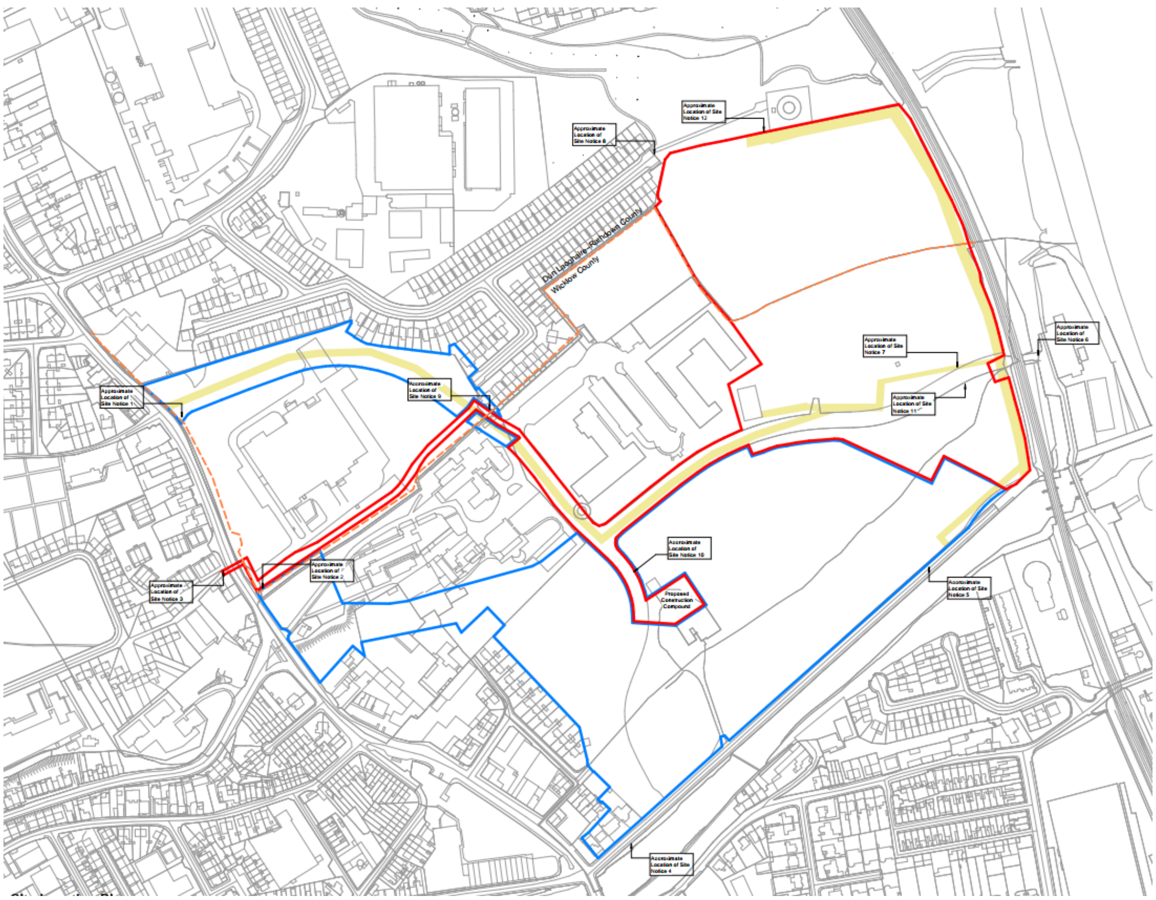


Figure 1.1: Proposed Coastal Quarter - Strategic Housing Development - Site boundary

Figure 1.1 shows a view of the proposed development (colored blocks) in the existing urban context.

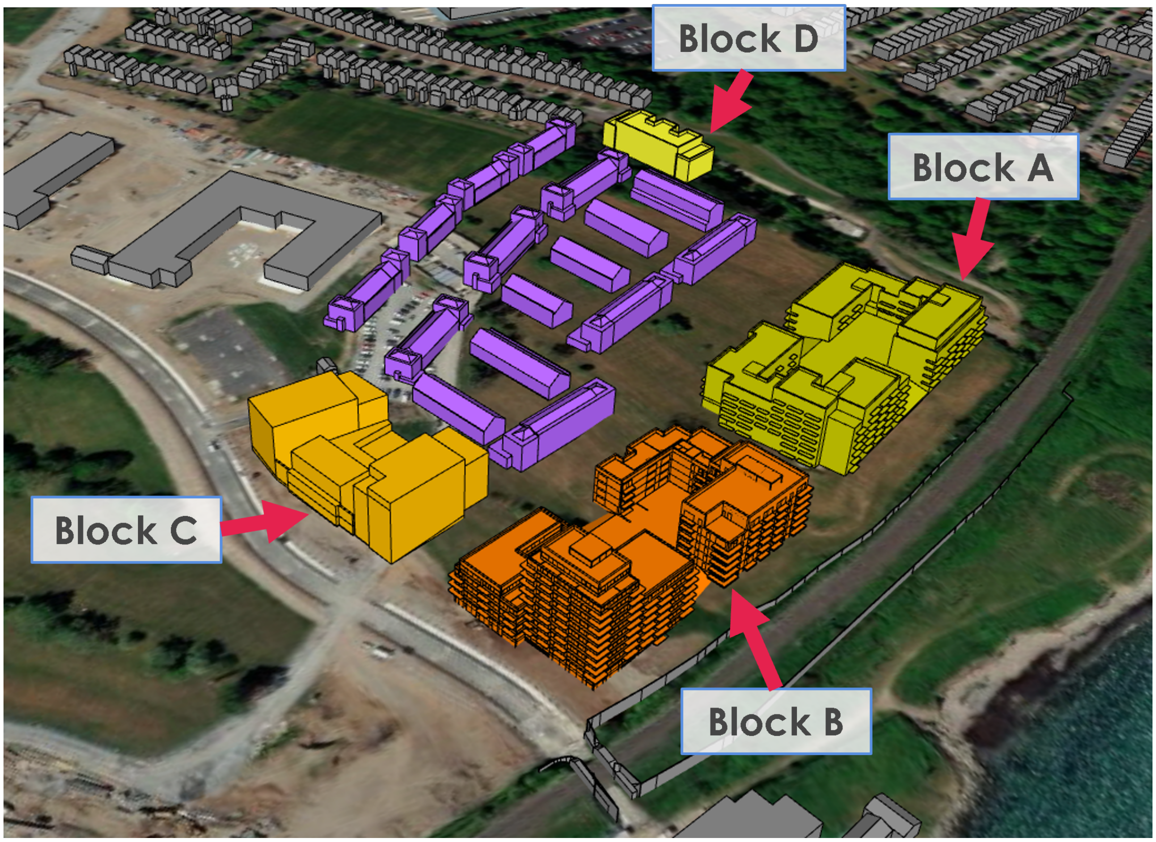


Figure 1.2: Proposed Coastal Quarter - Strategic Housing Development

Wind microclimate studies identify the possible wind patterns around the existing environment and proposed development under mean and peak wind conditions typically occurring in Dublin. A wind microclimate 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/funnelling/downdraft/critical flow accelerations that may likely occur. The Advanced CFD numerical algorithms applied here are solved using high performance computing cluster.

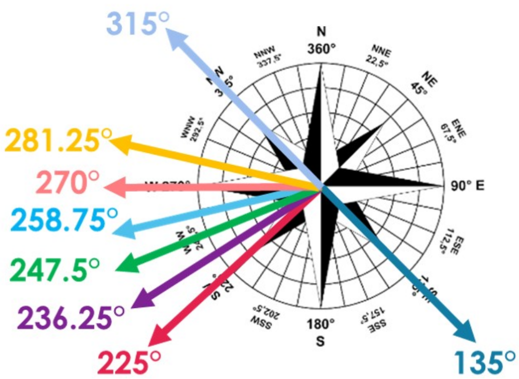
This study results have been utilized by the design team to configure the optimal layout for Coastal Quarter - Strategic Housing Development Development with the aim of achieving a high-quality environment for the scope of use intended of each areas/building (i.e. comfortable and pleasant for potential pedestrian) and not to introduce any critical wind impact on the surrounding areas and on the existing buildings.

This technical report describes the wind microclimate study performed and rationals of the methodology and assumptions that B-Fluid Ltd. has adopted for this analysis.

For the purpose of performing an elaborate wind microclimate study, 18 different wind scenarios and directions have been modeled as shown in Table 1.1 in order to take into account all the relevant wind directions in the subject site. 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 Proposed Development



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 1.3: Summary of 8 Wind Scenarios Reported

A qualitative and quantitative summary of the wind microclimate modelling study performed for Coastal Quarter - Strategic Housing Development shows that:

- The wind profile around the existing environment was created using the annual average 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 and adapted to the location of this development.
- The prevailing wind directions for the site are identified as West, West-South-West and South-West, South-East with magnitude of approximately 6m/s.
- The proposed Coastal Quarter - Strategic Housing Development has been designed in order to produce a high-quality environment that is attractive and comfortable for pedestrians of all categories. To achieve this objective, throughout the design process, the impact of wind has been considered and analysed, in the areas where critical patterns were found, the appropriate mitigation measures were introduced.
- A number of iterations of this study have been carried out to optimize the design in order to achieve a high quality and well sheltered scheme.
- Although some minor flow velocity accelerations are still noticeable on the final scheme, on the road south side of Block B and adjacent to Block C, as well as the area between Block A and the adjacent rail structure, the highlighted accelerations are well kept below the threshold limit; indeed the Lawson map (which is the map commonly adopted in wind microclimate studies to relate the wind conditions with the suitable pedestrian activities) indicates that this road can be utilised for the intended use (i.e. for those activities which include any type of walking and also short term sitting).
- Courtyards of Block A,B and C are well protected, a small area in the middle of both courtyards of Block A and B is suitable for short term sitting instead of long term-sitting due to minor re-circulation effects. These conditions are not occurring at

a frequency that would compromise the pedestrian comfort, according to the Lawson Criteria.

- The analysis carried out on the roof terrace on Block C shows that the area is well protected by a combination of glazed screen and parapet wall and long term sitting is achieved for the majority of the year.
- Regarding the balconies, higher velocities have been identified on a number of the balconies which is to be expected in a coastal location. However, these velocities are below the threshold values defined by the acceptance criteria and therefore are not critical for safety. On occasions when the private balconies may not be suitable for short term sitting, residents can use internal courtyard or communal amenity spaces.
- Tree planting all around the development has been utilised, with particular attention to the corners of the buildings and the courtyard and this has positively mitigated any critical wind effects. Thus, it can be concluded that at ground floor good shielding is achieved everywhere.
- The proposed development does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings, Corke Abbey houses and the Ravenswell Schools complex. In particular, the development is acting as a shield to the Corke Abbey houses and the Ravenswell Schools complex from any winds coming from the East direction, while it does not have any impact on the wind coming from the South or West direction.
- Moreover, in terms of distress, no critical conditions were found for ”Frail persons or cyclists” and for members of the ”General Public” in the surrounding of the development, including the Corke Abbey houses and the Ravenswell Schools complex.

2. PROJECT DESCRIPTION

2.1 INTRODUCTION

This technical report presents a wind microclimate study carried out for Coastal Quarter - Strategic Housing Development ; The image in Figures 2.1 shows the site boundary in the red line.

The following paragraphs detail all the project information used throughout the study, together with results of the assessment carried out.

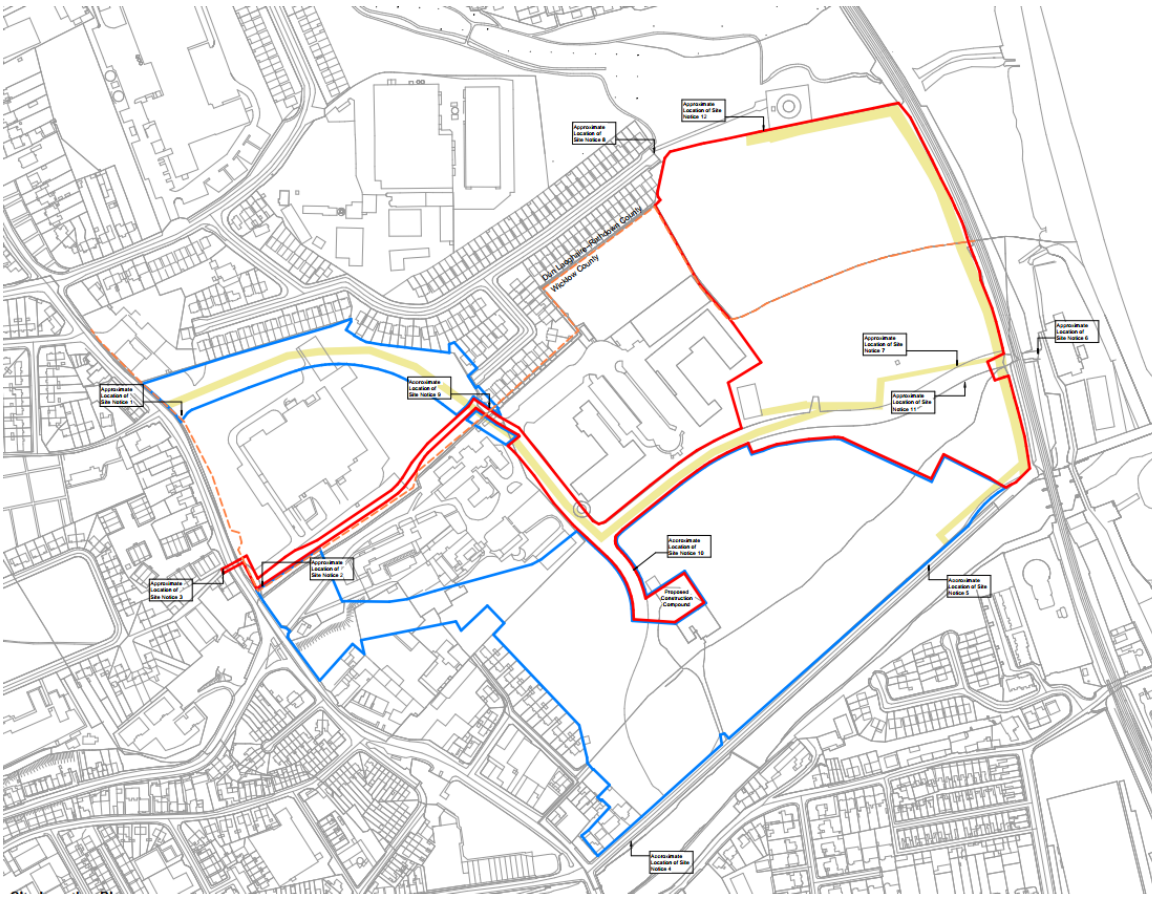


Figure 2.1: Site boundary in the red line

2.2 DESCRIPTION OF DEVELOPMENT

The applicant intends to apply to An Bord Pleanála for permission for a Strategic Housing Development (SHD) comprising 586 no. residential units in a mix of apartments, duplexes and houses. In addition, a childcare facility, café, retail unit and 1 no. commercial unit (incorporating a gym and a juice bar) are proposed along with all associated and ancillary development and infrastructural works, hard and soft landscaping, open spaces, boundary treatment works, ancillary car and bicycle parking spaces at surface, undercroft and basement levels. The proposed houses and duplexes range in height from 2 – 3 storeys with the proposed 4 no. apartment blocks ranging in height from 3 – 12 storeys. Block A will accommodate 162 no. Build-to-Rent (BTR) units. It is proposed that 274 no. units will be located within the administrative area of Dun Laoghaire-Rathdown County Council and 312 no. units will be located within the administrative area of Wicklow County Council. The childcare facility, retail, café and commercial unit will all be located in the administrative area of Wicklow County Council.

Planning permission was granted on part of the subject site for 234 no. residential units, a childcare facility, café and retail unit subject to compliance with the terms of conditions attached to reference ABP-311181-21. The current proposed development includes the development as previously permitted under ABP-311181-21 including minor revisions chiefly addressing conditions and new proposals for Blocks A and B which were previously refused.

The image in Figure 2.2 shows the position of the proposed blocks (in color) within the existing urban context (in grey).

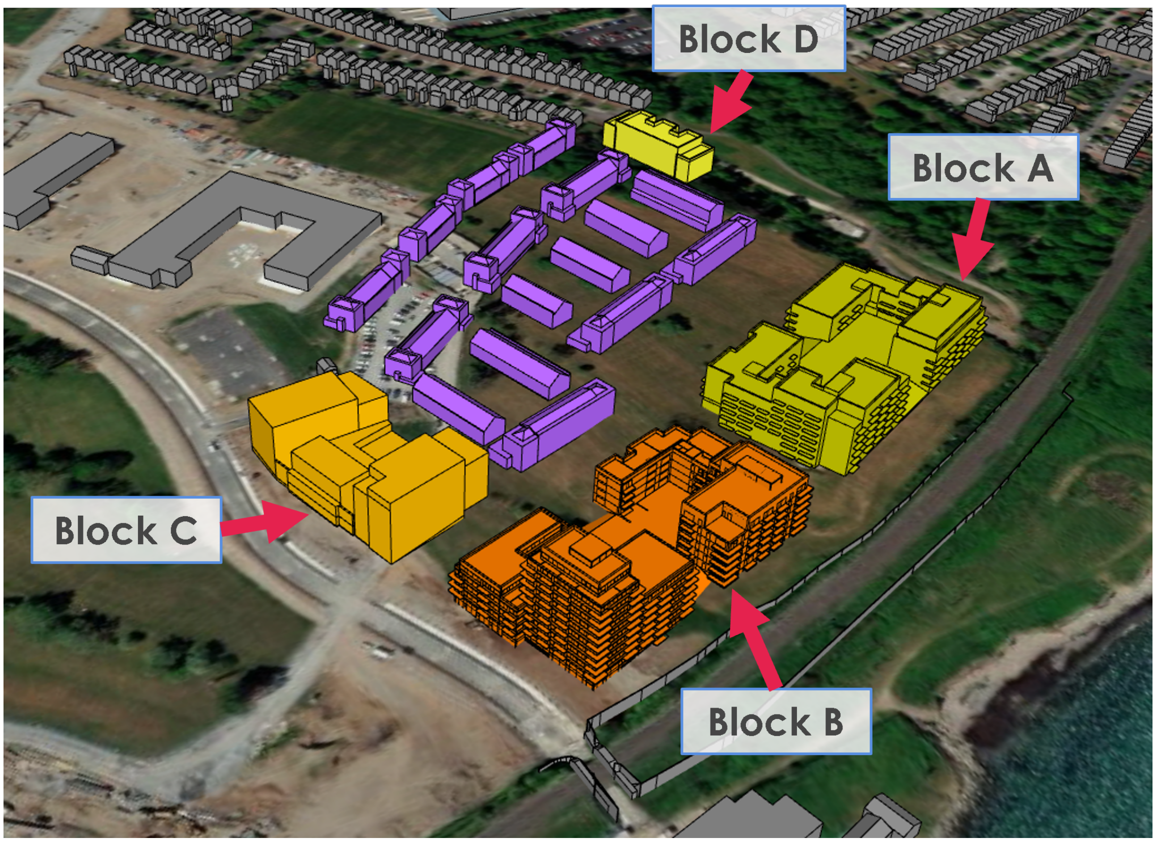


Figure 2.2: Coastal Quarter - Strategic Housing Development 3D Model

2.3 EXTENTS OF ANALYSED AREA

Coastal Quarter - Strategic Housing Development Development is located at an existing 7.66 ha parcel of land within the former Golf Course lands to the north of Bray Town Centre, in Bray, County Wicklow and County Dublin. The site is shown in Figure 2.3 and Figure 2.4.

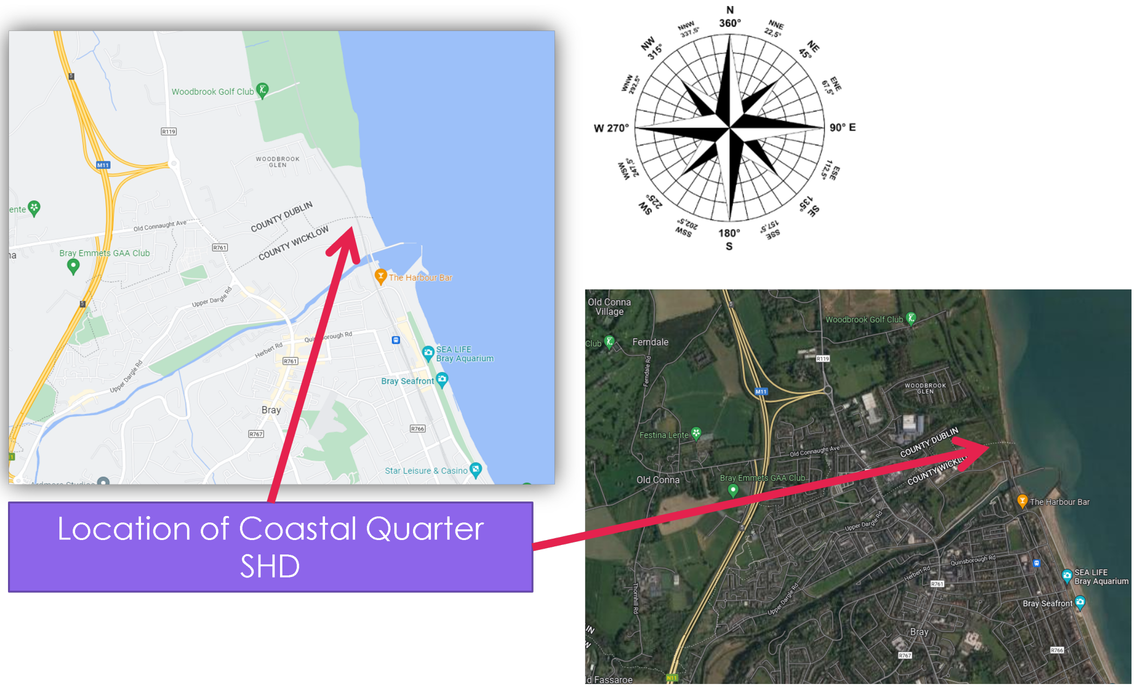


Figure 2.3: Coastal Quarter - Strategic Housing Development Actual Site Location

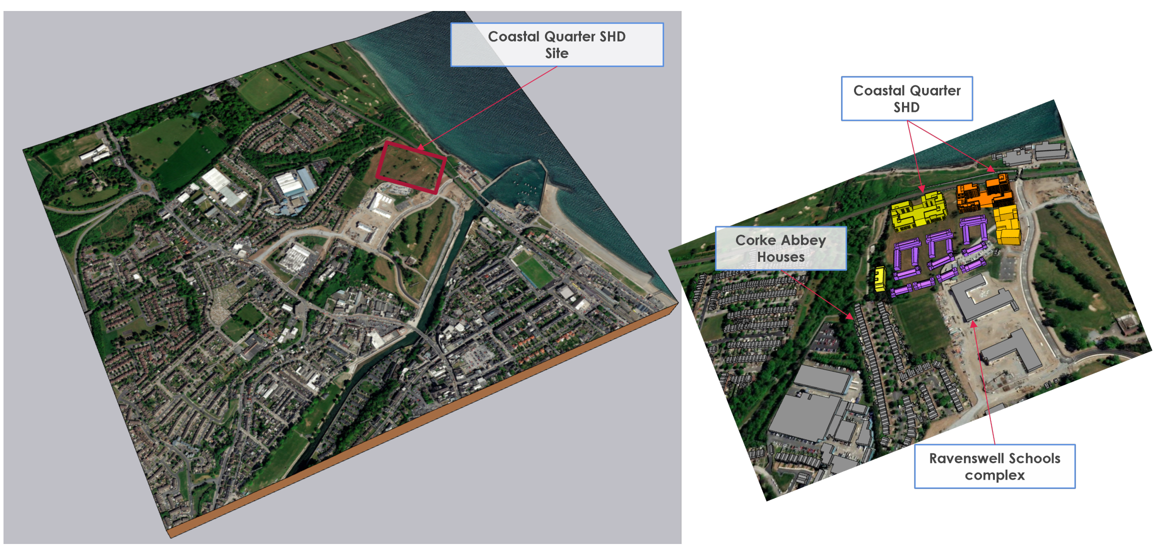


Figure 2.4: Extents of Analysed Area around Coastal Quarter - Strategic Housing Development Development

2.4 OBJECTIVE OF THE WIND MICROCLIMATE STUDY

The CFD wind model is adopted to identify areas of concern in terms of critical flows and areas where the 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 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 sidewalks and street frontages, pathways, building entrance areas, open spaces, amenity areas, outdoor sitting areas, and accessible roof top areas among others.

2.4.1 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 prescibed by the Wind Microclimate Guidelines for Developments in the City of London (August 2019).

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 2.5: 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)

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.

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 ahould 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.

3. STUDY METHODOLOGY

3.1 STUDY METHODOLOGY

The methodology adopted for the wind microclimate analysis of the proposed development is outlined as follows;

The following sections give details on the methodology utilized.

- Perform a wind desktop study of the existing environment.
- Perform computational wind microclimate analysis of the proposed development within the existing environment.

3.2 WIND IMPACT ASSESSMENT ON BUILDINGS

3.2.1 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 3.1 shows the wind velocity profile, as described above.

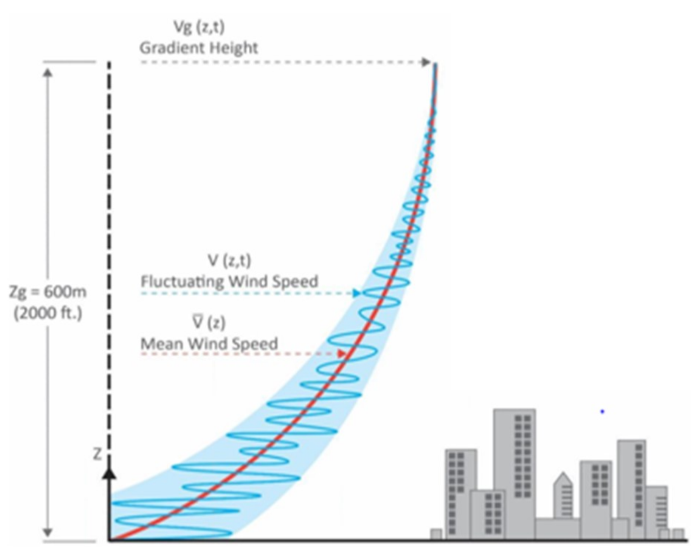


Figure 3.1: Wind Velocity Profile

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 windspeed. As a general rule, windspeed increases with height.

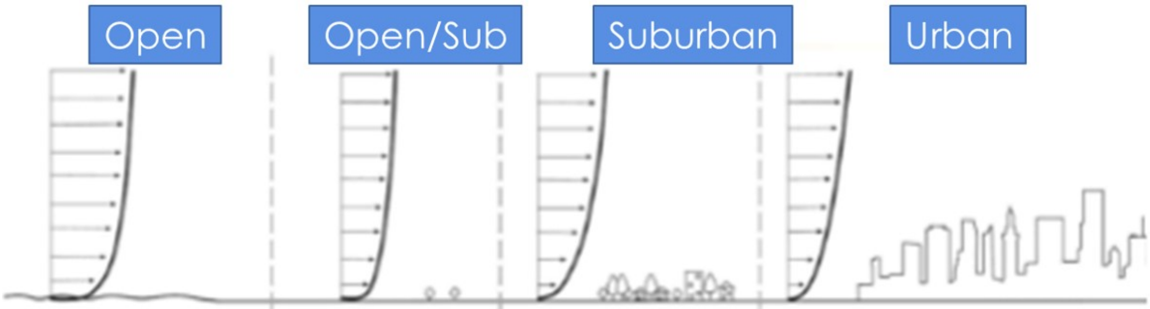


Figure 3.2: Wind Velocity Profile for different terrains

In order to assess the wind conditions in a particular area, it is important to know (Figure 3.3):

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

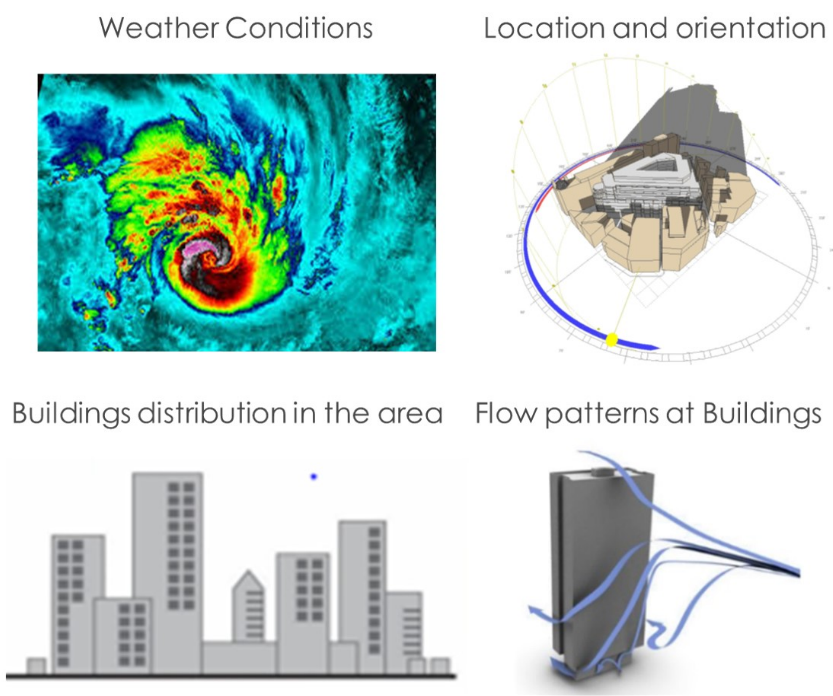


Figure 3.3: Parameters to know for Wind Conditions Assessment

Moreover, it is important to understand key flow features (Figure 3.4):

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

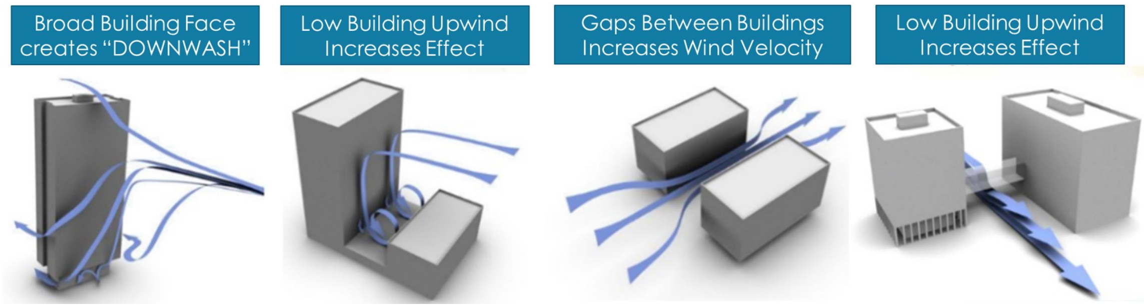


Figure 3.4: Parameters to know for Wind Conditions Assessment

3.3 ACCEPTANCE CRITERIA

3.3.1 PEDESTRIAN COMFORT AND LAWSON CRITERIA

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.

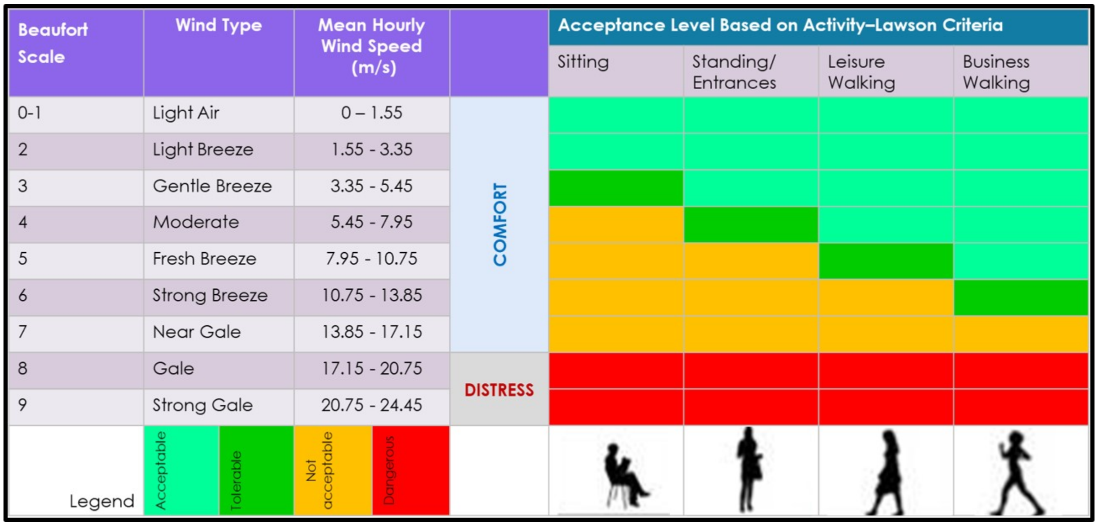
Only gust winds are considered in the safety criterion. These are usually rare events, but deserve special attention in city planning and building design due to their potential impact on pedestrian safety. Gusts cause the majority of cases of annoyance and distress and are assessed in addition to average 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.

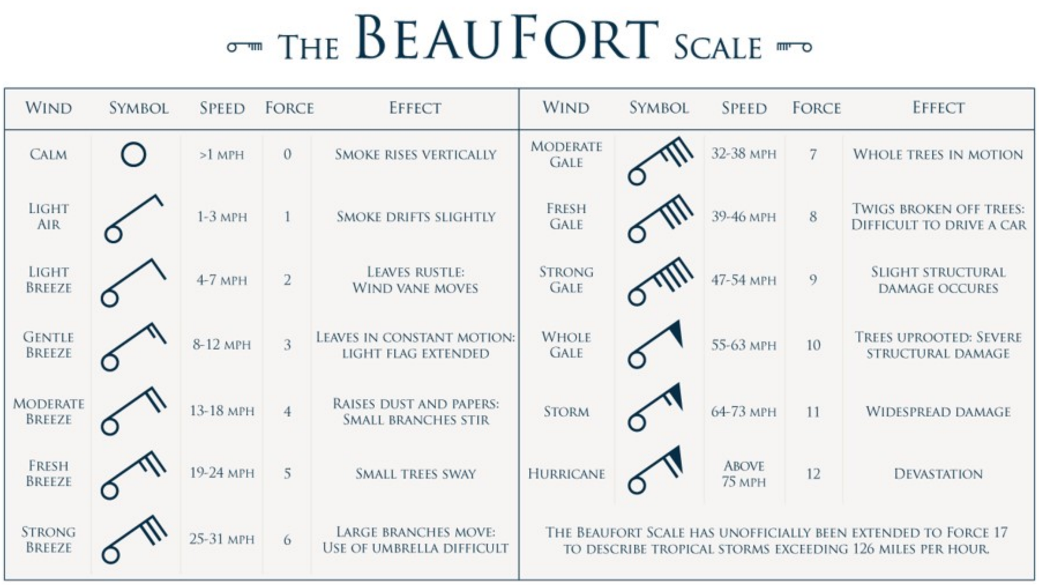
- DISTRESS CRITERIA: Relates to the physical well-being of the individual.
  Onset of distress:
  - ‘Frail Person Or Cyclist’: equivalent to an hourly mean speed of 15 m/s and a gust speed of 28 m/s (62 mph) to be exceeded less often than once a year. This is intended to identify wind conditions which 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 reflect the fact that calm activity requires calm wind conditions, which are summarised by the Lawson scale, shown in Figure 3.5. 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 3.6. 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.



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 3.5: 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 3.6: Beaufort Scale

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. 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 condition are unacceptable for the type of pedestrian activity and mitigation measure should be implemented into the design.

For the scope of this report, a qualitative analysis is undertaken, therefore the flow pattern will be highlighted but it will not reflect the velocity magnitude developed.

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 3.7 shows the hourly wind gust rose for Dublin, from 1990 to 2020. This will be necessary to assess how many hours per year on average the velocity exceed the threshold values.

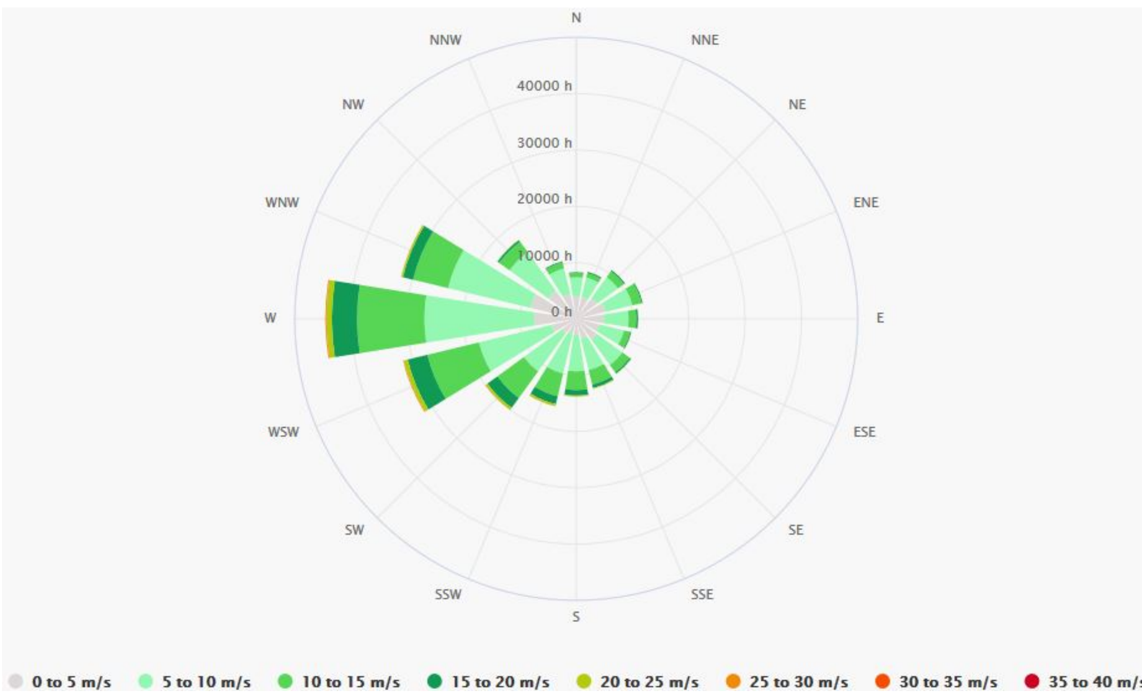


Figure 3.7: Hourly Dublin Wind Gust Rose

Distress for Frail Person or Cyclist

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 3.8 and 3.9 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.

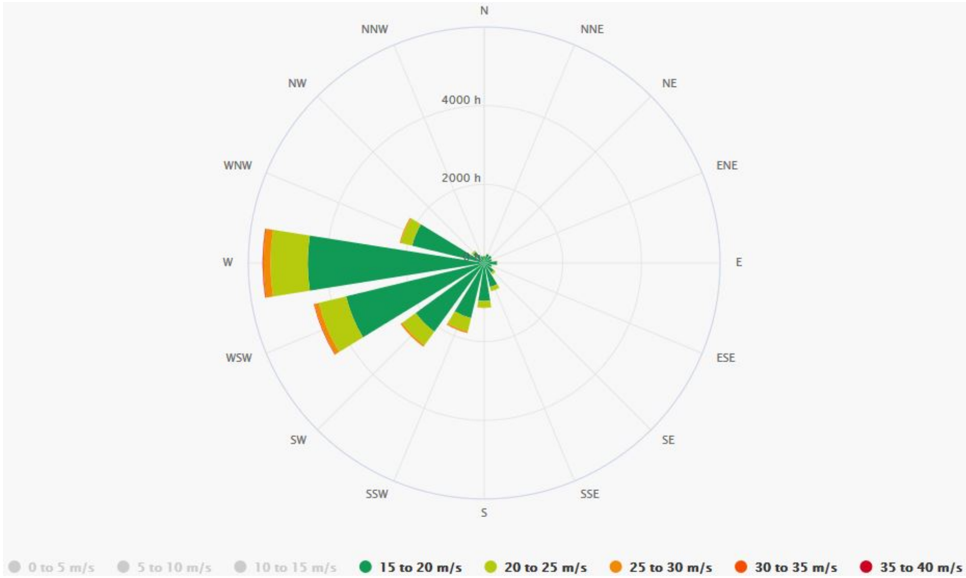


Figure 3.8: Hourly Dublin Wind Gust Rose - Cumulative hours when the velocity is above 15m/s

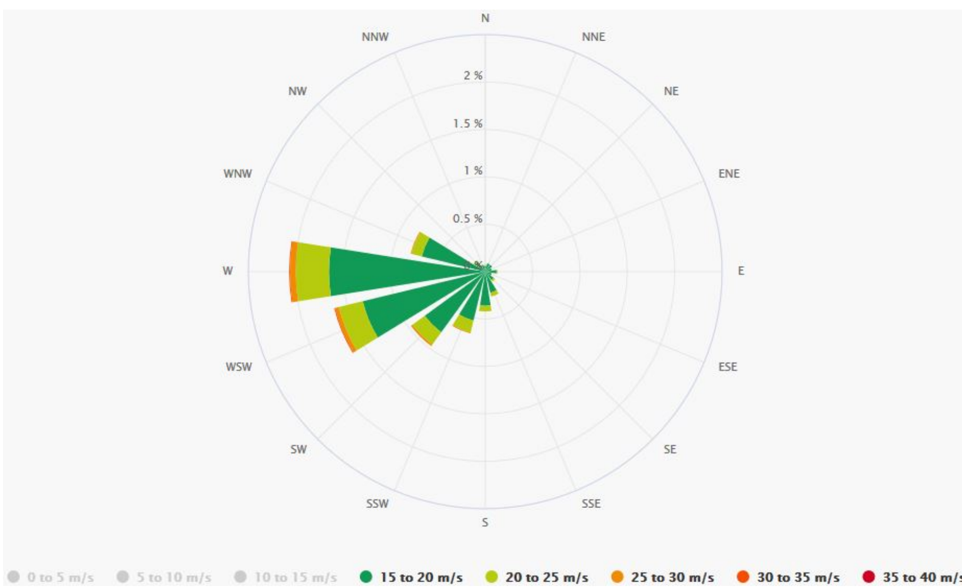


Figure 3.9: Hourly Dublin Wind Gust Rose - Cumulative percentage of time when the velocity is above 15m/s

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 1990-2020:

1. West 270°

2. West-South-West 247.5°
3. South-West 225°

Distress for General Public

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 3.10 and 3.11 respectively as comulative 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.

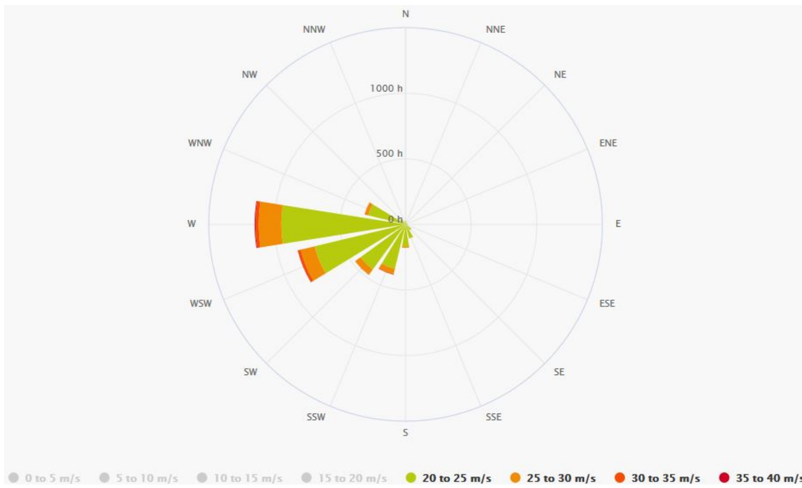


Figure 3.10: Hourly Dublin Wind Gust Rose - Cumulative hours when the velocity is above 20m/s

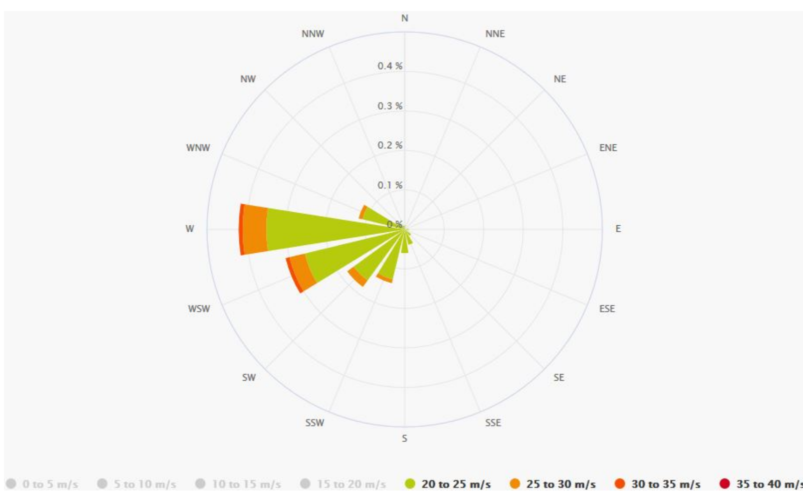


Figure 3.11: Hourly Dublin Wind Gust Rose - Cumulative percentage of time when the velocity is above 20m/s

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 1990-2020.

3.4 MITIGATION MEASURES

As stated in the previous section, if the predicted wind conditions exceed the threshold, then condition are unacceptable for the type of pedestrian activity and mitigation measure should be accounted for.

Possible Mitigation measures can be included:

- 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 3.12 and 3.13):

- **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.

  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.

  - a number of iterations of this study have been carried out as the design developed including adjusting and adding mitigation measures suggested above resulting in a high quality and well sheltered scheme.

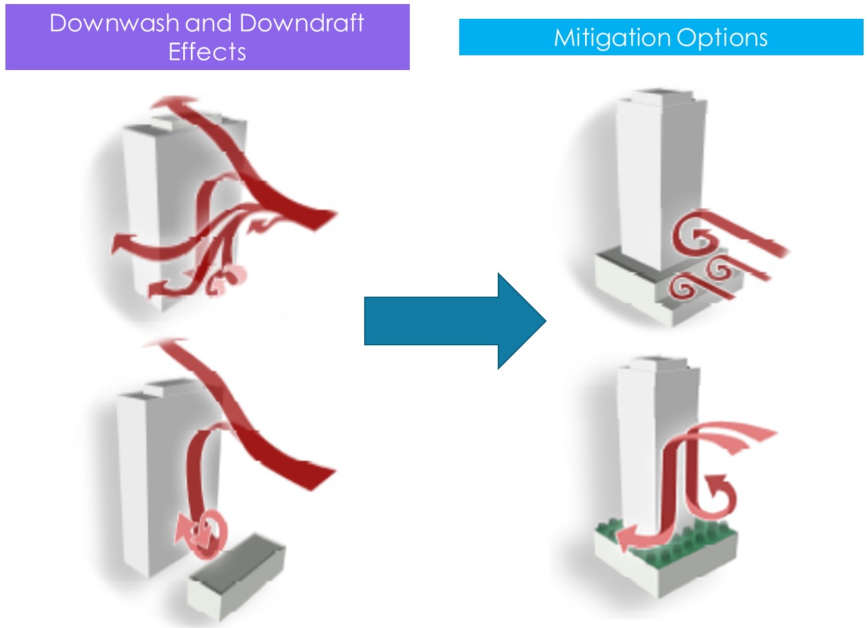


Figure 3.12: Mitigation Measures for Downwash and Downdraft Effects

- **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 .

  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.

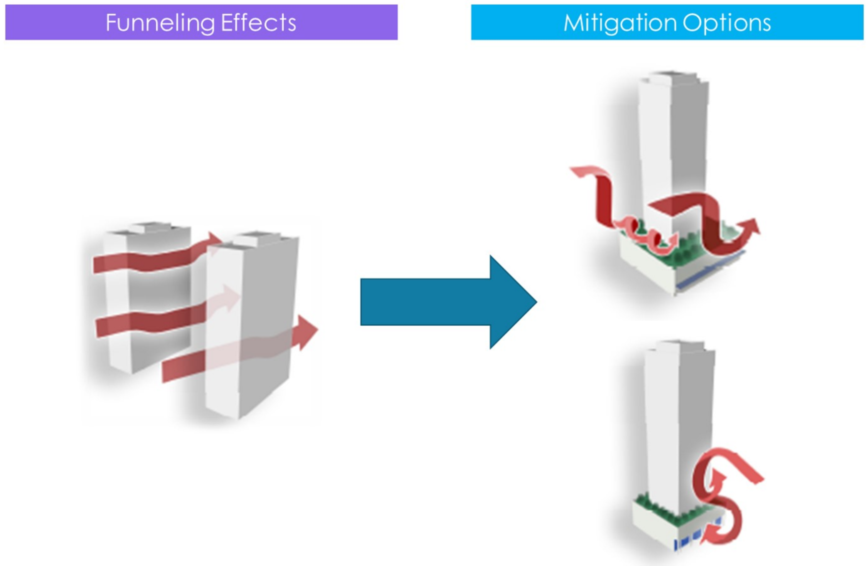


Figure 3.13: Mitigation Measures for Funnelling Effects

For Coastal Quarter - Strategic Housing Development , mitigation measures in the form of landscape is as shown in Figure 3.14

Figure 3.14: Landscape Masterplan Mitigation Measures for Coastal Quarter - Strategic Housing Development

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 are available. Figures 3.17 and 3.16 show the modelling approach of utilizing porous media within the CFD numeric code to implement the effect of landscape within the Coastal Quarter - Strategic Housing Development .

Figure 3.15: Modelling Landscape Trees As Porous Zones

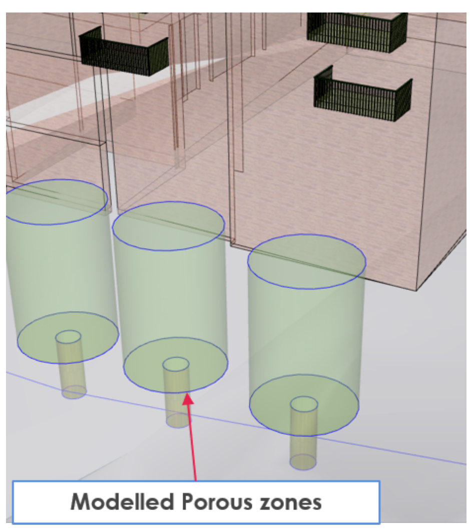


Figure 3.16: Modelling Landscape Trees As Porous Zones

Figure 3.17: Modelling Landscape Trees As Porous Zones- Rendering

4. CFD MODELLING METHOD

4.1 CFD MODELLING METHOD

Computational Fluid Dynamics (CFD) is a numerical technique 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 4.1. 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 providing that the scenario modelled is a good representation of reality.

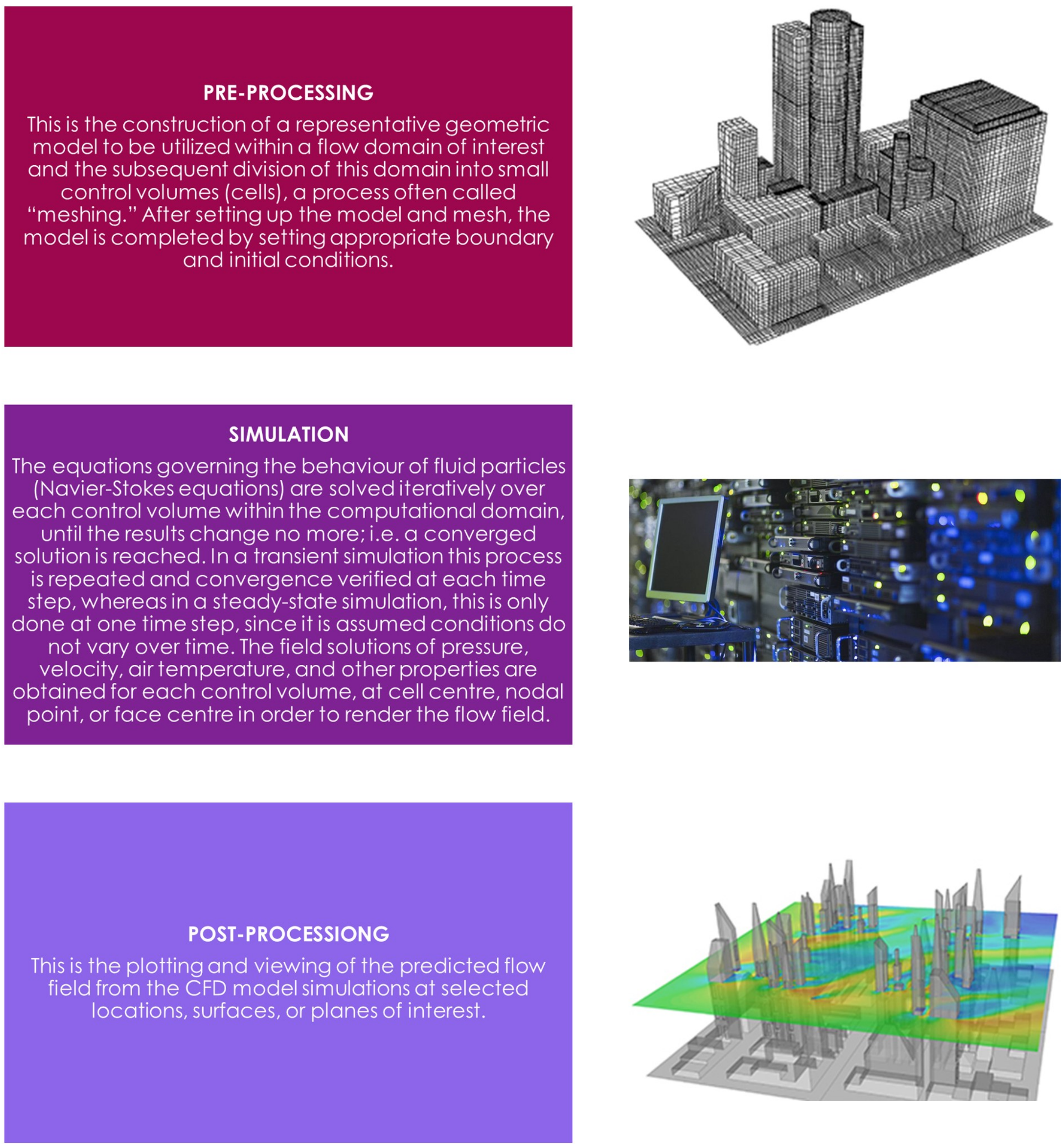


Figure 4.1: CFD Modelling Process Explanation

4.1.1 NUMERICAL SOLVER

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).

4.2 COMPUTATIONAL MESH

The level of accuracy of the CFD results are determined by the level of refinement of the computational mesh. Details of parameters used to calculate the computational mesh are presented in Table 4.1. Figure 4.2 shows the mesh utilised.

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.

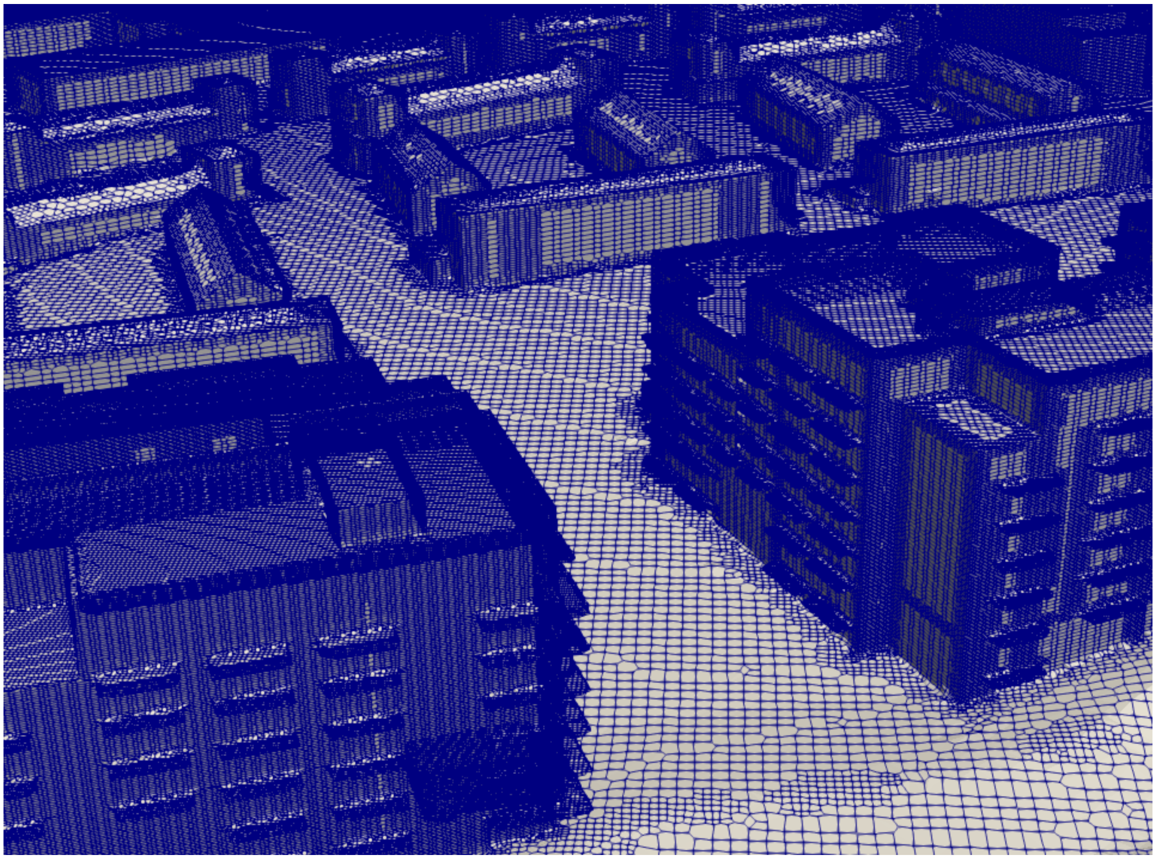


Figure 4.2: An example of Coastal Quarter - Strategic Housing Development Development Mesh

4.3 BOUNDARY CONDITIONS

A rectangular computational domain was used for the analysis. The wind direction were altered without changing the computational mesh. For each dimension, an initial wind velocity was set according to the weather data collected, in order to consider the worst case scenario (see Chapter 5). Surfaces within the model were specified as having ‘no slip’. This condition ensures that flow moving parallel to a surface is brought to rest at the point where it meets the surface. all the other domain boundaries are set as ”Open Boundaries”.

PARAMETERS TO CALCULATE COMPUTATIONAL MESH	
Air Density ρ	$1.2 kg/m^3$
Ambient Temperature (T)	$288K(approx.15C^{\circ})$
Gravity Acceleration (g)	$9.8m/s^2$
dx	0.5 m at the building 1m in the surroundings 2m elsewhere
Background mesh ratio	1:1
Total mesh size	Approx. cells number = 26 million

Table 4.1: Paramenters To Calculate Computational Mesh

5. WIND DESKTOP STUDY

5.1 LOCAL WIND CONDITIONS

This analysis consider the whole development being exposed to the typical wind condition of the site. The building is 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. Figure 5.1 shows on the map the position of Coastal Quarter - Strategic Housing Development Development and the position of Dublin Airport.

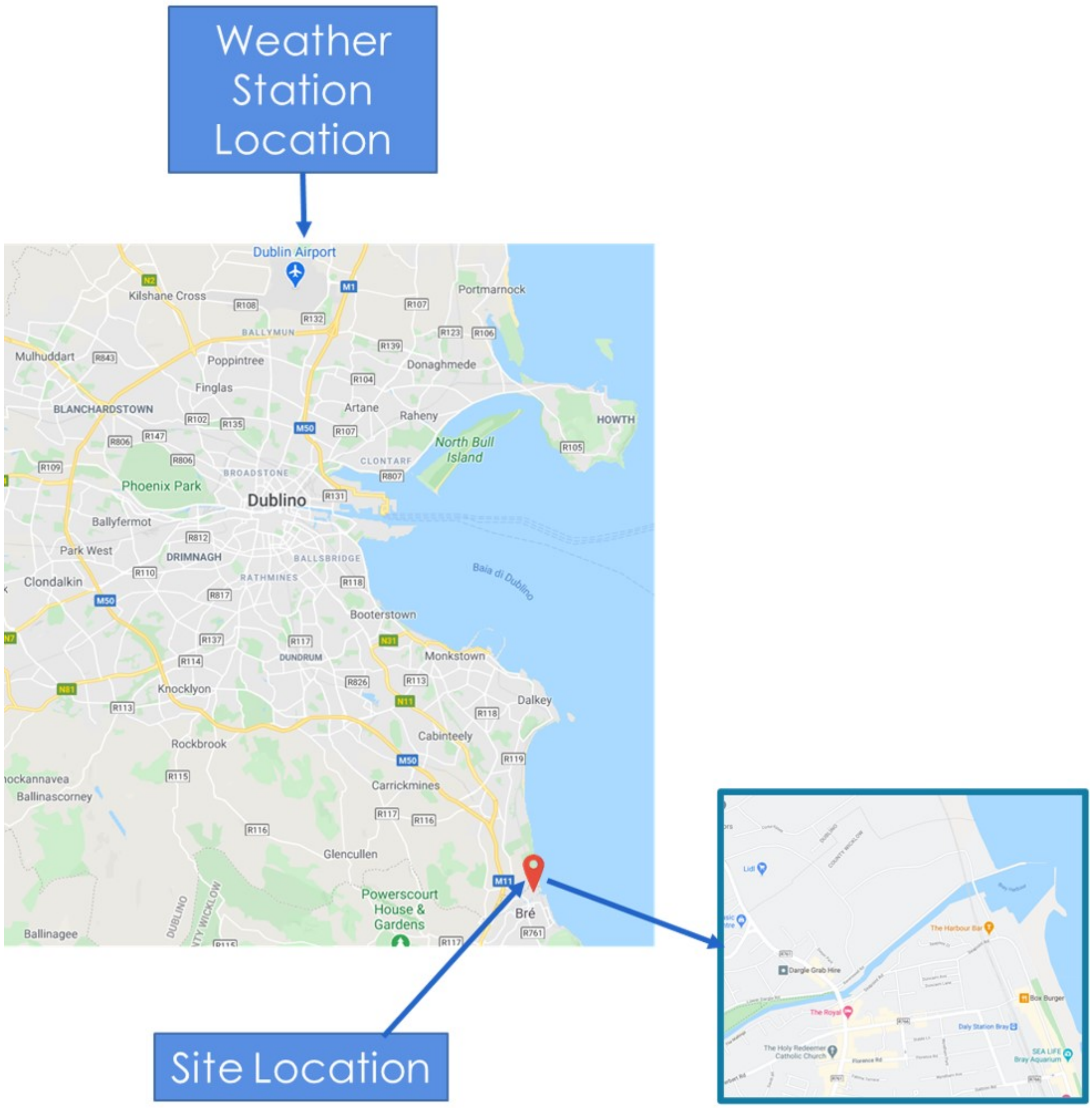


Figure 5.1: Map showing the position of Coastal Quarter - Strategic Housing Development and Dublin Airport

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

- *Terrain*: The meteorological station is located on the flat open terrain of the airport, whereas the development site is in an urban area with dense built-in structure with buildings of more than 20 m height in average and with some buildings even taller.

- *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.

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. The data set analyzed for this assessment is as follows:

- The meteorological data associated with the maximum daily wind speeds recorded over a 30 year period between 1990 and 2020 and,

- The mean hourly wind speeds recorded over a 10 year period between 1990 and 2020. The data is recorded at a weather station at the airport, which is located 10m above ground or 71mOD.

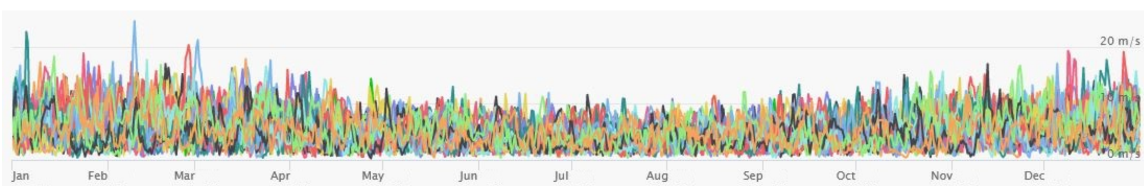


Figure 5.2: Local Wind Conditions - Wind Speed - 2017-2021

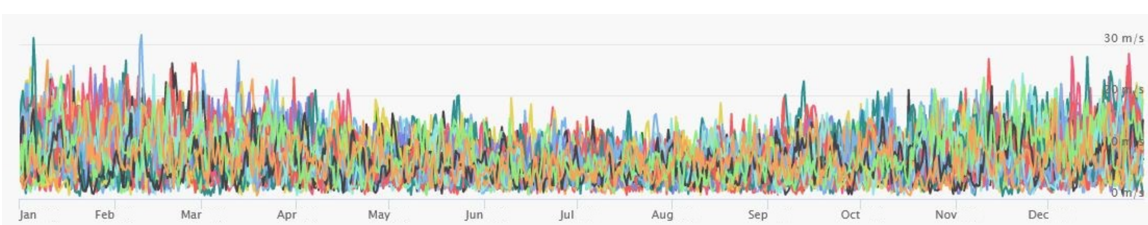


Figure 5.3: Local Wind Conditions - Wind Gust - 1990-2020

Figure 5.4, presenting the wind speed diagram for Dublin, shows the days per month, during which the wind reaches a certain speed. In Figure 5.5, the wind rose for Dublin shows how many hours per year the wind blows from the indicated direction, confirming how the predominant directions are West-South-West, West, South-East and South-West.

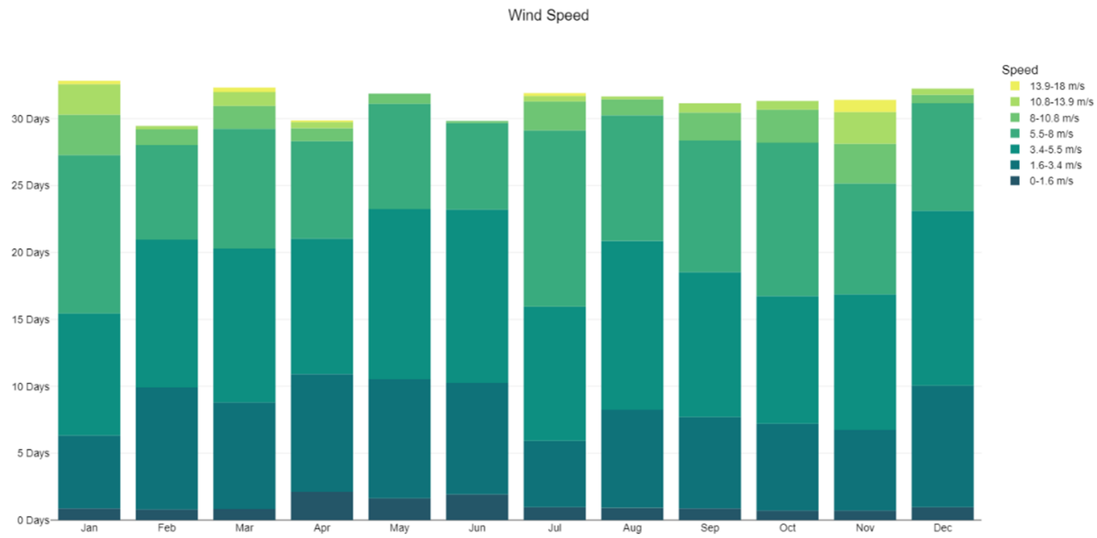


Figure 5.4: Dublin Wind Speed Diagram

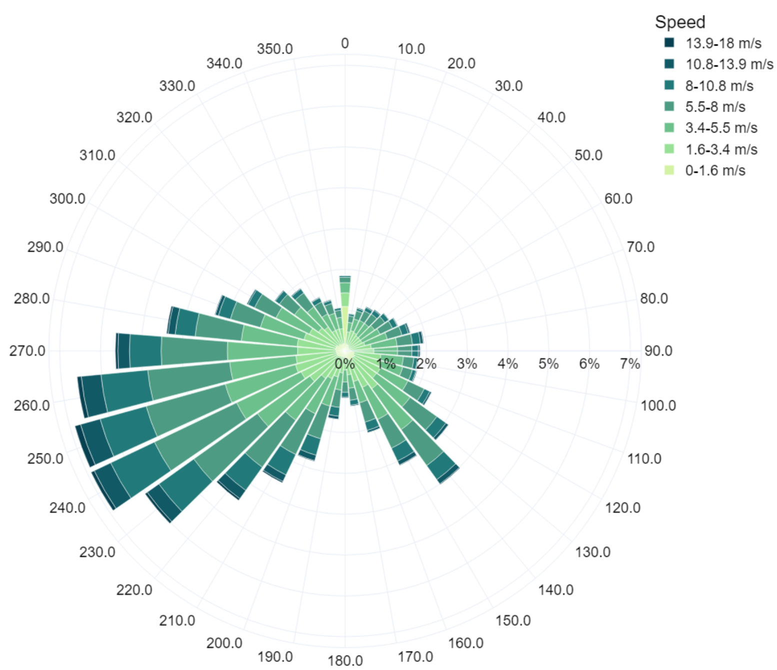


Figure 5.5: Dublin Wind Rose

Statistical analysis of the number of hours and magnitudes of wind is performed in order to indicate the pedestrian comfort and distress analysis as per Lawson Criteria. Each of the wind directions were interpolated to calculate the probability that a velocity threshold will be exceeded.

Based on the criterion of occurrence frequency, if the proposed site is exposed to a wind from a specific direction for more than 5 percent of the time, then the microclimate analysis should consider the impact of this wind (accounting for its direction and most frequent speed) on the local microclimate. In addition, seasonal changes were analysed in order to indicate the prevailing wind directions (Fig 5.6).

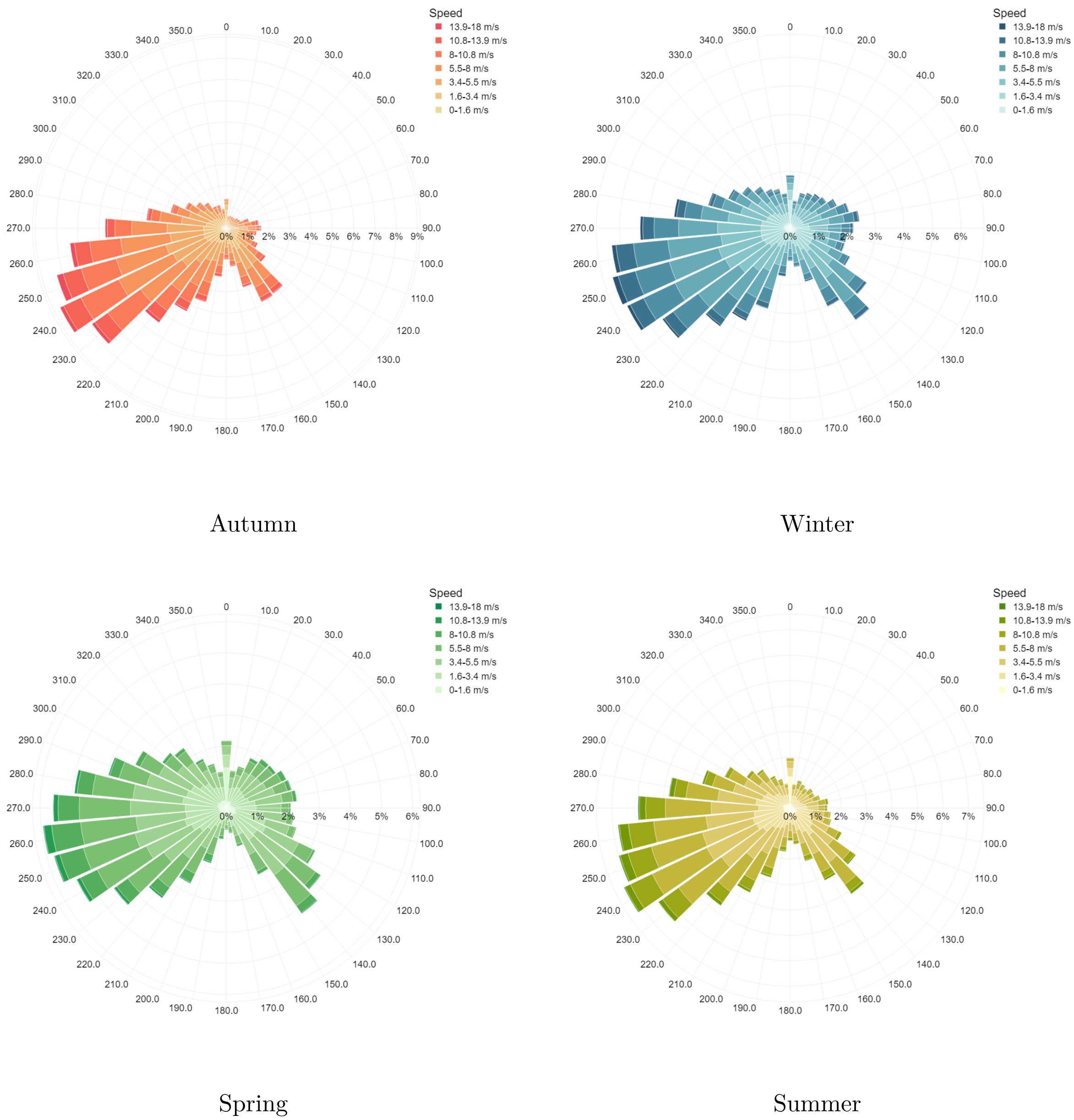


Figure 5.6: Wind speeds and wind directions at different seasons

5.2 TOPOGRAPHY AND BUILT IN ENVIRONMENT

Figure 5.7 shows an aerial photograph of the terrain surrounding the site at Coastal Quarter - Strategic Housing Development .

Coastal Quarter - Strategic Housing Development will be located in Bray, County Wicklow and County Dublin, close to the seafront and the harbour and next to the Dargle river.

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.

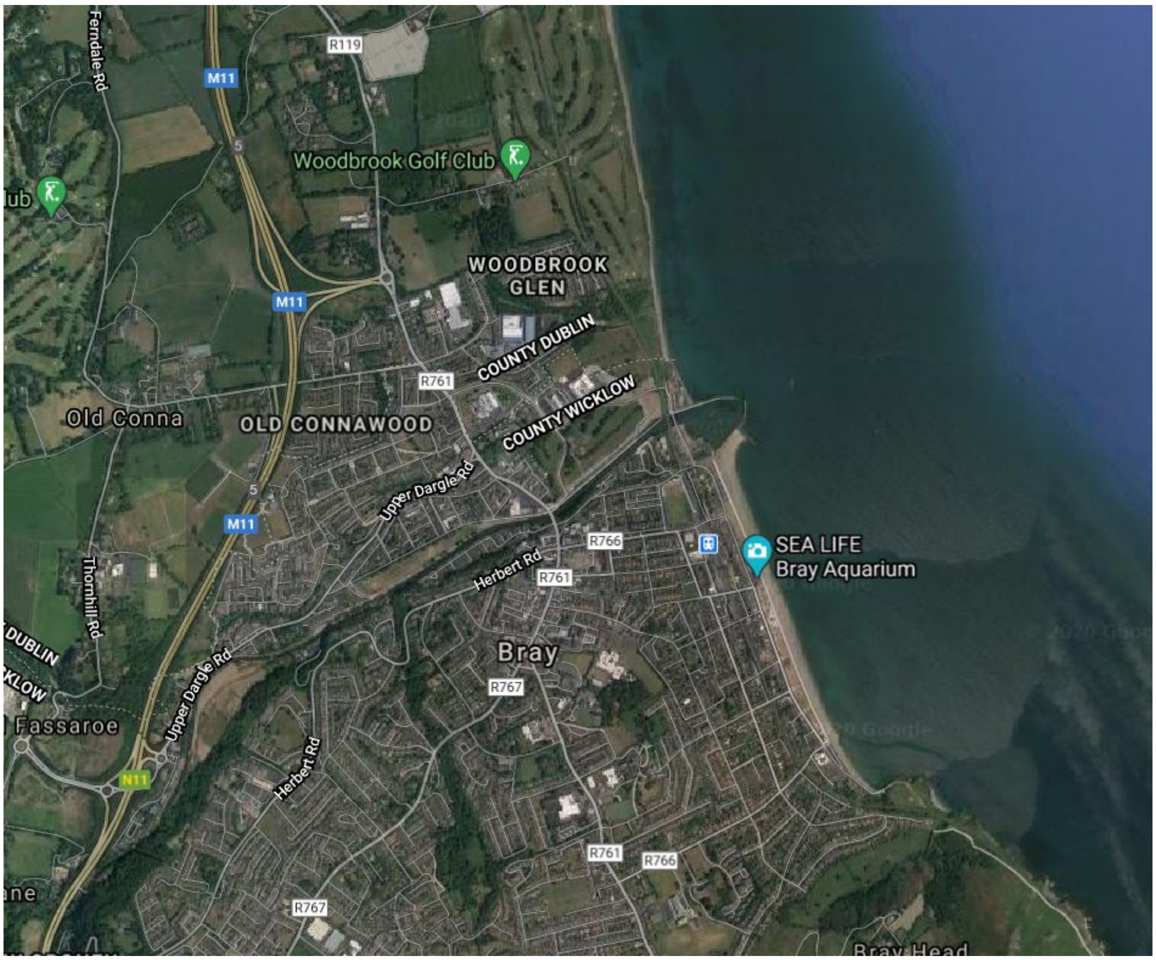


Figure 5.7: Built-in Environment around Construction Site at Coastal Quarter - Strategic Housing Development

5.3 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 5.8: Main Categories for Pedestrian Activities

6. ANALYSIS OF CFD RESULTS

6.1 CFD RESULTS

It is of interest at this point to underline again the objectives of the CFD 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.

- 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 sidewalks and street frontages, pathways, building entrance areas, open spaces, amenity areas, outdoor sitting areas, and accessible roof top areas among others.

Results of the simulations carried out are detailed in the following Sections. The results present the parameters outlined in the acceptance criteria section described previously. Slices of the following parameters are collected throughout the simulation time and shown for steady state times:

- Flow Velocity
- Lawson Map

6.2 MICROCLIMATE ASSESSMENT OF PROPOSED DEVELOPMENT

This section aims to show wind patterns around the proposed development under mean and peaks wind conditions typically occurring in the area. 3D views of the proposed development massing model in the domain are presented below.

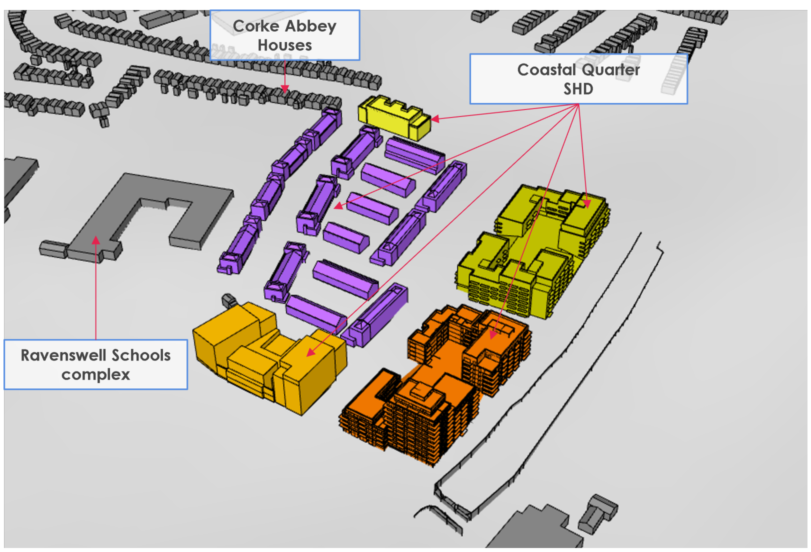


Figure 6.1: 3D View of the Proposed Coastal Quarter - Strategic Housing Development Massing Model Development and Adjacent Buildings

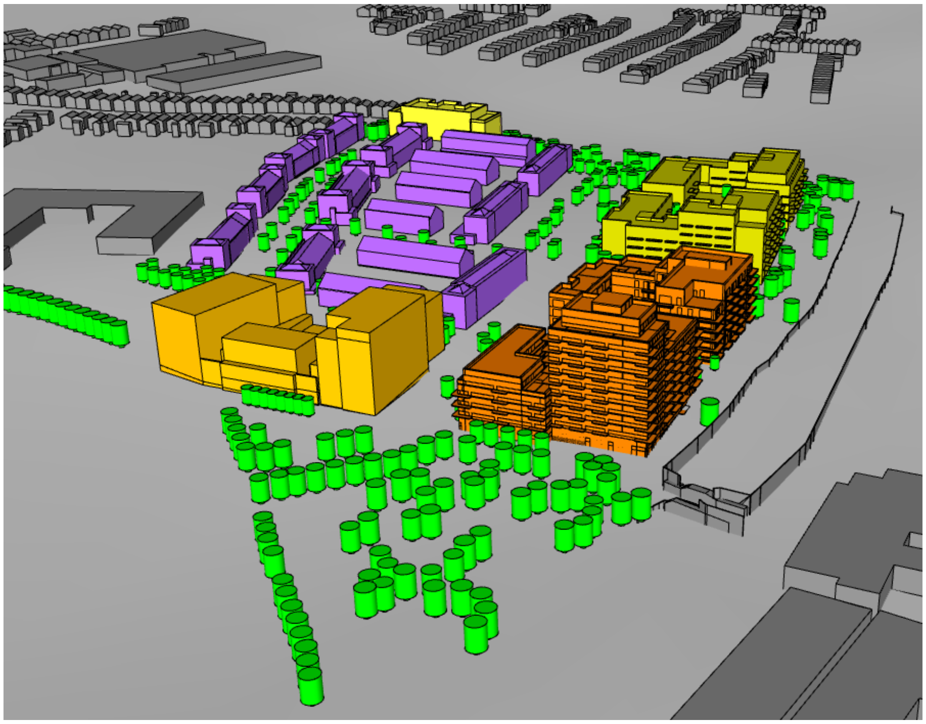


Figure 6.2: 3D View of the Proposed Coastal Quarter - Strategic Housing Development Massing Model Development and Adjacent Buildings

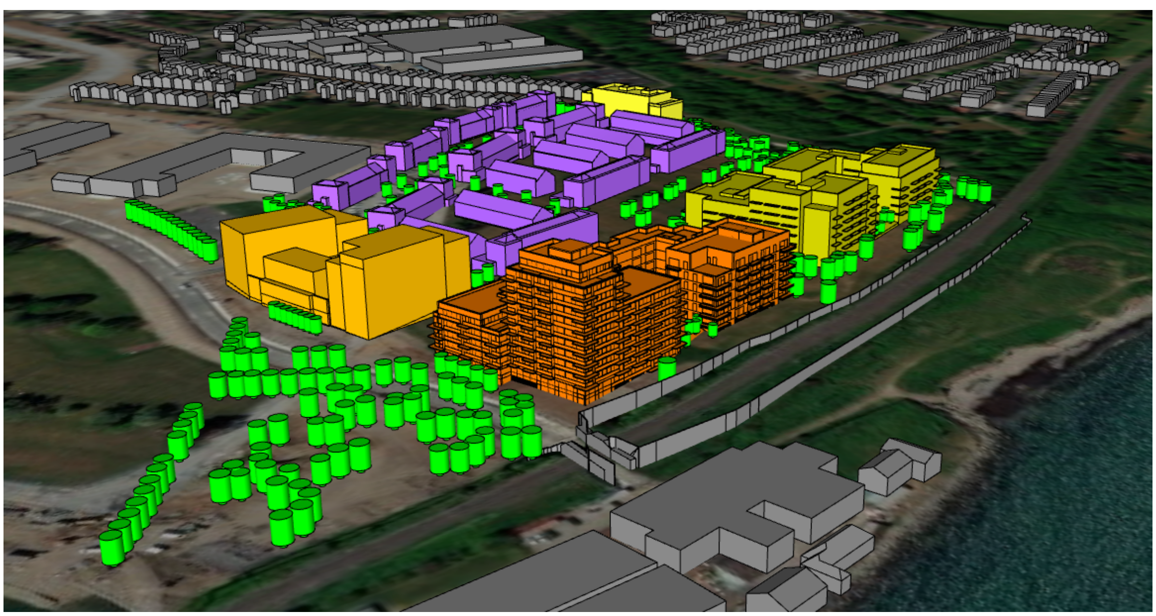


Figure 6.3: 3D View of the Proposed Coastal Quarter - Strategic Housing Development Massing Model Development and Adjacent Buildings

The results present the parameters outlined within the acceptance criteria section described previously. The images within the following subsections show the flow velocity results obtained and maps to assess the pedestrian comfort in the area.

From the simulation results the following observations are pointed out:

- The proposed Coastal Quarter - Strategic Housing Development has been designed in order to produce a high-quality environment that is attractive and comfortable for pedestrians of all categories. To achieve this objective, throughout the design process, the impact of wind has been considered and analysed, in the areas where critical patterns were found, the appropriate mitigation measures were introduced.
- A number of iterations of this study have been carried out to optimize the design in order to achieve a high quality and well sheltered scheme.
- Although some minor flow velocity accelerations are still noticeable on the final scheme, on the road south side of Block B and adjacent to Block C, as well as the area between Block A and the adjacent rail structure, the highlighted accelerations are well kept below the threshold limit; indeed the Lawson map (which is the map commonly adopted in wind microclimate studies to relate the wind conditions with the suitable pedestrian activities) indicates that this road can be utilised for the intended use (i.e. for those activities which include any type of walking and also short term sitting).
- Courtyards of Block A,B and C are well protected, a small area in the middle of both courtyards of Block A and B is suitable for short term sitting instead of long term-sitting due to minor re-circulation effects. These conditions are not occurring at a frequency that would compromise the pedestrian comfort, according to the Lawson Criteria.
- The analysis carried out on the roof terraces on Block C shows that the areas are well protected by a combination of glazed screen and parapet wall and long term sitting is achieved for the majority of the year.
- Regarding the balconies, higher velocities have been identified on a number of the balconies which is to be expected in a coastal location. However, these velocities are below the threshold values defined by the acceptance criteria and therefore are not critical for safety. On occasions when the private balconies may not be suitable for short term sitting, residents can use internal courtyard or communal amenity spaces.
- Tree planting all around the development has been utilised, with particular attention to the corners of the buildings and the courtyard and this has positively mitigated any critical wind effects. Thus, it can be concluded that at ground floor good shielding is achieved everywhere.
- The proposed development does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings, Corke Abbey houses and the Ravenswell Schools complex. In particular, the development is acting as a shield to the Corke Abbey houses and the Ravenswell Schools complex from any winds coming from the East direction, while it does not have any impact on the wind coming from the South or West direction.
- Moreover, in terms of distress, no critical conditions were found for ”Frail persons or cyclists” and for members of the ”General Public” in the surrounding of the development, including the Corke Abbey houses and the Ravenswell Schools complex.

6.2.1 FLOW VELOCITY RESULTS - Ground Floor Level

Results of wind speeds and their circulations around the proposed development at pedestrian level of 1.5m above the development ground and courtyards are presented for all the simulated wind directions in Figures 6.6 to 6.37 (both top views and courtyard results).

Figure 6.5 shows an example of wind data mapped on surface, located at 1.5m above the ground. Red colors indicate critical values while blue colors indicate tenable conditions. The scale used for all flow velocity results is set out in Figure 6.4.

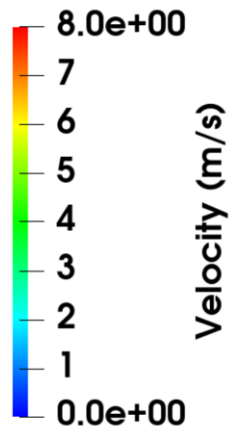


Figure 6.4: Velocity Colour Map

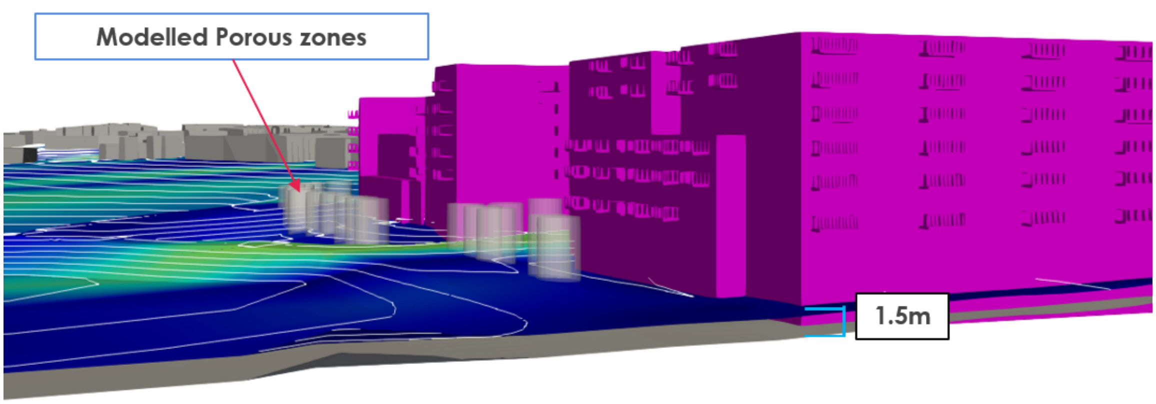


Figure 6.5: An example of wind data mapped on surface at 1.5m above the ground

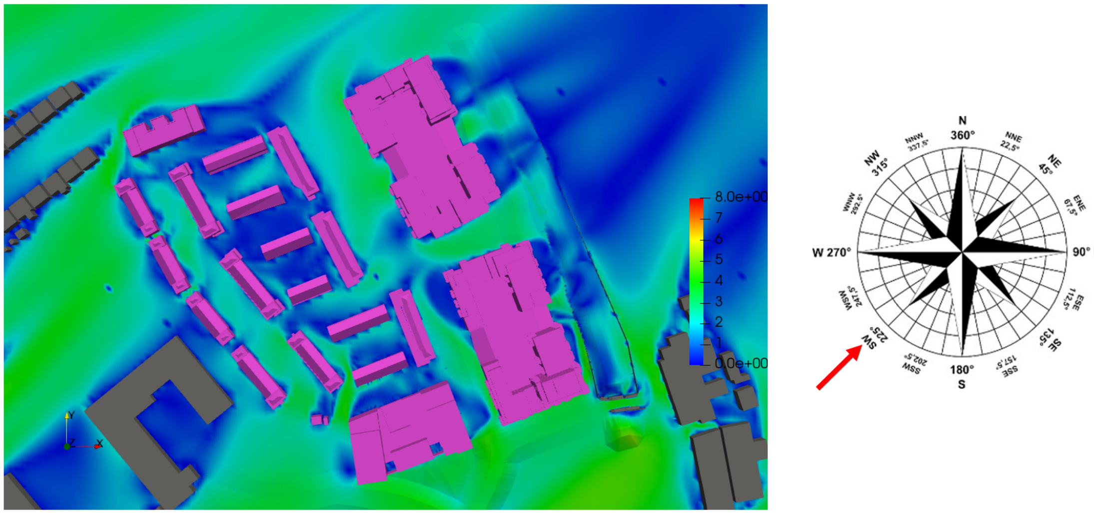


Figure 6.6: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 225°

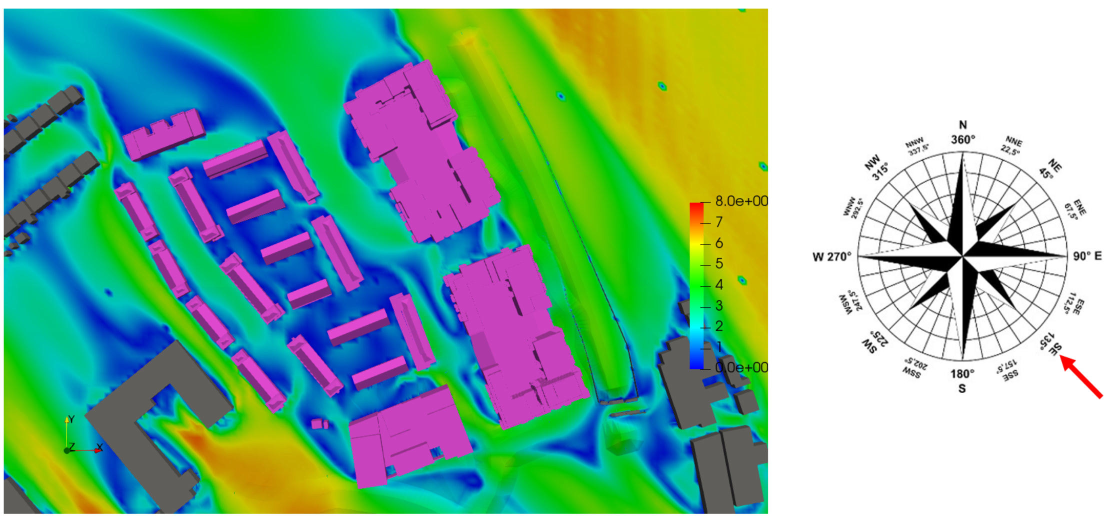


Figure 6.7: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 135°

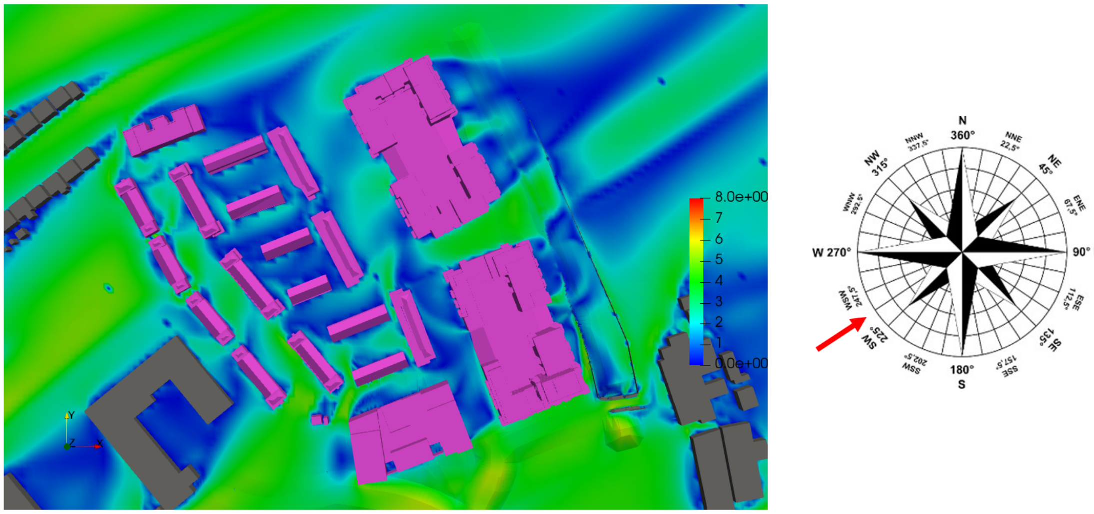


Figure 6.8: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 236°

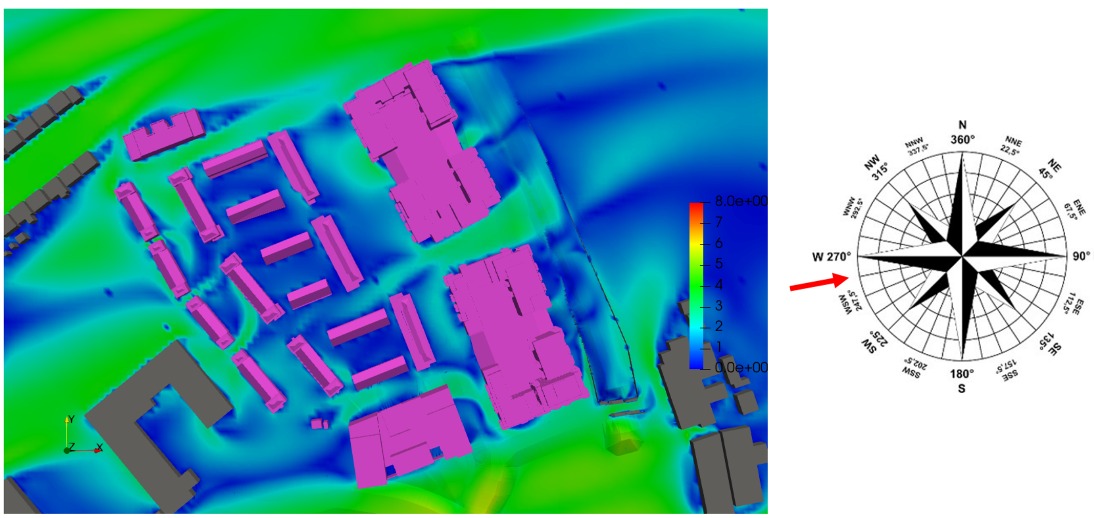


Figure 6.9: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 258°

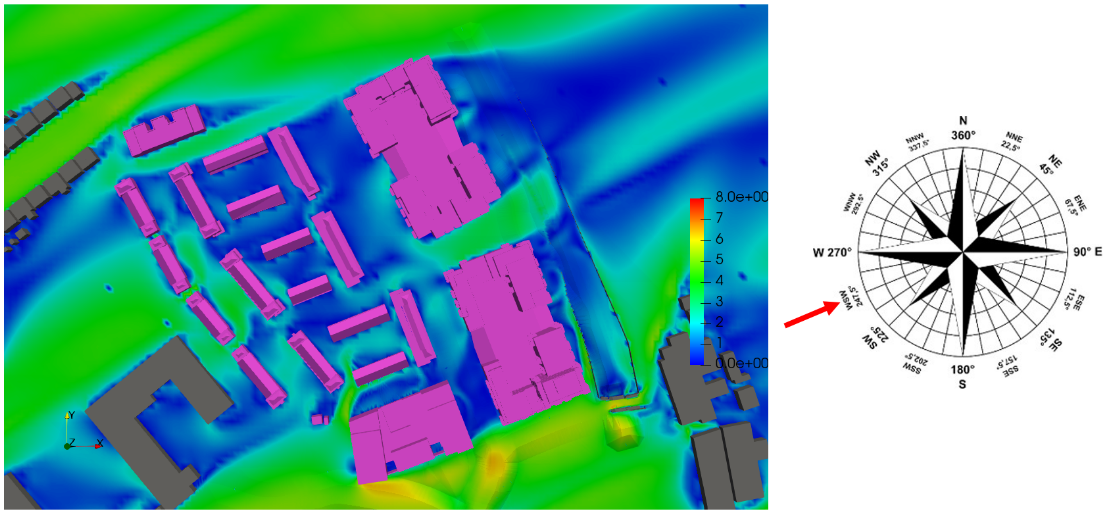


Figure 6.10: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 247°

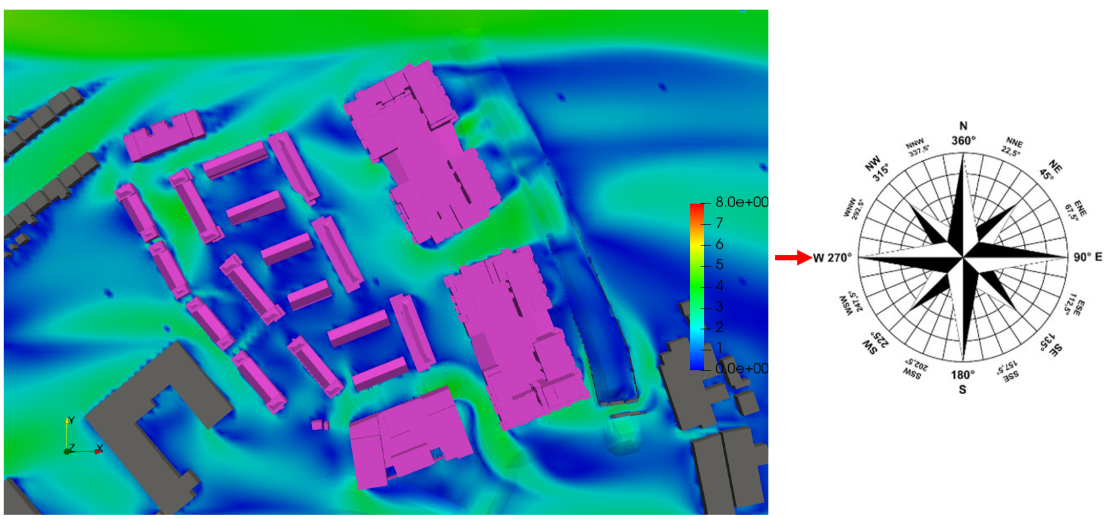


Figure 6.11: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 270°

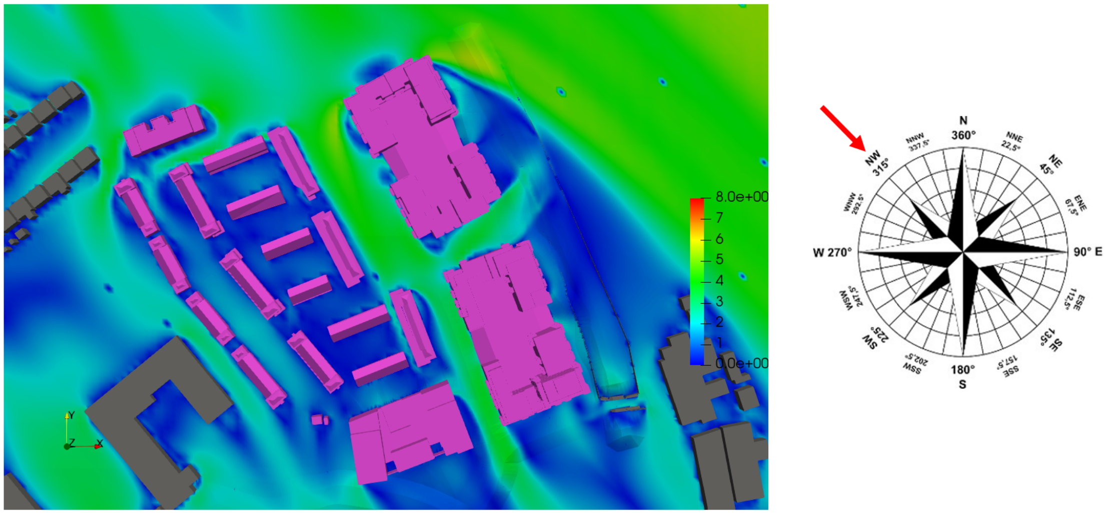


Figure 6.12: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 315°

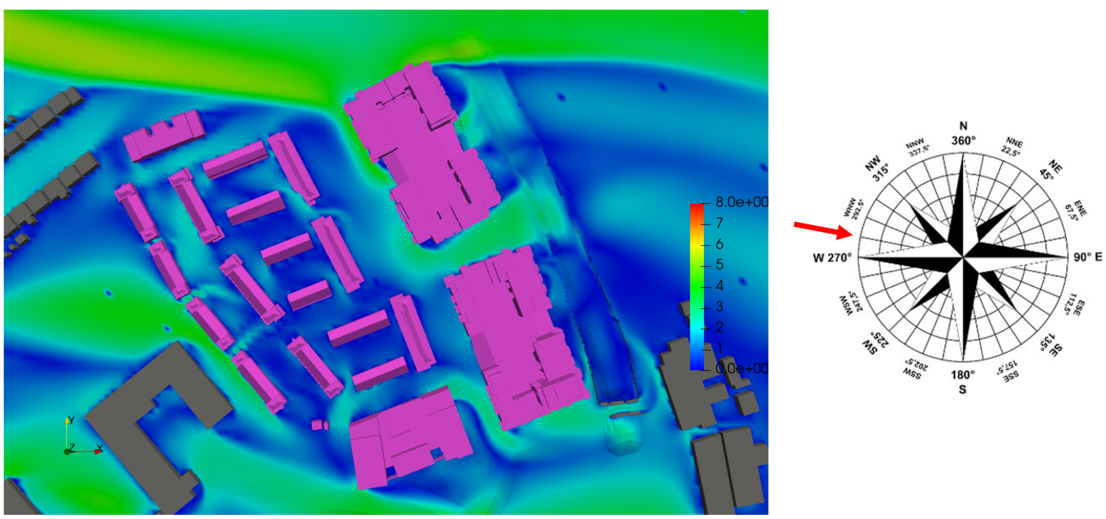


Figure 6.13: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 281°

6.2.2 FLOW VELOCITY RESULTS - Courtyard of Block A

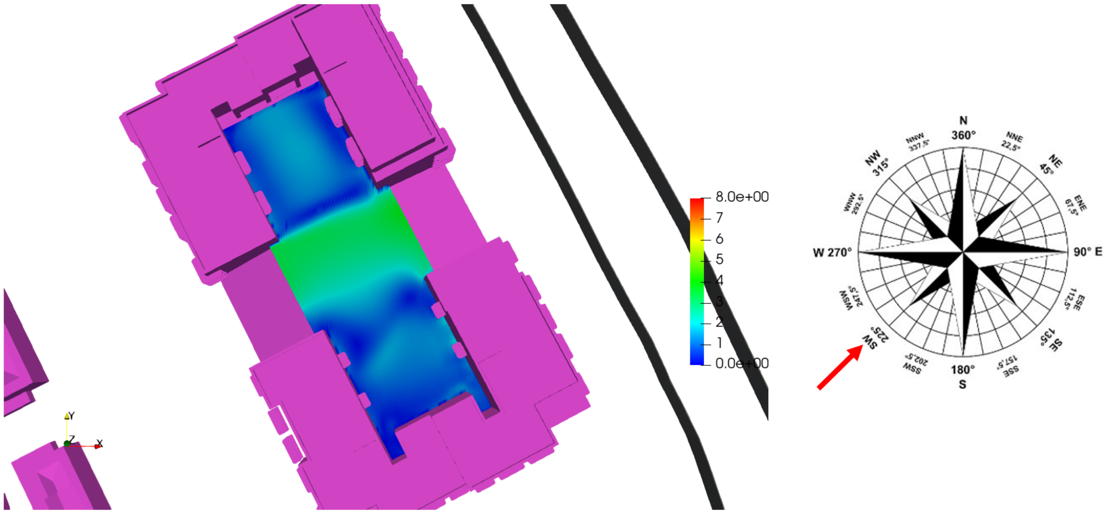


Figure 6.14: Courtyard Block A - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 225°

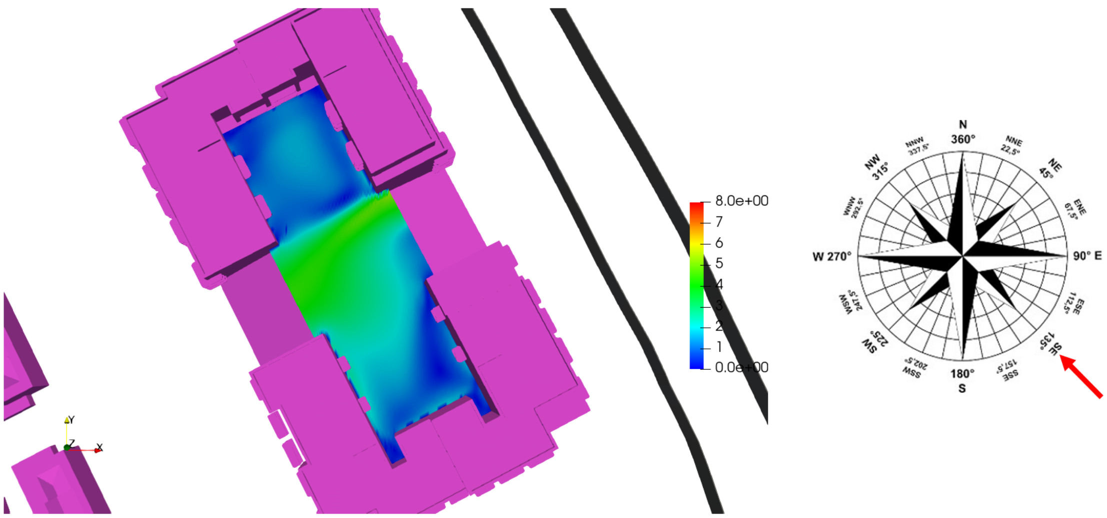


Figure 6.15: Courtyard Block A - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 135°

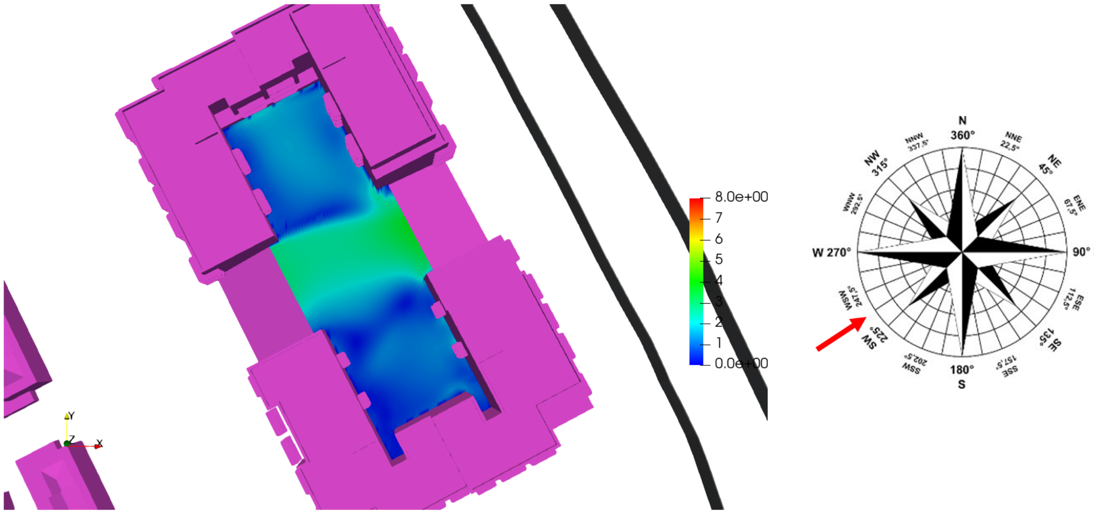


Figure 6.16: Courtyard Block A - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 236°

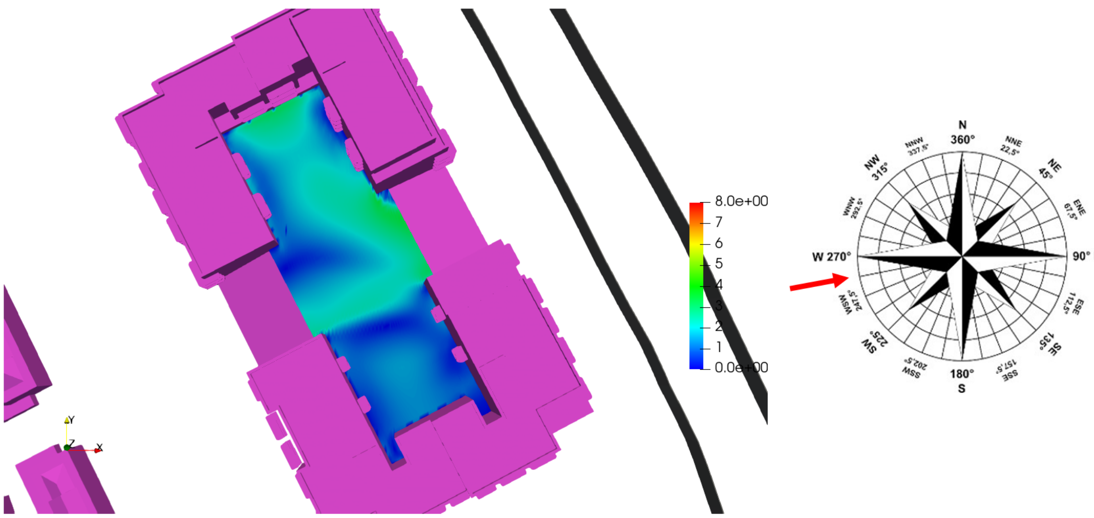


Figure 6.17: Courtyard Block A - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 258°

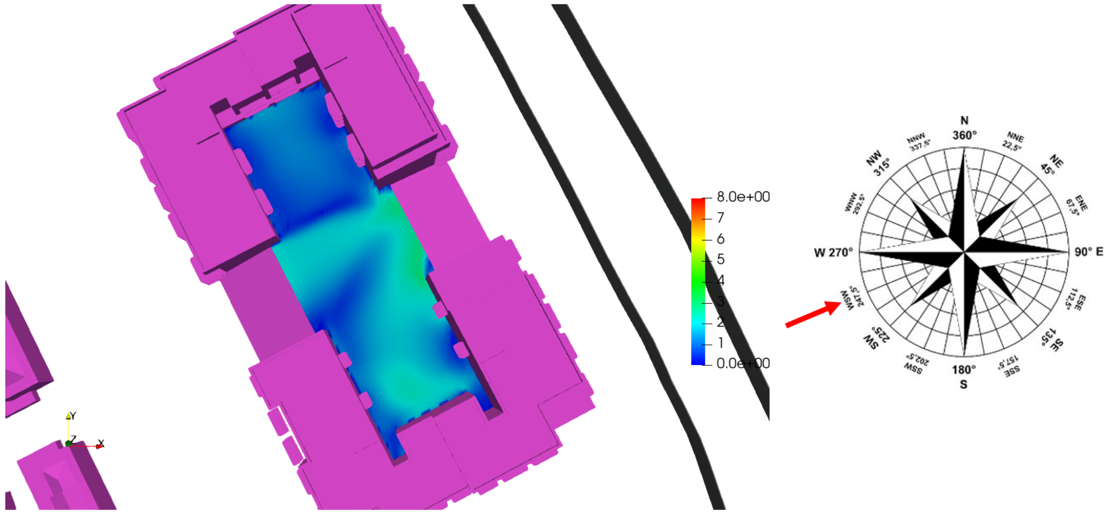


Figure 6.18: Courtyard Block A - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 247°

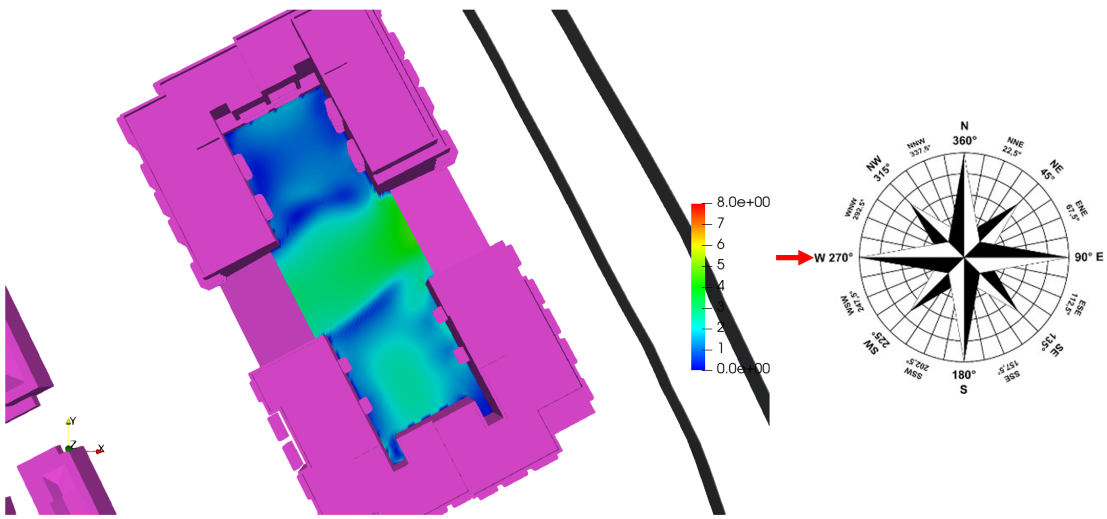


Figure 6.19: Courtyard Block A - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 270°

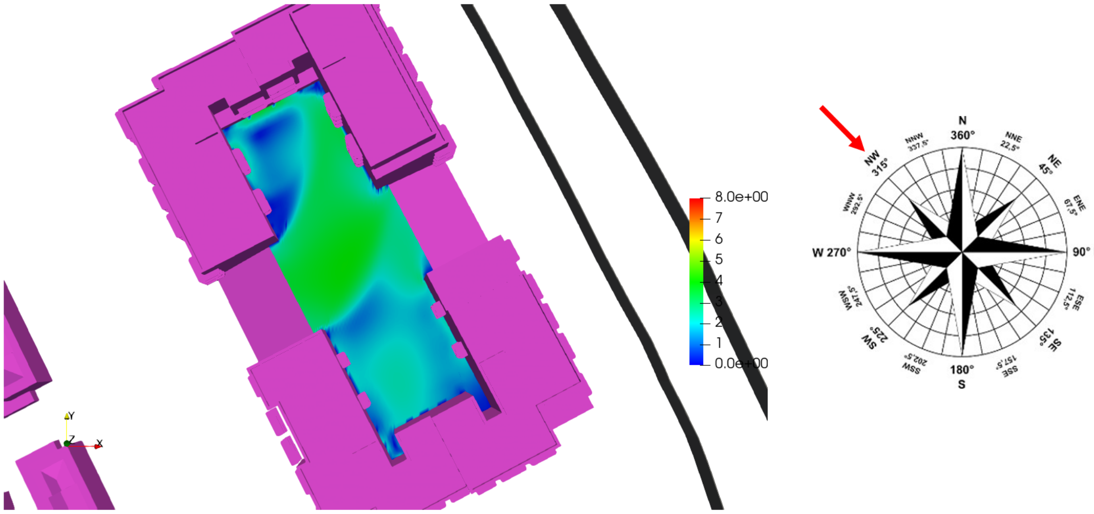


Figure 6.20: Courtyard Block A - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 315°

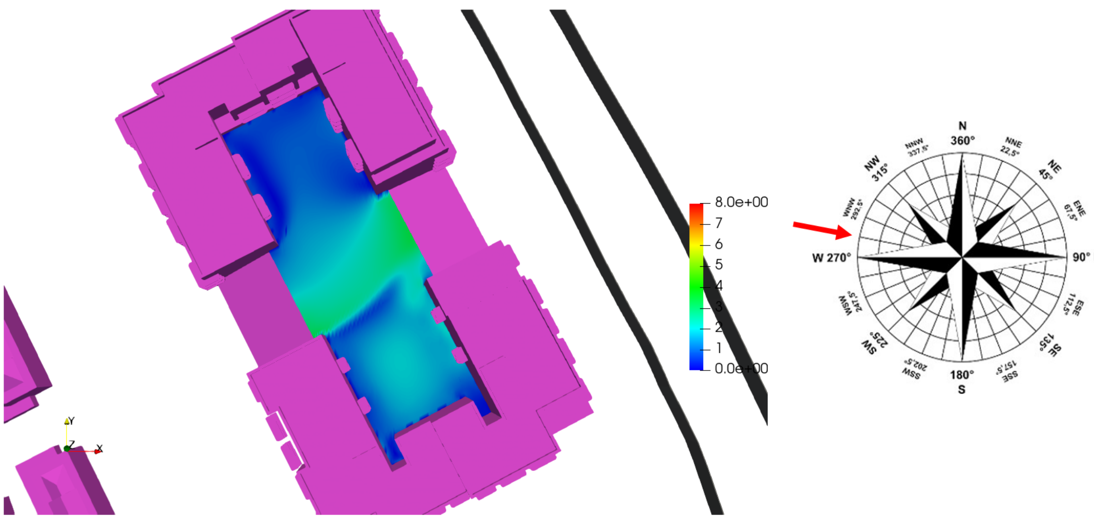


Figure 6.21: Courtyard Block A - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 281°

6.2.3 FLOW VELOCITY RESULTS - Courtyard of Block B

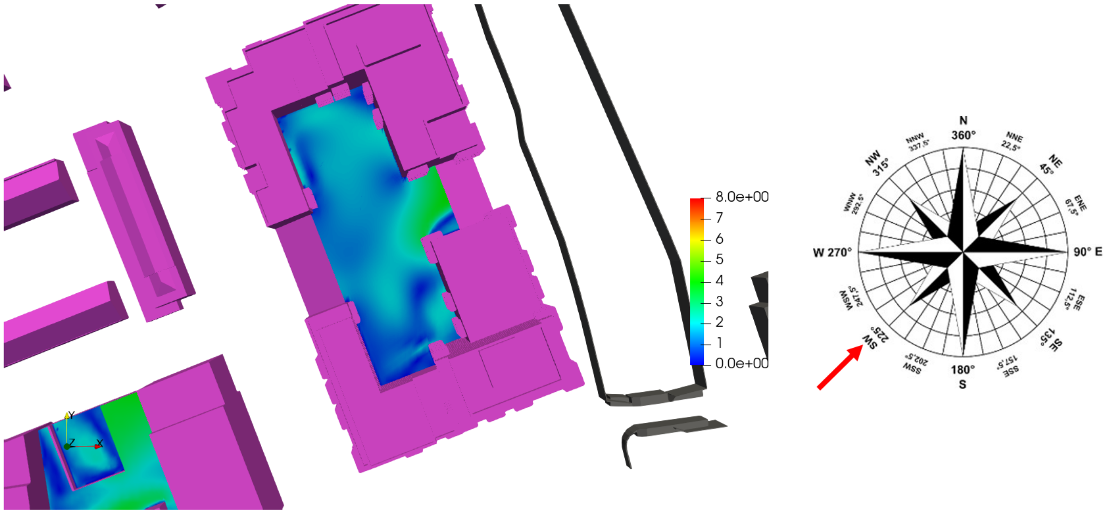


Figure 6.22: Courtyard Block B - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 225°

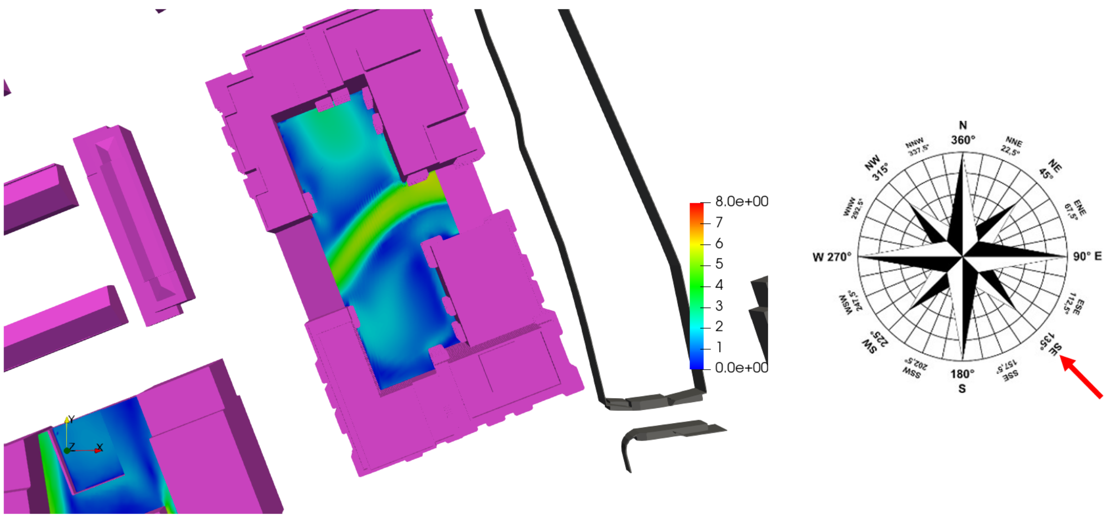


Figure 6.23: Courtyard Block B - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 135°

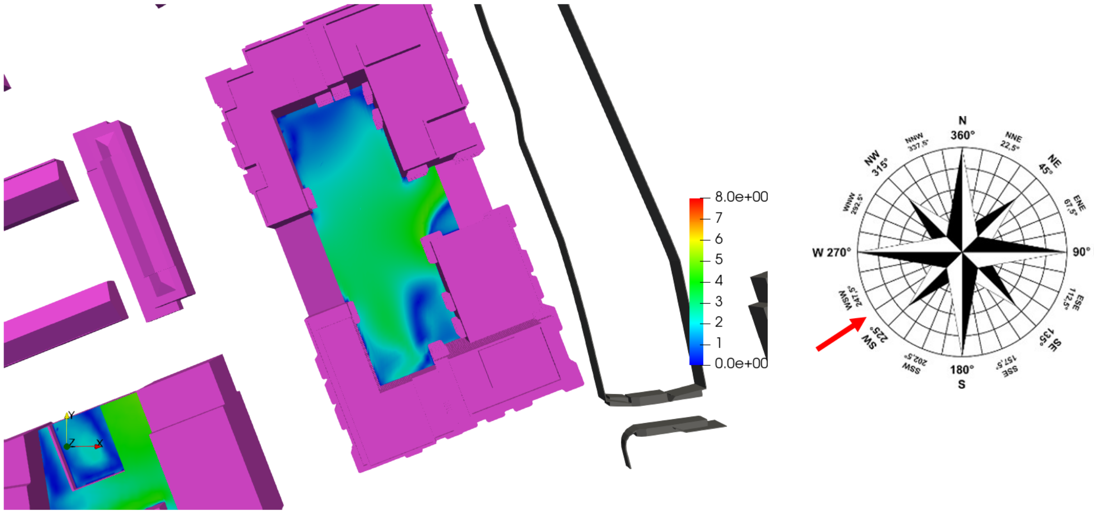


Figure 6.24: Courtyard Block B - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 236°

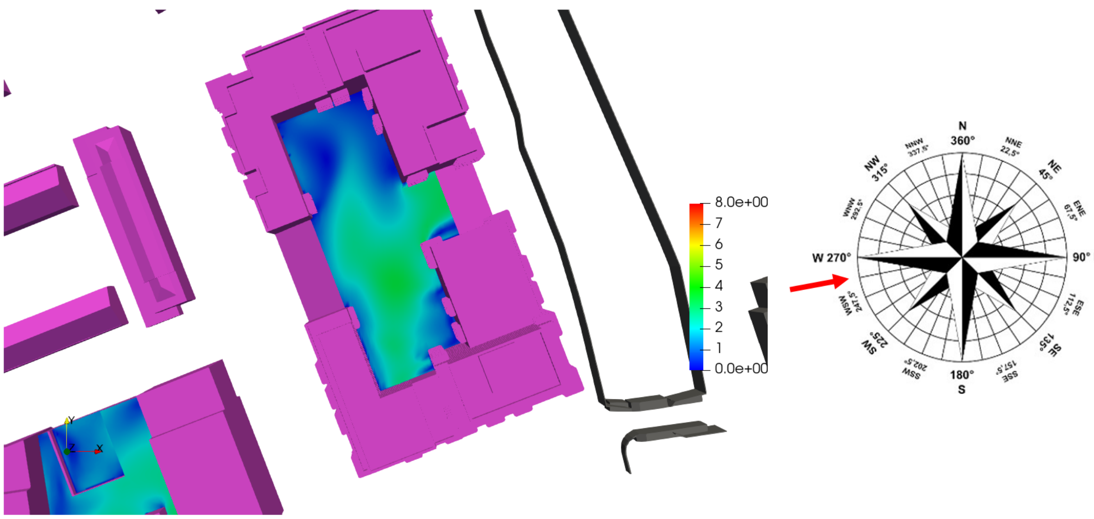


Figure 6.25: Courtyard Block B - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 258°

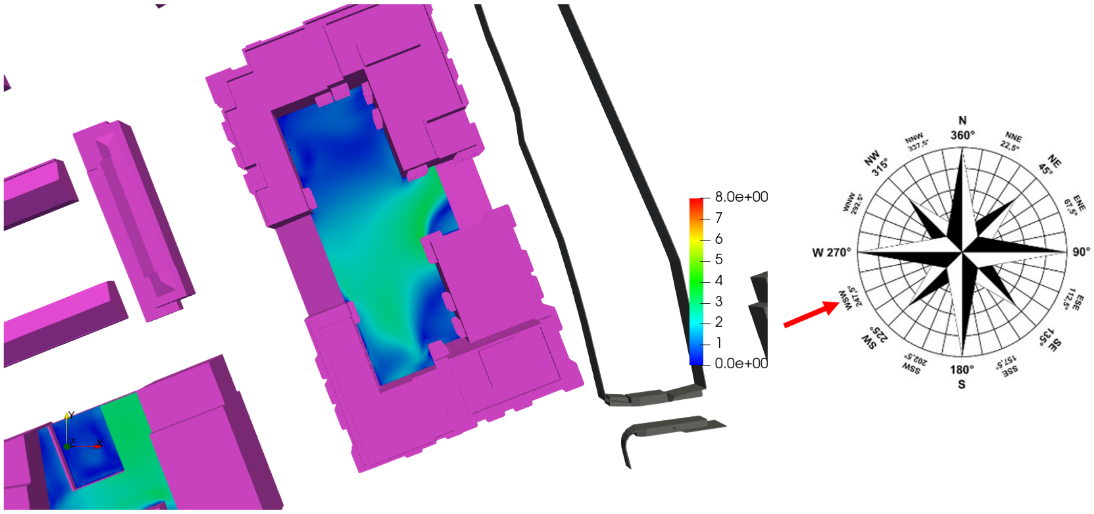


Figure 6.26: Courtyard Block B - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 247°

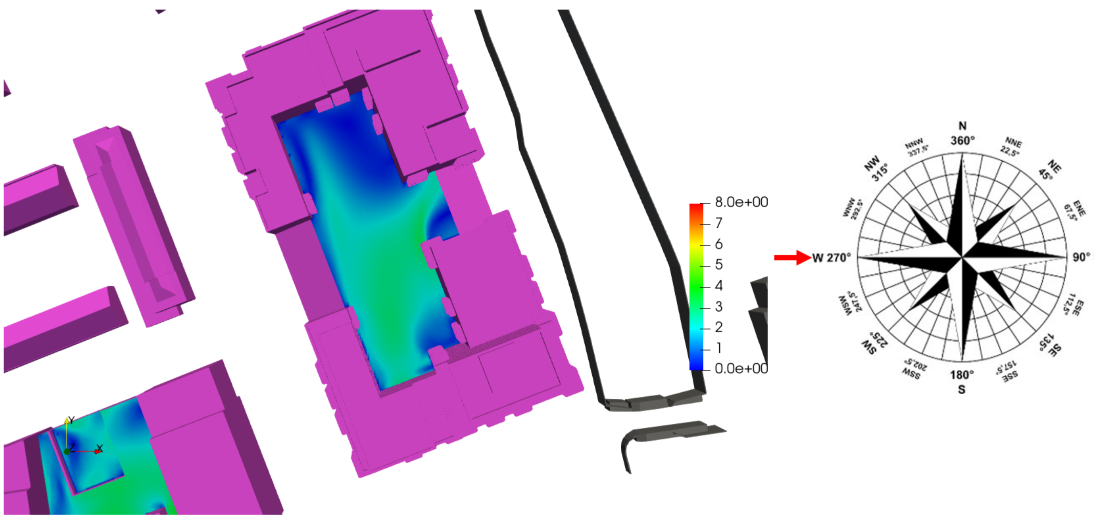


Figure 6.27: Courtyard Block B - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 270°

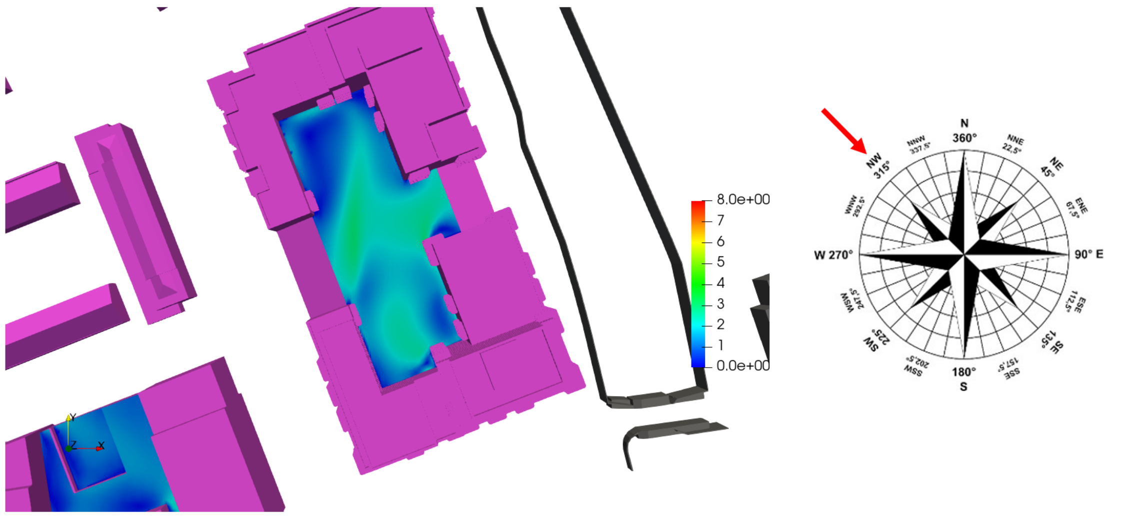


Figure 6.28: Courtyard Block B - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 315°

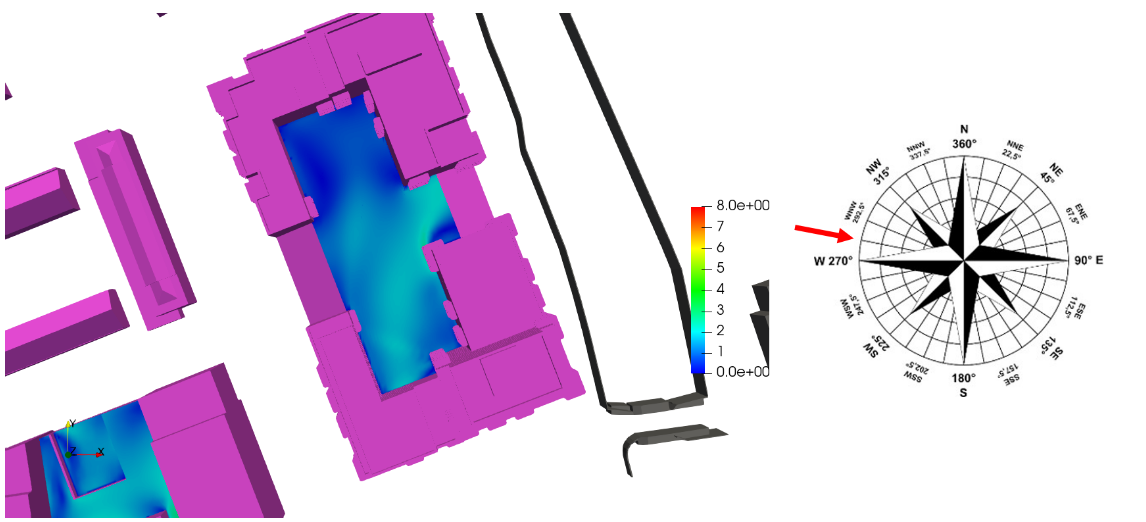


Figure 6.29: Courtyard Block B - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 281°

6.2.4 FLOW VELOCITY RESULTS - Courtyard of Block C

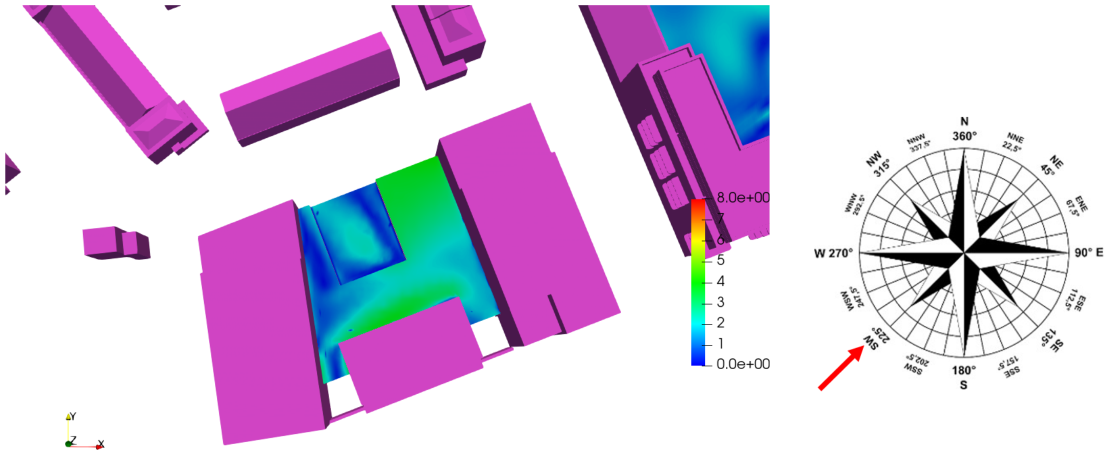


Figure 6.30: Courtyard Block C - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 225°

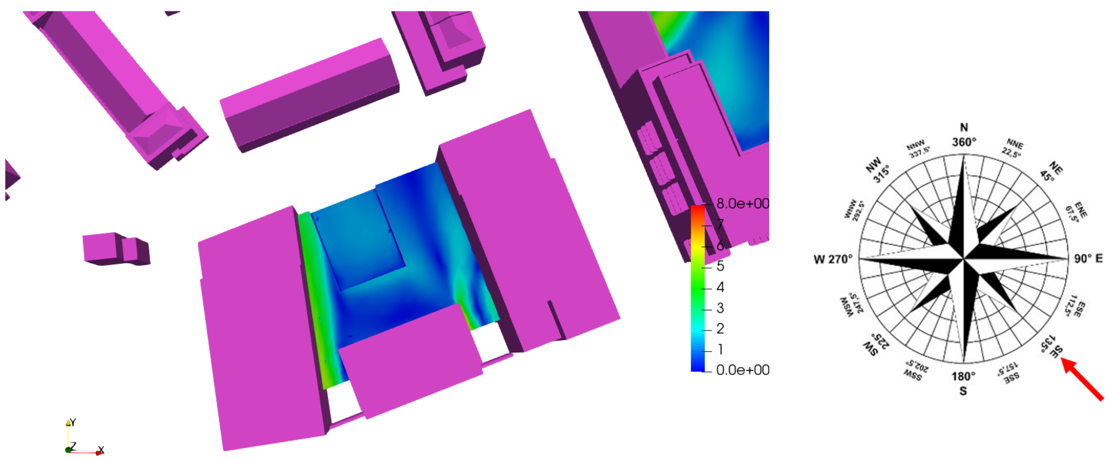


Figure 6.31: Courtyard Block C - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 135°

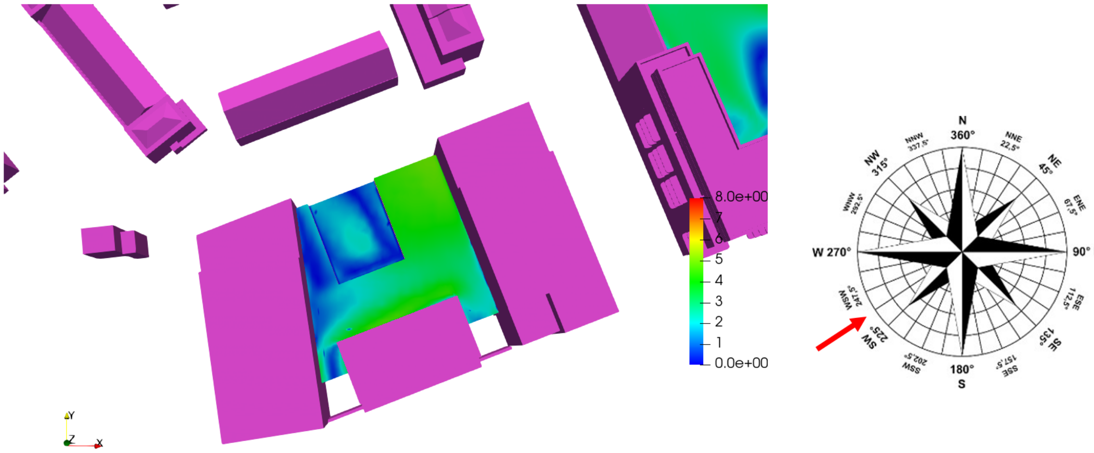


Figure 6.32: Courtyard Block C - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 236°

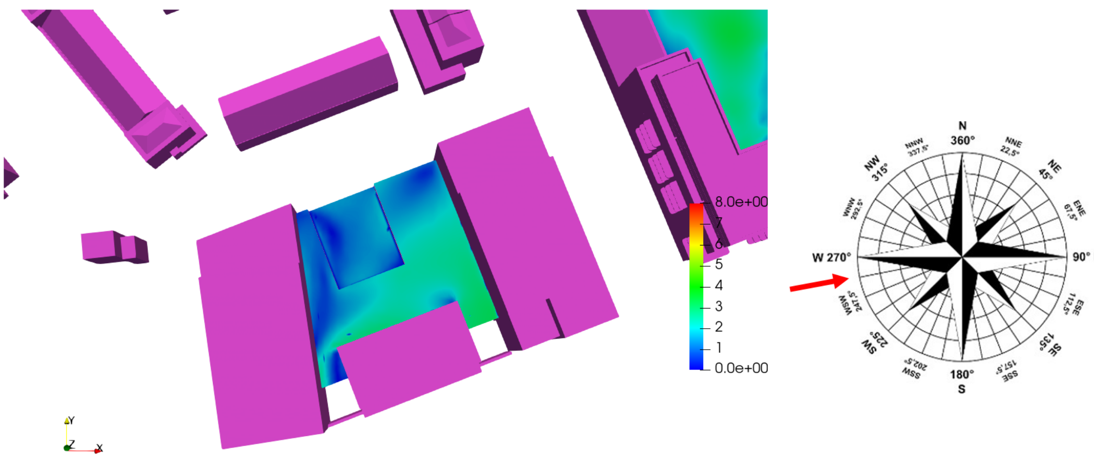


Figure 6.33: Courtyard Block C - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 258°

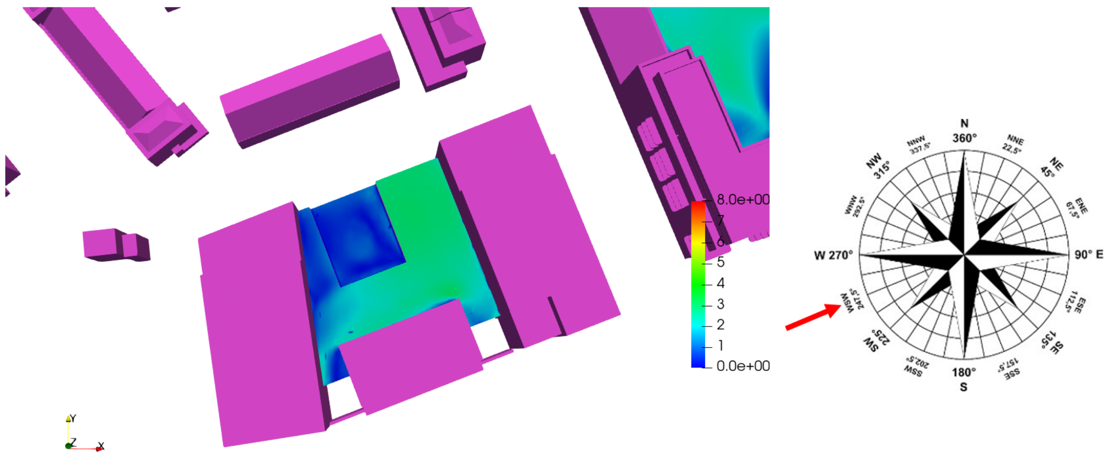


Figure 6.34: Courtyard Block C - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 247°

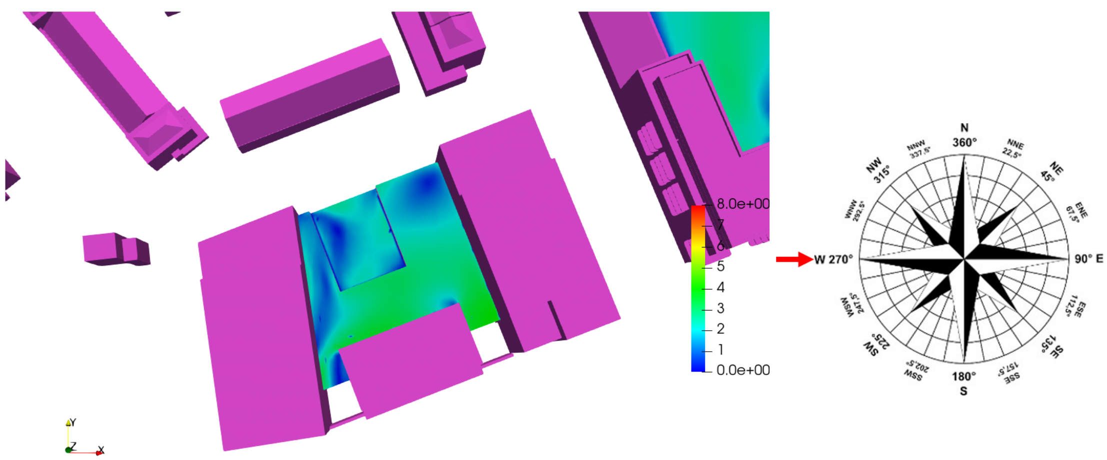


Figure 6.35: Courtyard Block C - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 270°

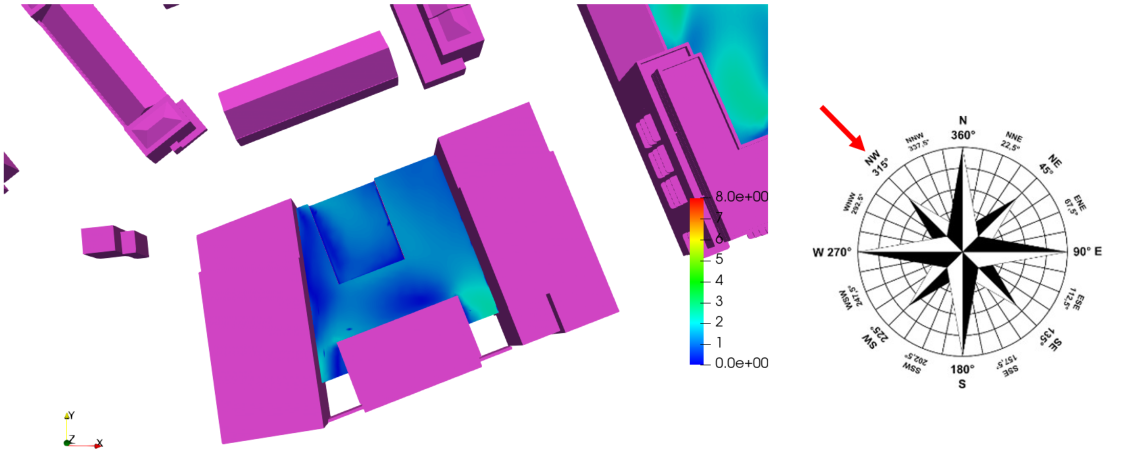


Figure 6.36: Courtyard Block C - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 315°

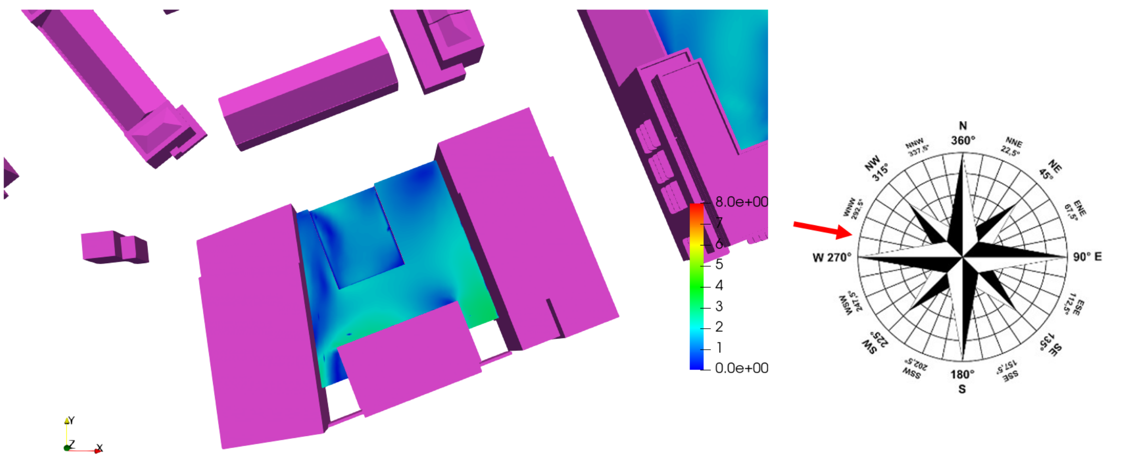


Figure 6.37: Courtyard Block C - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 281°

6.2.5 FLOW VELOCITY RESULTS - Roof Terrace on Block C

Block C is provided with a roof terrace on the fifth floor which is accessabile to residents. In Figure 6.38 the location of the terrace is visible.

Results of velocity at slice location of 1.5m above the terrace are presented in Figures 6.40 to 6.47, for wind assessment of the roof terrace of the Coastal Quarter - Strategic Housing Development (Block C). The analysis shows that the roof terrace is well protected by a combination of glazed screen and parapet wall reaching a height of at least 1.6m above the terrace floor. It must be noted that this analysis has been performed considering the worst case scenario conditions which considered the whole year. Terraces are not areas that are used all year around and long term sitting is an activity performed during spring/summer months.The wind roses collected for the seasonal effect have shown that critical speeds are not occurring in spring /summer months, when the frequency of such high wind is below 5%. In any case, there are not critical issues in regard to safety throughout the year.

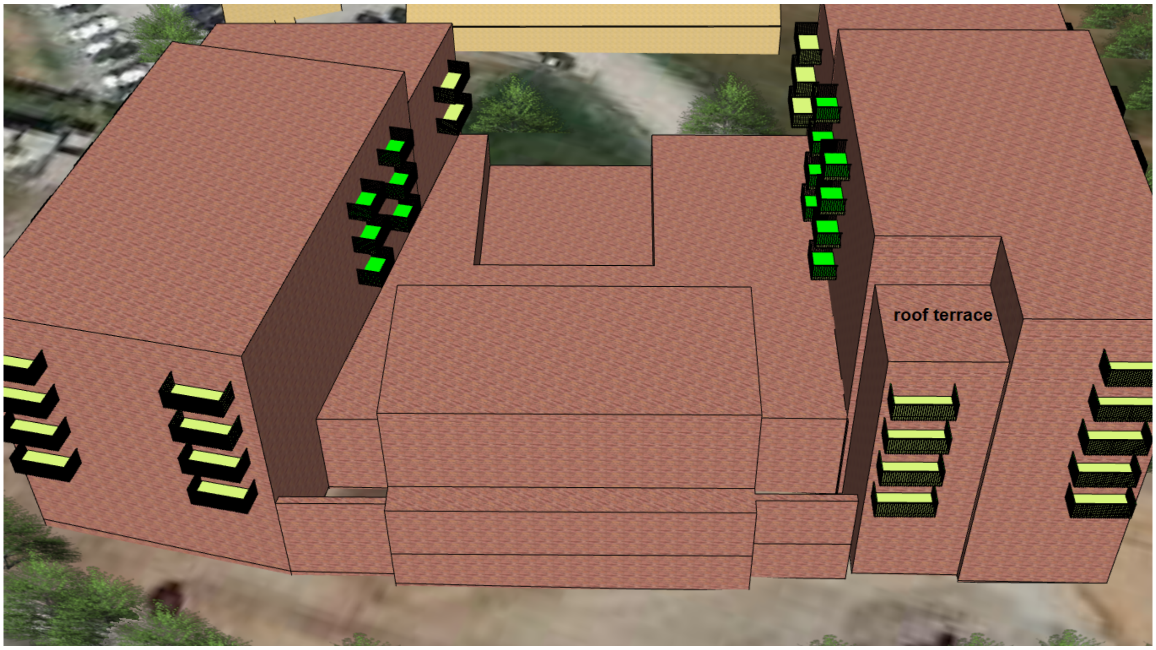


Figure 6.38: Location of Roof Terrace on Block C

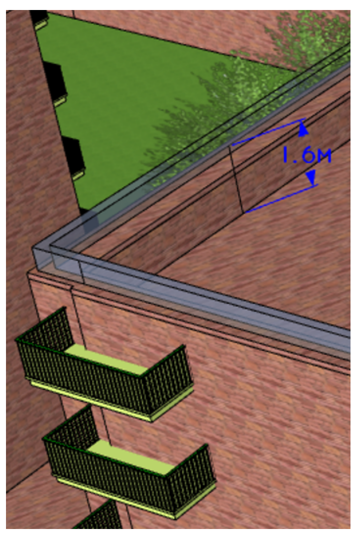


Figure 6.39: Example of Parapet/Glazing protection for the Roof Terrace on Block C

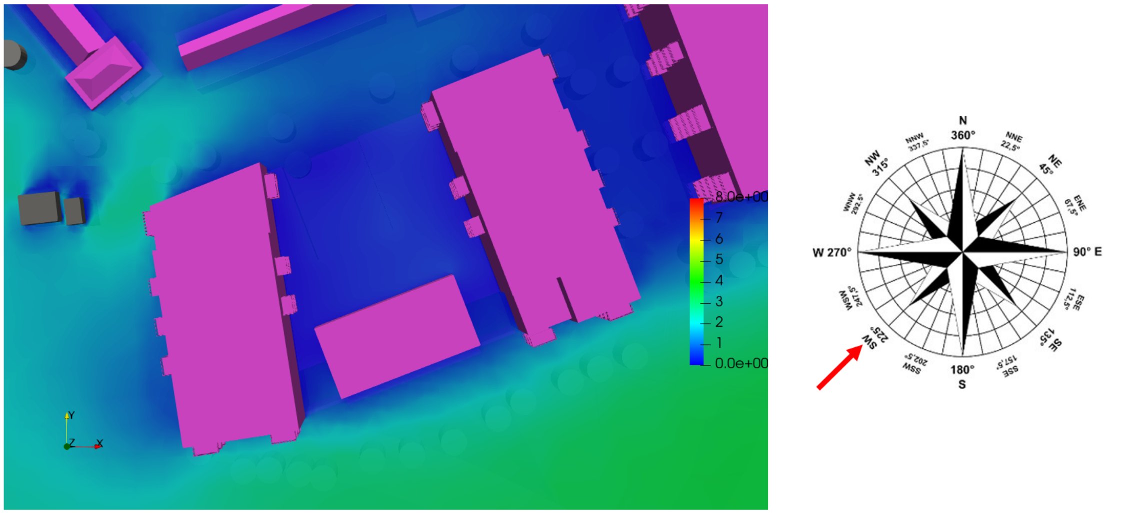


Figure 6.40: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 225°

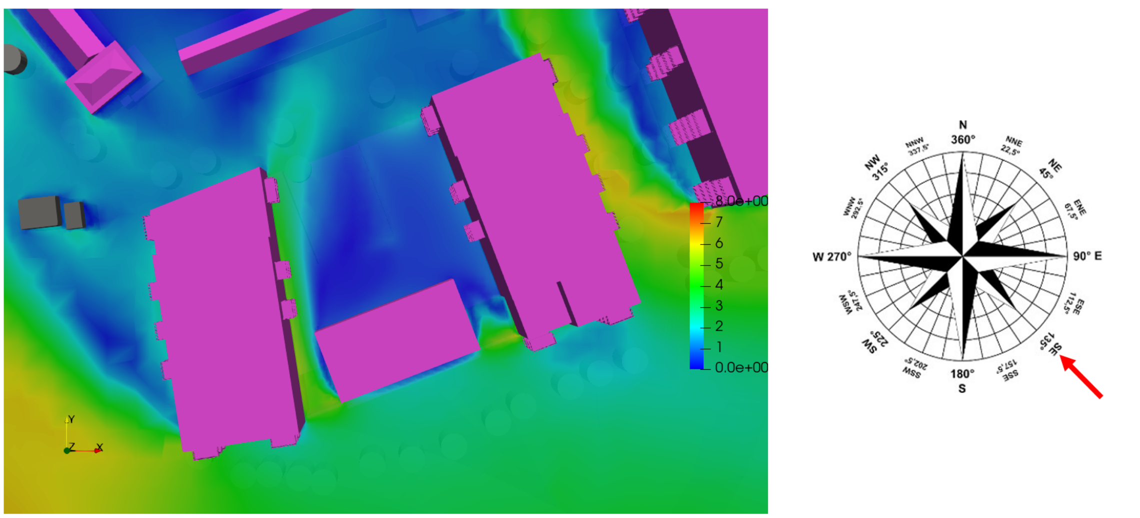


Figure 6.41: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 135°

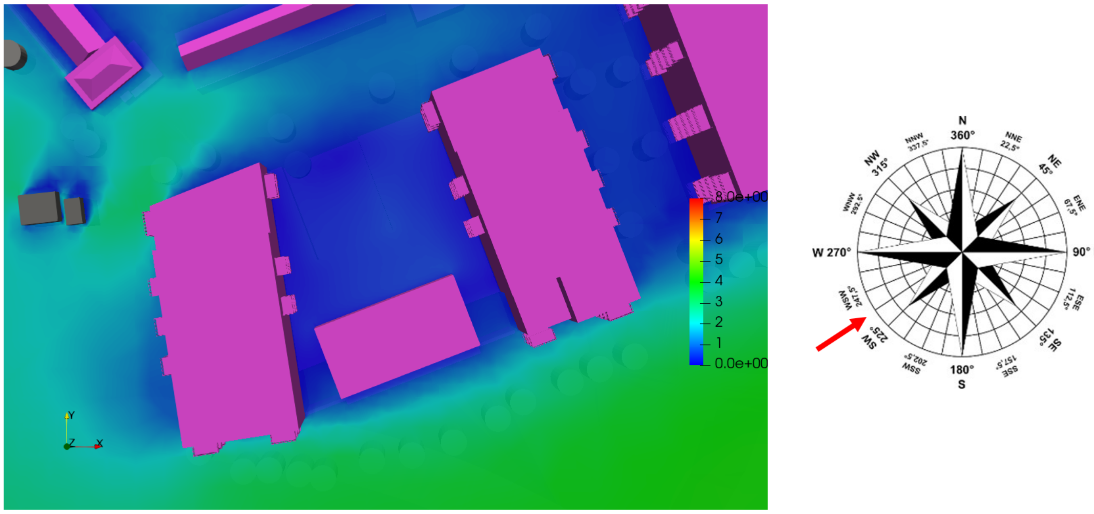


Figure 6.42: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 236°

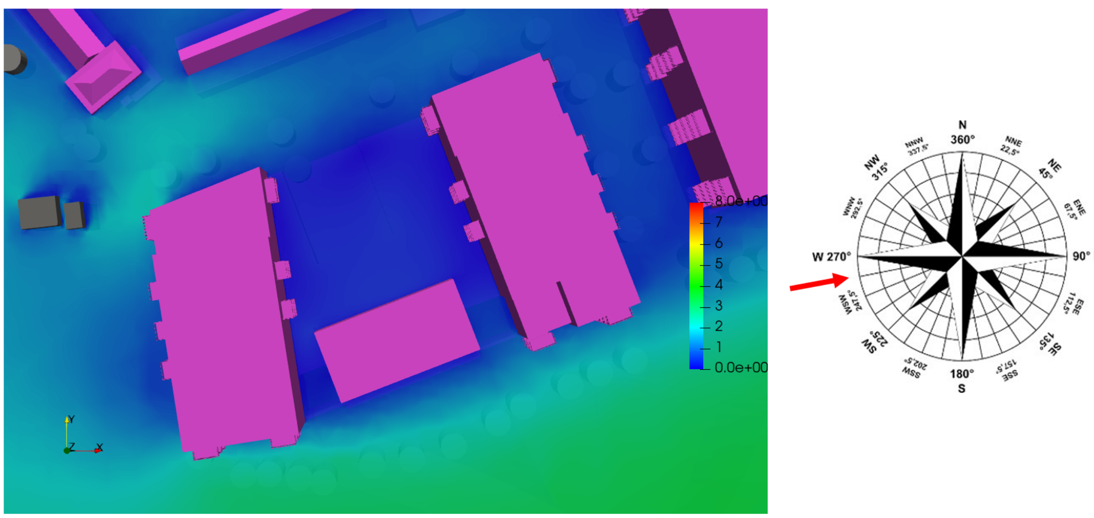


Figure 6.43: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 258°

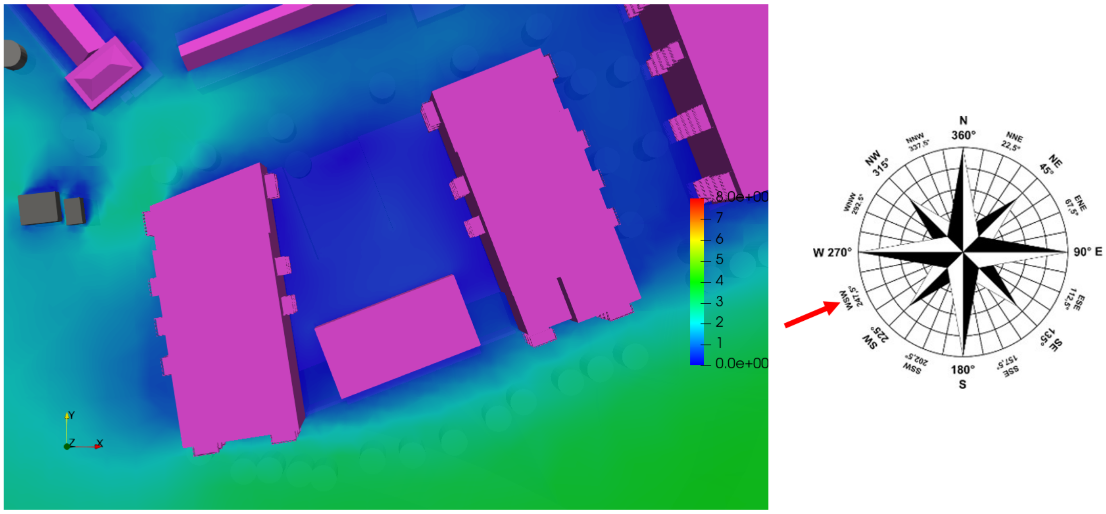


Figure 6.44: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 247°

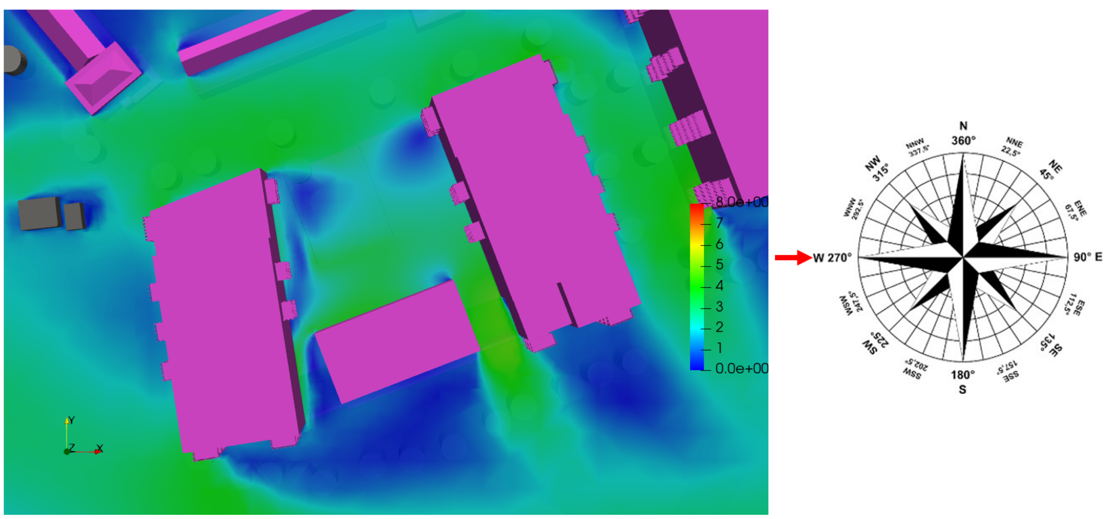


Figure 6.45: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 270°

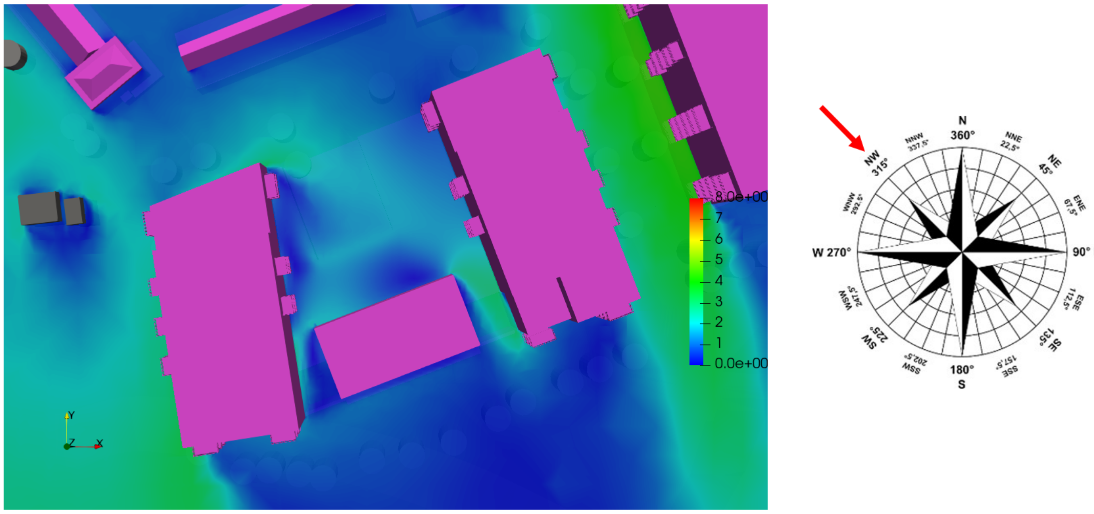


Figure 6.46: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 315°

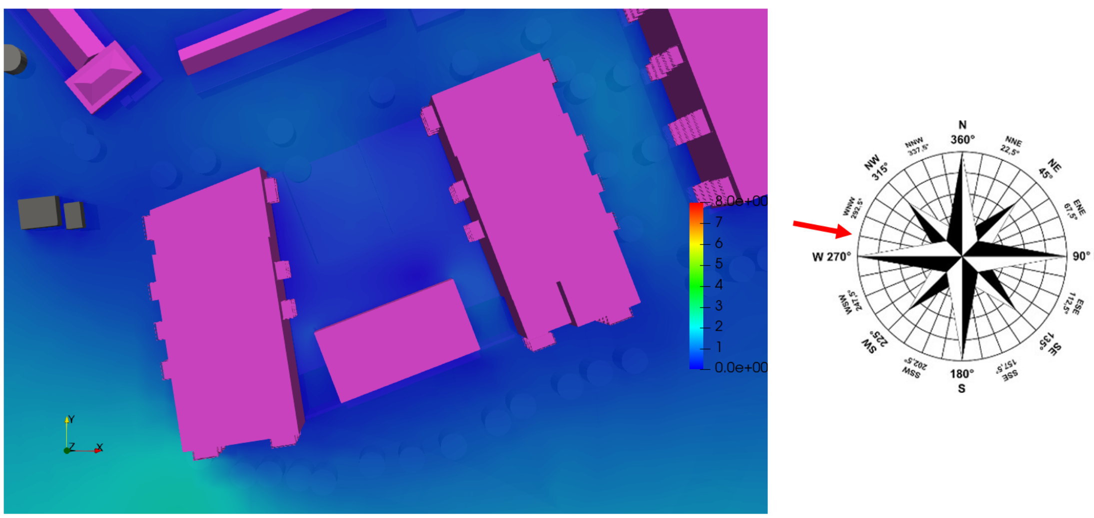


Figure 6.47: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 281°

6.2.6 FLOW VELOCITY RESULTS - Balconies

Results of velocity at slice location across the balconies are presented in Figures 6.48 to 6.55, for wind assessment of the balconies of the Coastal Quarter - Strategic Housing Development . Higher velocities can be found for some directions, only on some of the balconies. However, these velocities are below the threshold values defined by the acceptance criteria and therefore are not critical for safety.

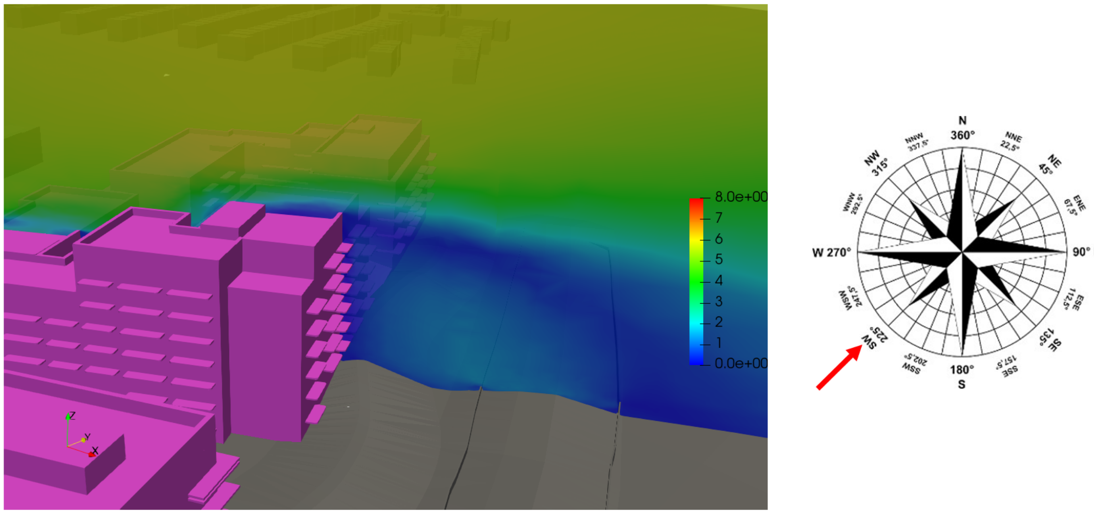


Figure 6.48: Balconies - Flow Velocity Results - Wind Direction: 225°

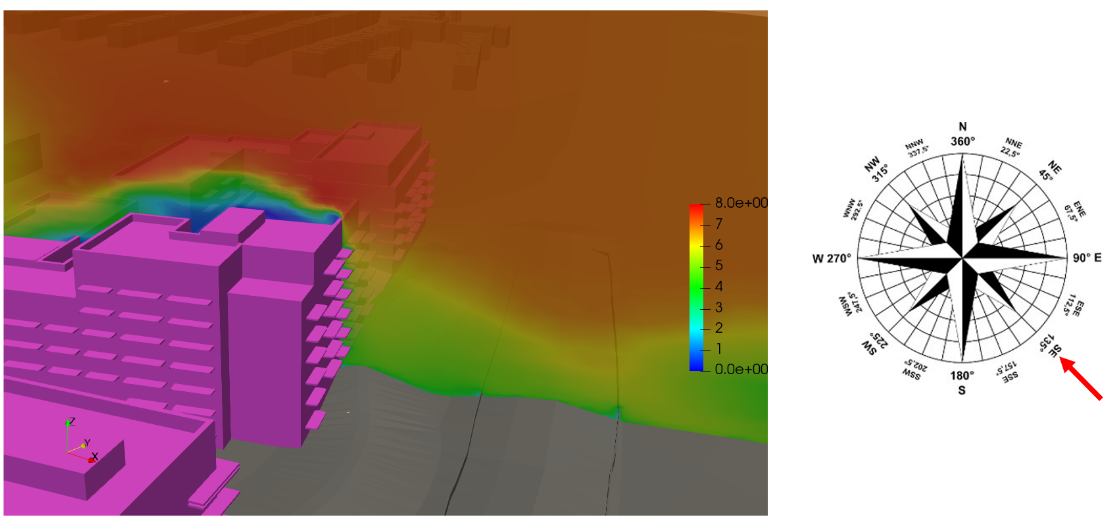


Figure 6.49: Balconies - Flow Velocity Results - Wind Direction: 135°

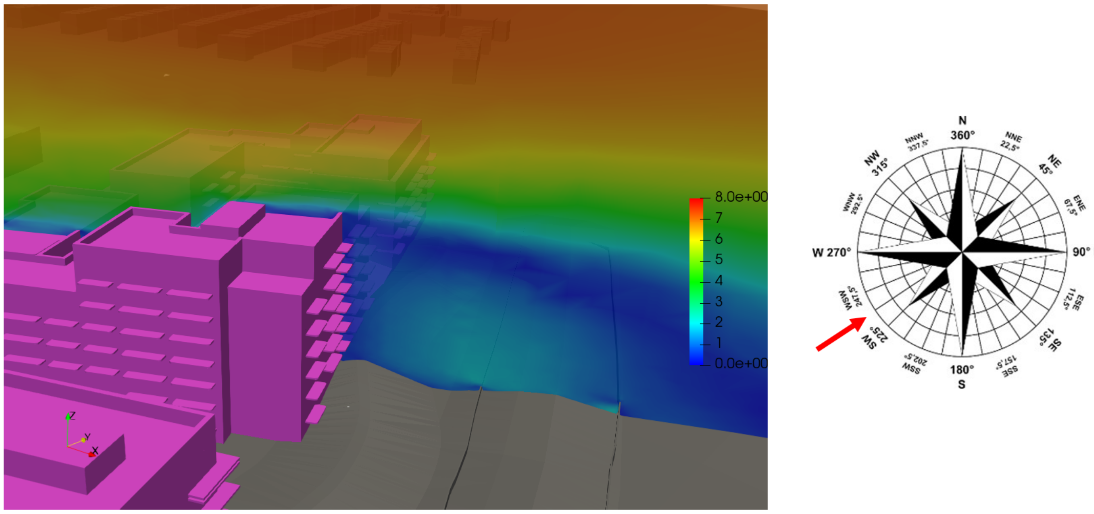


Figure 6.50: Balconies - Flow Velocity Results - Wind Direction: 236°

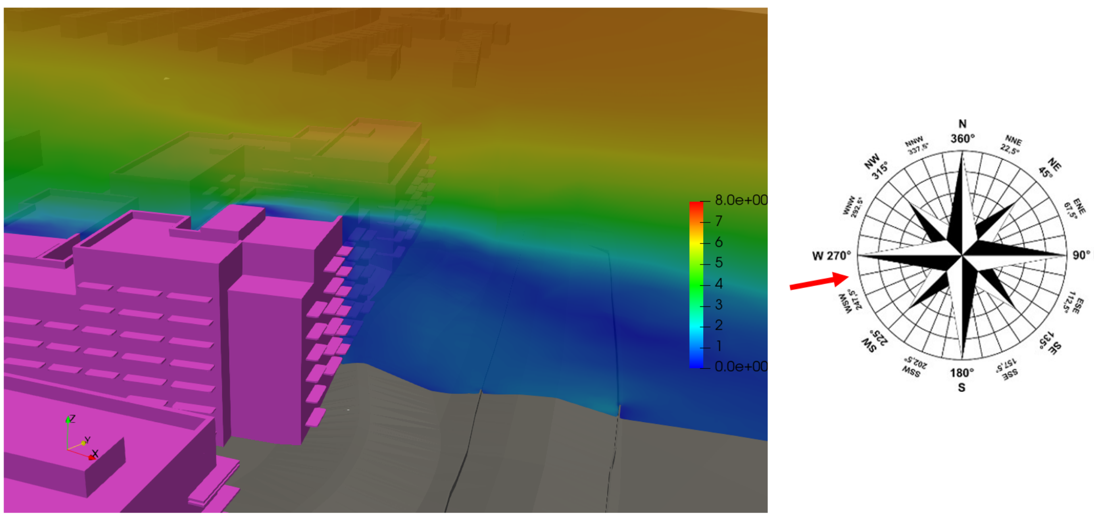


Figure 6.51: Balconies - Flow Velocity Results - Wind Direction: 258°

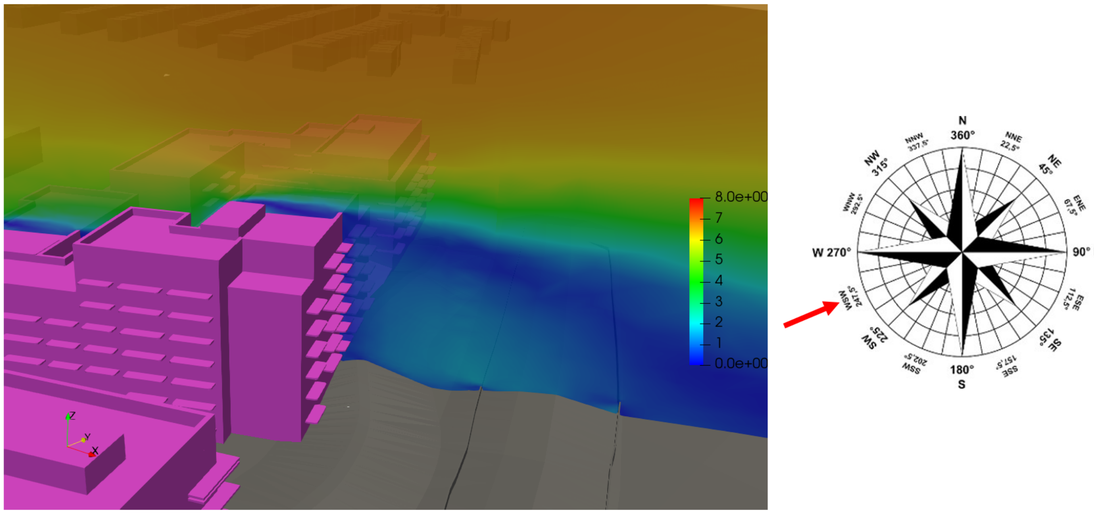


Figure 6.52: Balconies - Flow Velocity Results - Wind Direction: 247°

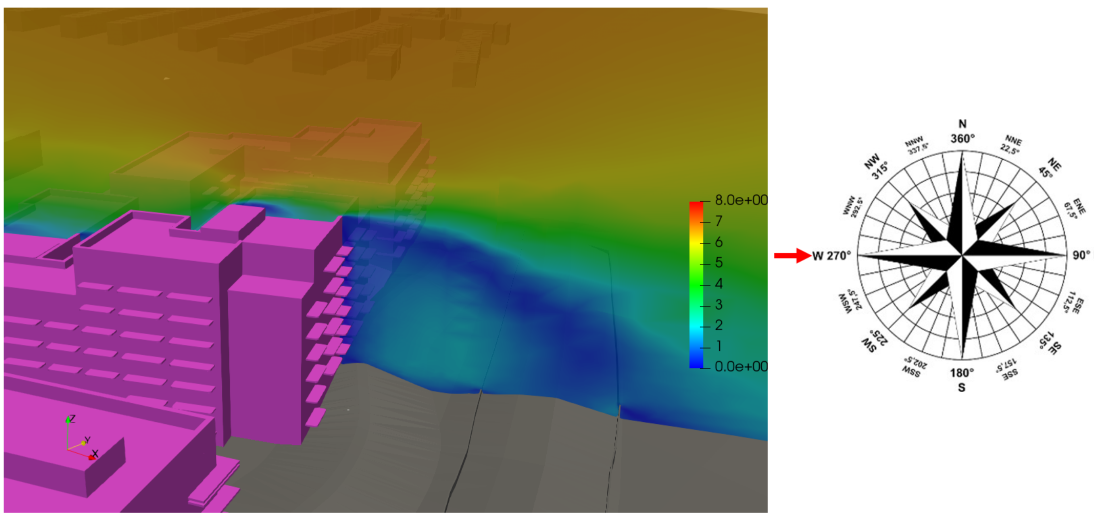


Figure 6.53: Balconies - Flow Velocity Results - Wind Direction: 270°

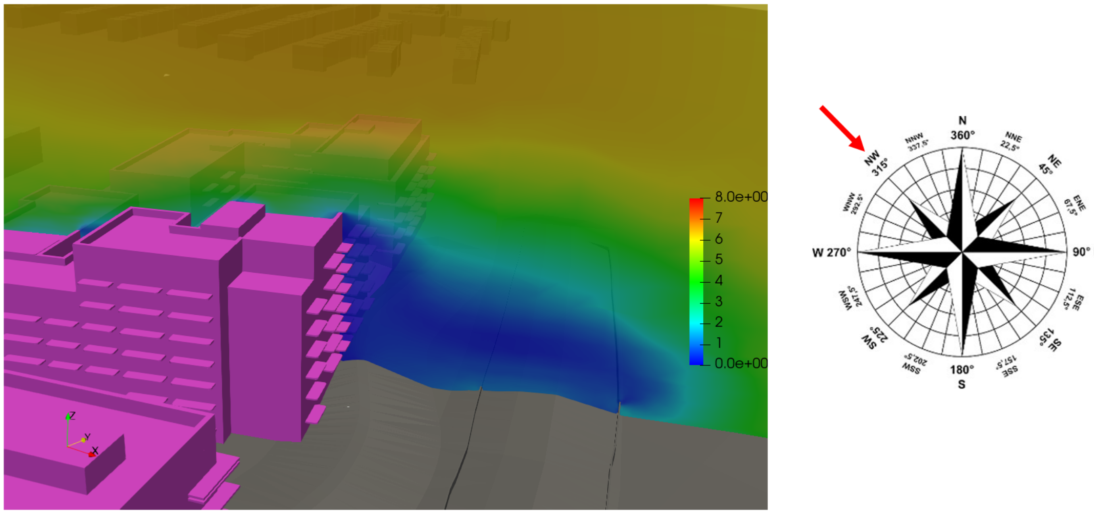


Figure 6.54: Balconies - Flow Velocity Results - Wind Direction: 315°

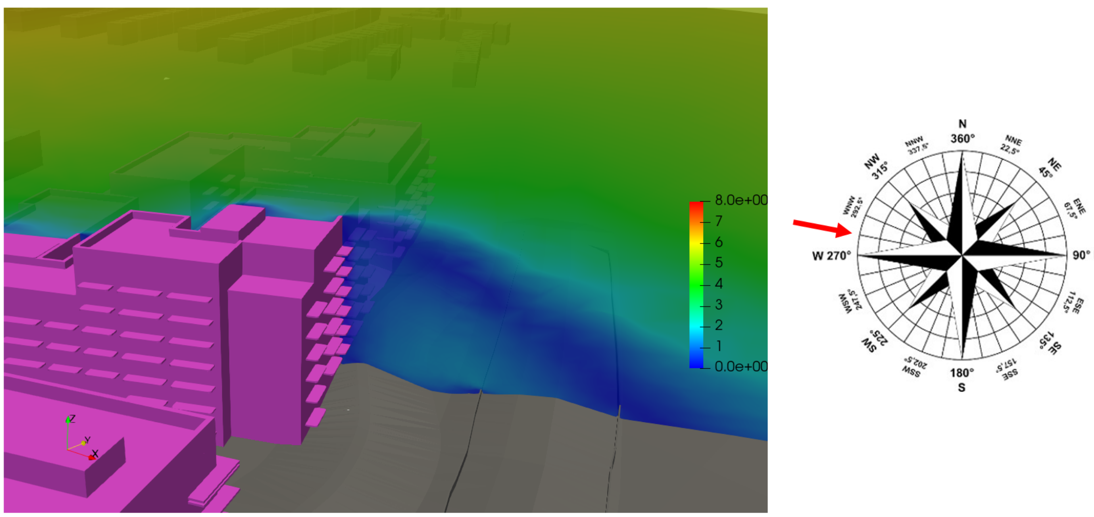


Figure 6.55: Balconies - Flow Velocity Results - Wind Direction: 281°

6.2.7 PEDESTRIAN COMFORT ASSESSMENT

This section aims to identify areas of the Coastal Quarter - Strategic Housing 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.

DISCOMFORT CRITERIA

Figures 6.57 to 6.61 show Lawson comfort categories over the ground floor area and terraces of Coastal Quarter - Strategic Housing Development for the most prevailing wind directions. Thus, depending on the wind direction, the suitability of the different areas can be assessed using those maps.

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. 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 maps show that for the Ground Floor Level there are no critical area which are unacceptable for pedestrian comfort.

Some higher velocity indicating minor funnelling effects are found, on the road between Block B and Block C, as well as the area between Block A and the adjacent rail structure. As it can be seen, both areas were mitigated with landscaping and the flow velocities shown in the Lawson map indicate that the road can be utilised for the intended use (i.e. for those activities which include any type of walking and also short term sitting).

Courtyards on Block A,B and C are well protected, however there is a small area in the middle of courtyard Block B is suitable for short term sitting due to minor re-circulation effects. These conditions are not occurring at a frequency that would compromise the pedestrian comfort, according to the Lawson Criteria.

The scale used in the following images is set out in Figure 6.56.

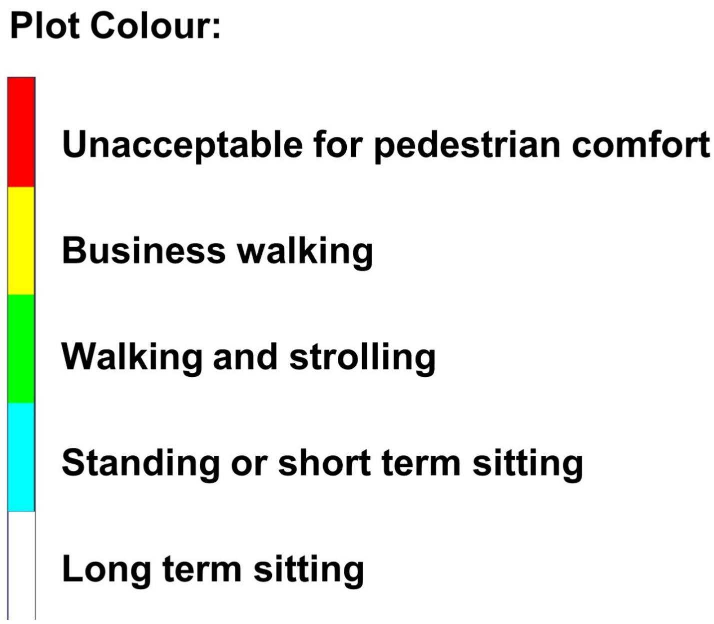


Figure 6.56: Lawson Comfort Categories

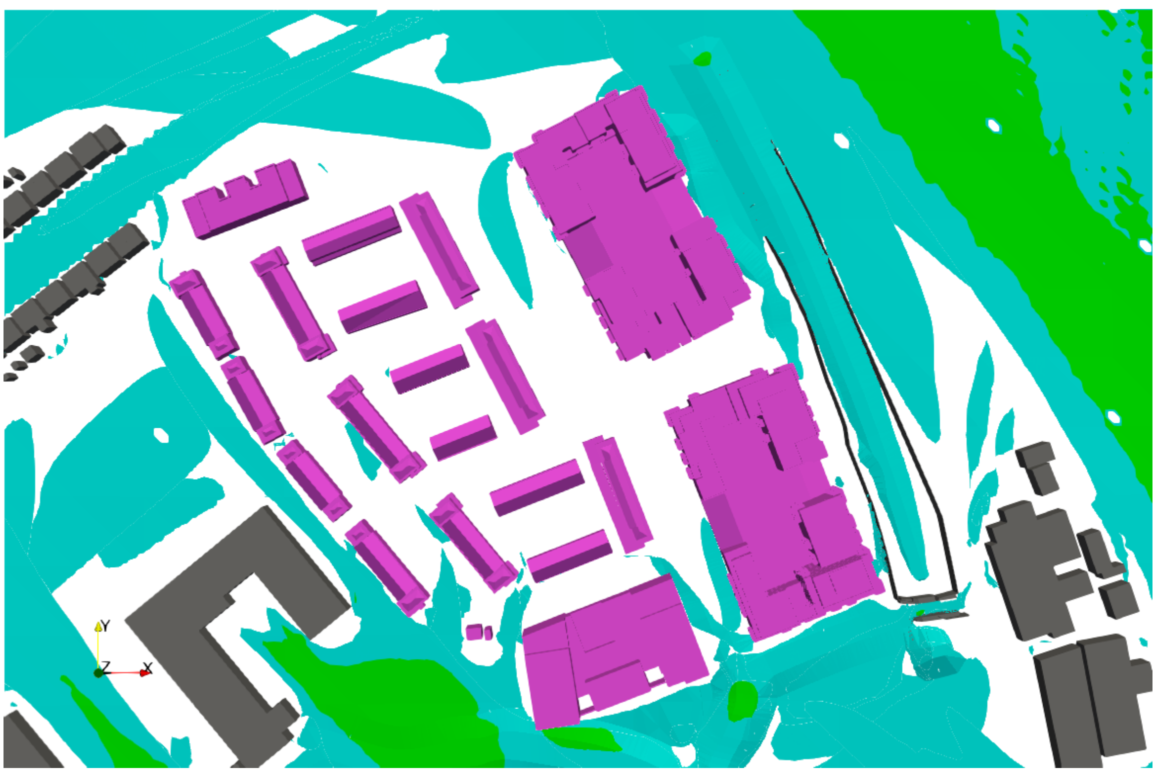


Figure 6.57: Ground Floor - Lawson Discomfort Map

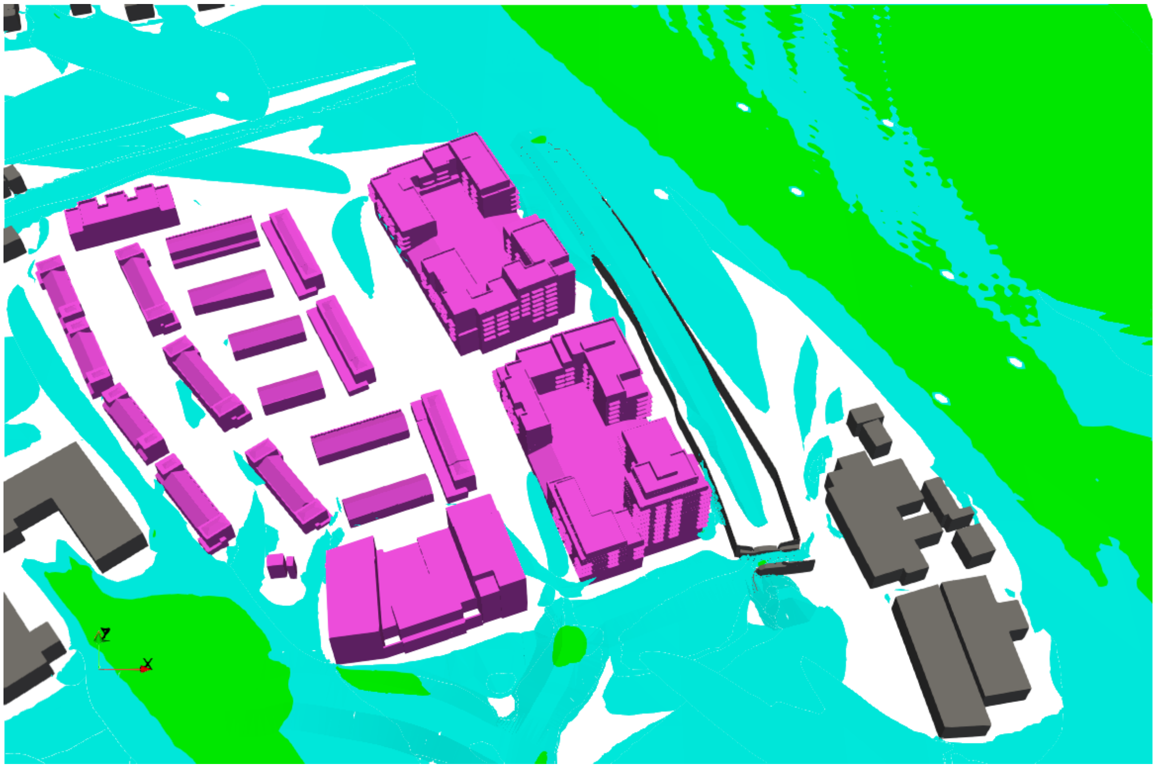


Figure 6.58: Ground Floor - Lawson Discomfort Map (3D View)

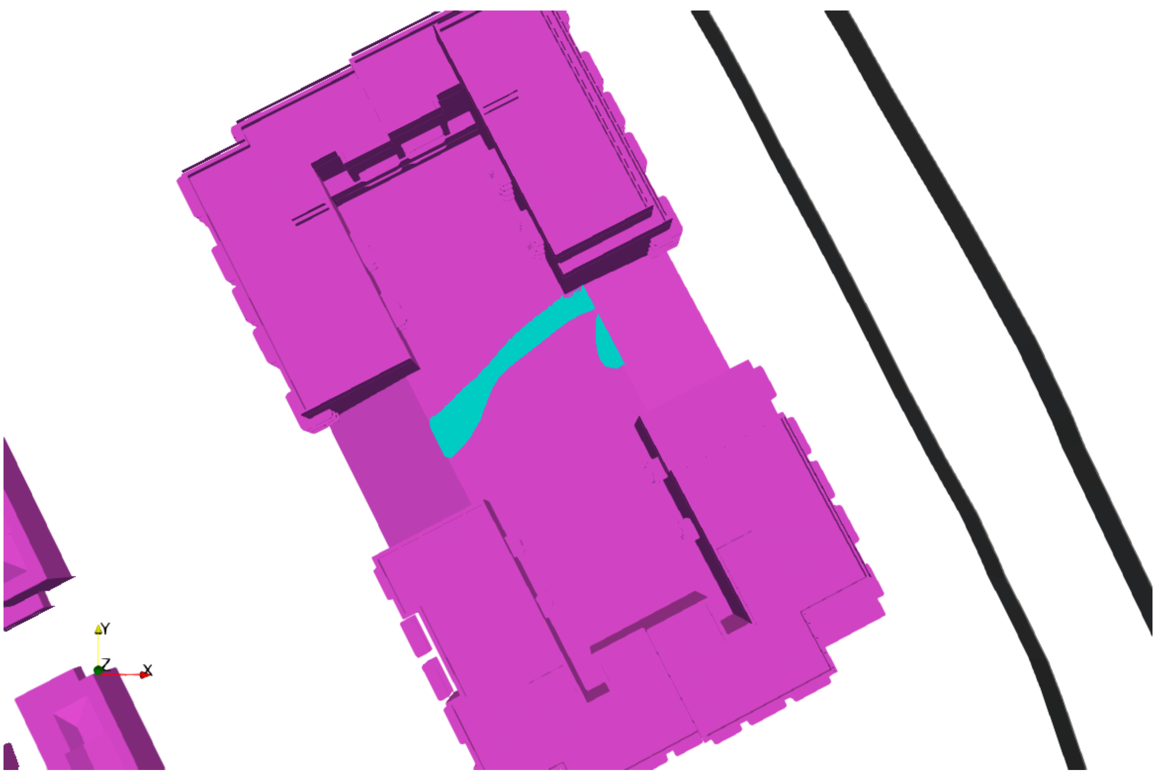


Figure 6.59: Courtyard Block A - Lawson Discomfort Map

Figure 6.60: Courtyard Block B - Lawson Discomfort Map

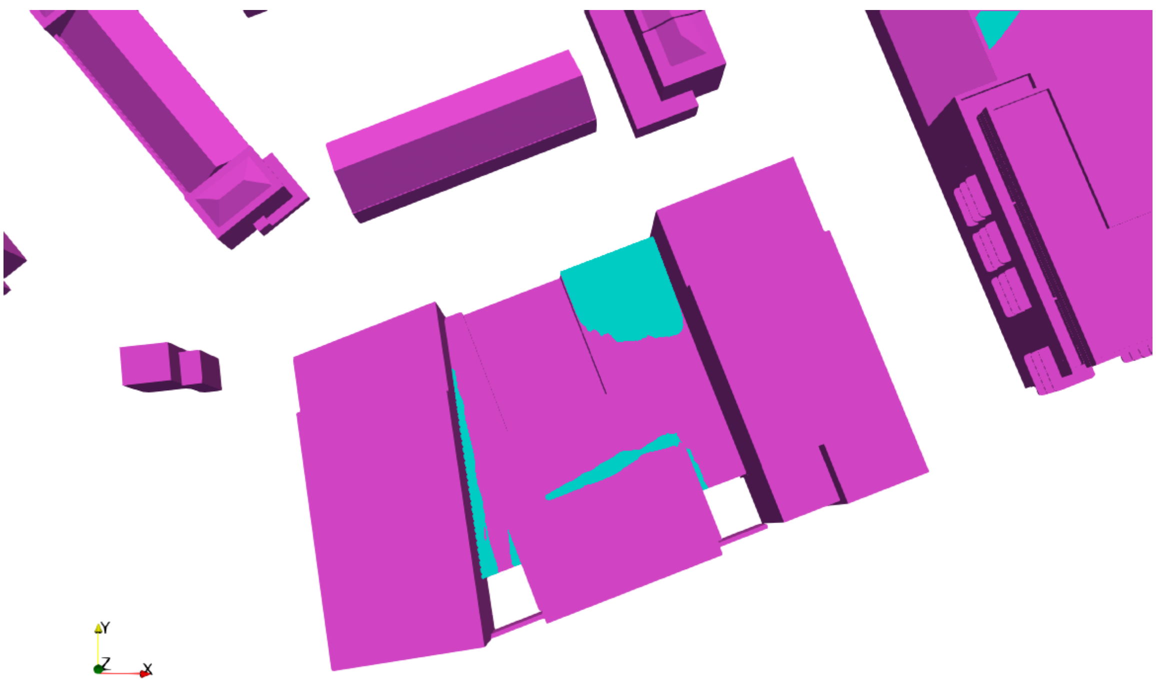


Figure 6.61: Courtyard and Roof terrace at Block C- Lawson Discomfort Map

DISTRESS CRITERIA

The criteria for distress for a frail person or cyclist is 15m/s wind occurring for more than two hours per year.

As explained above, a velocity of 15m/s was reached in Dublin only for the following directions (in increasing order of percentage) over the years 1990-2020:

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. Figure 6.63 below combines all the above directions together and shows the areas where the measured velocity is above 15 m/s. Figure 6.62 shows the scale used in this case. Results show that there are not critical areas where the velocity increases above 15 m/s, thus the criteria is always satisfied.

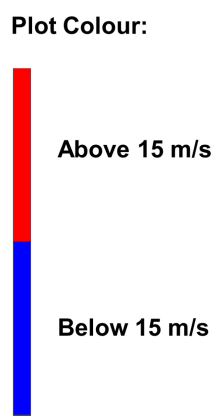


Figure 6.62: Lawson Distress Categories - Frail Person or Cyclist

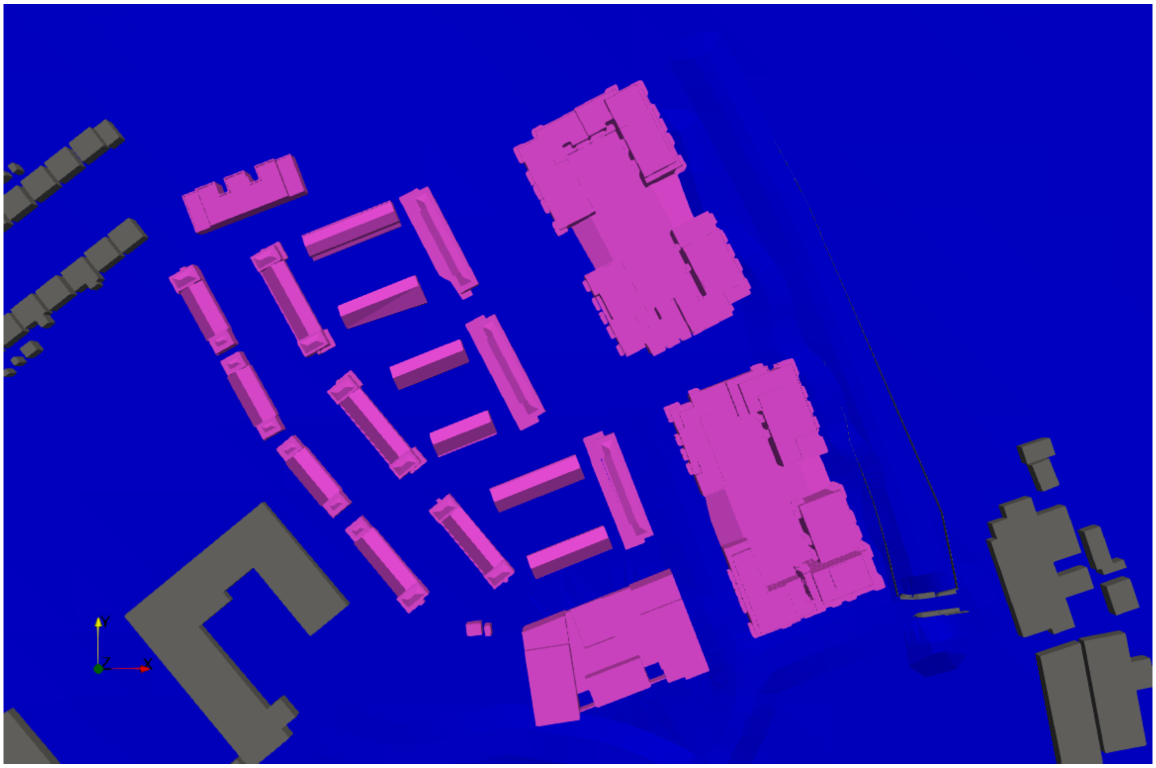


Figure 6.63: Lawson Distress Map - Frail Person or Cyclist

The criteria for distress for a member of the general population is 20m/s wind occurring for more than two hours per year. As explained above, a velocity of 20m/s was never reached in Dublin over the years 1990-2020.

7. CUMULATIVE IMPACT

7.1 MICROCLIMATE ASSESSMENT OF CUMULATIVE 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. The buildings that have been added in this cumulative analysis are the Landmark building and the River Quarter buildings, that will be potentially constructed in the incoming years.

Coastal Quarter - Strategic Housing Development and adjacent buildings Model is shown in Figure 7.1.

Figure 7.1: Coastal Quarter - Strategic Housing Development Development, Landmark building and River Quarter buildings - Extents of Modelled Area

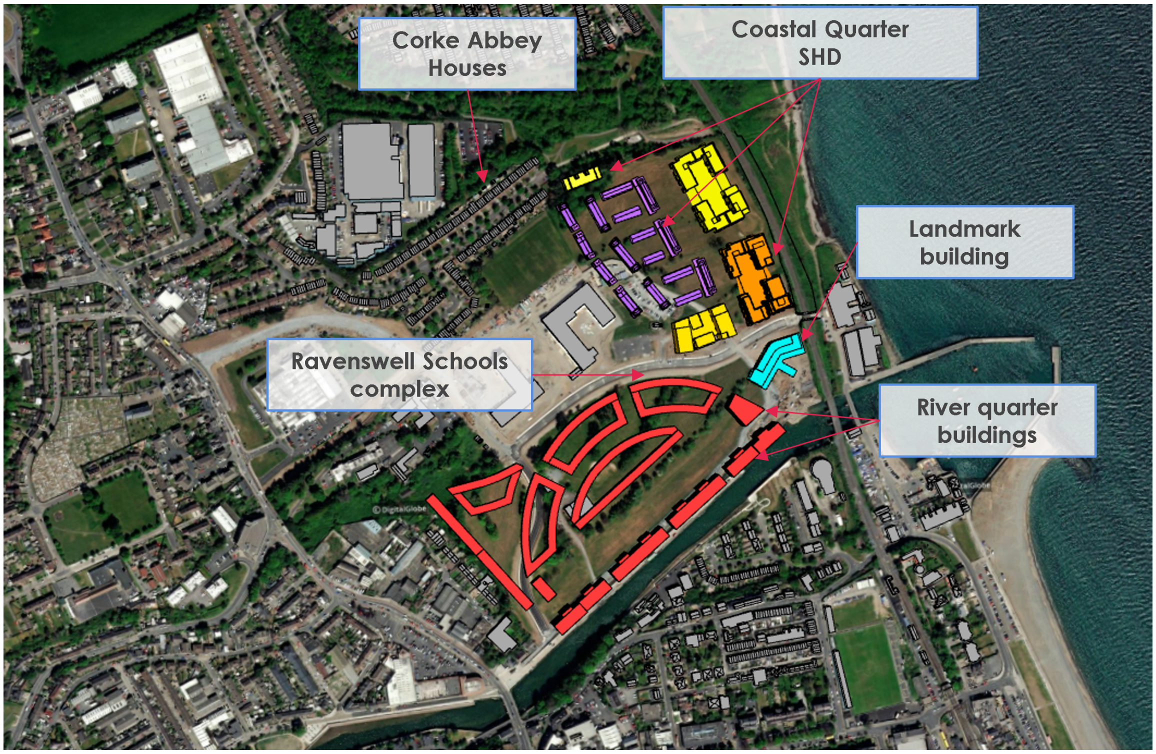


Figure 7.2: Top View - Coastal Quarter - Strategic Housing Development Development, Landmark building and River Quarter buildings - top view with an aerial photograph

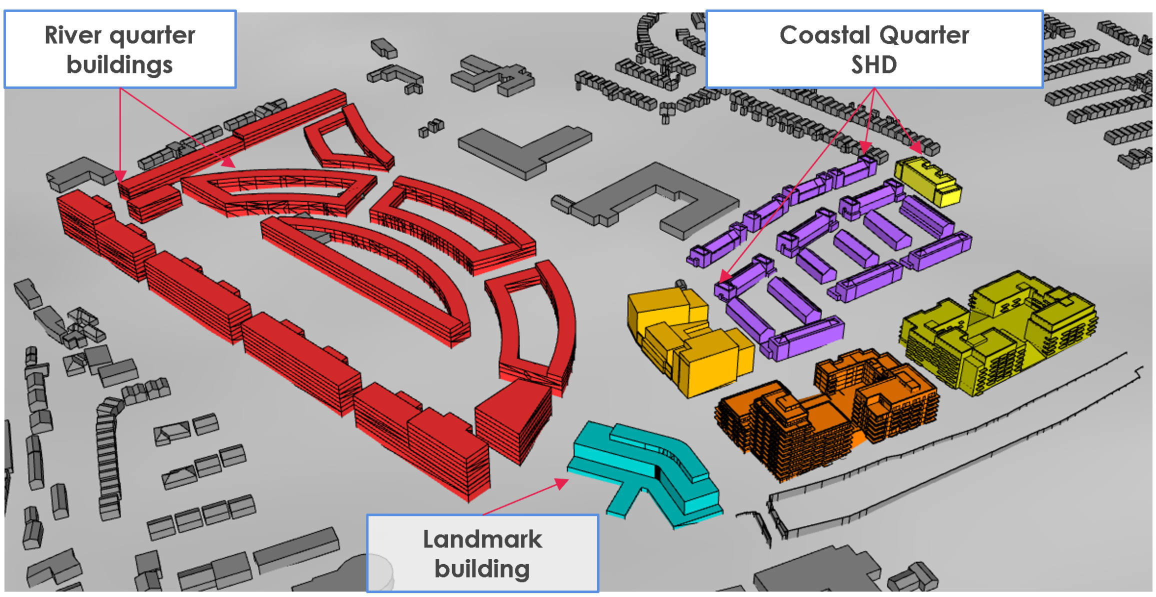


Figure 7.3: 3D View - Coastal Quarter - Strategic Housing Development Development, Landmark building and River Quarter buildings - Cumulative Impact

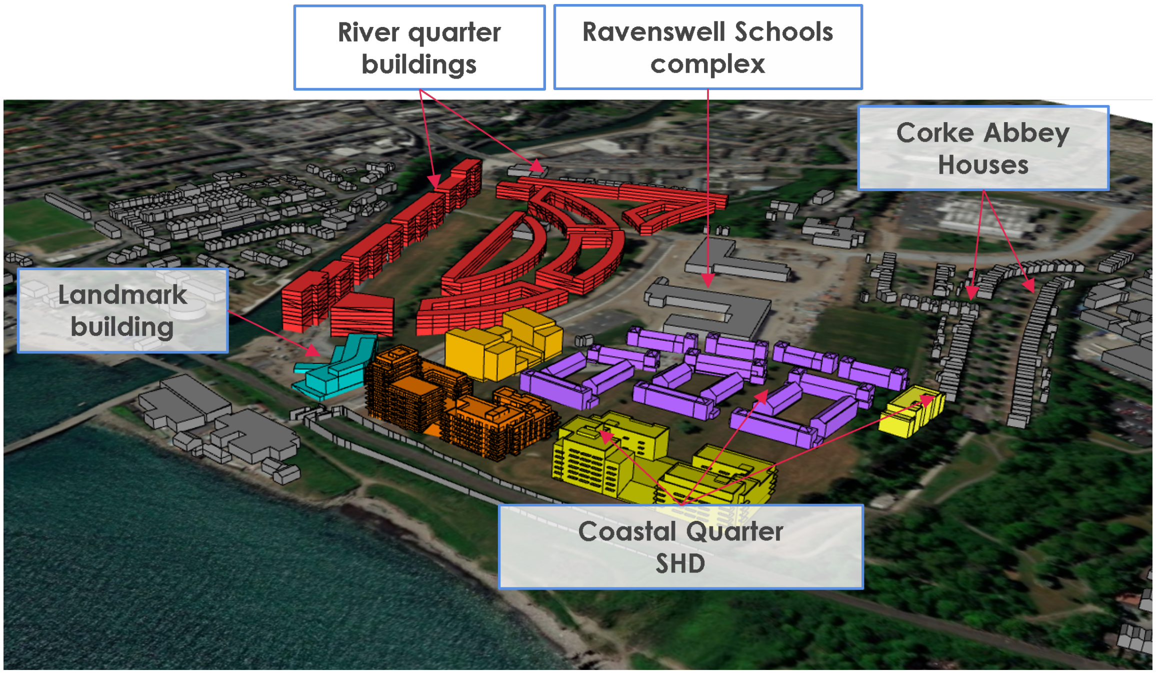


Figure 7.4: 3D View with satellite image - Coastal Quarter - Strategic Housing Development Development, Landmark building and River Quarter buildings - Cumulative Impact

Computational Mesh
An example of the utilized computational mesh grid is as shown in Figure 7.5.

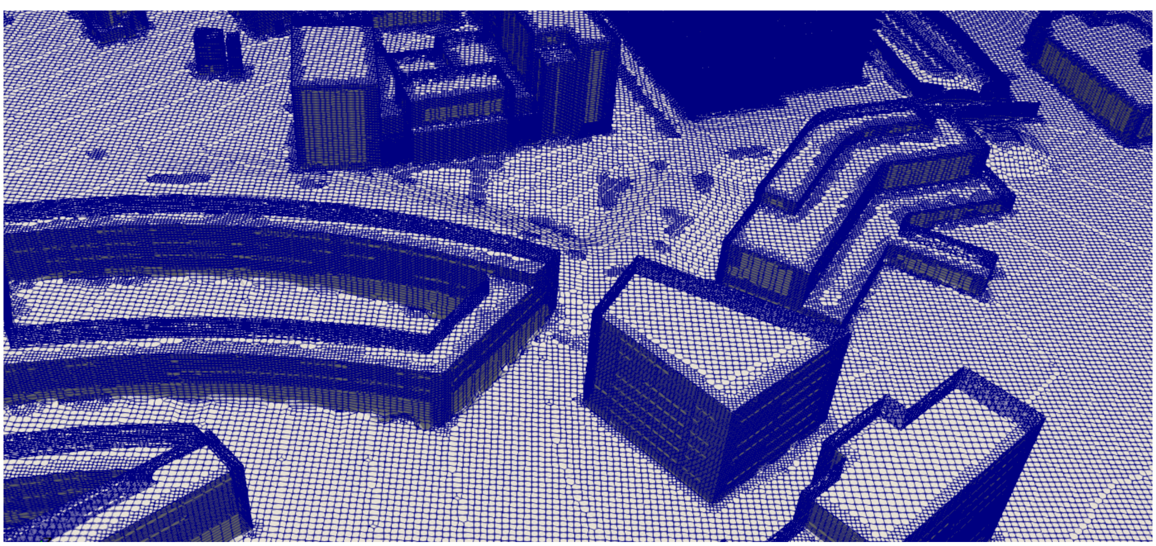


Figure 7.5: Coastal Quarter - Strategic Housing Development and adjacent buildings - Computational Mesh Utilized for cumulative impact assessment

7.1.1 FLOW VELOCITY RESULTS - Ground Floor Level

Results of wind speeds and their circulations around the proposed development at pedestrian level of 1.5m above the development ground are presented for all the simulated wind directions in Figures 7.6 to 7.13, in order to assess wind flows at ground floor level of Coastal Quarter - Strategic Housing Development .

The proposed Coastal Quarter - Strategic Housing Development will produce a quality environment that is attractive and comfortable for pedestrians at ground floor also when the Landmark building and the River Quarter buildings were introduced for the cumulative impact assessment. The introduction of the Landmark building and the River Quarter buildings modifies the flow behaviour on the South and West sides of Block B.

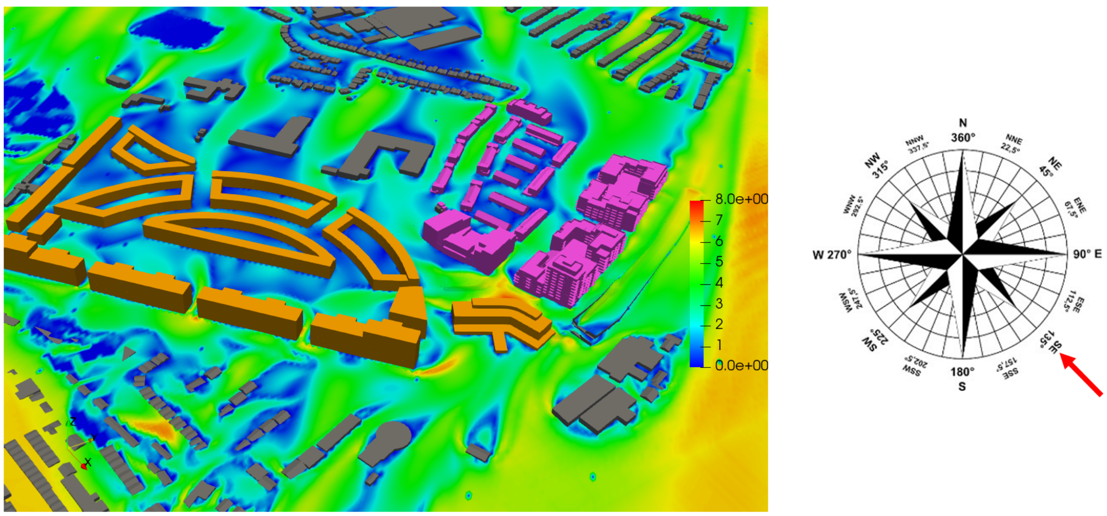


Figure 7.6: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 135°

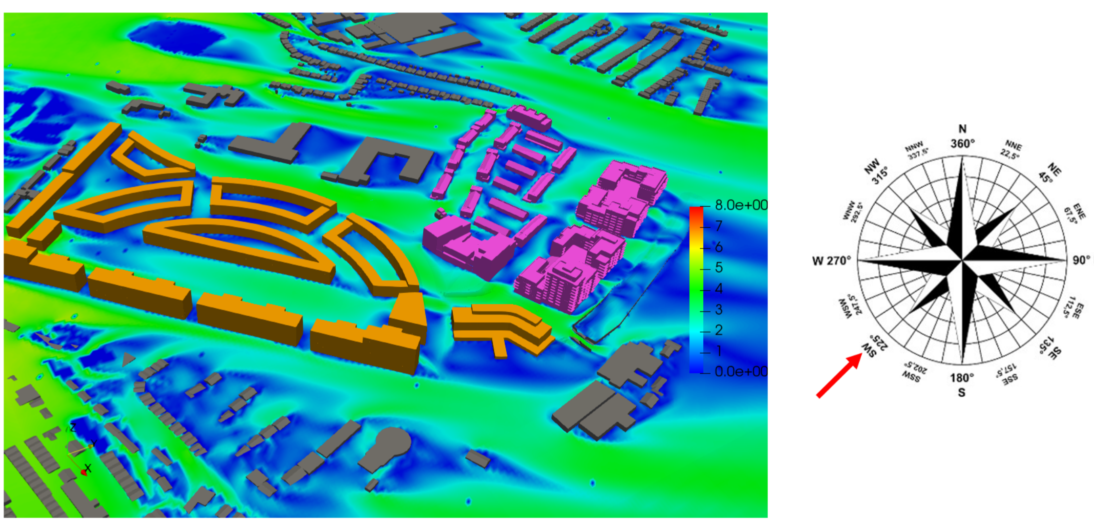


Figure 7.7: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 225°

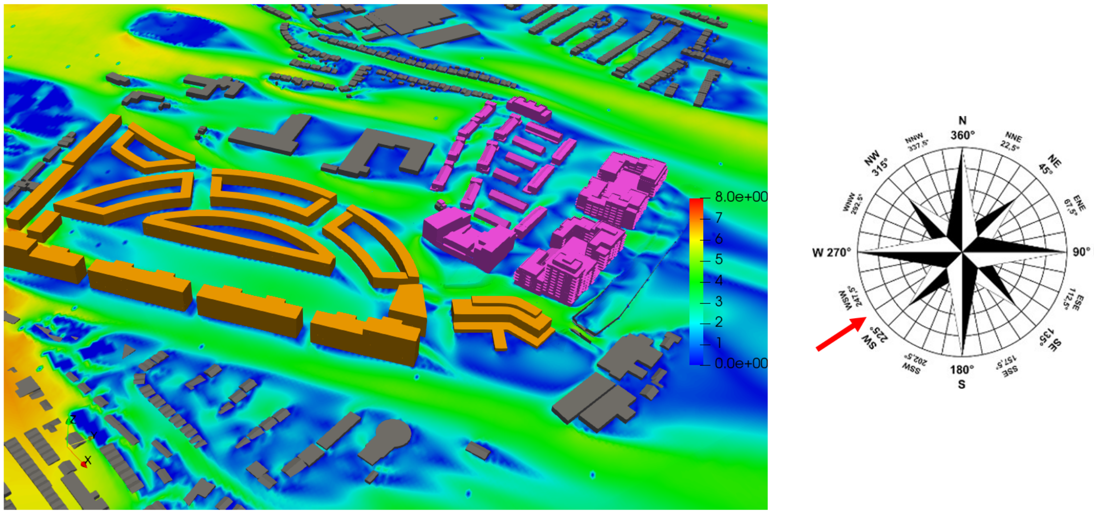


Figure 7.8: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 236°

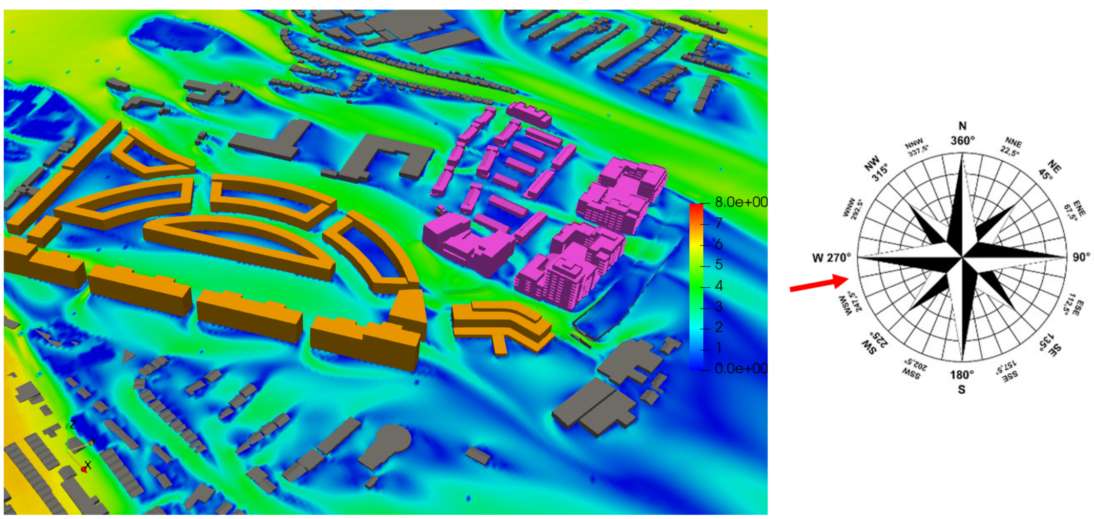


Figure 7.9: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 258°

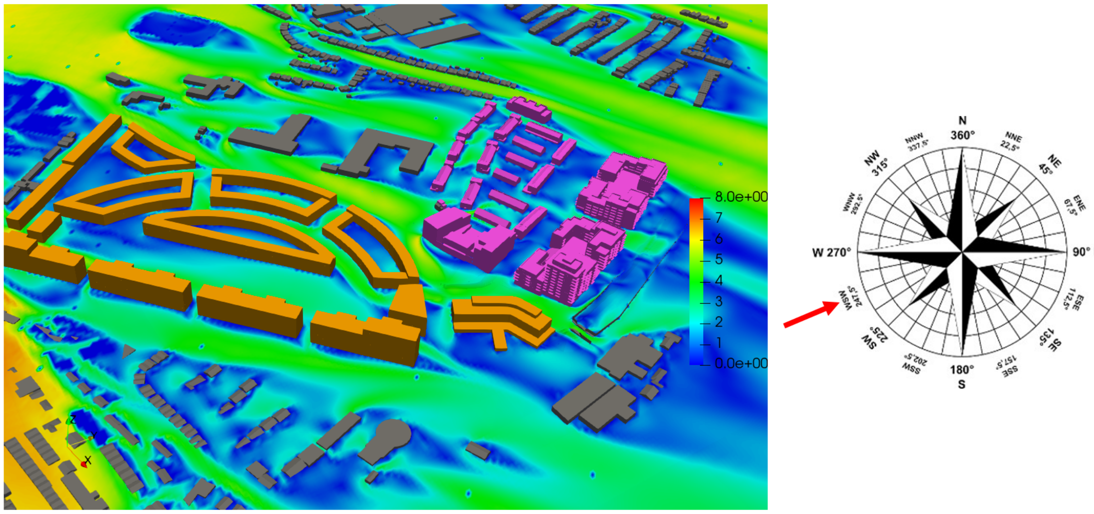


Figure 7.10: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 247°

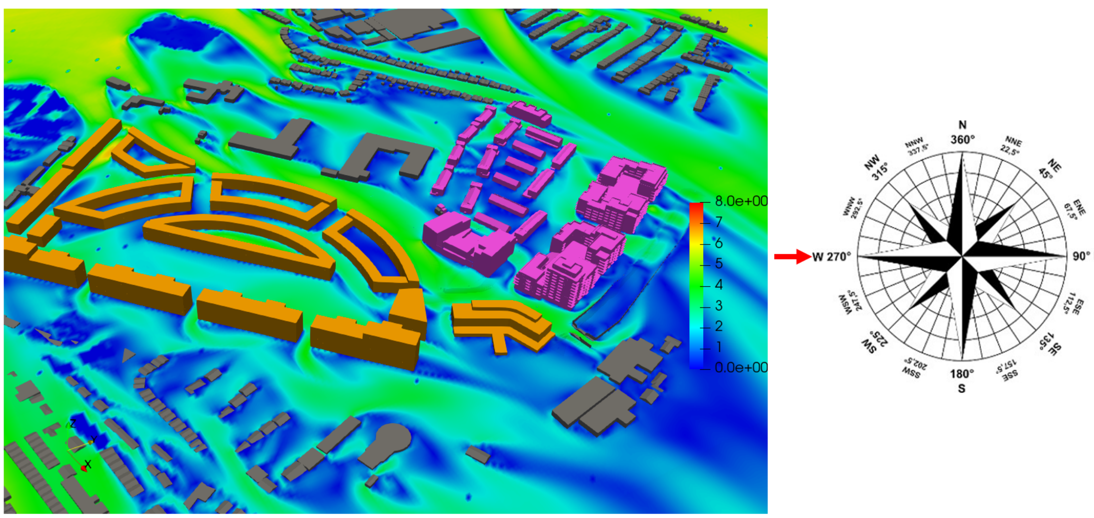


Figure 7.11: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 270°

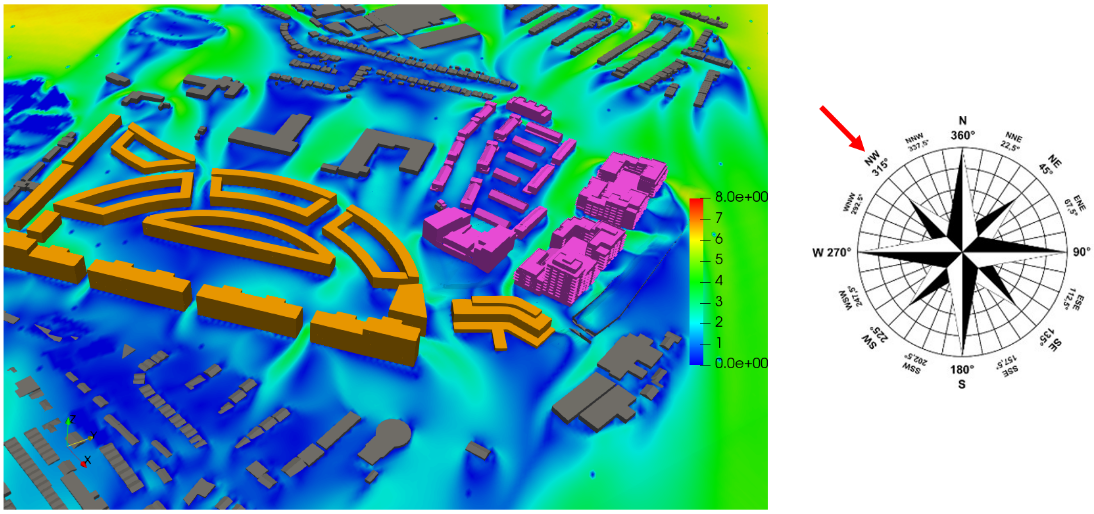


Figure 7.12: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 315°

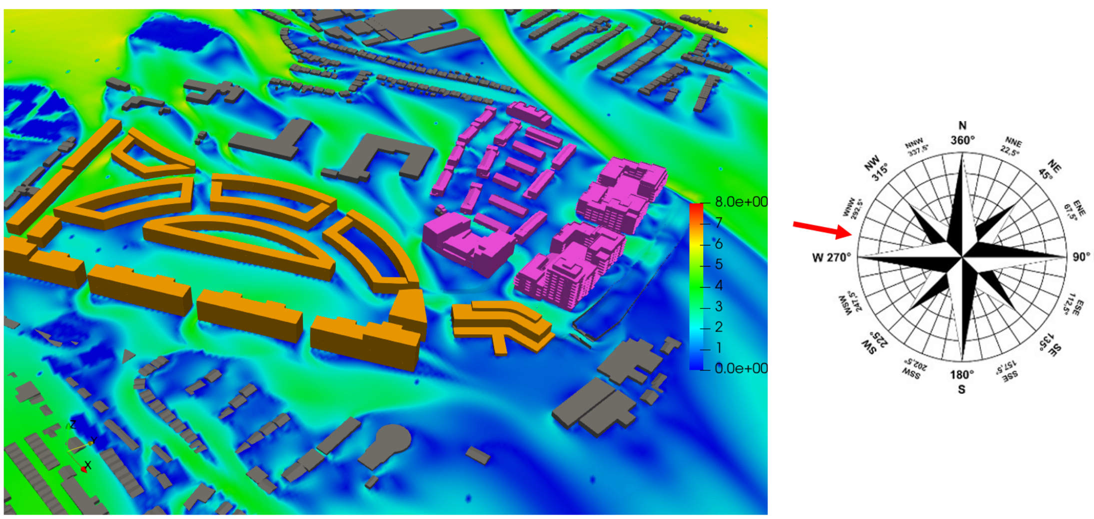


Figure 7.13: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 281°

7.1.2 FLOW VELOCITY RESULTS - Roof Terrace on Block C

The roof terrace at Block C is again assessed for the cumulative impact as this, differently from the Courtyards of Block A and Block B may experience a variation of the fow patterns due to the construction of the River Quarter Development and the Landmark Building. As it can be seen from the results, also for the cumulative scenario, the roof terrace is well protected and in particular, in this scenario, the terrace is further shielded by the presence of the buildings mentioned above. It must be noted that also this analysis has been performed considering the worst case scenario conditions which considered the whole year. Terraces are not areas that are used all year around and long term sitting is an activity performed during spring/summer months. The wind roses collected for the seasonal effect have shown that critical speeds are not occurring in spring /summer months, when the frequency of such high wind is below 5%. In any case, there are not critical issues in regard to safety throughout the year.

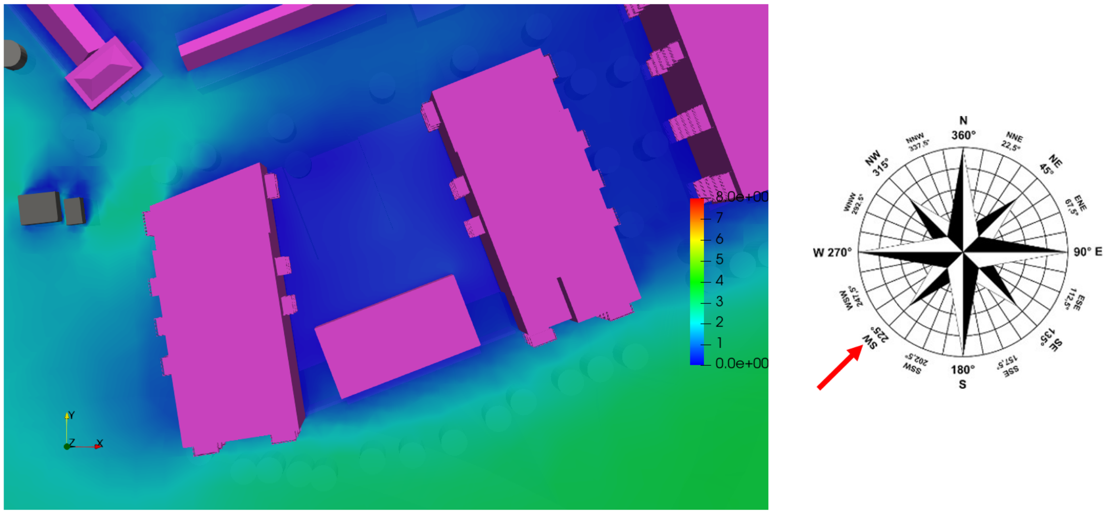


Figure 7.14: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 225° - Cumulative Impact Assessment

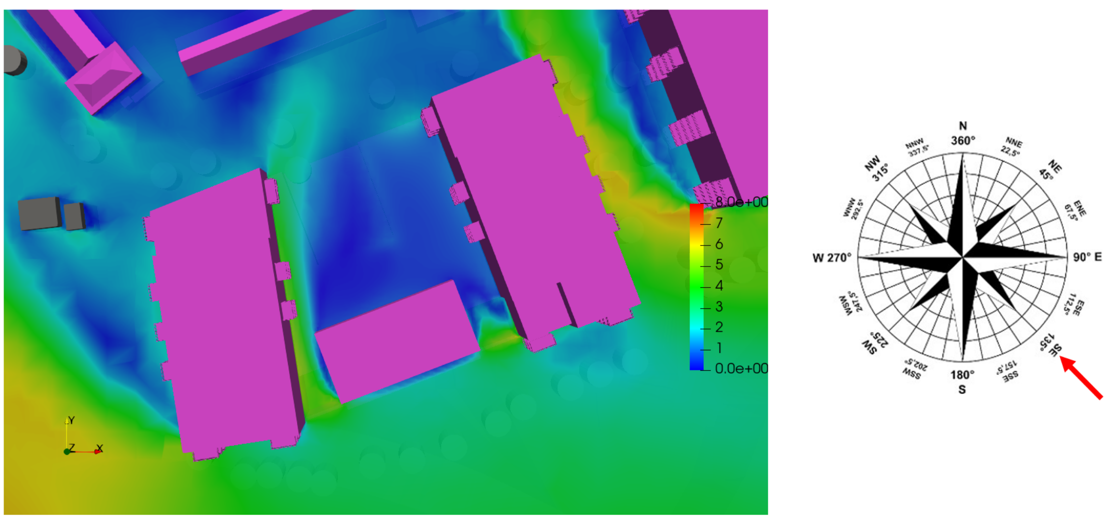


Figure 7.15: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 135° - Cumulative Impact Assessment

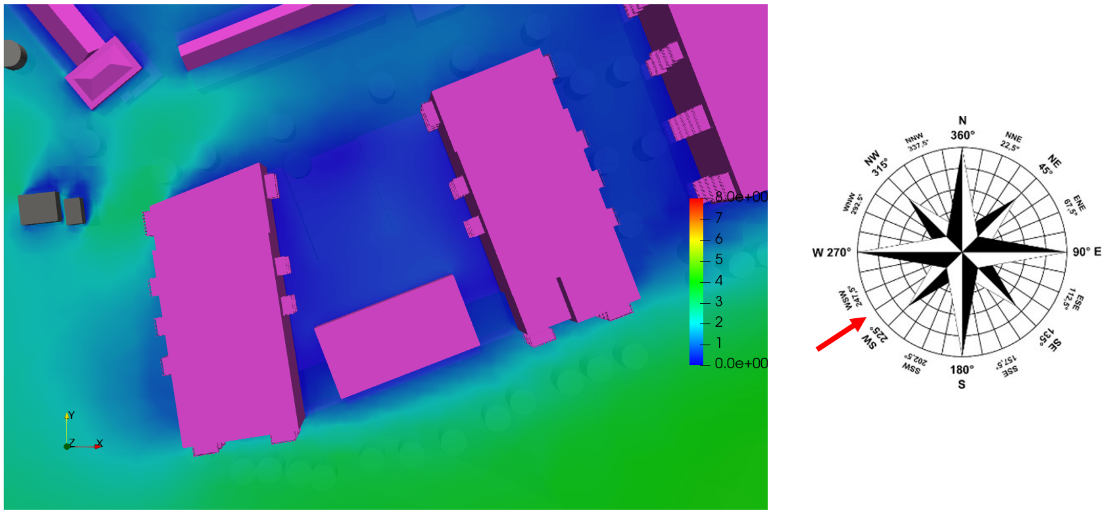


Figure 7.16: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 236° - Cumulative Impact Assessment

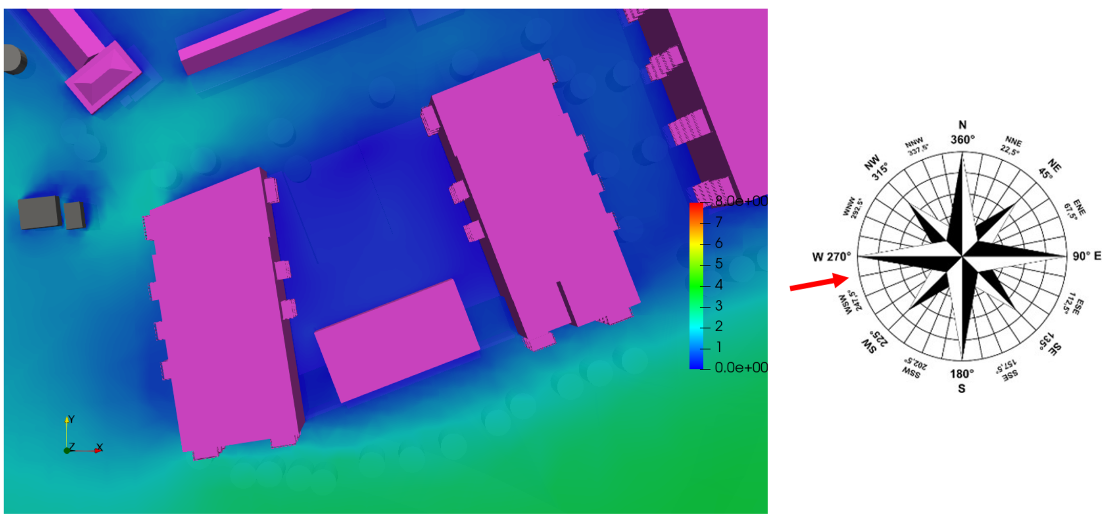


Figure 7.17: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 258° - Cumulative Impact Assessment

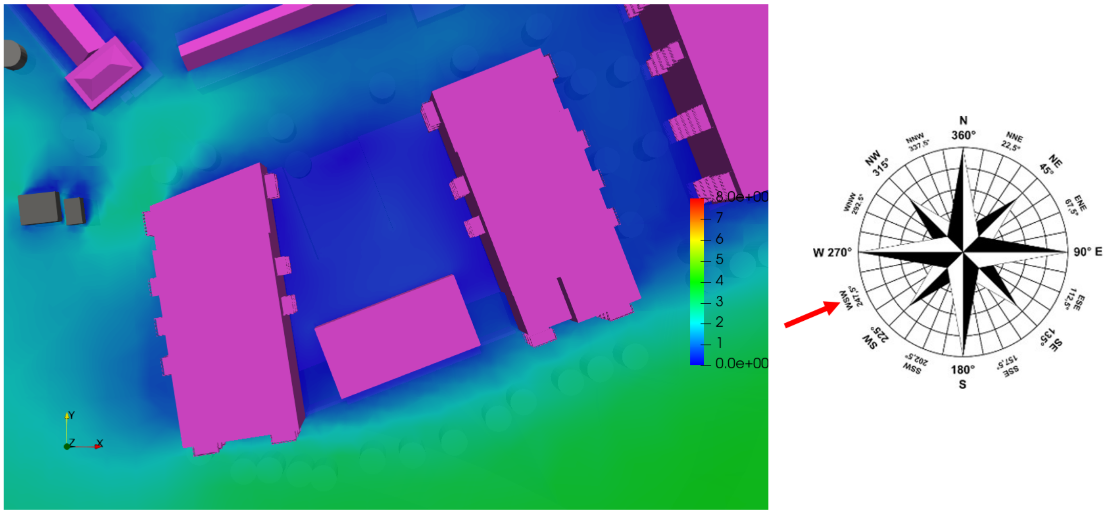


Figure 7.18: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 247° - Cumulative Impact Assessment

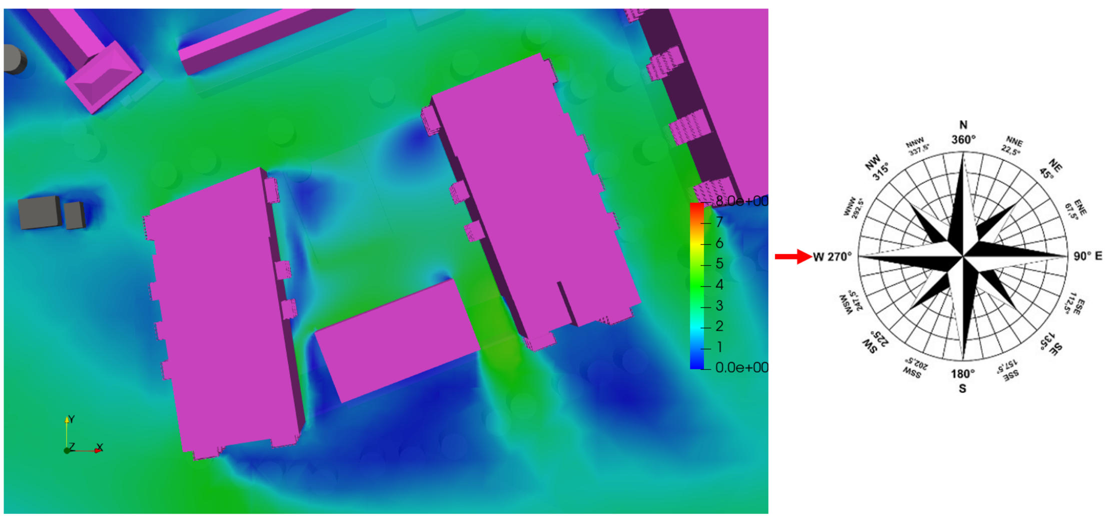


Figure 7.19: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 270° - Cumulative Impact Assessment

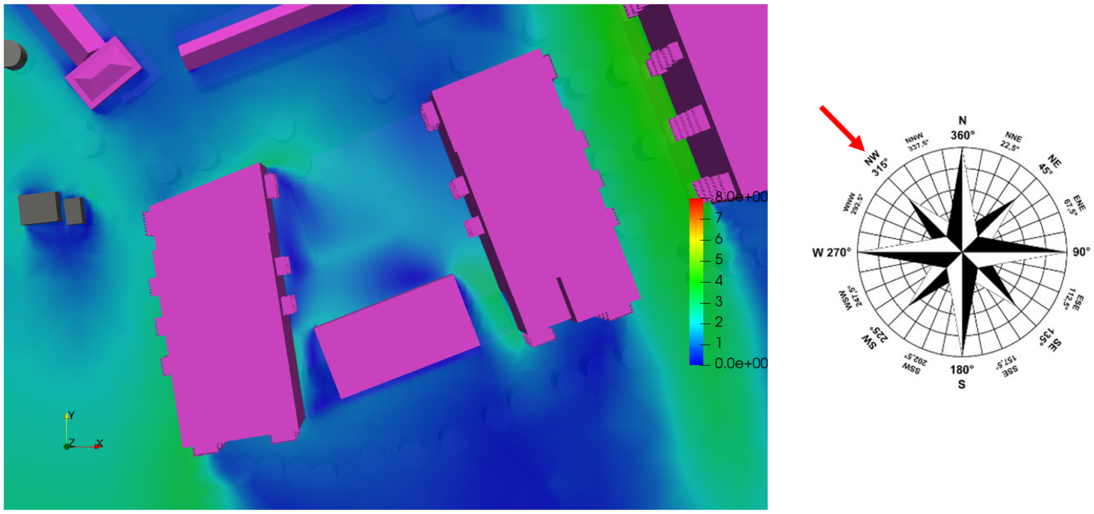


Figure 7.20: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 315° - Cumulative Impact Assessment

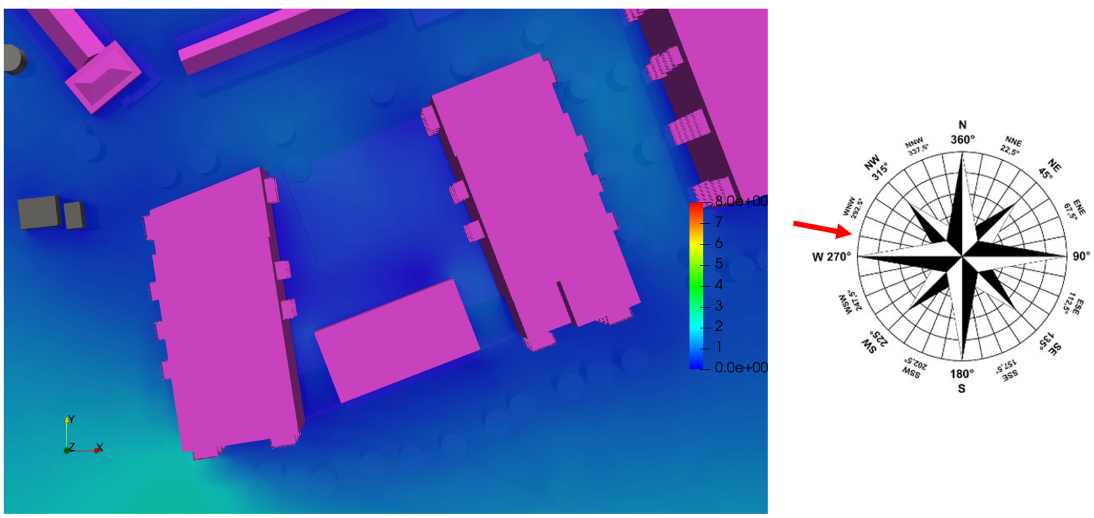


Figure 7.21: Roof Terrace Block C - Flow Velocity Results at Z=1.5m above the terrace - Wind Direction: 281° - Cumulative Impact Assessment

Comments on Cumulative Impact Results

The existing environment and proposed Coastal Quarter - Strategic Housing Development Development would receive prevailing winds from South-East. 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 (including developments that have been granted planning application and that have not been built yet) as the presence of adjacent buildings dictates how the wind will approach the proposed development.

From the wind modelling results, Coastal Quarter - Strategic Housing Development Development will introduce no negative wind effect on future developments within its vicinity which have been granted planning application. Wind modelling of future phases around this development will need to be performed for all future phase developments.

7.2 RISKS TO HUMAN HEALTH

This section aims to identify areas of Coastal Quarter - Strategic Housing Development 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.

Discomfort Criteria

Figure 7.28 show the Lawson comfort categories over the ground floor area of Coastal Quarter - Strategic Housing Development Development for the prevailing wind directions. The scale used is set out in Figure 7.22.

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 "unaccettable for pedestrian comfort".

At ground floor there are no critical area which are unacceptable for pedestrian comfort. The introduction of the Landmark building and the River Quarter buildings modifies the flow behaviour on the South and West sides of Block B. This can be seen when observing the Lawson map of the cumulative study in relation to the same map obtained for the development only Figure 7.25.

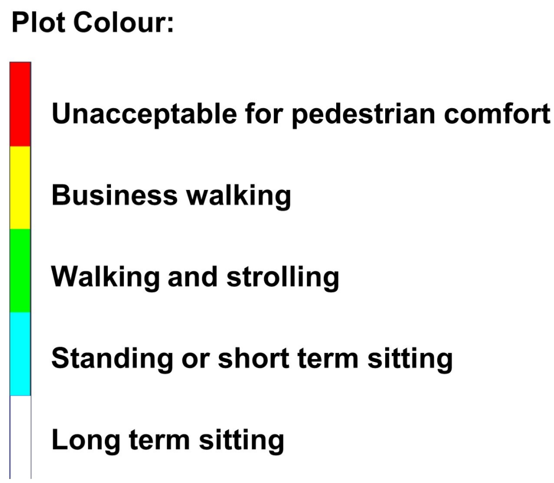


Figure 7.22: Lawson Comfort Categories

Figure 7.23: Ground Floor - Lawson Discomfort Map - Cumulative Impact

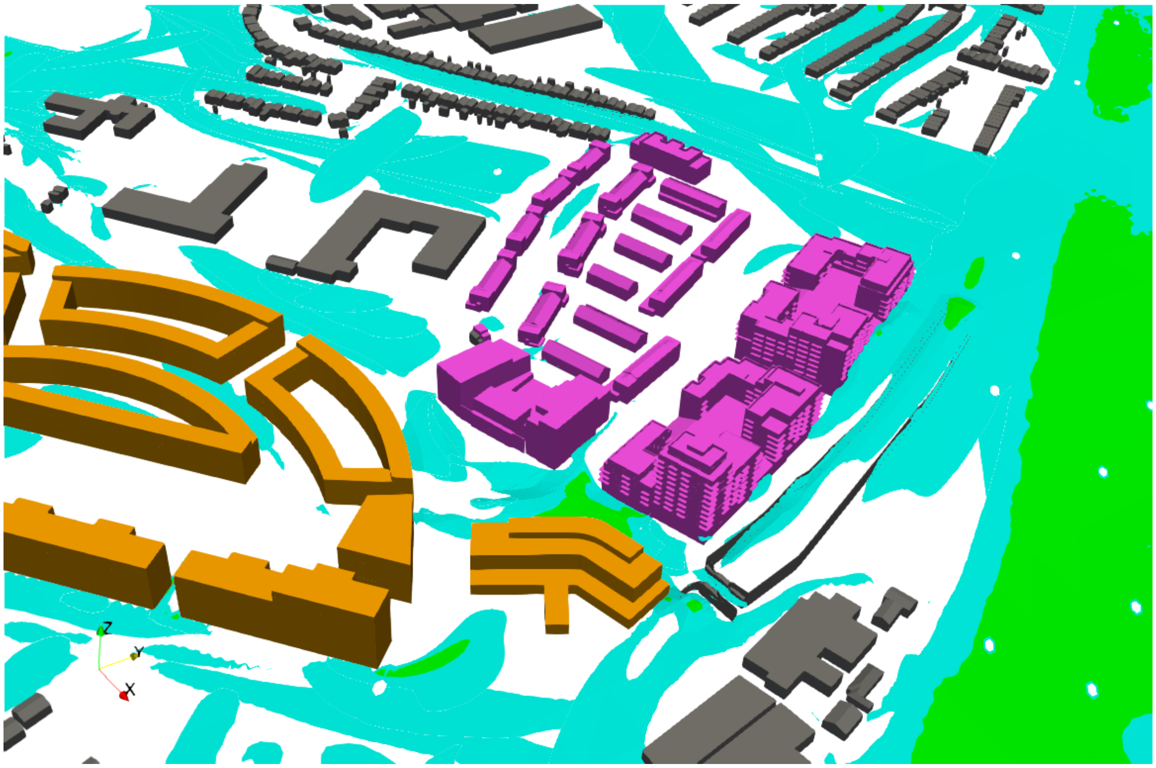
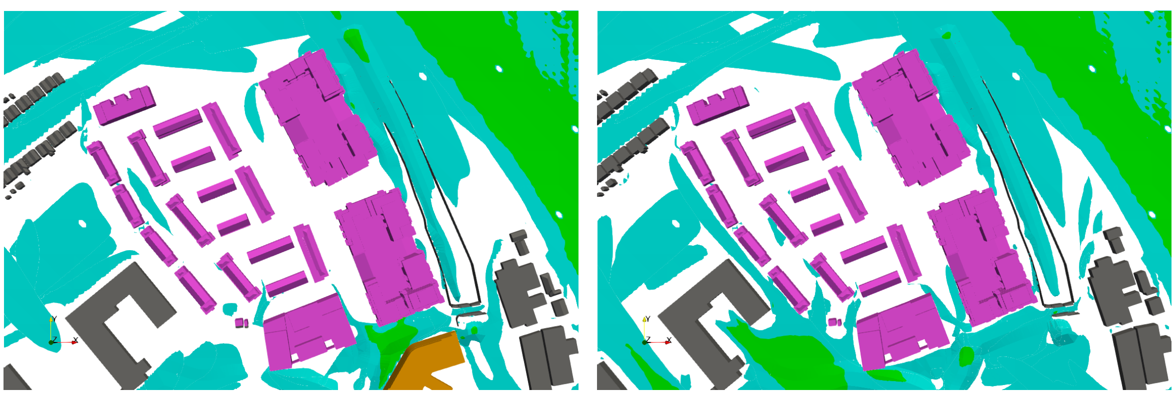


Figure 7.24: Ground Floor - Lawson Discomfort Map - Cumulative Impact



(a) with cumulative buildings

(b) without cumulative buildings

Figure 7.25: Ground Floor - Lawson Discomfort Map - Comparison between proposed development with and without Cumulative buildings

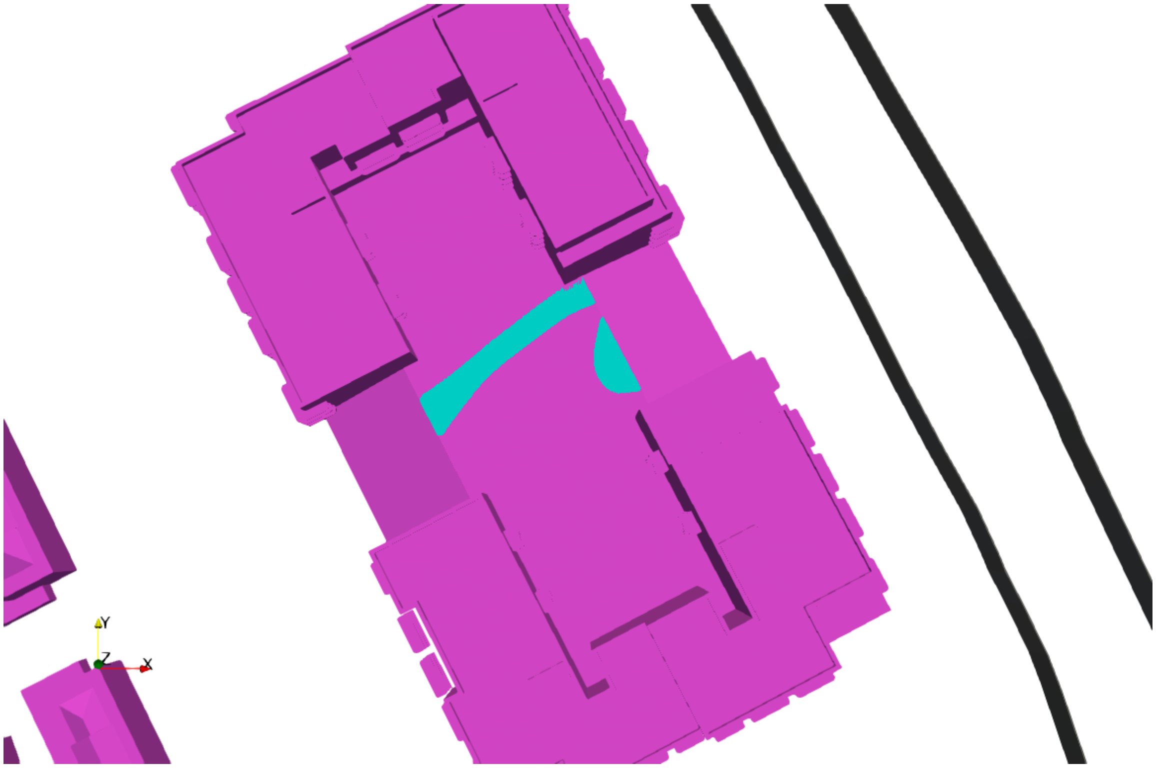


Figure 7.26: Courtyard Block A - Lawson Discomfort Map - Cumulative Impact

Figure 7.27: Courtyard Block B - Lawson Discomfort Map - Cumulative Impact

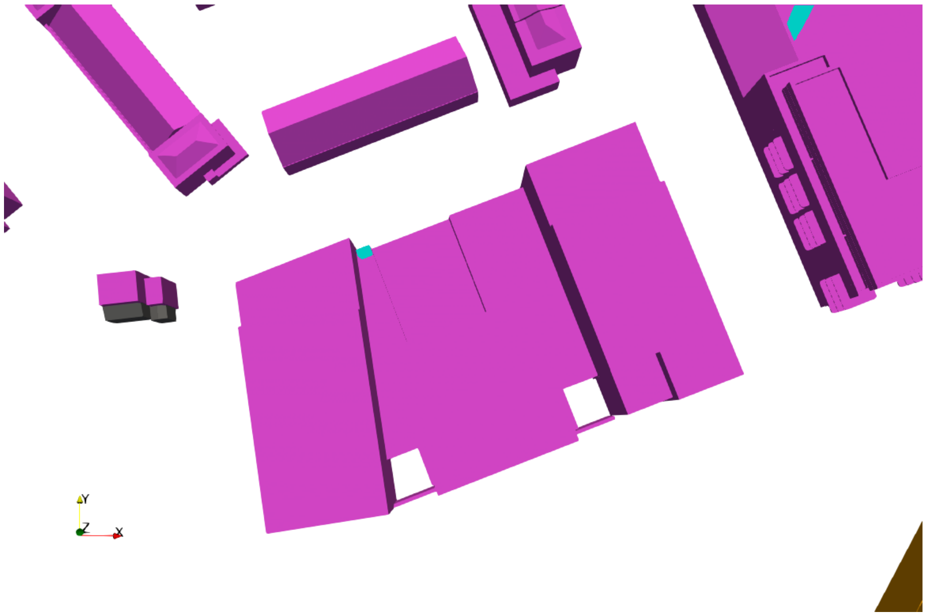


Figure 7.28: Courtyard and Roof terrace at Block C - Lawson Discomfort Map - Cumulative Impact

Summary of Cumulative Impact of the Proposed Development

From the simulation results the following observations are pointed out:

- The proposed Coastal Quarter - Strategic Housing Development will produce a quality environment that is attractive and comfortable for pedestrians at ground floor also when the Landmark building and the River Quarter buildings were introduced for the cumulative impact assessment.
- When the wider Masterplan is included in the analysis including the Landmark Building and River Quarter Blocks, the flow behaviour from the South-East direction is effected which impacts the road on the South side of Block B. This can be seen when observing the Lawson map of the cumulative study in relation to the same map obtained for the development only (Figure 7.25).
- In particular, the area on the South-West side of Block B in the cumulative assessment appears suitable for walking/strolling when previously it was suitable also for short term sitting. This effect is caused by the Landmark Building and the River Quarter Buildings, which now restrict the flow passage. In response to this and in the interest of maintaining the quality of the Market Square, sheltered seating areas have been created along the south elevation of Block C. As a result, these areas are suitable for short term sitting even when the cumulative impact of the wider Masterplan are considered.
- There was a minor funneling effect on the West side of Block B due to South-East wind, however this effect is mitigated after the introduction of the Landmark building and River Quarter buildings.

8. CONCLUSIONS

8.1 CONCLUSIONS AND COMMENTS ON CFD WIND STUDY

This report presented the Wind Microclimate Modelling study performed for Coastal Quarter - Strategic Housing Development Development in Bray, County Wicklow and County Dublin. This study has been carried out to identify the possible wind patterns around the area proposed, under mean and gust wind conditions typically occurring in Dublin, and also to assess impacts of the wind on pedestrian level comfort.

This study results have been utilized by the design team to configure the optimal layout for Coastal Quarter - Strategic Housing Development Development with 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.

A qualitative and quantitative summary of the wind microclimate modelling study performed for Coastal Quarter - Strategic Housing Development Development shows that:

- The wind profile around the existing environment was created using the annual average 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 and adapted to the location of this development.
- The prevailing wind directions for the site are identified as West, West-South-West and South-West, South-East with magnitude of approximately 6m/s.
- The proposed Coastal Quarter - Strategic Housing Development has been designed in order to produce a high-quality environment that is attractive and comfortable for pedestrians of all categories. To achieve this objective, throughout the design process, the impact of wind has been considered and analysed, in the areas where critical patterns were found, the appropriate mitigation measures were introduced.
- A number of iterations of this study have been carried out to optimize the design in order to achieve a high quality and well sheltered scheme.
- Although some minor flow velocity accelerations are still noticeable on the final scheme, on the road south side of Block B and adjacent to Block C, as well as the area between Block A and the adjacent rail structure, the highlighted accelerations are well kept below the threshold limit; indeed the Lawson map (which is the map commonly adopted in wind microclimate studies to relate the wind conditions with the suitable pedestrian activities) indicates that this road can be utilised for the intended use (i.e. for those activities which include any type of walking and also short term sitting).
- Courtyards of Block A,B and C are well protected, a small area in the middle of both courtyards of Block A and B is suitable for short term sitting instead of long term-sitting due to minor re-circulation effects. These conditions are not occurring at a frequency that would compromise the pedestrian comfort, according to the Lawson Criteria.
- The analysis carried out on the roof terrace on Block C shows that the area is well protected by a combination of glazed screen and parapet wall and long term sitting is

achieved for the majority of the year.

- Regarding the balconies, higher velocities have been identified on a number of the balconies which is to be expected in a coastal location. However, these velocities are below the threshold values defined by the acceptance criteria and therefore are not critical for safety. On occasions when the private balconies may not be suitable for short term sitting, residents can use internal courtyard or communal amenity spaces.

- Tree planting all around the development has been utilised, with particular attention to the corners of the buildings and the courtyard and this has positively mitigated any critical wind effects. Thus, it can be concluded that at ground floor good shielding is achieved everywhere.

- The proposed development does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings, Corke Abbey houses and the Ravenswell Schools complex. In particular, the development is acting as a shield to the Corke Abbey houses and the Ravenswell Schools complex from any winds coming from the East direction, while it does not have any impact on the wind coming from the South or West direction.

- Moreover, in terms of distress, no critical conditions were found for ”Frail persons or cyclists” and for members of the ”General Public” in the surrounding of the development, including the Corke Abbey houses and the Ravenswell Schools complex.

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