

WIND MICROCLIMATE ANALYSIS

Galway Port LRD

Galway City

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

For: The Land Development Agency



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1. EXECUTIVE SUMMARY

B-Fluid Limited has been commissioned to perform a Wind Microclimate Study for the Proposed Galway Port LRD in Galway Port, Galway. This report is prepared on behalf of the The Land Development Agency.

Figure 1.1 shows a view of the proposed development (coloured) within the existing urban context.

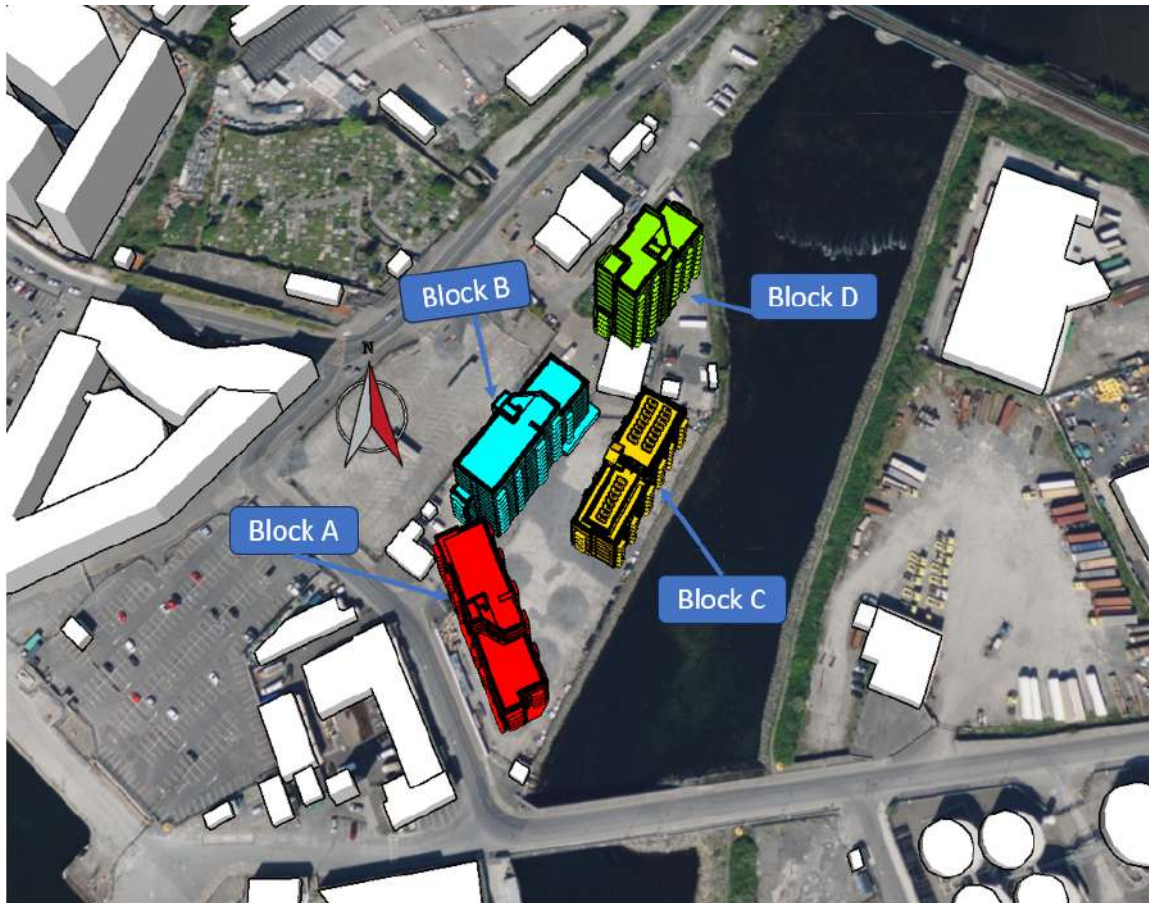


Figure 1.1: Proposed Galway Port LRD

The method for the study of wind microclimate combines the use of Computational Fluid Dynamics (CFD) to predict wind velocities and wind flow patterns, with the use of wind data from a suitable meteorological station and the recommended comfort and safety standards (Lawson Criteria).

The effect of the geometry, height and massing of the proposed development, existing surroundings, and cumulative buildings, including topography, ground roughness and landscaping of the site, on local wind speed and direction is considered as well as the pedestrian activity to be expected (sitting, standing, strolling and fast walking).

The results of the assessment are presented in the form of contours of the Lawson criteria at pedestrian/occupant level for each amenity area (including balconies and communal open space).

The assessment has comprised the following scenarios:

- **Baseline Existing Scenario:** this consists of the existing wind microclimate at the site without the proposed development. Figure 1.2 shows a view of the existing surrounding buildings (in white).



Figure 1.2: Buildings in the Baseline Scenario (Existing buildings in white)

- **Proposed Development Scenario:** this consists of the assessment of the wind microclimate of the site with the proposed development surrounded by existing buildings. Figure 1.3 shows a view of the buildings in the proposed development (coloured) and existing surrounding buildings (in white).



Figure 1.3: Buildings in the Proposed Scenario (Galway Port LRD-coloured and existing buildings- in white)

- **Cumulative Scenario:** this consists of the assessment of the wind microclimate of the site with the proposed development, surrounded by existing buildings as well as potential buildings that are envisioned as part of the Galway Harbour Company Masterplan and will be subject to future planning application. This detailed wind analysis, conducted with the presence of existing and potential future buildings, provides crucial insights into the current conditions that could affect the immediate surroundings of the area. Figure 1.4 shows a view of the buildings in the proposed development (in red), existing surrounding buildings (in white), and cumulative buildings that may be built in the future (in orange).



Figure 1.4: Buildings in the Cumulative Scenario (Galway Port LRD in red, existing buildings in white, cumulative buildings in orange (potential buildings that are envisioned as part of the Galway Harbour Company Masterplan))

Based on the analysis conducted, it can be concluded that:

- The wind profile was built using the annual average of meteorology data collected at Galway Airport purchased from Open Weather. The local wind speed was determined from CFD simulations with combination of the parameters inside Weibull probability distribution function, which was obtained from historical meteorological data recorded 10m above ground level at Galway Airport.
- A 12-discrete set of wind directions is used to evaluate the probability of exceedance at any given threshold speed. It was found that the prevailing wind directions in the west and south-west make the most significant contribution to the probability of discomfort exceedance.
- Microclimate Assessment of Galway Port LRD and its environment was performed utilizing a CFD (Computational Fluid Dynamics) methodology.
- The evaluation of the proposed scenario indicates that the planned development aligns with the Lawson Comfort Criteria, confirming that no areas are unsafe and the proposed development does not create conditions of distress. All the ground amenities outlined in the report can be utilized according to their intended scope.

-
- The Lawson Comfort and Distress Map on 1.5m above balcony floor indicates that all balconies are safe for occupants with no identified distress areas.
 - The following mitigation measures will be implemented to further improve pedestrian comfort around the development:
 - *Introducing additional trees on ground amenities of the development:*
These additional plants will help reduce wind speed, increasing comfort levels in all ground amenities of the development.
 - As a result of the proposed development construction, the wind on the surrounding urban context remains suitable for the intended use when compared with the baseline situation.
 - The proposed development does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings. 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.
 - As a result of the construction of cumulative buildings in the future, the wind conditions on the surrounding urban context remains the same when compared with the proposed development situation. The cumulative buildings will have a negligible effect on the surrounding wind microclimate.

Therefore, the CFD study carried out has shown that under the assumed wind conditions typically occurring within Galway for the past 16 years:

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

2. INTRODUCTION

B-Fluid Limited has been commissioned ‘The Land Development Agency’ to perform a Wind Microclimate Study for the Galway Port LRD in Galway Port, Galway.

Figure 2.1 shows a view of the existing surrounding buildings (in white). Figure 2.2 shows a view of the proposed development within the existing urban context. Figure 2.3 shows buildings within the cumulative scenario which include the buildings in the proposed development, existing surrounding buildings, and the buildings that are not yet built (colored in orange).



Figure 2.1: Baseline Galway Port LRD



Figure 2.2: Proposed Galway Port LRD



Figure 2.3: Galway Port LRD (colored in red) and Future Masterplan Development (colored in orange)

This report is completed by Dr. Cristina Paduano, Dr. Sadia Siddiqi and Dr. Arman Safdari.

Dr. Cristina Paduano is a Chartered Engineer (CEng) and member of Engineers Ireland who specialises in computational fluid dynamics applications for urban environment and the construction industry with over 18 years experience. She holds a PhD in Mechanical Engineering from Trinity College Dublin, with M.Eng and B.Eng in Aerospace Engineering.

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

A wind microclimate study considers the possible wind patterns formed under both mean and peak wind conditions typically occurring on the site area, accounting for a scenario where the proposed development is inserted in the existing environment (potential impact) and, for a scenario where the proposed development is analyzed together with the existing environment and any potential development (that may be built in the future not constructed yet) that can be influenced by the wind patterns generated by the proposed one (cumulative impact).

The potential receptors include those areas, in the surrounding of the development, which can be exposed to potential risks generated by the elevated wind speed or building massing wind effects. In particular:

- Amenity areas (pedestrian level), areas likely to be utilised for leisure purposes and as such should be comfortable surroundings.
- Pedestrian routes and seating areas – to determine if locations are comfortable for leisure activities.
- Entrance to the buildings – to determine if there is potential for pressure related issues for entrances or lobbies.
- Landscaped areas – where there are sheltered areas.
- Impact to existing or adjoining developments – where the proposed buildings will cause discomfort conditions through proximity related issues.

The acceptance criteria which define the acceptable wind velocities in relation to the perception of comfort level experienced while carrying out a specific pedestrian activity is known as the “Lawson Criteria for Pedestrian Comfort and Distress”. A wind microclimate study analyzes the wind flow in an urban context (considering the wind conditions typically occurring on the site during a typical year) to develop the so called “Lawson Comfort and Distress Map”; the map identifies where a specific pedestrian activity can be carried out comfortably during most of the time.

The assessment can be performed by physical testing in wind tunnels or by performing “virtual wind tunnel testing” through numerical simulation using Computational Fluid Dynamics (CFD), as done for this project. The scope of the numerical study is to simulate the wind around the development, in order to predict the wind speeds the pedestrians will be exposed to and the level of comfort they will experience when carrying out a specific activity (i.e. walking, strolling, sitting).

The following sections details the methodology, acceptance criteria, CFD wind simulations and the impact of the proposed development on the local wind microclimate against best practice guidelines for pedestrian comfort and safety.

2.1 GUIDANCE and LEGISLATION

According to the ‘Urban Development and Building Heights, Guidelines for Planning Authorities (Government of Ireland, December 2020)’ document, specific wind impact assessment of the microclimatic 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’.

The recommended approach to wind microclimate studies is outlined in the “Wind Microclimate Guidelines for Developments in the City of London ‘(August 2019) and in the guidelines and recommendations contained in BRE Digest (DG) 520, “Wind Microclimate Around Buildings” (BRE, 2011). The Lawson Criteria of Comfort and Distress is used to benchmark the pedestrian wind microclimate.

The document also indicates how to use Computational fluid dynamics (CFD) to assess wind microclimate conditions and how to generate high quality outputs to provide a good understanding of the fundamental flow features around an urban context.

Usually, the recommended approach to wind microclimate studies is based on the building height, as presented in Figure 2.4.

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 Fluid Dynamics (CFD) Simulations OR Wind Tunnel Testing
Up to 4 times the average height of surrounding buildings 50m to 100m	Computational Fluid Dynamics (CFD) Simulations AND Wind Tunnel Testing
High Rise Above 100m	Early-Stage Massing Optimization: Wind Tunnel Testing OR Computational Fluid Dynamics (CFD) Simulations Detailed Design: Wind Tunnel Testing AND Computational Fluid Dynamics (CFD) Simulations

Figure 2.4: 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)

2.2 URBAN WIND EFFECTS

Buildings and topography affect the speed and direction of wind flows. Wind speed increases with increasing height above the ground, assuming a parabolic profile.

Flow near the ground level encounters obstacles represented by terrain roughness/buildings 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 wind velocity profile is given by a fluctuating velocity along a mean velocity value. Figure 2.5 shows the wind velocity profile, as described above.

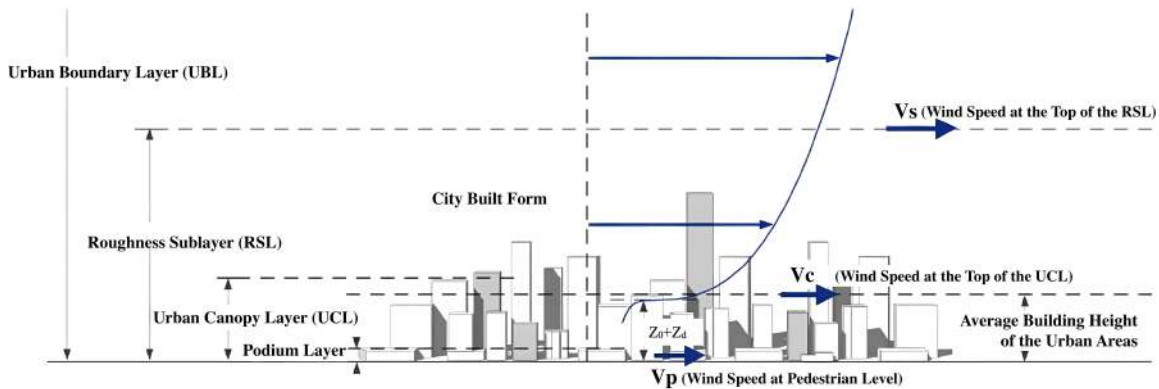


Figure 2.5: Wind Velocity Profile

In an urban context, wind speeds at pedestrian level are generally low compared with upper-level wind speeds, however, the wind can create adverse patterns when flowing in between buildings which can cause local wind accelerations or re-circulations. This wind patterns effect pedestrian safety and comfort. In general, the wind effects to be avoided/mitigated in an urban context include the following:

- **Funnelling Effects:** The wind can accelerate significantly when flowing through a narrow passage between building structures. The highest speeds are experienced at the point where the restriction of the area is the greatest.
- **Downwash Effects:** The air stream when striking a tall building can flow around it, over it and a part can be deflected towards the ground. This downward component is called downwash effect and its intensity depends on the pressure difference driving the wind. The higher the building, the higher this pressure difference can be.
- **Corner Effects:** Wind can accelerate around the corners of the buildings. Pedestrians can experience higher wind speeds as well as more sudden changes in wind speeds. The reason for this is that there are narrow transition zones between the accelerated flows and the adjacent quiescent regions. This effect is linked to the downwash effect as the downward stream component subsequently flows around the corners towards the leeward side of the building.

- **Wake Effect:** Excessive turbulence can occur in the leeward side of the building. This can cause sudden changes in wind velocity and can raise dust or lead to accumulation of debris. This effect is also dependent on the height of the building.

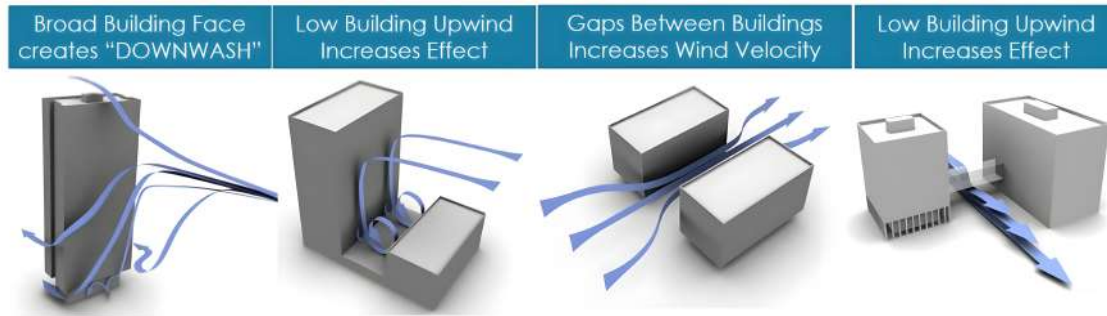


Figure 2.6: Parameters to know for Wind Conditions Assessment

The anticipation of the likely wind conditions resulting from new developments are important considerations in the context of pedestrian comfort and the safe use of the public realm. While it is not always practical to design out all the risks associated with the wind environment, it is possible to provide local mitigation to minimise risk or discomfort where required.

3. ASSESSMENT METHODOLOGY

3.1 METHOD OF ASSESSMENT

The method for the study of wind microclimate combines the use of Computational Fluid Dynamics (CFD) to predict wind velocities and wind flow patterns, with the use of wind data from suitable meteorological station and the recommended comfort and safety standards (Lawson Criteria). The effect of the geometry, height and massing of the proposed development and existing surroundings including topography, ground roughness and landscaping of the site, on local wind speed and direction is considered as well as the pedestrian activity to be expected (sitting, standing, strolling and fast walking). The results of the assessment are presented in the form of contours of the Lawson criteria at pedestrian level.

The assessment has comprised the following scenarios:

- **Baseline Existing Scenario:** this consists of the existing wind microclimate at the site without the proposed development.
- **Proposed Development in the Existing Scenario:** this consists of the assessment of the wind microclimate of the site with the proposed development surrounded by existing buildings.
- **Cumulative Scenario:** this consists of the assessment of the wind microclimate of the site with the proposed development, surrounded by existing buildings as well as buildings that may be built in the future, as envisaged in the Masterplan prepared by Galway Harbour Company.

In accordance with the guideline cited in section 2.1, the wind microclimate study should consider the effect of the proposed development together with buildings (existing and/or potential future developments) that are within 700 m from the centre of the site, as shown in Figures 3.1 and 3.2. 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.

In particular, the following has been undertaken:

- Topography of the site with buildings (proposed and adjacent existing or potential future developments massing, depending on the scenario assessed “baseline or proposed or cumulative”) have been modelled using OpenFOAM Software.
- Suitable wind conditions have been determined based on historic wind data. Criteria and selected wind scenarios included means and peaks wind conditions that need to be assessed in relation to the Lawson Criteria.
- Computational Fluid Dynamics (CFD) has been used to simulate the local wind environment for the required scenarios (“baseline, proposed, cumulative”).
- The impact of the proposed development massing on the local wind environment has been determined (showing the wind flows obtained at pedestrian level).
- Potential receptors (pedestrian areas) have been assessed through review of external amenity/public areas (generating the Lawson Comfort and Distress Map).
- Potential mitigation strategies for any building related discomfort conditions (where

necessary) have been explored and their effect introduced in the CFD model produced.



Figure 3.1: Area of interest to be modelled - **Top View**



Figure 3.2: Area of interest to be modelled - **3D View**

3.2 ACCEPTANCE 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 to be exceeded more than 0.023% per 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 or larger speed to be exceeded more than 0.023% per year, when aerodynamic forces approach body weight makes it impossible for anyone to remain standing. If 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 3.3. 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. 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 3.3: Lawson 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.

Pedestrian comfort criteria are assessed at 1.5m above ground level. Unless in extremely unusual circumstances, velocities at pedestrian level increase as you go higher from ground level.

A breach of the distress criteria requires a consideration of:

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

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

Pedestrian Comfort Category (Lawson Scale)	Mean and Gem wind speed not to be exceeded more than 5% of the time	Description
Sitting	4m/s	Acceptable for frequent outdoor sitting use, i.e., restaurant /café
Standing	6m/s	Acceptable for occasional outdoor sitting use, i.e., public outdoor spaces
Walking/Strolling	8m/s	Acceptable for entrances/bus stops /covered walkaways
Business Walking	10m/s	Acceptable for external pavements, walkways
Unacceptable/Distress	>10m/s	Start of not comfortable/distress level for pedestrian access

Figure 3.4: Lawson Categories Scale - Comfort

Pedestrian Safety Category (Lawson Scale)	Mean and Gem wind speed not to be exceeded more than 0.0022% of the time	Description
Unsafe for public	>20m/s	Distress/safety concern for pedestrian
Unsafe for cyclists or frail person	>15m/s	Distress/safety concern for cyclist/frail person

Figure 3.5: Lawson Categories Scale - Distress/Safety

3.3 SIGNIFICANCE CRITERIA

The significance of on-site measurement locations are defined by comparing the wind comfort/safety levels with the intended pedestrian activity at each location, using the table provided by the Lawson Comfort and Distress Criteria.

The significance of off-site measurement locations are defined by comparing the wind comfort/safety levels with the intended pedestrian activity at each location, prior and after the introduction of the proposed development.

Significance	Trigger	Mitigation required?
Major Adverse	Conditions are “unsafe”	Yes
Moderate Adverse	Conditions are “unsuitable” (in terms of comfort) for the intended pedestrian use.	Yes
Negligible	Conditions are “suitable” for the intended pedestrian use.	No
Moderate Beneficial	Conditions are calmer than required for the intended pedestrian use (by at least one comfort category).	No

Figure 3.6: Significance Criteria for On-site Receptors

Significance	Trigger	Mitigation required?
Major Adverse	<p>Conditions that were “safe” in the baseline scenario became “unsafe” as a result of the Proposed Development.</p> <p><i>OR</i></p> <p>Conditions that were “suitable” in terms of comfort in the baseline scenario became “unsuitable” because of the Proposed Development.</p> <p><i>OR</i></p> <p>Conditions that were “unsafe” in the baseline scenario are made worse because of the Proposed Development.</p>	Yes
Moderate Adverse	Conditions that were “suitable” in terms of comfort in the baseline scenario are made windier (by at least one comfort category) as a result of the Proposed Development but remain “suitable” for the intended pedestrian activity.	No
Negligible	Conditions remain the same as in the baseline scenario.	No
Major Beneficial	Conditions that were “unsafe” in the baseline scenario became “safe” because of the Proposed Development.	No
Moderate Beneficial Potential Receptors	<p>Conditions that were “unsuitable” in terms of comfort in the baseline scenario became “suitable” because of the Proposed Development.</p> <p><i>OR</i></p> <p>Conditions that were “unsafe” in the baseline scenario are made better as a result of the Proposed Development (but not so as to make them “safe”).</p>	No

Figure 3.7: Significance Criteria for Off-site Receptors

4. CFD MODELLING METHOD

4.1 INTRODUCTION OF CFD TECHNIQUE

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.

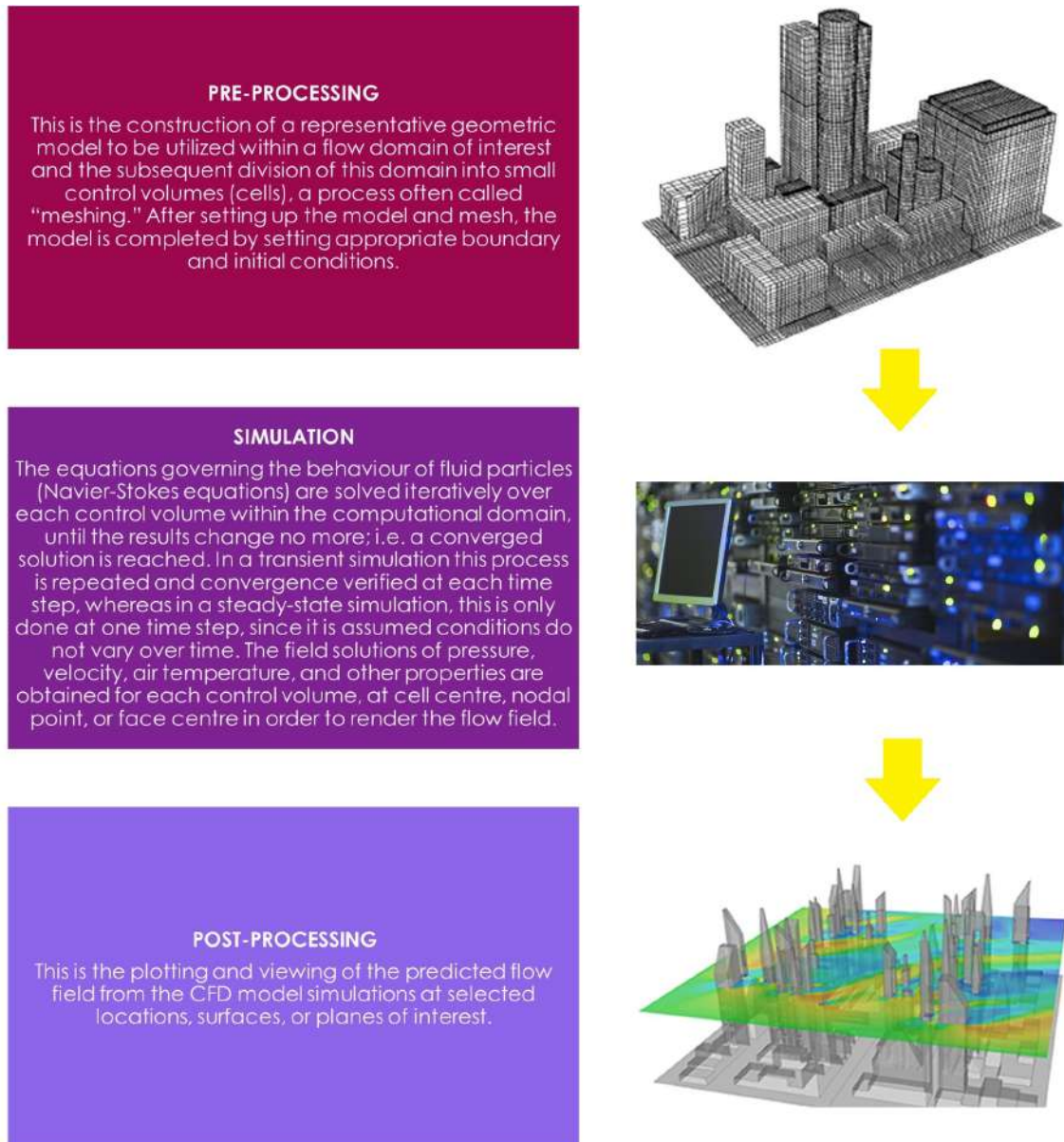


Figure 4.1: CFD Modelling Process Explanation

4.2 CFD SOFTWARE DETAILS

This report employs OpenFOAM Code, based on the concept of Reynolds-Averaged Navier-Stokes (RANS) formulations and the post-processing visualisation tool ParaView. OpenFOAM is a CFD software 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 has an extensive range of features to solve anything from complex fluid flows involving chemical reactions, turbulence and heat transfer, to acoustics, solid mechanics and electromagnetics.

4.3 CFD MODEL DETAILS

FLOW ASSUMPTIONS & TURBULENCE MODELLING

In this study, the air flow is assumed to be incompressible, Newtonian, and statistically steady with temperature and gravity effects neglected. The flow is governed by the Reynolds-Averaged Navier-Stokes (RANS) formulation for mass and momentum where the turbulence is modeled using the $k-\omega$ SST turbulence model.

MODELED GEOMETRIES

The extent of the built area (e.g. buildings, structures or topography) that is represented in the numerical domain depends on the influence of the features on the region of interest. According to the Best Practice Guideline (COST Action 732), a building with height H (height of the tallest proposed building is ≈ 22 m) may have a minimal influence if its distance from the region of interest is greater than $6-10H$ (we considered 600 m which is even larger than required).

The modelled layout and dimensions of the surrounding environment are outlined in the table below (Table 4.1).

Table 4.1: Modelled Environment Dimensions

	MODELLED CFD ENVIRONMENT DIMENSIONS		
	Width	Length	Height
Computational Domain	1200 m	1200 m	160 m

A 3D view of the proposed development massing model in the domain is presented in Figure 4.2. Geometries used in this study include two parts:

- The massing model of the proposed Galway Port LRD, which is generated based on drawings provided by the The Land Development Agency;
- The massing model of the building blocks within 700 m from the development (colored in white).



Figure 4.2: 3D View of the Massing Models of the Proposed Galway Port LRD (colored) and Surrounding Building Blocks (in white)

COMPUTATIONAL MESH

The computational mesh used in this report is created using OpenFOAM utilities blockMesh and snappyHexMesh. It is a hybrid mesh containing a structured background grid and an unstructured hexahedron-dominated mesh in the near-wall region. The largest cell has a depth of 5 m, where the smallest has a depth of 0.15 m. The total cell count is approx. 120 million. An isometric view of the geometry captured by the computational mesh is shown in Figure 4.3.

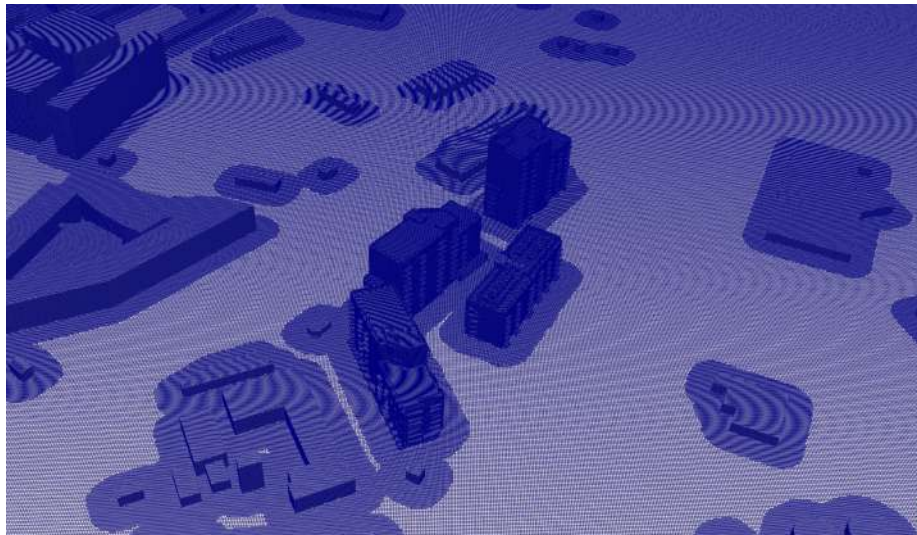


Figure 4.3: Computational Mesh of Galway Port LRD

BOUNDARY CONDITIONS

For each wind directions, an initial wind velocity was set based on logarithmic wind profile. Surfaces within the model were specified as having ‘no slip’ condition. This boundary 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”.

ATMOSPHERIC BOUNDARY LAYER

The atmospheric boundary layer is the lowest part of the atmosphere, extending from the earth’s surface to a height of approximately 1-2 km, where the wind speed and direction are influenced by the terrain and surface roughness. Eurocode 1: 2005 provides guidelines for determining the wind profile in the atmospheric boundary layer, using the following equation:

$$u_{(z)} = \frac{u^*}{K} \cdot \ln\left(\frac{z+z_0}{z_0}\right) \quad (4.1)$$

where:

- $u_{(z)}$ = wind speed measured at the reference height z
- z = reference height to measure $u_{(z)}$
- z_0 = roughness length selected
- u^* = friction velocity
- K = Karman constant

The roughness value, as recommended by the Eurocode standard (Table 4.2), is used to determine the atmospheric wind profiles.

Category	Description	z_0
0	Coastal regions	0.003
I	Flat terrain with minimal obstacles	0.01
II	Open terrain	0.05
III	Suburban area	0.3
IV	Urban area	1

Table 4.2: Eurocode Standard: Roughness Height Parameters by Terrain Category

Figure 4.4 shows the atmospheric boundary layer profile, highlighting the difference in wind profiles between open terrain and urban areas. The open terrain wind profile ($z_0 = 0.05$) is steeper than the urban wind profile ($z_0 = 1$), resulting in a faster increase in wind speed with height. However, when wind approaches from an open terrain area to an urban area, the wind speed decreases due to the “exposure correction factor”. This factor scales down the velocity profile, with a correction factor of 1 for open terrain and 0.7 for urban areas.

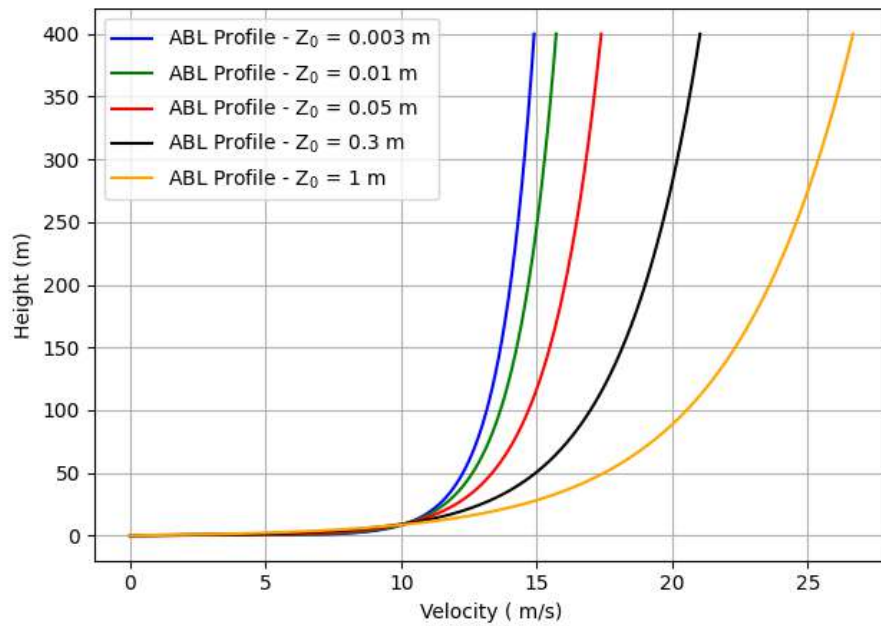


Figure 4.4: Atmospheric Wind Profiles Corresponding to a 10 m/s Wind Speed Reference

NUMERICAL CONFIGURATIONS

In this study, all simulations employ the SIMPLE algorithm to perform the pressure–velocity coupling (simpleFoam solver in OpenFOAM). All terms in the RANS equations are discretized using the nominally second-order cell-centred finite volume method, where gradient and Laplacian terms are discretized using Gaussian integration with linear interpolation. Convection/advection terms are discretized using a second-order accurate linear-upwind scheme.

PARALLEL CONFIGURATIONS

The computational mesh was decomposed using the SCOTCH algorithm. All simulations in this study are performed in parallel on an in-house HPC cluster. Key parameters of the CFD model used in this wind microclimate study are summarised in Table 4.3.

Table 4.3: Key parameters of the CFD model for each wind scenario

KEY PARAMETERS OF THE CFD MODEL	
Air Density (ρ)	1.2 kg/m ³
Turbulence Model	k- ω SST Model
Cell Size	Approx. 0.15 m at the development Approx. 0.3 m in the surroundings 5 m elsewhere
Total Cell Count	Approx. 120 million

5. LOCAL WIND CLIMATE

5.1 THE EXISTING RECEIVING ENVIRONMENT

In this chapter, wind impact has been assessed on the existing receiving environment considered as the existing buildings and the topography of the site prior of the construction of the proposed development. A statistical analysis of 16 years historical weather wind data has been carried out to assess the most critical wind speeds, directions and frequency of occurrence of the same. The aim of this assessment has been to identify if comfort and safety of pedestrian/occupants are inline with the criteria outlined by Lawson for each specific wind condition and human activity carried out.

5.1.1 SITE LOCATION AND SURROUNDING AREA

The Proposed Galway Port LRD will be situated in Galway Port, Galway. The existing environment is shown in Figure 5.1. The area considered for the existing environment and proposed development assessment comprises an Approx. 1.54 km² area around the Proposed Galway Port LRD as represented in Figure 5.2.



Figure 5.1: Galway Port LRD Site Location and Existing Environment



Figure 5.2: Extents of Analyzed Existing Environment Around the Proposed Galway Port LRD

5.1.2 TOPOGRAPHY AND BUILT IN ENVIRONMENT

Figure 5.3 shows an aerial photograph of the terrain surrounding the construction site at the Proposed Galway Port LRD. The Proposed Galway Port LRD Site is located in Galway City. The area surrounding the site can be characterized as an urban environment.

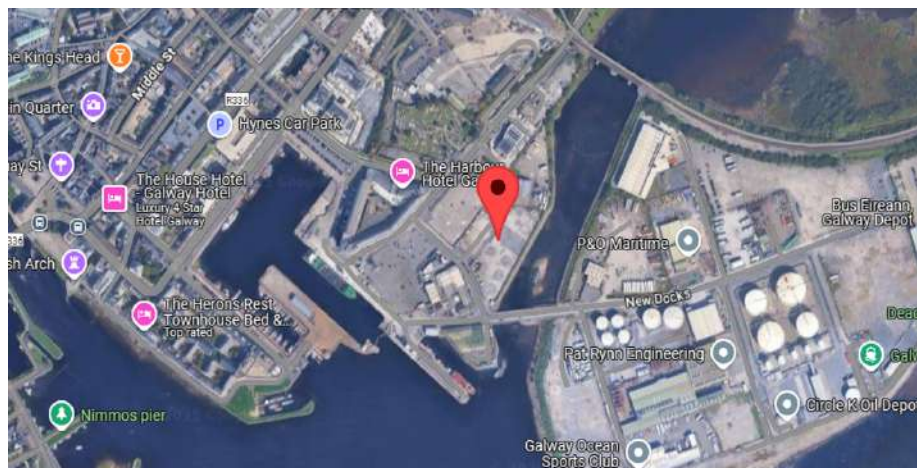


Figure 5.3: Built-in Environment Around Construction Site at the Proposed Galway Port LRD

5.2 LOCAL WIND CONDITIONS

This analysis considers 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 Galway Airport Weather Station. Figure 5.4 shows on the map, the position of the Proposed Galway Port LRD and the position of Galway Airport.

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

- *Terrain:* The meteorological station is located on the flat, open terrain of the airport, while the development site is situated on flat terrain surrounded by residential buildings of around 10 meters in average height.
- *Wind Directions:* The landscape around the development site can, in principle, be characterized as Terrain Category II according to Eurocode 2005. 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 Galway Airport are applicable for the assessment of the wind comfort at the development site.



Figure 5.4: Map showing the position of the Proposed Galway Port LRD and Galway Airport

The assessment of the wind comfort conditions at the new development will be based on a discrete set of wind data throughout a year (annual wind statistic) provided by Open Weather for Galway Airport meteorological wind station. In this study, a 12-discrete set of wind directions is utilized to evaluate the probability of exceedance at any given threshold speed. A Weibull probability distribution is employed to transform the provided wind data into a continuous distribution for each wind direction. From the Weibull distribution

function, the probability (P) for each wind direction can be obtained by:

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

Where c is the scale parameter and k is the shape parameter for a wind speed U.

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. However, to get complete picture we ran simulations for wind from 12 distinct directions equally spaced around the development (every 30°).

As stated above, the local wind climate is determined from historical meteorological data recorded at Galway Airport meteorological wind station. The data set analyzed for this assessment is based on the meteorological data associated with the maximum daily wind speeds recorded over a 16-year period between 2008 and 2024 at a weather station at the airport, which is located 10m above ground. Figure 5.5 shows the wind speed record during the latest 5 years.

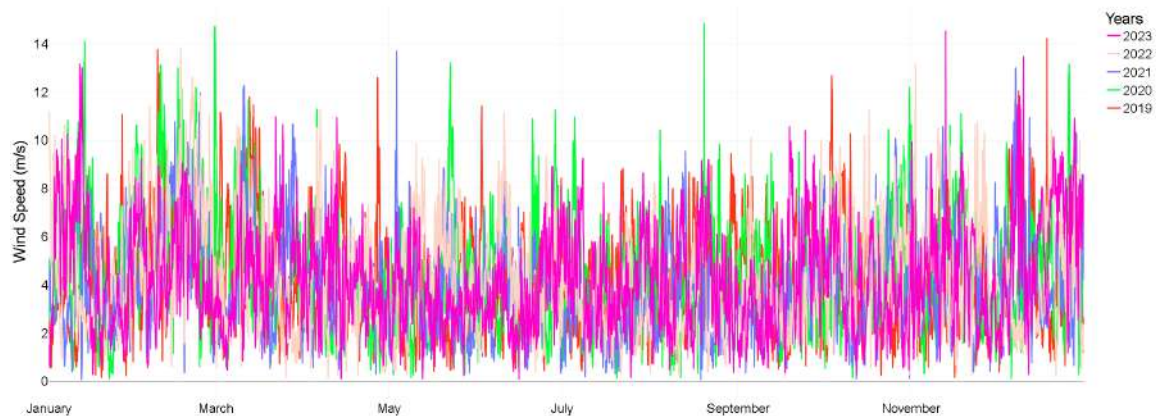


Figure 5.5: Local Wind Conditions - Wind Speed - 2019-2024

Figure 5.6 displays a wind speed diagram for Galway, illustrating the number of days per month when the wind attains specific speeds. It is evident from this figure that strong winds are more prevalent during the winter season (December, January, and February) and the start of spring season (March) compared to other seasons.

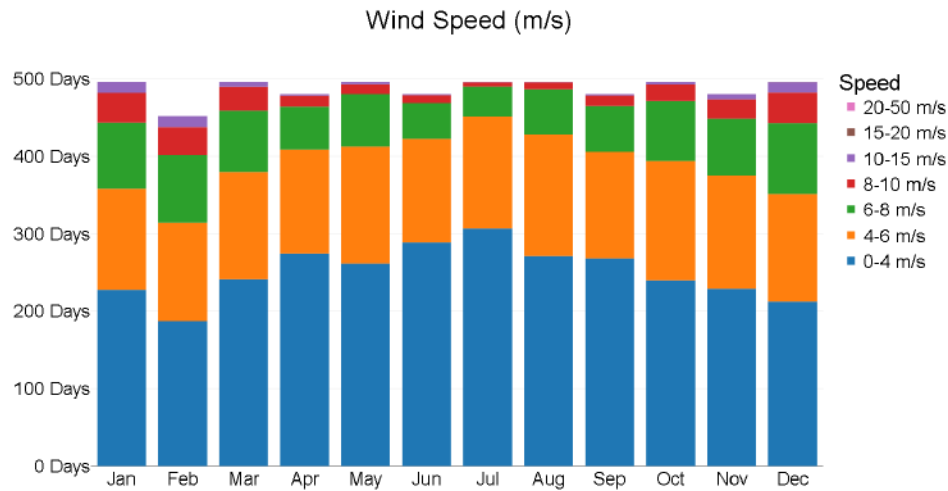


Figure 5.6: Galway Wind Speed Diagram

Figure 5.7 displays the wind rose for the Proposed Galway Port LRD, revealing the percentage of wind coming from different directions over a 16-year period. Detailed percentages for each direction are outlined in Table 5.1. As depicted in Figure 5.7 and highlighted in Table 5.1, the highest probability of wind occurrence lies in the wind blowing from 240° to 300° with 270° being most prevalent. This finding indicates that west winds contribute significantly to the probability of discomfort exceedance. In addition, seasonal changes were analyzed in order to indicate the prevailing wind directions (Fig 5.8).

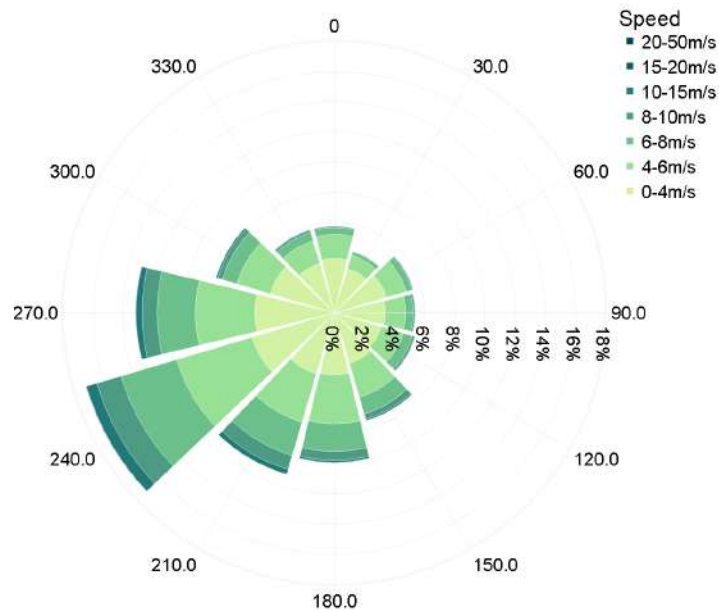


Figure 5.7: Galway Wind Rose

Table 5.1: A detailed table includes wind occurrences, wind patterns, and roughness lengths for different wind directions.

Wind Direction	Scale Parameter	Shape Parameter	Roughness Length (z_0)	Frequency
270.00°	1.80	6.11	0.30	22.22%
240.00°	2.07	6.55	0.30	13.98%
300.00°	1.66	5.18	0.30	12.83%
150.00°	1.35	3.88	0.30	8.10%
210.00°	2.05	6.02	0.30	6.75%
180.00°	1.49	4.62	0.30	6.33%
330.00°	1.60	4.38	0.30	6.14%
120.00°	0.92	1.70	0.30	5.86%
90.00°	1.15	3.08	0.30	5.74%
60.00°	1.82	4.80	0.30	4.42%
0.00°	1.42	3.81	0.30	4.28%
30.00°	1.22	3.33	0.30	3.34%

In addition to the annual statistical analysis of wind occurrences (Figure 5.7), a detailed examination has been conducted to comprehend the wind conditions during each season. As illustrated in Figure 5.8, the wind patterns in spring closely resemble those in summer, with a higher percentage of winds coming from the east and north-east compared to the same direction in summer. Although in autumn the wind pattern is similar to winter, during winter, the winds occur more frequently and are stronger. In general, the predominant winds come from the west at higher speeds compared to other wind directions throughout all seasons.

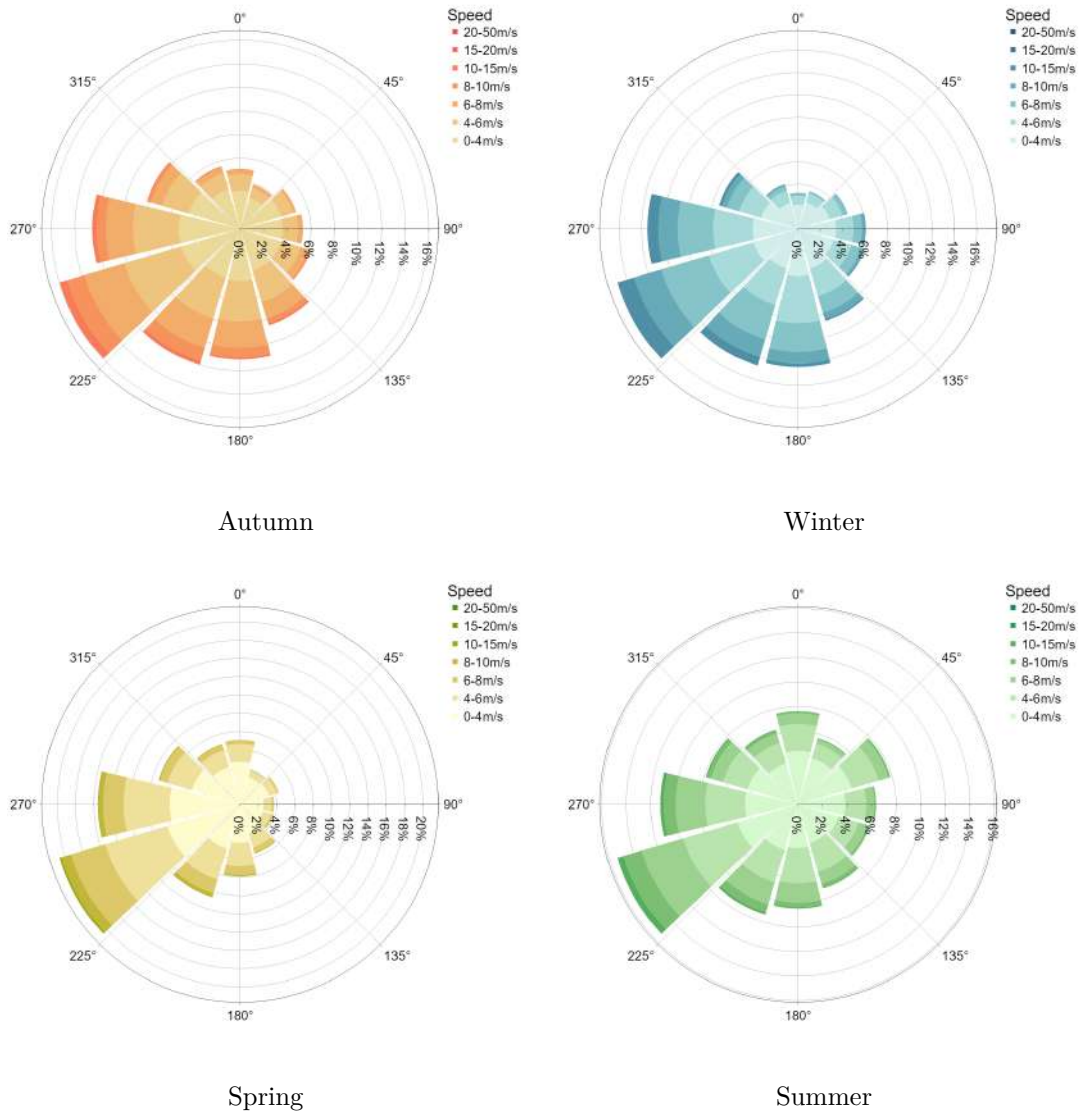


Figure 5.8: Wind speeds and wind directions at different seasons

6. CHARACTERISTICS OF THE PROPOSED DEVELOPMENT

6.1 DESCRIPTION OF PROPOSED DEVELOPMENT

The Land Development Agency intends to apply to Galway City Council for permission for a ‘Large-Scale Residential Development’ (LRD) at a site of 1.621 Ha in Galway Port at Dock Road and Lough Atalia Road, Galway City, and extending to include parts of both roads for road infrastructure works and water services infrastructure works.

The proposed development principally consists of: the demolition of the existing office / bus depot building (370.2 sq m) and ancillary building (26 sq m); the partial demolition of the existing ESB sub-station (67.4 sq m); the demolition of existing boundary walls at the south-west and north-west; and the construction of a mixed-use development.

The proposed mixed-use development primarily comprises: 356 No. residential apartments (172 No. 1-bed, 169 No. 2-bed and 15 No. 3-bed); crèche (255.9 sq m); 2 No. café/restaurant units (totalling 428.4 sq m) and 1 No. retail unit (156.0 sq m). The development has a total floor area of 32,096.0 sq m and is primarily proposed in 4 No. blocks (identified as A–D) that generally range in height from 6 No. to 13 No. storeys.

The proposed development also includes: new internal street and pedestrian network, including a one-way vehicular route at the north-western side of the site and new junctions with Dock Road at the south-west and with the access road from Lough Atalia at the north-west; upgrades to Lough Atalia Road and the access road from it at the north-west of the site, including the provision of a new toucan pedestrian/cycle crossing at Lough Atalia Road; upgrades to the footpath and road interface with Dock Road to the south-west; 37 No. car parking spaces; 1 No. set-down/delivery bay; 748 No. cycle parking spaces; hard and soft landscaping, including public open spaces and communal amenity spaces; private amenity spaces as balconies and terraces facing all directions; boundary treatments; public lighting; bin stores; plant rooms; rooftop lift overruns; rooftop telecommunications and plant infrastructure and enclosure at Block C; recladding of the existing sub-station and pumping station; and all associated works above and below ground.

The proposed development is displayed alongside the existing surrounding buildings, depicted in white, in Figures 6.1. Figure 6.2 shows buildings within the cumulative scenario which include the proposed development, existing surrounding buildings, and the potential buildings that are envisioned as part of the Galway Harbour Company Masterplan and will be subject to future planning application.



Figure 6.1: Proposed Galway Port LRD



Figure 6.2: Galway Port LRD (colored in red) and Future Masterplan Development (colored in orange)

6.2 POTENTIAL RECEPTORS

Potential receptors for the wind assessment are all pedestrian circulation routes, building entrances and leisure open areas within the site and in neighboring adjacent areas. The pedestrian level is considered at 1.5m above ground.

The pedestrian activity areas are highlighted in Figure 6.3. It focuses on the areas within the development site, including the communal open space between Blocks A, B, C and D along with the areas outside the development site. These areas are considered sensitive potential receptors for the wind micro-climate.

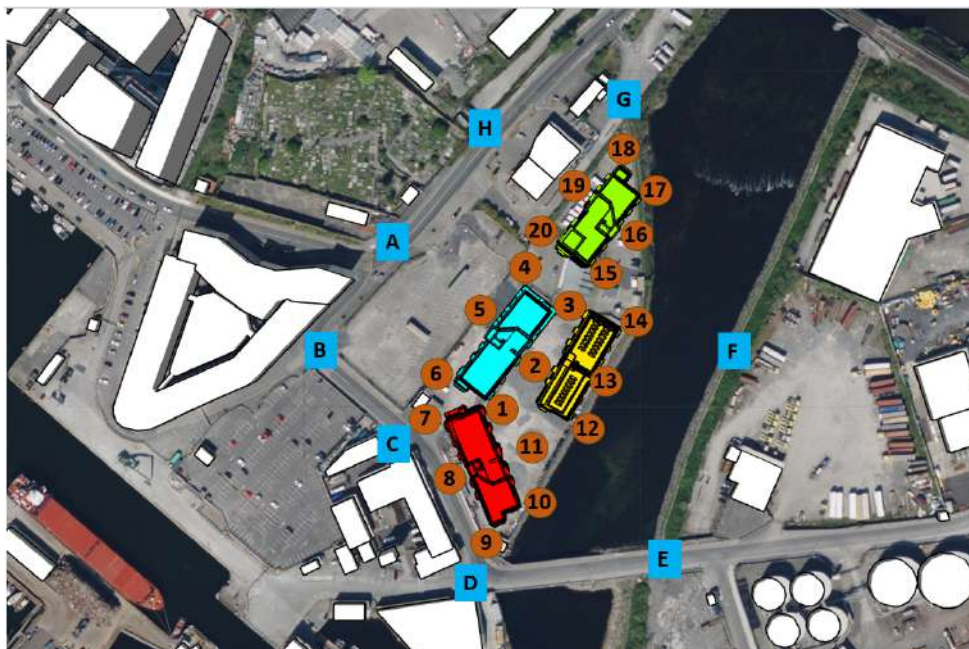


Figure 6.3: Potential Sensitive Receptors on the Ground - On-Site and Off-Site - Pedestrian Activities Area

Tables 6.1-6.2 lists the descriptions of potential receptors as shown in Figure 6.3.

Table 6.1: List of the Receptors

On-Site Potential Receptors ID	Description	On-Site Potential Receptors ID	Description
1.	Southwest Corner	11.	Central Zone b/w Blocks
2.	Central West	12.	East-Northeast Boundary
3.	Northeast Corner	13.	East Courtyard Access
4.	Northwest Corner	14.	Southeast Corner (Block C)
5.	Southwest Side	15.	Northern Block C Edge
6.	West Courtyard	16.	Southern Block D Interface
7.	Boundary edge	17.	Eastern Edge (Facing River)
8.	Southwest Pedestrian Access	18.	North Edge
9.	Lower Southwest Boundary	19.	West Block D Side
10.	Southeast Outer Edge	20.	Southwest Block D Corner

Table 6.2: List of the Receptors

Off-Site Potential Receptors ID	Description	Off-Site Potential Receptors ID	Description
A.	Northwest	E.	Southeast
B.	West	F.	East
C.	Southwest	G.	Northeast
D.	South	H.	North

7. BASELINE WIND MICROCLIMATE

7.1 BASELINE SCENARIO

The wind microclimate of the baseline scenario is defined by the wind patterns that develop on the site and its surroundings (existing buildings and topography) under the local wind conditions relevant for the assessment of the Pedestrian Comfort and Distress.

In this scenario the assessment has considered the impact of wind on the existing area. Results of wind microclimate at pedestrian level (1.5m height - flow speeds) are collected throughout the modelled site. These flow velocities identify if locally, wind speeds at pedestrian-level are accelerated or decelerated in relation to the undisturbed reference wind speed due to the presence of the existing baseline environment.

The impact of these speeds are then combined with their specific frequency of occurrence and presented in the maps that show the area of comfort and distress in accordance with Lawson Criteria, these maps are produced at pedestrian level on the ground and identify the suitability of each area to its prescribed level of usage and activity.



Figure 7.1: CFD Model of the Baseline Scenario

7.1.1 WIND SPEEDS - Pedestrian Level

Results of wind speeds and their circulations at pedestrian level of 1.5m above the development ground are presented in Figures 7.2 to 7.25 in order to assess wind flows at ground floor level of Galway Port LRD.

Wind flow speeds are shown to be within tenable conditions. Higher velocity and recirculation effects are found in the existing site.

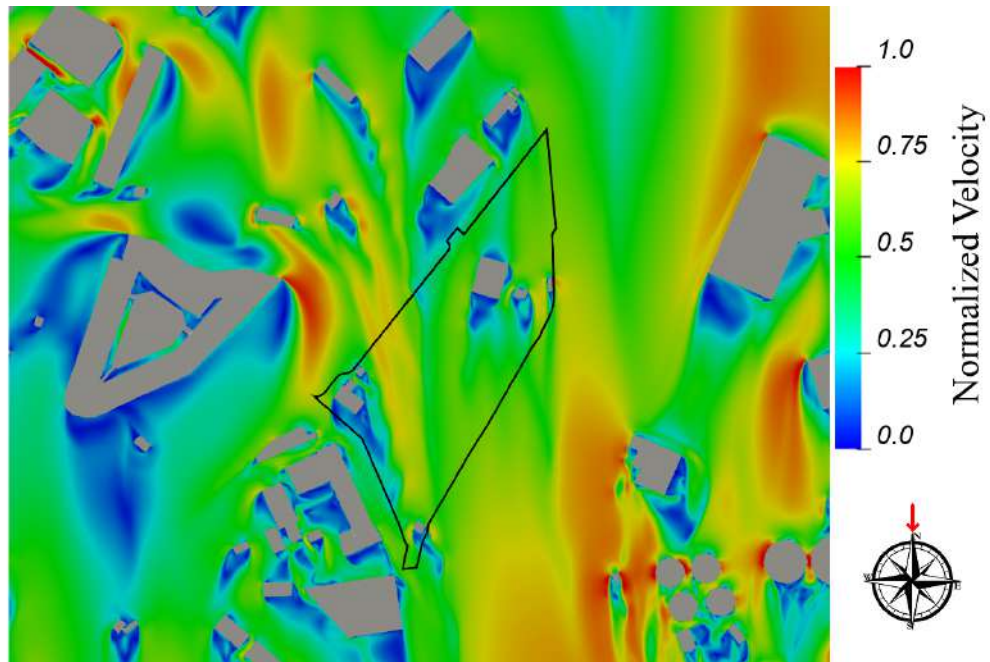


Figure 7.2: Top View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 0°

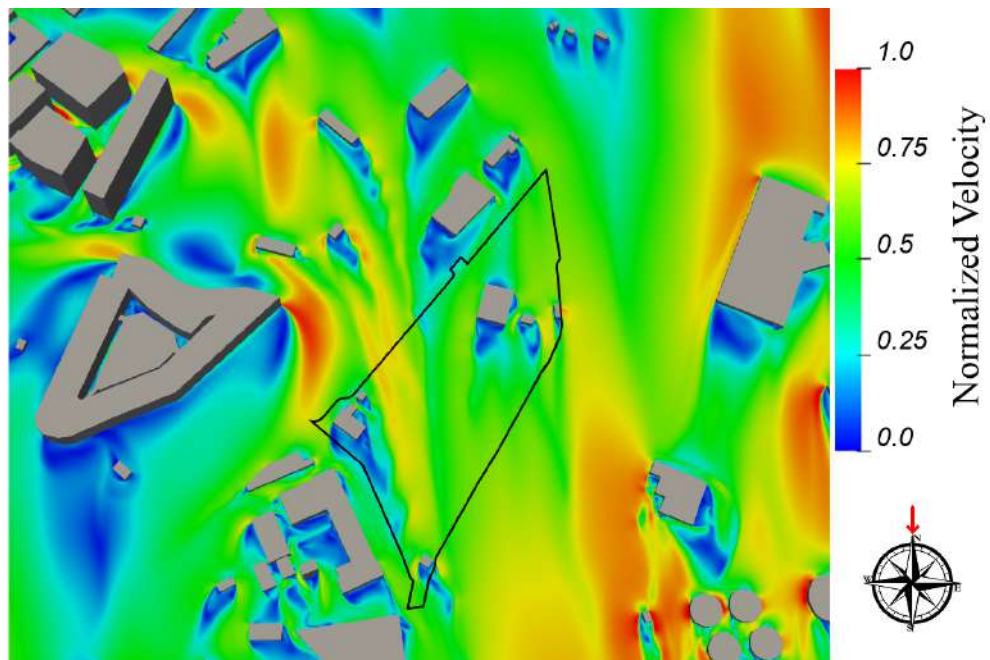


Figure 7.3: 3D View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 0°

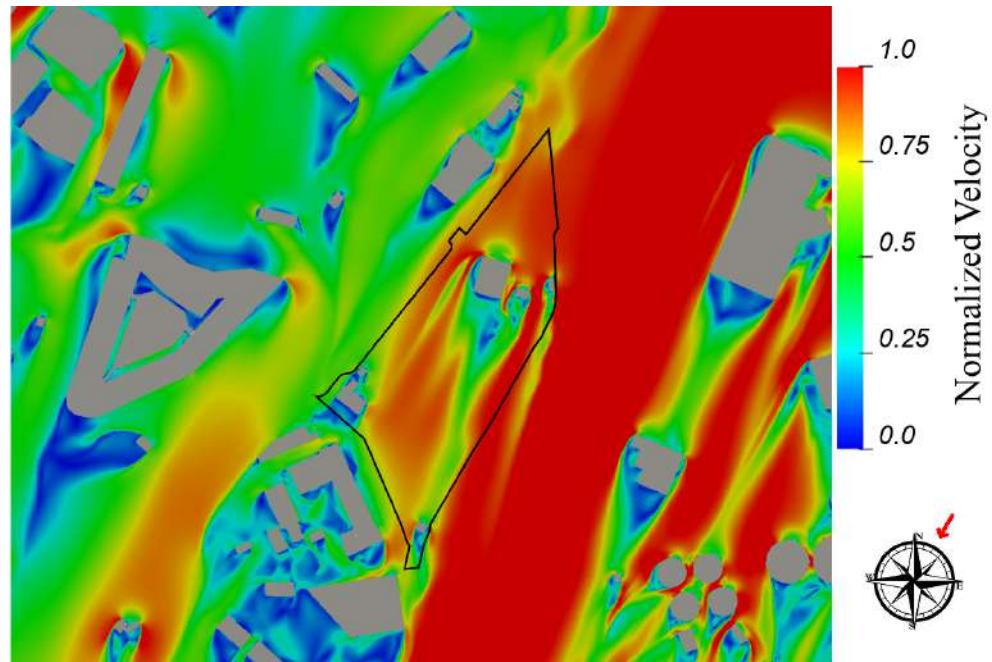


Figure 7.4: Top View - Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 30°

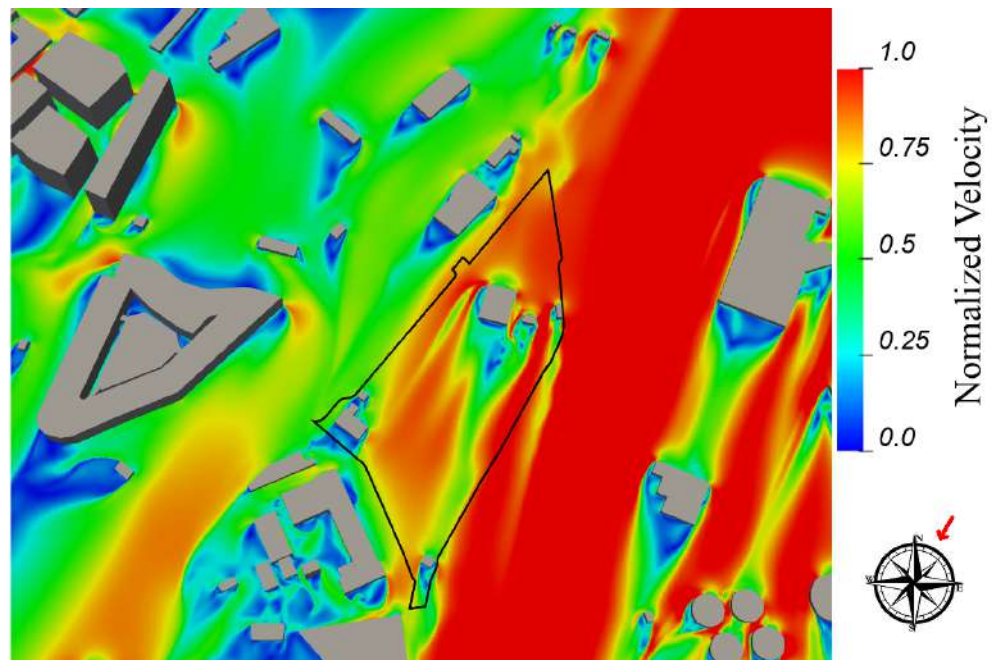


Figure 7.5: 3D View - Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 30°

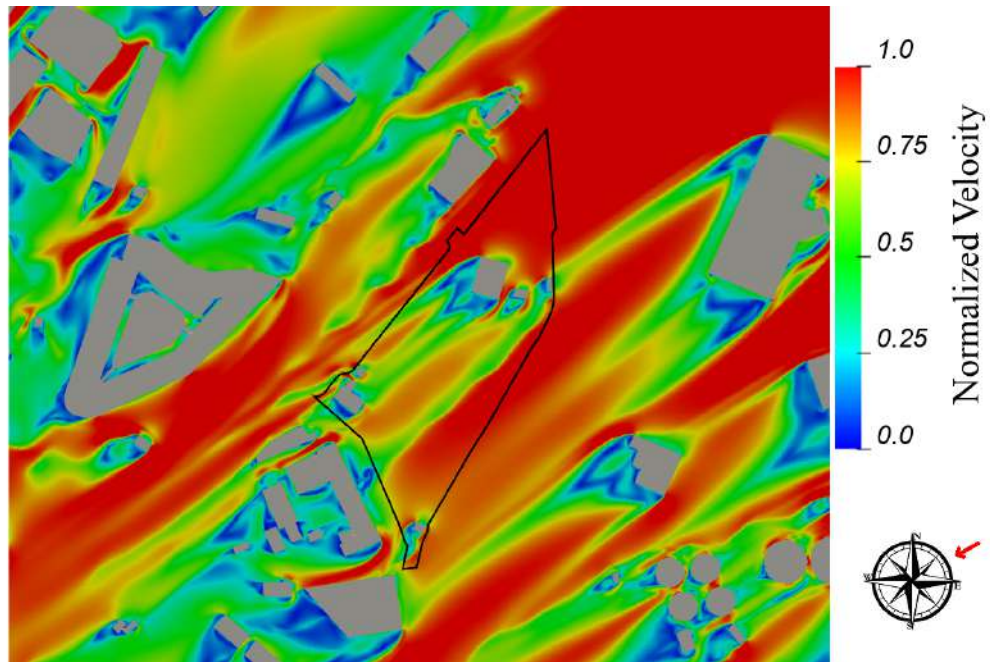


Figure 7.6: Top View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 60°

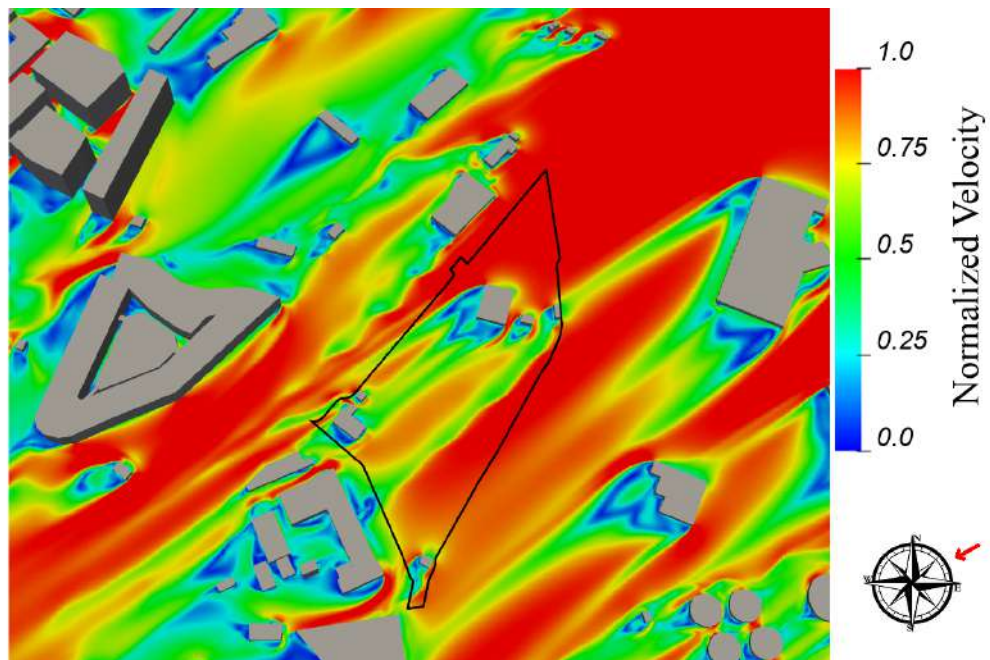


Figure 7.7: 3D View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 60°

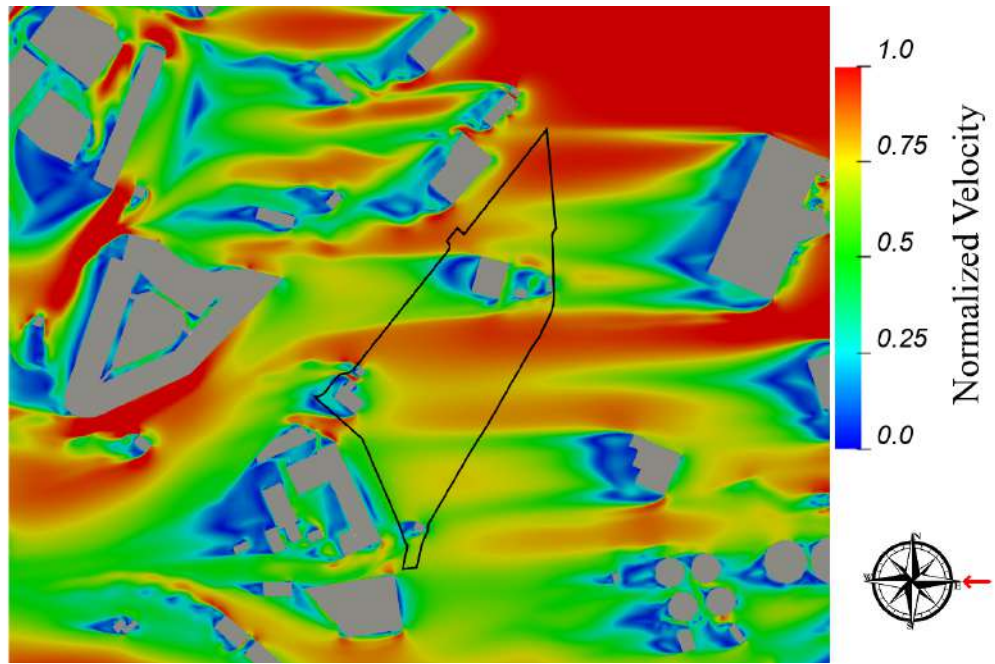


Figure 7.8: Top View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 90°

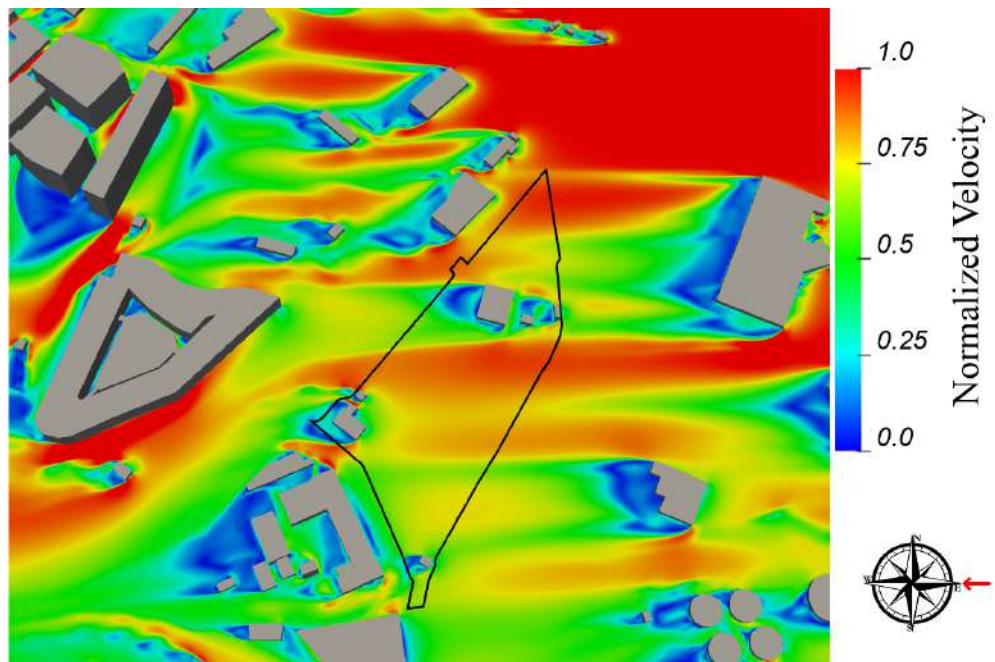


Figure 7.9: 3D View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 90°

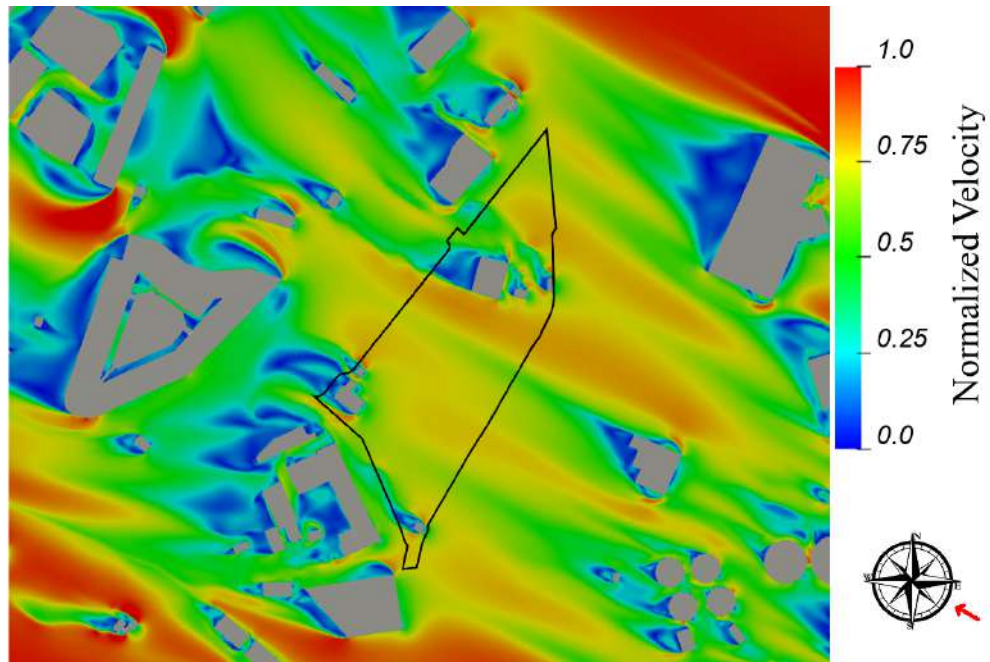


Figure 7.10: Top View - Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 120°

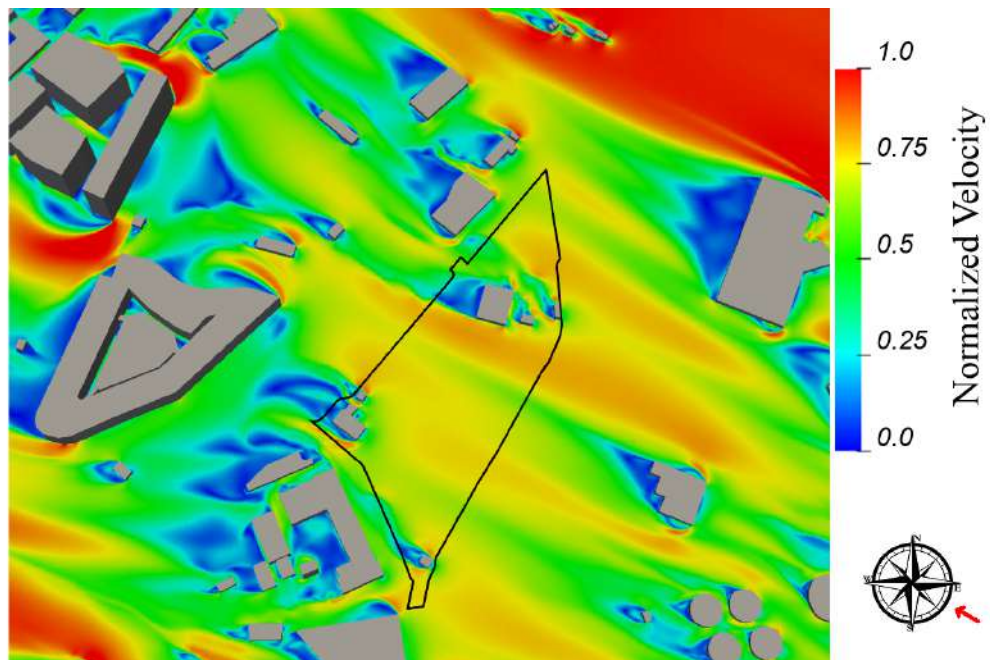


Figure 7.11: 3D View - Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 120°

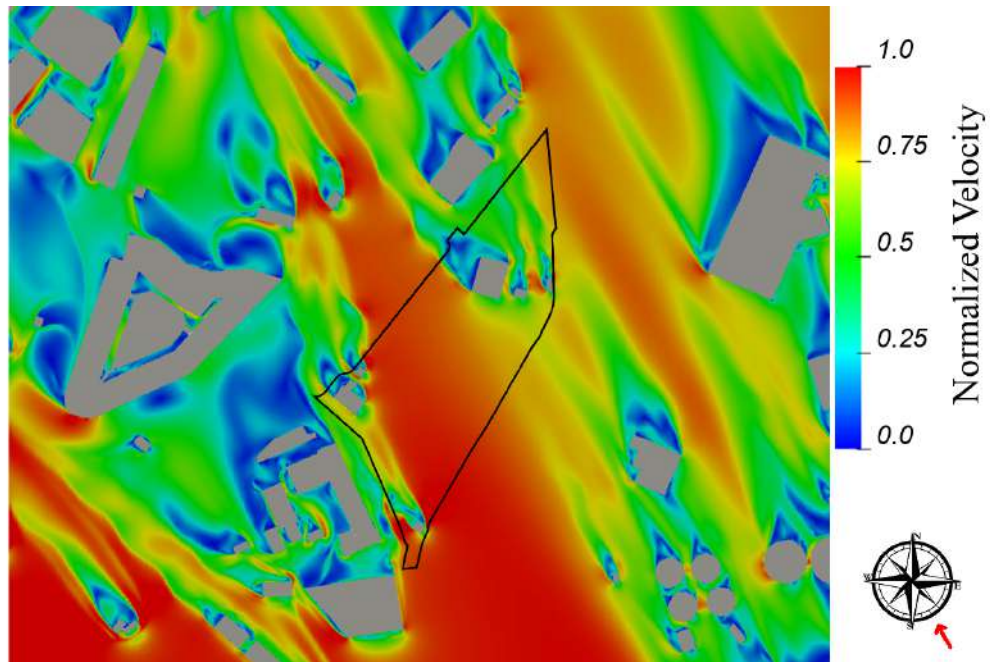


Figure 7.12: Top View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 150°

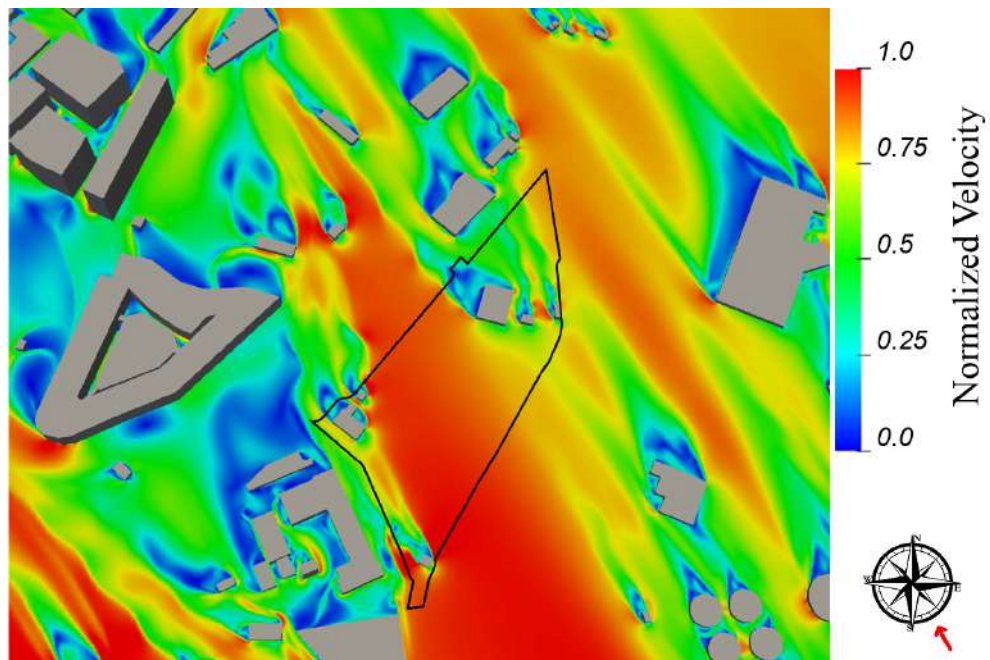


Figure 7.13: 3D View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 150°

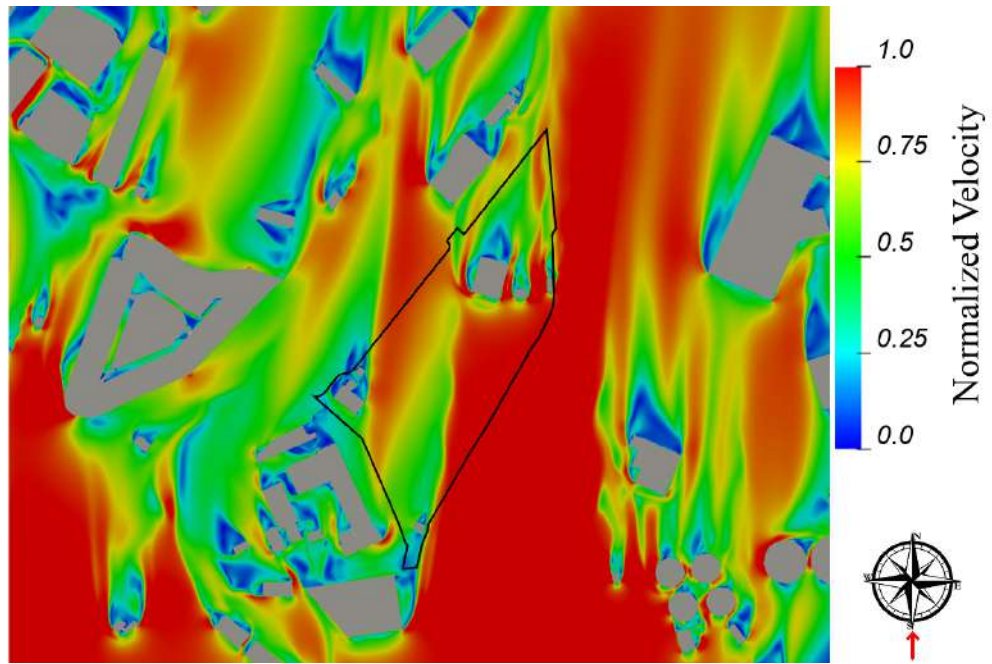


Figure 7.14: Top View - Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 180°

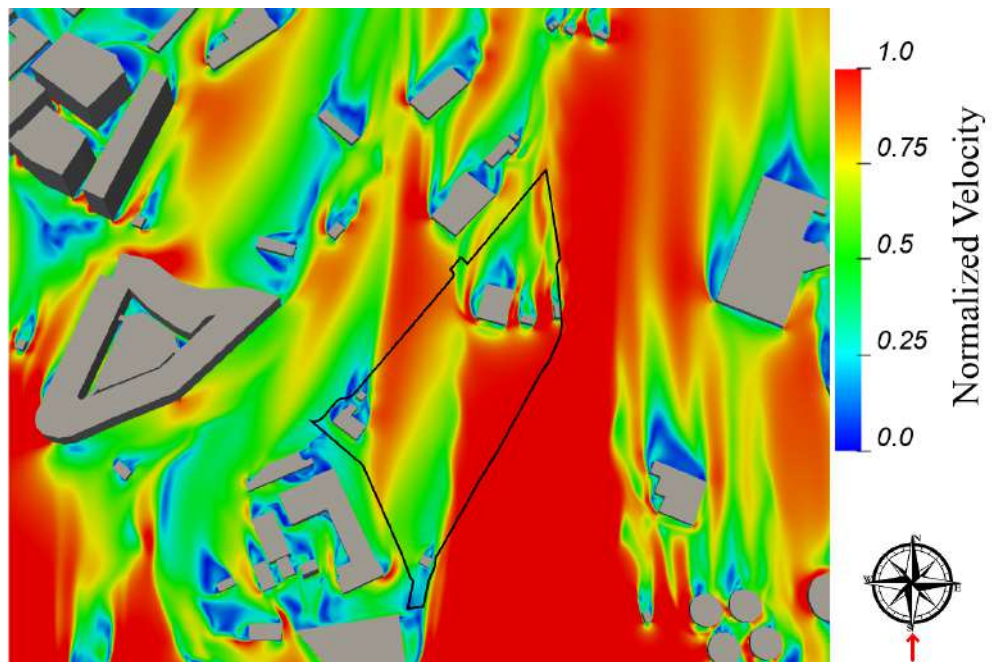


Figure 7.15: 3D View - Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 180°

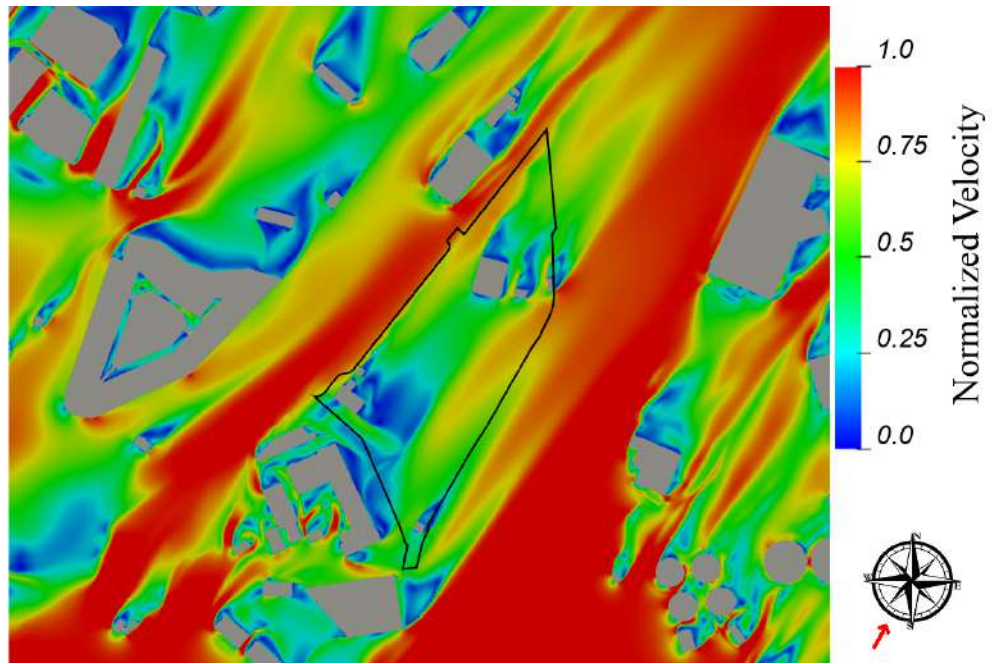


Figure 7.16: Top View - Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 210°

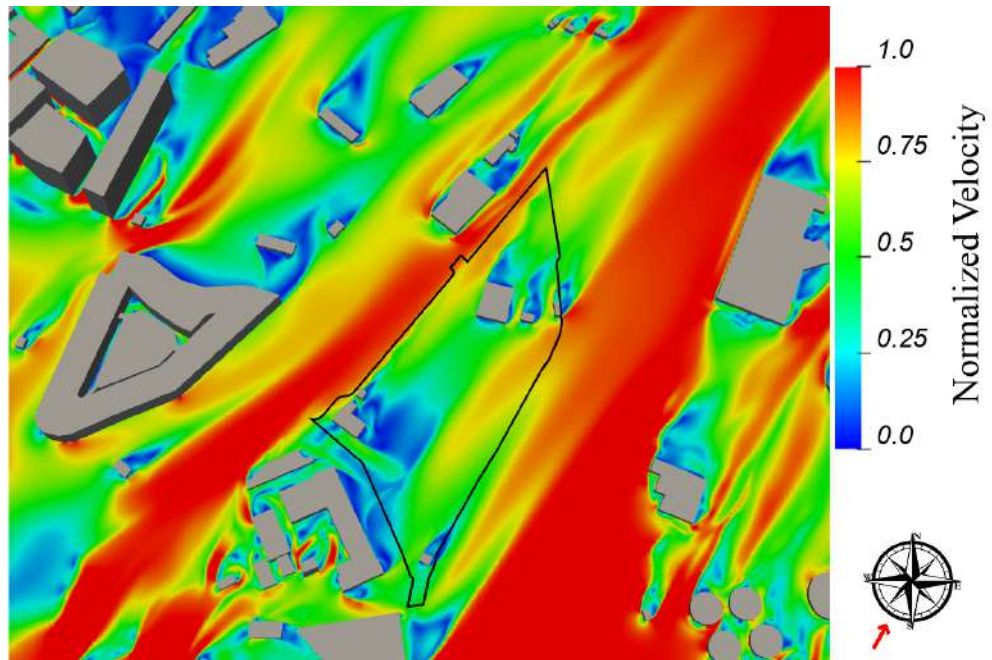


Figure 7.17: 3D View - Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 210°

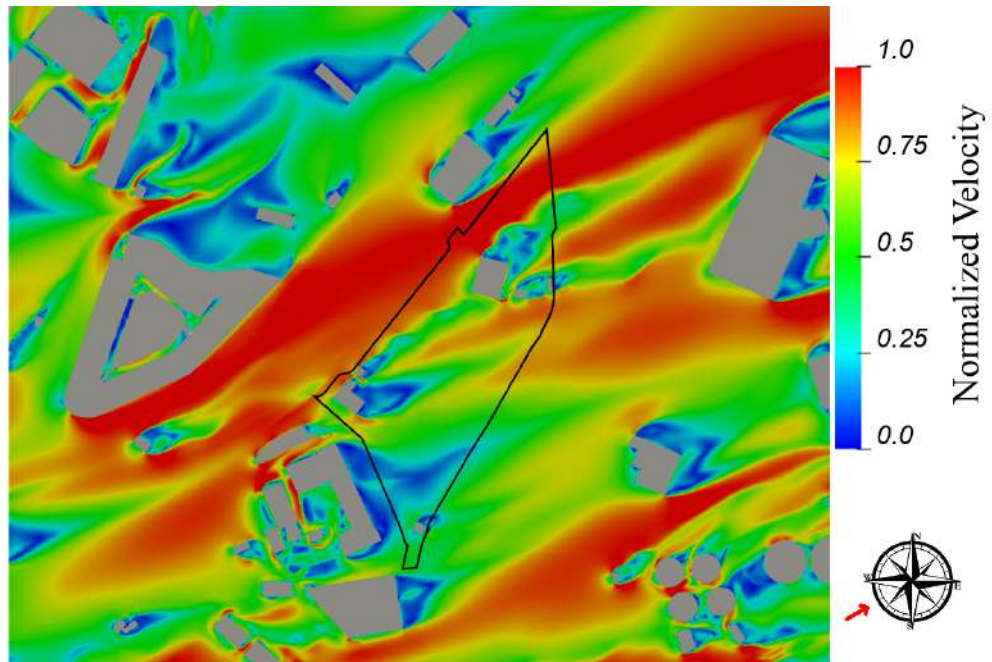


Figure 7.18: Top View - Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 240°

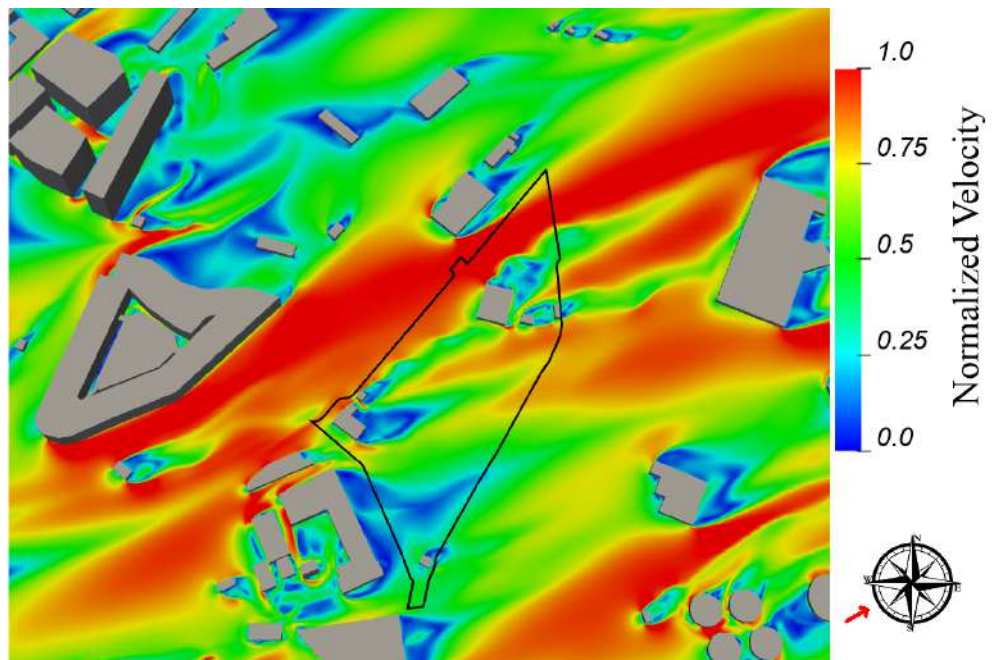


Figure 7.19: 3D View - Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 240°

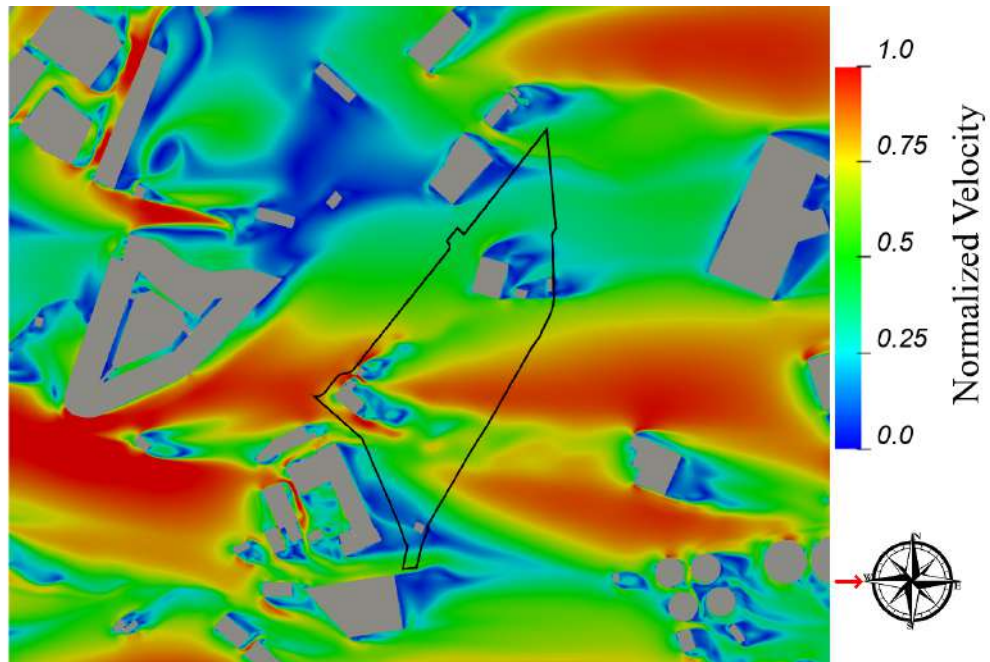


Figure 7.20: Top View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 270°

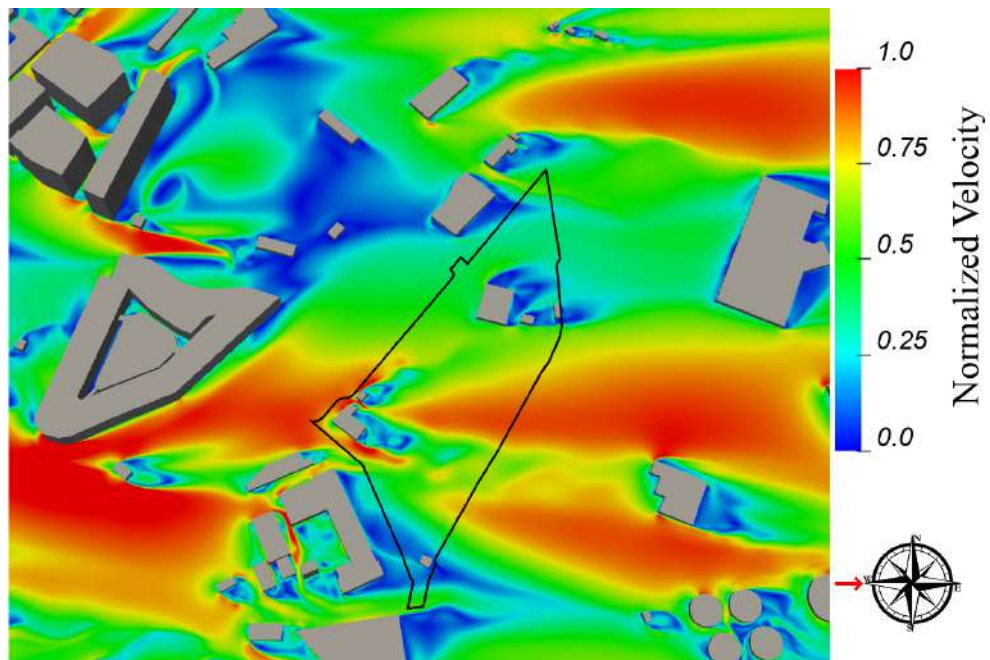


Figure 7.21: 3D View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 270°

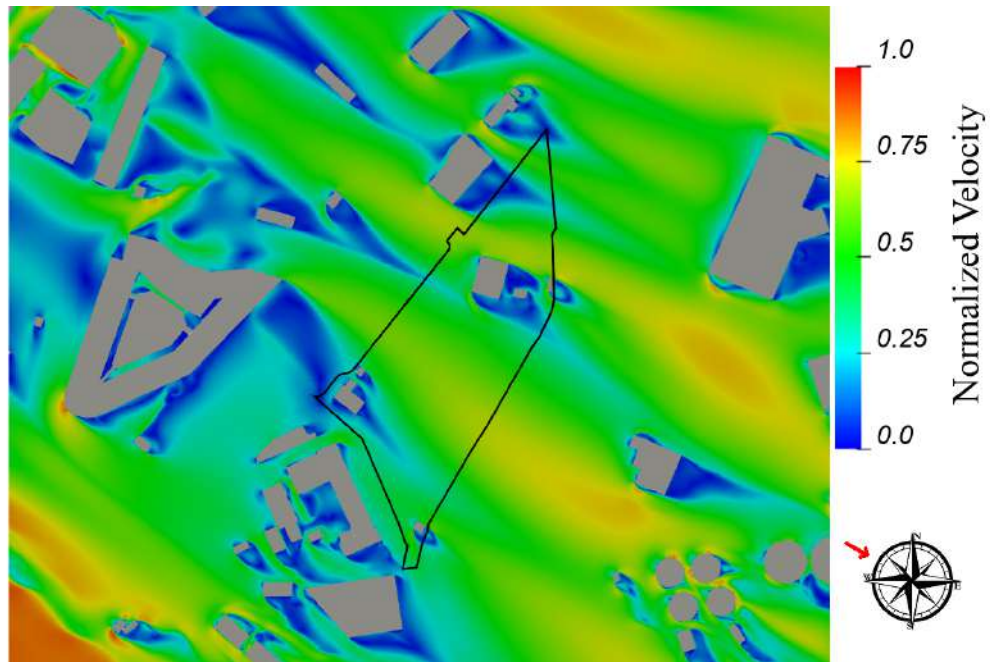


Figure 7.22: Top View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 300°

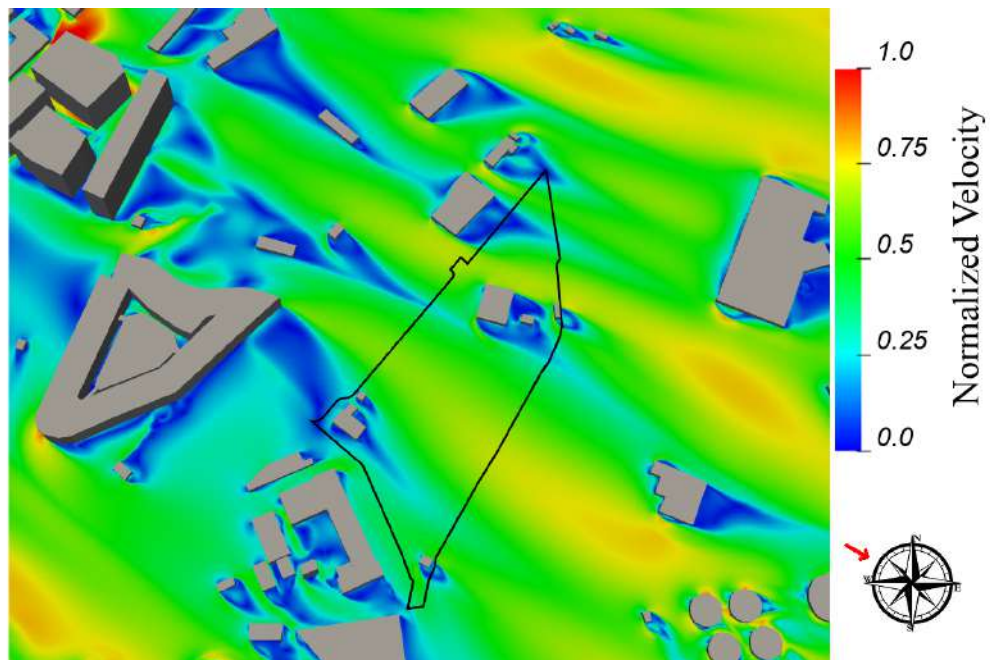


Figure 7.23: 3D View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 300°

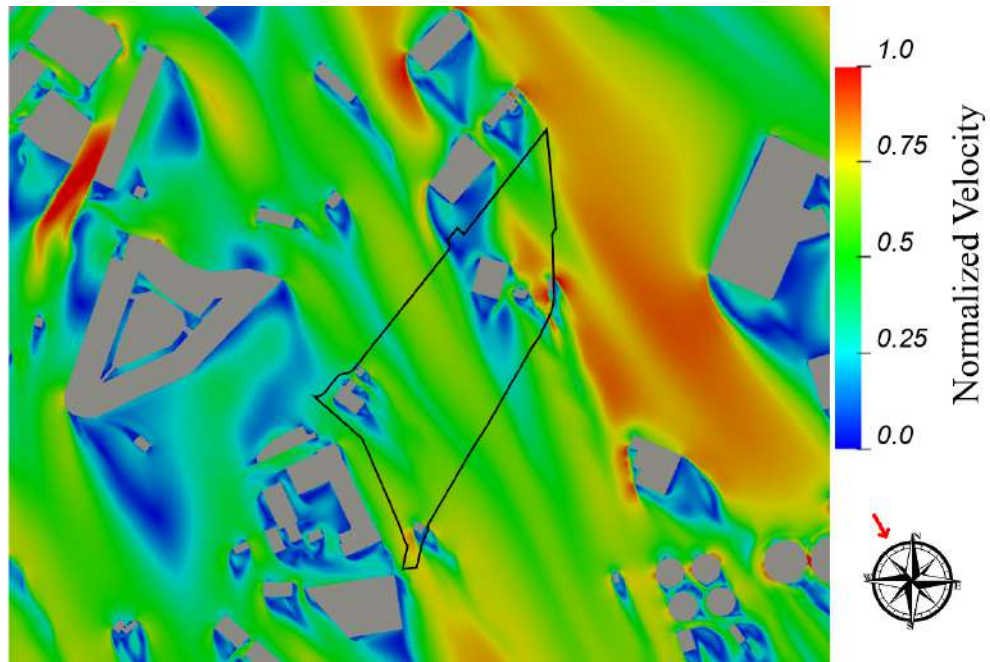


Figure 7.24: Top View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 330°

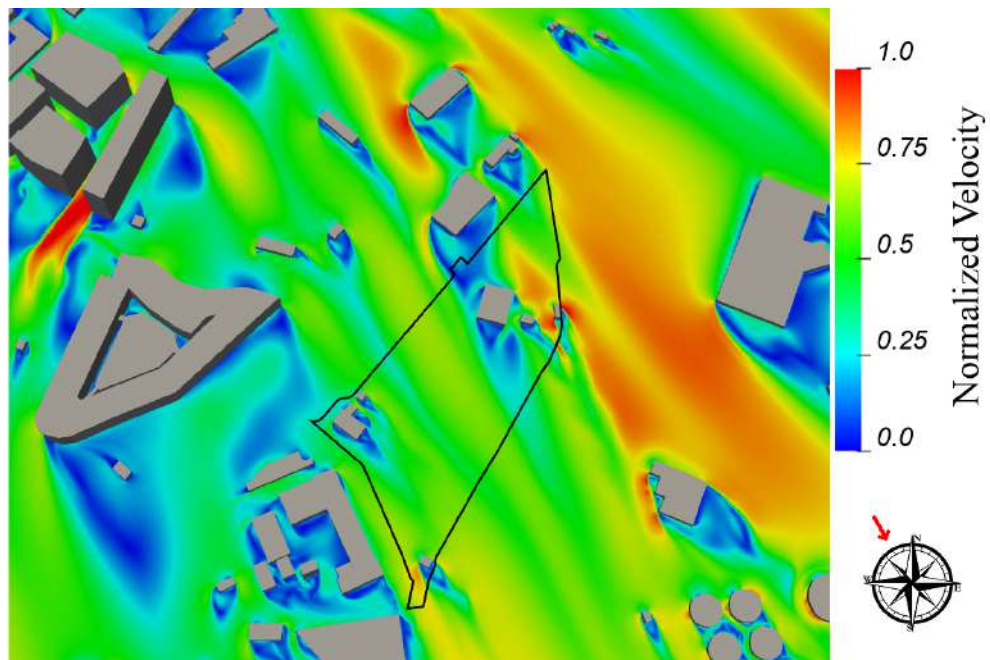


Figure 7.25: 3D View - Ground Floor Level - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 330°

7.1.2 BASELINE WIND MICROCLIMATE - Lawson Criteria

The wind flow results obtained simulating the different direction and wind speeds, are combined with wind frequencies of occurrence to obtain comfort ratings at pedestrian level in all areas included within the model. The comparison of comfort ratings with intended pedestrian activities is shown in the Lawson Comfort and Distress Map that follows. The comfort/distress conditions are presented in Figures 7.26 and 7.27 using a colour coded diagram formulated in accordance with the Lawson Criteria.

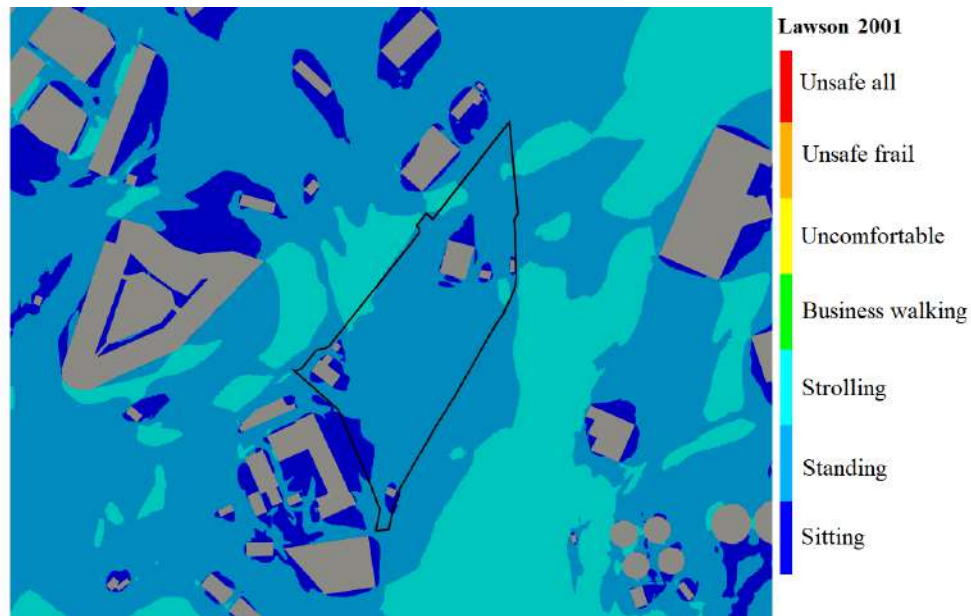


Figure 7.26: Ground Floor - Lawson Discomfort Map - **Top View**

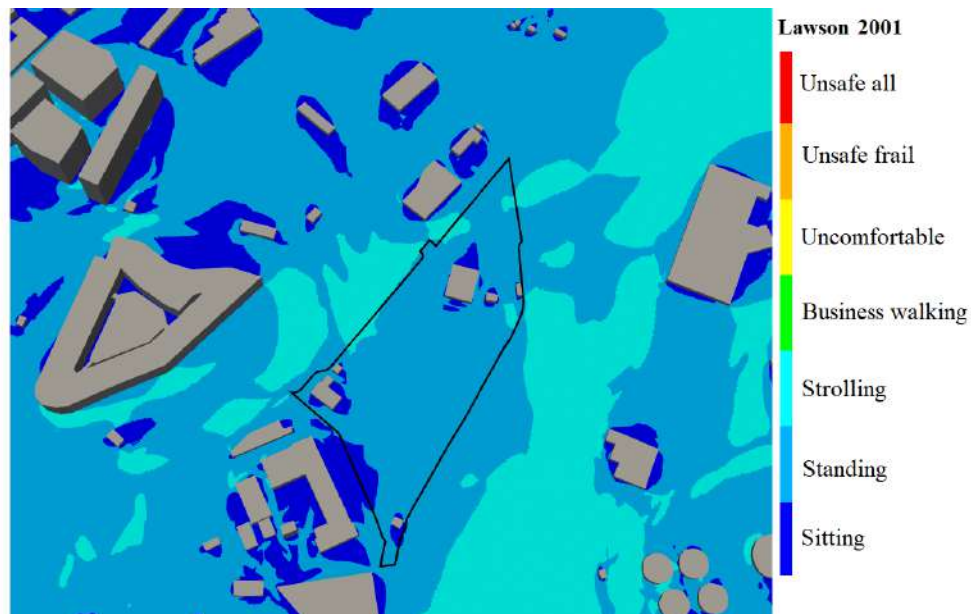


Figure 7.27: Ground Floor - Lawson Discomfort Map - **3D View**

From the simulation results the following observations are pointed out:

- The assessment of the baseline scenario has shown that no area is unsafe and no conditions of distress are created in the existing environment under the local wind climate.
- The site is usable for sitting/standing, the roads in the surrounding are usable for their intended scope.

8. IMPACT OF THE PROPOSED DEVELOPMENT

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



Figure 8.1: CFD Model of Proposed Scenario

8.1 CONSTRUCTION PHASE

As the finalization of the development proceeds, the wind setting at the site would progressively conform to those of the completed development. Due to the fact that windier conditions are acceptable within a construction area (not accessible to the public), and the proposed development would not be the reason for critical wind conditions on-Site (and are slightly calmer when the development is in site), the impacts evaluated on-Site are considered to be insignificant. Thus, the predicted impacts during construction phase are identified as negligible.

In summary, as construction of the Galway Port LRD progresses, the wind conditions at the site would gradually adjust to those of the completed development. During the construction phase, predicted impacts are classified as negligible.

8.2 OPERATIONAL PHASE

This section shows CFD results of wind microclimate assessment carried out considering the "Operational Phase" of Galway Port LRD. In this case the assessment has considered the impact of wind on the existing area including the proposed Galway Port LRD. Wind simulations have been carried out on all the various directions for which the development could show critical areas in terms of pedestrian comfort and safety.

Results of wind microclimate at pedestrian level (1.5m height - flow speeds) are collected throughout the modelled site (potential receptors). These flow velocities identify if locally, wind speeds at pedestrian-level are accelerated or decelerated in relation to the undisturbed reference wind speed due to the presence of the existing baseline environment.

The impact of these speeds are then combined with their specific frequency of occurrence and presented in the maps that show the area of comfort and distress in accordance with Lawson Criteria, these maps are produced at pedestrian level on the ground or on the courtyards, and identify the suitability of each areas to its prescribed level of usage and activity.

8.2.1 WIND SPEEDS - Pedestrian Level

Results of wind speeds and their circulations at pedestrian level of 1.5m above the potential receptors are presented in Figures 8.2 to 8.25 in order to assess wind flows at the ground floor level of Galway Port LRD.

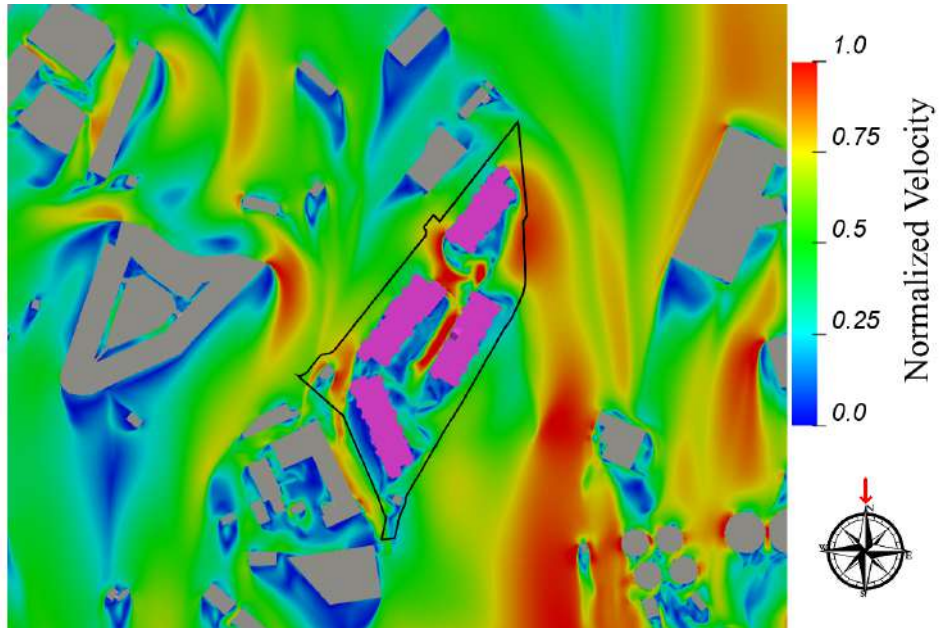


Figure 8.2: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 0°

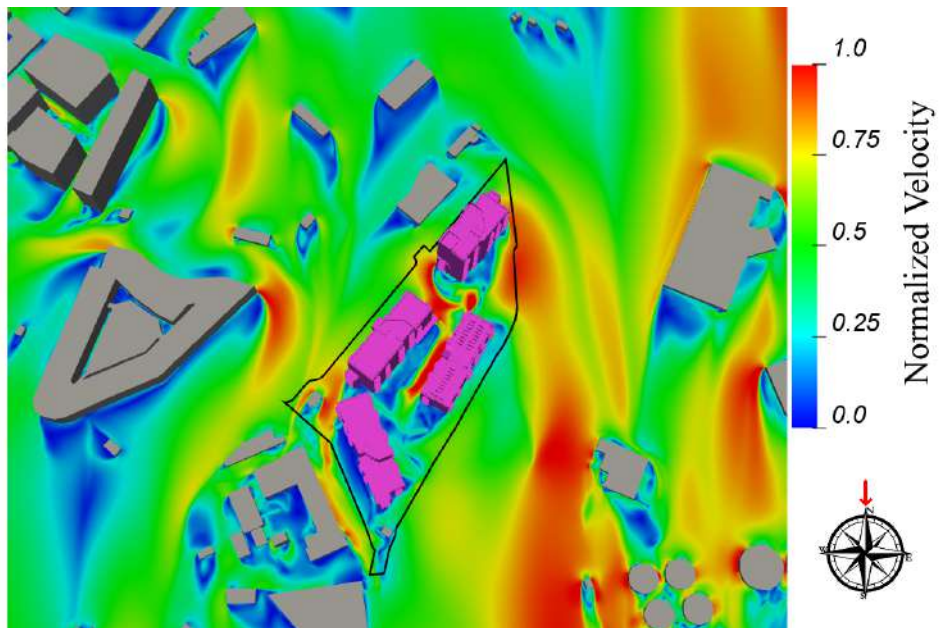


Figure 8.3: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 0°

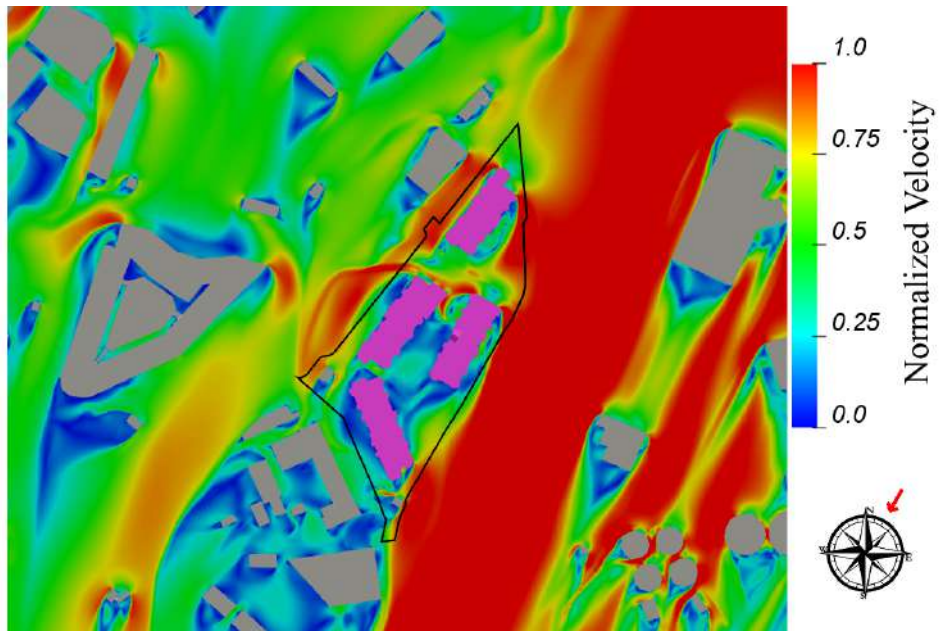


Figure 8.4: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 30°

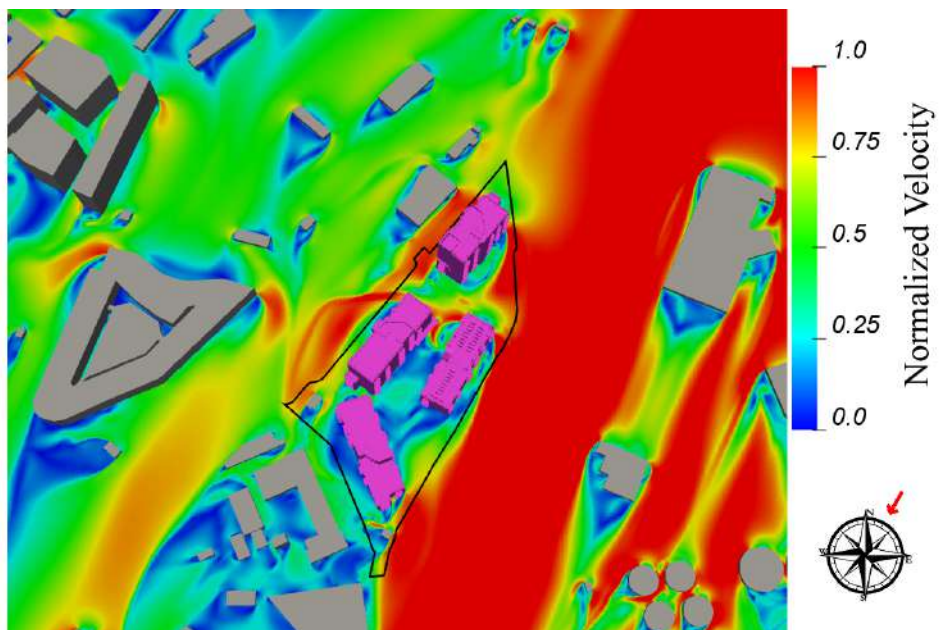


Figure 8.5: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 30°

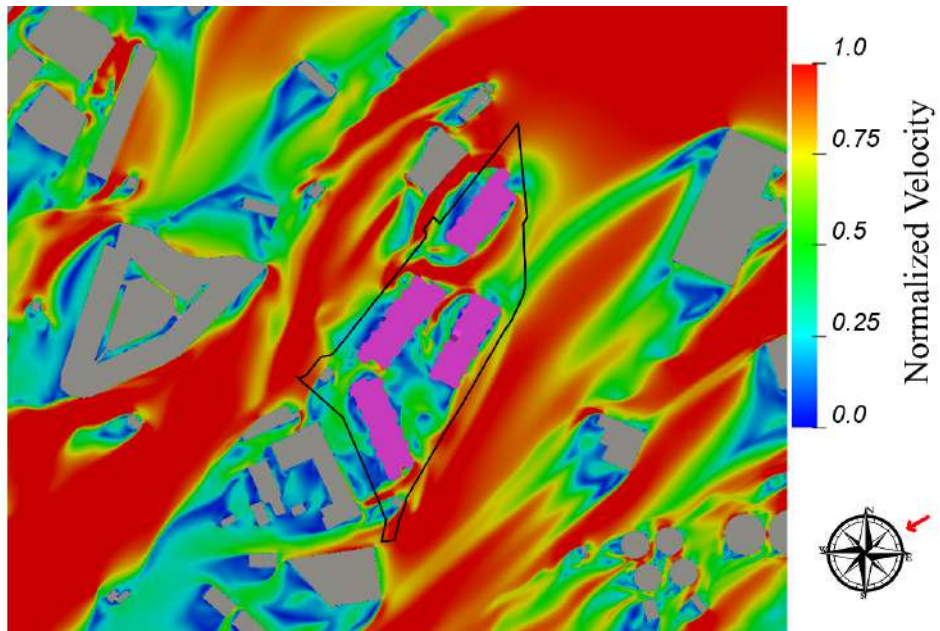


Figure 8.6: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 60°

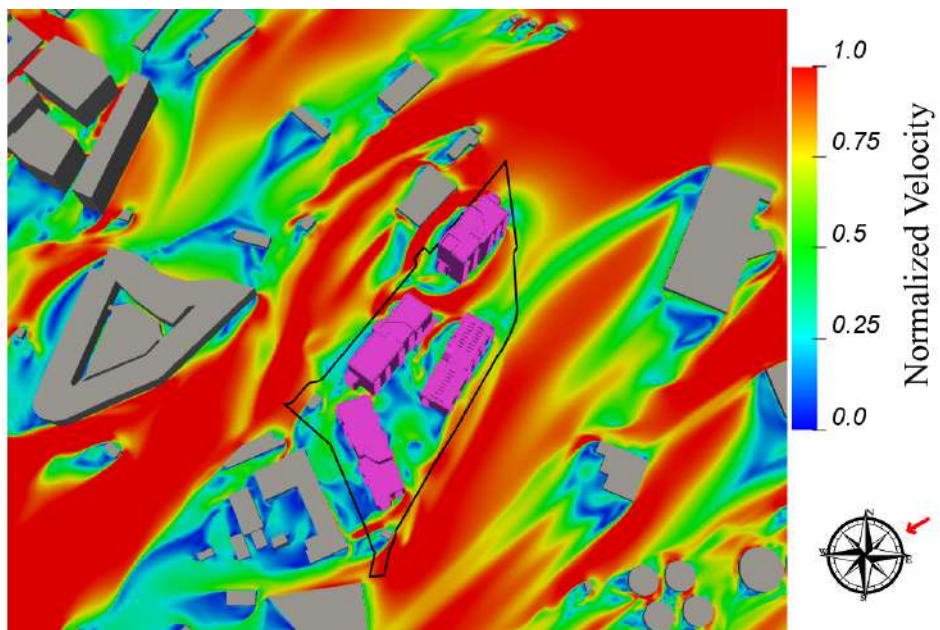


Figure 8.7: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 60°

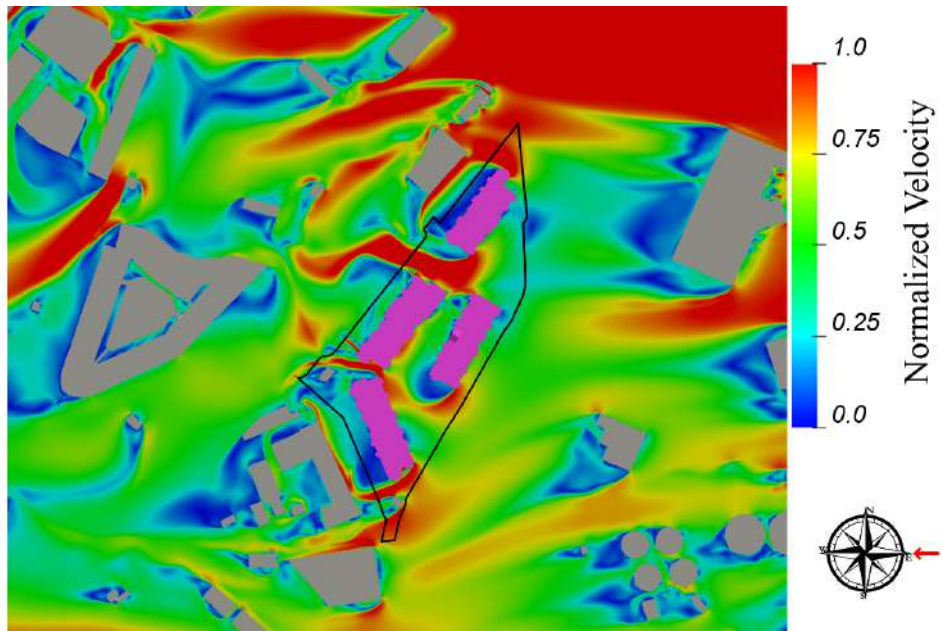


Figure 8.8: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 90°

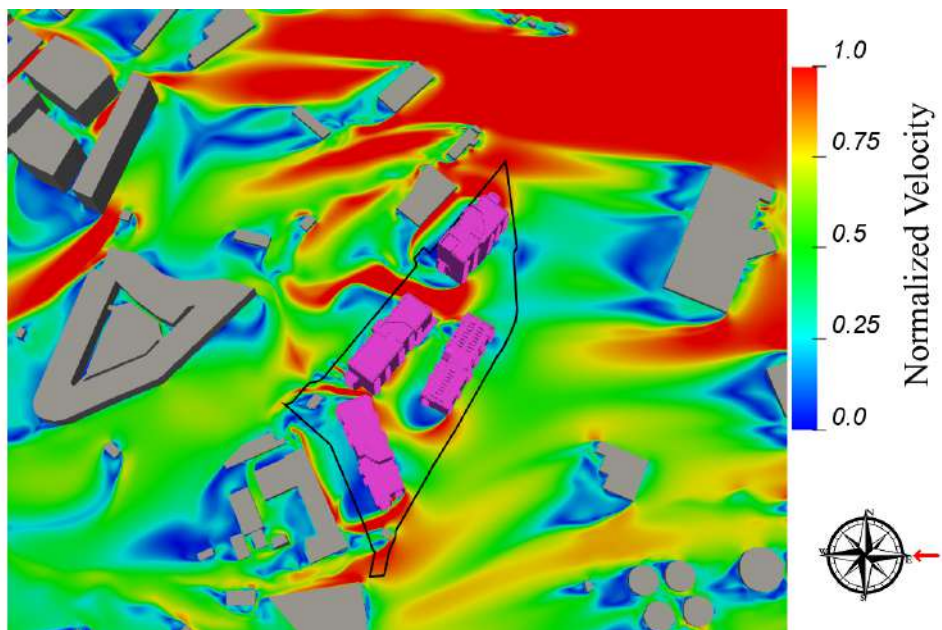


Figure 8.9: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 90°

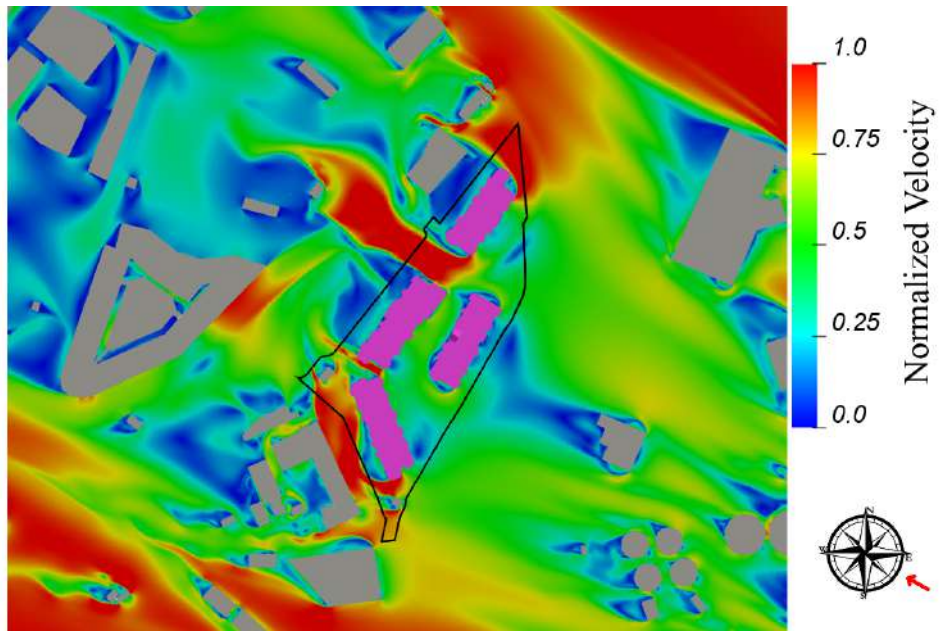


Figure 8.10: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 120°

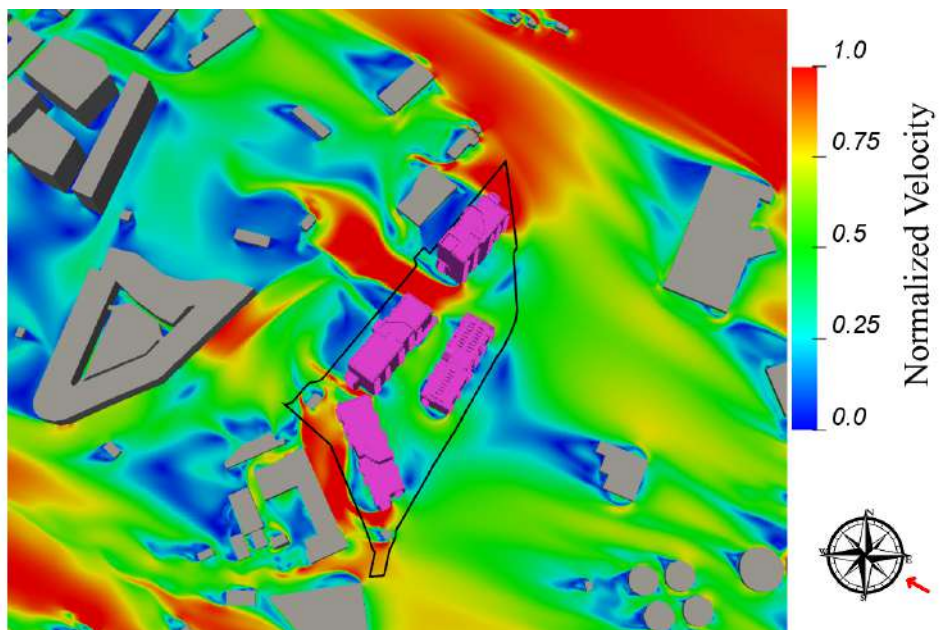


Figure 8.11: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 120°

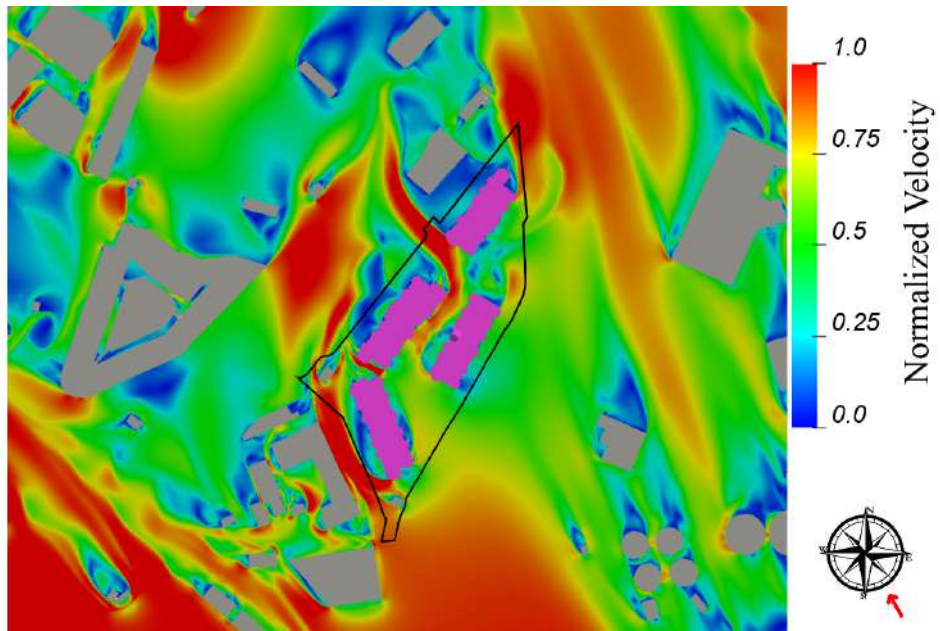


Figure 8.12: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 150°

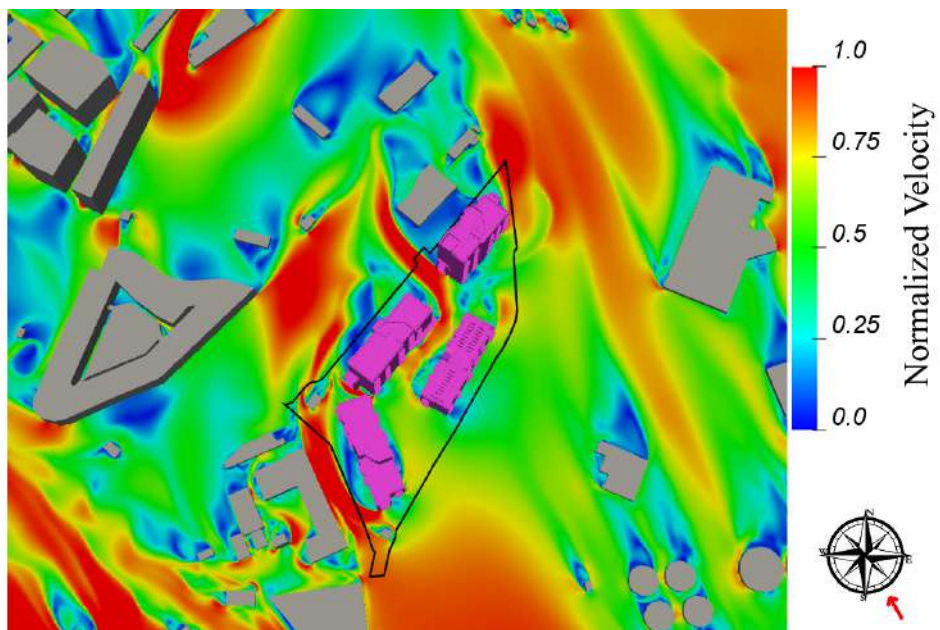


Figure 8.13: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 150°

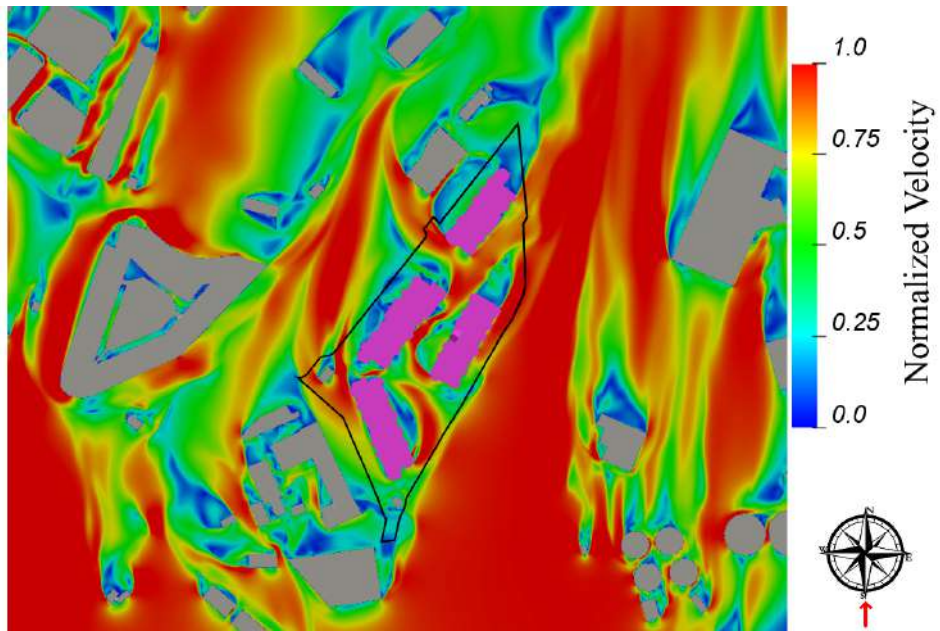


Figure 8.14: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 180°

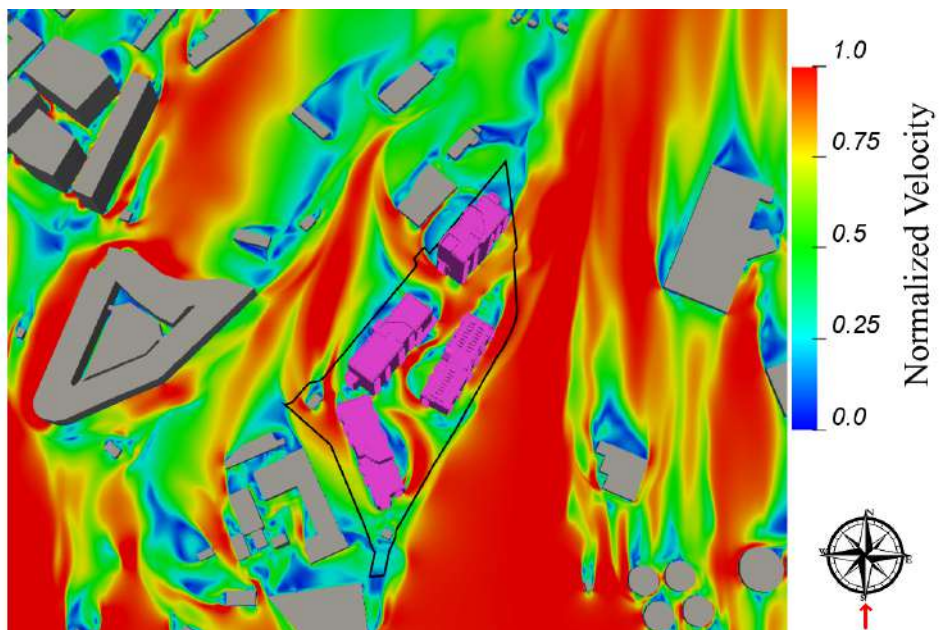


Figure 8.15: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 180°

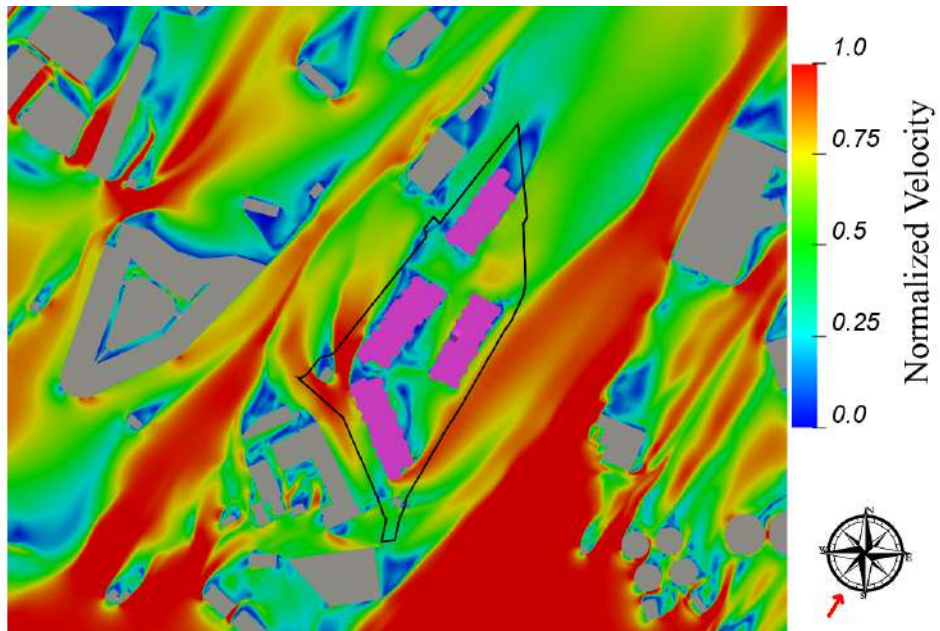


Figure 8.16: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 210°

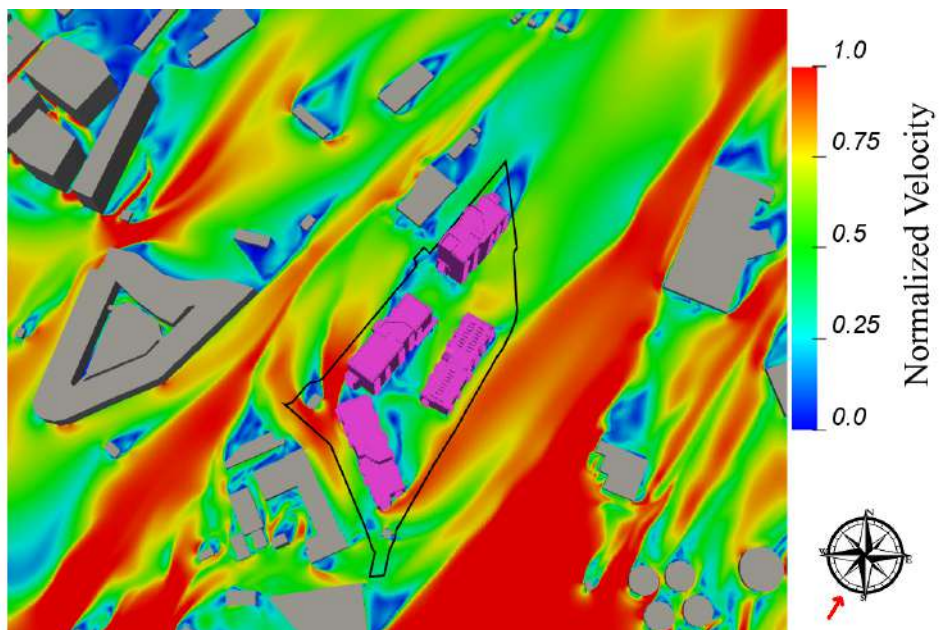


Figure 8.17: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 210°

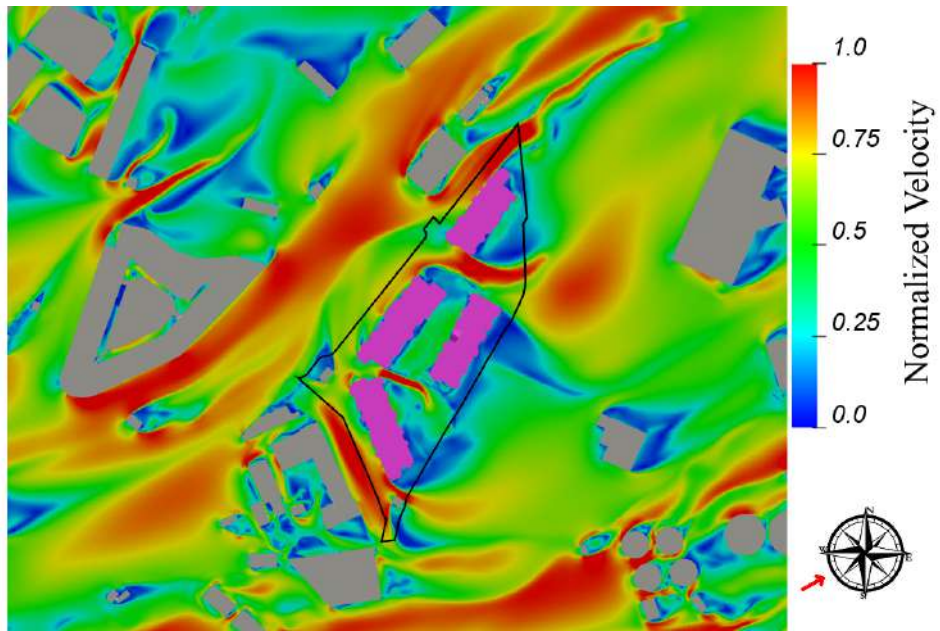


Figure 8.18: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 240°

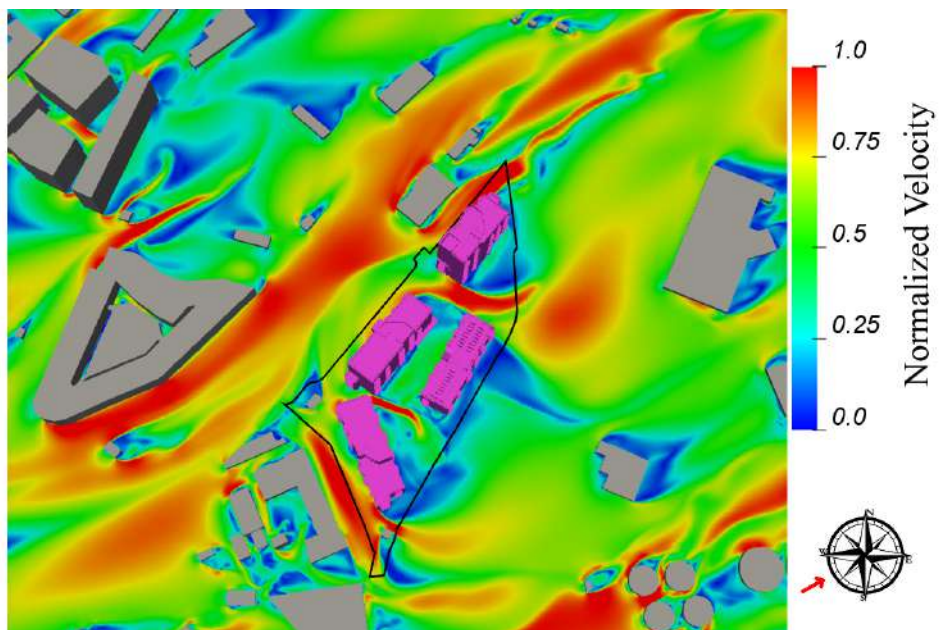


Figure 8.19: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 240°

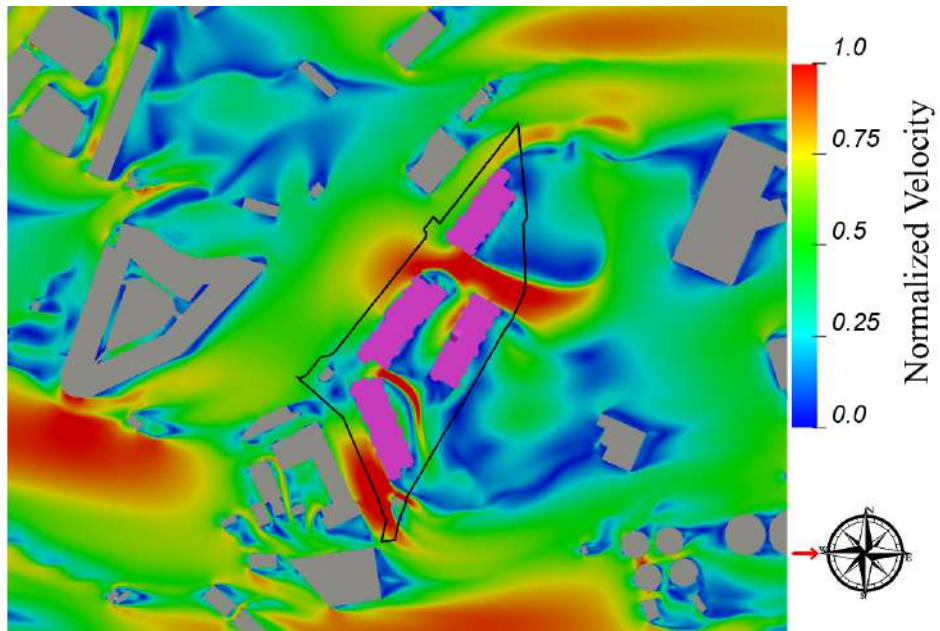


Figure 8.20: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 270°

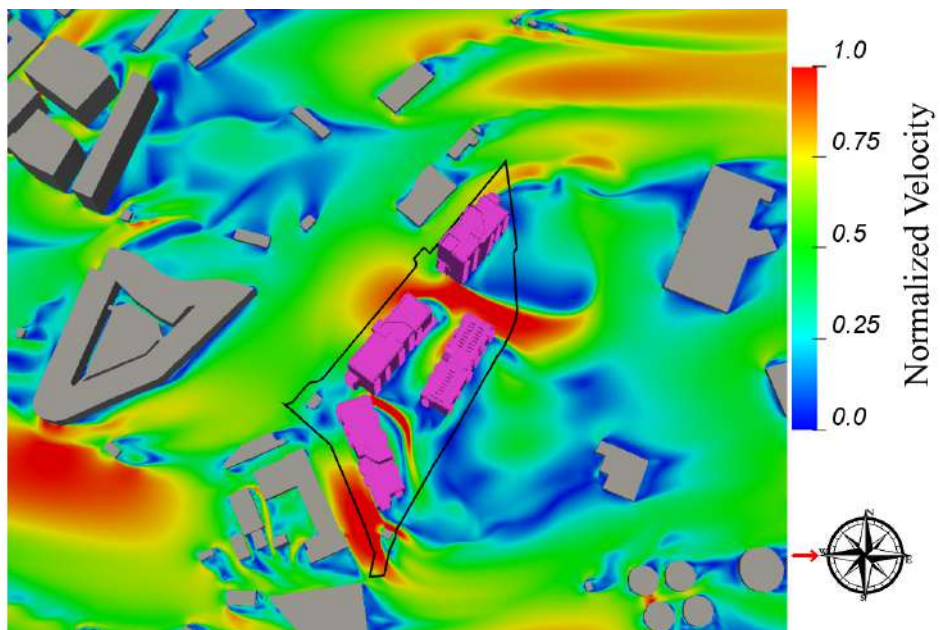


Figure 8.21: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 270°

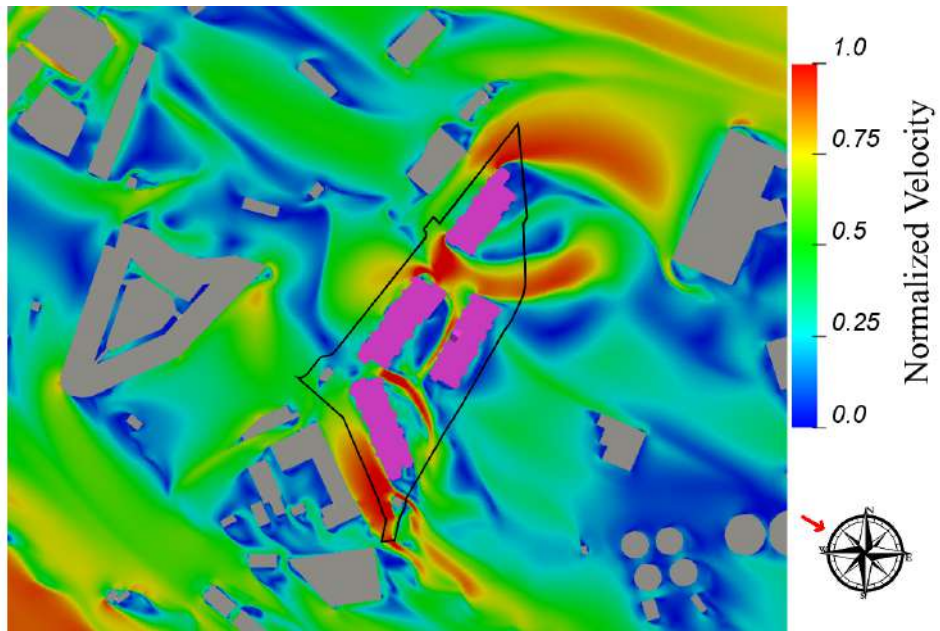


Figure 8.22: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 300°

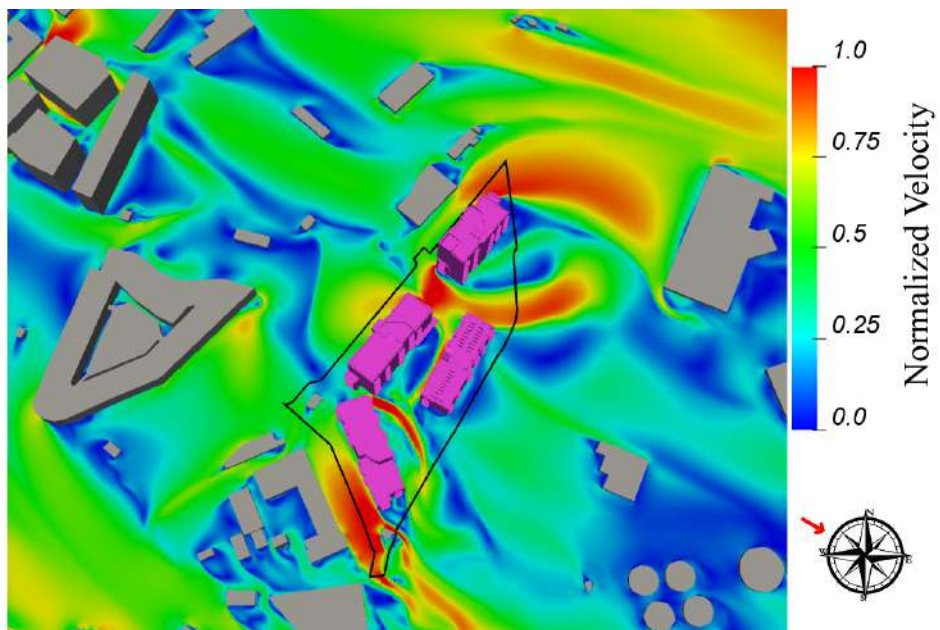


Figure 8.23: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 300°

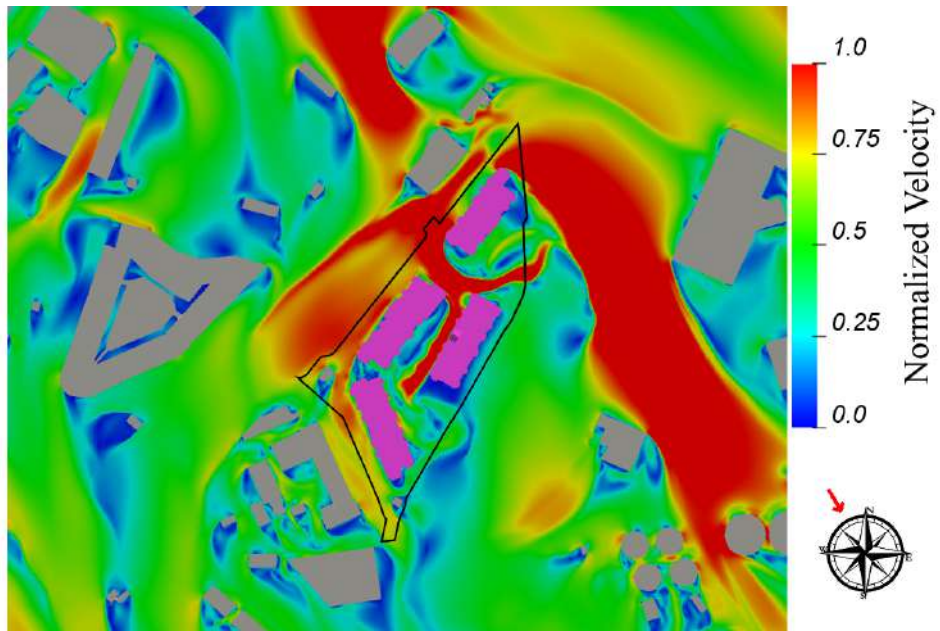


Figure 8.24: Top View -Flow Velocity Results at 1.5m above the ground - Wind Direction: 330°

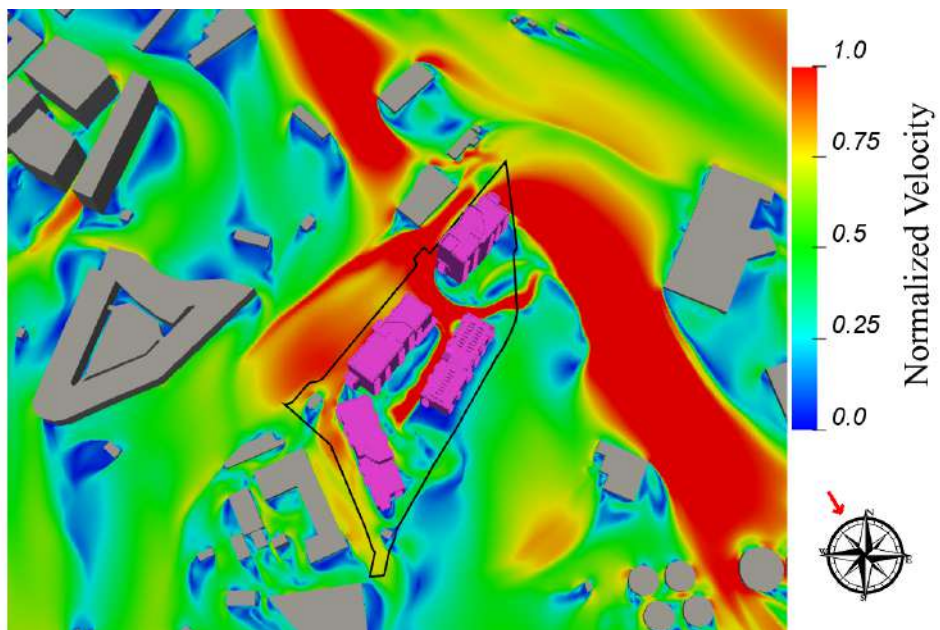


Figure 8.25: 3D View - Flow Velocity Results at 1.5m above the ground - Wind Direction: 330°

8.2.2 PROPOSED DEVELOPMENT WIND MICROCLIMATE - Lawson Criteria

The wind flow results obtained simulating the different direction and wind speeds, are combined with wind frequencies of occurrence to obtain comfort ratings at pedestrian level in all areas included within the model. The comparison of comfort ratings with intended pedestrian activities is shown in the Lawson Comfort and Distress Map that follows. The comfort/distress conditions are presented in Figures 8.26 and 8.27 using a colour coded diagram formulated in accordance with the Lawson Criteria.

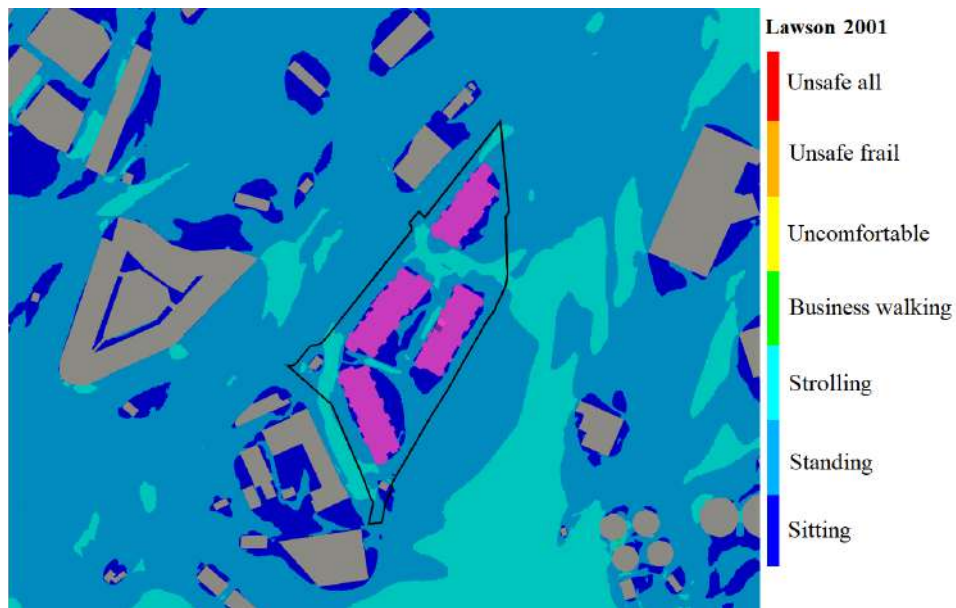


Figure 8.26: Lawson Discomfort Map - Top View

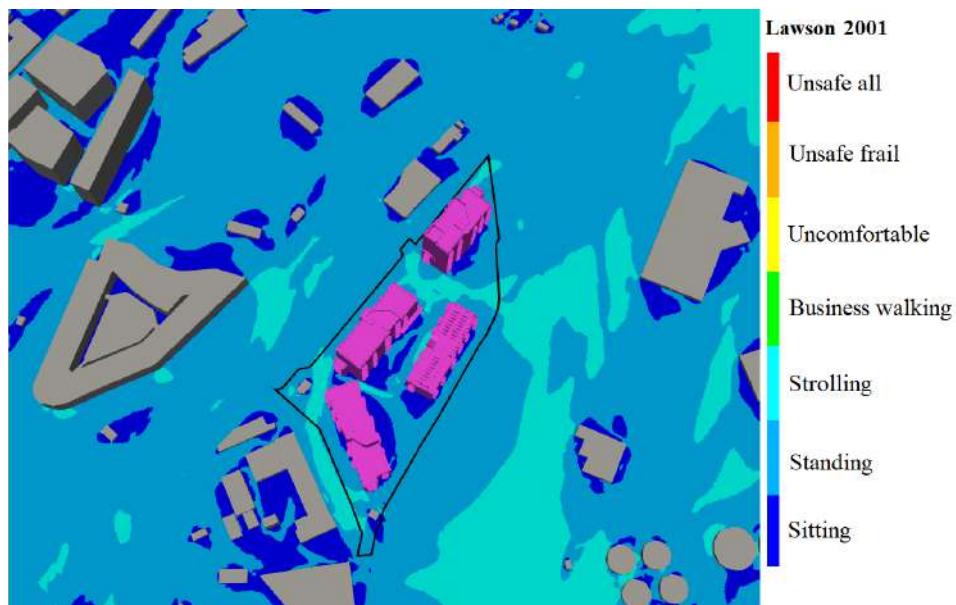


Figure 8.27: Lawson Discomfort Map - 3D View

In summary, the following conclusions can be made observing the results of the wind microclimate analysis and comparing the results obtained, under the same wind conditions for the baseline scenario versus the proposed development scenario:

- The assessment of the proposed scenario has shown that no area is unsafe, and no conditions of distress are created by the proposed development.
- All the roads proposed can be used for their intended scope.
- The wind microclimate of the proposed development is comfortable and usable for pedestrians.

As a result of the proposed development construction, the wind on the surrounding urban context maintains the suitability of the surrounding urban environment for its intended purpose.

8.2.3 ON-SITE AND OFF-SITE RECEPTORS

Table 8.1-8.2 presents the pedestrian comfort levels for various off-site and on-site locations. As shown in the table, none of the areas are deemed unsafe, and all on-site receptors around the development are suitable for at least standing comfort level.

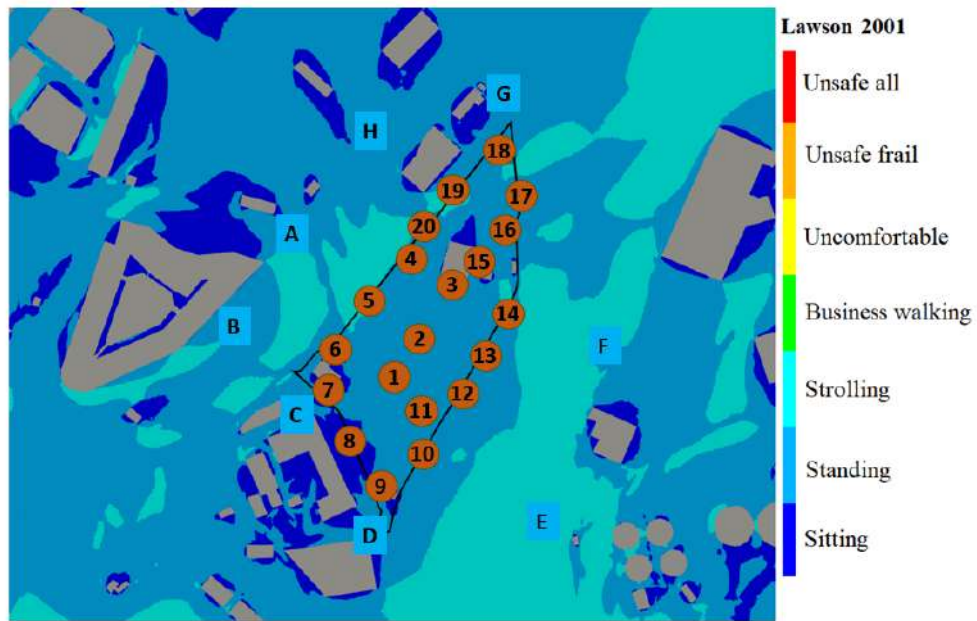
Table 8.1: Off-Site Pedestrian Comfort Levels versus Proposed Pedestrian Activities

Reference point	Description	Sitting	Standing	Strolling	Business walking	Distress and Safety
A.	Northwest	Tolerable	Tolerable	Acceptable	Acceptable	Safe.
B.	West	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
C.	Southwest	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
D.	South	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
E.	Southeast	Tolerable	Tolerable	Acceptable	Acceptable	Safe.
F.	East	Tolerable	Tolerable	Acceptable	Acceptable	Safe.
G.	Northeast	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
H.	North	Tolerable	Acceptable	Acceptable	Acceptable	Safe.

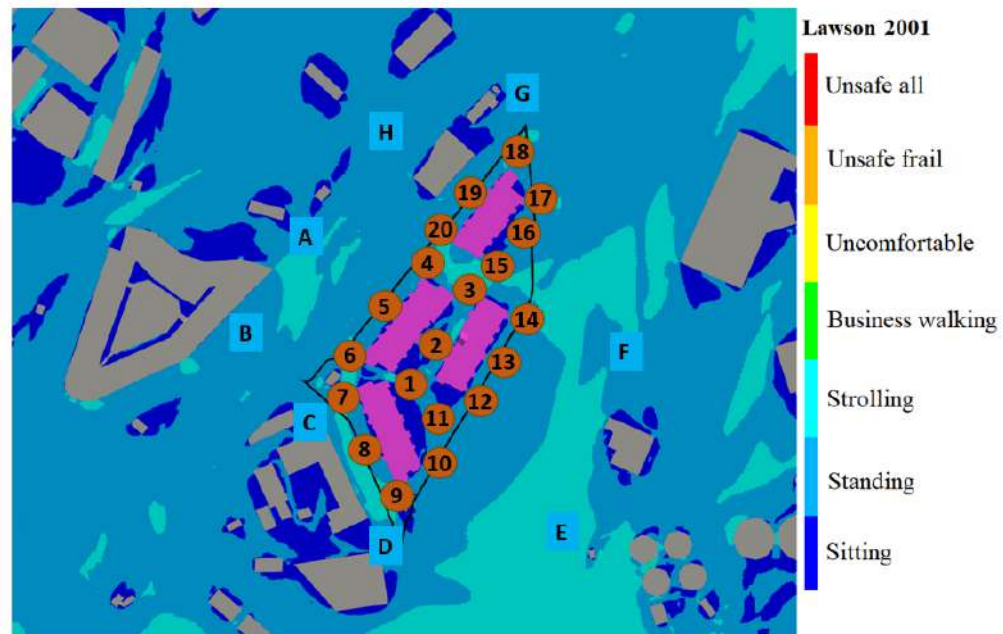
Table 8.2: On-Site Pedestrian Comfort Levels versus Proposed Pedestrian Activities

Reference point	Description	Sitting	Standing	Strolling	Business walking	Distress and Safety
1.	Southwest Corner	Acceptable	Acceptable	Acceptable	Acceptable	Safe.
2.	Central West	Acceptable	Acceptable	Acceptable	Acceptable	Safe.
3.	Northeast Corner	Tolerable	Tolerable	Acceptable	Acceptable	Safe.
4.	Northwest Corner	Tolerable	Tolerable	Acceptable	Acceptable	Safe.
5.	Southwest Side	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
6.	West Courtyard	Tolerable	Tolerable	Acceptable	Acceptable	Safe.
7.	Boundary edge	Tolerable	Tolerable	Acceptable	Acceptable	Safe.
8.	Southwest Pedestrian Access	Tolerable	Tolerable	Acceptable	Acceptable	Safe.
9.	Lower Southwest Boundary	Tolerable	Tolerable	Acceptable	Acceptable	Safe.
10.	Southeast Outer Edge	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
11.	Central Zone b/w Blocks	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
12.	East-Northeast Boundary	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
13.	East Courtyard Access	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
14.	Southeast Corner (Block C)	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
15.	Northern Block C Edge	Tolerable	Tolerable	Acceptable	Acceptable	Safe.
16.	Southern Block D Interface	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
17.	Eastern Edge (Facing River)	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
18.	North Edge	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
19.	West Block D Side	Tolerable	Acceptable	Acceptable	Acceptable	Safe.
20.	Southwest Block D Corner	Tolerable	Tolerable	Acceptable	Acceptable	Safe.

A comparison of Lawson Discomfort Maps for the baseline scenario and the proposed scenario is presented in Figure 8.28.



Baseline Scenario



Proposed Development Scenario

Figure 8.28: Comparison Wind Microclimate Conditions (Lawson Comfort/Distress Map)

Tables 8.3 and 8.4 show the intended baseline and proposed wind conditions on-site as well as some potential off-site receptors around the development. These tables show that there are no distress areas for pedestrians including frail users and cyclists. Furthermore, the site and surrounding urban areas are safe for all users.

Table 8.3: Significance Impact of the Proposed Development Versus Baseline Conditions for Comfort - On Site Receptors

On-Site Potential Receptors	Baseline Conditions	Proposed Development Conditions	Impact Significance
1. Southwest Corner	Suitable for Standing/Strolling.	Suitable for Sitting/Standing/Strolling. (Safe/No distress)	Negligible
2. Central West	Suitable for Standing/Strolling.	Suitable for Sitting/Standing/Strolling. (Safe/No distress)	Negligible
3. Northeast Corner	Suitable for Standing/Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible
4. Northwest Corner	Suitable for Standing/Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible
5. Southwest Side	Suitable for Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
6. West Courtyard	Suitable for Standing/Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible
7. Boundary edge	Suitable for Sitting/Standing/Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible
8. Southwest Pedestrian Access	Suitable for Sitting/Standing/Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible
9. Lower Southwest Boundary	Suitable for Standing/Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible
10. Southeast Outer Edge	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
11. Central Zone b/w Blocks	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
12. East-Northeast Boundary	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
13. East Courtyard Access	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
14. Southeast Corner (Block C)	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
15. Northern Block C Edge	Suitable for Sitting/Standing/Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible
16. Southern Block D Interface	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
17. Eastern Edge (Facing River)	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
18. North Edge	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
19. West Block D Side	Suitable for Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
20. Southwest Block D Corner	Suitable for Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible

Table 8.4: Significance Impact of the Proposed Development Versus Baseline Conditions for Comfort - Off Site Receptors

Off-Site Potential Receptors	Baseline Conditions	Proposed Development Conditions	Impact Significance
A. Northwest	Suitable for Standing/Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible
B. West	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
C. Southwest	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
D. South	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
E. Southeast	Suitable for Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible
F. East	Suitable for Strolling.	Suitable for Strolling. (Safe/No distress)	Negligible
G. Northeast	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
H. North	Suitable for Standing/Strolling.	Suitable for Standing/Strolling. (Safe/No distress)	Negligible

8.2.4 BALCONIES

The comparison of comfort ratings with the intended pedestrian activities is depicted in the Lawson Comfort and Distress Map on the 1.5m balcony floor, as illustrated in Figures 8.29 to 8.36. It is evident that all the balconies are deemed safe for occupants, with no distress areas identified.

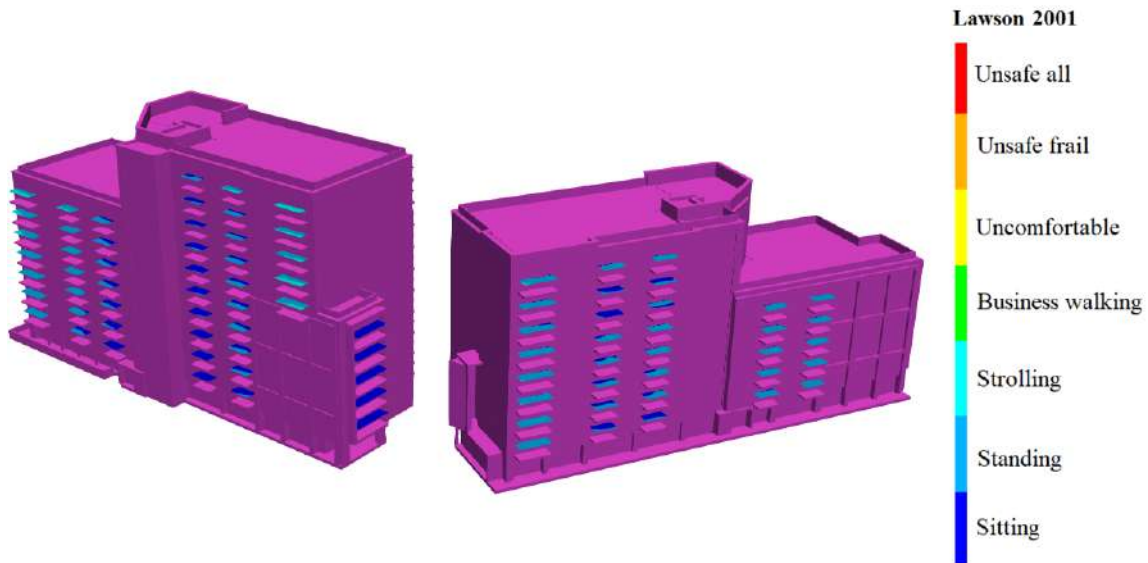


Figure 8.29: Balconies of Block A and B - Lawson Discomfort Map - Proposed scenario - View from West

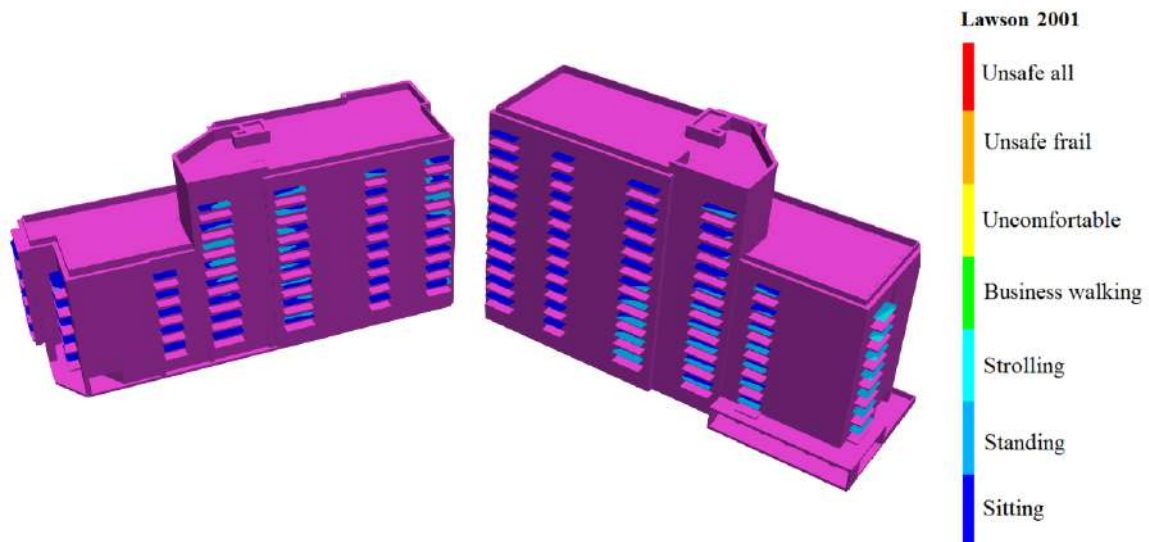


Figure 8.30: Balconies of Block A and B - Lawson Discomfort Map - Proposed scenario - View from East

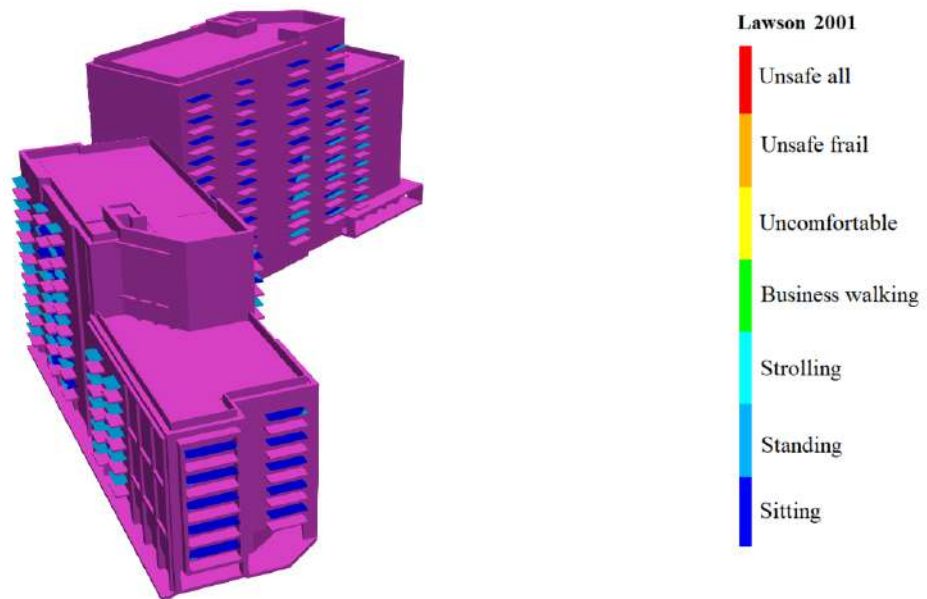


Figure 8.31: Balconies of Block A and B - Lawson Discomfort Map - Proposed scenario - View from South

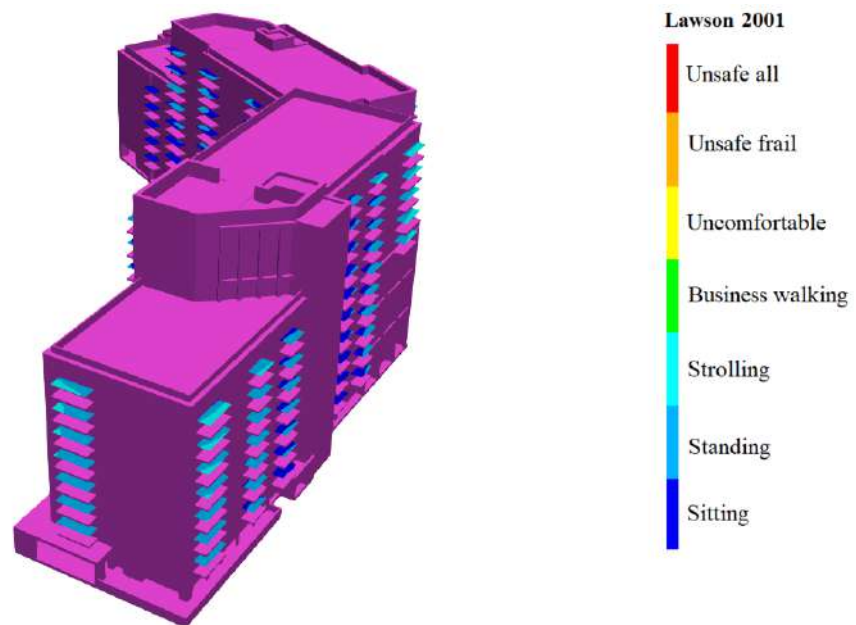


Figure 8.32: Balconies of Block A and B - Lawson Discomfort Map - Proposed scenario - View from North

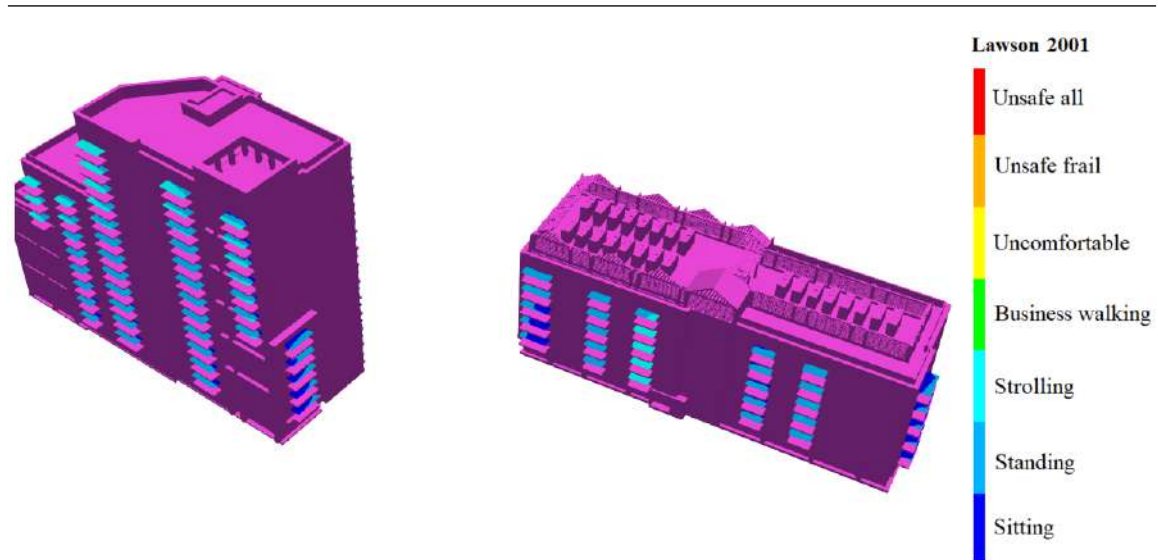


Figure 8.33: Balconies of Block C and D - Lawson Discomfort Map - Proposed scenario - View from West

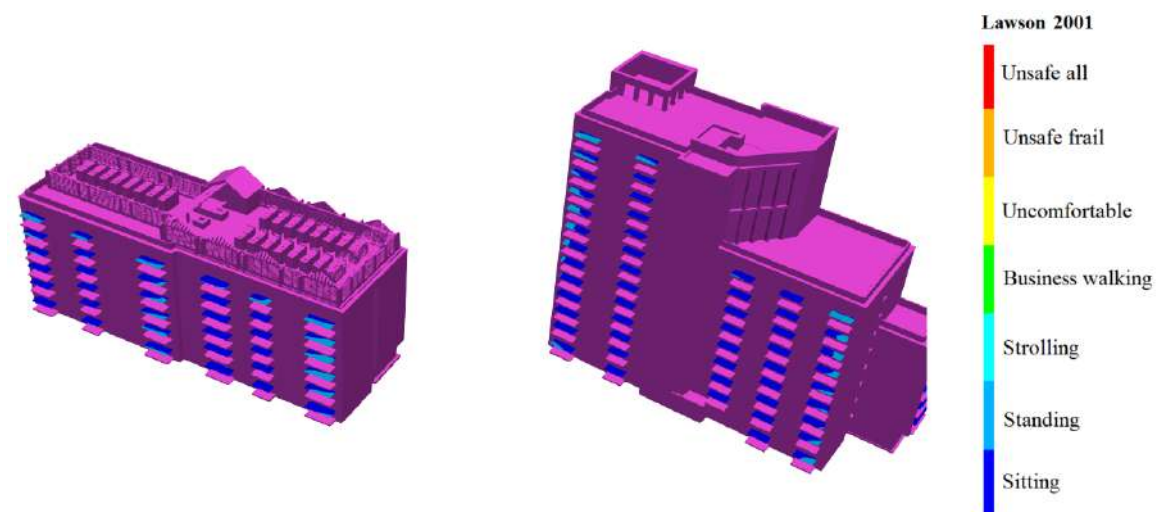


Figure 8.34: Balconies of Block C and D - Lawson Discomfort Map - Proposed scenario - View from East

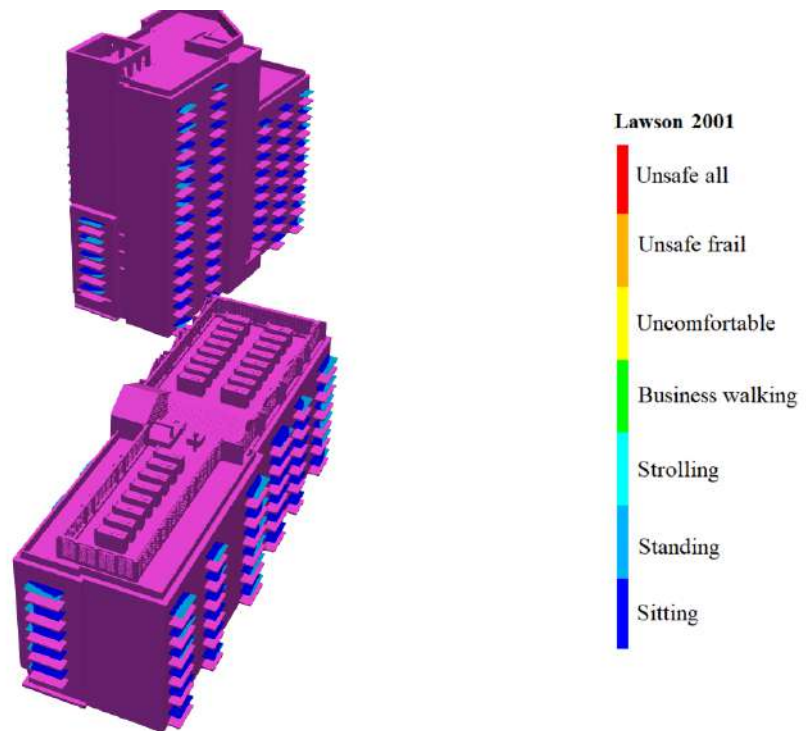


Figure 8.35: Balconies of Block C and D - Lawson Discomfort Map - Proposed scenario - View from South

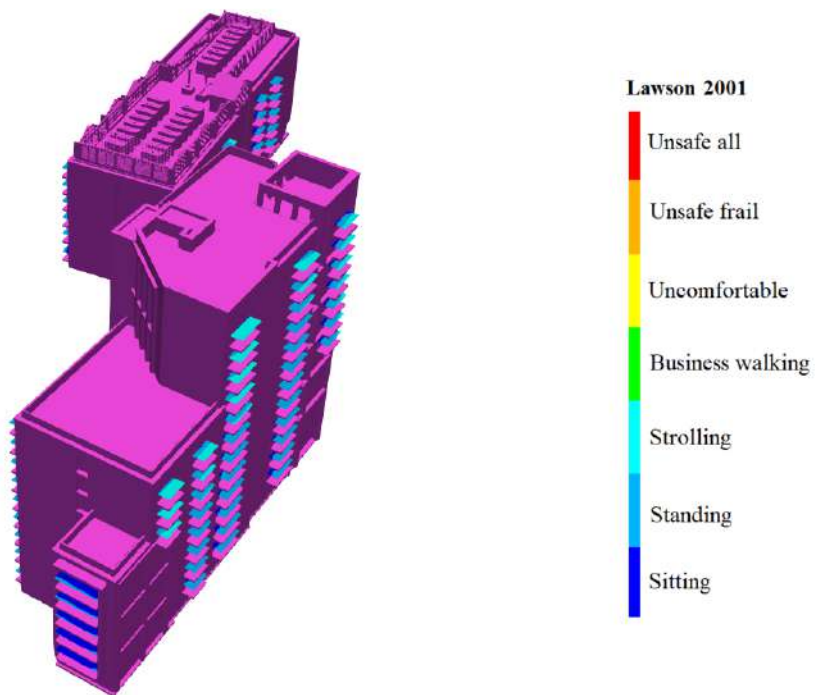


Figure 8.36: Balconies of Block C and D - Lawson Discomfort Map - Proposed scenario - View from North

9. CUMULATIVE IMPACT

This section assessed the potential impact of potential cumulative buildings (that are envisioned as part of the Galway Harbour Company Masterplan and will be subject to future planning application) on the proposed development, and the suitability of these potential cumulative buildings to create and maintain a suitable and comfortable environment for different pedestrian activities.

9.1 OPERATIONAL PHASE

This section shows CFD results of wind microclimate assessment carried out considering the "Operational Phase" of Galway Port LRD. In this case the assessment has considered the impact of wind on the existing area including the proposed Galway Port LRD and the potential future buildings but not constructed yet. They are envisioned as part of the Galway Harbour Company Masterplan and will be subject to future planning application. Wind simulations have been carried out on all the various directions for which the development could show critical areas in terms of pedestrian comfort and safety.

Results of wind microclimate at pedestrian level (1.5m height - flow speeds) are collected throughout the modelled site. These flow velocities identify if locally, wind speeds at pedestrian-level are accelerated or decelerated in relation to the undisturbed reference wind speed due to the presence of the existing baseline environment and potential future buildings (but not built yet).

The impact of these speeds are then combined with their specific frequency of occurrence and presented in the maps that show the area of comfort and distress in accordance with Lawson Criteria, these maps are produced at pedestrian level on the ground and on the roof terraces and identify the suitability of each areas to its prescribed level of usage and activity.



Figure 9.1: A 3D View of the Proposed Development Buildings (colored in red) and the Cumulative Buildings (colored in orange)

9.1.1 WIND SPEEDS - Pedestrian Level

Results of wind speeds and their circulations at pedestrian level of 1.5m above the ground are presented in Figures 9.2 to 9.25 in order to assess wind flows at ground floor level of Galway Port LRD.

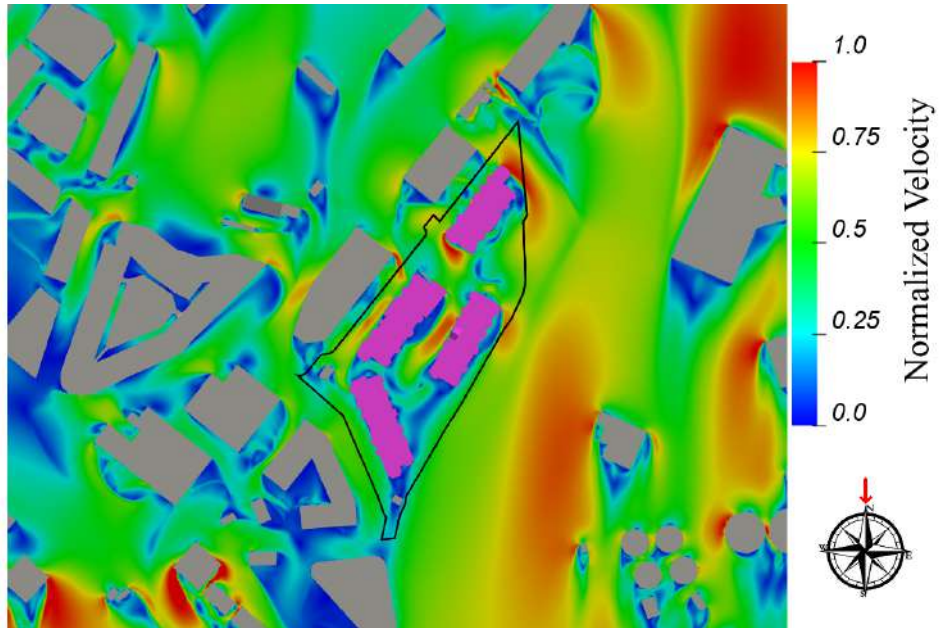


Figure 9.2: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 0°

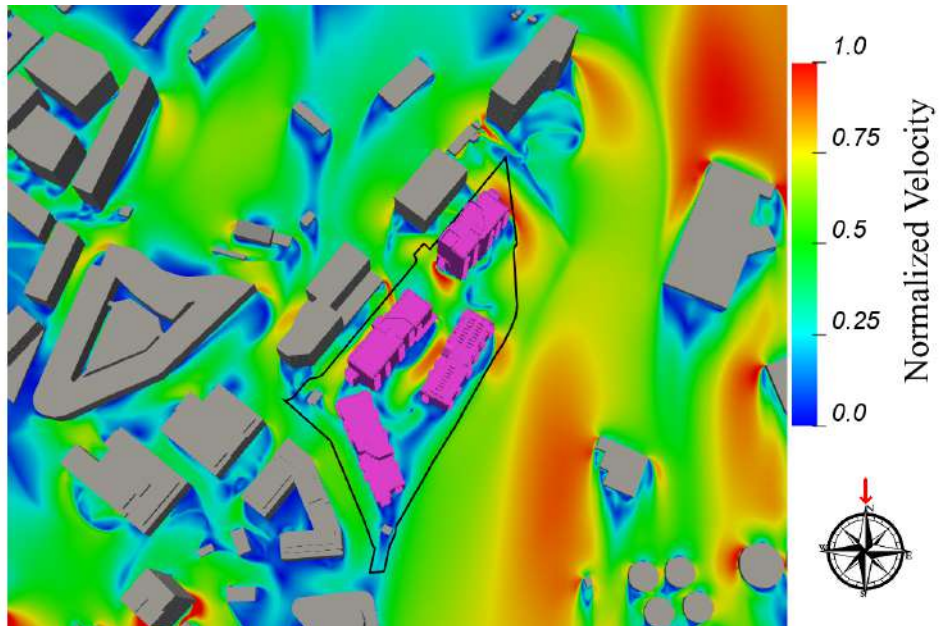


Figure 9.3: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 0°

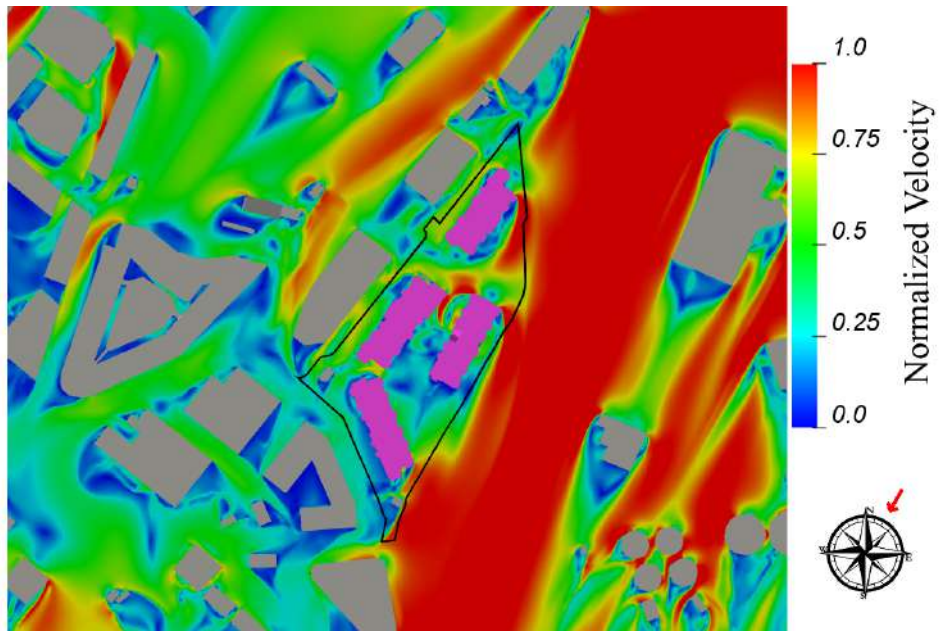


Figure 9.4: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 30°

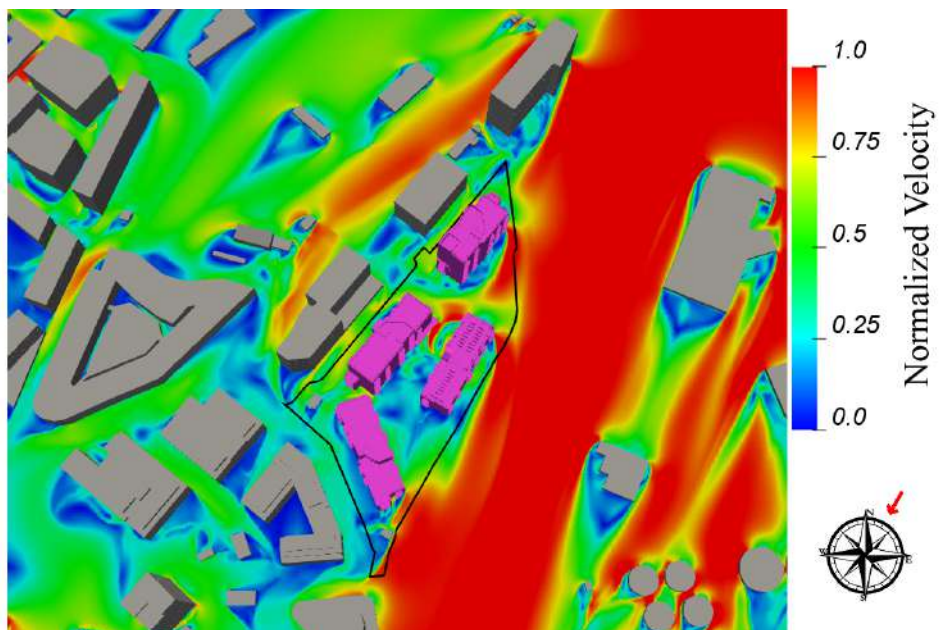


Figure 9.5: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 30°

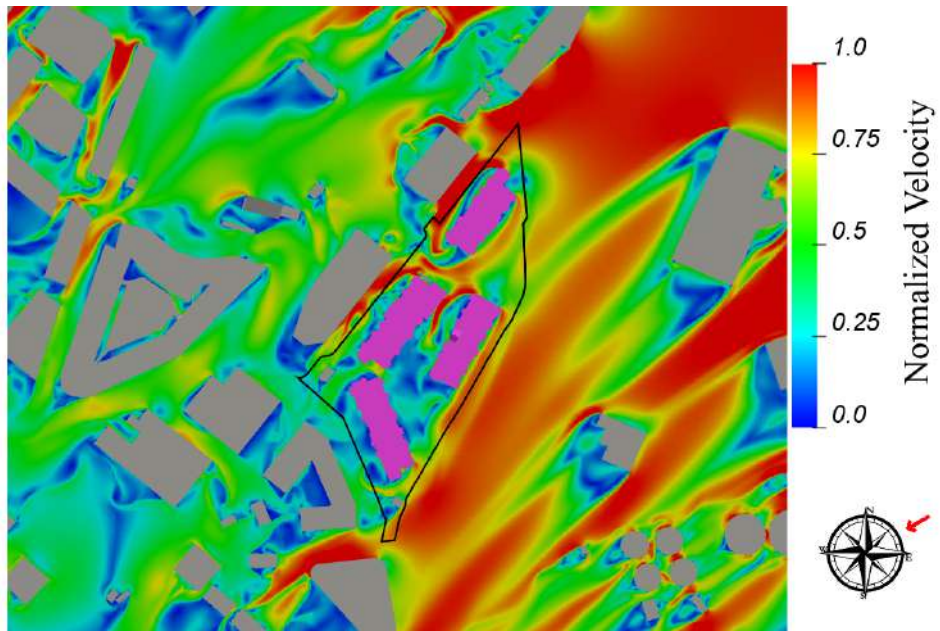


Figure 9.6: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 60°

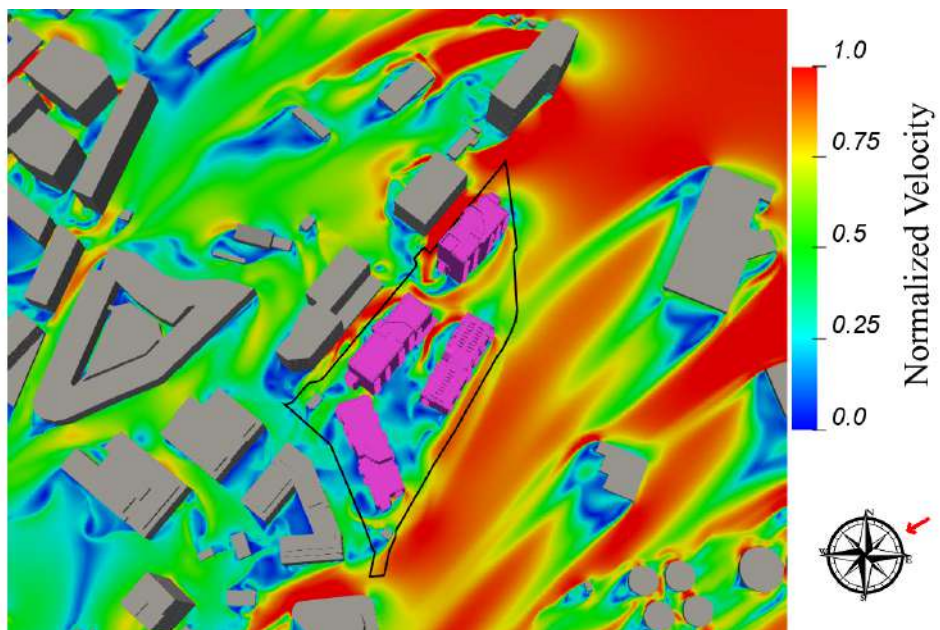


Figure 9.7: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 60°

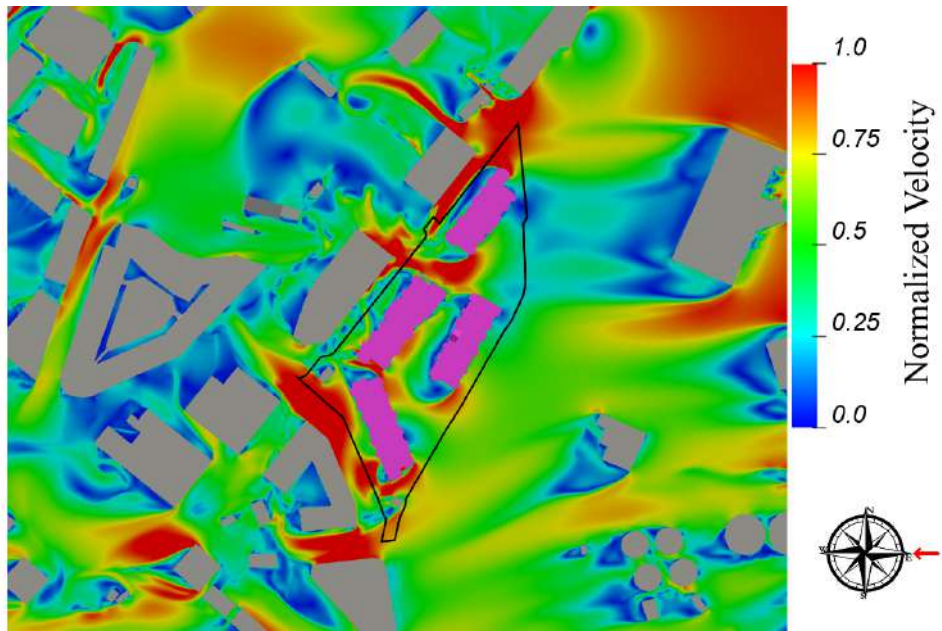


Figure 9.8: Top View - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 90°

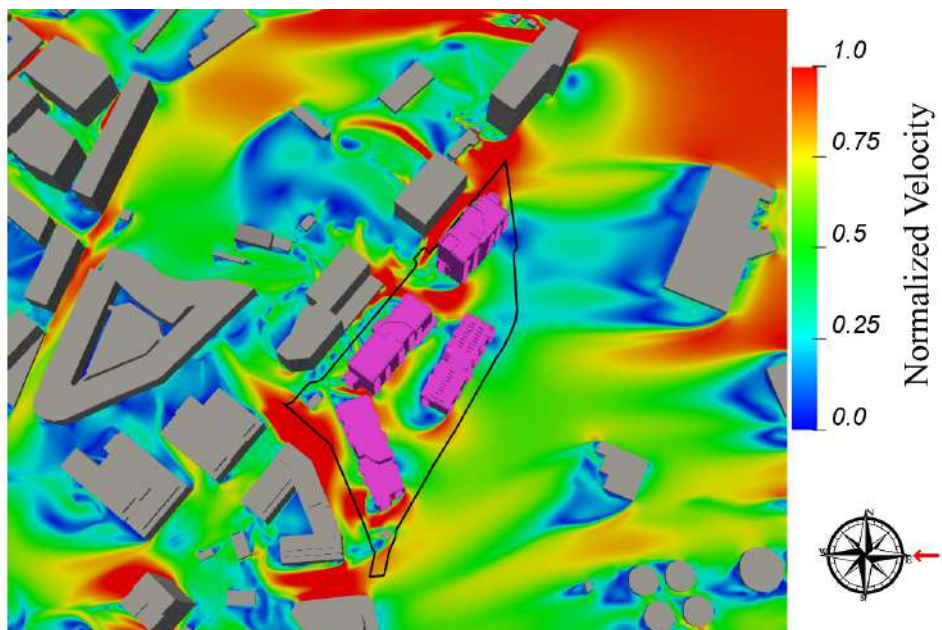


Figure 9.9: 3D View - Flow Velocity Results at $Z=1.5\text{m}$ above the ground - Wind Direction: 90°

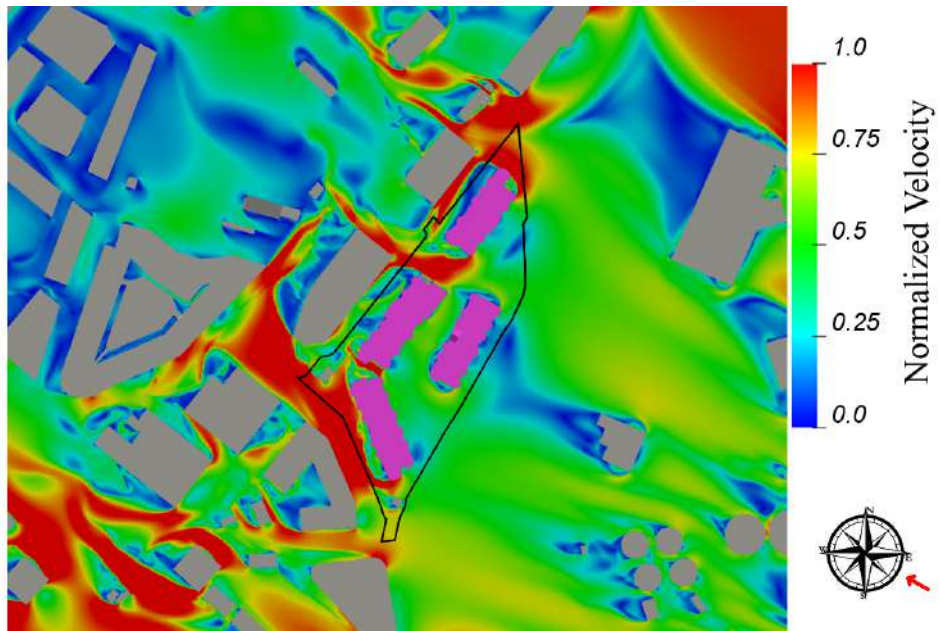


Figure 9.10: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 120°

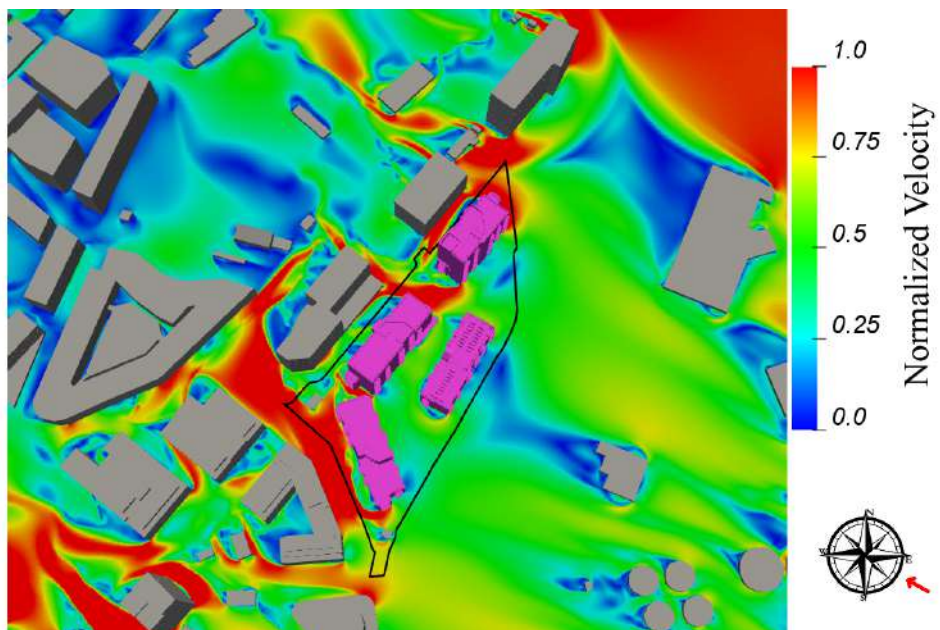


Figure 9.11: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 120°

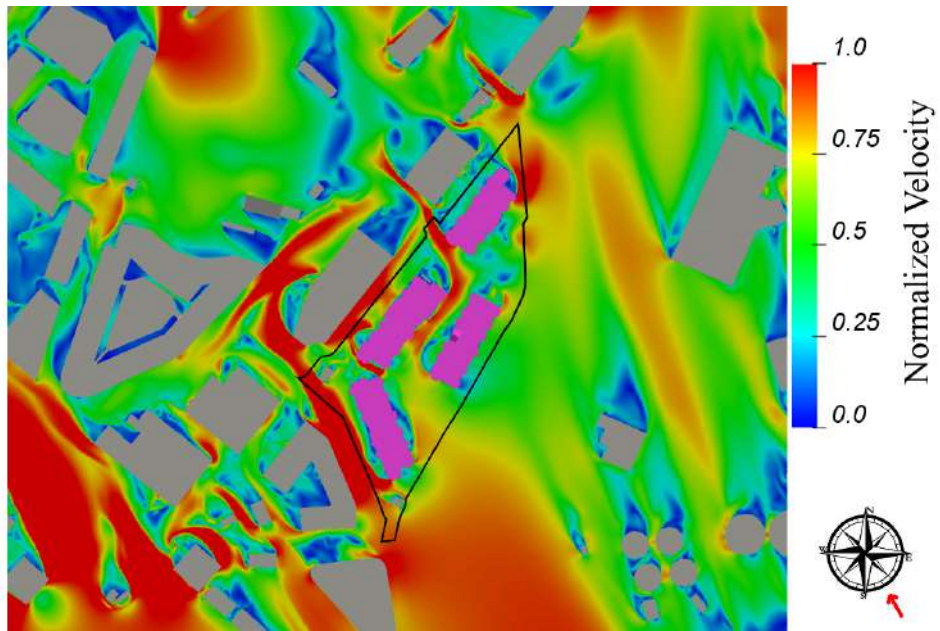


Figure 9.12: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 150°

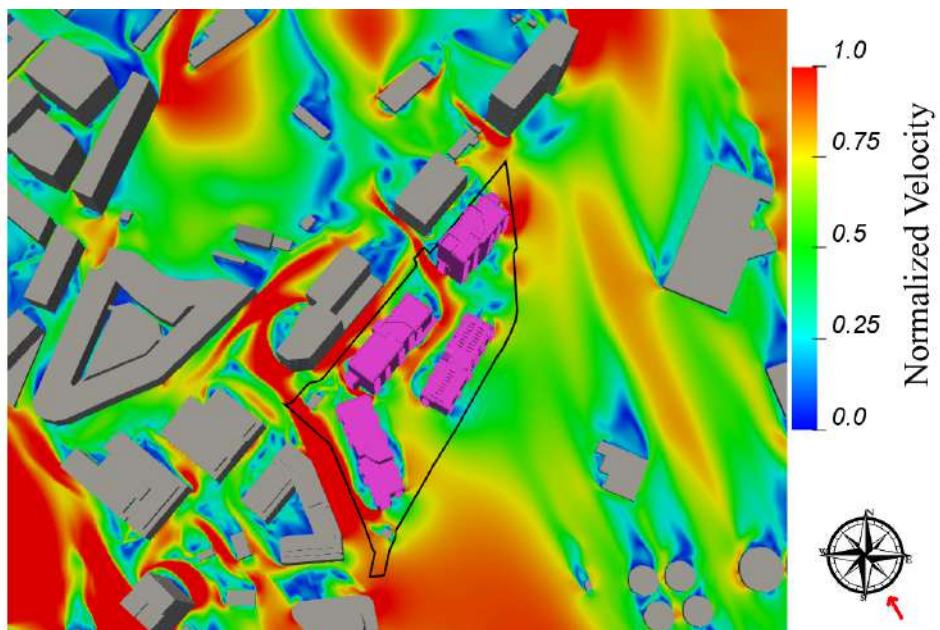


Figure 9.13: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 150°

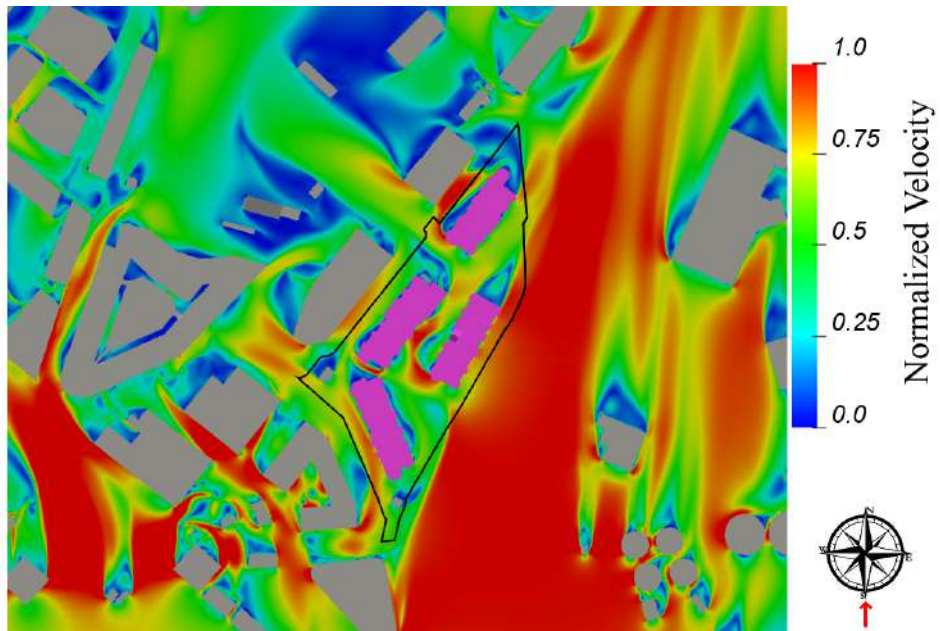


Figure 9.14: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 180°

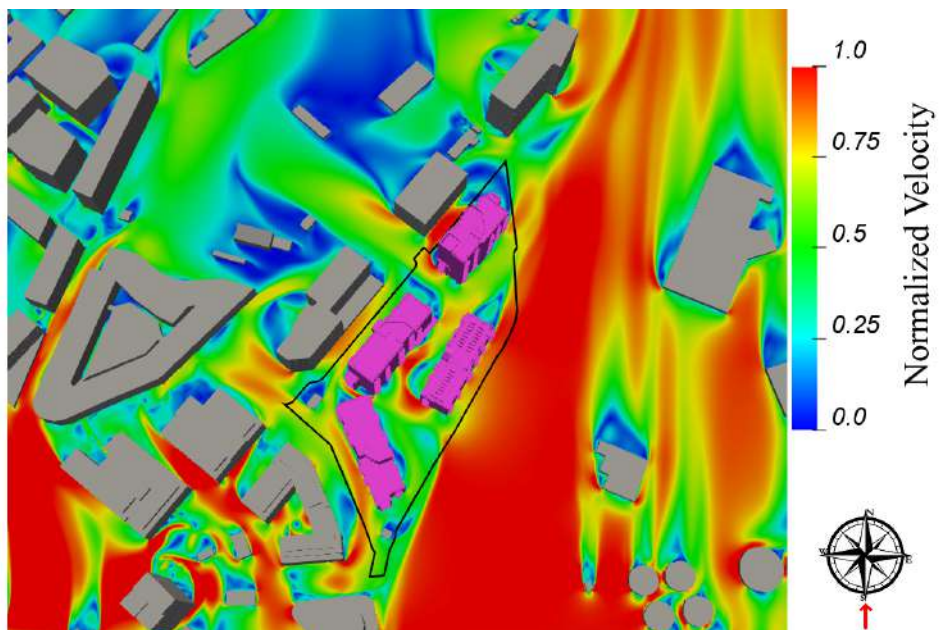


Figure 9.15: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 180°

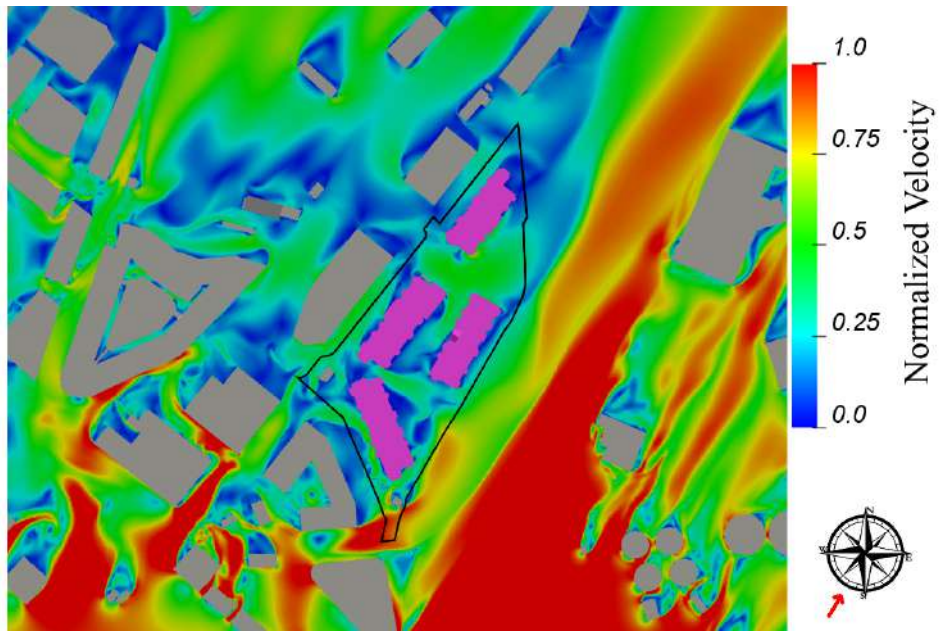


Figure 9.16: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 210°

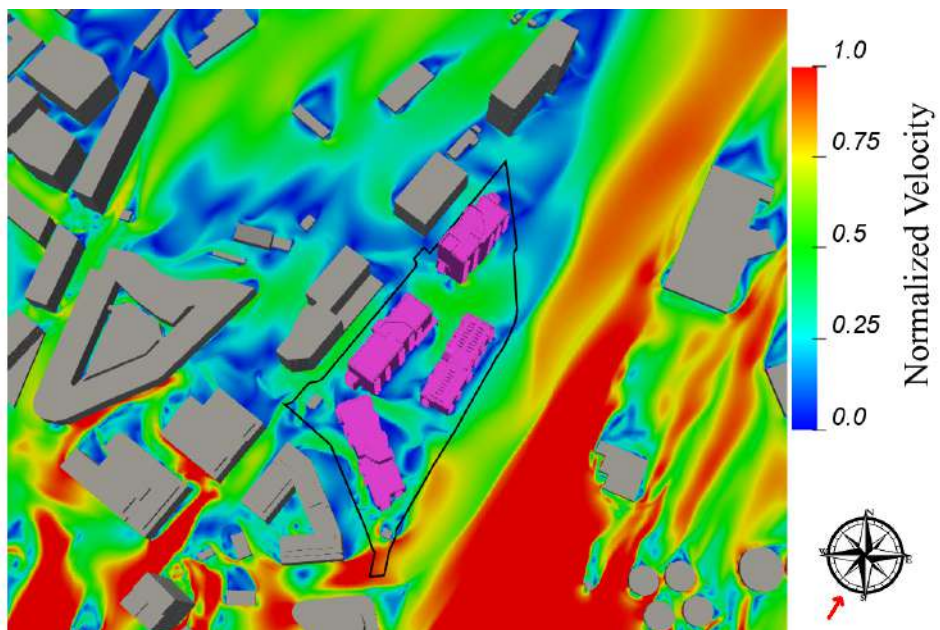


Figure 9.17: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 210°

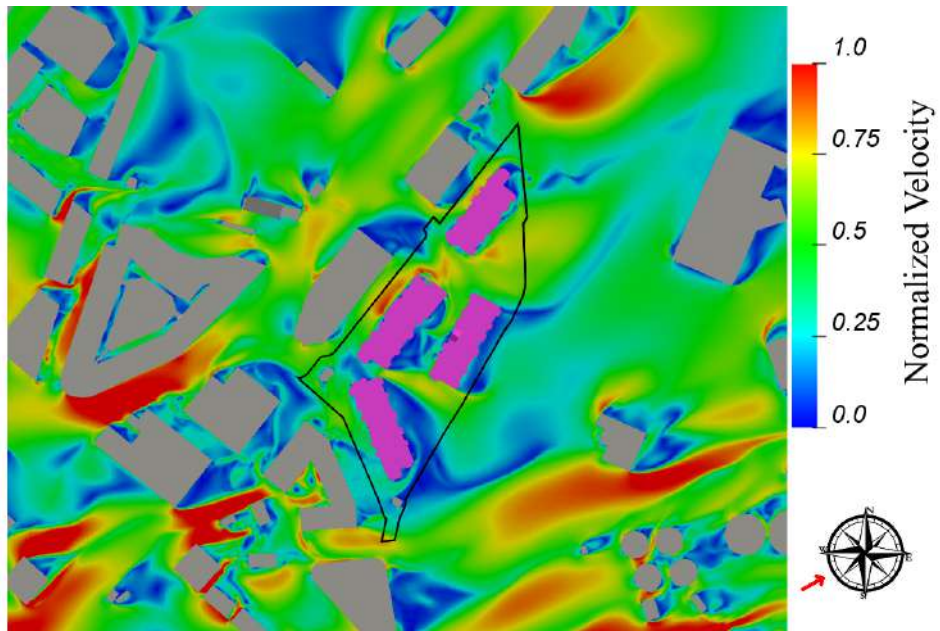


Figure 9.18: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 240°

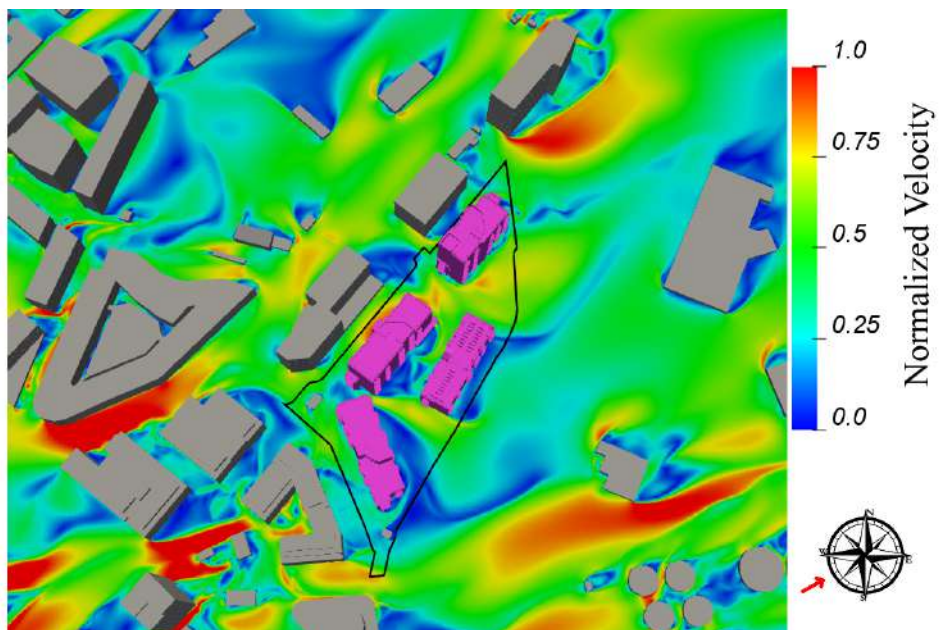


Figure 9.19: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 240°

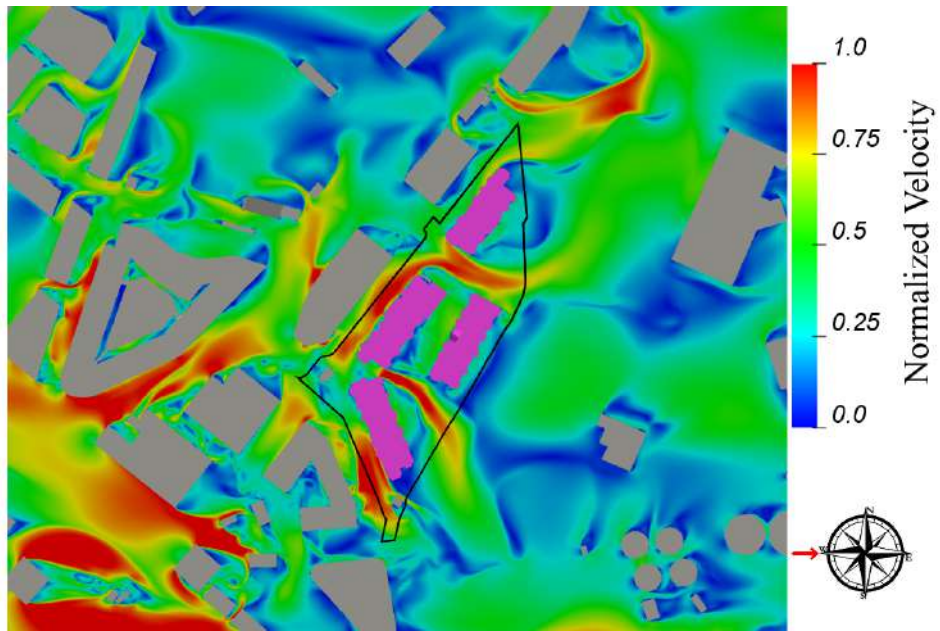


Figure 9.20: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 270°

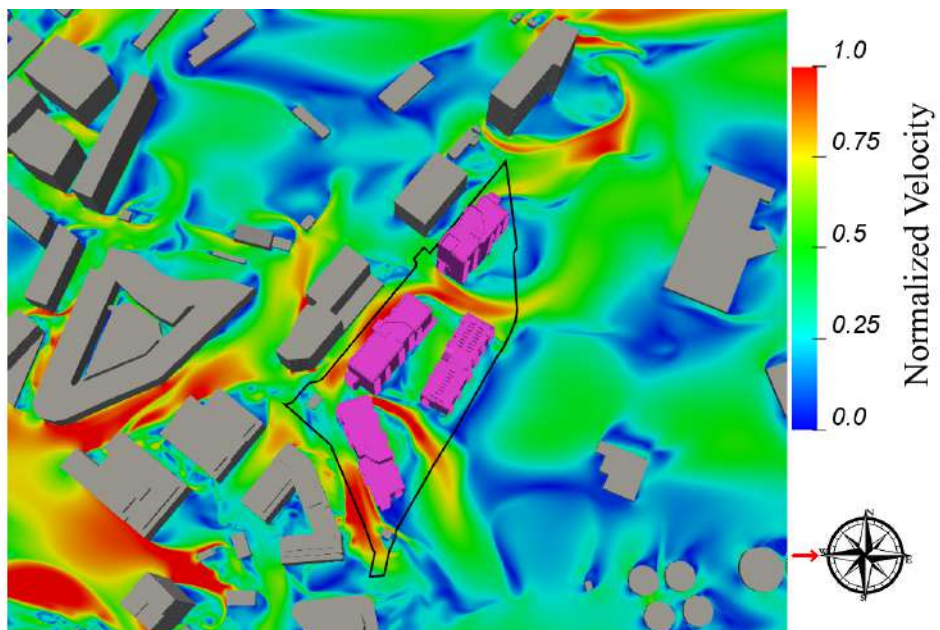


Figure 9.21: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 270°

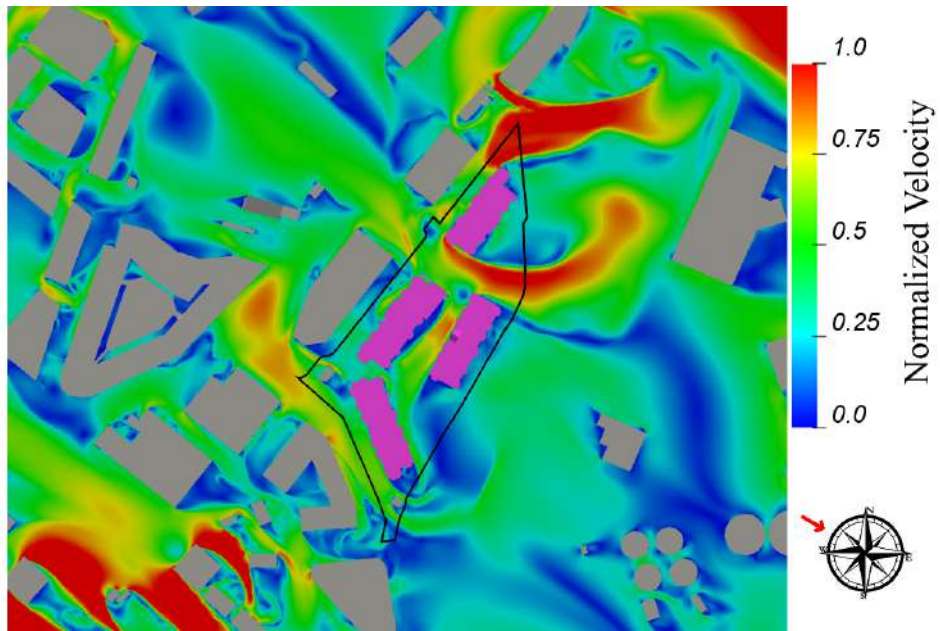


Figure 9.22: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 300°

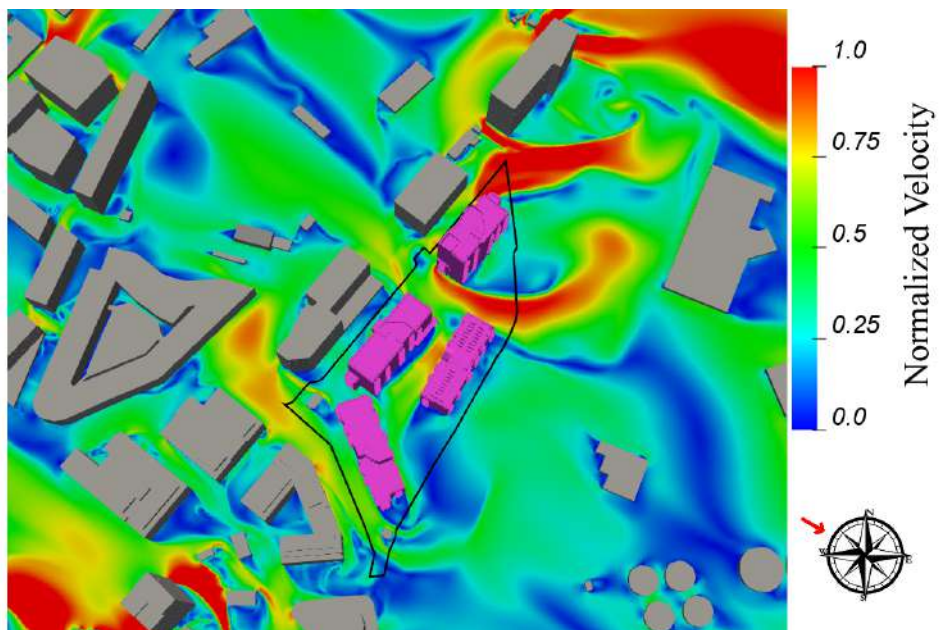


Figure 9.23: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 300°

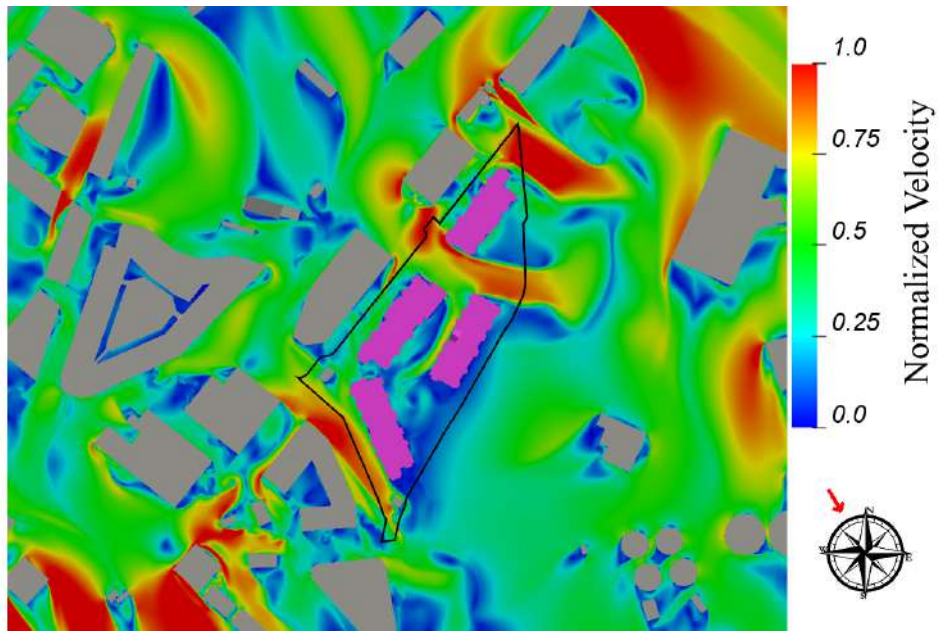


Figure 9.24: Top View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 330°

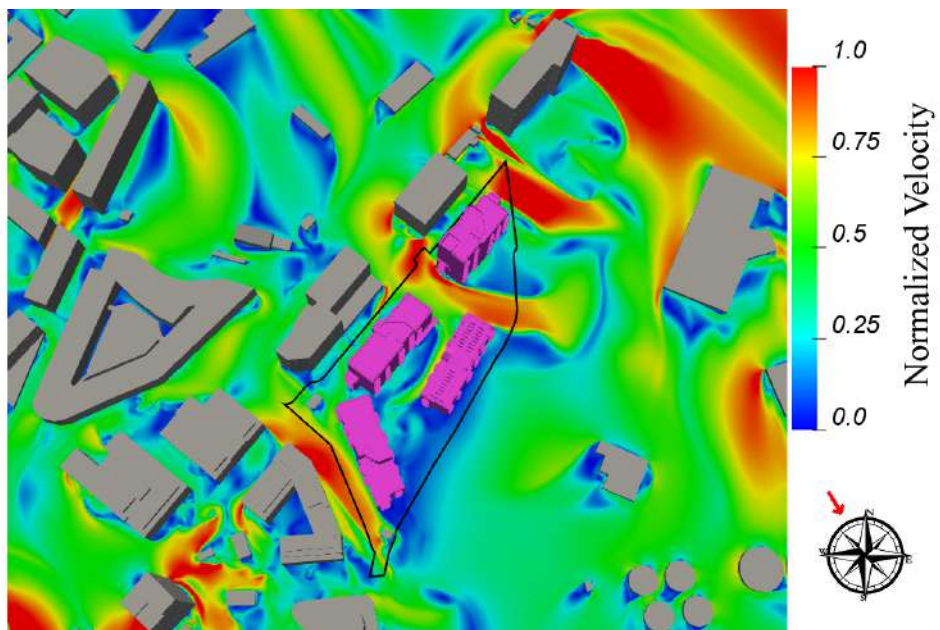
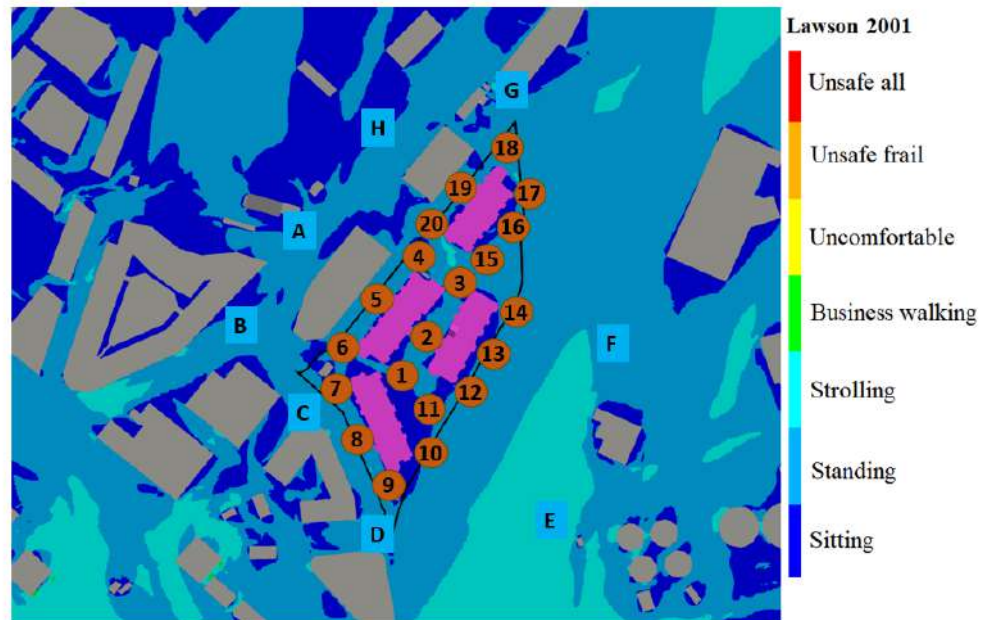


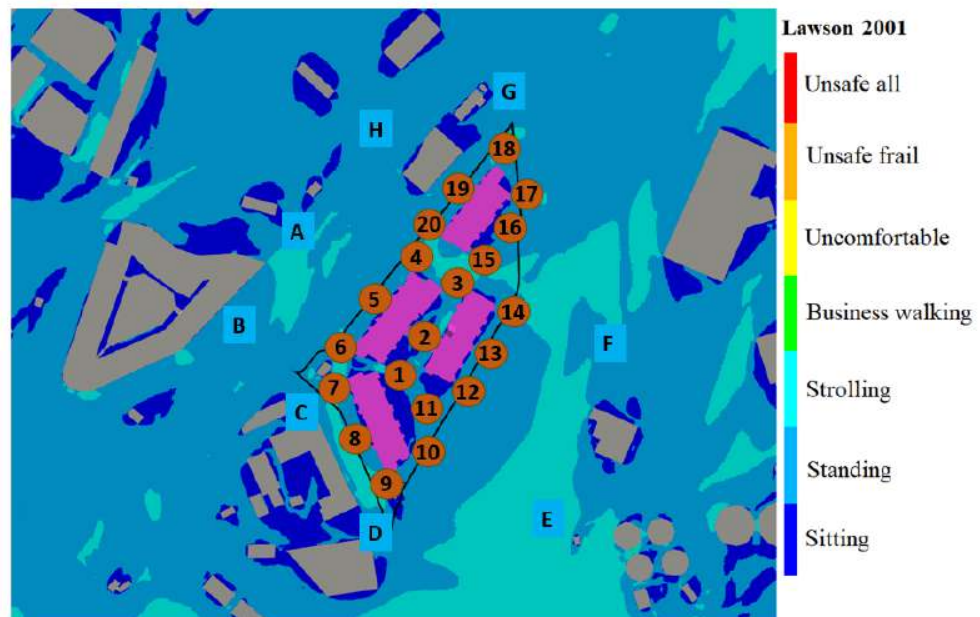
Figure 9.25: 3D View - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 330°

9.1.2 CUMULATIVE IMPACT - Lawson Criteria

A comparison of Lawson Comfort and Distress Maps for proposed development scenario and the cumulative scenario is presented in Figure 9.26.



Cumulative Scenario



Proposed Development Scenario

Figure 9.26: Comparison Wind Microclimate Conditions (Lawson Comfort/Distress Map)

Tables 9.1 and 9.2 show the proposed and cumulative wind conditions on-site as well as some potential off-site receptors around the development. Locations of the ground amenity areas listed in these Tables are indicated in Figure 9.26.

Table 9.1: Significance Impact of the Cumulative Scenario Versus Proposed Conditions for Comfort - On Site Receptors

On-Site Potential Receptors	Proposed Development Conditions	Cumulative Conditions	Impact Significance
1. Southwest Corner	Suitable for Sitting/Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
2. Central West	Suitable for Sitting/Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
3. Northeast Corner	Suitable for Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
4. Northwest Corner	Suitable for Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
5. Southwest Side	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
6. West Courtyard	Suitable for Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
7. Boundary edge	Suitable for Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
8. Southwest Pedestrian Access	Suitable for Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
9. Lower Southwest Boundary	Suitable for Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
10. Southeast Outer Edge	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Sitting/Standing/Strolling. (Safe/No distress)	Negligible
11. Central Zone b/w Blocks	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Sitting/Standing/Strolling. (Safe/No distress)	Negligible
12. East-Northeast Boundary	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
13. East Courtyard Access	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
14. Southeast Corner (Block C)	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
15. Northern Block C Edge	Suitable for Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
16. Southern Block D Interface	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
17. Eastern Edge (Facing River)	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
18. North Edge	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
19. West Block D Side	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
20. Southwest Block D Corner	Suitable for Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible

Table 9.2: Significance Impact of the Cumulative Scenario Versus Proposed Conditions for Comfort - Off Site Receptors

Off-Site Potential Receptors	Proposed Development Conditions	Cumulative Conditions	Impact Significance
A. Northwest	Suitable for Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
B. West	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
C. Southwest	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
D. South	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
E. Southeast	Suitable for Strolling. (Safe/No distress)	Suitable for Strolling. (Safe/No distress)	Negligible
F. East	Suitable for Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
G. Northeast	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Standing/Strolling. (Safe/No distress)	Negligible
H. North	Suitable for Standing/Strolling. (Safe/No distress)	Suitable for Sitting/Standing/Strolling. (Safe/No distress)	Negligible

As shown in Tables 8.3 and 8.4, there are no distress area for pedestrians including frail users and cyclist. furthermore, the site and surrounding urban areas are safe for all users.

10. CONCLUSIONS

CONCLUSIONS and COMMENTS ON MICROCLIMATE STUDY

This report presents the CFD modelling assumptions and results of Wind and Microclimate Modelling of Galway Port LRD, Galway Port, Galway.

This study has been carried out to identify the possible wind patterns around the area proposed, under mean and peak wind conditions typically occurring in Galway, and also to assess impacts of the wind on pedestrian levels of comfort/distress.

The results of this wind microclimate study are utilized by The Land Development Agency to configure the optimal layout for Galway Port LRD for the aim of achieving a high-quality environment for the scope of use intended of each areas/building (i.e. comfortable and pleasant for potential pedestrian) and not to introduce any critical wind impact on the surrounding areas and on the existing buildings.

- The wind profile was built using the annual average of meteorology data collected at Galway Airport Weather Station purchased from Open Weather. The local wind speed was determined from CFD simulations with combination of the parameters inside Weibull probability distribution function, which was obtained from historical meteorological data recorded 10m above ground level at Galway Airport.
- A 12-discrete set of wind directions is used to evaluate the probability of exceedance at any given threshold speed. It was found that the prevailing wind directions in the west and south-west make the most significant contribution to the probability of discomfort exceedance.
- Microclimate Assessment of Galway Port LRD and its environment was performed utilizing a CFD (Computational Fluid Dynamics) methodology.
- The evaluation of the proposed scenario indicates that the planned development aligns with the Lawson Comfort Criteria, confirming that no areas are unsafe and the proposed development does not create conditions of distress. All the ground amenities outlined in the report can be utilized according to their intended scope.
- The Lawson Comfort and Distress Map on 1.5m above balcony floor indicates that all balconies are safe for occupants with no identified distress areas.
- The following mitigation measures has been implemented to further improve pedestrian comfort around the development:
 - *Introducing additional trees on ground amenities of the development:*
These additional plants will help reduce wind speed, increasing comfort levels in all ground amenities of the development.
- As a result of the proposed development construction, the wind on the surrounding urban context remains suitable for the intended use when compared with the baseline situation.
- The proposed development does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings. 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.

-
- As a result of the construction of potential cumulative buildings that are envisioned as part of the Galway Harbour Company Masterplan and will be subject to future planning application, the wind conditions on the surrounding urban context remains the same when compared with the proposed development situation. The cumulative buildings will have a negligible effect on the surrounding wind microclimate.

Therefore, the CFD study carried out has shown that under the assumed wind conditions typically occurring within Galway for the past 16 years:

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

11. REFERENCES

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