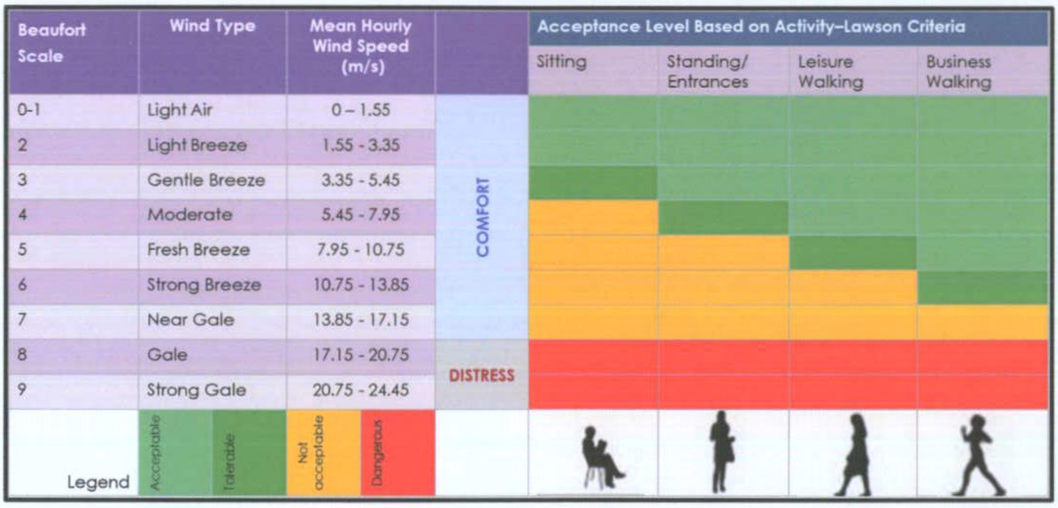
find physically difficult. Conditions in excess of this limit may be acceptable for optional routes and routes which less physically able individuals are unlikely to use.

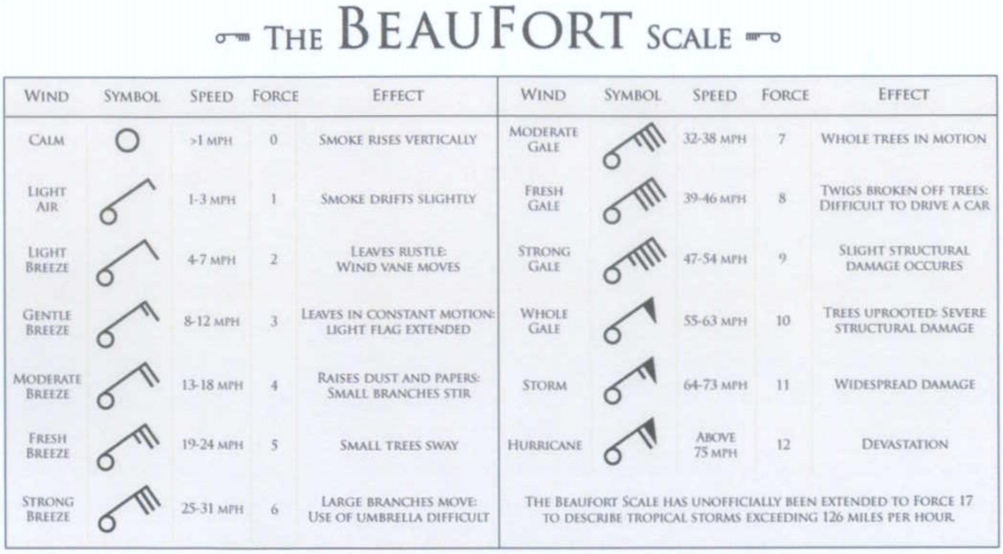
– 'General Public': A mean speed of 20 m/s and a gust speed of 37 m/s (83 mph) to be exceeded less often than once a year. Beyond this gust speed, aerodynamic forces approach body weight and it rapidly becomes impossible for anyone to remain standing. Where wind speeds exceed these values, pedestrian access should be discouraged.

The above criteria set out six pedestrian activities and reflect the fact that calm activity requires calm wind conditions, which are summarised by the Lawson scale, shown in Figure 3.5. Lawson scale assesses pedestrian wind comfort in absolute terms and defines the reaction of an average person to the wind. Each wind type is associated to a number, corresponding to the Beaufort scale, which is represented in Figure 3.6. Beaufort scale is an empirical measure that relates wind speed to observed conditions at sea or on land. A 20% exceedance is used in these criteria to determine the comfort category, which suggests that wind speeds would be comfortable for the corresponding activity at least 80% of the time or four out of five days.



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

Figure 3.5: Lawson Scale



THE BEAUFORT SCALE

Wind	Symbol	Speed	Force	Effect	Wind	Symbol	Speed	Force	Effect
Calm		>1 mph	0	Smoke rises vertically	Moderate Gale		32-38 mph	7	Whole trees in motion
Light Air		1-3 mph	1	Smoke drifts slightly	Fresh Gale		39-46 mph	8	Twigs broken off trees: Difficult to drive a car
Light Breeze		4-7 mph	2	Leaves rustle: Wind vane moves	Strong Gale		47-54 mph	9	Slight structural damage occures
Gentle Breeze		8-12 mph	3	Leaves in constant motion: Light flag extended	Whole Gale		55-63 mph	10	Trees uprooted: Severe structural damage
Moderate Breeze		13-18 mph	4	Raises dust and papers: Small branches stir	Storm		64-73 mph	11	Widespread damage
Fresh Breeze		19-24 mph	5	Small trees sway	Hurricane		Above 75 mph	12	Devastation
Strong Breeze		25-31 mph	6	Large branches move: Use of umbrella difficult	The Beaufort Scale has unofficially been extended to Force 17 to describe tropical storms exceeding 126 miles per hour.				

Figure 3.6: Beaufort Scale

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

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

A breach of the distress criteria requires a consideration of:

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

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

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

Distress Criteria

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

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

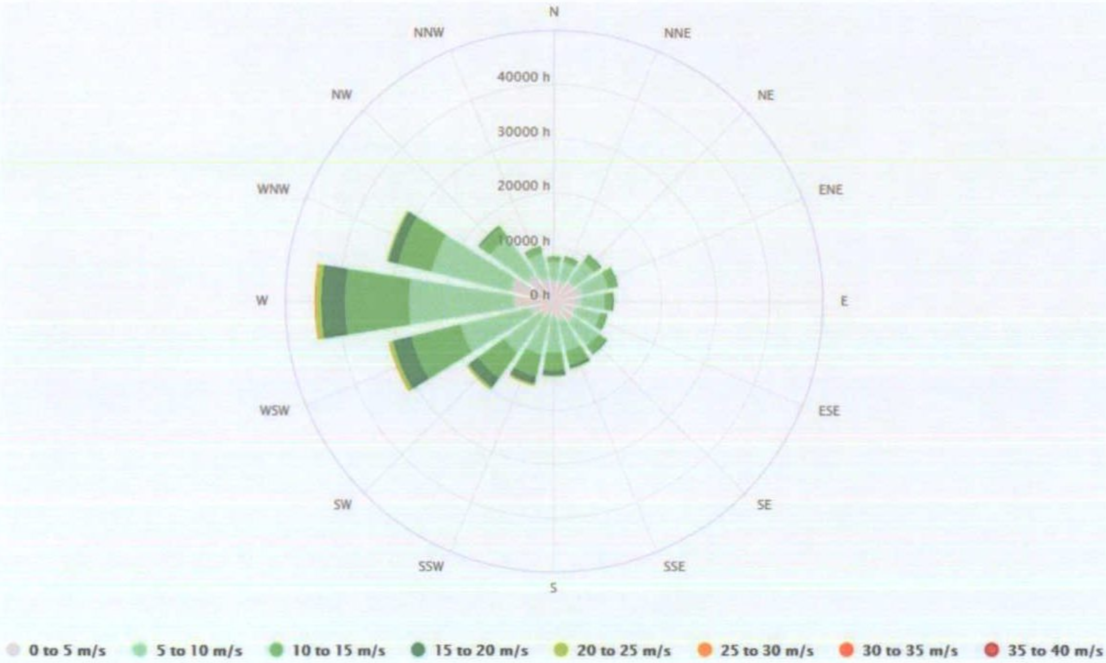


Figure 3.7: Hourly Dublin Wind Gust Rose

Distress for Frail Person or Cyclist

The criteria for distress for a frail person or cyclist is 15m/s wind occurring for more than two hours per year. Limiting the results from the above wind rose to the only values above 15m/s (as reported in Figures 3.8 and 3.9 respectively as cumulative hours and cumulative percentage), it is possible to see how many hours in 30 years the gust velocity of 15m/s is exceed at pedestrian level in each direction.

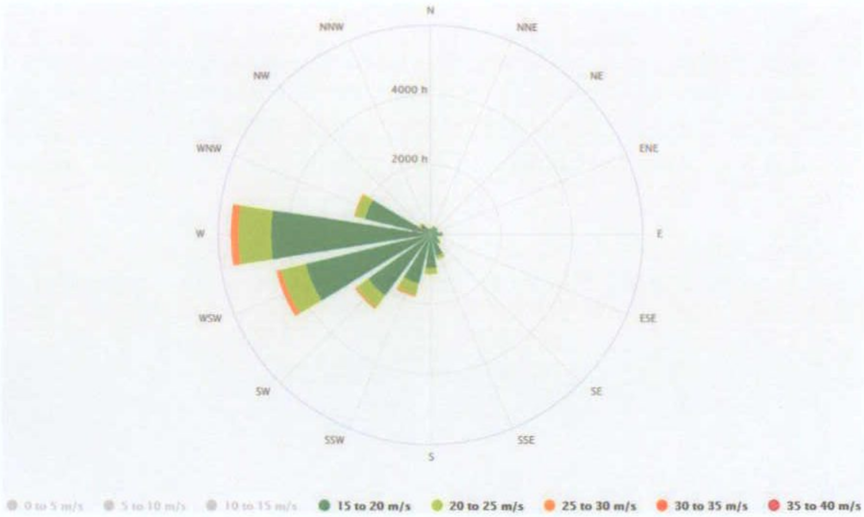


Figure 3.8: Hourly Dublin Wind Gust Rose - Cumulative hours when the velocity is above 15m/s

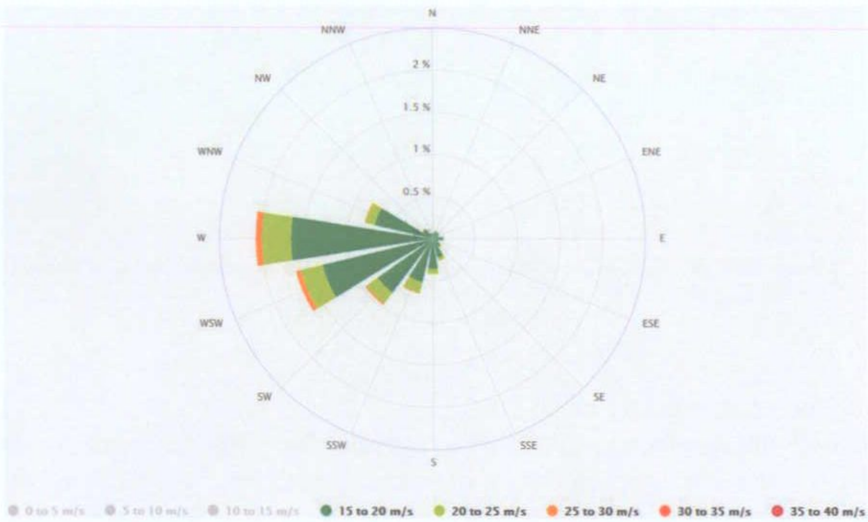


Figure 3.9: Hourly Dublin Wind Gust Rose - Cumulative percentage of time when the velocity is above 15m/s

A total of 2 hours per years corresponds to 0.02% in one year, which means 0.6% in 30 years. Looking at the wind roses above, it is possible to notice that a velocity of 15m/s was reached in Dublin only for the following directions (in increasing order of percentage) over the years 1990-2020:

1. West 270°
2. West-South-West 247.5°
3. South-West 225°

Distress for General Public

The criteria for distress for a member of the general population is 20m/s wind occurring for more than two hours per year. Limiting the results from the above wind rose to the only values above 20m/s (as reported in Figures 3.10 and 3.11 respectively as comulative hours and cumulative percentage), it is possible to see how many hours in 30 years the gust velocity of 20m/s is exceed at pedestrian level in each direction.

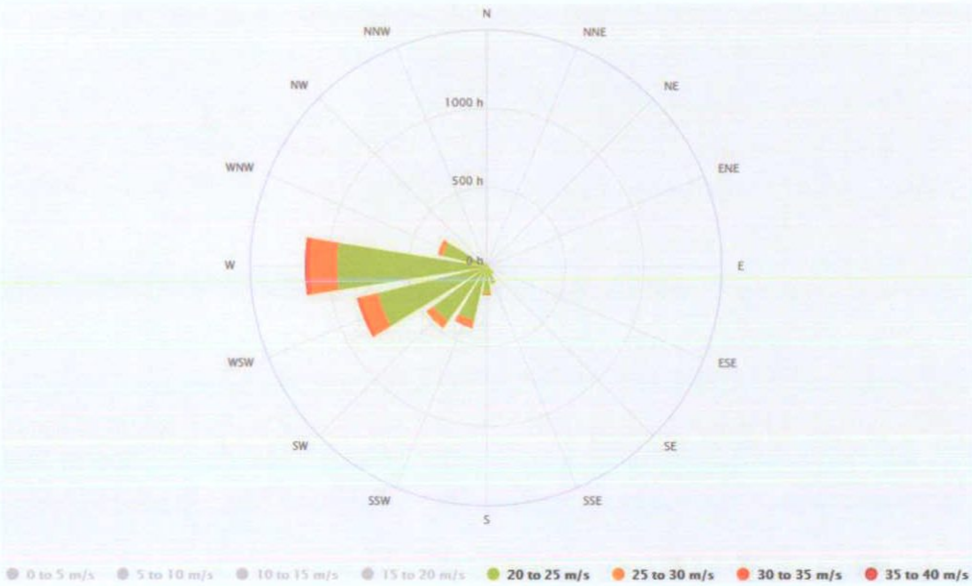


Figure 3.10: Hourly Dublin Wind Gust Rose - Cumulative hours when the velocity is above 20m/s

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

A total of 2 hours per years corresponds to 0.02% in one year, which means 0.6% in 30 years. Looking at the wind roses above, it is possible to notice that a velocity of 20m/s was never reached in Dublin over the years 1990-2020.

3.4 MITIGATION MEASURES

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

Mitigation measures include:

- Landscaping: the use vegetation to protect buildings from wind
- Sculptural screening (solid or porous): to either deflect the wind or bleed the wind by removing its energy.
- Canopies and Wind gutters: horizontal canopies are used to deflect the wind and redirect the wind around the building and above the canopy.

In particular, it is possible to summarise the different flow features and the corresponding mitigation option as follows (Figures 3.12 and 3.13):

- **Downwash Effects**: when wind hits the windward face of a tall building, the building tends to deflect the wind downwards, causing accelerated wind speeds at pedestrian level and around the windward corners of the building. This can occur when Tall and wide building facades face the prevailing winds.
  Downdraft Effects: When the leeward face of a low building faces the windward face of a tall building, it causes an increase in the downward flow of wind on the windward face of the tall building. This results in accelerated winds at pedestrian level in the space between the two buildings and around the windward corners of the tall building.

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

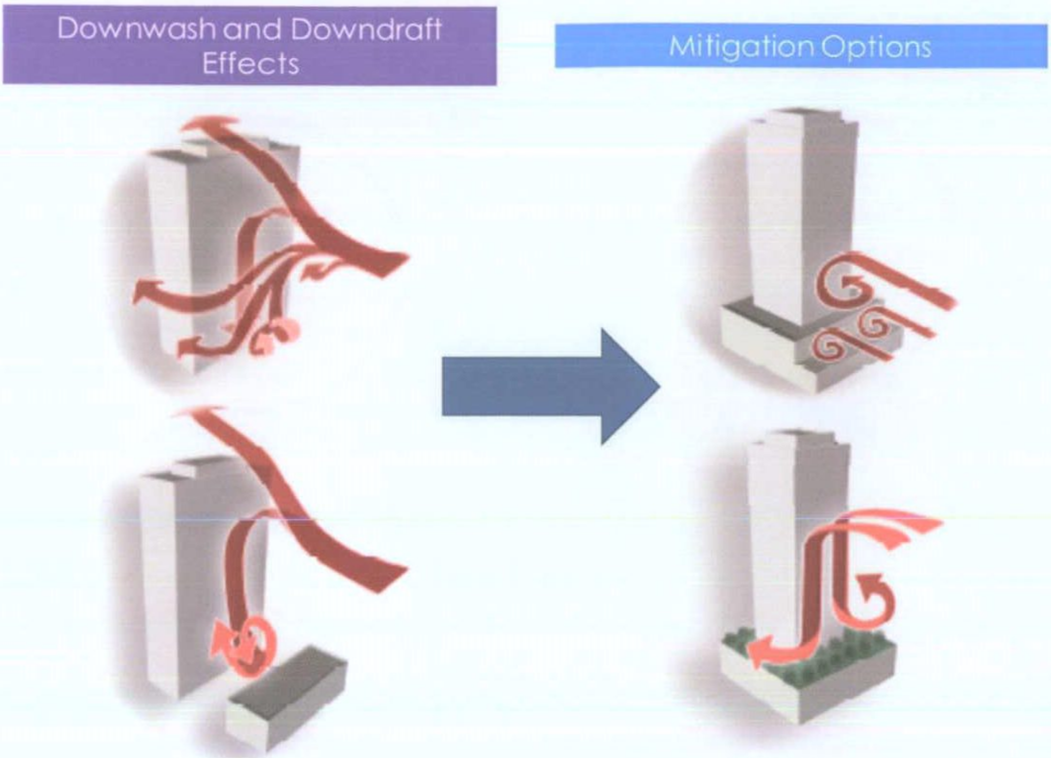


Figure 3.12: Mitigation Measures for Downwash and Downdraft Effects

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

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

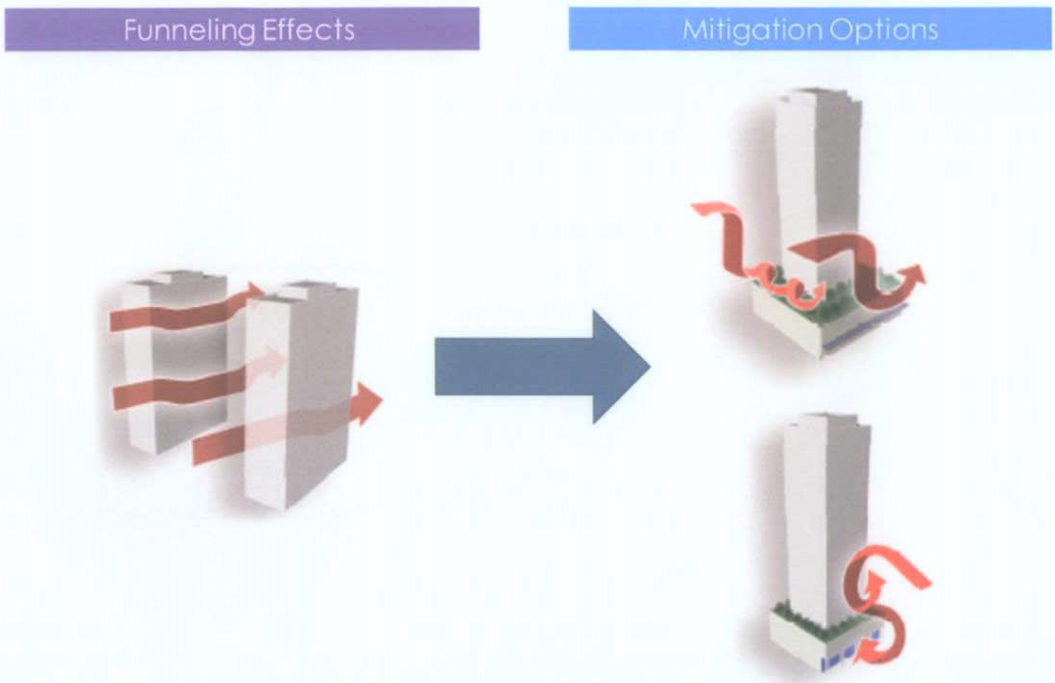


Figure 3.13: Mitigation Measures for Funnelling Effects

Landscape Trees Modelling (Using Porous Media)

Through CFD Modelling, it is possible to implement the effects of landscaping trees on the wind flowing through an urban environment. Urban landscape managers, local councils and architects can now observe and assess the effects of landscaping trees in their urban landscape models. The landscape trees are simulated as comprising effects of porous zones within the urban environments. This is an essential tool for accurately assessing the actual wind speed and pattern at a pedestrian level when landscape are available. Figure 3.14 shows a plan view of the proposed landscape which is also mitigating the wind flow approaching the development. The landscaping is implemented within the CFD model as shown in the figure 3.15

PLAN NO: LRD6002/22-S3 REC:06/09/2022

Figure 3.14: Plan View of the Mitigation Measures that will be implemented around the proposed Mixed Use Residential Development

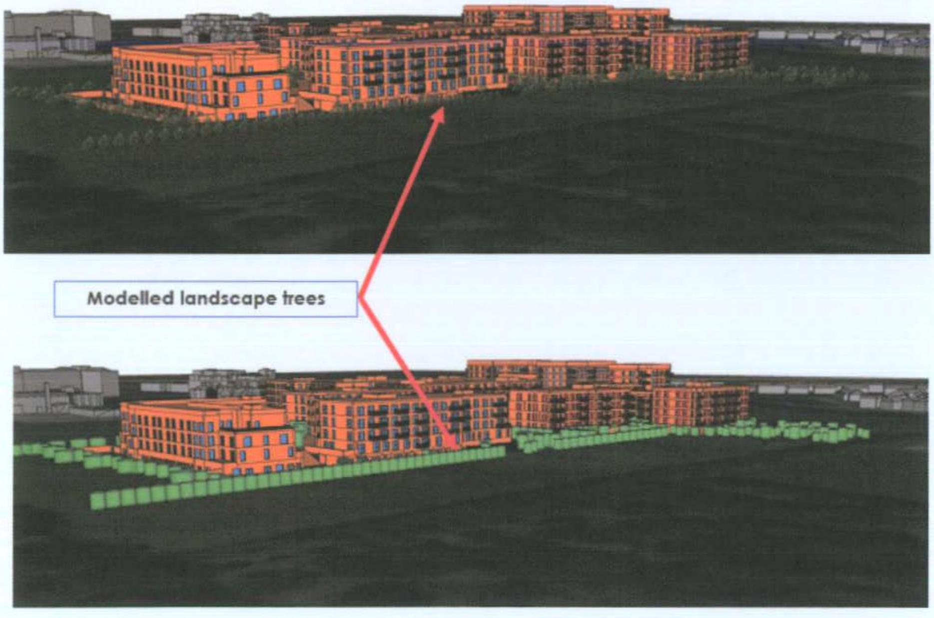


Figure 3.15: Modelling Landscape Trees As Porous Zones

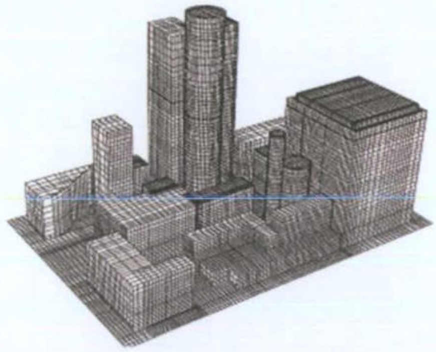
4. CFD MODELLING METHOD

4.1 CFD MODELLING METHOD

Computational Fluid Dynamics (CFD) is a numerical technique to simulate fluid flow, heat and mass transfer, chemical reaction and combustion, multiphase flow, and other phenomena related to fluid flows. CFD modelling includes three main stage: pre-processing, simulation and post-processing as described in Figure 4.1. The Navier-Stokes equations, used within CFD analysis, are based entirely on the application of fundamental laws of physics and therefore produce extremely accurate results providing that the scenario modelled is a good representation of reality.

PRE-PROCESSING

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



SIMULATION

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

POST-PROCESSIONG

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

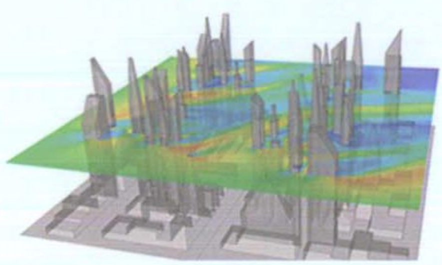


Figure 4.1: CFD Modelling Process Explanation

4.1.1 NUMERICAL SOLVER

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

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

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

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

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

4.2 COMPUTATIONAL MESH

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

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

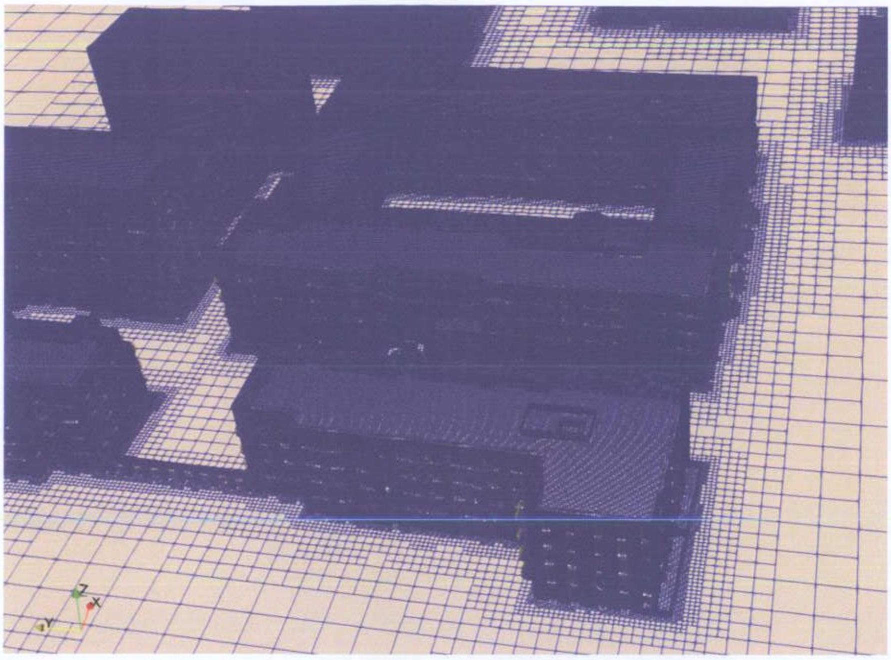


Figure 4.2: The proposed Mixed Use Residential Domain Computational Mesh Utilized

4.3 BOUNDARY CONDITIONS

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

PARAMETERS TO CALCULATE COMPUTATIONAL MESH	
Air Density ρ	$1.2kg/m^3$
Ambient Temperature (T)	$288K(approx.15C^{\circ})$
Gravity Acceleration (g)	$9.8m/s^2$
dx	0.5 m at the building 1m in the surroundings 2m elsewhere
Background Mesh ratio	1:1
Total mesh size	Approx. cells number = 10 million

Table 4.1: Paramenters To Calculate Computational Mesh

5. WIND DESKTOP STUDY

5.1 LOCAL WIND CONDITIONS

This analysis consider the whole development being exposed to the typical wind condition of the site. The building is oriented as shown in the previous sections. The wind profile is built using the annual average of meteorology data collected at Dublin Airport Weather Station. Figure 5.1 shows on the map the position of the proposed Mixed Use Residential Development and the position of Dublin Airport.

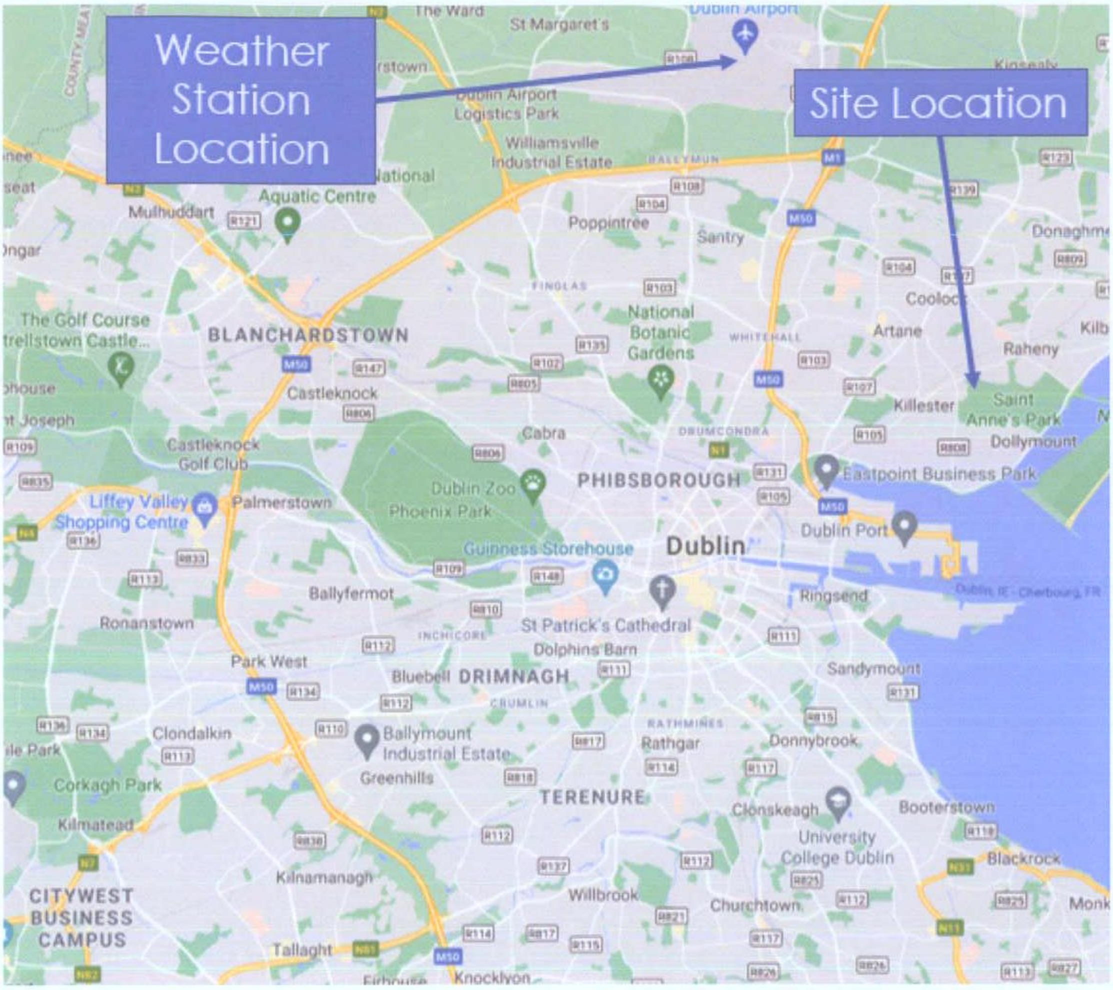


Figure 5.1: Map showing the position of the proposed Mixed Use Residential Development and Dublin Airport

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

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

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

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

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

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

- The meteorological data associated with the maximum daily wind speeds recorded over a 30 year period between 1990 and 2020 and,
- The mean hourly wind speeds recorded over a 10 year period between 1990 and 2020. The data is recorded at a weather station at the airport, which is located 10m above ground or 71mOD.

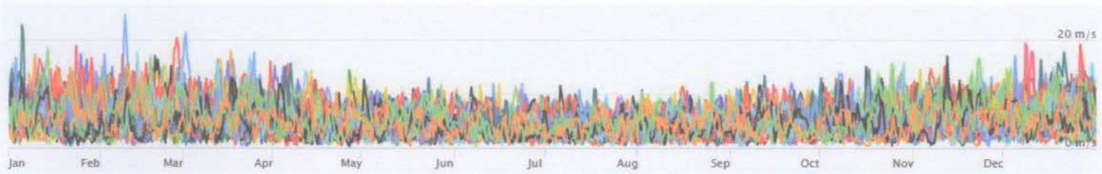


Figure 5.2: Local Wind Conditions - Wind Speed - 2017-2021

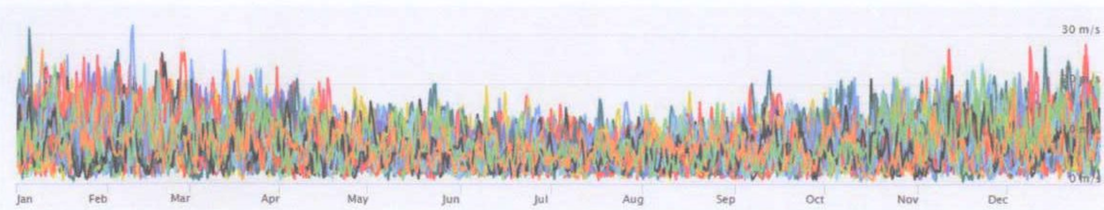


Figure 5.3: Local Wind Conditions - Wind Gust - 1990-2020

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

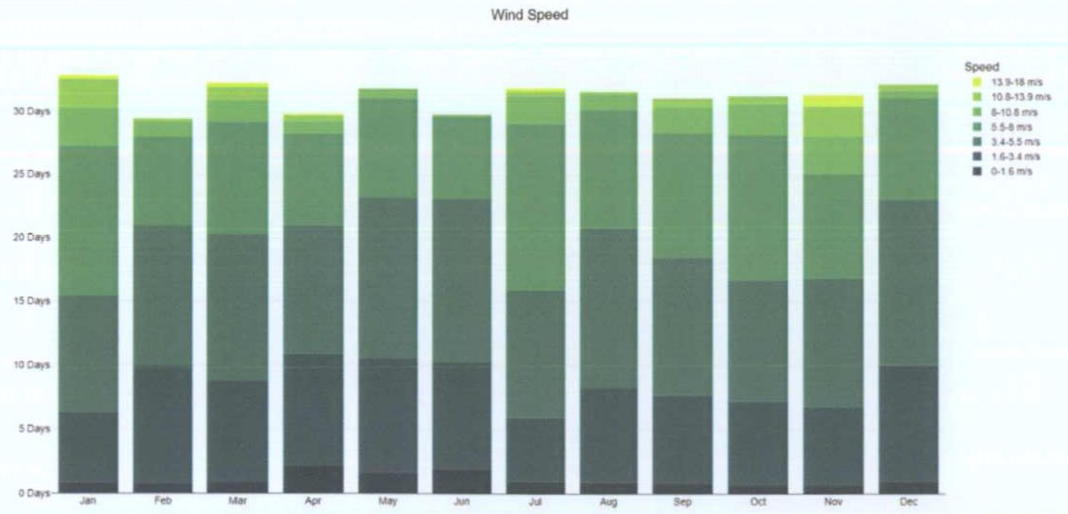


Figure 5.4: Dublin Wind Speed Diagram

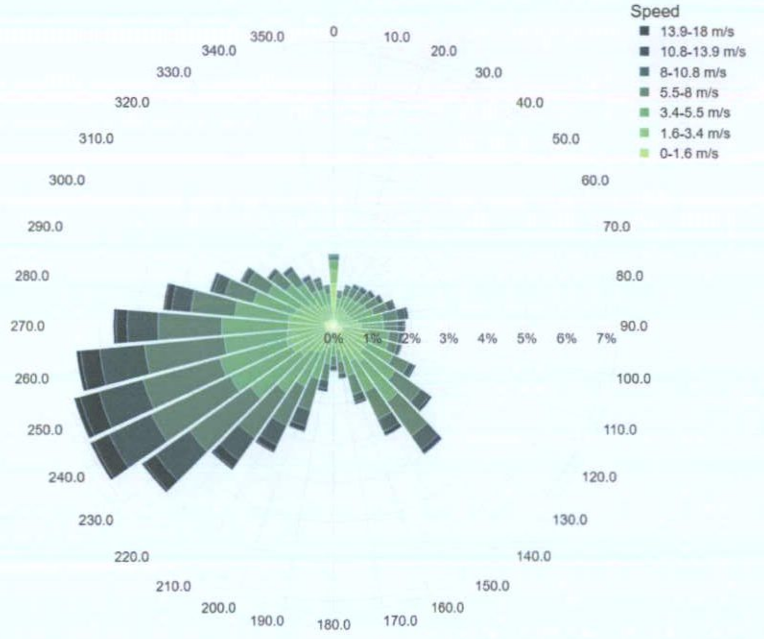
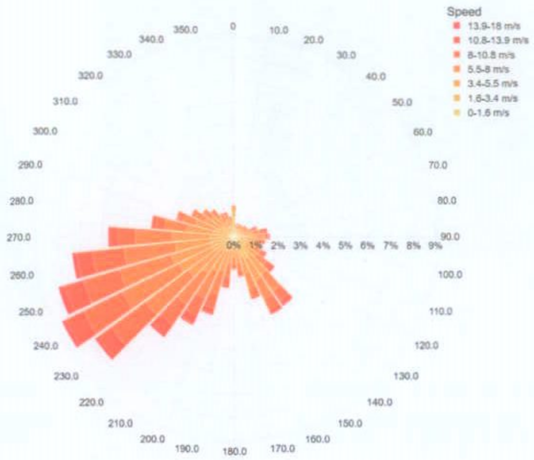


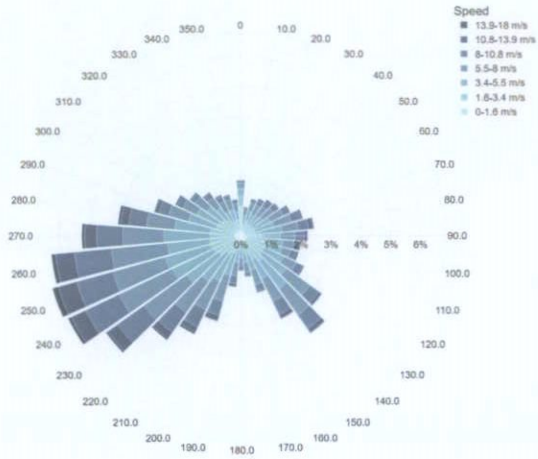
Figure 5.5: Dublin Wind Rose

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

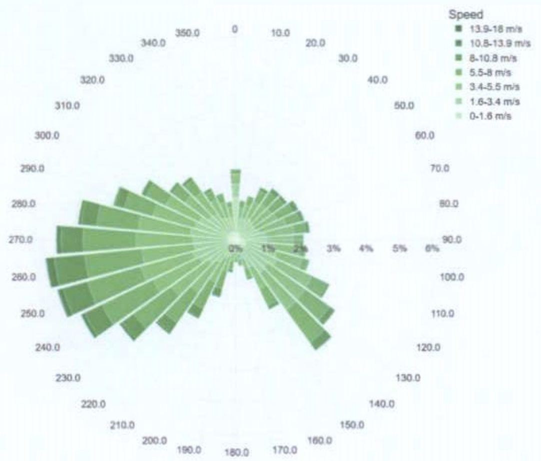
Based on the criterion of occurrence frequency, if the proposed site is exposed to a wind from a specific direction for more than 5 percent of the time, then the microclimate analysis should consider the impact of this wind (accounting for its direction and most frequent speed) on the local microclimate.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



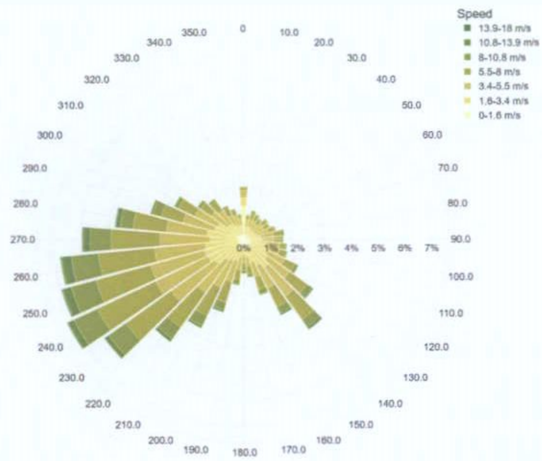
Autumn



Winter



Spring



Summer

Figure 5.6: Wind speeds and wind directions at different seasons

5.1.1 TOPOGRAPHY and BUILT IN ENVIRONMENT

Figure 5.7 shows an aerial photograph of the terrain surrounding the construction site at the proposed Mixed Use Residential Development.

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

Figure 5.7: Built-in Environment Around Construction Site at the proposed Mixed Use Residential Development

5.1.2 OPEN AREA FUNCTIONS

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

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

Table 5.1: Main Categories for Pedestrian Activities

6. ANALYSIS OF CFD RESULTS

6.1 CFD RESULTS

It is of interest at this point to underline again the objectives of the CFD simulations performed. In particular:

- Pedestrian Wind Comfort and Safety Studies are conducted to predict, assess and, where necessary, mitigate the impact of the development on pedestrian level wind conditions.
- The objective is to maintain comfortable and safe pedestrian level wind conditions that are appropriate for the season and the intended use of pedestrian areas. Pedestrian areas include sidewalks and street frontages, pathways, building entrance areas, open spaces, amenity areas, outdoor sitting areas, and accessible roof top areas among others.

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

- Flow Velocity
- Lawson Map

6.2 MICROCLIMATE ASSESSMENT OF PROPOSED DEVELOPMENT

This section aims to show wind patterns around the proposed development under mean and peaks wind conditions typically occurring in the area. A 3D view of the proposed development massing model in the domain is presented in Figures from 6.1 to 6.2.

Figure 6.1: 3D View of the Proposed Mixed Use Residential Development and Adjacent Buildings - Generic View

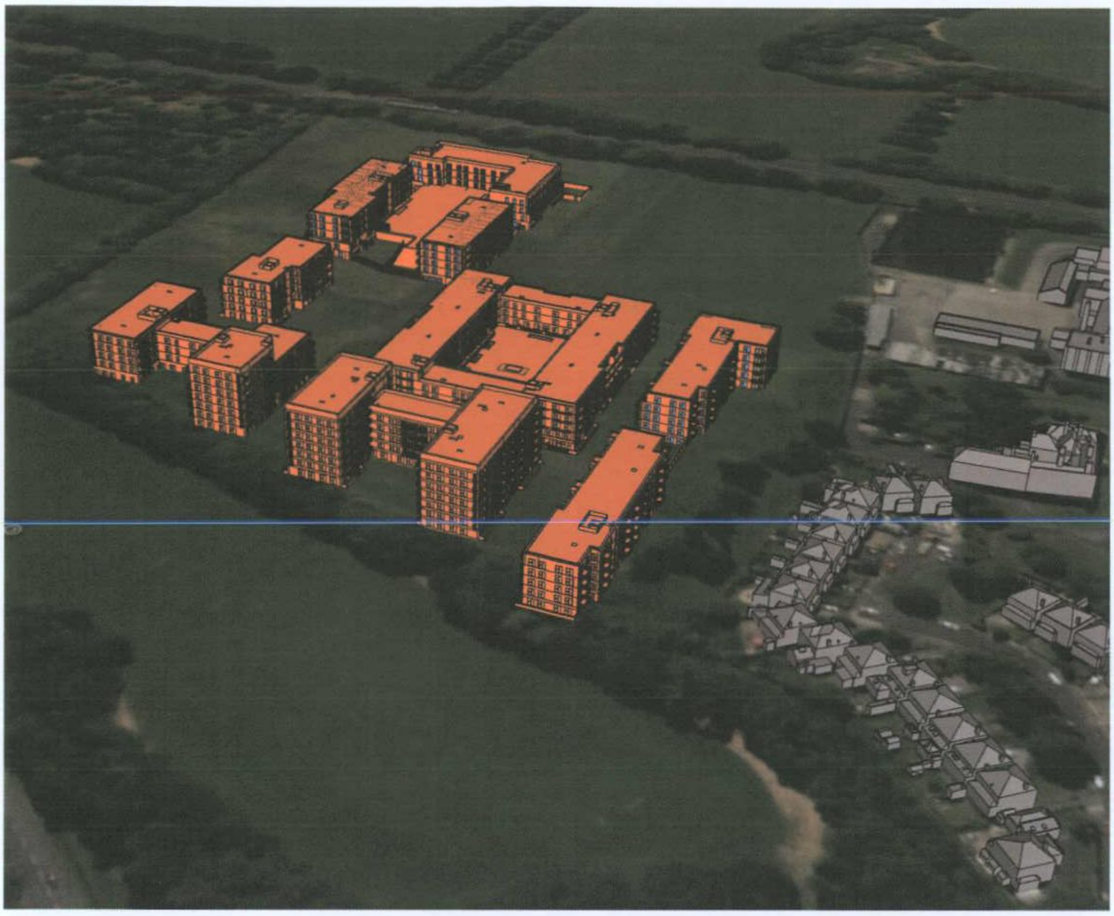


Figure 6.2: 3D View of the Proposed Mixed Use Residential Development and Adjacent Buildings - North Side View

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

From the simulation results the following observations are pointed out:

- The proposed Mixed Use Residential Development has been designed in order to produce a high-quality environment that is attractive and comfortable for pedestrians of all categories. To achieve this objective, throughout the design process, the impact of wind has been considered and analysed, in the areas where critical patterns were found, the appropriate mitigation measures were introduced.
- As a result of the final proposed and mitigated design, wind flow speeds at ground floor are shown to be within tenable conditions. Some higher velocity indicating minor funnelling effects are found between block D and G and the corners of block A, B, C and G. However, these areas can be utilised for the intended use such as short-term sitting, walking and strolling.
- Area between Block A and Block D is suitable for short-term sitting instead of long-term sitting due to flow acceleration between the Blocks.
- Courtyard on Block D is well protected and good shielding is achieved. Therefore, it can be used for all activities including long-term sitting.
- Small areas of Courtyard on Block G are suitable for short term sitting instead of long-term sitting, however the majority of the area is appropriate for long term sitting.
- Tree planting all around the development has been utilised, with particular attention to the corners of the Blocks has positively mitigated any critical wind effects.
- Regarding the balconies, higher velocities are found for some directions, only on some of the balconies (mostly on the South and West sides of the blocks). However, these velocities are below the threshold values defined by the acceptance criteria and therefore are not critical for safety.
- 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.

6.2.1 Flow Velocity Results - Ground Floor

Results of wind speeds and their circulations at pedestrian level of 1.5m above the development ground are presented in Figures 6.5 to 6.20 in order to assess wind flows at ground floor level of the proposed Mixed Use Residential Development.

Wind flow speeds are shown to be within tenable conditions. Some higher velocity indicating minor funnelling effects are found between block D and G and the corners of block A, B, C and G. However, these areas can be utilised for the intended use such as short-term sitting, walking and strolling. Therefore, it can be concluded that the wind speeds do not attain critical levels around the development.

Figure 6.4 shows an example of wind data mapped on surface, located at 1.5m above the ground. The scale used for all flow velocity results is set out in Figure 6.3. Red colors indicate critical values while blue colors indicate tenable conditions.

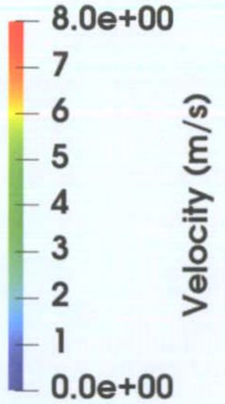


Figure 6.3: Velocity Colour Map

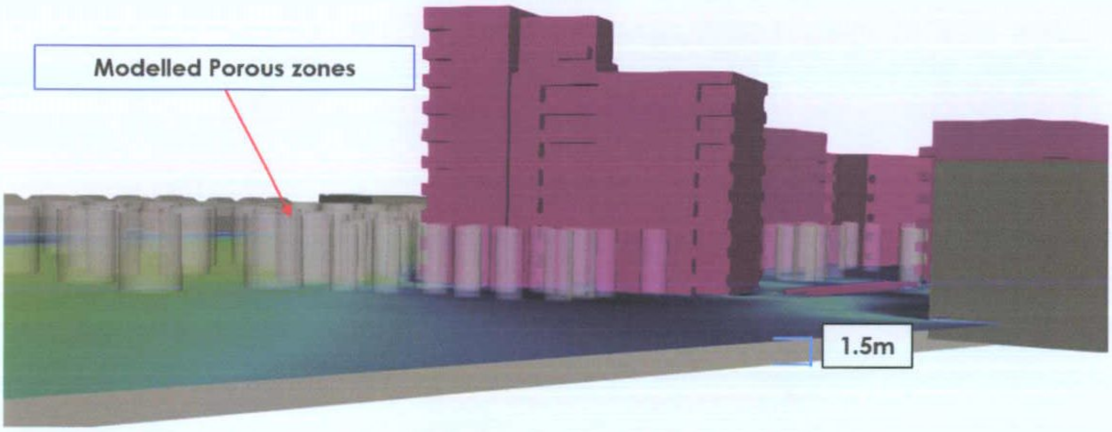


Figure 6.4: An example of wind data mapped on surface at 1.5m above the ground

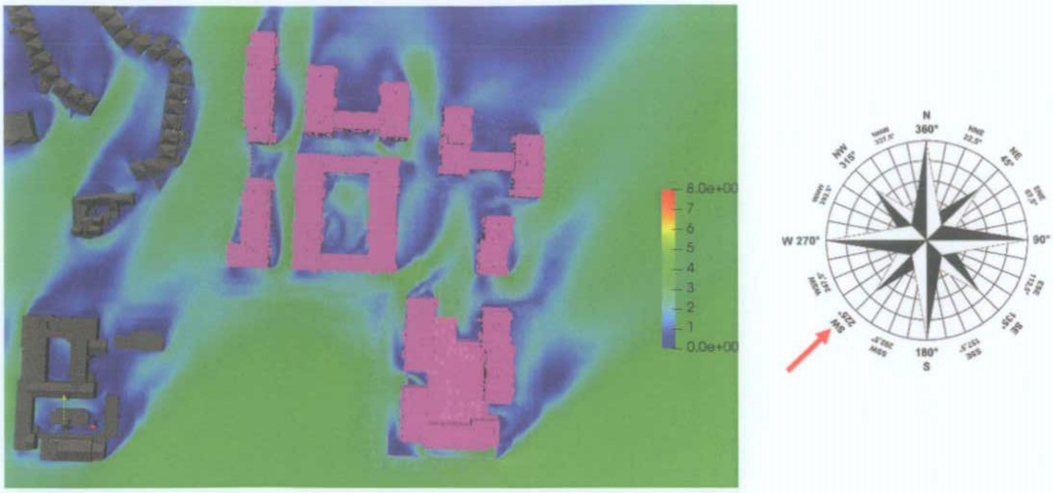


Figure 6.5: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 225°

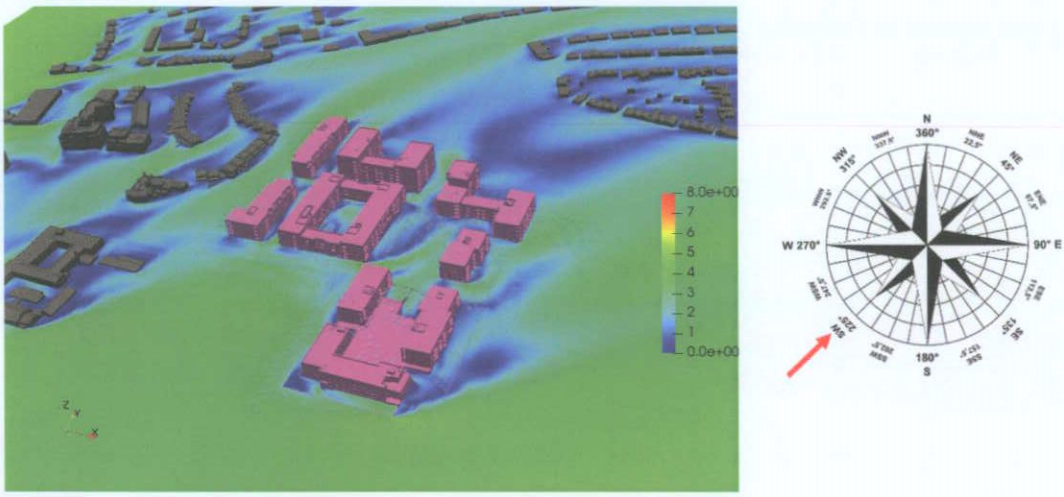


Figure 6.6: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 225°

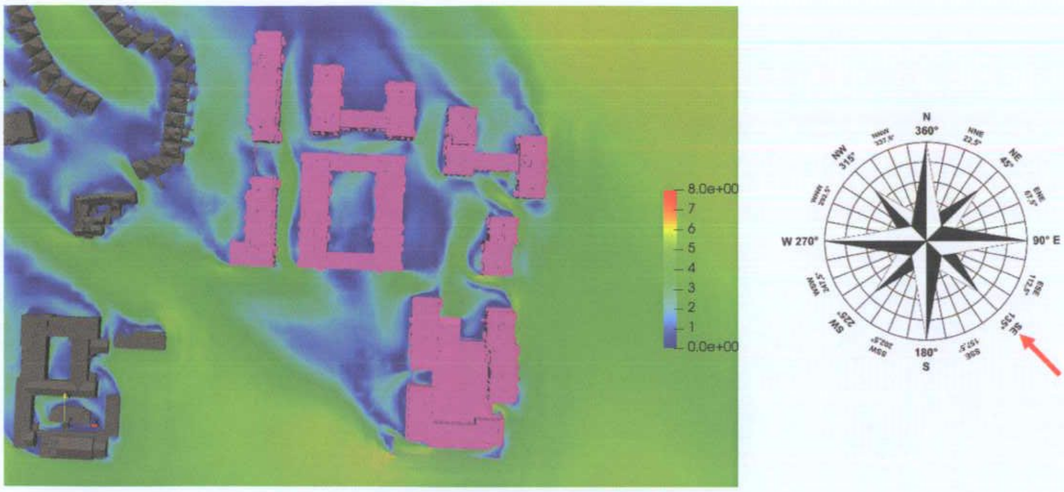


Figure 6.7: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 135°

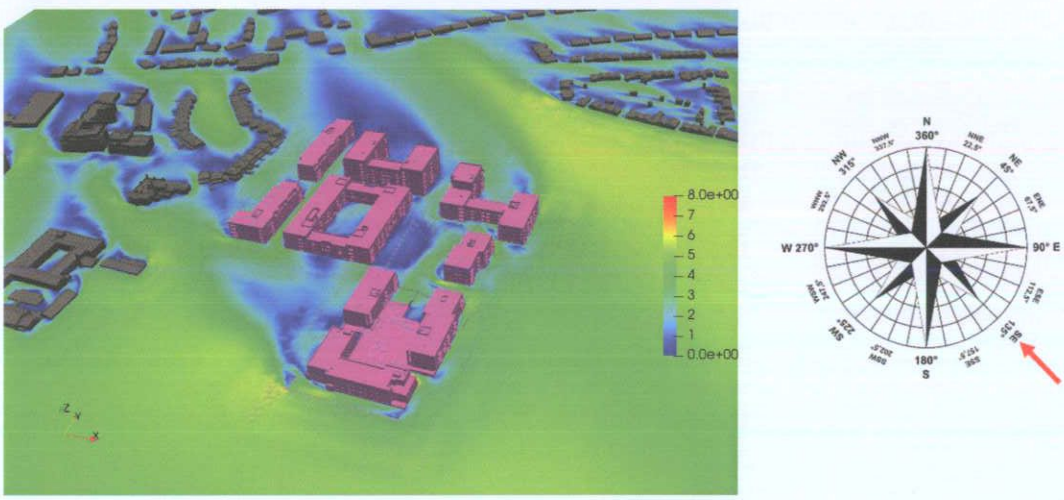


Figure 6.8: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 135°

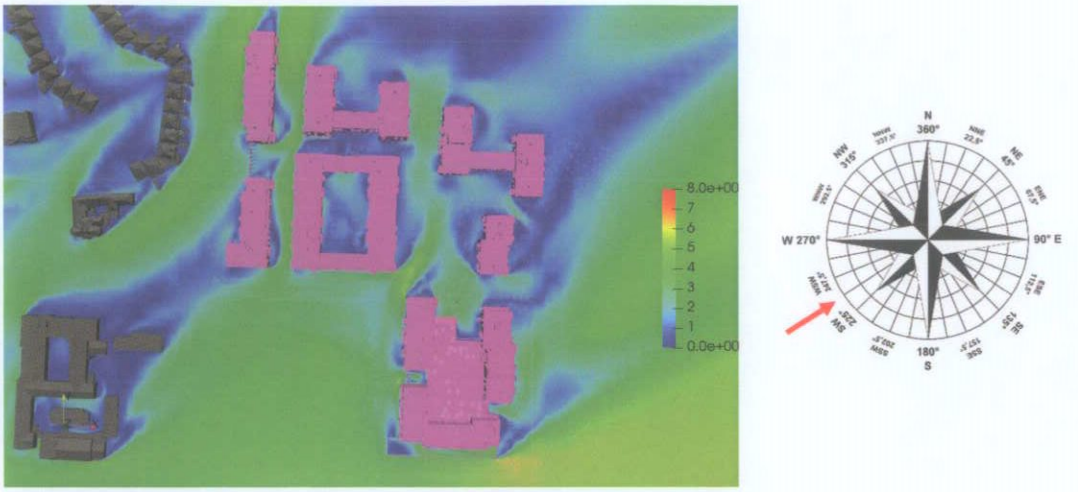


Figure 6.9: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 236°

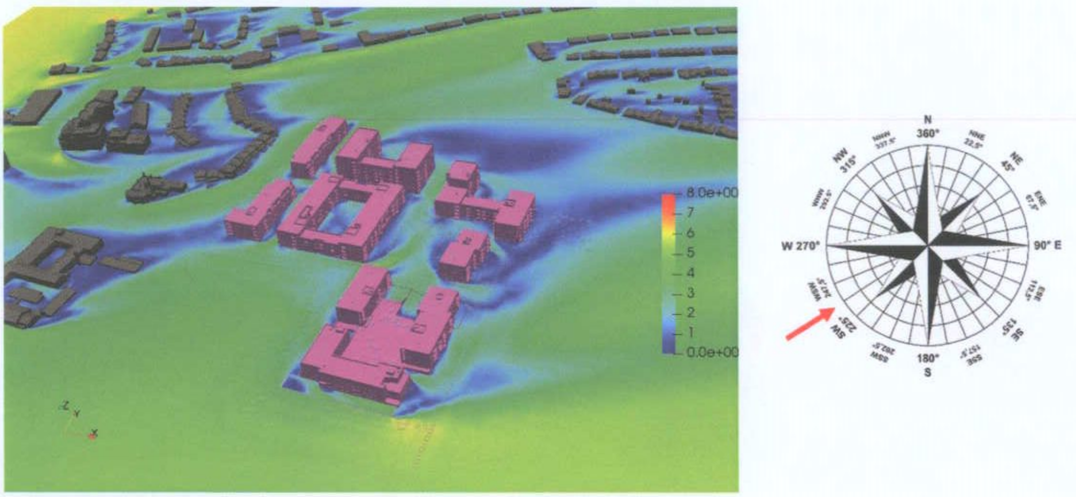


Figure 6.10: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 236°

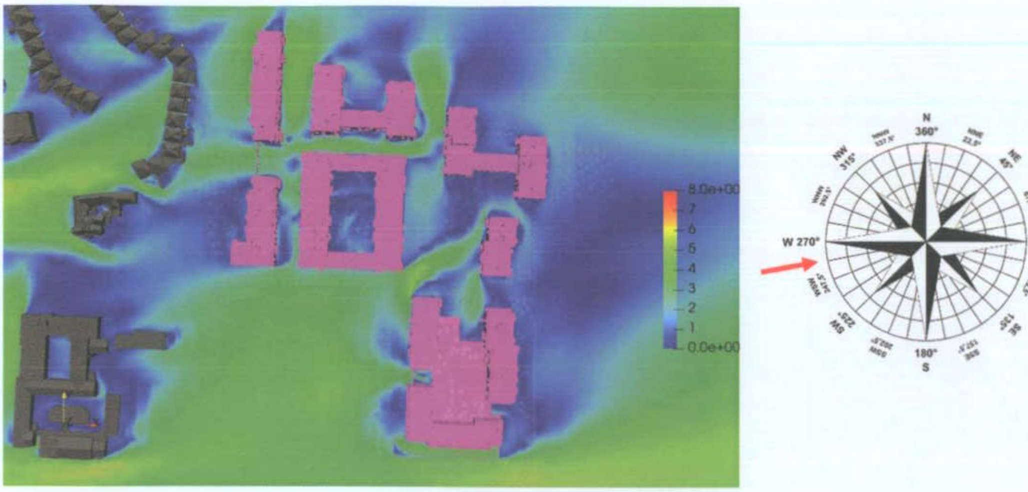


Figure 6.11: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 258°

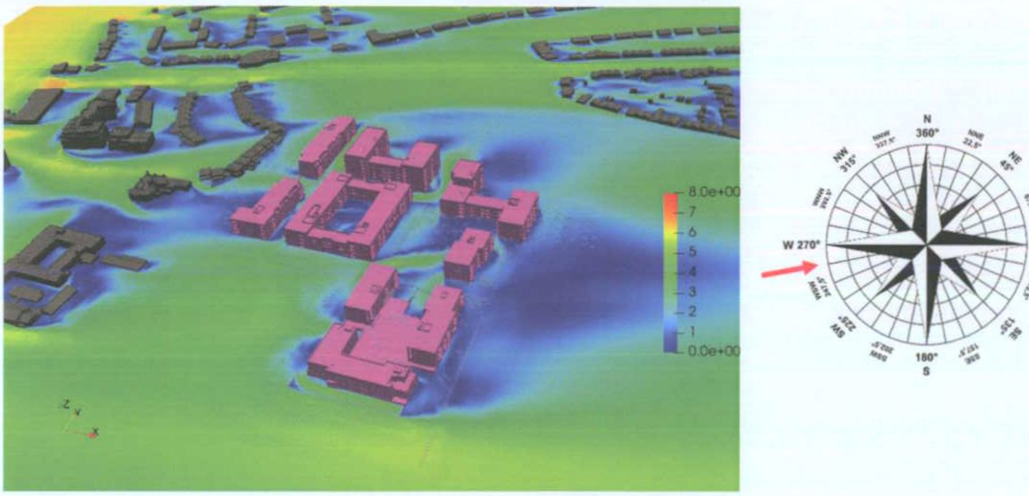


Figure 6.12: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 258°

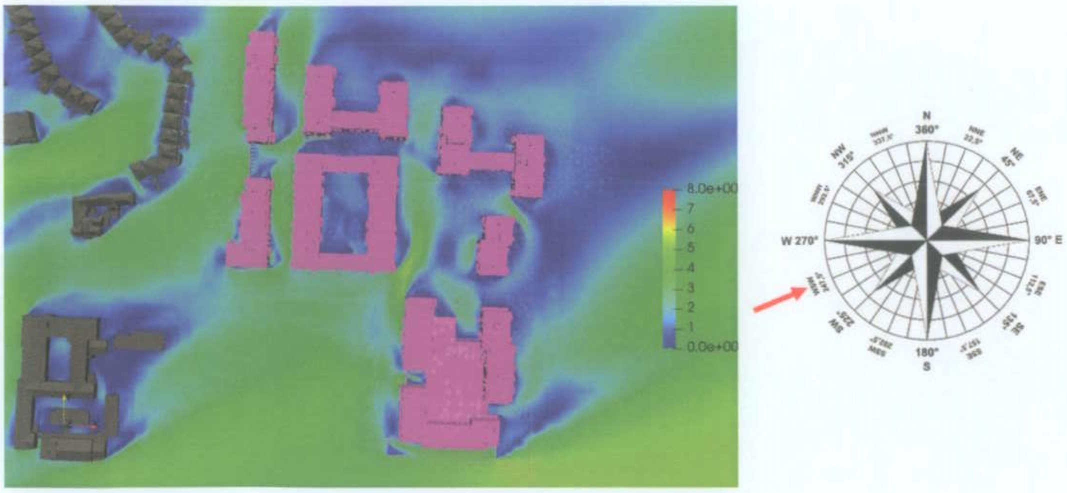


Figure 6.13: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 247°

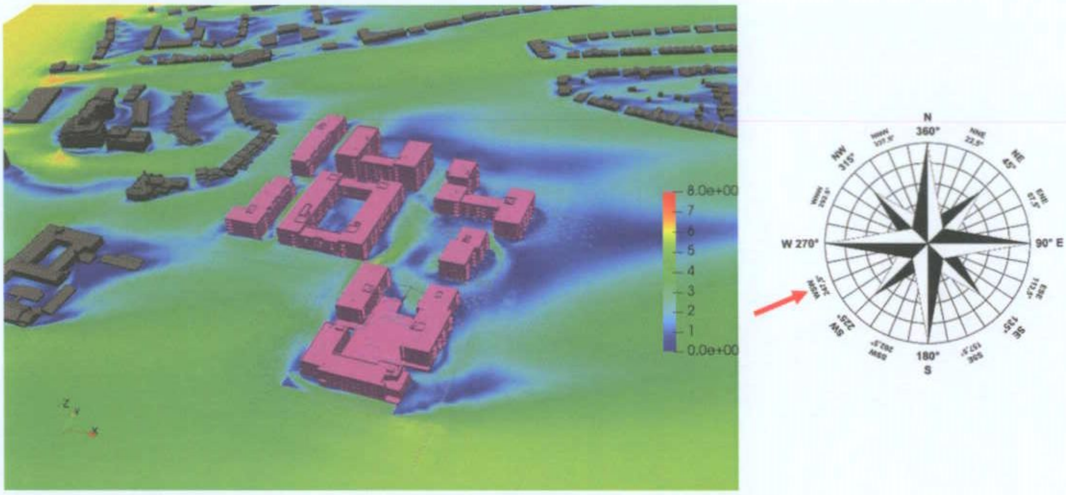


Figure 6.14: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 247°

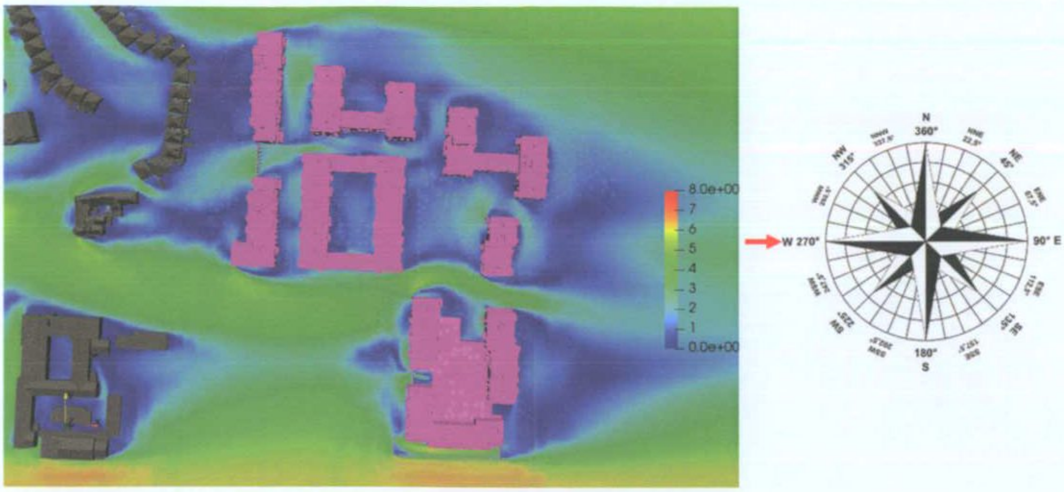


Figure 6.15: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 270°

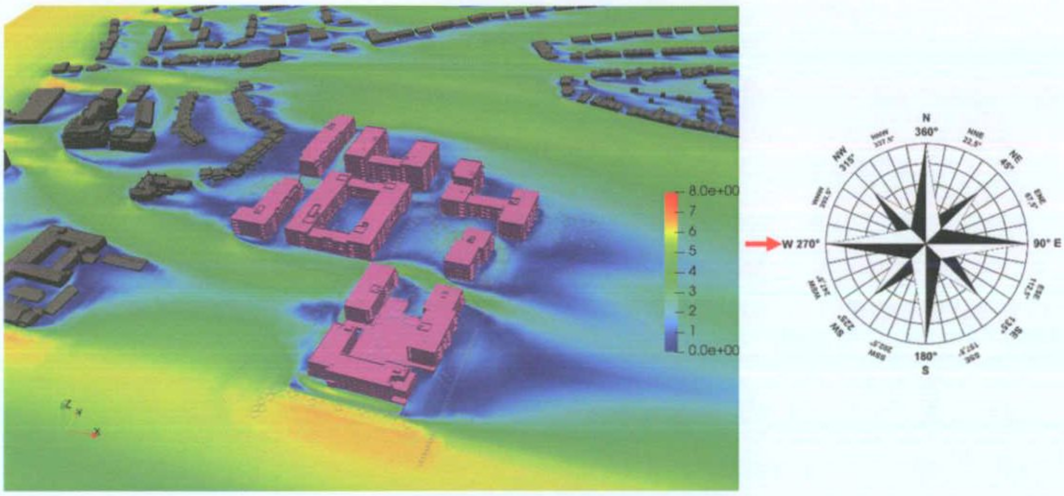


Figure 6.16: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 270°

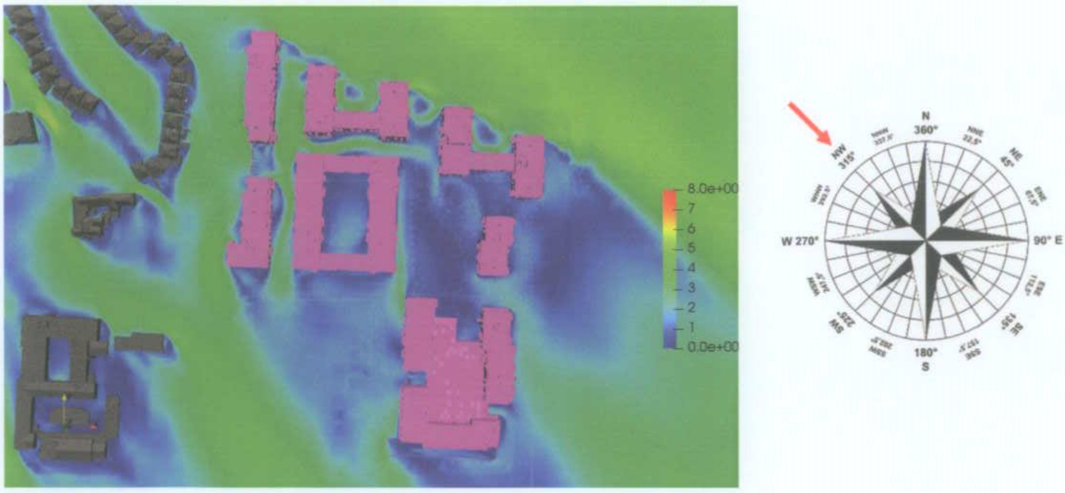


Figure 6.17: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 315°

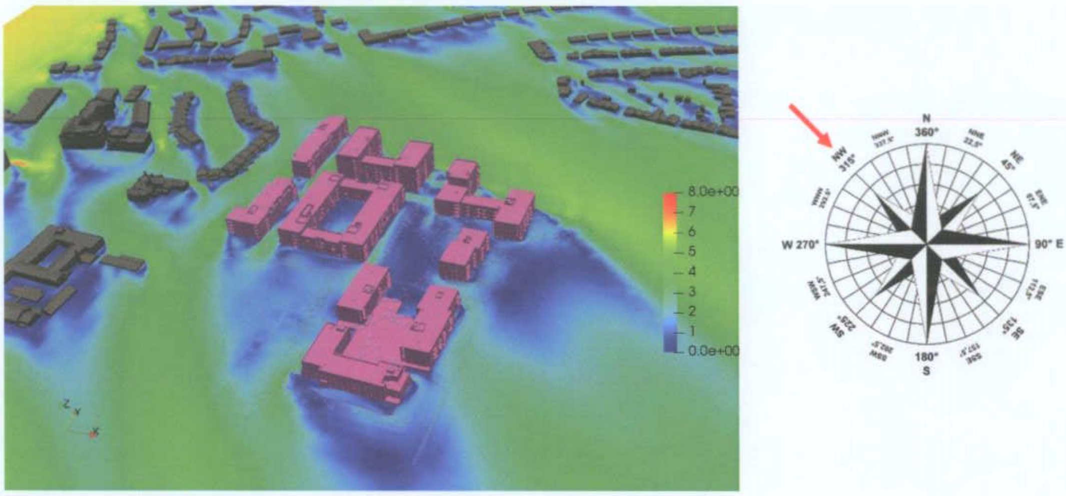


Figure 6.18: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 315°

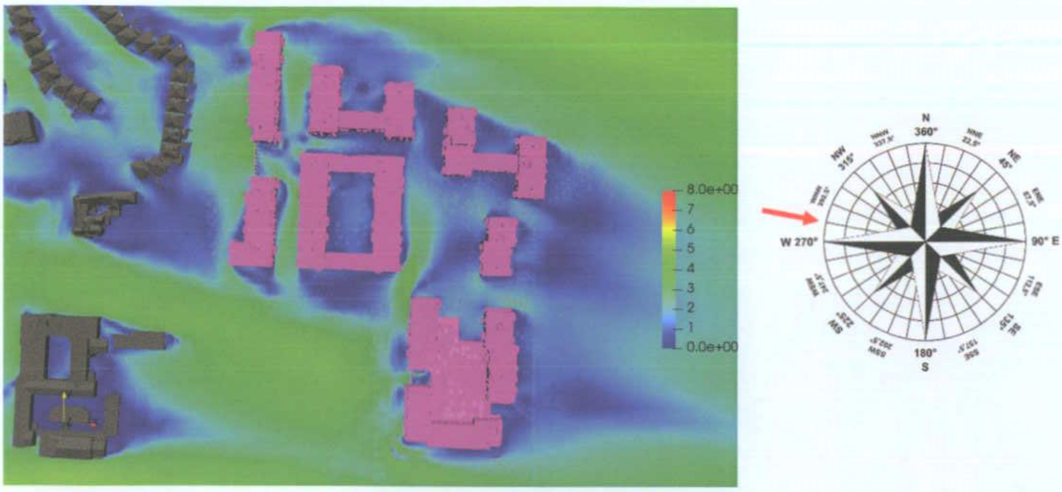


Figure 6.19: Ground Floor Level - Flow Velocity Results at Z=1.5m above the ground - Wind Direction: 281°

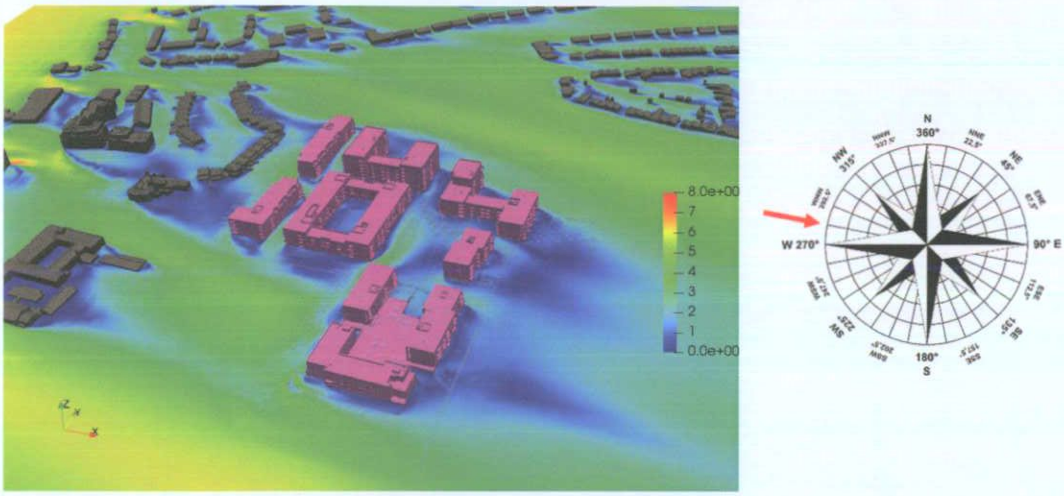


Figure 6.20: Wind Speed Results at 1.5m Above Development Ground Floor - 3D View - Wind Direction: 281°

6.2.2 Flow Velocity Results - Courtyard

Results of velocity at 1.5m above the Courtyard for development are presented in Figures 6.21 to 6.36, for wind assessment of the Courtyards of the proposed Mixed Use Residential Development.

Good shielding seems to be guaranteed in the internal courtyard on Block D and No major issues are found to be critical. however some higher velocities and recirculation effects are experienced at the West and South-East side of the courtyard on Block G.

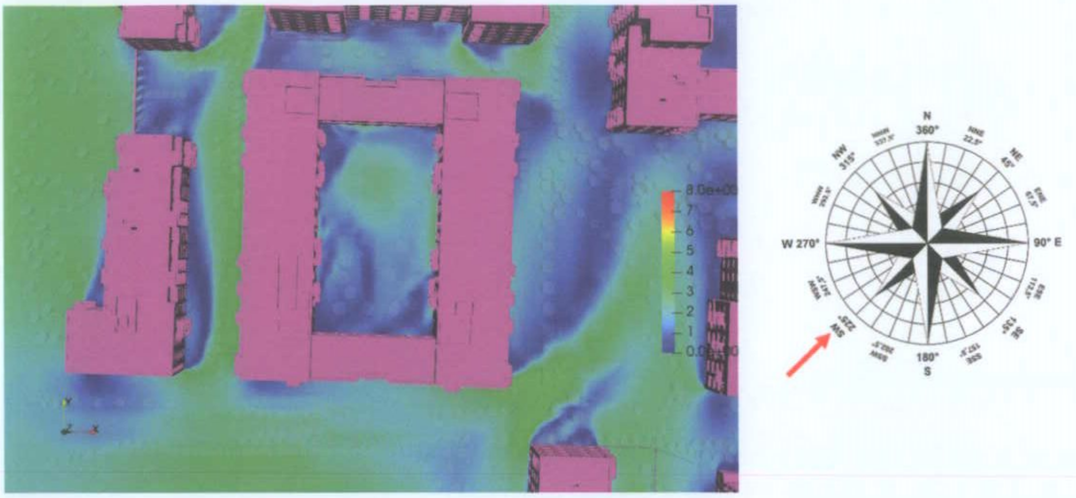


Figure 6.21: Courtyard Block D - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 225°

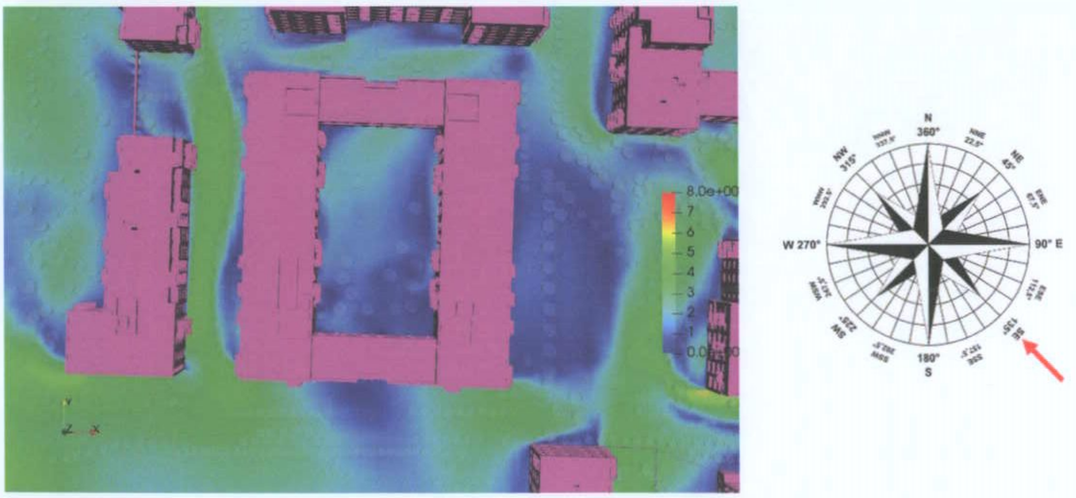


Figure 6.22: Courtyard Block D - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 135°

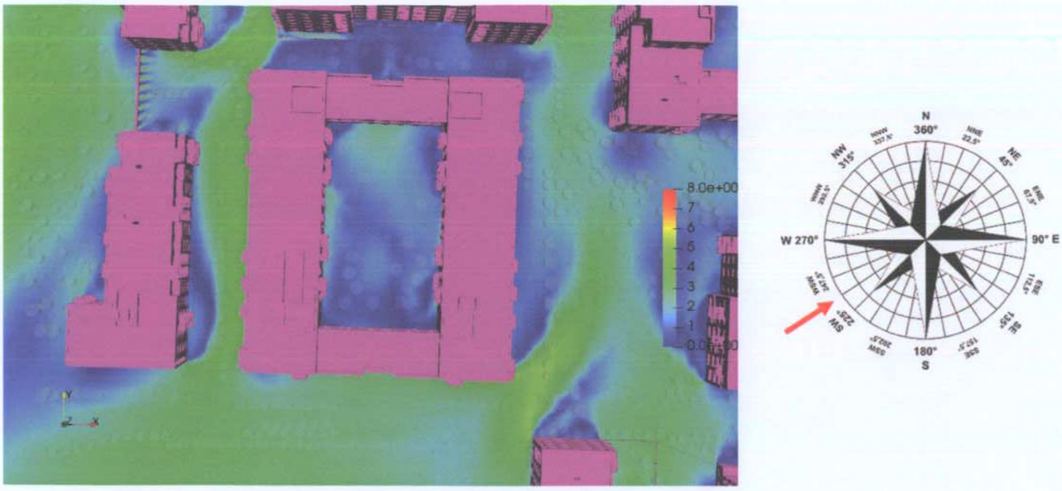


Figure 6.23: Courtyard Block D - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 236°

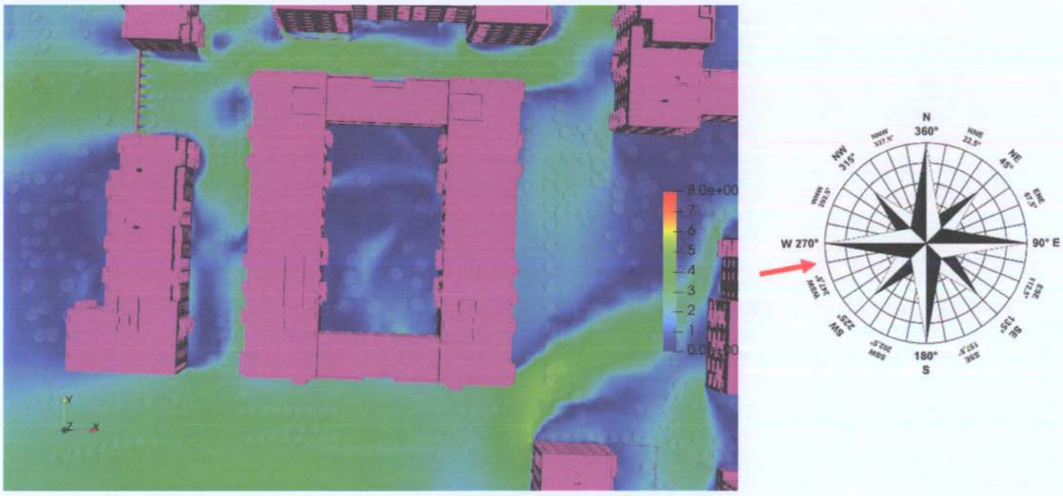


Figure 6.24: Courtyard Block D - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 258°

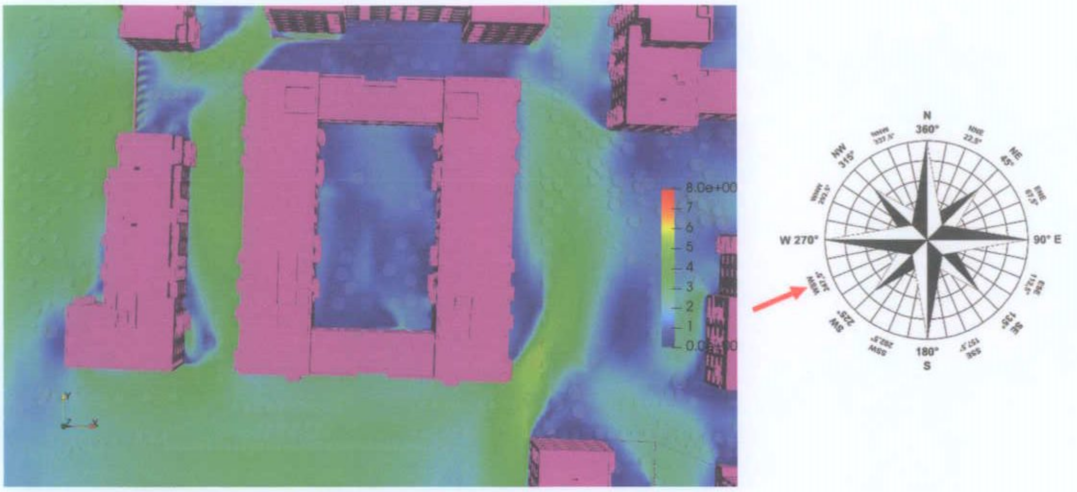


Figure 6.25: Courtyard Block D - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 247°

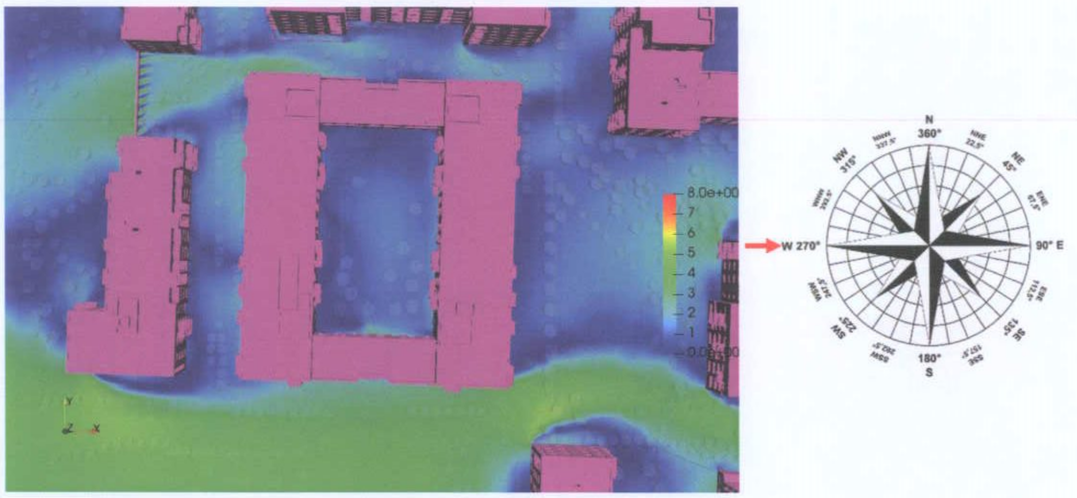


Figure 6.26: Courtyard Block D - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 270°

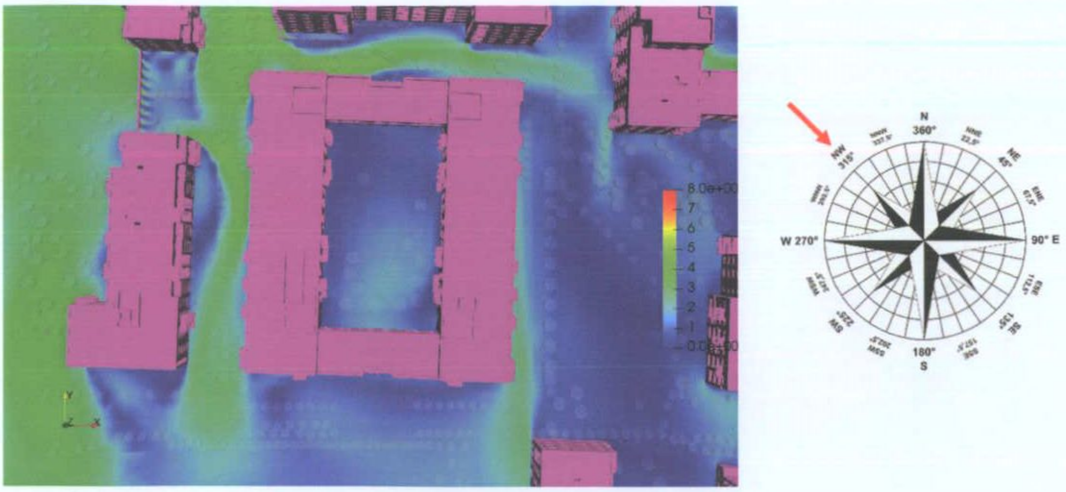


Figure 6.27: Courtyard Block D - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 315°

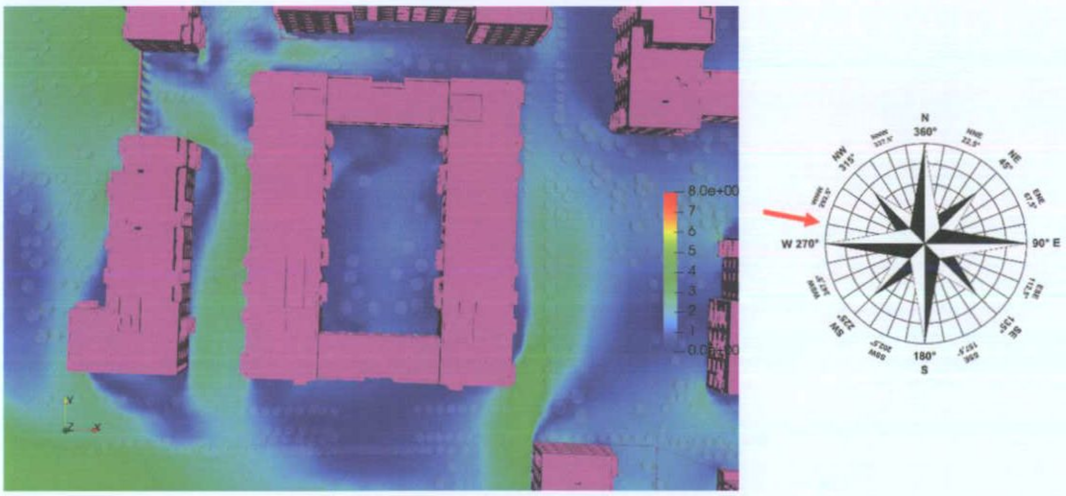


Figure 6.28: Courtyard Block D - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 281°

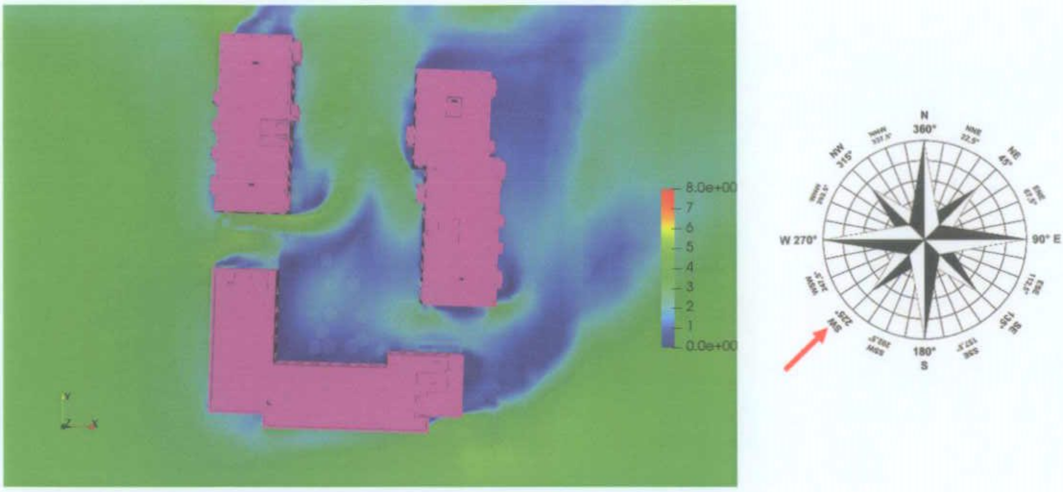


Figure 6.29: Courtyard Block G - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 225°

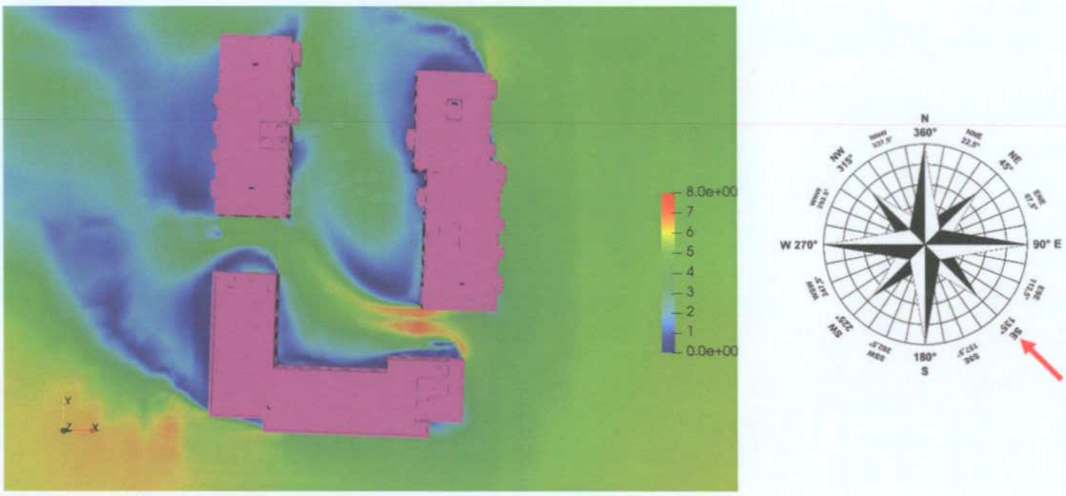


Figure 6.30: Courtyard Block G - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 135°

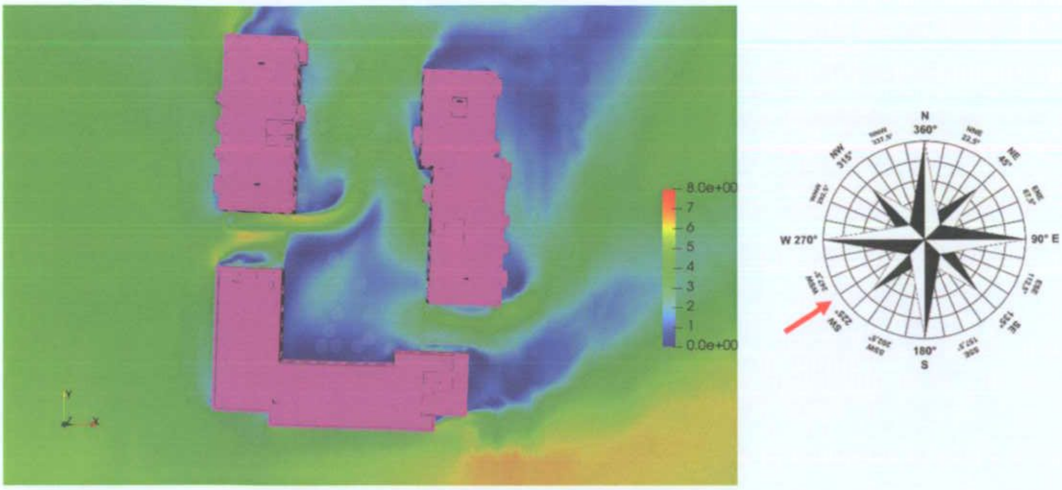


Figure 6.31: Courtyard Block G - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 236°

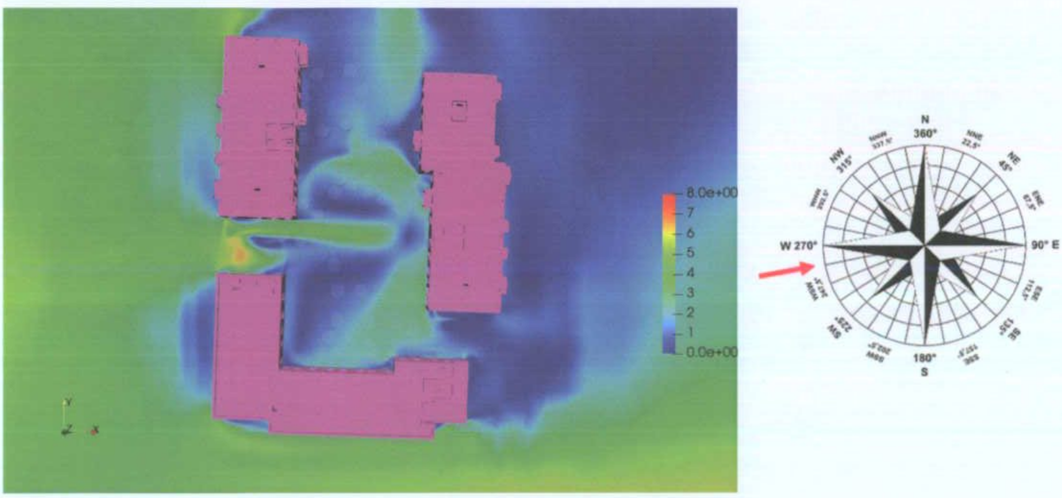


Figure 6.32: Courtyard Block G - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 258°

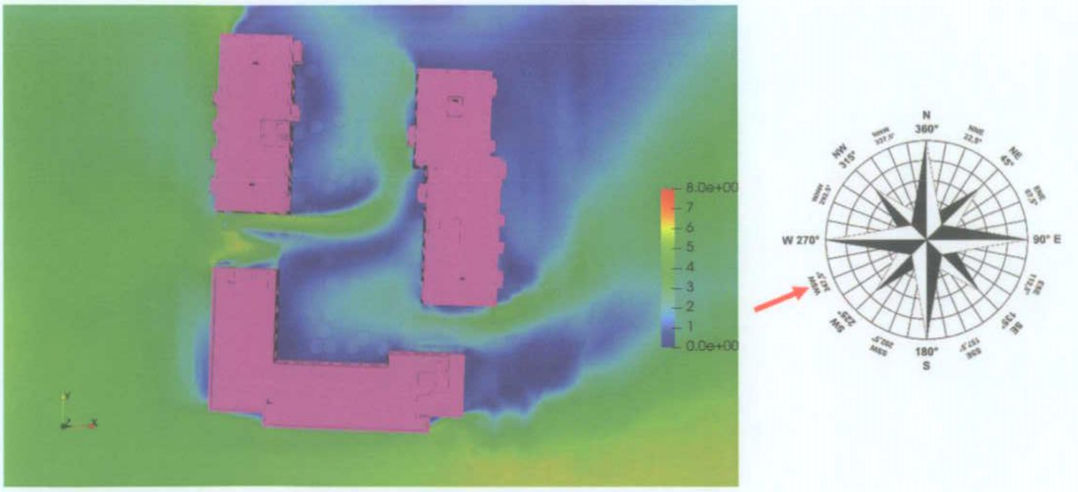


Figure 6.33: Courtyard Block G - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 247°

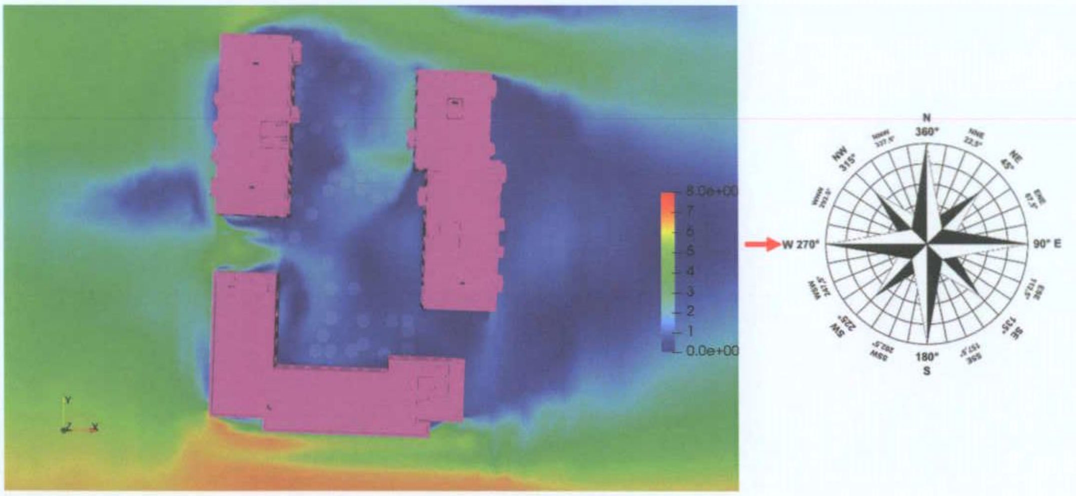


Figure 6.34: Courtyard Block G - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 270°

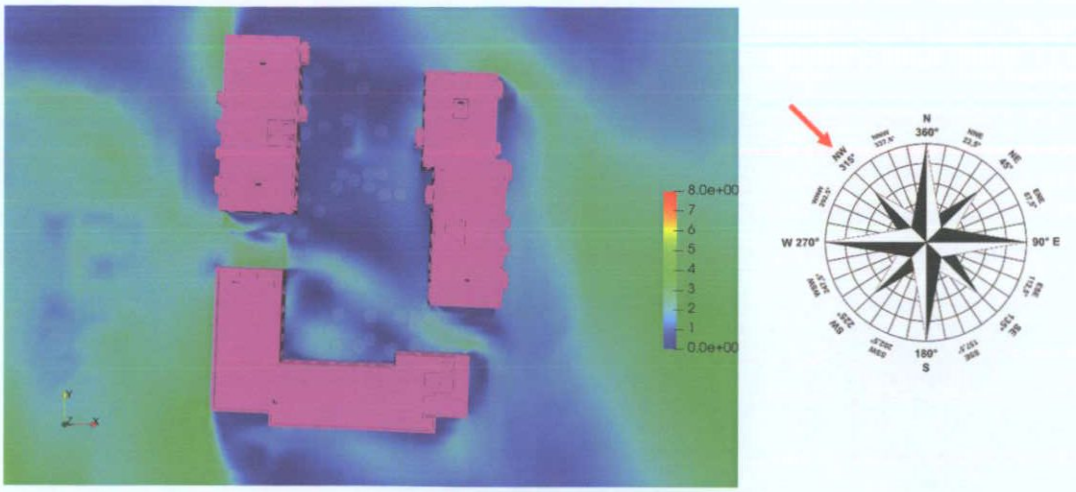


Figure 6.35: Courtyard Block G - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 315°

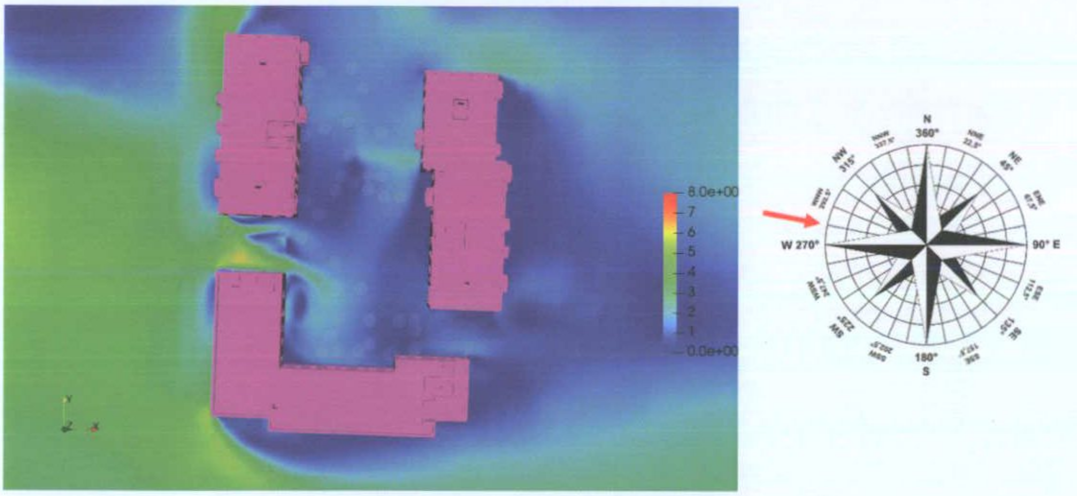


Figure 6.36: Courtyard Block G - Flow Velocity Results at Z=1.5m above the Courtyard - Wind Direction: 281°

6.2.3 Flow Velocity Results - Balconies

Results of velocity at slice location across the balconies are presented in Figures 6.37 to 6.52, for wind assessment of the balconies of the proposed Mixed Use Residential Development.

Higher velocities can be found for some directions, only on some of the balconies. However, these velocities are below the threshold values defined by the acceptance criteria and therefore are not critical for safety.

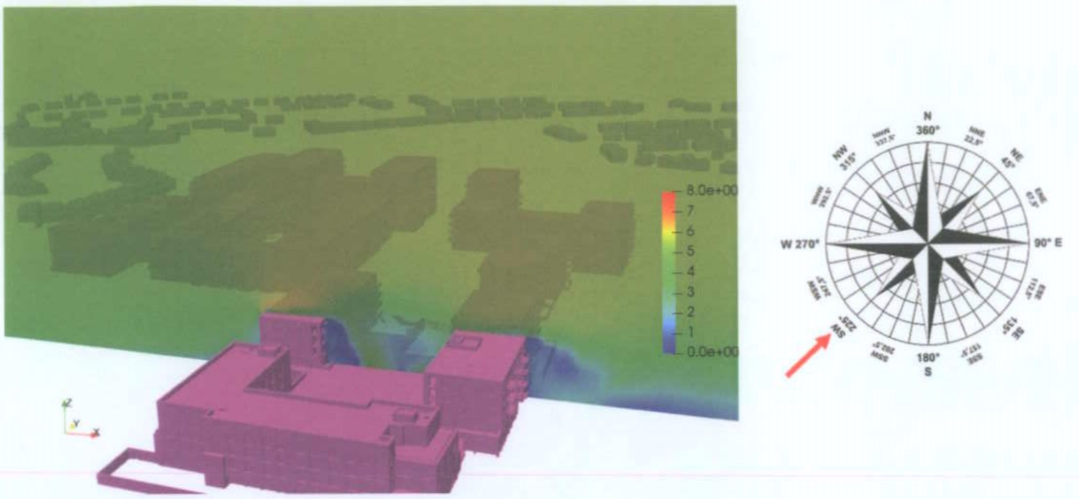


Figure 6.37: Flow Velocity Results of some balconies - Wind Direction: 225°

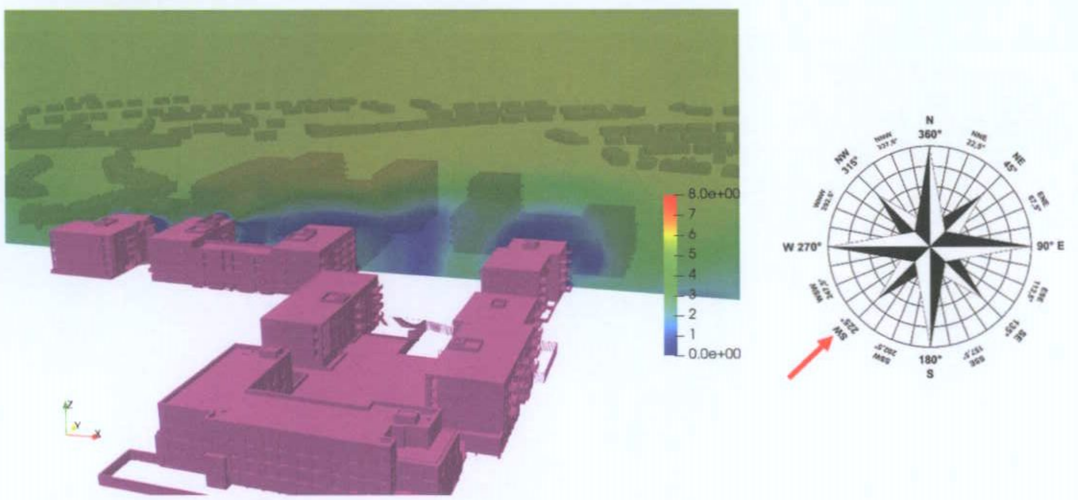


Figure 6.38: Flow Velocity Results of some balconies - Wind Direction: 225°

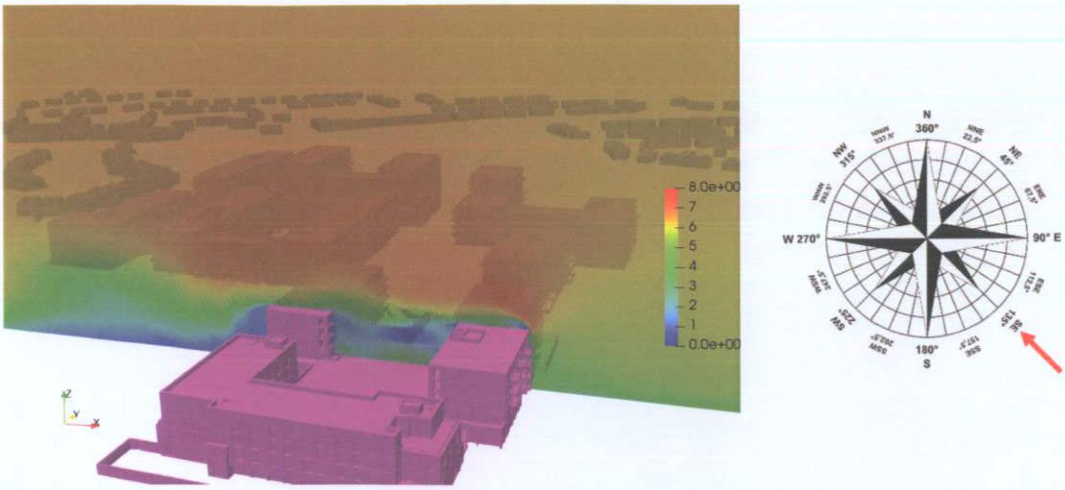


Figure 6.39: Flow Velocity Results of some balconies - Wind Direction: 135°

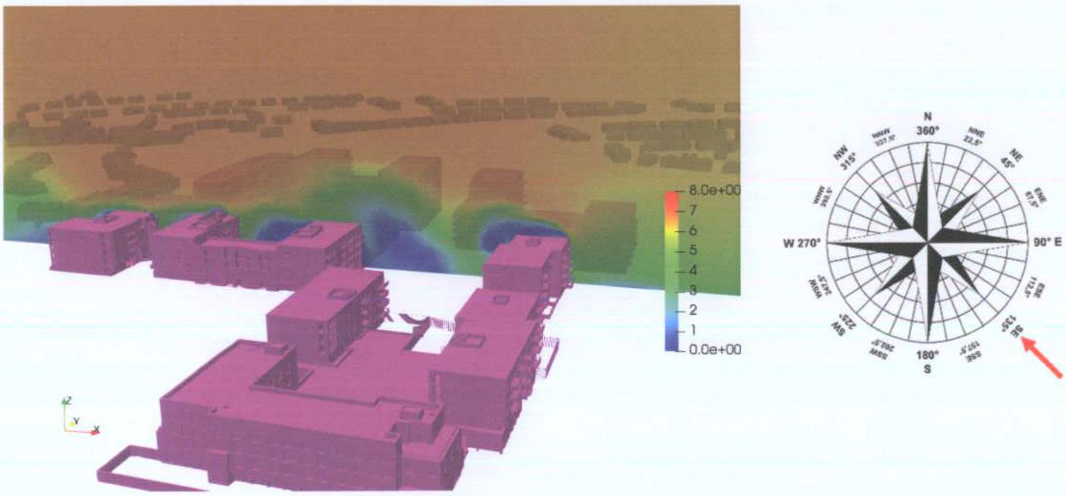


Figure 6.40: Flow Velocity Results of some balconies - Wind Direction: 135°

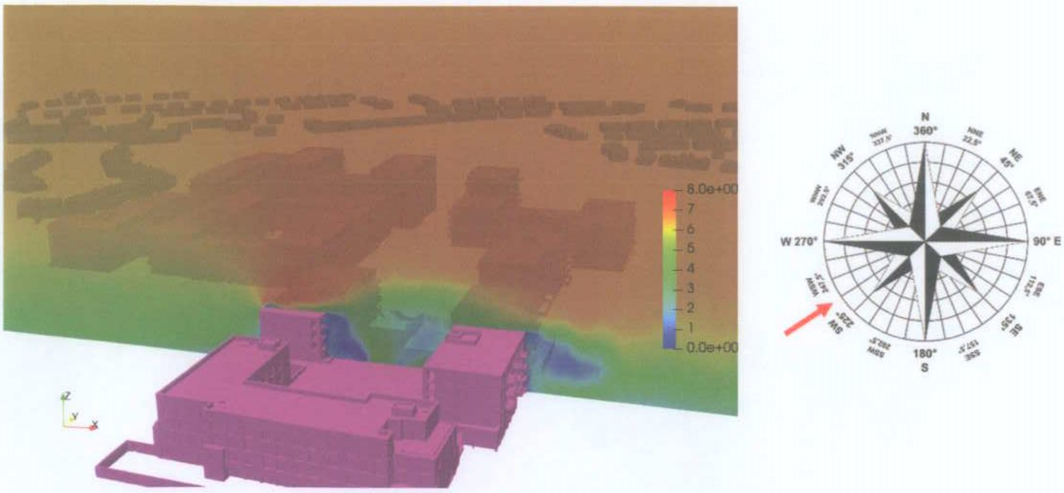


Figure 6.41: Flow Velocity Results of some balconies - Wind Direction: 236°

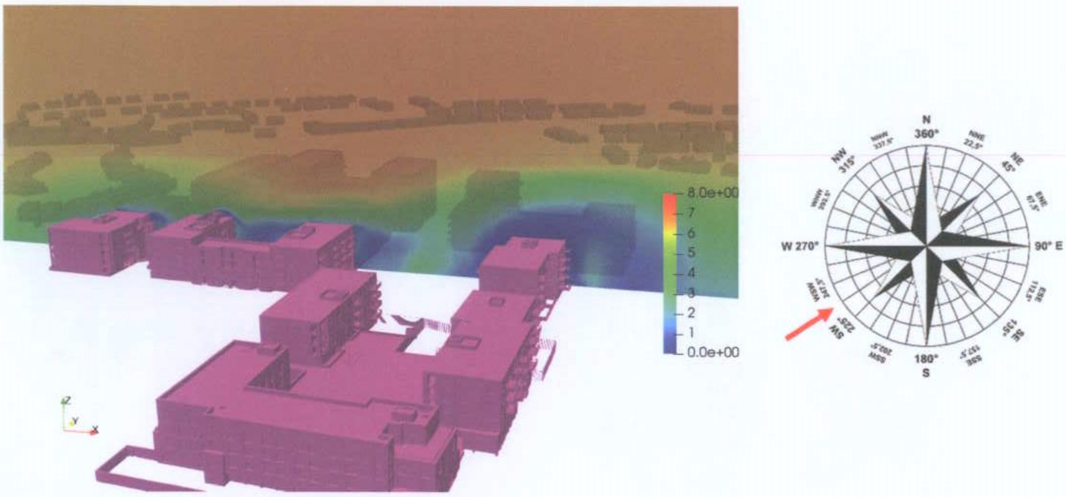


Figure 6.42: Flow Velocity Results of some balconies - Wind Direction: 236°

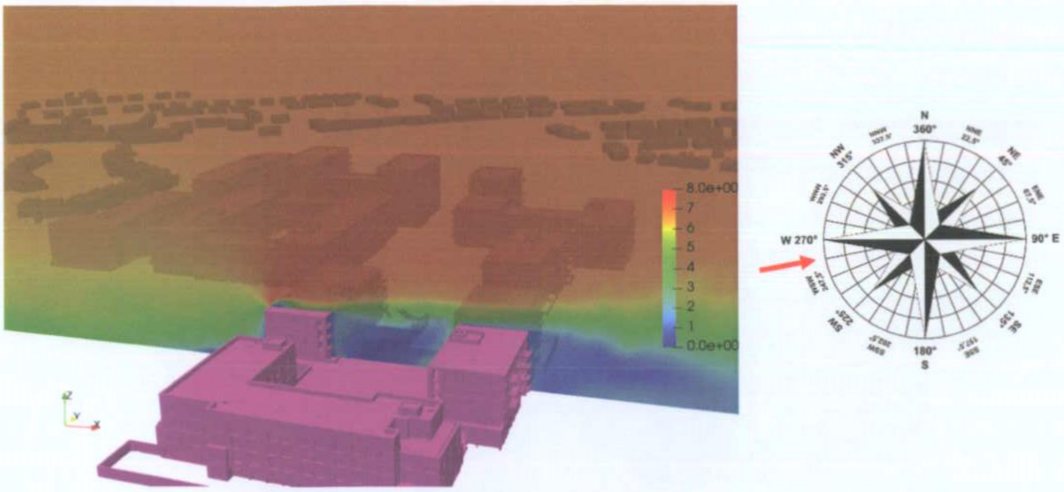


Figure 6.43: Flow Velocity Results of some balconies - Wind Direction: 258°

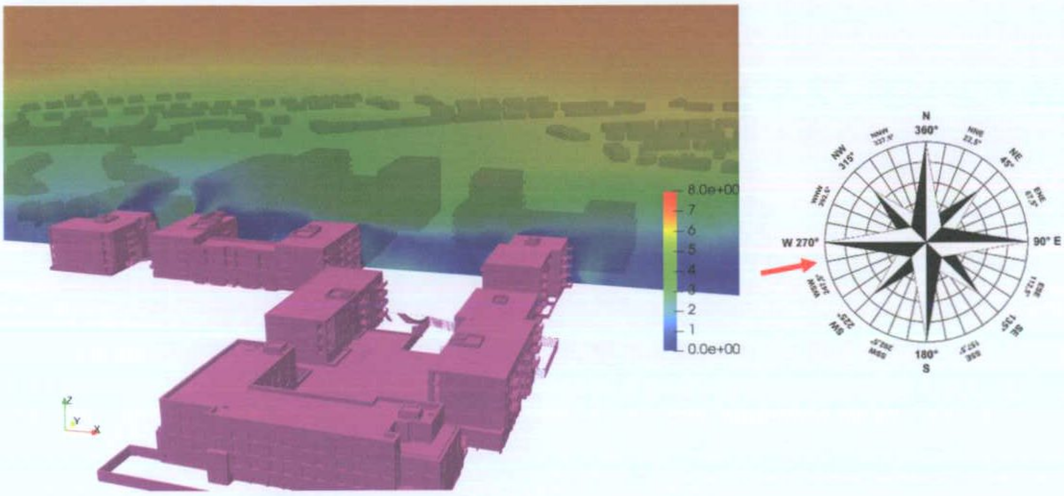


Figure 6.44: Flow Velocity Results of some balconies - Wind Direction: 258°

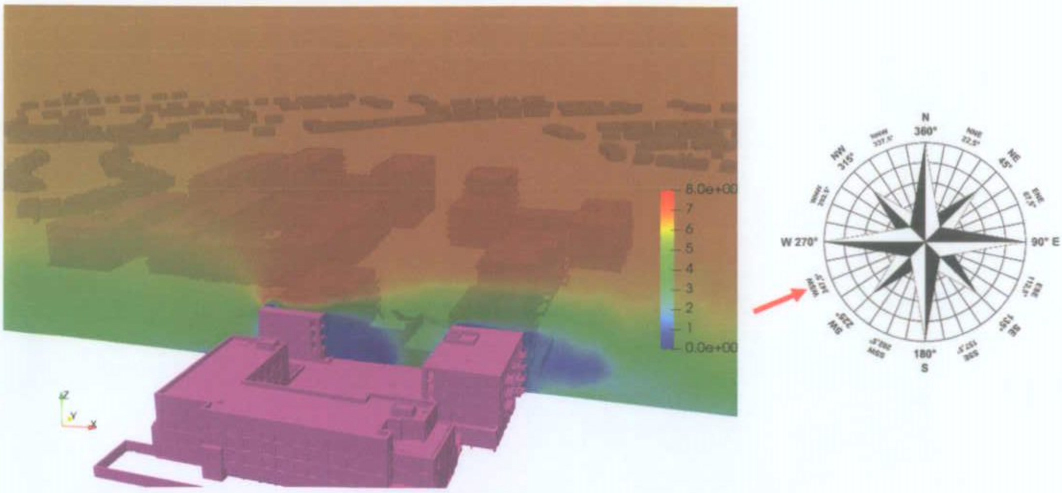


Figure 6.45: Flow Velocity Results of some balconies - Wind Direction: 247°

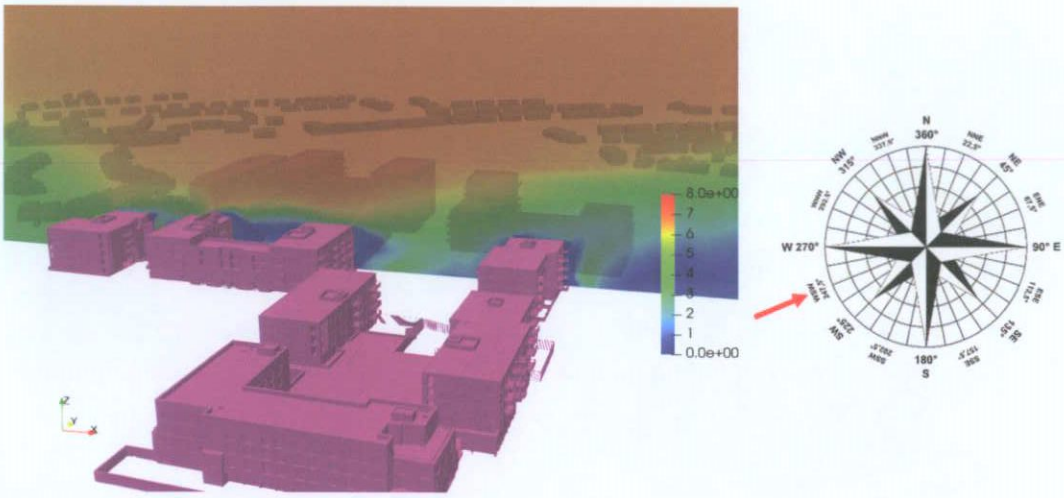


Figure 6.46: Flow Velocity Results of some balconies - Wind Direction: 247°

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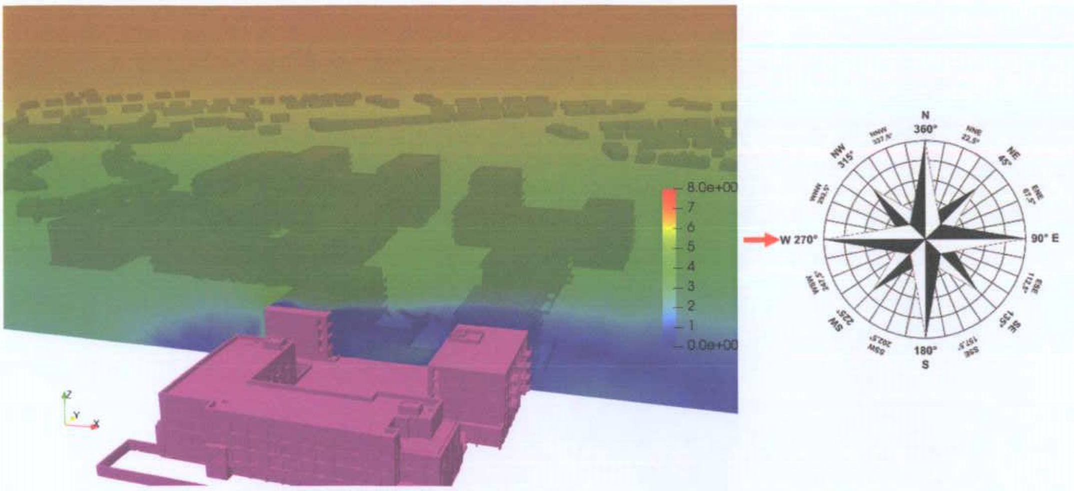

Figure 6.47: Flow Velocity Results of some balconies - Wind Direction: 270°

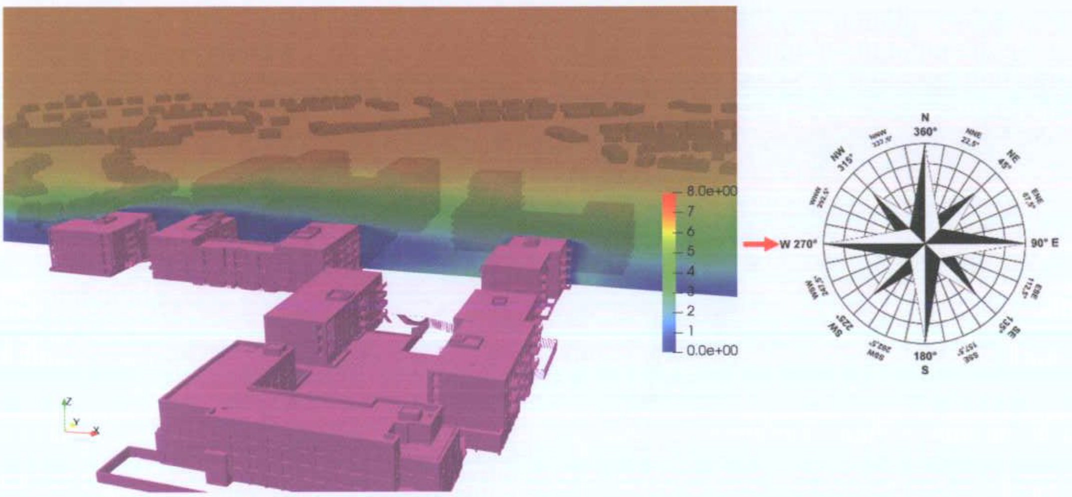

Figure 6.48: Flow Velocity Results of some balconies - Wind Direction: 270°

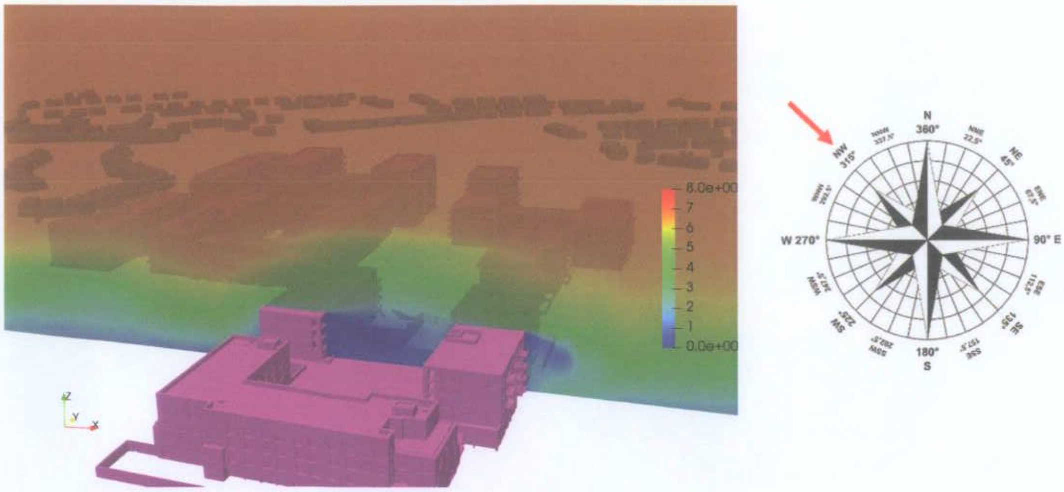

Figure 6.49: Flow Velocity Results of some balconies - Wind Direction: 315°

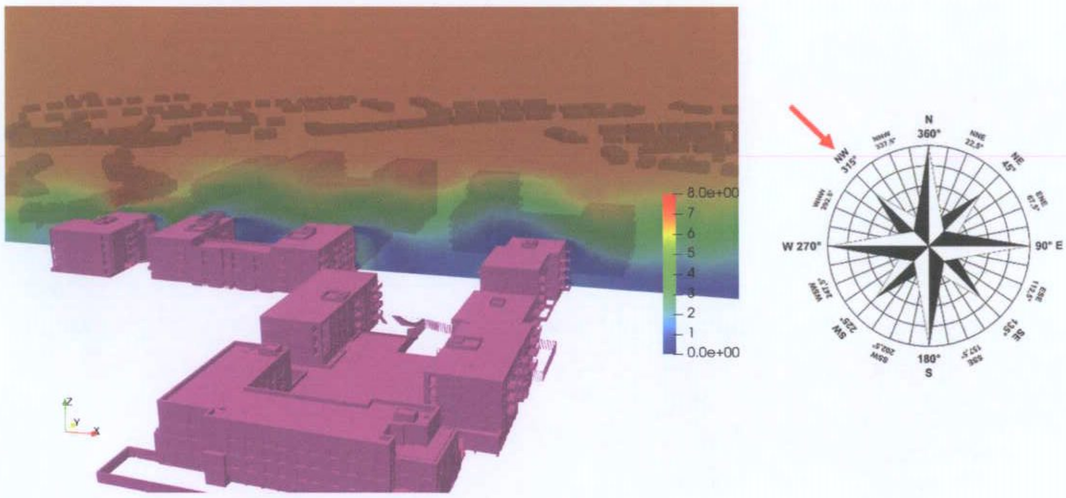

Figure 6.50: Flow Velocity Results of some balconies - Wind Direction: 315°

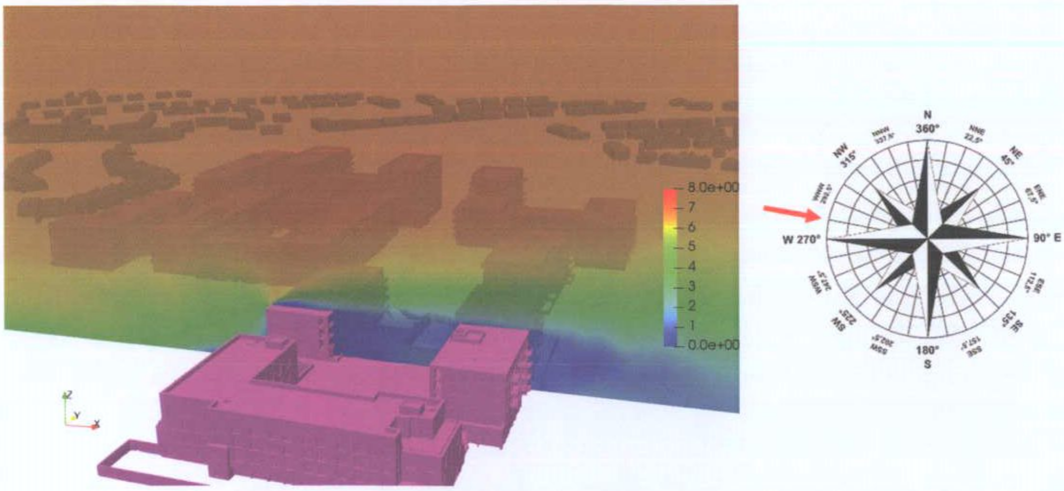

Figure 6.51: Flow Velocity Results of some balconies - Wind Direction: 281°

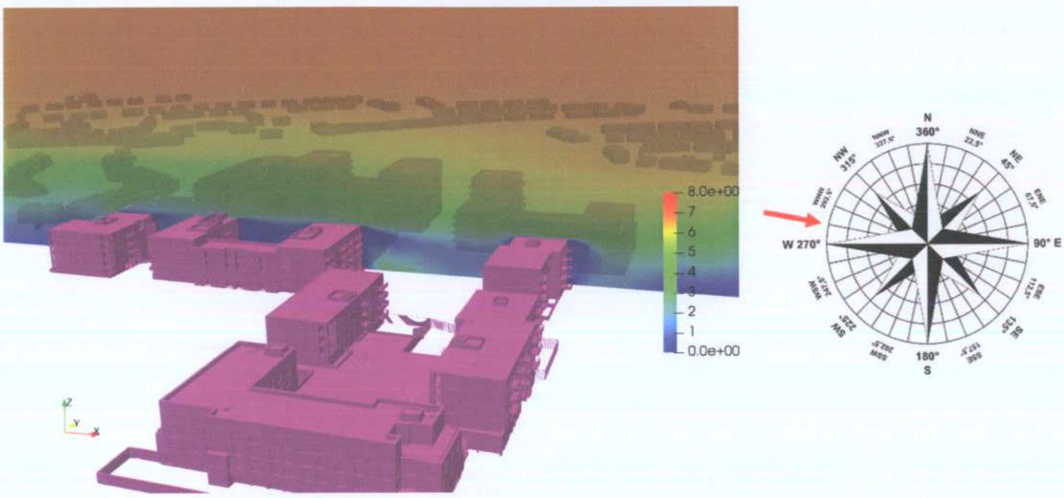

Figure 6.52: Flow Velocity Results of some balconies - Wind Direction: 281°

6.2.4 Pedestrian Comfort Assessment

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

Discomfort Criteria

Figures from 6.54 to 6.55 show the Lawson comfort categories over the ground floor area around the proposed Mixed Use Residential Development. In all cases, the scale used is set out in Figure 6.53.

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

The results shown in these maps show that there are no critical area which are unacceptable for pedestrian comfort. Some higher velocity indicating minor funnelling effects are found between block D and G and the corners of block A, B, C and G. However, these areas can be utilised for the intended use such as short-term sitting, walking and strolling (shown in the Lawson map).

Courtyard on Block D is well protected and good shielding is achieved. Therefore, it can be used for all activities including long-term sitting. Small areas of Courtyard on Block G are suitable for short term sitting instead of long-term sitting, however the majority of the area is appropriate for long term sitting.

Figure 6.53: Lawson Comfort Categories

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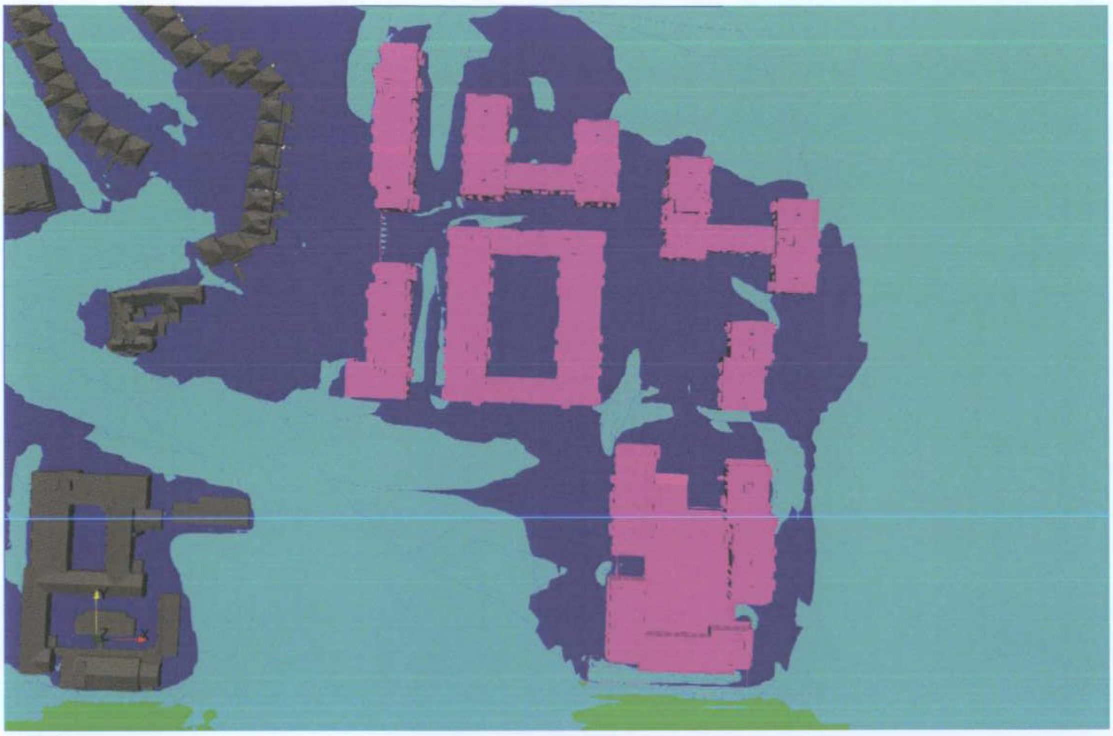

Figure 6.54: Ground Floor - Lawson Discomfort Map - Top View

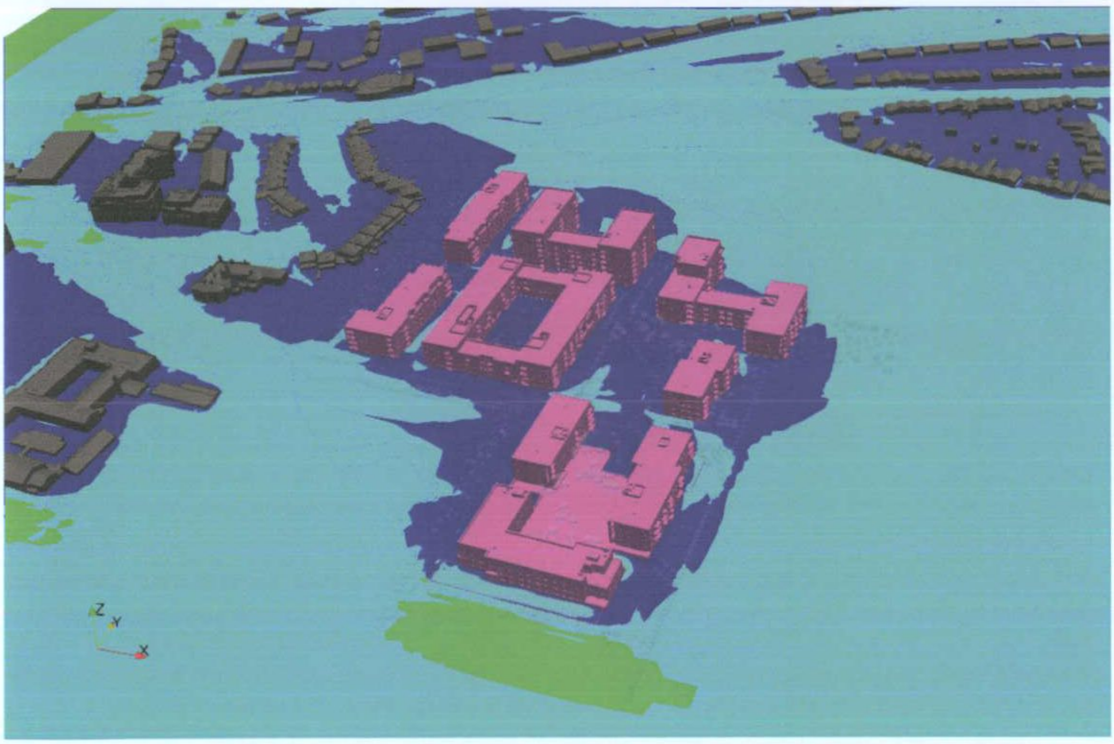

Figure 6.55: Ground Floor - Lawson Discomfort Map - 3D view

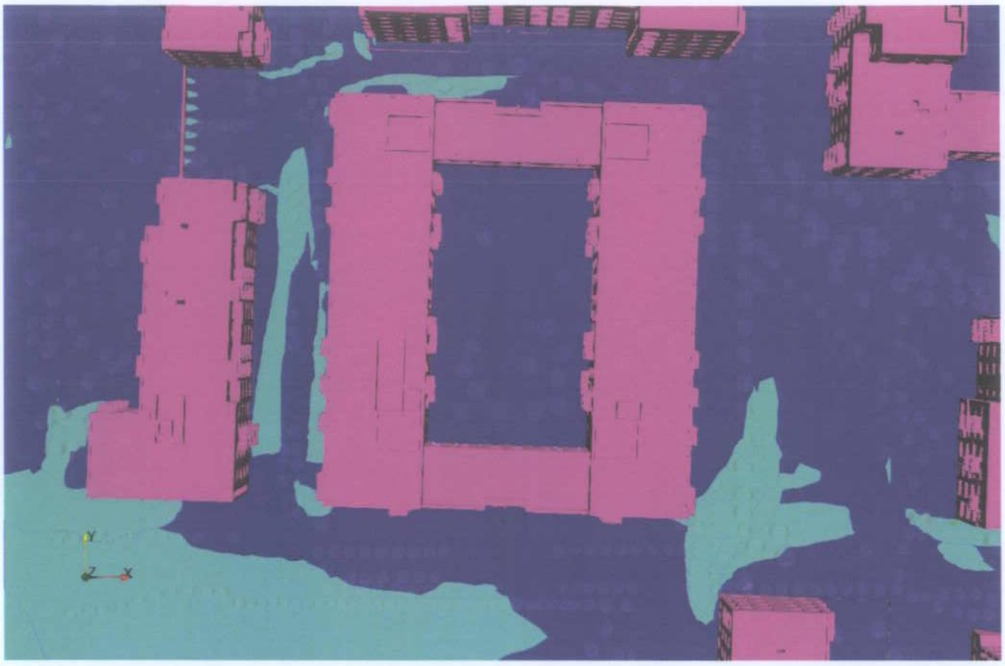

Figure 6.56: Courtyard Block D - Lawson Discomfort Map at Z=1.5m above the Courtyard

Figure 6.57: Courtyard Block G - Lawson Discomfort Map at Z=1.5m above the Courtyard

Distress Criteria

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

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

1. West 270°
2. West-South-West 247.5°
3. South-West 225°

For this reason, it is of interest to show the distress results for these directions. Figure 6.59 below combines all the above directions together and shows the areas where the measured velocity is above 15 m/s. Figure 6.58 shows the scale used in this case. Results show that there are not critical areas where the velocity increases above 15 m/s, thus the criteria is always satisfied.

Figure 6.58: Lawson Distress Categories - Frail Person or Cyclist

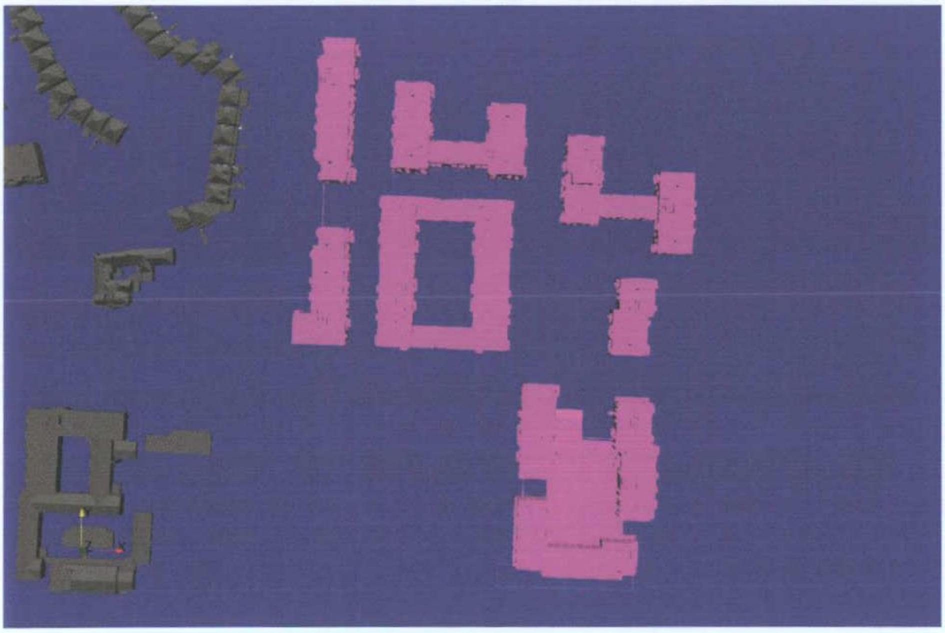

Figure 6.59: Lawson Distress Map - Frail Person or Cyclist

7. CONCLUSIONS

7.1 CONCLUSIONS and COMMENTS ON CFD WIND STUDY

This report presented the Wind Microclimate Modelling study performed for the proposed Mixed Use Residential Development, at lands to the East of St. Pauls College, Sybil Hill Road, Dublin 5. This study has been carried out to identify the possible wind patterns around the area proposed, under mean and peaks wind conditions typically occurring in Dublin, and also to assess impacts of the wind on pedestrian level comfort.

The results of this wind microclimate study are utilized by Raheny 3 Limited Partnership to configure the optimal layout for the proposed Mixed Use Residential Development 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.

A qualitative and quantitative summary of the wind microclimate modelling study performed for the proposed Mixed Use Residential Development shows that:

- The wind profile around the existing development environment was built using the annual average meteorology data collected at Dublin Airport Weather Station. In particular, the local wind climate was determined from historical meteorological data recorded 10 m above ground level at Dublin Airport.
- The prevailing wind directions for the site are identified as West, South-East and West-South-West, with magnitude of approximately 6m/s.
- The proposed Mixed Use Residential Development has been designed in order to produce a high-quality environment that is attractive and comfortable for pedestrians of all categories. To achieve this objective, throughout the design process, the impact of wind has been considered and analysed, in the areas where critical patterns were found, the appropriate mitigation measures were introduced.
- As a result of the final proposed and mitigated design, wind flow speeds at ground floor are shown to be within tenable conditions. Some higher velocity indicating minor funnelling effects are found between block D and G and the corners of block A, B, C and G. However, these areas can be utilised for the intended use such as short-term sitting, walking and strolling.
- Area between Block A and Block D is suitable for short-term sitting instead of long-term sitting due to flow acceleration between the Blocks.
- Courtyard on Block D is well protected and good shielding is achieved. Therefore, it can be used for all activities including long-term sitting.
- Small areas of Courtyard on Block G are suitable for short term sitting instead of long-term sitting, however the majority of the area is appropriate for long term sitting.
- Tree planting all around the development has been utilised, with particular attention to the corners of the Blocks has positively mitigated any critical wind effects.
- Regarding the balconies, higher velocities are found for some directions, only on some of the balconies (mostly on the South and West sides of the blocks). However,

these velocities are below the threshold values defined by the acceptance criteria and therefore are not critical for safety.

- 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.
- The proposed development does not impact or give rise to negative or critical wind speed profiles at the nearby adjacent roads, or nearby buildings.

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

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

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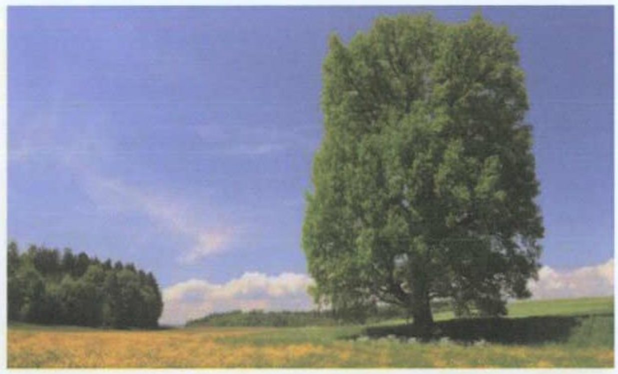
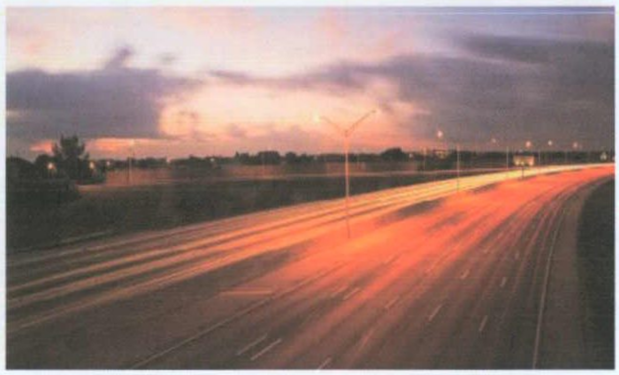
Appendix L Flood Risk Assessment

Waterman Moylan
Engineering Consultants



Flood Risk Assessment

Proposed Large Residential Development (LRD) at Foxlands, Raheny, Dublin 5

August 2022

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Client Name: Raheny 3 Limited Partnership
Document Reference: 21-083r.002 Flood Risk Assessment
Project Number: 21-083

Quality Assurance – Approval Status

This document has been prepared and checked in accordance with
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Issue	Date	Prepared by	Checked by	Approved by
1	18 February 2022	Stephen Dent-Neville	Mark Duignan	Mark Duignan
2	1 July 2022	Stephen Dent-Neville	Mark Duignan	Mark Duignan
3	31 August 2022	Stephen Dent-Neville	Mark Duignan	Mark Duignan

Comments

Waterman Moylan
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Contents

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1. Introduction

1.1 Context

This Flood Risk Assessment has been prepared by Waterman Moylan as part of the documentation in support of a planning application for a proposed mixed-use development at Foxlands in Raheny, Dublin 5.

This Flood Risk Assessment has been carried out in accordance with the *DEHLG/OPW Guidelines on the Planning Process and Flood Risk Management* published in November 2009. This assessment identifies the risk of flooding at the site from various sources and sets out possible mitigation measures against the potential risks of flooding. Sources of possible flooding include coastal, fluvial, pluvial (direct heavy rain), groundwater and human/mechanical errors. This report provides an assessment of the subject site for flood risk purposes only.

1.2 Site Description

Raheny 3 Limited Partnership are applying for permission for development on lands east of St. Paul's College, Sybil Hill Road, Raheny, Dublin 5. The site is bounded to the north, east and south by St Anne's Park and to the west by residential development at The Meadows, Sybil Hill House (a Protected Structure) and St. Paul's College. Vehicular access to the site is from Sybil Hill Road.

The site location is indicated on the Figure below:

Figure 1 | *Site Location (Source: Google Maps)*

The site is a greenfield site. Topographic survey data indicates that the site falls generally from west to east, with a high point of approximately 25.5m OD Malin at the west of the site and a low point of approximately 21.4m OD Malin at the south-eastern corner of the site.

1.3 Proposed Development

The proposed development consists of the construction of a residential and nursing home development set out in 7 no. blocks, ranging in height from 4 to 7 storeys to accommodate 580 no. apartments, residential tenant amenity spaces, a crèche, and a 100-bed nursing home, as set out in the schedule of accommodation below:

Description		1-Bed	2-Bed	3-Bed	Total
Apartment Blocks	Block A	31	25	5	61
	Block B	44	26	-	70
	Block C	46	57	9	112
	Block D	56	58	22	136
	Block E	47	46	3	96
	Block F	23	9	4	36
Mixed-Use (Block G)	Apartments	25	27	17	69
	Nursing Home	100 Bedspaces			-
	Crèche	6 Classrooms			-
Total		272	248	60	580

Table 1 | *Schedule of Accommodation*

The site will accommodate car parking spaces, bicycle parking spaces, storage, services and plant areas at both basement and podium level. Landscaping will include extensive communal amenity areas, and a significant public open space provision on the east and south of the site. The proposed application includes all site landscaping works, green roofs, substations, boundary treatments, lighting, servicing, signage, surface water attenuation facilities and associated and ancillary works, including site development works and services above and below ground.

1.4 Guidelines and Resources

The Department of Environment, Heritage and Local Government (DEHLG) and the Office of Public Works (OPW) published the adopted version of the document "The Planning System and Flood Risk Management Guidelines for Planning Authorities" in November 2009.

These Guidelines provide guidance on flood risk and development. A precautionary approach is recommended when considering flood risk management in the planning system. The core principle of the guidelines is to adopt a risk-based sequential approach to managing flood risk and to avoid development in areas that are at risk. The sequential approach is based on the identification of flood zones for river and coastal flooding.

This approach is based on the identification of flood zones for river and coastal flooding. "Flood Zones" are geographical areas used to identify areas at various levels of flood risk. There are three flood zones defined:

- Flood Zone A: (high probability of flooding) is for lands where the probability of flooding is greatest (greater than 1% or 1 in 100 for river flooding and 0.5% or 1 in 200 for coastal flooding).
- Flood Zone B: (moderate probability of flooding) refers to lands where the probability of flooding is moderate (between 0.1% or 1 in 1,000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 and 0.5% or 1 in 200 for coastal flooding).

- Flood Zone C: (low probability of flooding) refers to lands where the probability of flooding is low (less than 0.1% or 1 in 1000 for both river and coastal flooding).

Once a flood zone has been identified, the guidelines set out the different types of development appropriate to each zone. Exceptions to the restriction of development due to potential flood risks are provided for through the use of the Justification Test, where the planning need and the sustainable management of flood risk to an acceptable level must be demonstrated. This recognises that there will be a need for future development in existing towns and urban centres that lie within flood risk zones, and that the avoidance of all future development in these areas would be unsustainable.

Planning Authorities are required to introduce flood risk assessment as an integral and leading element of their development planning functions. Volume 7 of the Dublin City Development Plan 2016-2022 provides a Strategic Flood Risk Assessment for the area, which was informed by the DEHLG/OPW 2009 Guidelines for Planning Authorities.

The following guidelines and resources were referred to in preparing this flood risk assessment:

- The Planning System and Flood Risk Management Guidelines for Planning Authorities, 2009 (DEHLG/OPW)
- Dublin City Development Plan 2016-2022, Volume 7: Strategic Flood Risk Assessment
- Fingal East Meath Flood Risk Assessment and Management Study (FEMFRAMS)
- The OPW's National Flood Hazard Map
- Geological Survey Ireland (GSI) datasets

1.5 Assessment Methodology

This Flood Risk Assessment report follows the guidelines set out in the Guidelines on the Planning Process and Flood Risk Management. The components to be considered in the identification and assessment of flood risk are as per Table A1 of the above guidelines:

- Tidal – flooding from high sea levels
- Fluvial – flooding from water courses
- Pluvial – flooding from rainfall / surface water
- Groundwater – flooding from springs / raised groundwater
- Human/mechanical error – flooding due to human or mechanical error

Each component will be investigated from a Source, Pathway and Receptor perspective, followed by an assessment of the likelihood of a flood occurring and the possible consequences.

1.5.1 Assessing Likelihood

The likelihood of flooding falls into three categories of low, moderate and high, which are described in the OPW Guidelines as follows:

Flood Risk Components	**Likelihood: % chance of occurring in a year**		
	Low	***Moderate***	***High***
Tidal	*Probability < 0.1%*	*0.5% > Probability > 0.1%*	*Probability > 0.5%*
Fluvial	*Probability < 0.1%*	*1% > Probability > 0.1%*	*Probability > 1%*
Pluvial	*Probability < 0.1%*	*1% > Probability > 0.1%*	*Probability > 1%*

Table 2 | *From Table A1 of "DEHLG/OPW Guidelines on the Planning Process and Flood Management"*

For groundwater and human/mechanical error, the limits of probability are not defined and therefore professional judgment is used. However, the likelihood of flooding is still categorized as low, moderate and high for these components.

From consideration of the likelihoods and the possible consequences a risk is evaluated. Should such a risk exist, mitigation measures will be explored, and the residual risks assessed.

1.5.2 Assessing Consequence

There is not a defined method used to quantify a value for the consequences of a flooding event. Therefore, in order to determine a value for the consequences of a flooding event, the elements likely to be adversely affected by such flooding will be assessed, with the likely damage being stated, and professional judgement will be used in order to determine a value for consequences. Consequences will also be categorized as low, moderate, and high.

1.5.3 Assessing Risk

Based on the determined 'likelihood' and 'consequences' values of a flood event, the following 3x3 Risk Matrix will then be referenced to determine the overall risk of a flood event.

		Consequences		
		Low	***Moderate***	***High***
Likelihood	**Low**	*Extremely Low Risk*	*Low Risk*	*Moderate Risk*
	Moderate	*Low Risk*	*Moderate Risk*	*High Risk*
	High	*Moderate Risk*	*High Risk*	*Extremely High Risk*

Table 3 | *3x3 Risk Matrix*

2. Sequential Test

2.1 General

A sequential approach to planning is a key tool in ensuring that a development, particularly any new development, is first and foremost directed towards land that is at low risk of flooding. The sequential approach is set out in "The Planning System and Flood Risk Management Guidelines for Planning Authorities, 2009" and is referred to in the Dublin City Council Development Plan 2016-2022, Volume 7: Strategic Flood Risk Assessment (SFRA). The sequential approach is illustrated in the Figure below:

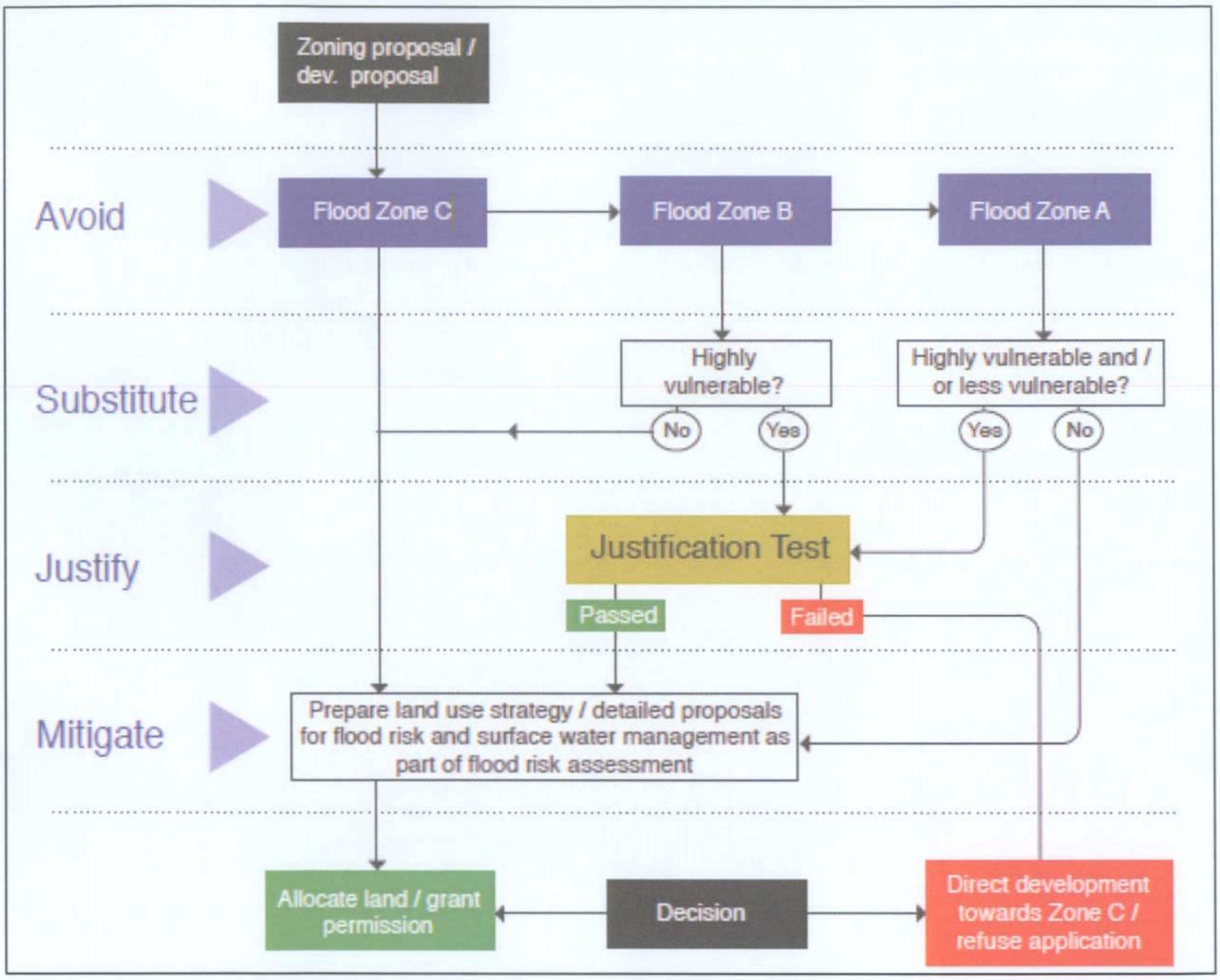

Figure 2 | *Sequential Approach (Extract from Dublin City Council Development Plan 2016-2022 SFRA)*

2.2 Establish Flood Zone

The first step of the sequential test is to establish the flood zone within which the site lies.

The subject site is in Flood Zone C, as it is outside the 1-in-1,000-year flood zone for both tidal and fluvial flooding – refer to Sections 3 and 4, below, for further information.

2.3 Establish Vulnerability Class

The next step is to establish the vulnerability class of the proposal. The Table below, taken from the OPW's "Planning and Flood Risk Management Guidelines for Planning Authorities, 2009" document, lists the vulnerability classes assigned to various land uses and types of development:

Vulnerability Class	Land Uses and Types of Development which include*:
Highly vulnerable development (including essential infrastructure)	Garda, ambulance and fire stations and command centres required to be operational during flooding; Hospitals; Emergency access and egress points; Schools; Dwelling houses, student halls of residence and hostels; Residential institutions such as residential care homes, children's homes and social services homes; Caravans and mobile home parks; Dwelling houses designed, constructed or adapted for the elderly or other people with impaired mobility; and Essential infrastructure, such as primary transport and utilities distribution, including electricity generating power stations and sub-stations, water and sewage treatment, and potential significant sources of pollution (SEVESO sites, IPPC sites, etc.) in the event of flooding.
Less vulnerable development	Buildings used for: retail, leisure, warehousing, commercial, industrial and non-residential institutions; Land and buildings used for holiday or short-let caravans and campong, subject to specific warning and evacuation plans; Land and buildings used for agriculture and forestry; Waste treatment (except landfill and hazardous waste); Mineral working and processing; and Local transport infrastructure.
Water-compatible development	Flood control infrastructure; Docks, marinas and wharves; Navigation facilities; Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location; Water-based recreation and tourism (excluding sleeping accommodation); Lifeguard and coastguard stations; Amenity open space, outdoor sports and recreation and essential facilities such as changing rooms; and Essential ancillary sleeping or residential accommodation for staff required by uses in this category (subject to a specific warning and evacuation plan).

*Uses not listed here should be considered on their own merits

Table 4 | *Vulnerability Classification of Different Types of Development*

The proposed development is a residential development, including a nursing home, and is therefore considered highly vulnerable development.

2.4 Assess Justification Test Requirement

The Table below outlines the matrix of vulnerability based on the Flood Zone:

Description	Flood Zone A	Flood Zone B	Flood Zone C
Highly vulnerable development (including essential infrastructure)	Justification Test	Justification Test	Appropriate
Less vulnerable development	Justification Test	Appropriate	Appropriate
Water-compatible development	Appropriate	Appropriate	Appropriate

Table 5 | *Vulnerability Matrix*

Given that the subject site is within Flood Zone C, no justification test is required for the development.

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3. Tidal Flooding

3.1 Source

Tidal flooding occurs when normally dry, low-lying land is flooded by seawater. The extent of tidal flooding is a function of the elevation inland flood waters penetrate, which is controlled by the topography of the coastal land exposed to flooding.

3.2 Pathway

The site is approximately 1.2km west of the nearest coastline at Dublin Bay, between North Bull Island and the mainland. The Dublin Coastal Protection Project indicated that the 2002 high tide event reached 2.95m OD Malin. The lowest proposed ground floor finished floor level is c.22m OD Malin, well above the historic high tide event.

Coastal Flood Extent Maps, developed as part of the Catchment Flood Risk Assessment and Management (CFRAM) Study, have been consulted as part of this assessment. These maps outline existing and potential flood hazard and risk areas which are being incorporated into a Flood Risk Management Plan. An extract of the CFRAM Coastal Flood Extents Map is shown in the Figure below:

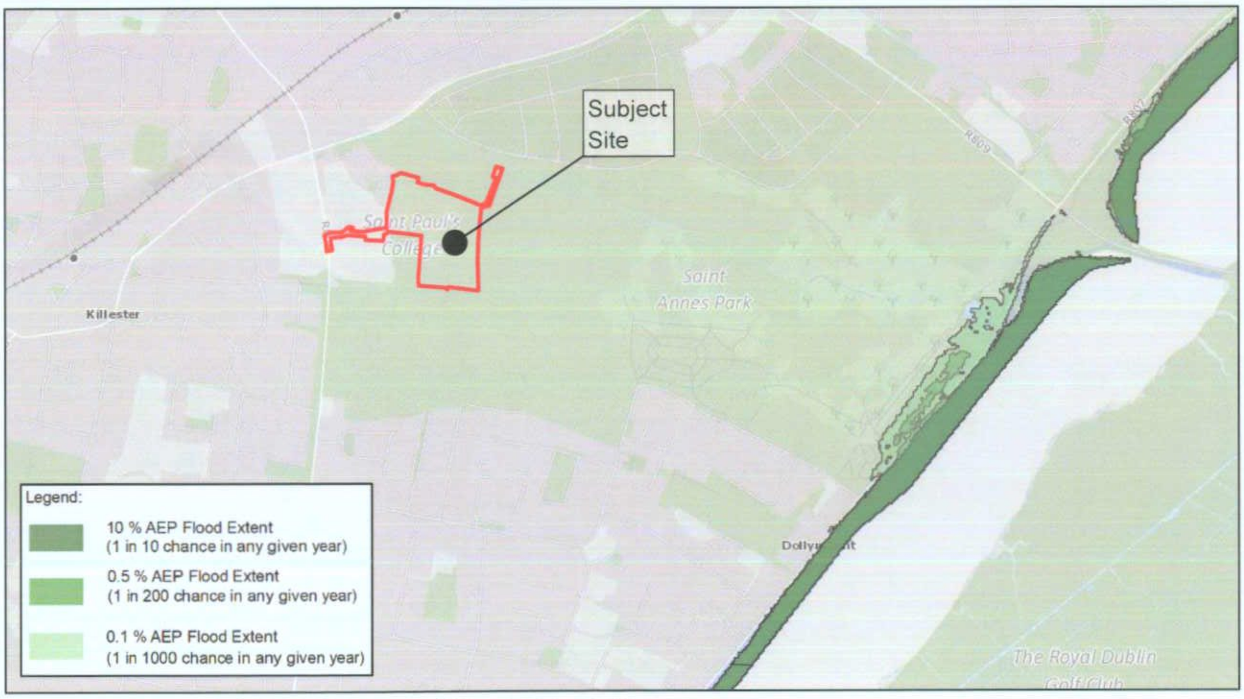

***Figure 3** | Extract of CFRAM Coastal Flood Extents Map*

High probability flood events, as shown in the above map, are defined as having approximately a 1-in-10 chance of occurring or being exceeded in any given year (10% Annual Exceedance Probability), medium probability flood events are defined as having an AEP of 0.5% (1-in-200 year storm), while low probability events are defined having an AEP of 0.1% (1-in-1,000 year storm). The map indicates that the subject development is not at risk of flooding for the 1-in-1,000 year event.

Given that the site is located 1.2km inland from the Irish Sea, that there is at least a 19m level difference between the subject lands and the high tide, and given that the site is outside of the 1-in-1,000 year tidal flood plain, it is evident that a pathway does not exist between the source and the receptor. A risk from tidal flooding is therefore extremely low and no flood mitigation measures need to be implemented.

4. Fluvial Flooding

4.1 Source

Fluvial flooding occurs when a river's flow exceeds its capacity, typically following excessive rainfall, though it can also result from other causes such as heavy snow melt and ice jams.

4.2 Pathway

The Naniken River flows approximately 100m north of the subject site, and the Santry River flows approximately 850m north of the subject site. Fluvial flood extent maps, developed as part of the Catchment Flood Risk Assessment and Management (CFRAM) Study and made available on the OPW's National Flood Information Portal, have been consulted as part of this assessment. These maps outline existing and potential flood hazard and risk areas which are being incorporated into a Flood Risk Management Plan. An extract of the map is shown in the Figure below:

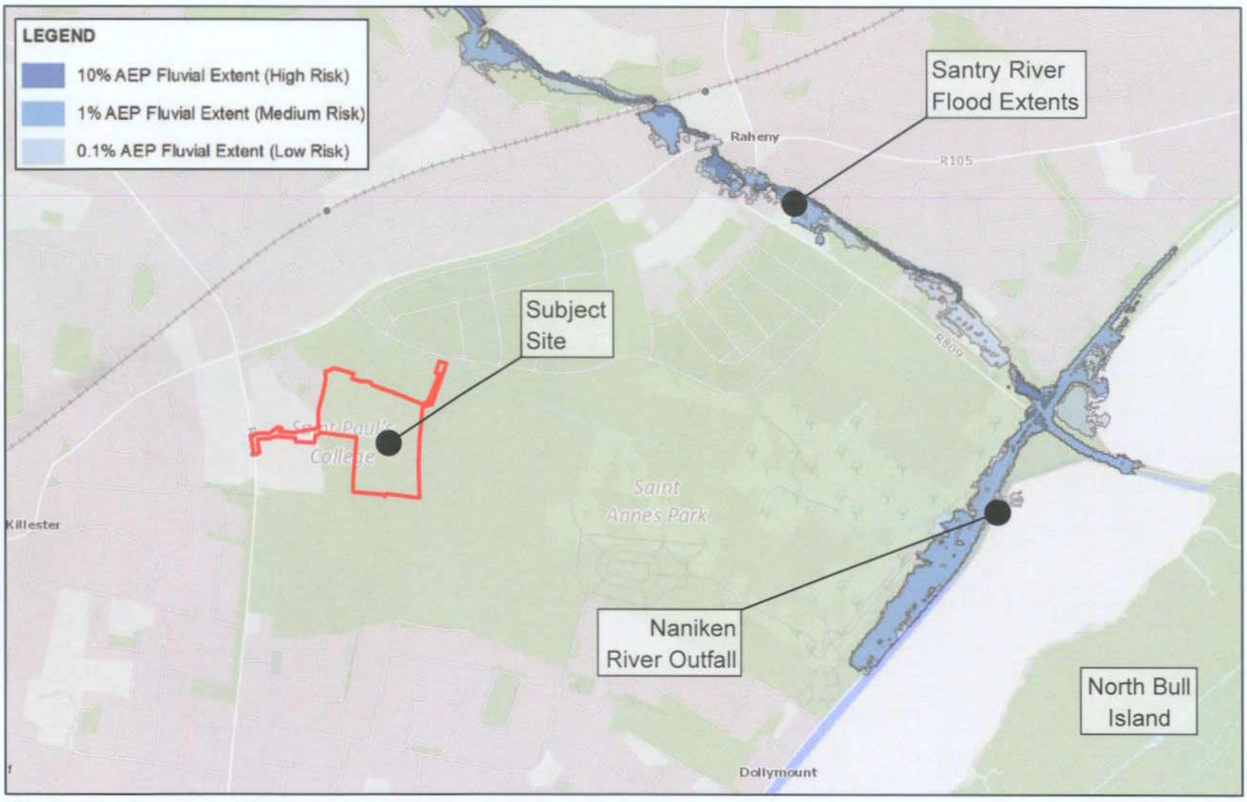

Figure 4 | *Extract of CFRAM Fluvial Flood Extents Map*

High probability flood events, as shown in the above map, are defined as having approximately a 1-in-10 chance of occurring or being exceeded in any given year (10% Annual Exceedance Probability), medium probability flood events are defined as having an AEP of 1% (1-in-100 year storm), while low probability events are defined having an AEP of 0.1% (1-in-1,000 year storm). The map indicates that the subject site is outside of the 0.1% AEP (1-in-1,000 year) flood plain.

The subject site is not within the flood plain of the Santry River. The Naniken River is small and the CFRAM Study does not include any flood information for it. However, adjacent to the site the Naniken has a bed level of c.18.375m OD Malin, with the typical water level less than 0.1m above the riverbed. The lowest point of the site is 21.4m OD Malin, more than 3m above the riverbed.

Furthermore, there is no history of flooding at the site. The OPW's National Flood Hazard Maps, extracted below, have been consulted to identify recorded instances of flooding in the vicinity of the site. The nearest recorded flood event occurred approximately 340m north of the site at Howth Road in June 1963, with no recent recorded flood events in the vicinity of the site.

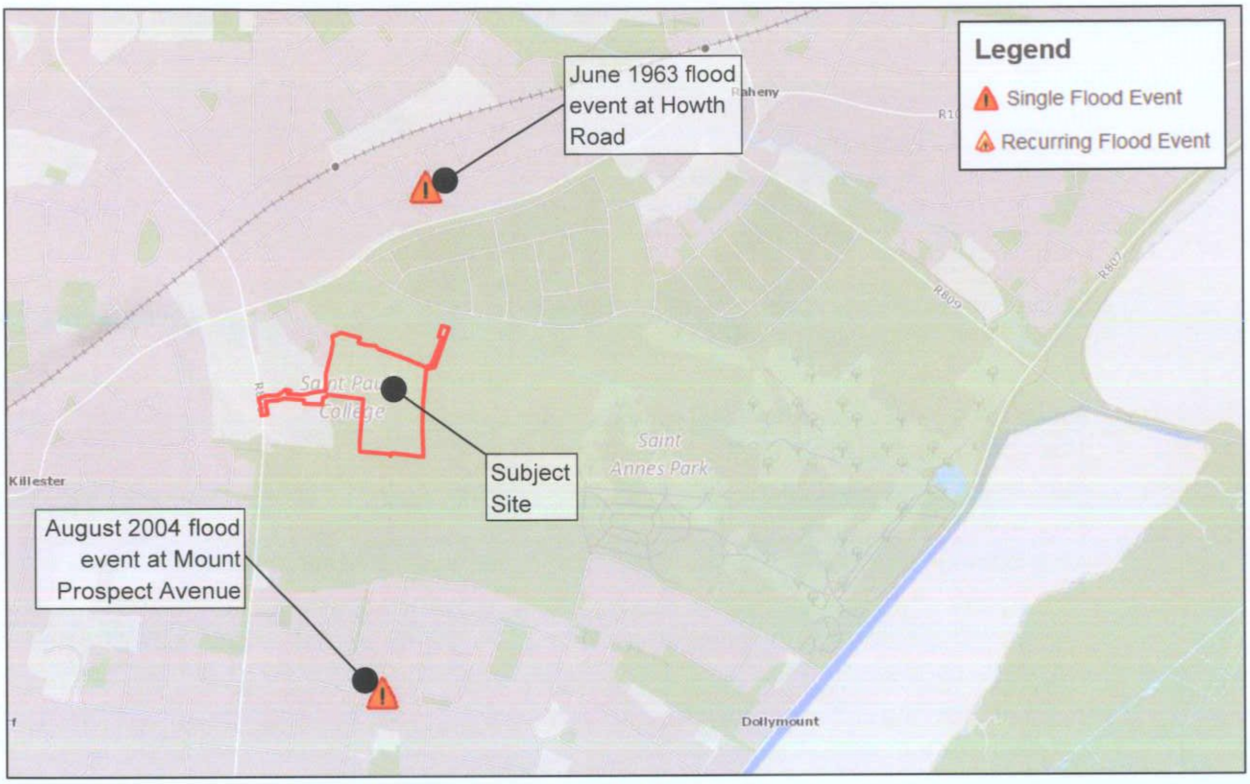

***Figure 5** | Extract from the OPW's Past Flood Events Map*

Given that the site is outside of the 1-in-1,000 year flood plain, that it is more than 3m above the nearest river and that there is no history of flooding, it is evident that a pathway does not exist between the source and the receptor. A risk from fluvial flooding is therefore extremely low and no flood mitigation measures need to be considered.

5. Pluvial Flooding

5.1 Source

Pluvial flooding occurs when heavy rainfall creates a flood event independent of an overflowing water body. Pluvial flooding can happen in any urban area, including higher elevation areas that lie above coastal and river floodplains.

5.2 Pathway & Receptors

During periods of extreme prolonged rainfall, pluvial flooding may occur through the following pathways:

	Pathway	Receptor
1	Surcharging of the proposed internal drainage systems during heavy rain events leading to internal flooding	Proposed development – properties and roads
2	Surcharging from the existing surrounding drainage system leading to flooding within the subject site by surcharging surface water pipes	Proposed development – properties and roads
3	Surface water discharging from the subject site to the existing drainage network leading to downstream flooding	Downstream properties and roads
4	Overland flooding from surrounding areas flowing onto the subject site	Proposed development – properties and roads
5	Overland flooding from the subject site flowing onto surrounding areas	Downstream properties and roads

Table 6 | *Pathways and Receptors*

5.3 Likelihood

The likelihood of each of the 5 pathway types are addressed individually as follows:

5.3.1 Surcharging of the proposed on-site drainage systems:

The proposed on-site surface water drainage sewers have been designed to accommodate flows from a 5-year return event, which indicates that on average the internal system may surcharge during rainfall events with a return period in excess of five years. Therefore, the likelihood surcharging of the on-site drainage system is considered high.

5.3.2 Surcharging from the existing surrounding drainage system:

The OPW's National Flood Hazard Maps, extracted in Section 3.2 above, have been consulted to identify recorded instances of flooding in the vicinity of the site. The nearest recorded flood event occurred approximately 340m north of the site at Howth Road in June 1963. The next closest event occurred approximately 620m south of the site in August 2004. There have been no recent recorded flood events in the vicinity of the site. With no history of flooding in the area due to surcharging, the likelihood of such flooding occurring is considered low.