13.0 WIND

13.1 Introduction

B-Fluid Limited has been commissioned by "Sandyford GP Limited' to carry out a wind microclimate modelling study for the proposed strategic housing development at a 1.54 ha site at the former Aldi Site, Carmanhall Road, Sandyford Business District, Dublin 18. This EIAR chapter is completed as part of the An Bord Pleanála application and outlines the methodology used to assess the wind microclimate impacts of the proposed development.

This Chapter is completed by Dr. Cristina Paduano, Dr. Patrick Okolo and Dr. Eleonora Neri.

Dr. Cristina Paduano is a Chartered Engineer (CEng) and member of Engineers of Ireland who specialises in computational fluid dynamics applications for urban environment and the construction industry, she has prepared multiple EIS and EIAR documents throughout her 10 years of post-qualification experience. She holds a PhD in Mechanical Engineering from Trinity College Dublin specialised in numerical fluid dynamics, with M.Eng and B.Eng in Aerospace Engineering.

Dr. Patrick Okolo is a Chartered Engineer (CEng) and member of Engineers Ireland who specialises in computational fluid dynamics applications for aerospace industry, urban environments, construction industry and marine industry. He holds a PhD in Computational Aeroacoustics branch of Mechanical Engineering from Trinity College Dublin, with M.Eng and B.Eng in Mechanical Engineering.

Dr. Eleonora Neri is a CFD Aerodynamics Engineer and member of Engineers Ireland who specialises in computational fluid dynamics applications for the urban environment, the construction industry and wind tunnel measurement techniques. She holds a PhD in Aeroacoustics branch of Mechanical Engineering from Trinity College Dublin, with M.Eng and B.Eng in Aeronautical Engineering.

Wind microclimate study identifies the possible wind patterns around the existing environment and proposed development under mean and peak wind conditions typically occurring in Dublin. Wind microclimate assessment is performed through advanced Computational Fluid Dynamics (CFD) which is a numerical method used to simulate wind conditions and its impact on the development and to identify areas of concern in terms of downwash, funnelling, downdraft, critical flow accelerations that may likely occur. The Advanced CFD numerical algorithms applied here are solved using high speed supercomputing computer clusters.

The objective of the wind microclimate assessment is to ensure that the proposed design of the development can maintain comfortable and safe pedestrian level wind conditions that are appropriate for seasons and the intended use of pedestrian areas within and close to the development. Pedestrian areas include sidewalks, street frontages, pathways, building entrance areas, open spaces, amenity areas, outdoor sitting areas, and accessible roof top areas among others.

The assessment detailed in this chapter has been carried out considering the impact of wind on the following scenarios:

- The "Existing Receiving Environment": in this case the assessment has considered the impact of the local wind on the area considering the existing buildings prior to the construction of the proposed development. A statistical analysis of 30 years of historical weather wind data has been carried out to find the most critical wind speeds and directions and the frequency of occurrence of the same, furthermore, B-Fluid's weather station has recorded locally 1 month of wind data on the existing site for comparison with the historical ones.

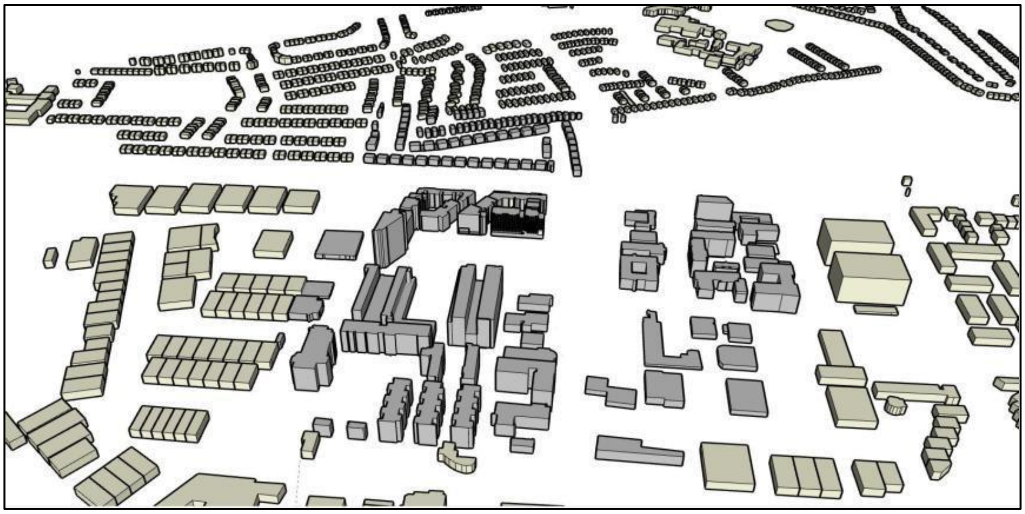


Figure 13.1: Image of Existing Receiving Environment.

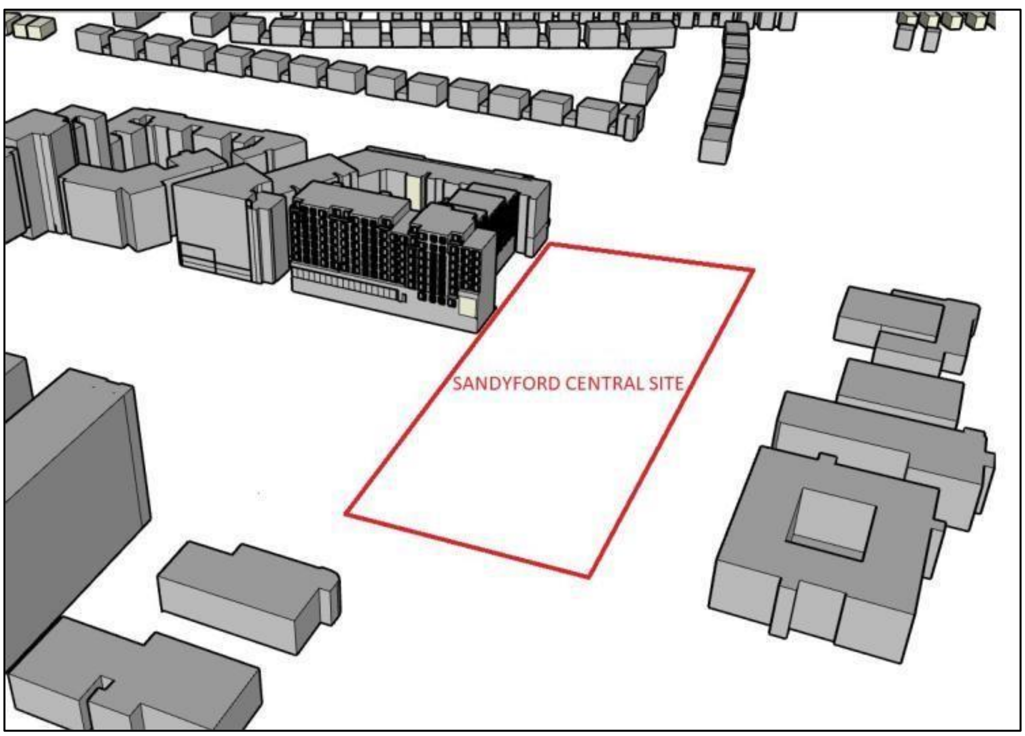


Figure 13.2: Image of Existing Receiving Environment with Highlighted Site Location.

- The "Proposed Development": in this case the assessment has considered the impact of wind on the existing area including the proposed Sandyford Central Development. For this scenario, the analysis has identified the critical areas of the proposed development that required the implementation of mitigations measures.

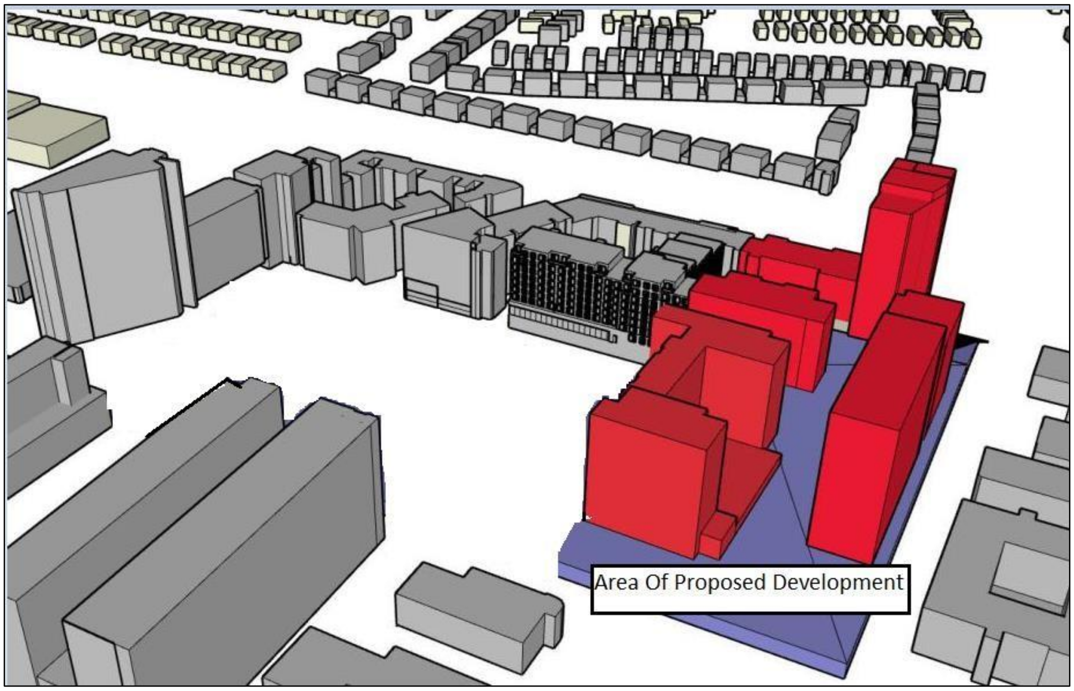


Figure 13.3: Image of the Proposed Development (in Red) with its Ground Occupied Modelled Surface (in violet).

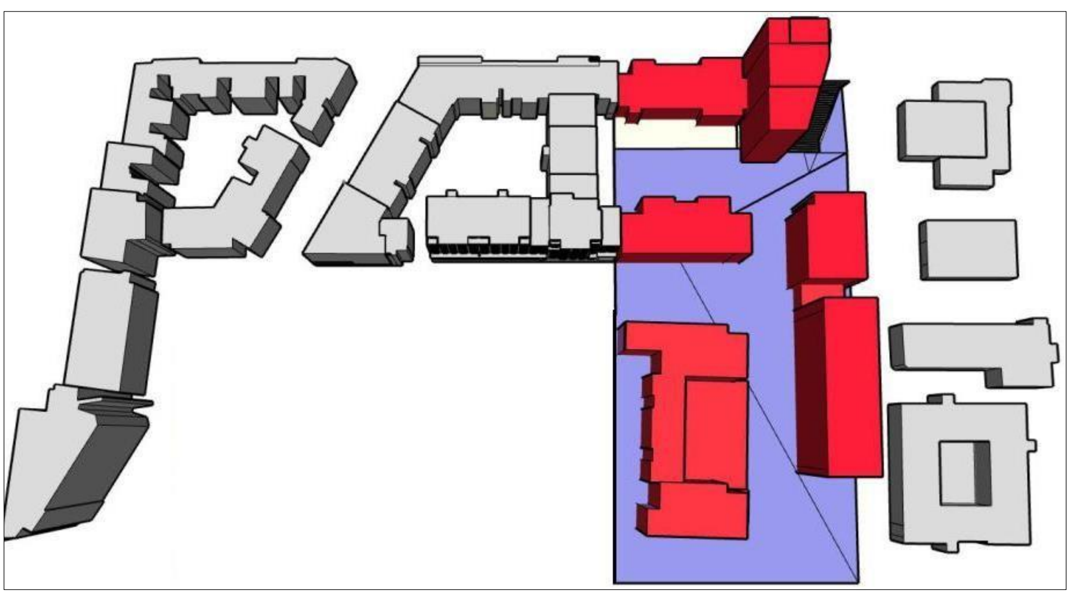


Figure 13.4: Image of Proposed Development - Top View.

- The "Cumulative Impact": in this case the assessment has considered the impact of wind on the existing area including the proposed Sandyford Central Development and the adjacent Rockbrook Phase 2 buildings for which a SHD application has recently been granted by ABP (Ref.PL06D.304405). For this scenario, the Sandyford Central Development has been simulated inclusive of its mitigation measures impact in the locations identified as critical during the "Proposed Development" scenario.

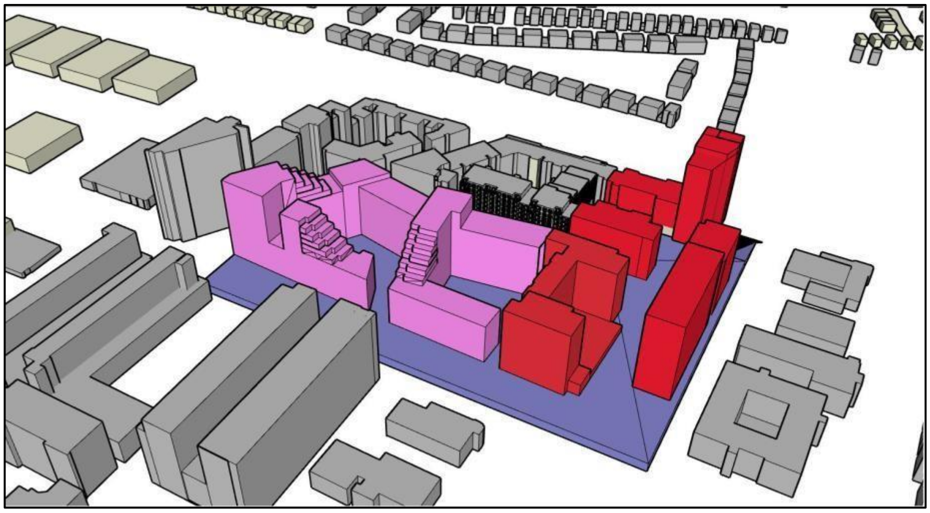


Figure 13.5: Proposed Development (Coloured in Red) and Adjacent Rockbrook Phase 2 Buildings (Coloured in Pink)- Ground Occupied Surface as Modelled in Violet.

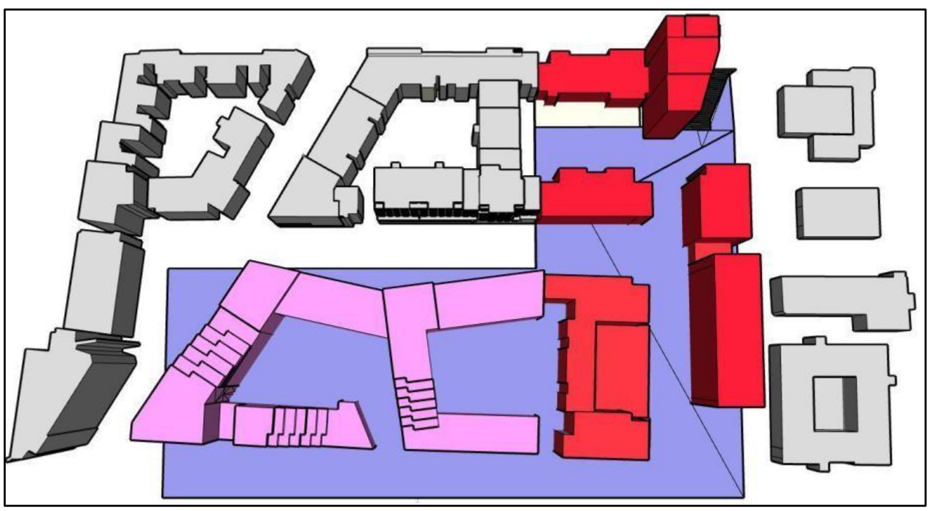


Figure 13.6: Proposed Development (Coloured in Red) and Adjacent Rockbrook Phase 2 Buildings (Coloured in Pink)-Top View.

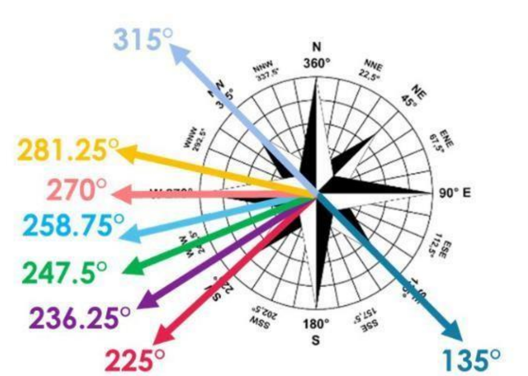
The wind and microclimate study, has been carried out through CFD modelling by B-Fluid Ltd. The objective of the analysis is to identify areas of concern in terms of critical flows and areas where the pedestrian safety and comfort could be compromised and to implement mitigation measures that can improve the comfort and safety of any critical areas identified.

In the following paragraphs, reports on all the project information and modelling assumptions used throughout the CFD study, together with results of the simulations carried out, are presented.

13.1.1 Objective of the CFD wind modelling

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

For this purpose, 16 different scenarios have been modelled, in order to take into consideration all the different relevant wind directions. In particular, a total of 16 compass directions on the wind rose are selected. For each direction, the reference wind speed is set to the 5% exceedance wind speed for that direction, i.e. the wind speed that is exceeded for only 5% of the time whenever that wind direction occurs. Figure 13.8 shows the 16 directions selected. This report focuses on the first 4 directions, which are the ones that have shown more relevant results. Each of the 4 modelled scenarios which are reported in this report, are the first 4 directions presented in the table that follows. The details of the design wind adopted are described in the next sections of this report.



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

Figure 13.7: Summary of the Dominant Wind Directions in Dublin.

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

Figure 13.8: Summary of the 16 Scenarios Modelled for the Wind Study.

13.2 Development Description

Sandyford GP Limited (acting in its capacity as general partner for the Sandyford Central Partnership) intend to apply to An Bord Pleanála for permission for a strategic housing development at a 1.54 ha site at the former Aldi Site, Carmanhall Road, Sandyford Business District, Dublin 18.

The development, which will have a Gross Floor Area of 49,342 sq m will principally consist of: the demolition of the existing structures on site and the provision of a Build-to-Rent residential development comprising 564 No. apartments (46 No. studio apartments, 205 No. one bed apartments, 295 No. two bed apartments and 18 No. three bed apartments) in 6 No. blocks as follows: Block A (144 No. apartments) is part 10 to part 11 No. storeys over basement; Block B (68 No. apartments) is 8 No. storeys over basement; Block C (33 No. apartments) is 5 No. storeys over lower ground; Block D (103 No. apartments) is part 16 to part 17 No. storeys over lower ground; Block E (48 No. apartments) is 10 No. storeys over semi-basement; and Block F (168 No. apartments) is 14 No. storeys over semi basement.

The development provides resident amenity spaces (1,095 sq m) in Blocks A, C and D including concierge, gymnasium, lounges, games room and a panoramic function room at Roof Level of Block D; a creche (354 sq m); café (141 sq m); a pedestrian thoroughfare from Carmanhall Road to Blackthorn Drive also connecting into the boulevard at Rockbrook to the west; principal vehicular access off Carmanhall Road with servicing and bicycle access also provided off Blackthorn Drive; 285 No. car parking spaces (254 No. at basement level and 31 No. at ground level); 21 No. motorcycle spaces; set-down areas; bicycle parking; bin storage; boundary treatments; hard and soft landscaping; lighting; plant; ESB substations and switchrooms; sedum roofs; and all other associated site works above and below ground.

The figures that follow show different views of the proposed development of the site.

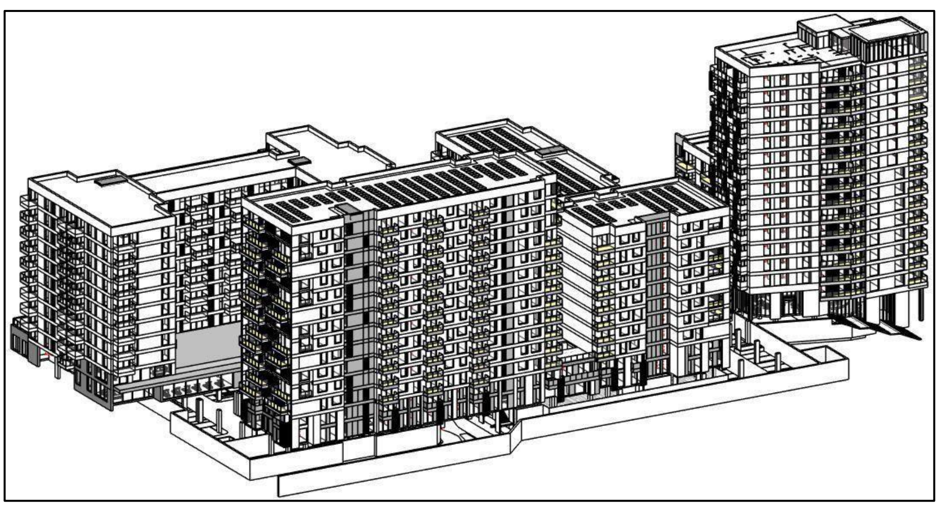


Figure 13.9: Iso View of Proposed Sandyford Central Development.

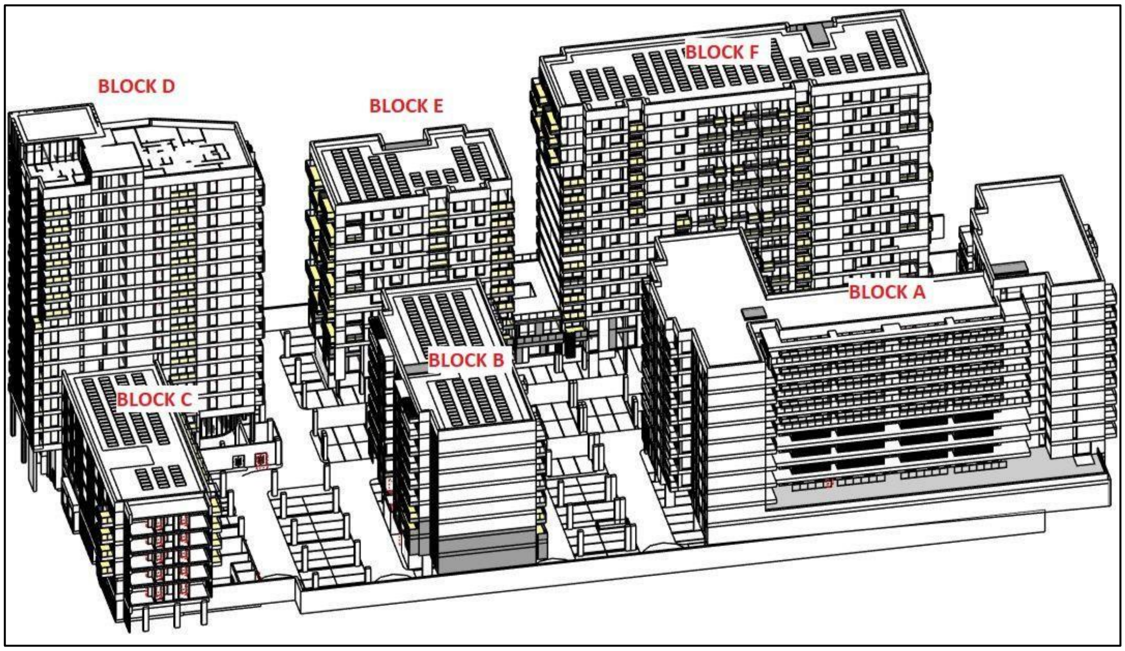


Figure 13.10: Iso View of Proposed Sandyford Central Development.

13.3 Wind Impact Assessment on Buildings

13.3.1 Planetary Boundary Layer and Terrain Roughness

Due to aerodynamic drag, there is a wind gradient in the wind flow just a few hundred meters above the Earth's surface – "the surface layer of the planetary boundary layer". Wind speed increases with increasing height above the ground, starting from zero, due to the no-slip condition. In particular, the wind velocity profile is parabolic. Flow near the surface encounters obstacles that reduce the wind speed and introduces random vertical and horizontal velocity components. This turbulence causes vertical mixing between the air moving horizontally at one level, and the air at those levels immediately above and below it. For this reason, the velocity profile is given by a fluctuating velocity along a mean velocity value.

Figure 13.11 13.11 shows the wind velocity profile, as described above.

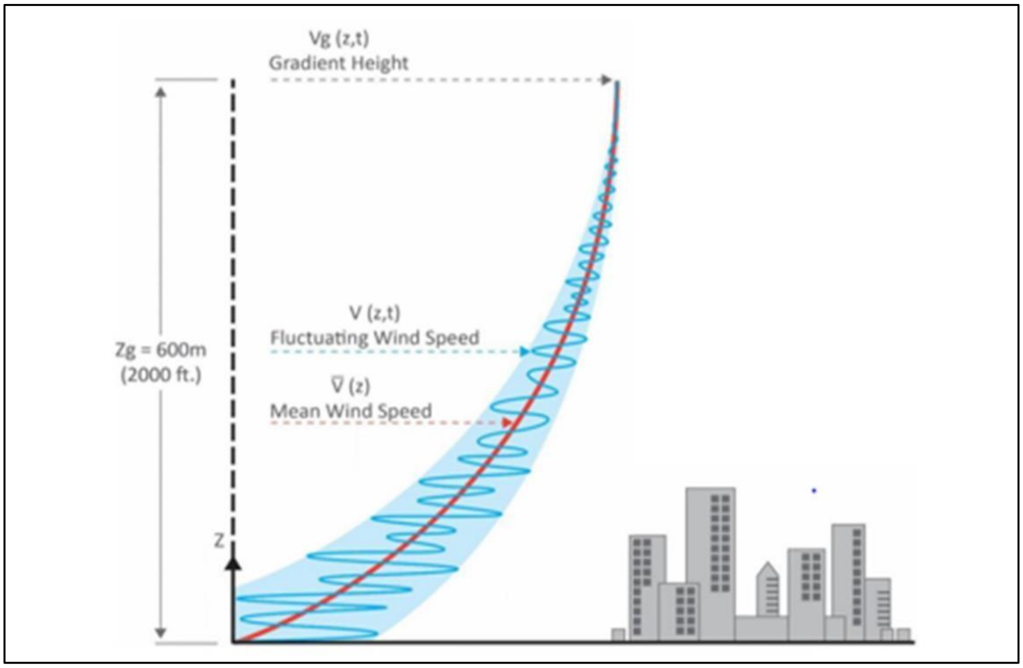


Figure 13.11: Wind Velocity Profile.

Two effects influence the shape of the wind speed profile:

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

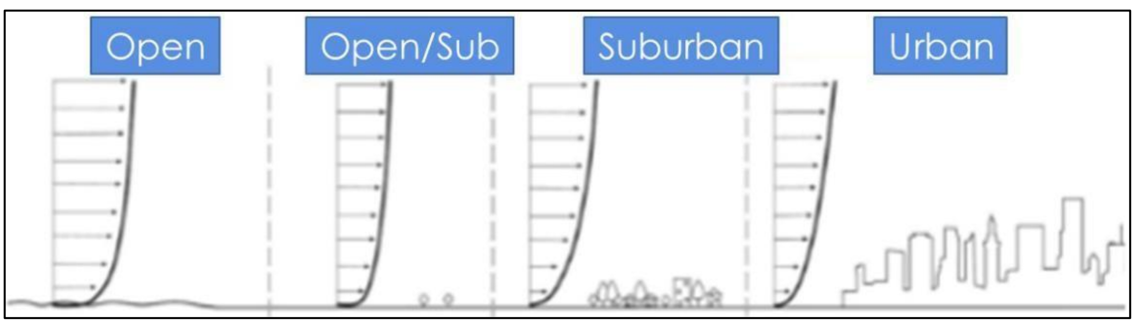


Figure 13.12: Wind Velocity Profile for Different Terrains.

In order to assess the wind conditions in a particular area, it is important to know (Figure 13.13):

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

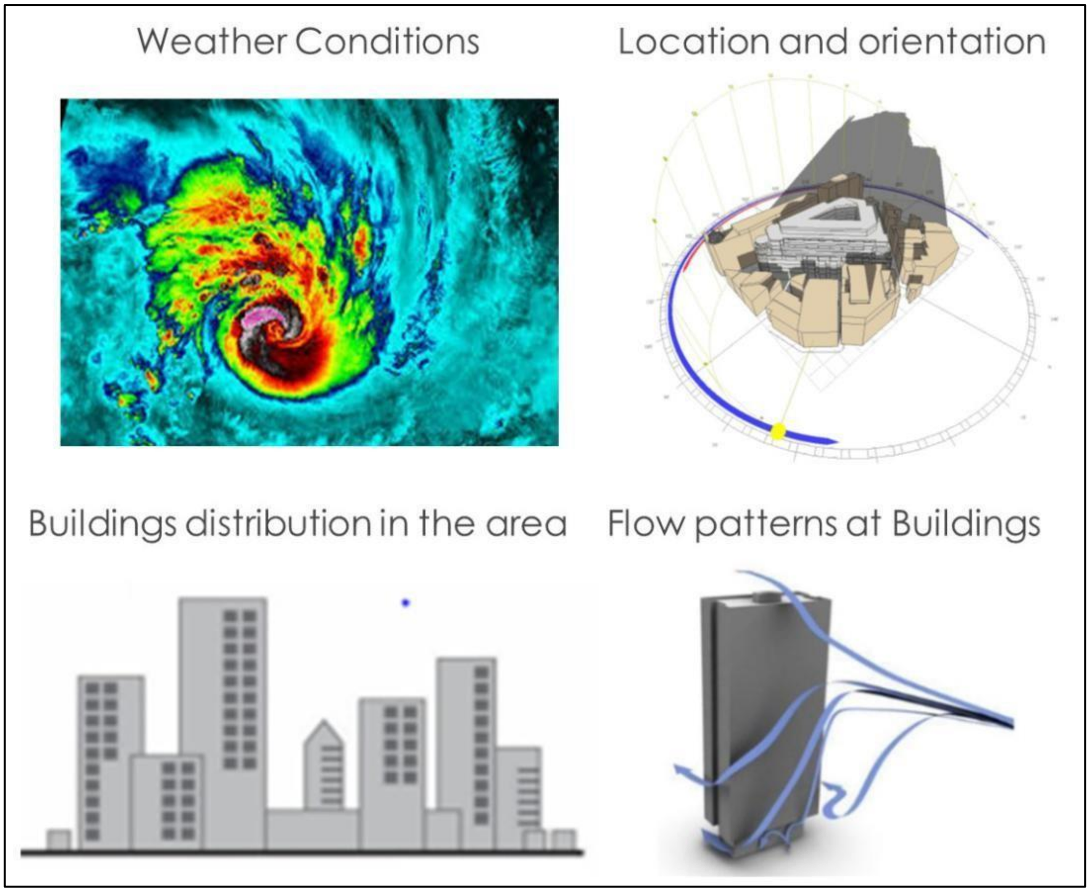


Figure 13.13: Parameters to know for Wind Conditions Assessment.

Moreover, it is important to understand key flow features (Figure 13.14):

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

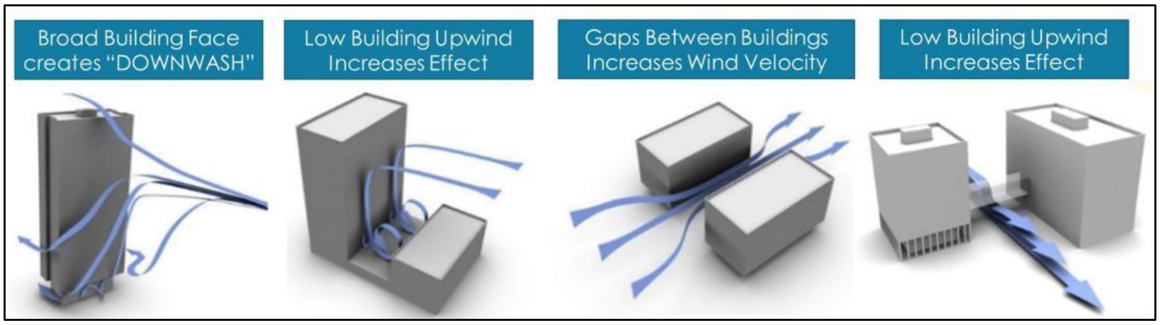


Figure 13.14: Parameters to know for Wind Conditions Assessment.

13.4 Acceptance Criteria

13.4.1 Pedestrian Comfort and Lawson Criteria

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

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

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

- DISCOMFORT CRITERIA: Relates to the activity of the individual. Onset of discomfort:
  - Depends on the activity in which the individual is engaged and is defined in terms of a mean hourly wind speed (or GEM) which is exceeded for 5% of the time.
- DISTRESS CRITERIA: Relates to the physical well-being of the individual. Onset of distress:
  - 'Frail Person Or Cyclist': equivalent to an hourly mean speed of 15 m/s and a gust speed of 28 m/s (62 mph) to be exceeded less often than once a year. This is intended to identify wind conditions which less able individuals or cyclists may find physically difficult. Conditions in excess of this limit may be acceptable for optional routes and routes which less physically able individuals are unlikely to use.
  - 'General Public': A mean speed of 20 m/s and a gust speed of 37 m/s (83 mph) to be exceeded less often than once a year. Beyond this gust speed, aerodynamic forces approach body weight and it rapidly becomes impossible for anyone to remain standing. Where wind speeds exceed these values, pedestrian access should be discouraged.

The above criteria set out six pedestrian activities and notes that calm activity requires calm wind conditions, which are summarised by the Lawson scale, shown in Figure 13.15 The Lawson scale assesses pedestrian wind comfort in absolute terms and defines the reaction of an average person to the wind. Each wind type is associated to a number, corresponding to the Beaufort scale, which is represented in Figure 13.16The 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 13.15: Lawson Scale.

THE BEAUFORT SCALE

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

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

Figure 13.16: 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 theyear.

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 measures should be implemented into the design.

13.5 Mitigation Measures

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

For this site, the mitigation uses directly connected to the wind assessment carried out are in the form of tree landscaping in appropriate location as shown in the following paragraphs. However, it must be noted that, as part of the design process and the architectural proposal, already features which are going to mitigate the wind have been introduced, these include parapets solid for the balconies, partially enclosure of the terrace on block D, covered entrances.

In particular, it is possible to summarise the different flow features and the corresponding mitigation option as follows (Figure 13.17 and Figure 13.18):

- **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.

AN EXAMPLE OF TYPICAL MITIGATION OPTIONS:

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

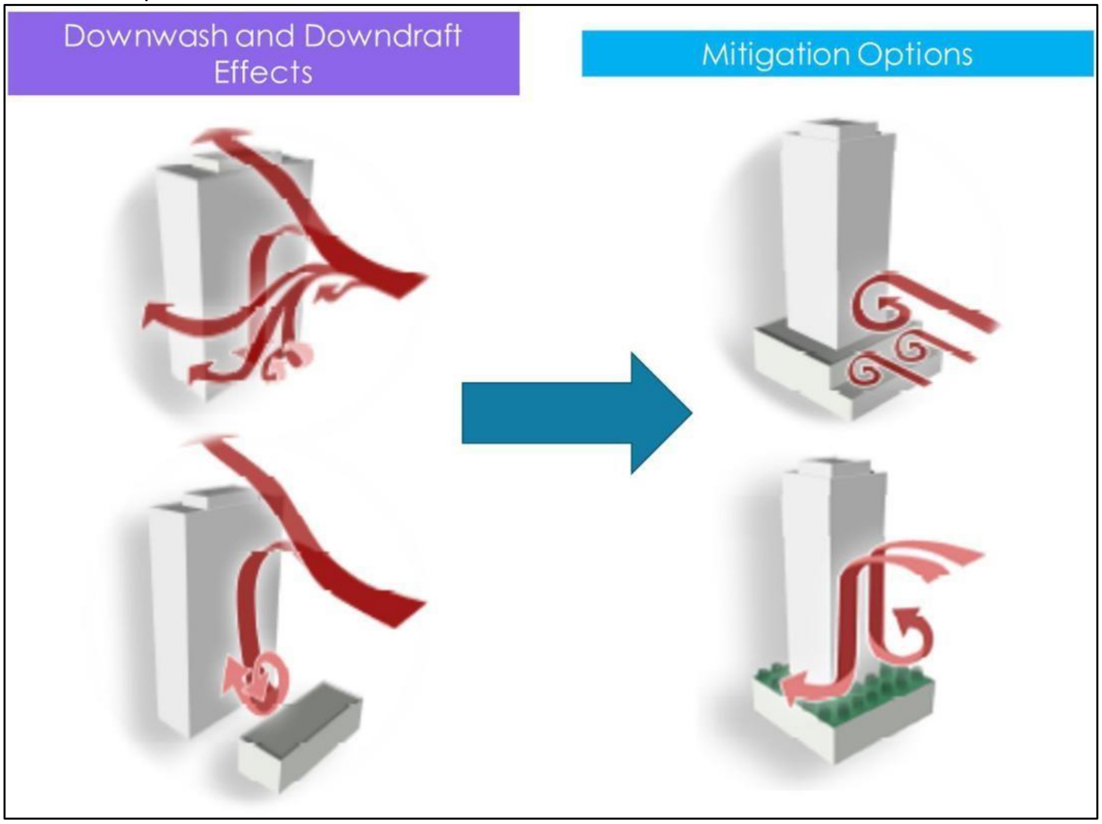


Figure 13.17: Mitigation Measures for Downwash and Downdraft Effects.

- **Funnelling Effects**: Wind speed is accelerated when wind is funnelled 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.

  AN EXAMPLE OF TYPICAL MITIGATION OPTIONS:
  – A horizontal canopy on the windward face of a base building can improve pedestrian level wind conditions. Parapet walls around a canopy can make the canopy more effective.
  – Sloped canopies only provide partial deflection of downward wind flow.

– A colonnade on the windward face of the base building provides the pedestrian with a calm area where to walk while being protected or a breeze walking space outside the colonnade zone.

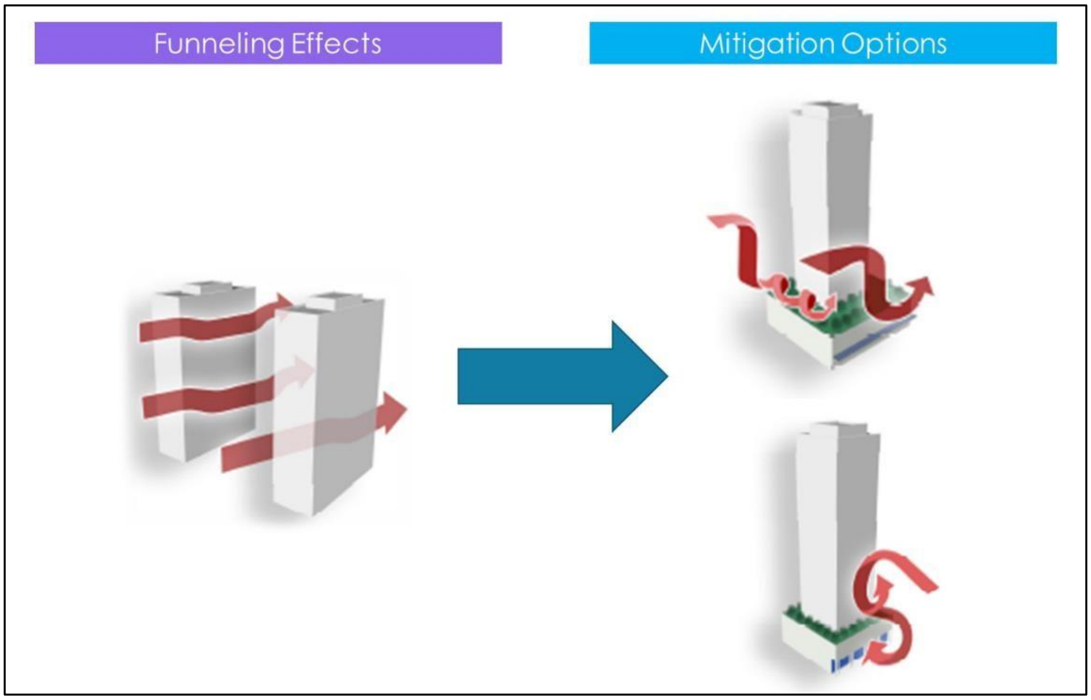


Figure 13.18 Mitigation Measures for Funnelling Effects.

13.6 Existing Receiving Environment Assessment

In this chapter the wind impact has been assessed on the existing receiving environment considered the existing buildings and the topography of the site prior of the construction of the proposed development. A statistical analysis of 30 years of historical weather wind data has been carried out to find the most critical wind speeds and directions and the frequency of occurrence of the same, furthermore, B-Fluid's weather station has recorded locally 1 month of wind data on the existing site for comparison with the historical ones. The aim of this assessment has been to identify the wind microclimate of the area that may cause critical conditions for the pedestrians' comfort criteria.

13.6.1 Site Location and Surrounding Area

Sandyford Central Development will be situated at the former Aldi Site, Carmanhall Road, Sandyford Business District, Dublin 18. It is located in the former Sandyford Industrial Estate south Dublin, approximately 8.25km from the city centre and adjacent to the Stillorgan LUAS stop. The site is bound by Blackthorn Drive to the north, Carmanhall Road to the south, commercial development to the east and residential to the west. The surrounding context south of the Luas line is mixed use ranging from 2-14 storey buildings providing office, industrial, residential and amenity provisions such as gyms, creches, retail (e.g. Aldi, Dunnes) and cultural venues. North of the Luas is predominantly traditional 2 storey semi-detached residential housing, the closest neighbour being Lakelands Estate. The site is shown in Figure 13.19 and Figure 13.20.

The modelled area for the wind modelling study comprises a 3km² area around the proposed Sandyford Central Site Development as represented in Figure 13.21.

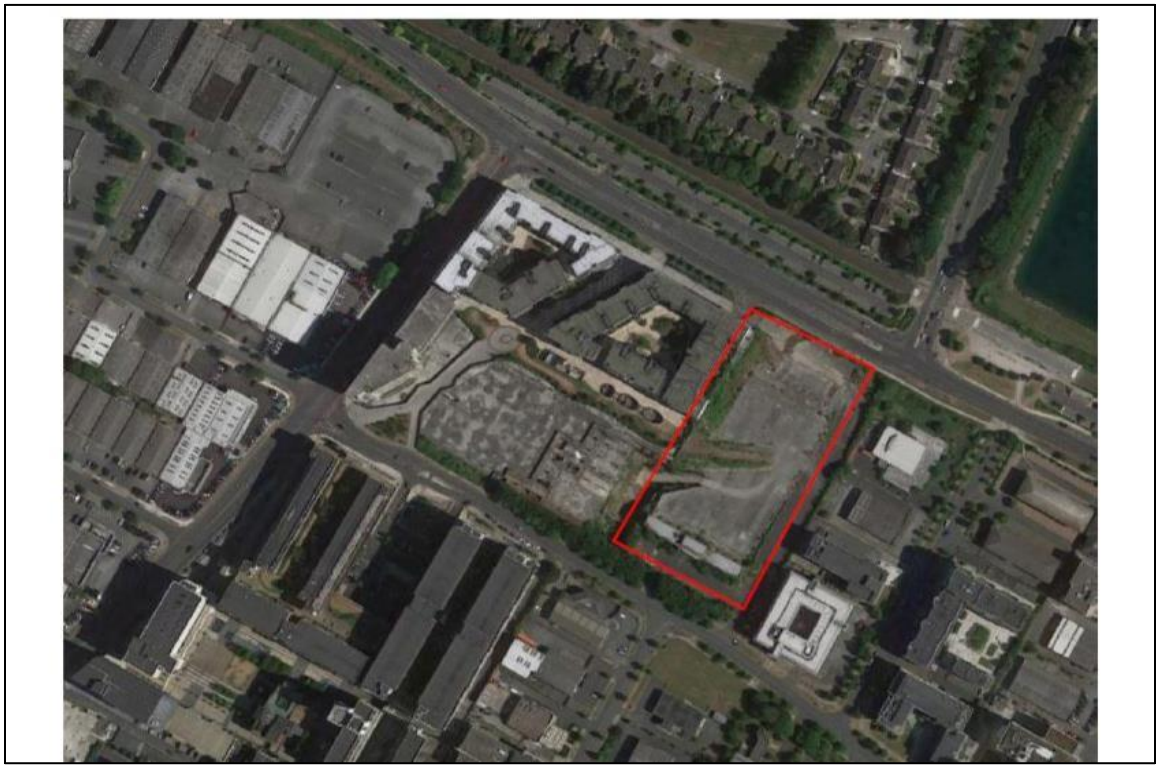


Figure 13.19: Sandyford Central Site Location.

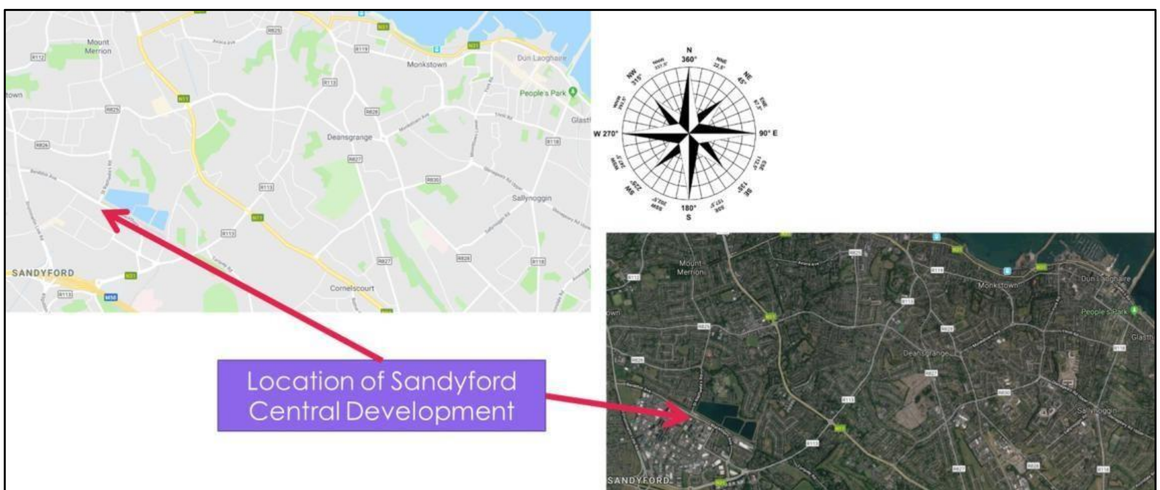


Figure 13.20: Sandyford Central Site Location.

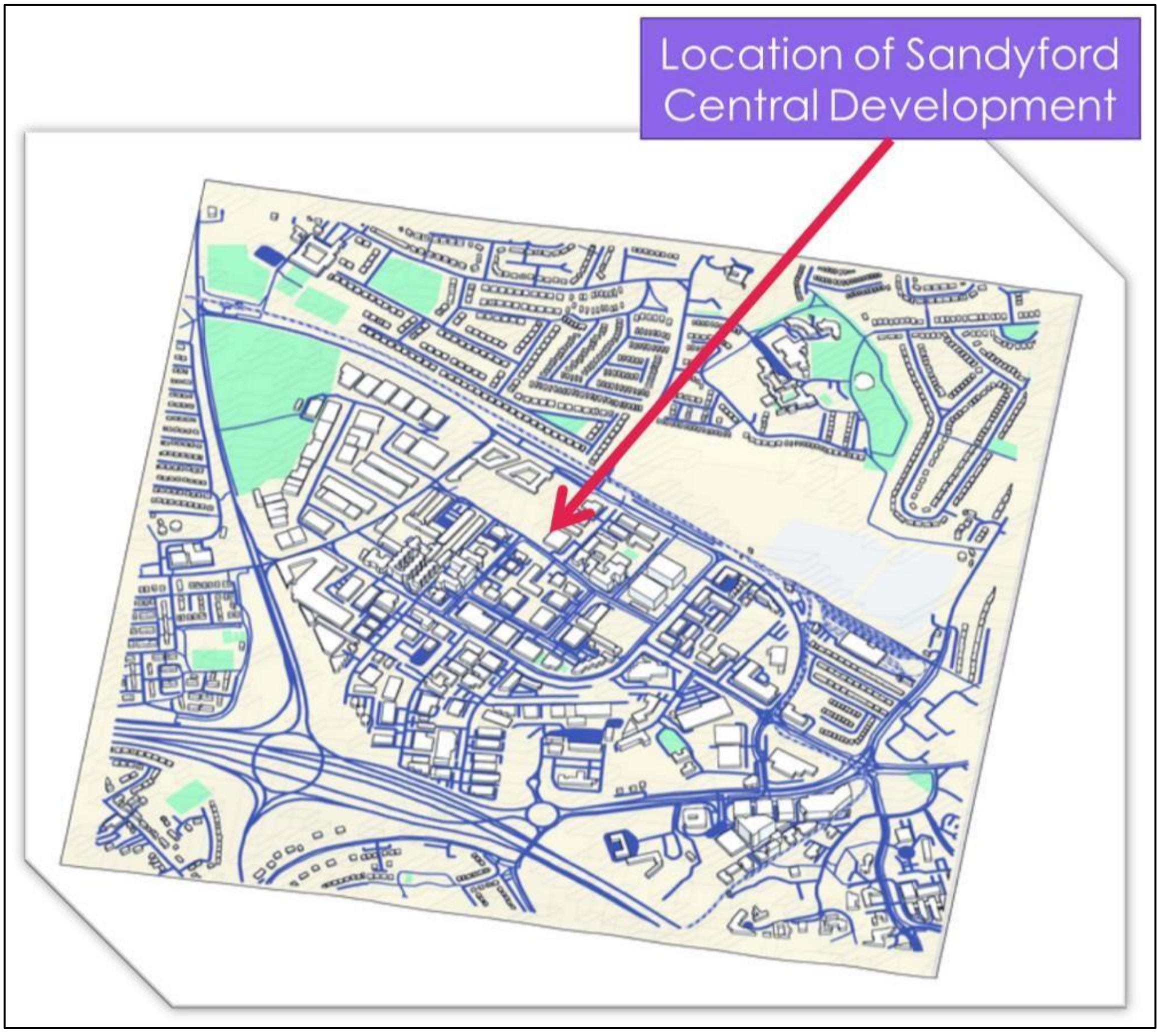


Figure 13.21: Extents of Analysed Area around Sandyford Central Development (3km² Area)

13.6.2 Topography and Built in Environment

Figure 13.22 shows an aerial photograph of the terrain surrounding the subject site at Sandyford Central. Figure 13.23 shows a model of the existing environment around the site of the proposed Sandyford Central Development.

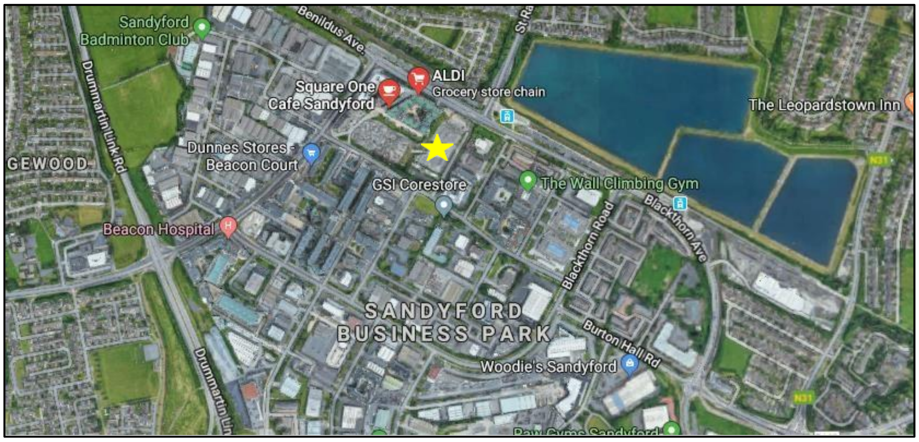


Figure 13.22: Built-in Environment Around the Site at the Proposed Sandyford Central Development

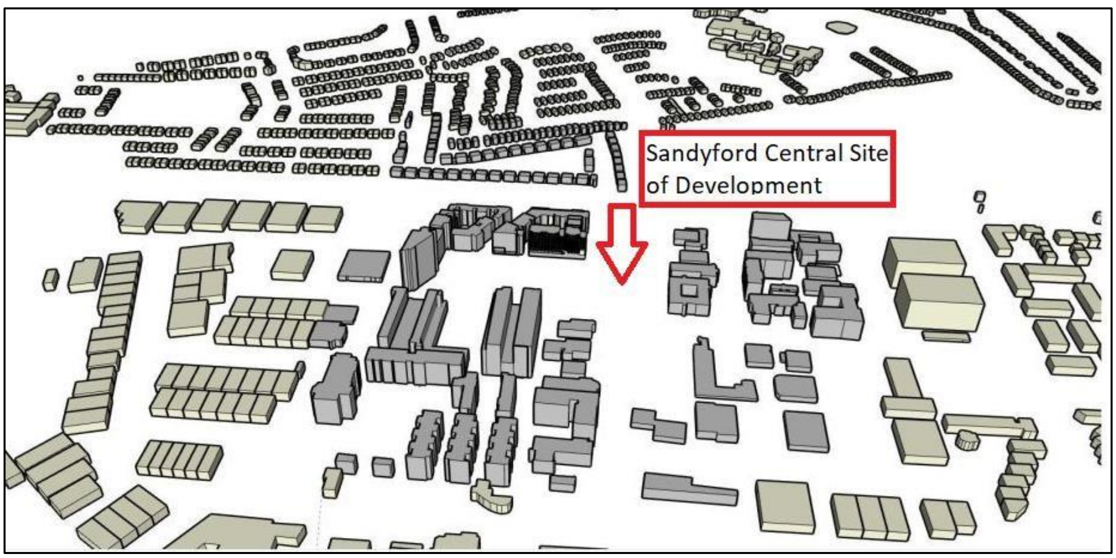


Figure 13.23: Model of the Built-in Environment around Construction Site at Sandyford Central Development.

13.7 Wind Microclimate Conditions

The simulations consider the whole development being exposed to the typical wind condition of the site, in order to assess the wind impact on the pedestrian areas. The building is oriented as shown in the previous sections. The wind is applied in the CFD model as a velocity boundary condition with a prescribed profile, which specifies the wind magnitude variation with the height and the wind direction. The wind profile is built using the annual average of meteorology data collected at Dublin Airport Weather Station. Figure 13.24 shows on the map the position of the proposed Sandyford Central Development and the position of Dublin Airport.

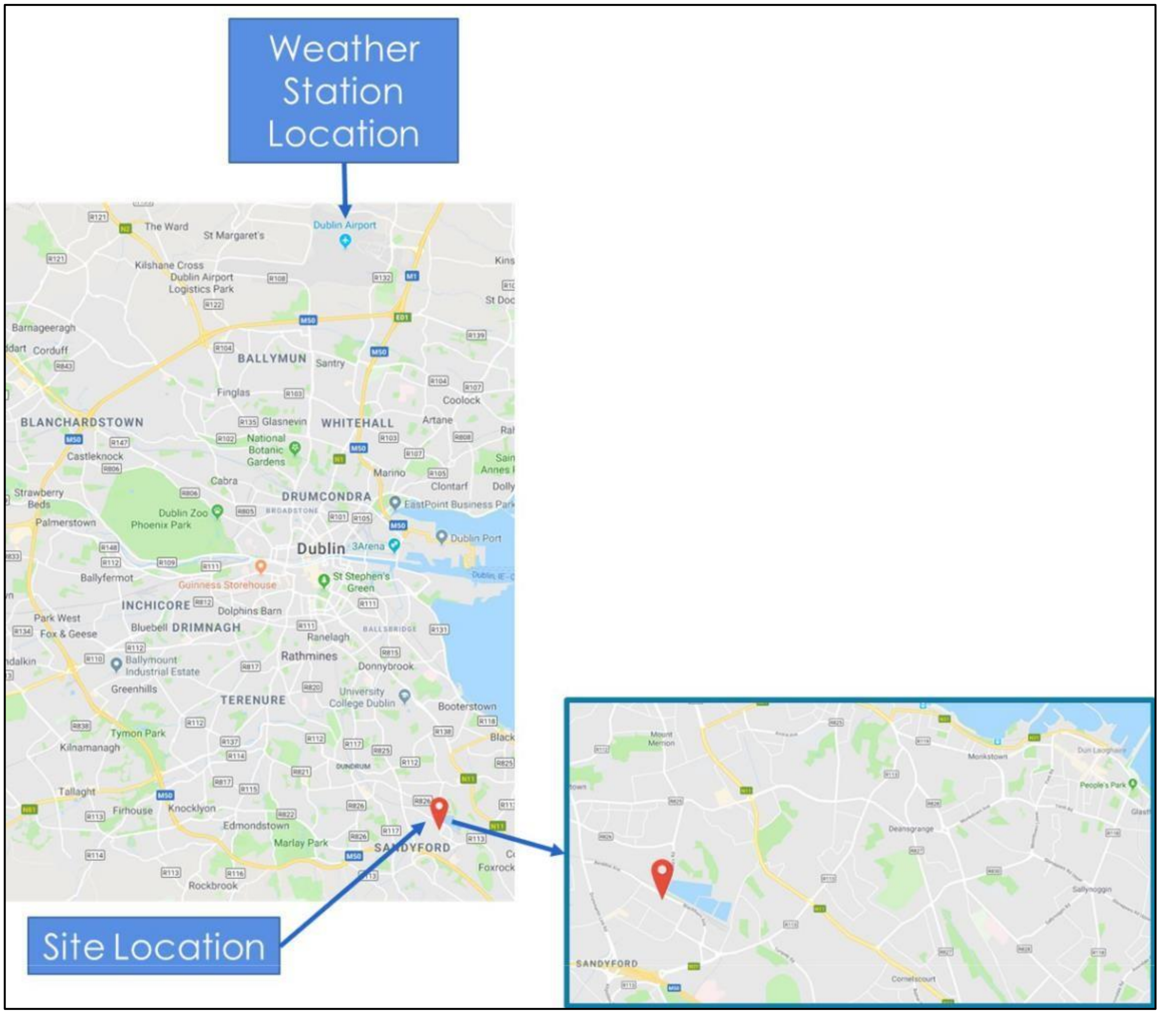


Figure 13.24: **Map Showing the Position of the Proposed Sandyford Central Development and Dublin Airport**

13.7.1 Local Wind Conditions

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

- The meteorological data associated with the maximum daily wind speeds recorded over a 30-year period between 1985 and 2019 and,
- The mean hourly wind speeds recorded over a 10-year period between 2005 and 2019. The data is recorded at a weather station at the airport, which is located 10m above ground or 71mOD.

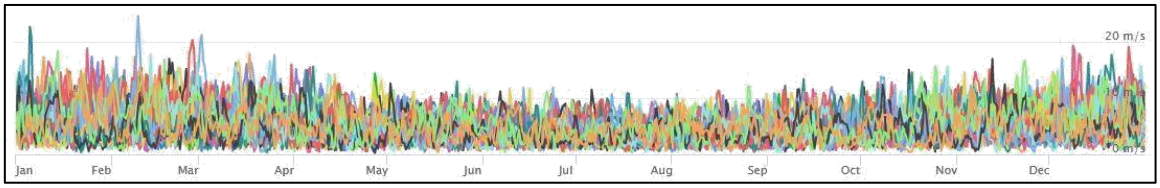


Figure 13.25: Local Wind Conditions - Wind Speed (10m) 1985-2019.

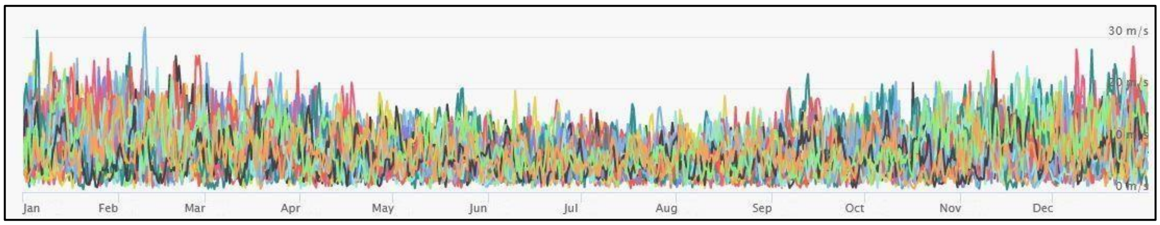


Figure 13.26: Local Wind Conditions - Wind Gust (10m) 1985-2019.

Figure 13.27 presents the wind speed diagram for Dublin, which indicates the number of days per month, during which the wind reaches a certain speed. In Figure 13.28, the wind rose for Dublin shows how many hours per year the wind blows from the indicated direction, confirming that the predominant directions are WSW, W, and SW.

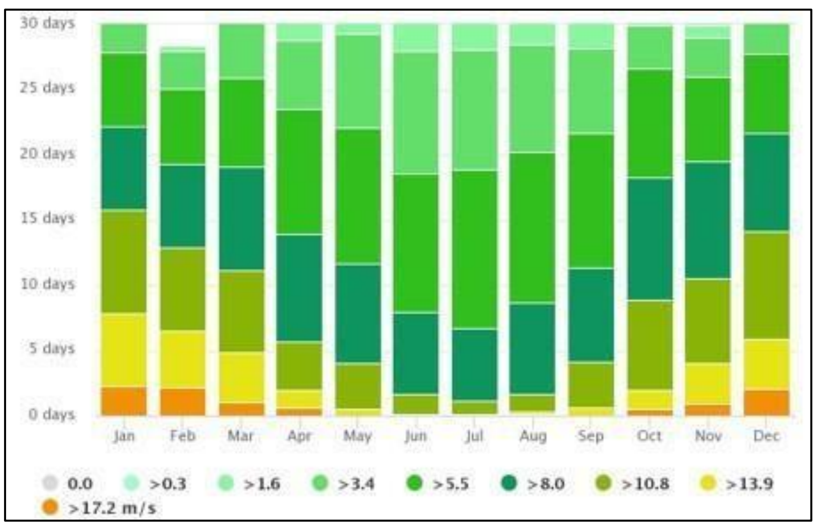


Figure 13.27: Dublin Wind Speed Diagram.

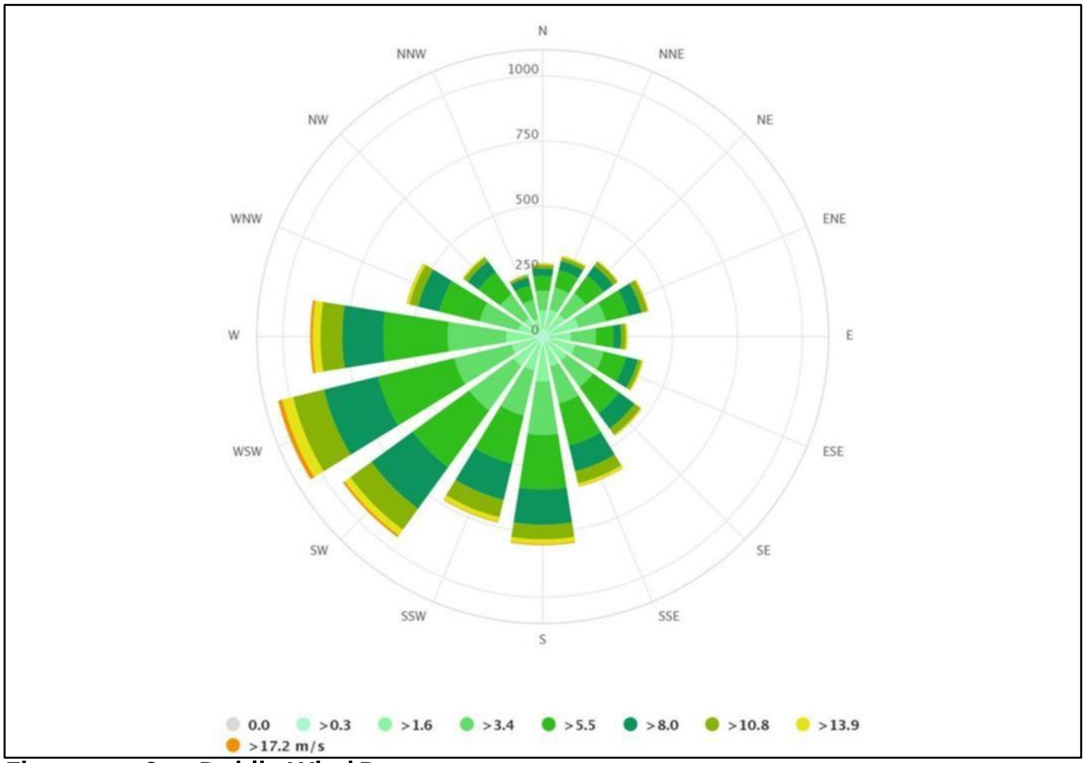


Figure 13.28: Dublin Wind Rose.

13.7.2 Mean and Maximum Wind Conditions

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

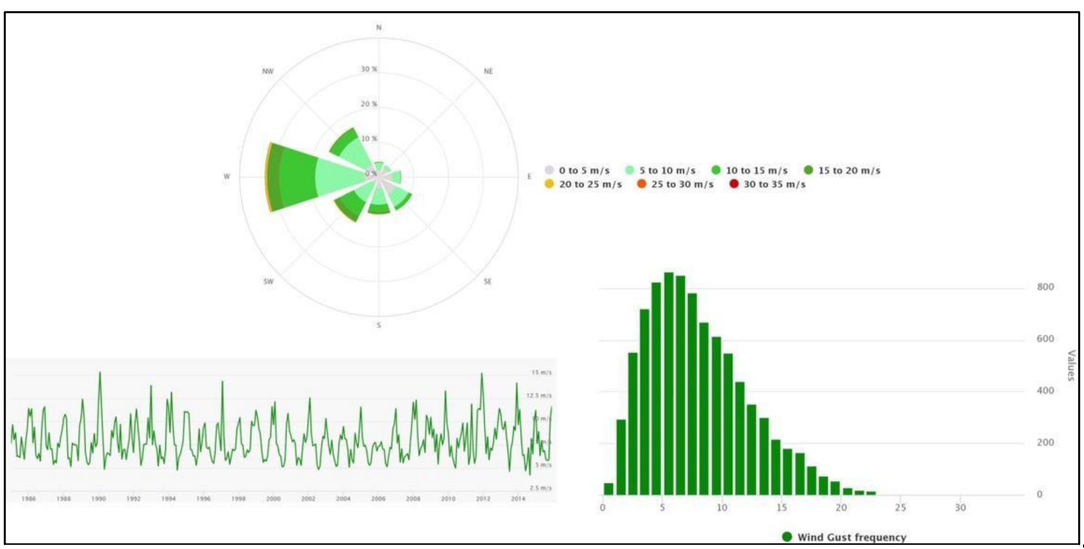


Figure 13.29: Maximum Wind Conditions

Based on the criterion of occurrence frequency, the main wind directions to be considered in pedestrian wind comfort assessment are presented in Figure 13.31. For each direction, the reference wind speed is set to the 5% exceedance wind speed for that direction, i.e. the wind speed that is exceeded for only 5% of the time whenever that wind direction occurs. A total of at least 4 compass directions will be selected from these directions, starting from the top of the table. Between all, the most frequent velocities are:

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

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

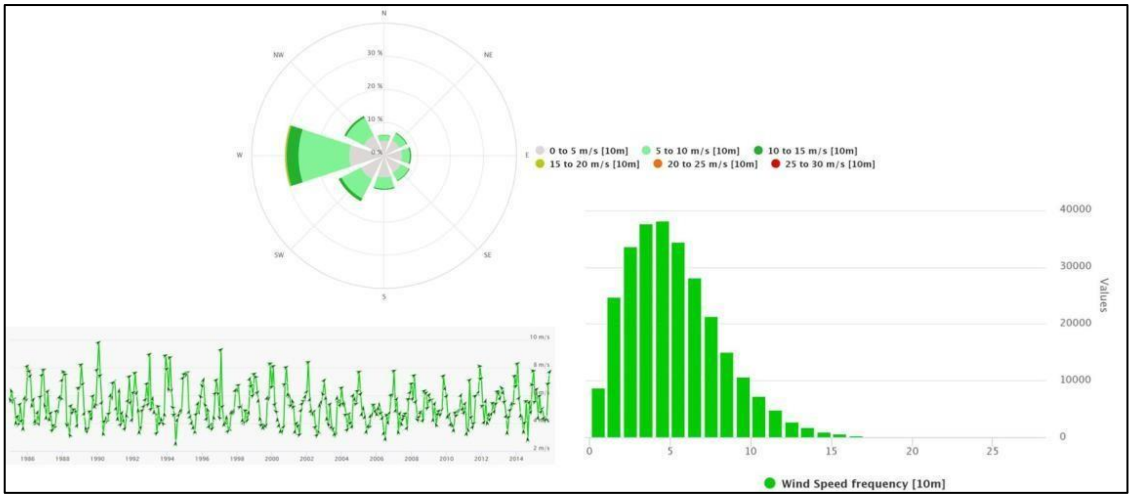


Figure 13.30: Mean Wind Conditions.

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

Figure 13.315: Main Wind Directions Occurrence Frequency

13.7.3 Comparison With The On-Site Weather Station

The wind profile built using the data from Dublin Airport, is also compared with the one obtained using the data collected on-site in the period 22nd February - 4th April 2019. Figure 13.32 shows B-Fluid weather station and its characteristics.

Figure 13.32: B-Fluid On-site Weather Station.

For clarity, Figure 13.33 and Figure 13.34 respectively show the last two weeks of the wind speed and direction and wind gust recorded by the on-site weather station. The green, blue and black data represent the wind speed/gust daily mean, max and min respectively.

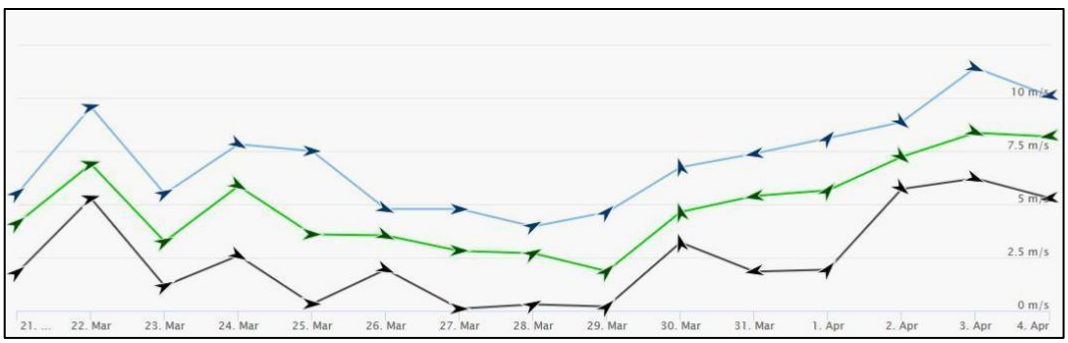


Figure 13.33: Wind Speed and Direction recorded by B-Fluid On-site Weather Station.

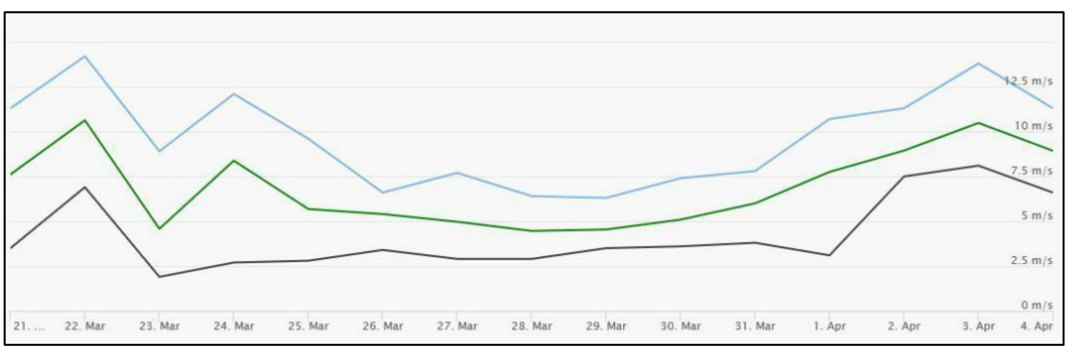


Figure 13.34: Wind Gust Recorded by B-Fluid On-site Weather Station.

As it is possible to assess the comparison between on-site and airport measurements, as presented in Figure 13.35 and Figure 13.36 it can be concluded that the wind speed daily meanand the wind gust daily mean recorded on site follow the same pattern as the one recorded at Dublin Airport. However, the trends of the wind speed levels and the gust wind speed levels registered on-site are slightly lower. This is due to the fact that the site is located in the urban environment thus much more shielded if compared with Dublin Airport. This confirms that using wind data from Dublin Airport ensures a conservative analysis of the wind impact on Sandyford Central.

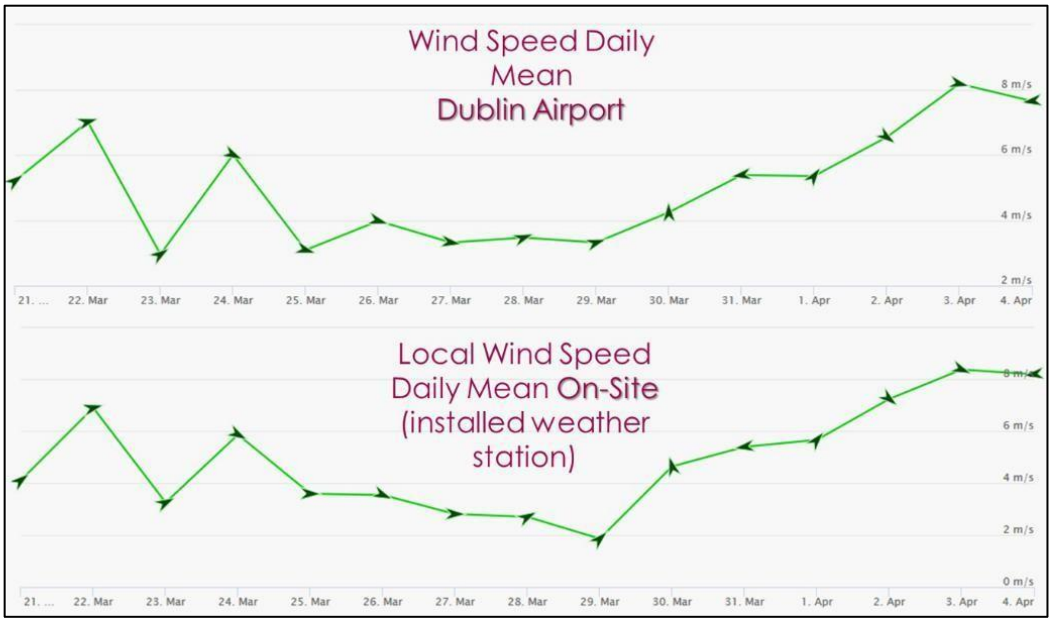


Figure 13.356: Wind Speed Daily Mean Comparison.

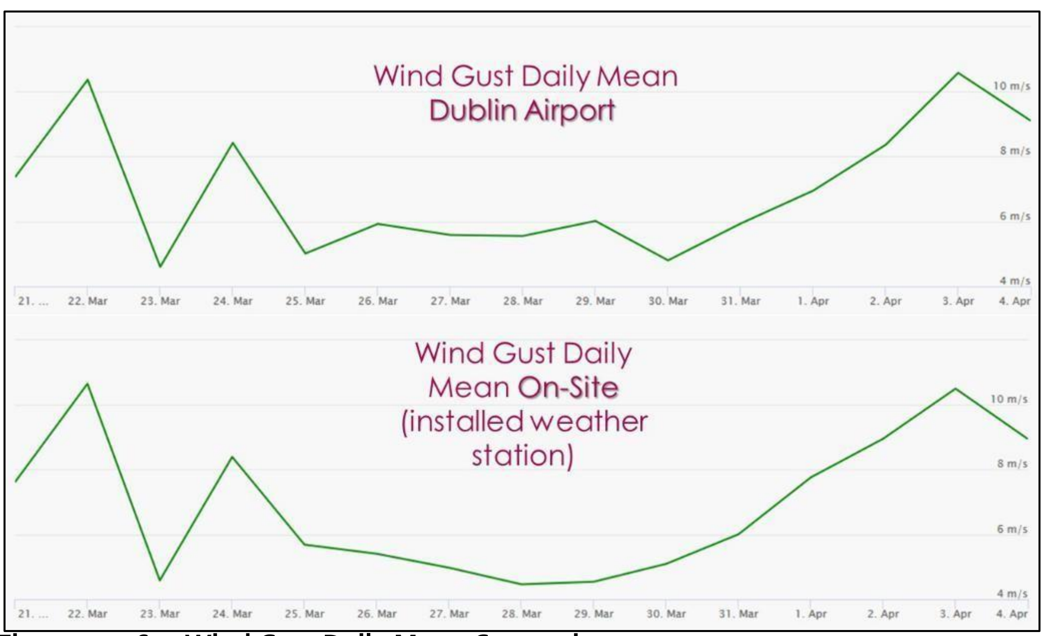


Figure 13.367: Wind Gust Daily Mean Comparison.

13.8 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 13.37. 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.

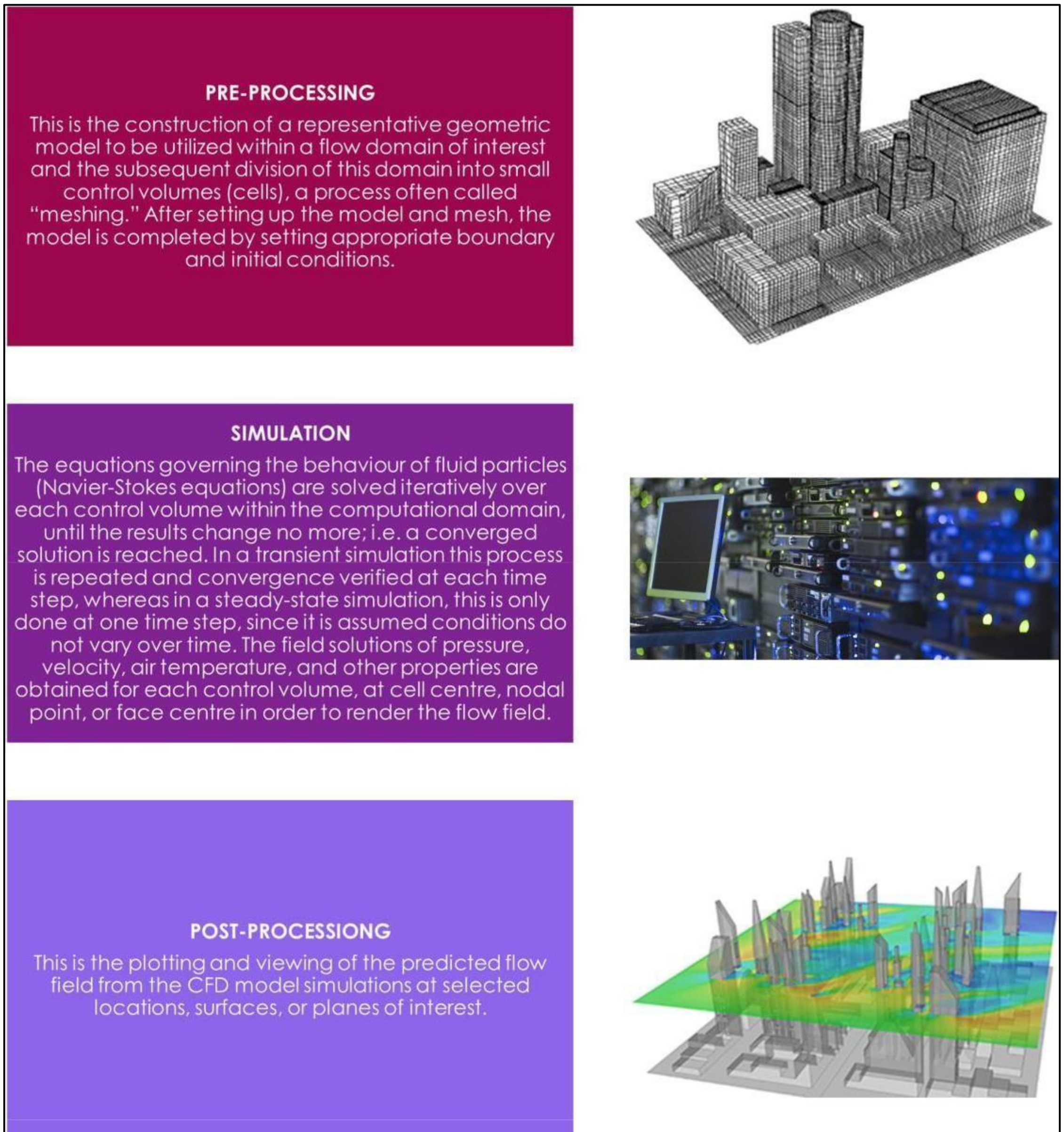


Figure 13.378: CFD Modelling Process Explanation.

OpenFoam SOFTWARE DETAILS

This report employs OpenFoam Code, based on the concept of Large Eddy Simulation (LES)and Reynolds Average Navier Stokes (RANS) and the post-processing visualisation tool Paraview version 5.5. 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. 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.

Numerical Solver

This report employs a CFD code based on the concept of LES and RANS simulations, which is 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 solver directly calculates the mass and momentum equations for the large eddies that comprise most of the fluid's energy.

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).

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 1.

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 centre of each of these cells and then an interpolation function is used by the software to provide the results in the entire domain.

Boundary Conditions

A rectangular computational domain was used for the analysis. The wind direction was 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. 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 *r*	$1:2kg=m^3$
Ambient Temperature (T)	288K(approx:15C°)
Gravity Acceleration (g)	$9:8m=s^2$
dx	0.5 m at the building 1m in the surroundings 2m elsewhere
Mesh cells size	0.1 m (ratio 1:1)
Total mesh size	Approx. cells number = 36 million

Table 13.1: Parameters to Calculate Computational Mesh.

Logarithmic Wind Profile

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

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

where:

- v_1 = wind speed measured at the reference height h_1
- h_1 = reference height to measure v_1
- h_2 = height of the wind speed v_2 calculated for the wind profile
- z_0 = 0.4 [m] roughness length selected (see table in Figure 13.38 below)

Roughness Classes and Lengths

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

Figure 13.38: Roughness Length and Class to be Used for the Logarithmic Wind Profile.

The wind profile used in the model has been calculated using the formula above and is represented in Figure 13.39.

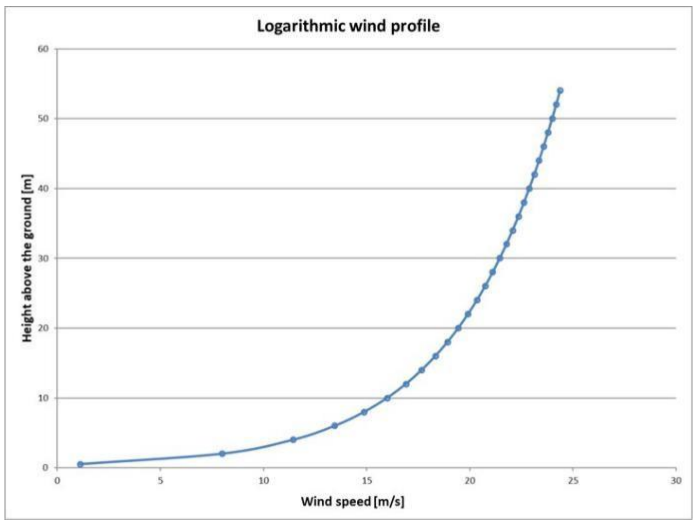


Figure 13.39: Wind Profile Used in the Model.

CFD Model Details

This section describes all the elements included in the geometrical and physical representation of the model. Any object which may have a significant impact on wind movement are represented within the model. The drawings used for building the model have been provided by Henry J Lyons (Ref: SFC-HJL-XX-ZZ-M3-A-0006-Massing and SFC-HJL-BA- ZZ-M3-A-0001-20190708-3).

To be accurate, the structural layout of the building being modelled should include only the obstacles, blockages, openings and closures which can impact the wind around the building.

It is important to remember that a CFD simulation approximates reality, so providing more details of the geometry within the model will not necessarily increase the understanding of the bulk flows in the real environment.

Modelled Geometries

The CFD simulation study has been carried out considering the following different geometries:

- The "Proposed Development" which includes the model of the proposed Sandyford Central Development and its surrounding environment. The overall proposed Sandyford Central Development dimensions considering all the blocks are approximately 80m (Width), 173m (Length) and the maximum height of the highest roof pitch is approx 55:4m. In order to represent reality and consider the actual wind impacting on the site, the modelled area for the wind modelling study comprises a wider urban area of 3km² around the proposed Sandyford Central Development. For this scenario, the analysis have identified the critical areas of the proposed development that required the implementation of mitigations measures.

- The "Cumulative Impact" which include the model of the proposed Sandyford Central Development and the adjacent Rockbrook Phase 2 buildings for which a SHD application has recently been granted by ABP (Ref. PL06D.304405) together with the surrounding existing environment. For this model, the Sandyford Central Development has been simulated inclusive of its mitigation measures impact in the locations identified as critical during the "Proposed Development" scenario.

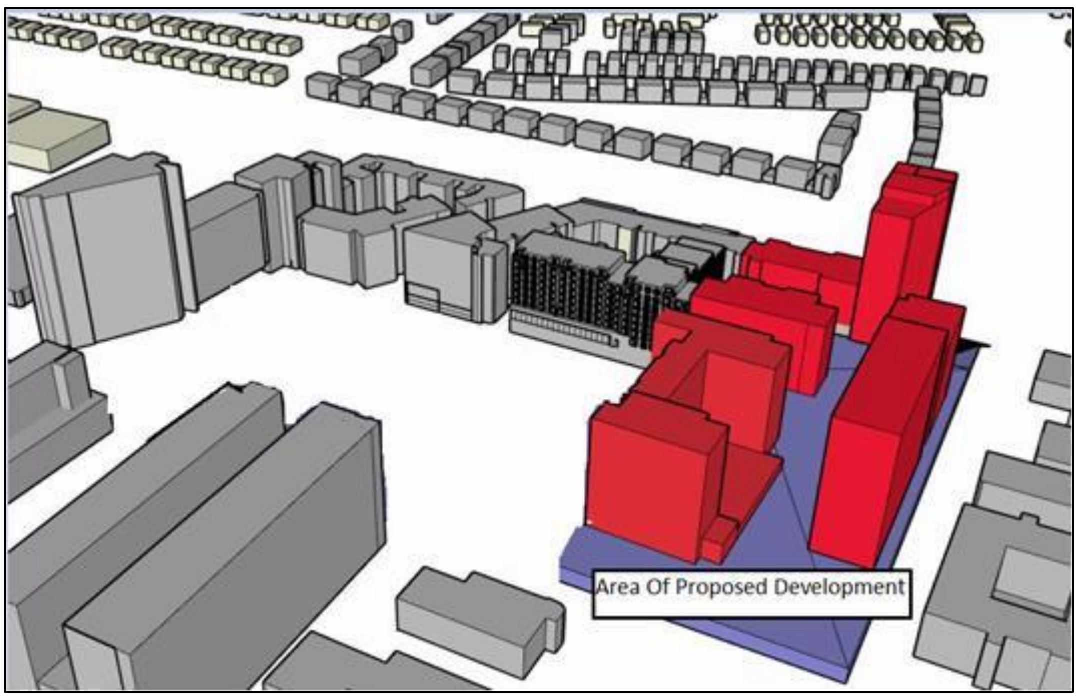


Figure 13.40: Image of Proposed Development.

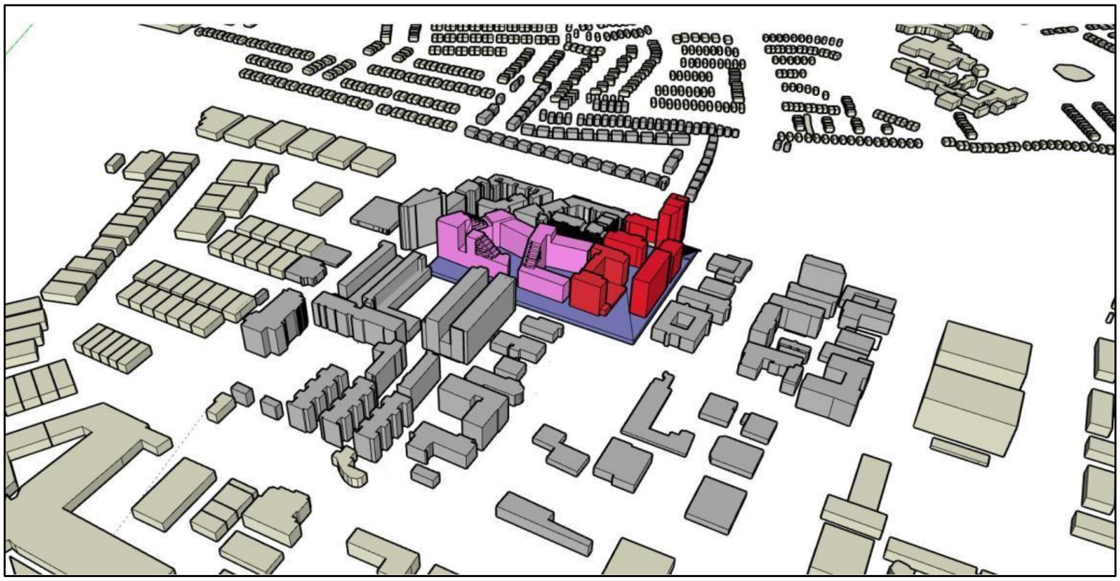


Figure 13.41: Proposed Development (Coloured in Red) and Adjacent Rockbrook Phase 2 Buildings (Coloured in Pink) for Cumulative Impact Assessment-Extents of Ground Surface Occupied in Violet

The model consists of the proposed Sandyford Central Development, which comprises six blocks (564 units), ranging in height from part 5 to part 17 storeys above podium. The model layout, dimensions and orientation are outlined in the table below (Table 13.2).

	MODELLED GEOMETRY DIMENSIONS		
	Width	Length	Height
Building	80m approx	173m approx	55.4m approx
CFD Mesh Domain	1066m approx	1066m approx	152m approx

Table 13.2: Modelled Geometry Dimensions

Modelling of Mitigation Measures

The mitigation measure that has been used for this project is landscaping using trees, which, creating a vorticity, make it possible to reduce the velocities, thus reducing the wind impact on the buildings. Small particles randomly distributed within an area are normally used in numerical modelling to model trees, as shown in Figure 13.42. These particles introduce a pressure drop in the model and therefore causes the wind to reduce its speed when passing through the area designated for a tree location, as expected in reality. The CFD plot shown in Figure 13.43 demonstrate this effect on the flow velocity and pressure.

Landscaping with trees around the development is useful to mitigate the impact of the wind around the buildings and protect the footpaths and the cycle paths, as well as the public areas and areas where is potentially possible to sit. In this way it is possible to target all the potentially critical high velocity areas.

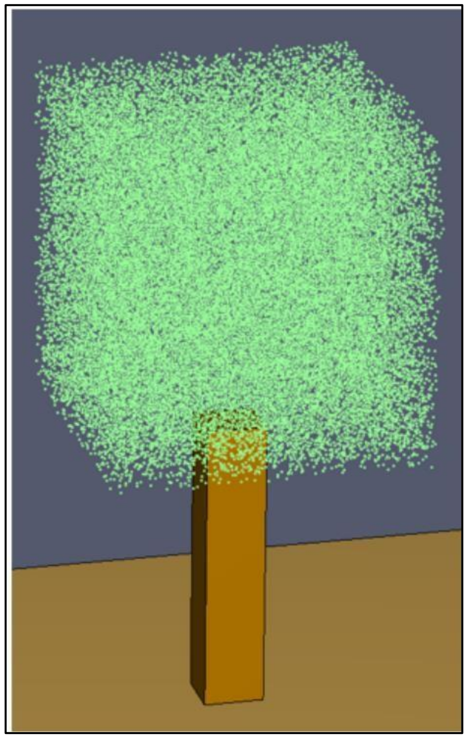


Figure 13.42: Impact of a Tree on Wind Flow.

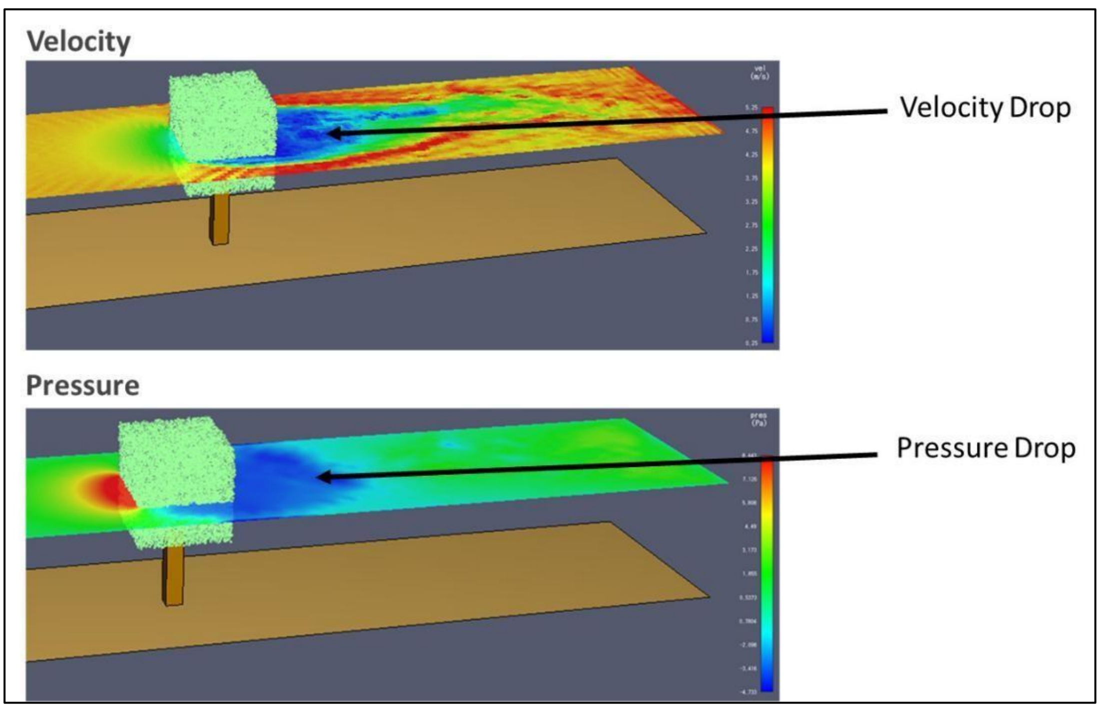


Figure 13.43: Generic Result of Wind Impacting on a Tree.

13.9 Wind Impact Assessment of the Proposed Development

This chapter presents the CFD results of the simulation carried out on the Sandyford Central Proposed Development and its existing surrounding environment. Figure 13.44 shows the orientation of the development, landscaping has been modelled as well in the same locations shown in the image below in order to mitigate the effect of wind.

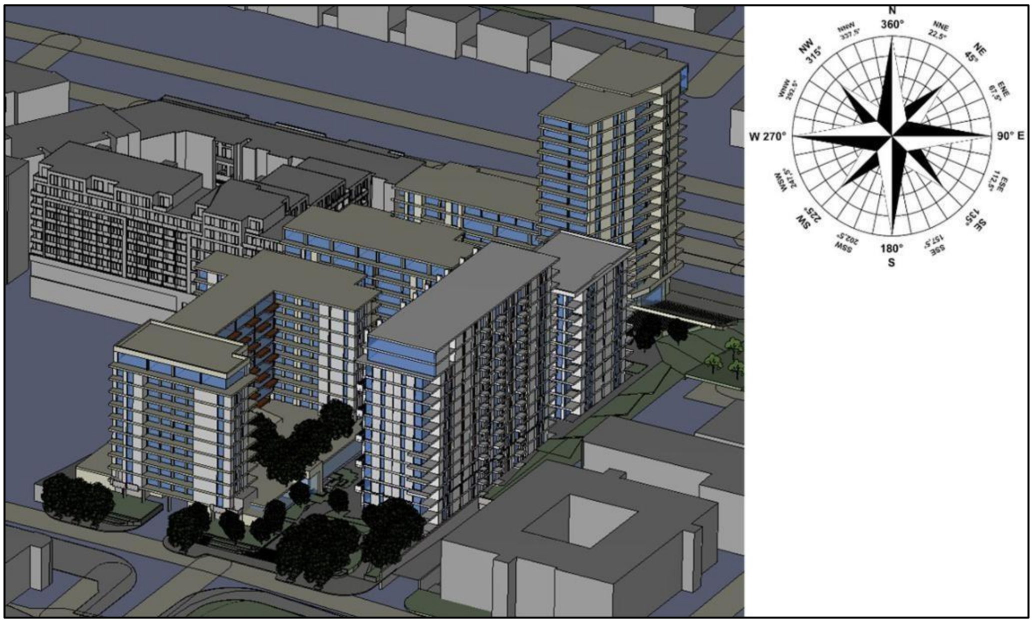


Figure 13.44: Orientation of Sandyford Central

Development. Wind From South-West

The results on the proposed development are presented in this report for the prevailing South-West wind direction in Dublin. The results for the different flow features are presented in Figures 13.46 – 13.50 and discussed in the following text. It should be kept in mind that the presented flow pattern is based on the available geometry and includes the initial landscaping which will mitigate concerning areas. Further landscaping could be still necessary and suggested after this wind analysis in those areas that remained critical. Red colours indicate critical values while blue colours indicate tenable conditions.

Figure 13.45 shows the South-West view of the development. As it is possible to see from the results presented in Figure 13.47 to Figure 13.50, no major critical areas are found, except for some higher velocities in the central area of the development, on the main central road and on the main road on the right side of the development. These are due to some funnelling effects generated between the buildings. Some landscaping has been already implemented at the initial stage of the design process. Further landscaping has been implemented by the landscaping architect as a consequence of the wind study undertaken. The final landscaping that was implemented within the design, in order to consider the necessity to mitigate the above effects is visible in Figure 13.52 and includes an increase of tree planting on the central part of the development, as well as on the roads around it (within the extents of the development). The north courtyard seems to be well protected and therefore it will be suitable for its intended use (long term sitting). The results of the analysis carried out have also demonstrated that the areas of the development subjected to the South -West wind are also protected and suitable for their specific intended use in accordance with the range of wind speeds recommended by the Lawson Criteria.

In general, critical issues are not found for the potential use of the roof terraces, however, some high velocities can be reached at the top corners of these so the use of trellis, pergola structures and planters are suggested to mitigate these effects on the south west direction. It must be noticed that the roof terraces will be used primarily during the spring and summer months. As anticipated in the wind data historical analysis, during this period of the year the wind conditions are in general less critical than the ones analysed for this CFD analysis.

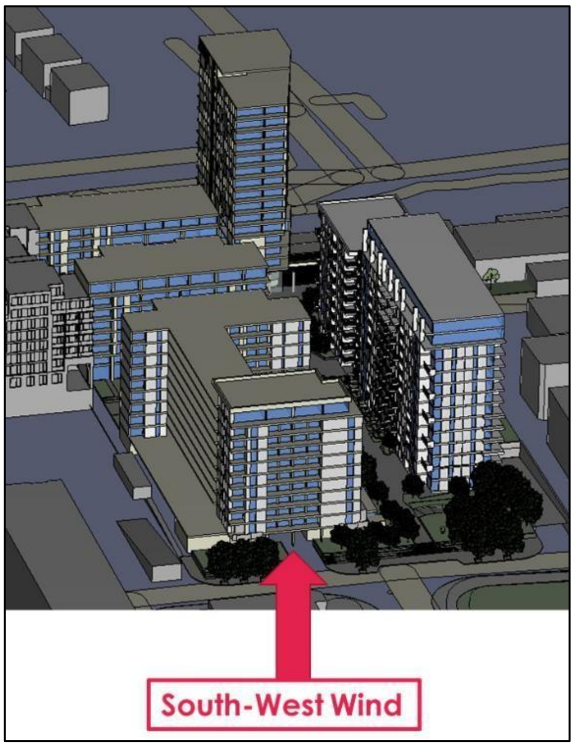


Figure 13.45: South-West View of the Development.

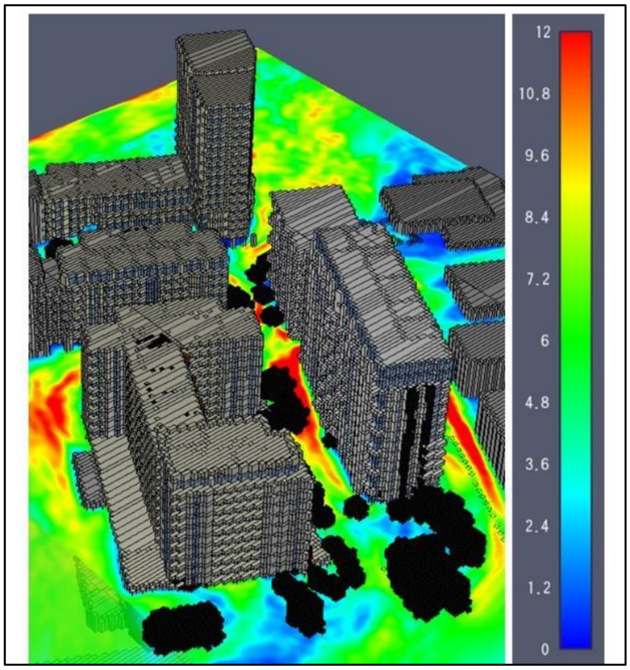


Figure 13.469: CFD Results - Flow around the Buildings at Sandyford Central Development for Wind from South-West - Slice at 1.5m.

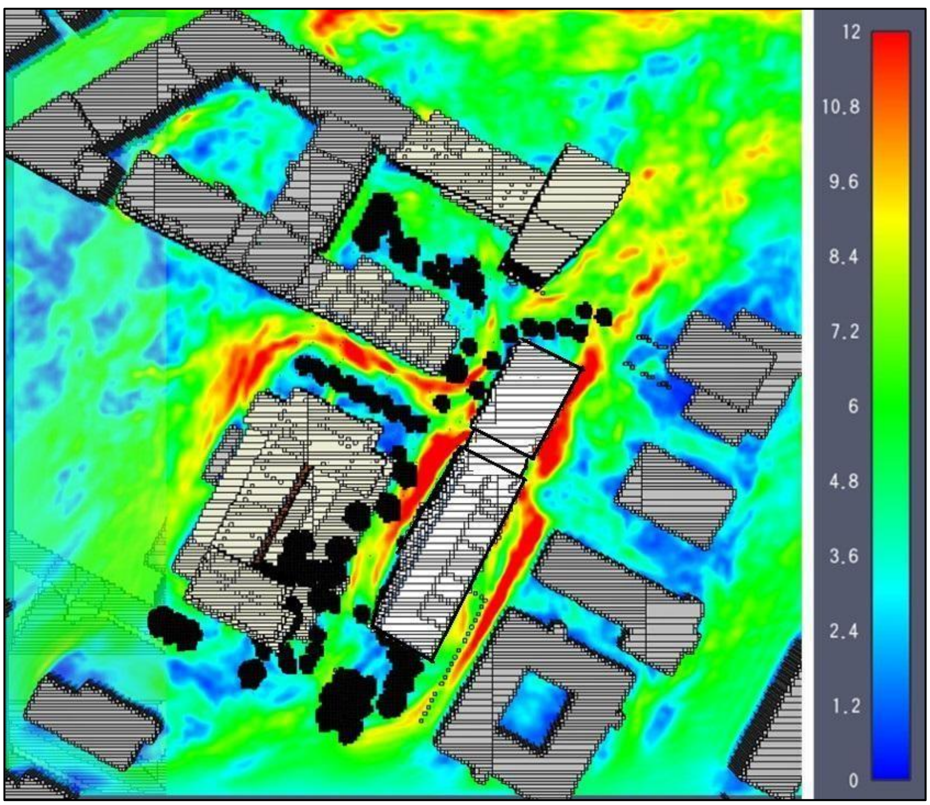


Figure 13.47: CFD Results - Flow around the Buildings at Sandyford Central Development for Wind from South-West – S8/lice at 1.5m.

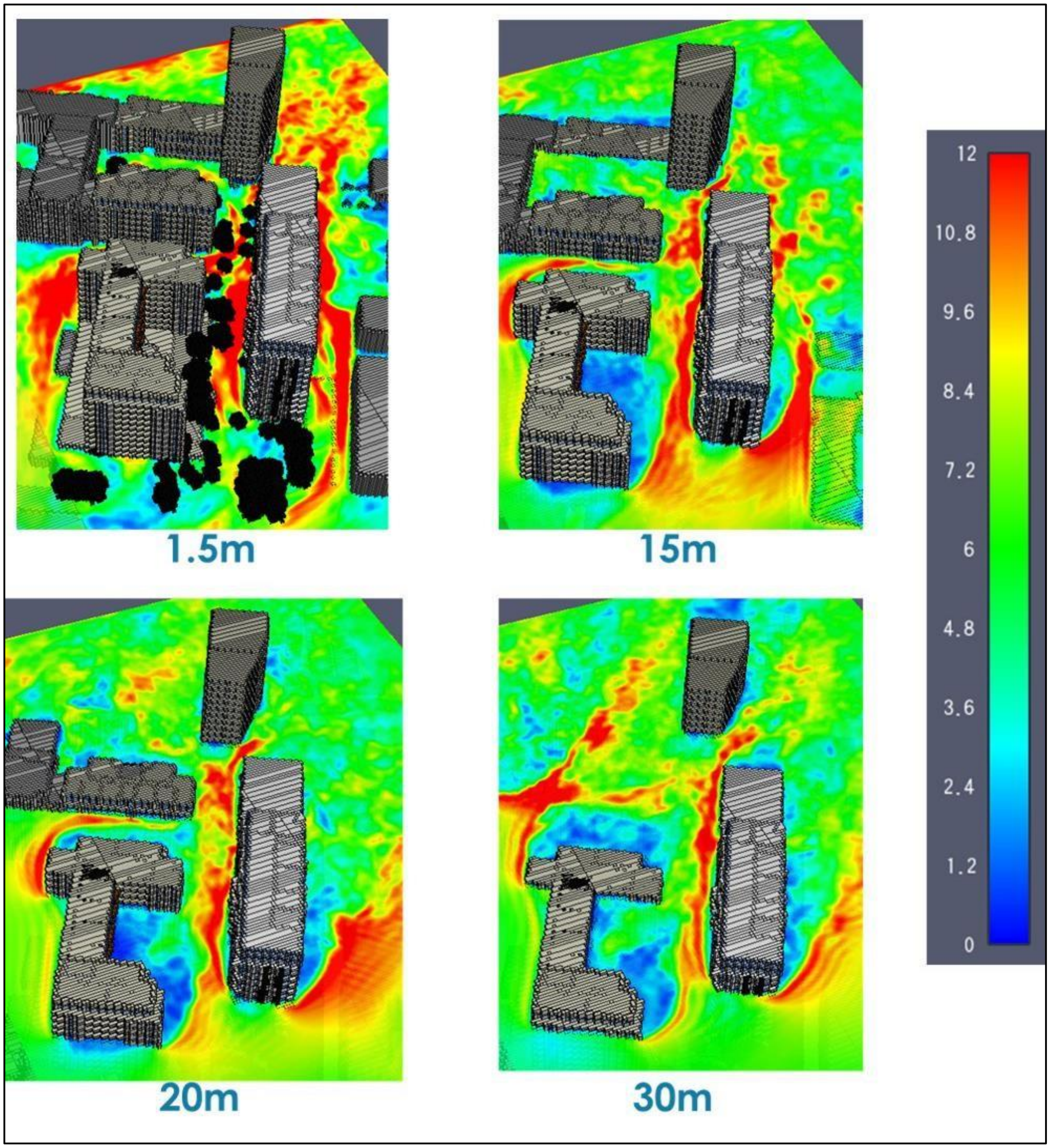


Figure 13.48: CFD Results - Flow around the Buildings at Sandyford Central Development for Wind from South-West - Slices at 1.5m, 15m, 20m and 30m.

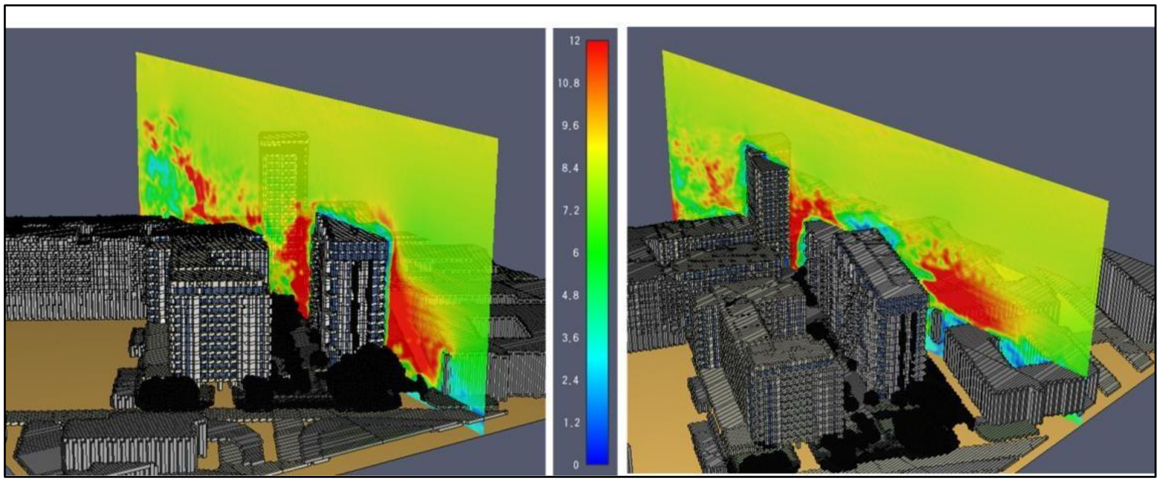


Figure 13.49: **CFD Results - Flow Around the Buildings at Sandyford Central Development for Wind from South-West - Slices Across the Building.**

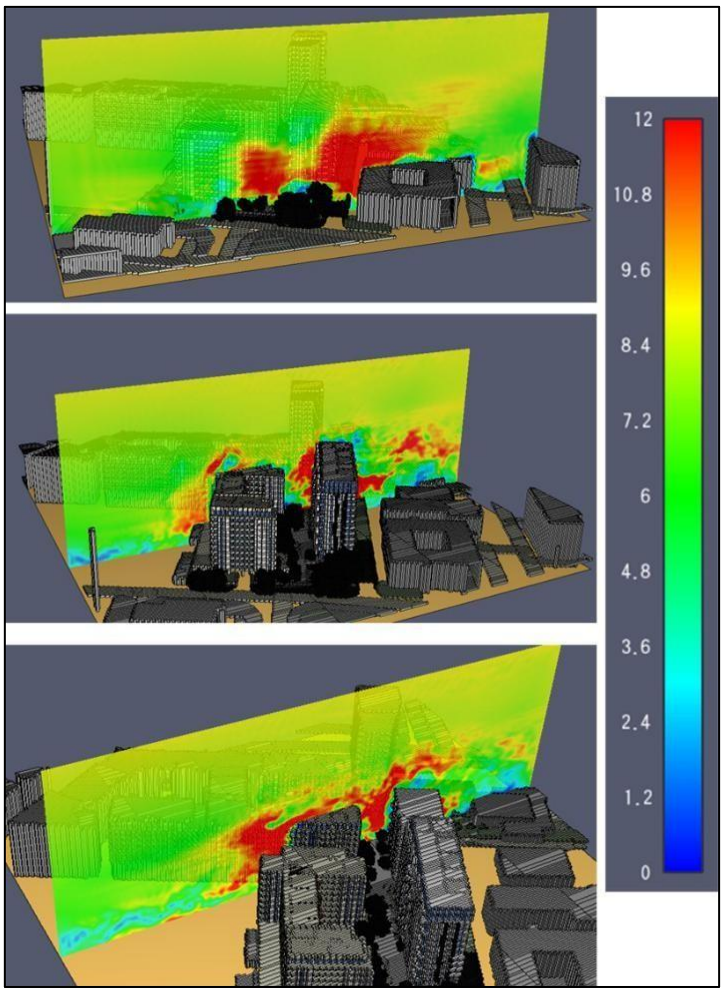


Figure 13.50: **CFD Results - Flow Around the Buildings at Sandyford Central Development for Wind from South-West - Slices across the Building.**

In summary, the ground level areas to be mitigated accordingly to this wind desktop study and preliminary CFD results have been identified to be the ones highlighted in red in Figure 13.51 below.

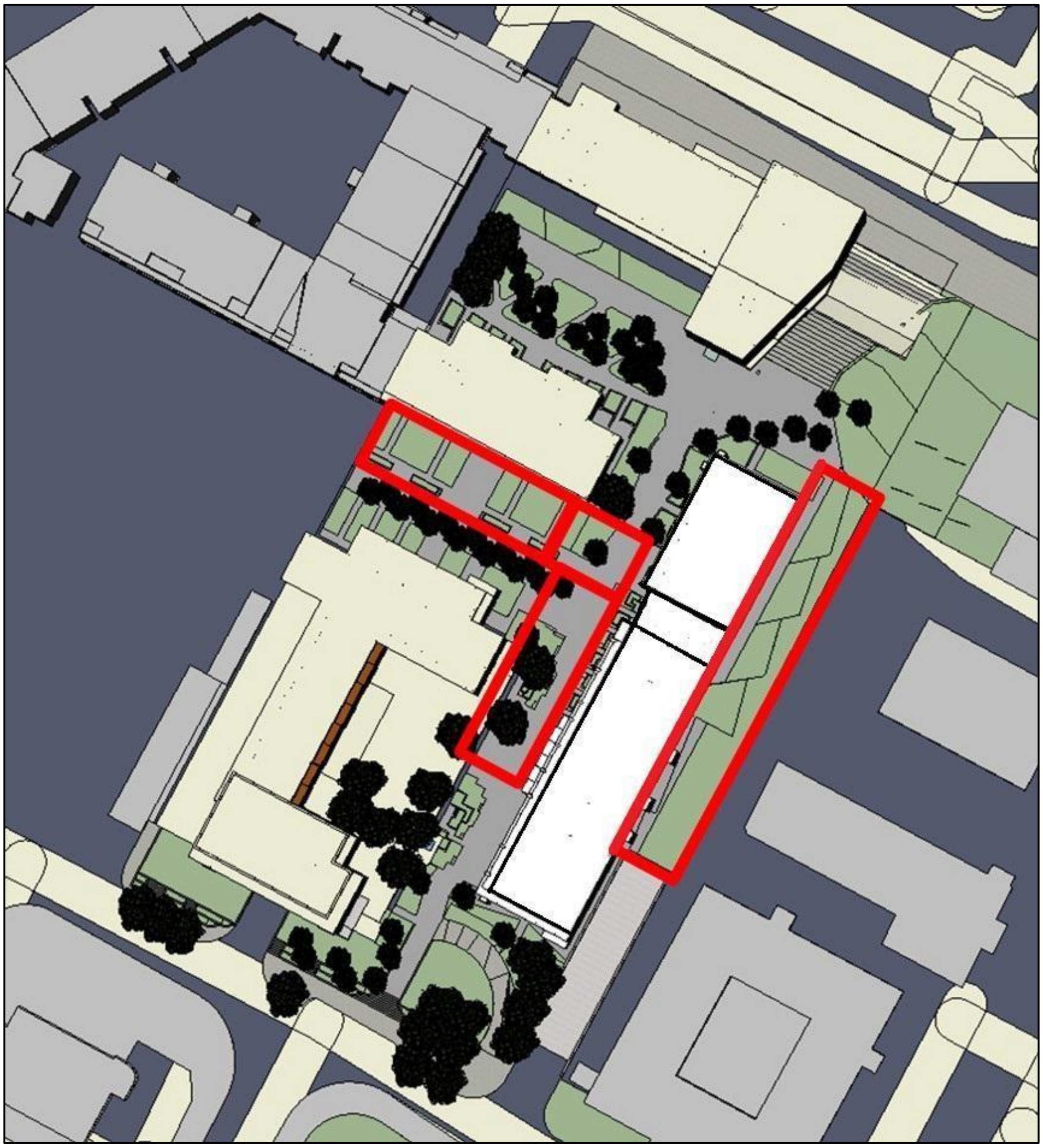


Figure 13.51: Ground Level Critical Areas Highlighted in Red to be Mitigated with Further Landscaping.

The results of the preliminary study were considered and taken into account during the design stages and the critical areas identified have been consequently mitigated as suggested. The tree planting and landscaping has been added as shown in the following image in correspondence of the areas identified as critical. The impact of landscaping has been implemented in the following analysis through numerical method as explained in the section "Modelling of Mitigation Measures". The results of the analysis shown in the following sections demonstrate that, with the mitigation measures implemented the Lawson Criteria is satisfied in accordance with the intended use of each area (and their seasonal usage) within the development.

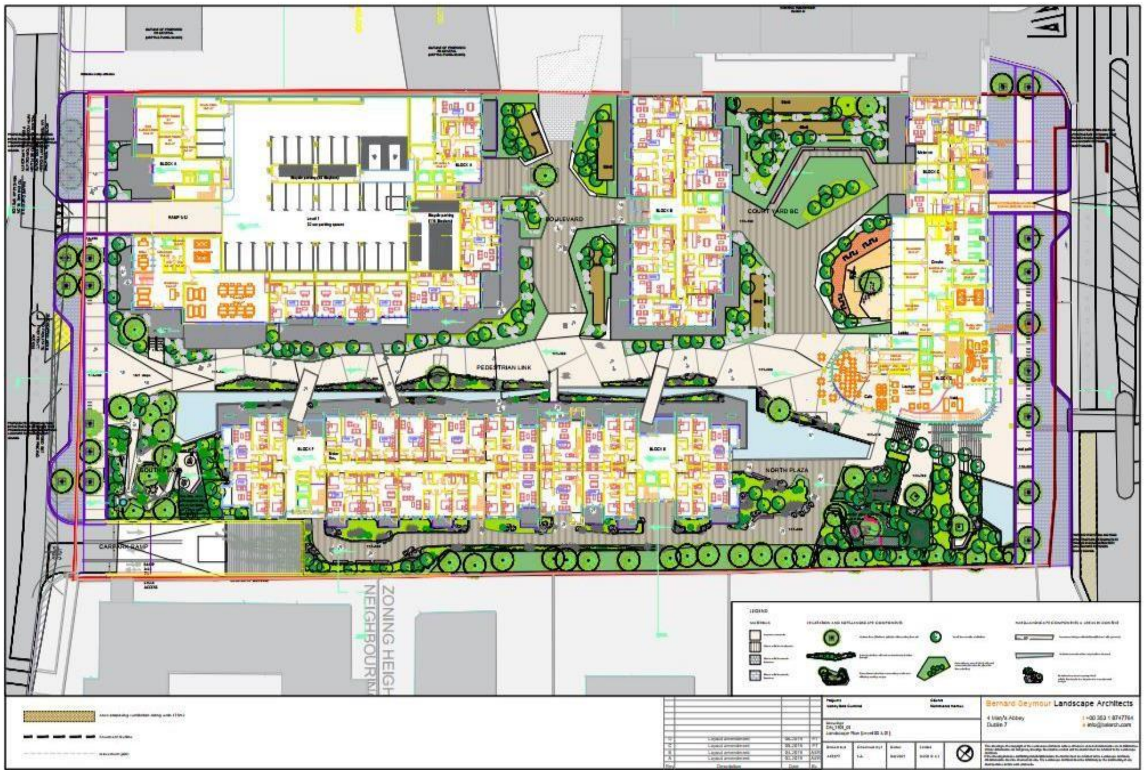


Figure 13.52: Ground Level Landscaping Design Implemented in the Critical Areas Detected by the Preliminary Wind Analysis.

13.10 Wind Impact Cumulative Assessment

This section shows the CFD results of the wind assessment carried out considering the "Cumulative Impact Scenario". In this case the assessment has considered the impact of wind on the existing area including the proposed Sandyford Central Development and the adjacent Rockbrook Phase 2 buildings for which a SHD application has recently been granted by ABP (Ref.PL06D.304405). For this scenario, the Sandyford Central Development has been simulated inclusive of its mitigation measures impact in the locations identified as critical during the "Proposed Development" scenario. The wind simulations have been carried out on all the various directions for which the cumulative development could show critical areas in terms of pedestrian comfort and safety. For this completed scenario the Lawson and Distress Maps have been also presented to identify the suitability of each areas to the prescribed level of usage and activity. The results present the parameters outlined within the acceptance criteria previously described in Section 13.4. 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 Sandyford Central Development will produce a high-quality environment that is attractive and comfortable for pedestrians. The development does not introduce major critical impacts on the existing environment and does not appear to be impacted negatively by the adjacent Rockbrook Phase 2 buildings once constructed, indeed Sandyford Central and Rockbrook Phase 2 have similar heights and massing and are surrounded by further developments with similar characteristics.

- Good shielding is achieved on all critical roads. There are some funnelling effects around both the roads abutting the Sandyford Central development and some high velocities in the main road on the east side of the development (Carmanhall Road). However, high velocity areas are limited to the part of the roads where the cars pass. Footpaths are successfully shielded by vegetation. The funnelling across the development does not reach critical velocities and would be mitigated by the presence of the trees. These high velocities appear to be already present before construction of Sandyford Central Development and not a consequence of its construction.

- Assessment of the velocities on the terrace of Block D shows that the velocities are always below critical values.

- The pedestrian comfort assessment, performed accordingly to the Lawson criteria, identified the areas that are suitable for the different pedestrian activities in order to guarantee pedestrian comfort and showed that the entire development is suitable for any activities. Moreover, in terms of distress, no critical conditions were found for "Frail persons or cyclists", neither for members of the "General Public", in the surrounding of the development.

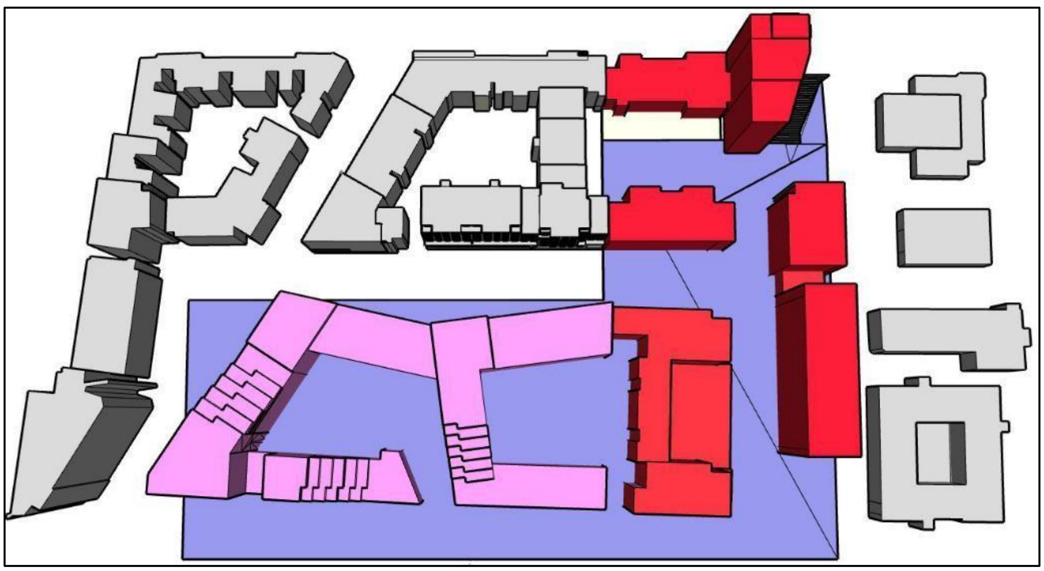


Figure 13.53: Image of Cumulative Scenario-Sandyford Central Development Coloured in Red and Rockbrook Phase 2 Coloured in Pink.

13.10.1 Flow Velocity Results (Cumulative Impact)

Results of velocity at slice location of 1.5m above the ground are presented in Figures 13.56 to Figure 13.75 for the previously selected 4 angles for wind assessment of Ground Floor Level of the proposed Sandyford Central Development.

For each of the modelled directions, no major issues where founded except for the corner's areas where some acceleration and detachment flow phenomena are occurring, however these phenomena are not considered to be critical. Indeed, these phenomena only occur at certain wind angles and include some funnelling around the main road across the development, some high velocities in the north courtyard.

However, these high velocity areas are limited to the part of the roads where the cars pass. Footpaths seem successfully shielded. The funnelling across the development does not reach critical velocities and would be mitigated by the presence of the trees.

Assessment of the velocities on the terrace of Block D shows that the velocities are always below critical values at 1.5m above its floor as the terrace has been protected by a high solid parapet consisting of glass balustrades and a roof.

It has been understood that a temporary school (highlighted in violet in the appropriate set of images) will be located in the proximity of the site, the school will take place in an existing building and no variations will be made to the current external shape. For this cumulative impact assessment and to account for the presence of the school, a further flow image (Figure 13.75) is provided at a lower height than 1.5m above ground to reflect the height of children and to verify that the flow velocities in the nearby of the school are not negatively impacted by the Sandyford Central Development. As the image shows, at 1 m height the flow is below 1.5 m/s in the area around the school and in particular in the area between the school and the proposed development; this range of velocity is in accordance with the Lawson category for long term sitting (for adults), therefore it can be considered safe and comfortable for children walking/sitting as well. Furthermore, in terms of Distress, the velocity is below the level for safe of frail person as well, this further confirms that children occupants are not impacted negatively should the school continue being utilised.

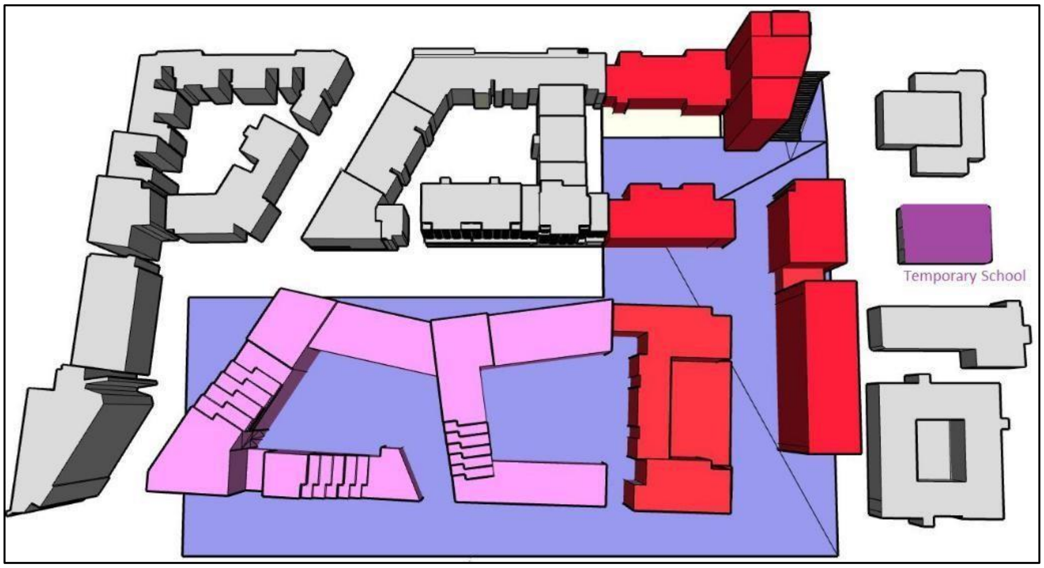


Figure 13.54: Image of Cumulative Scenario Identifying the Temporary School- Sandyford Central Development Coloured in Red and Rockbrook Phase 2 Coloured in Pink - Temporary School Coloured in Violet.

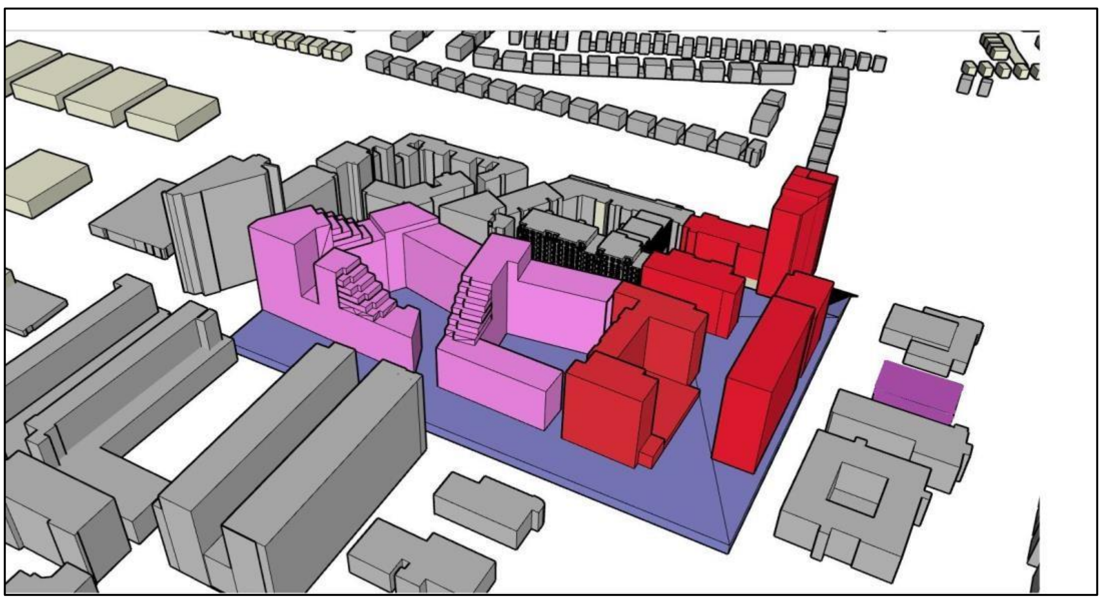


Figure 13.55: Image of Cumulative Scenario Identifying the Temporary School- Sandyford Central Development Coloured in Red and Rockbrook Phase 2 Coloured in Pink - Temporary School Coloured in Violet.

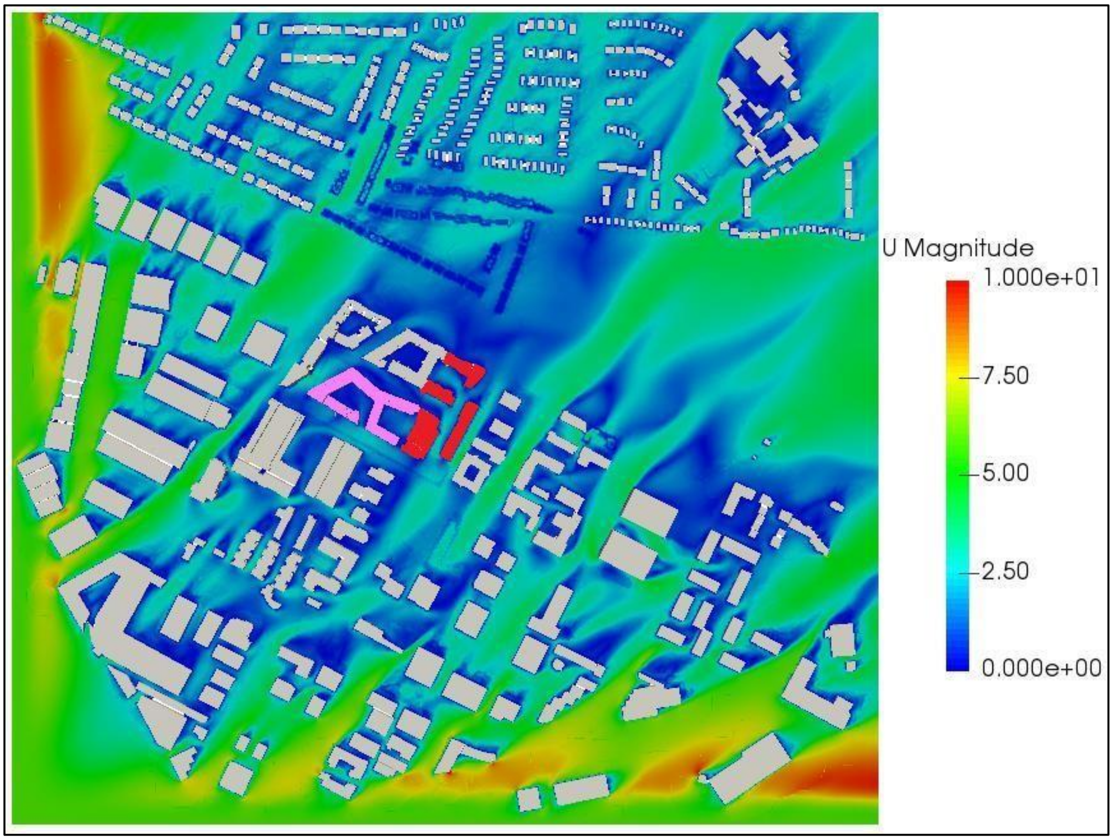


Figure 13.56: Flow Velocity Results at Z=1.5m Above the Ground - Direction: 225°.

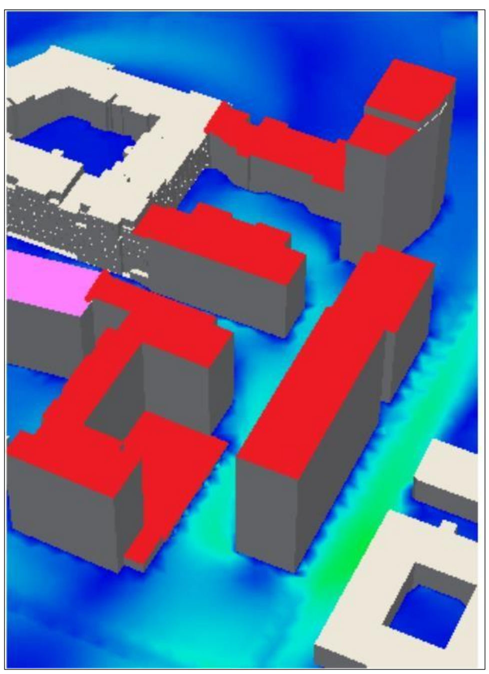


Figure 13.57: Flow Velocity Results at Z=1.5m Above the Ground - Direction: 225°.

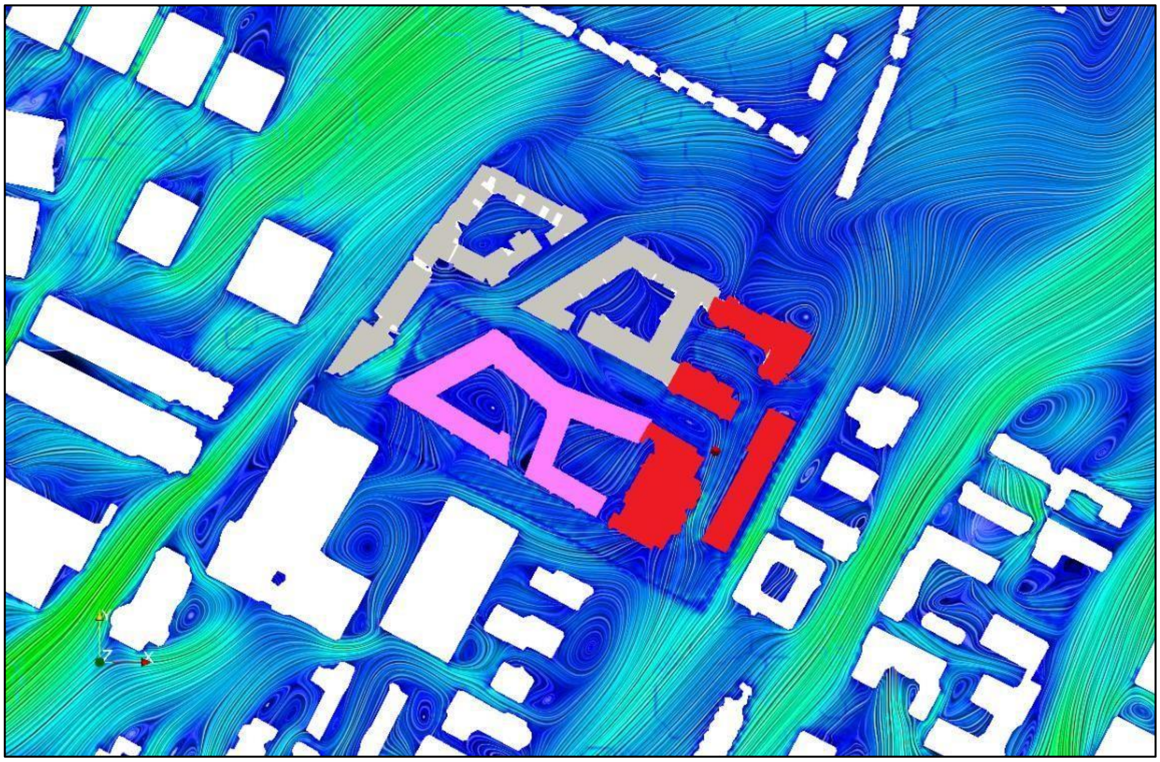


Figure 13.58: Wind Streamlines Circulation Around Development Z=1.5m Above the Ground-Direction: 225°.

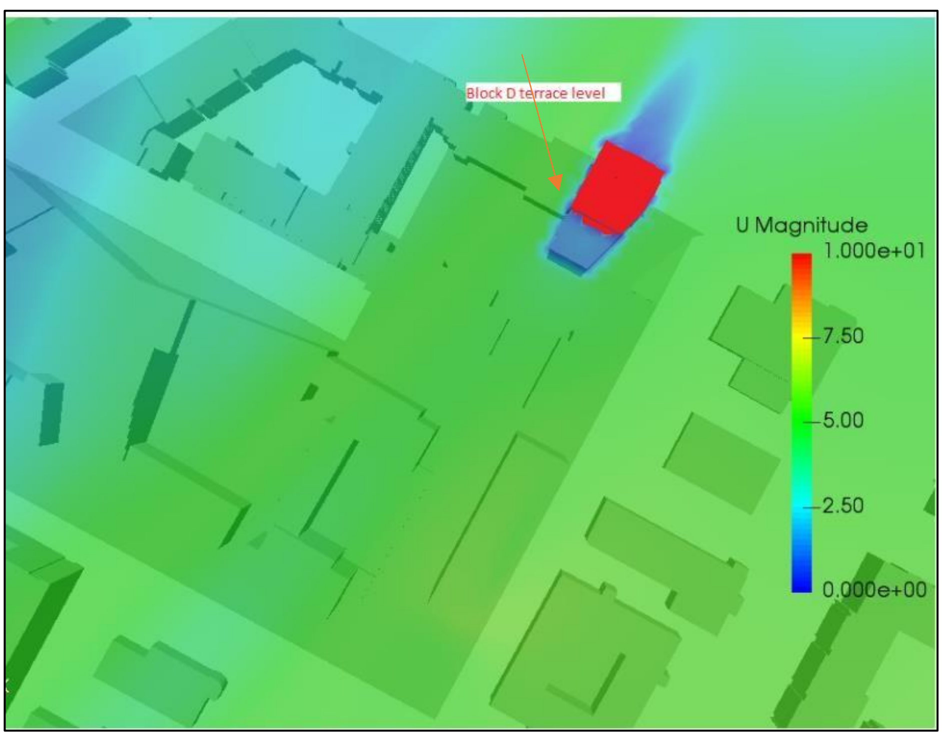


Figure 13.59: Flow Velocity Results at Z=1.5m Above the Terrace - Direction: 225°.

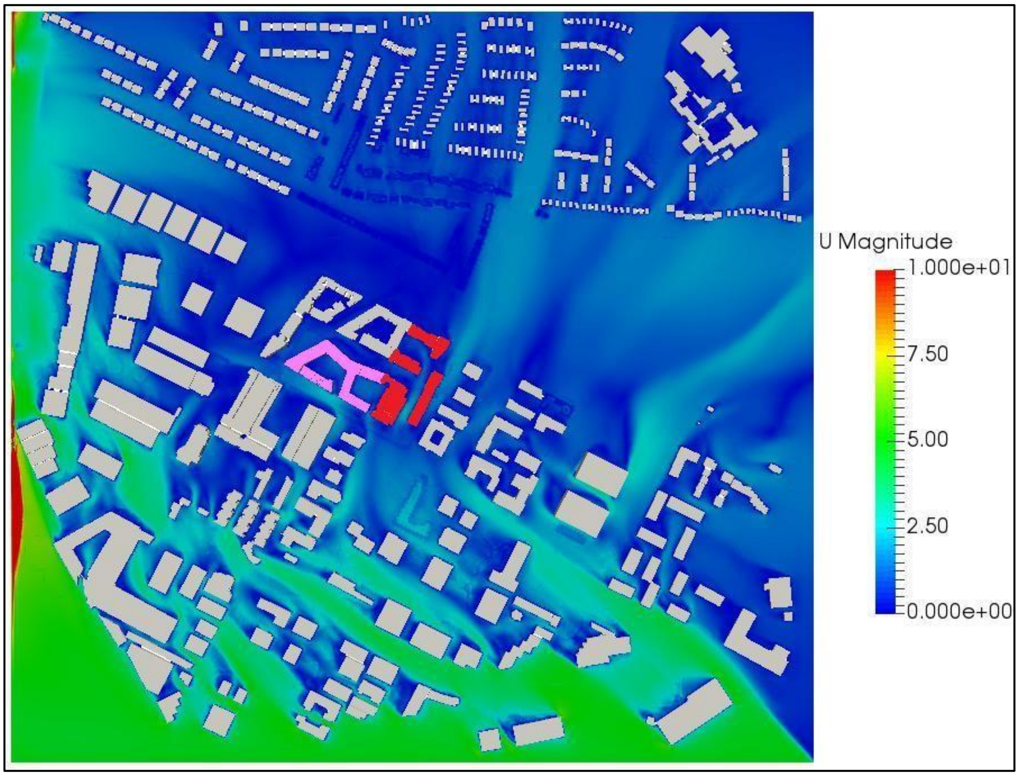


Figure 13.60: Flow Velocity Results at Z=1.5m above the Ground - Direction: 136°.

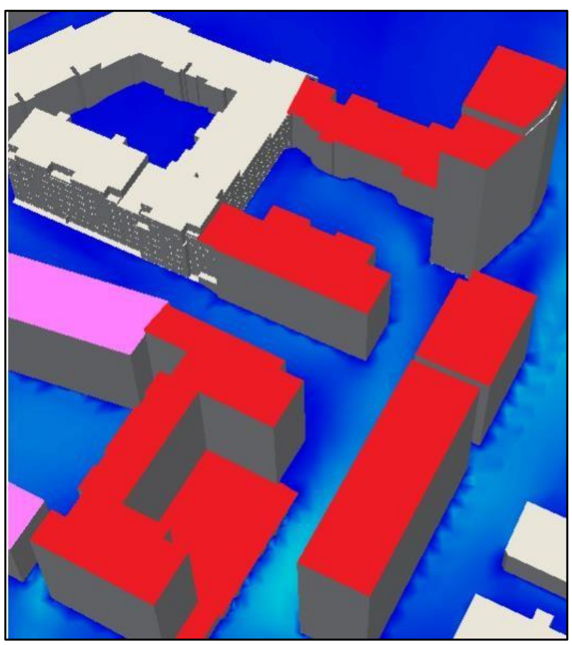


Figure 13.61: Flow Velocity Results at Z=1.5m Above the Ground - Direction: 136°. - Direction: 136°.

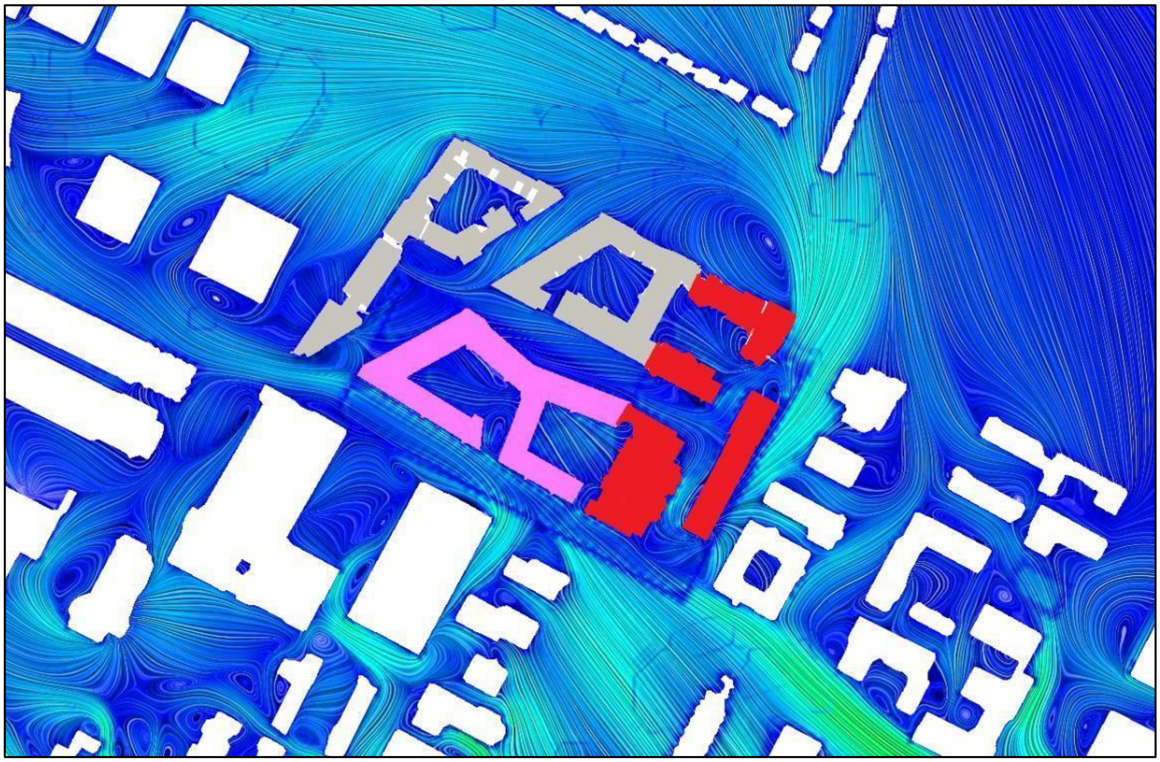


Figure 13.6212: Wind Streamlines Circulation Around Development Z=1.5m Above the Ground Direction: 136°.

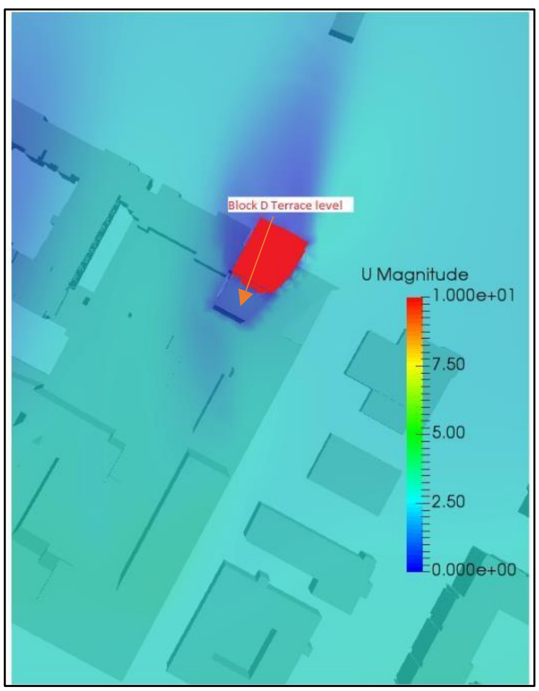


Figure 13.63: Flow Velocity Results at Z=1.5m Above the Terrace - Direction: 136°.

6482216.1

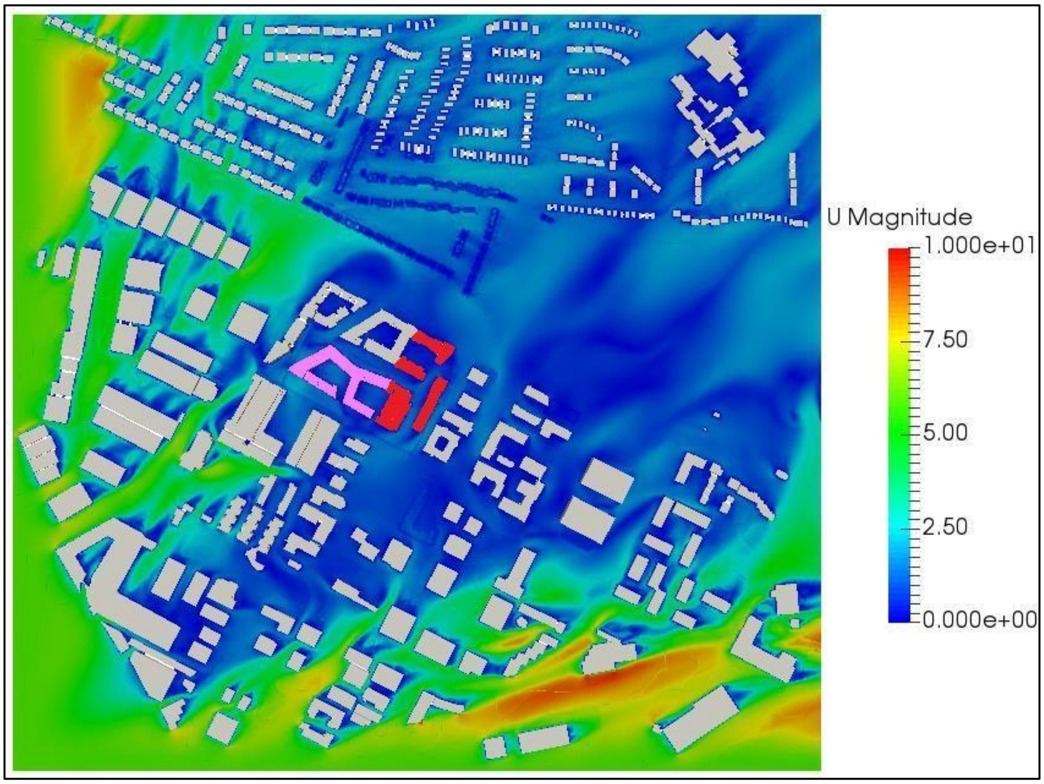


Figure 13.64: Flow Velocity Results at Z=1.5m Above the Ground - Direction: 236°.

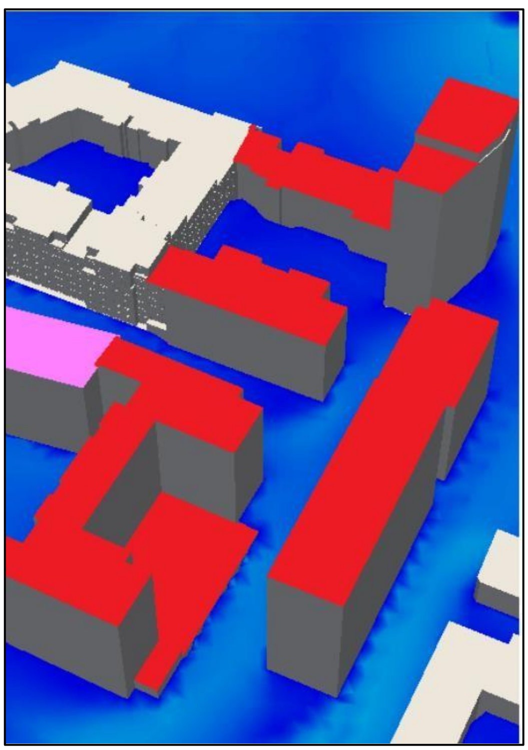


Figure 13.65: Flow Velocity Results at Z=1.5m Above the Ground - Direction: 236°.

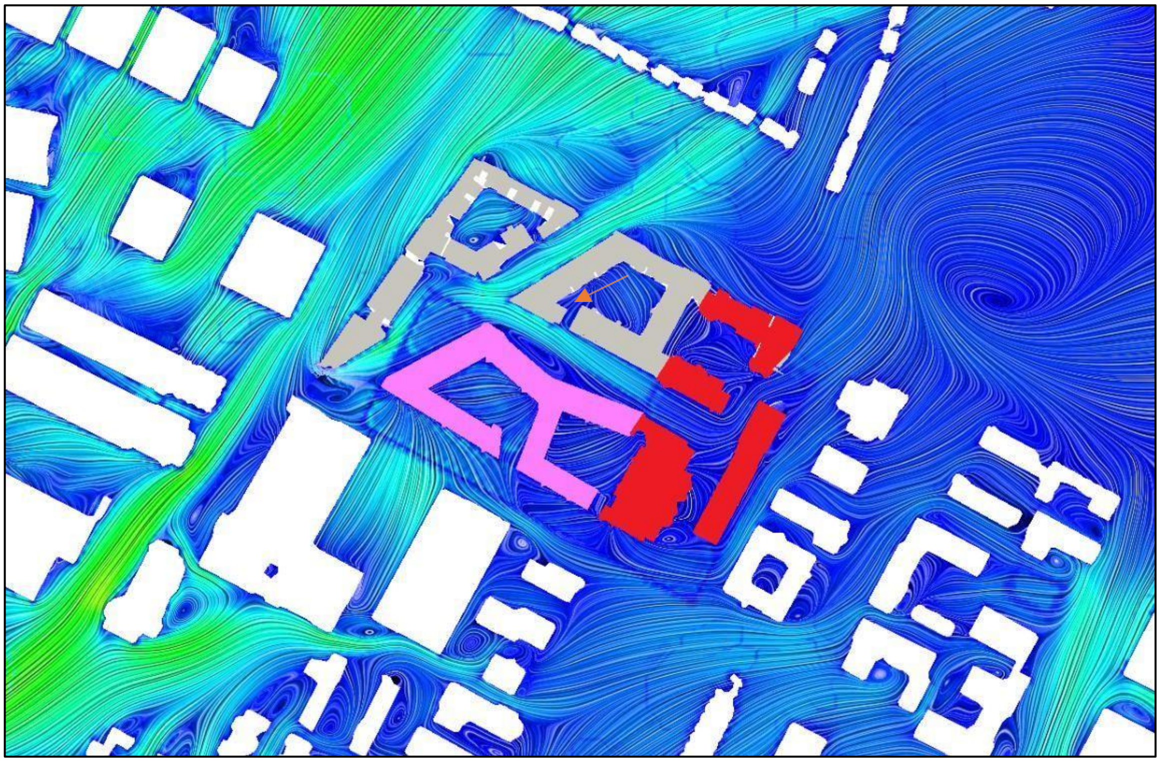


Figure 13.6613: Wind Streamlines Circulation Around Development Z=1.5m Above the Ground - Direction: 236°.

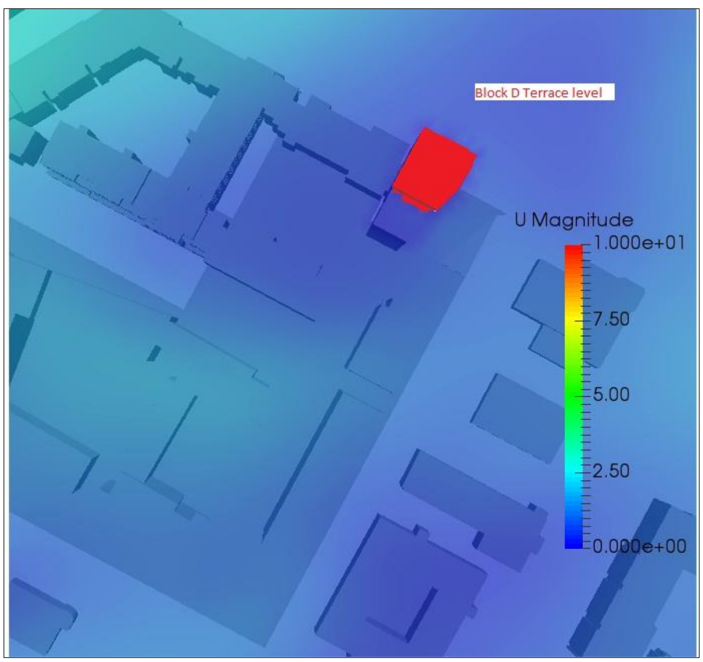


Figure 13.67: Flow Velocity Results at Z=1.5m Above the Terrace - Direction: 236°- The Red Colour on the Terrace Identifies the Building in The Model and Do Not Represent the Value of Velocities.

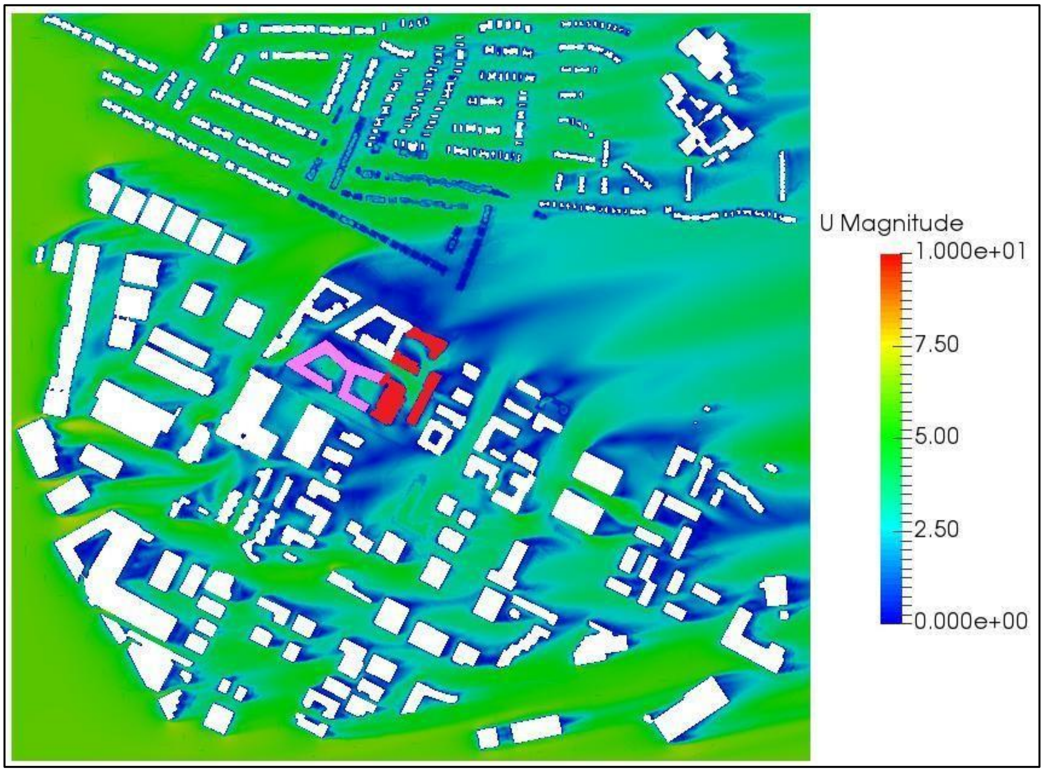


Figure 13.68: Flow Velocity Results at Z=1.5m Above the Ground - Direction: 258°.

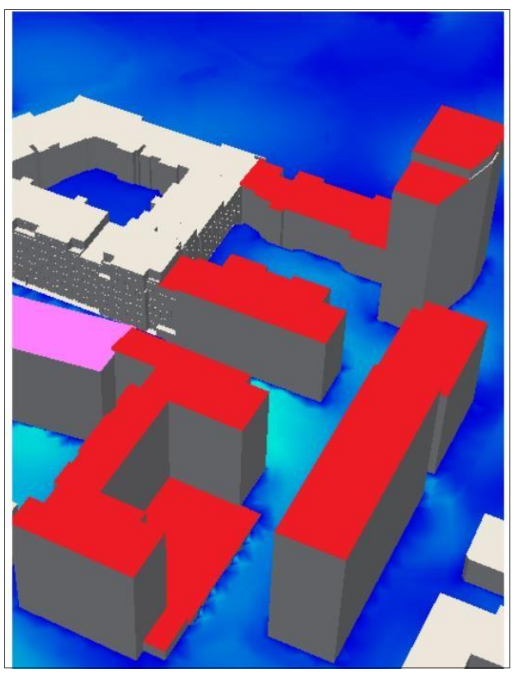


Figure 13.69: Flow Velocity Results at Z=1.5m Above the Ground - Direction: 258°.

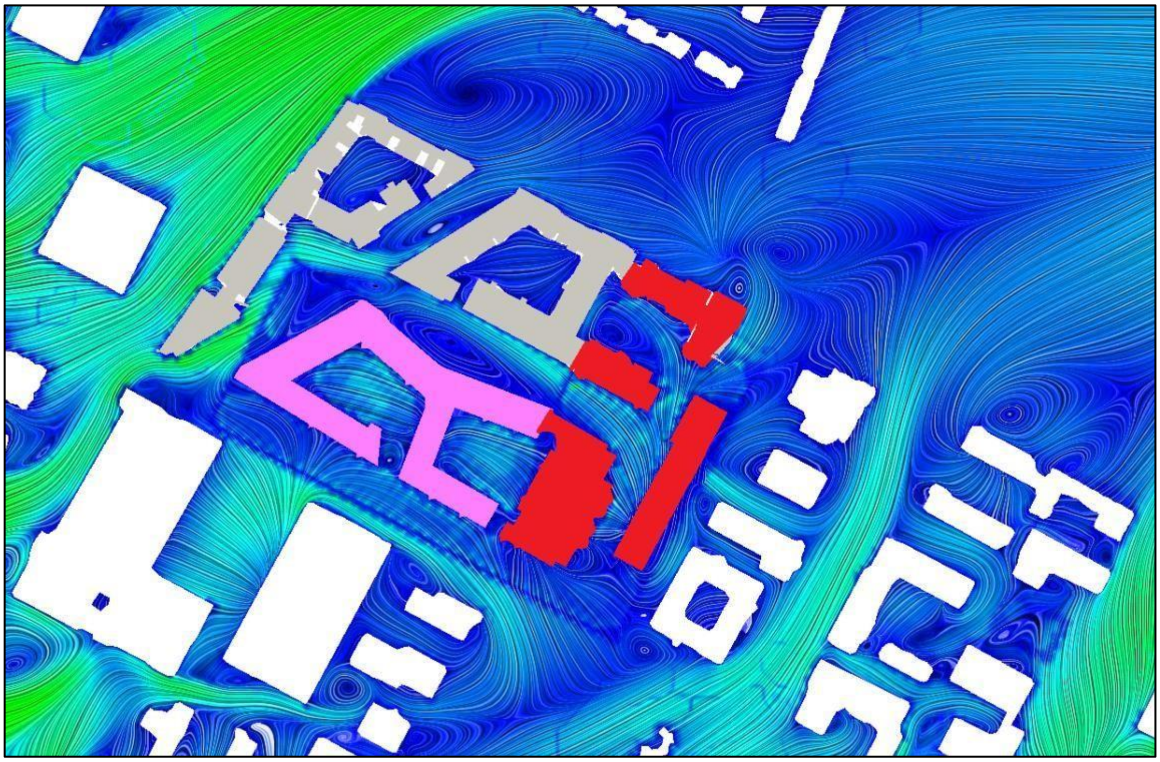


Figure 13.70: Wind Streamlines Circulation Around Development Z=1.5m Above the Ground - Direction: 258°.

Figure 13.71: Flow Velocity Results at Z=1.5m Above the Terrace - Direction: 258°.

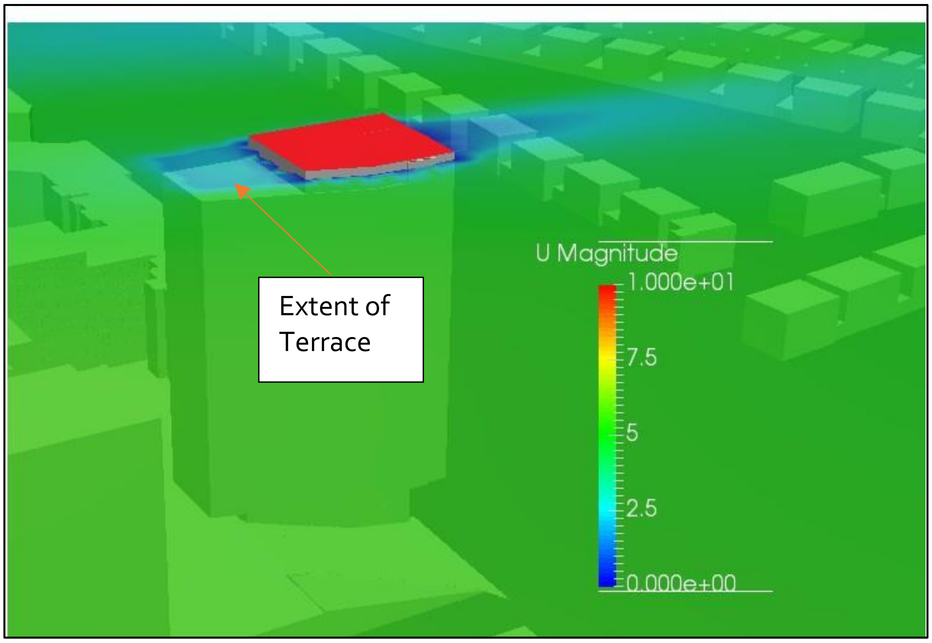


Figure 13.72: Flow Velocity Results at Z=1.5m above the terrace - Direction: 258°.

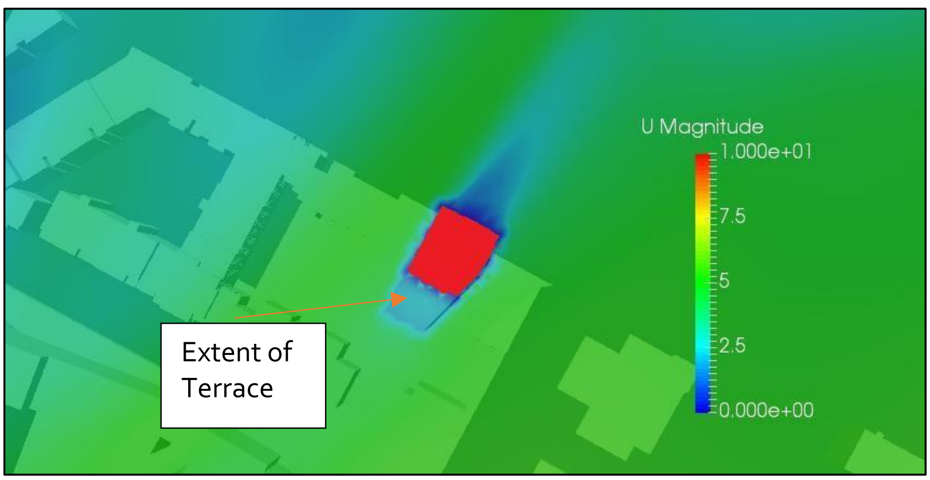


Figure 13.73: Flow Velocity Results at Z=1.5m Above the Terrace - Direction: 258°.

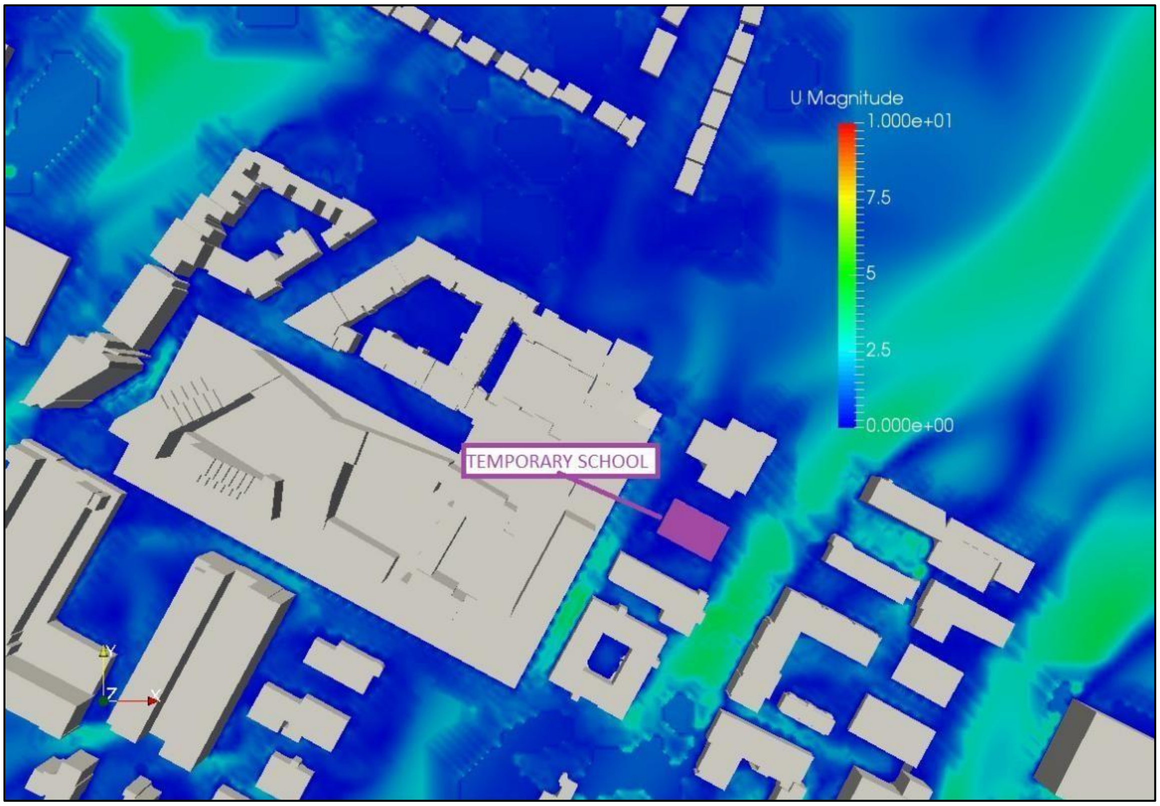


Figure 13.74: **Flow Velocity Results at Z=1.0m Above the Ground for Temporary School Flow Paths - Direction: 258°.**

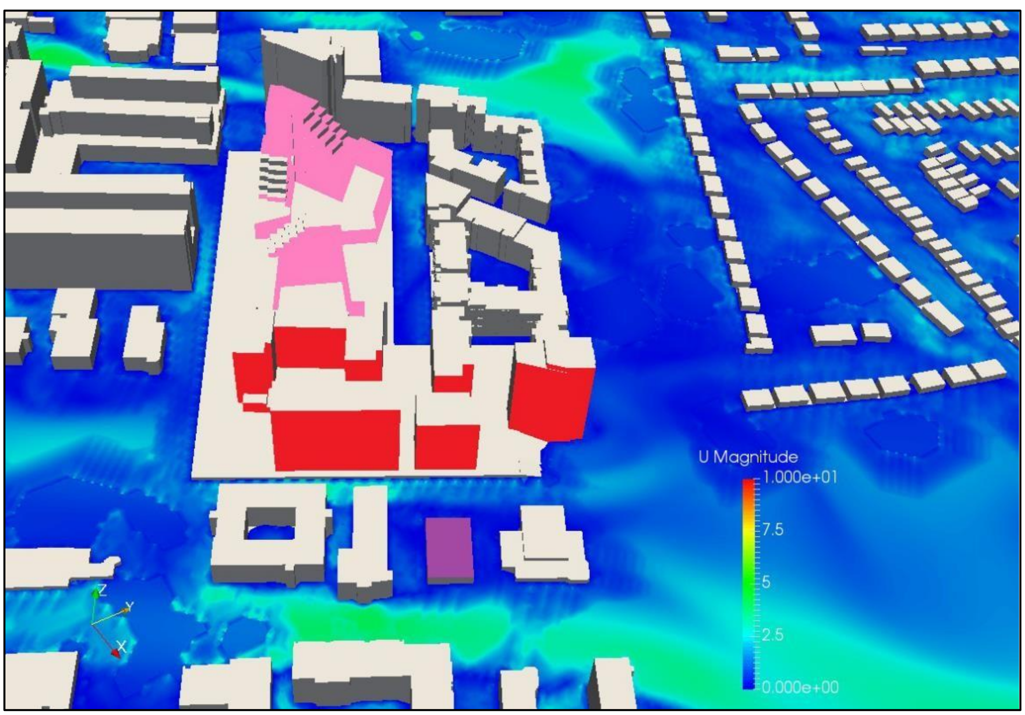


Figure 13.75: **Flow Velocity Results at Z=1.0m Above the Ground for Temporary School Flow Paths- Direction: 258°.**

13.10.2 Pedestrian Comfort Assessment (Lawson Maps)

This section aims to identify areas of the proposed Sandyford Central 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 13.77 and 13.80 show Lawson comfort categories over the ground floor area around the proposed Sandyford Central Development, for the 4 different directions. In all cases, the scale used is set out in Figure 13.76. Thus, depending on the wind direction, the suitability of the different areas can be assessed using those 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".

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.

The results show that the entire development and adjacent roads and courtyards seem to be always well shielded and suitable for any activity.

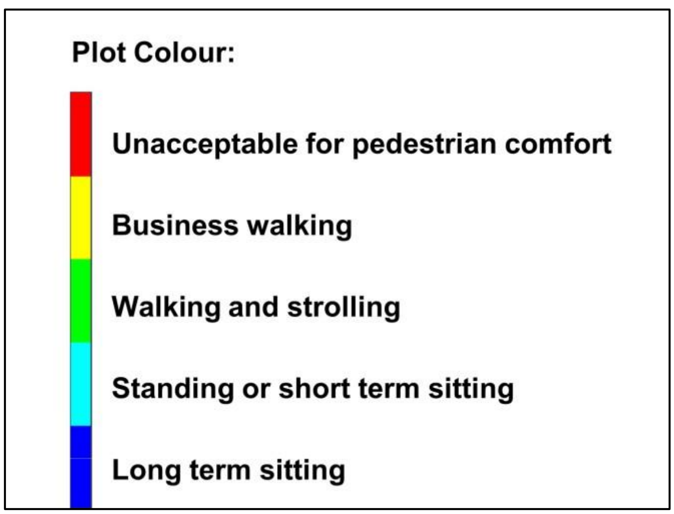


Figure 13.76: Lawson Comfort Categories and Colour Code for the Lawson Maps.

Figure 13.77: Lawson Discomfort Map - Directions: 225°.

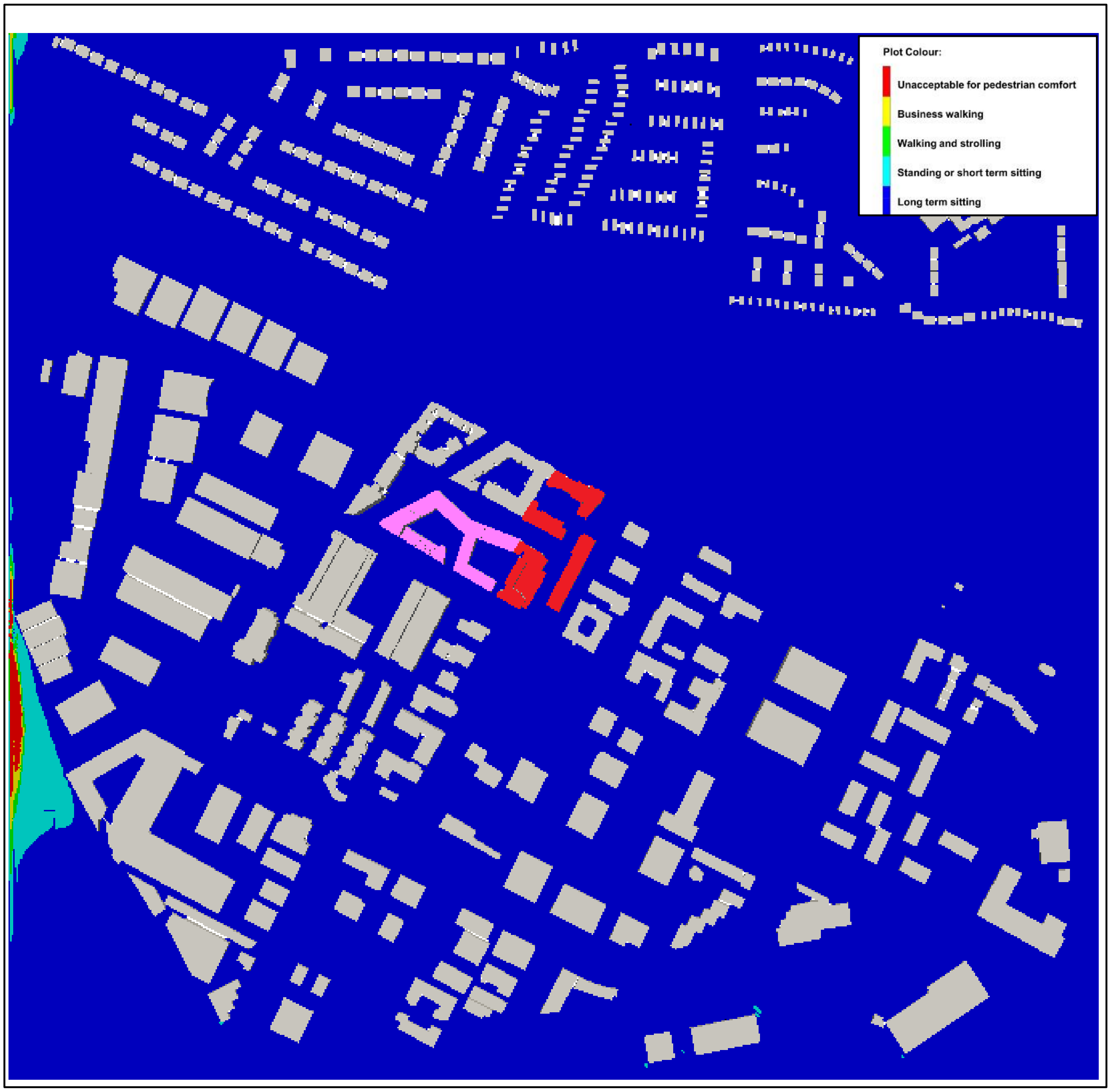


Figure 13.78: Lawson Discomfort Map - Directions: 136°.

Figure 13.79: Lawson Discomfort Map - Directions: 236°.

Figure 13.80: Lawson Discomfort Map - Directions: 258°.

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 13.81 shows the hourly wind gust rose for Dublin, from 1985 to 2019. This will be necessary to assess how many hours per year on average the velocity exceed the threshold values.

As shown in the resulting maps from Figure 13.84 to Figure 13.87 the results of simulations have demonstrated that, under the wind speed tested and in line with the requirements of the Lawson Distress category, there are no distress areas within the site of Sandyford Central Development and its surroundings, this for both frail persons and cyclists.

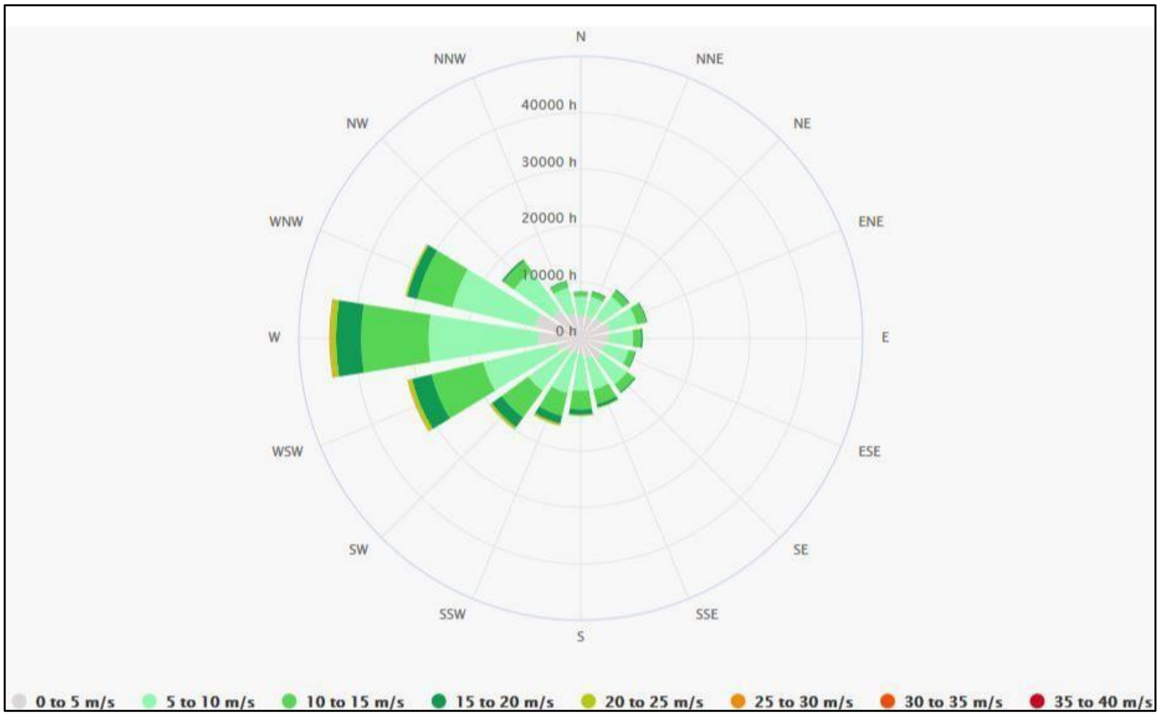


Figure 13.81: Hourly Dublin Wind Gust Rose.

Distress for Frail Person or Cyclist

The criteria for distress for a frail person or cyclist are 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 Figure 13.82 and Figure 13.83 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.

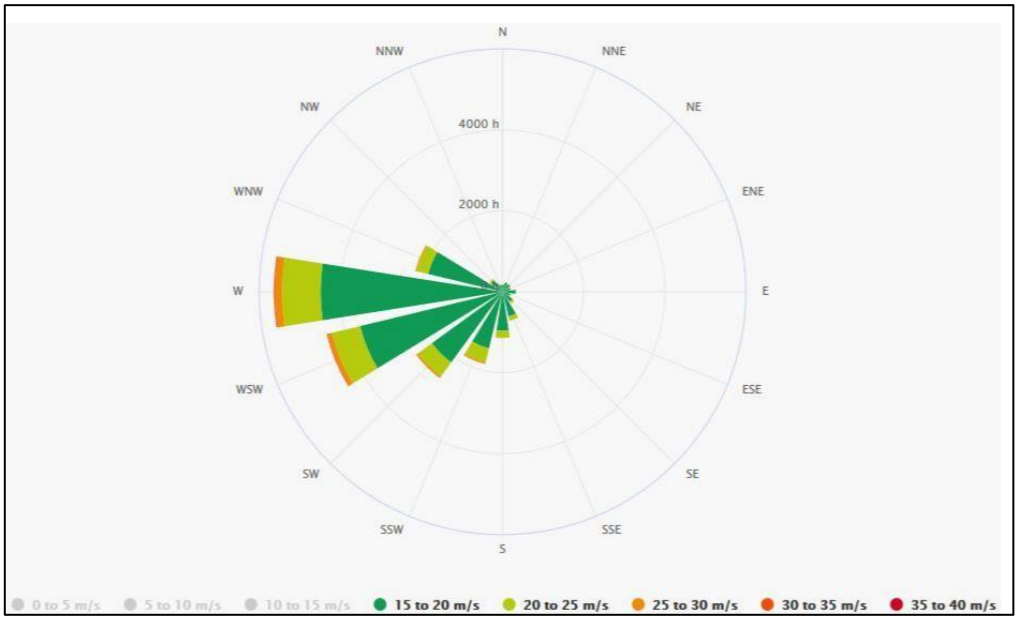


Figure 13.82: Hourly Dublin Wind Gust Rose - Cumulative Hours when the Velocity is above 15m/s.

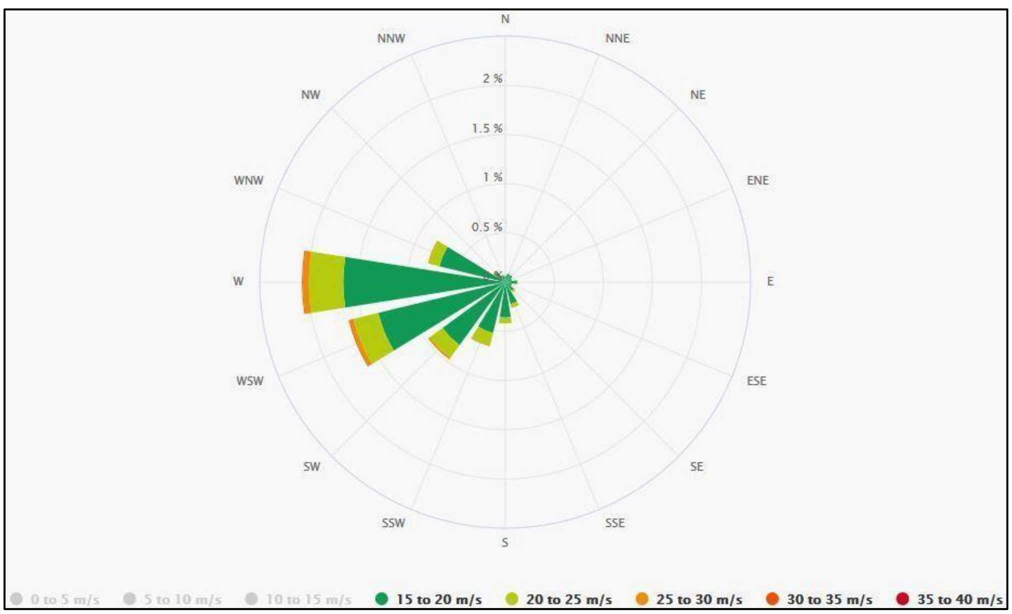


Figure 13.83: Hourly Dublin Wind Gust Rose - Cumulative Percentage of Time when the Velocity is above 15m/s.

A total of 2 hours per years corresponds to 0.02% in one year, which means 0.6% in 30 years. Looking at the wind roses above, it is possible to notice that a velocity of 15m/s was reached in Dublin only for the following directions (in increasing order of percentage) over the years 1985-2019:

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

For this reason, it is of interest to show the distress results for these directions. Figures 13.85 to 13.87 below show the areas where the measured velocity is above 15 m/s in each direction. Figure 13.84 shows the scale used in this case. Results show that, for any direction, there are not critical areas where the velocity increases above 15 m/s.

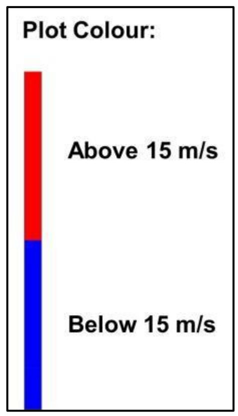


Figure 13.84: Lawson Distress Categories - Frail Person or Cyclist Colour Bar Applied to all Following Images.

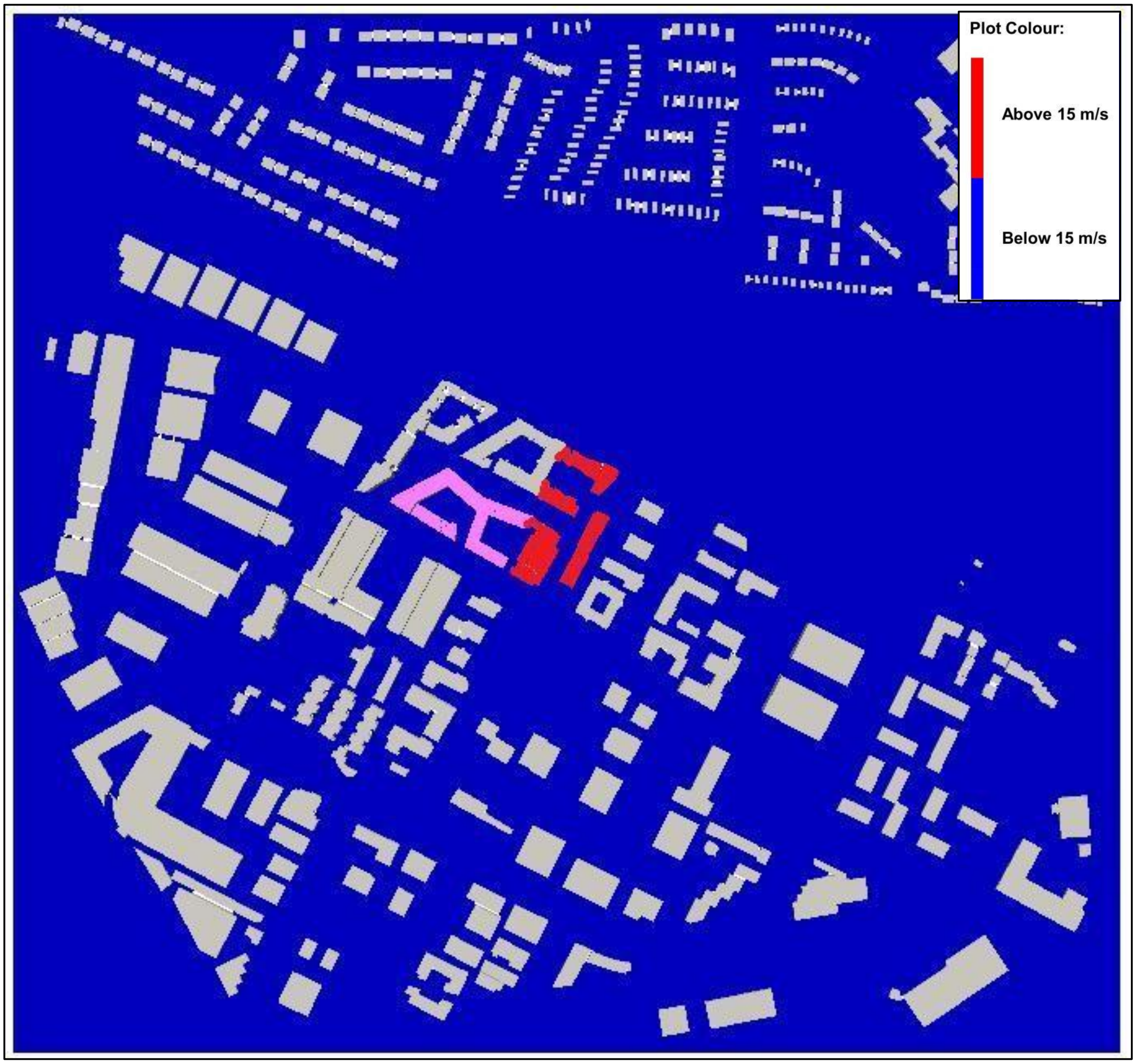


Figure 13.85: Lawson Distress Map - Frail Person or Cyclist - Directions: 270°.

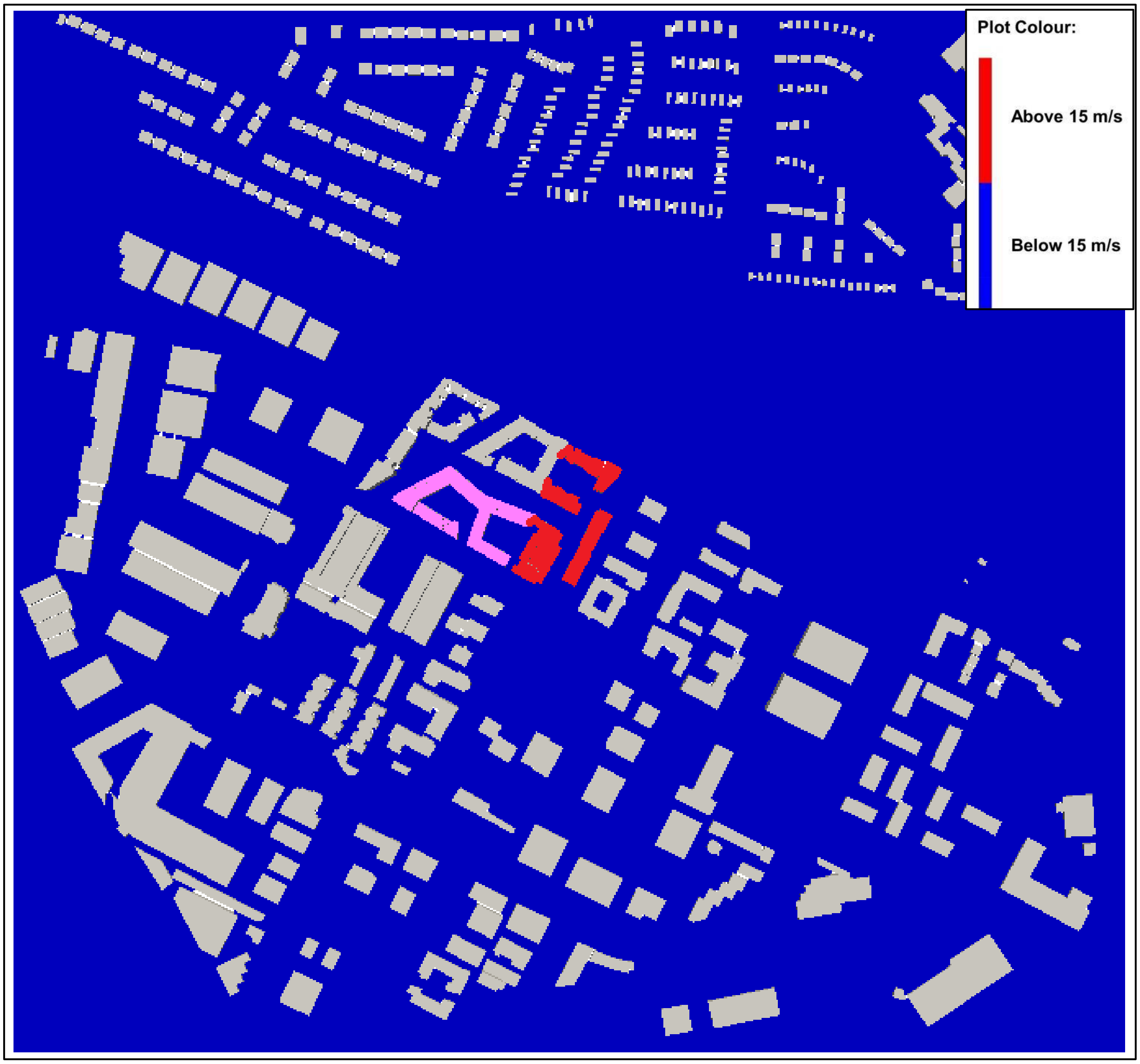


Figure 13.86: Lawson Distress Map - Frail Person or Cyclist - Directions: 247.5°.

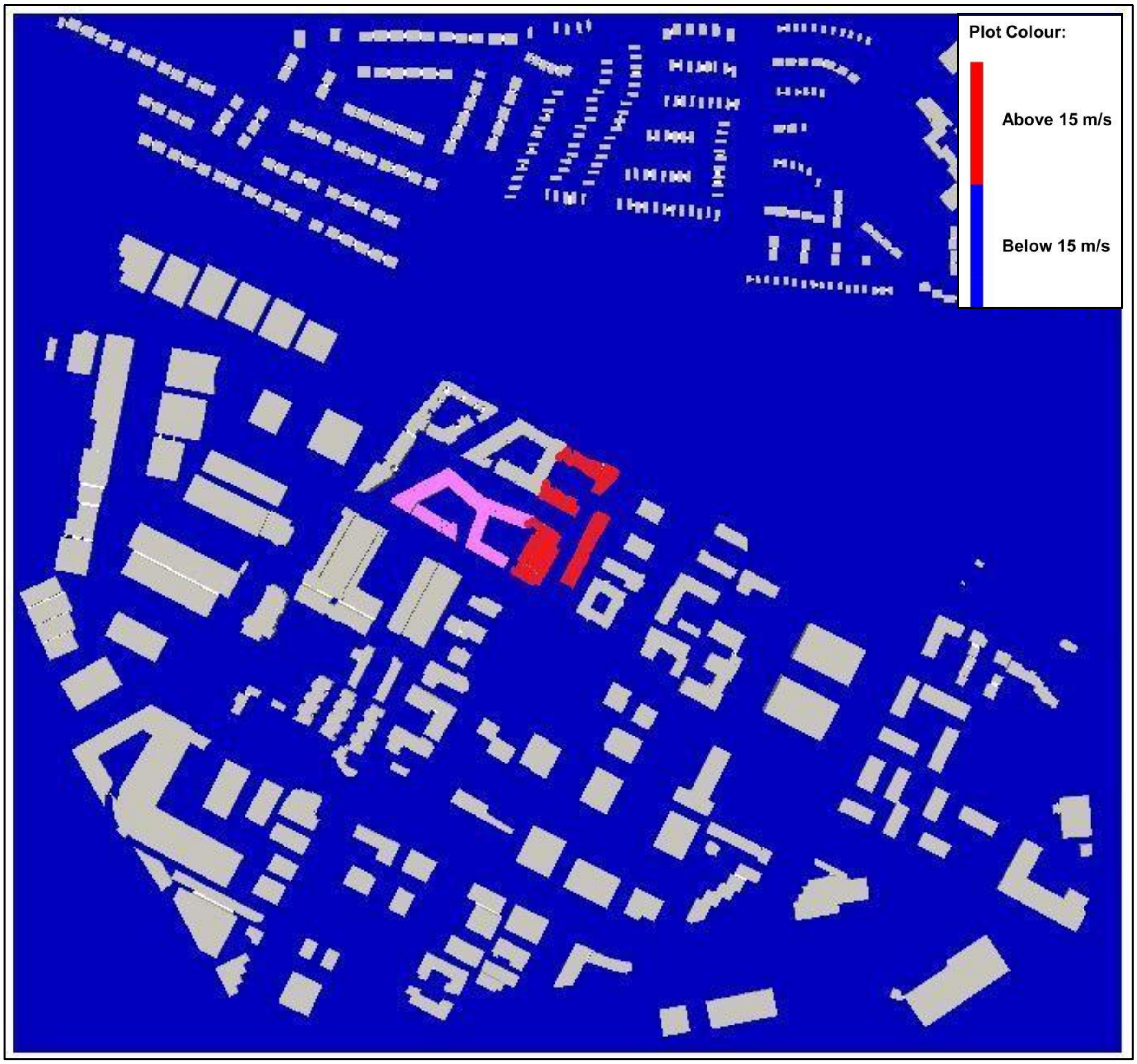


Figure 13.87: Lawson Distress Map - Frail Person or Cyclist - Directions: 225°.

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 Figure 13.88 and Figure 13.89 respectively as cumulative hours and cumulative percentage), it is possible to see how many hours in 30 years the gust velocity of 20m/s is exceed at pedestrian level in each direction.

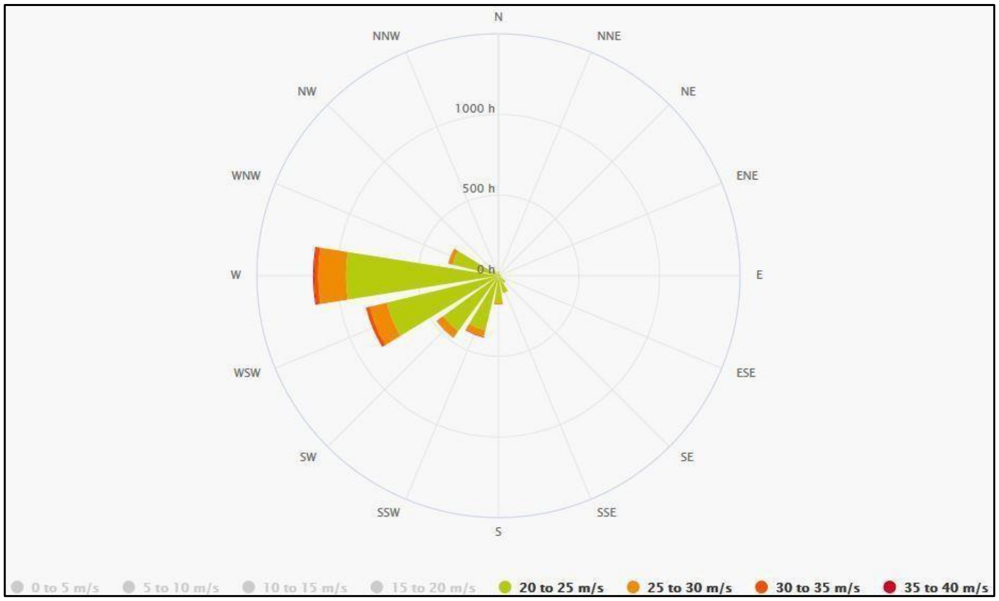


Figure 14: **Hourly Dublin Wind Gust Rose - Cumulative Hours when the Velocity is Above 20m/s.**

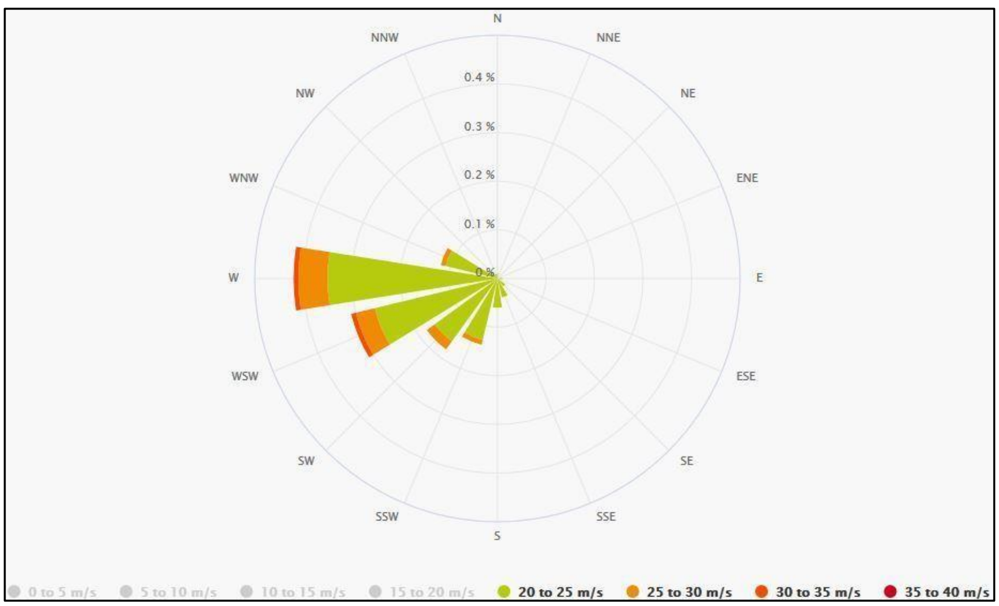


Figure 13.89: **Hourly Dublin Wind Gust Rose - Cumulative Percentage of Time when the Velocity is above 20m/s.**

A total of 2 hours per years corresponds to 0.02% in one year, which means 0.6% in 30 years. Looking at the wind roses above, it is possible to notice that a velocity of 20m/s was never reached in Dublin over the years 1985-2019. For this reason, it is not of interest to show the distress results for any of the wind directions and the criteria is always satisfied. Furthermore, as shown in the Lawson Distress maps previously presented, it can be concluded that the proposed development does not introduce any distress for both frail persons and cyclists both when these categories of people are within the development when they pass in the appropriate footpaths/intended areas.

13.11 Potential Wind Impact During Construction Phase

The possible effects on wind and microclimate at the site during the construction phase is evaluated based on professional judgement (fluid dynamic assessment). The wind data obtained with the on-site wind measurements have been used to carry on this analysis, that is based on the fact that the dominant wind direction is South-West.

As the finalisation of the development proceeds, the wind setting at the site would progressively conform to those of the completed development. It is possible that, in the final stages of construction, implementation of the suggested mitigation measures would be needed in those parts that are expected to be windier then acceptable, if some of the parts of the site are expected to be functional before the construction is finalised.

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 situ), the impacts evaluated on-Site are considered to be insignificant. Thus, the predicted impacts are identified as negligible.

In summary, as construction of the Sandyford Central Development progresses, the wind conditions at the Site would gradually adjust to those of the completed development, and mitigation measures would need to be implemented before completion and operation. During the construction phase the predicted impacts are classified as negligible.

13.12 Conclusions and Comments On CFD Study

This report has presented the CFD modelling assumptions and results of Wind and Microclimate Modelling carried out for the assessment of the proposed Sandyford Central Development in Dublin 18.

This assessment is used to identify areas of concern in terms of critical flows and areas where pedestrian safety and comfort could be compromised (in accordance with the Lawson Acceptance Criteria).

The assessment has been carried out considering the impact of wind on the following scenarios:

- The "Existing Receiving Environment": in this case the assessment has considered the impact of the local wind on the area considering the existing buildings prior of the construction of the proposed development. A statistical analysis of 30 years of historical weather wind data has been carried out to find the most critical wind speeds and directions and the frequency of occurrence of the same, furthermore, B-Fluid's weather station has recorded locally 1 month of wind data on the existing site for comparison with the historical ones.

- The "Proposed Development": in this case the assessment has considered the impact of wind on the existing area including the proposed Sandyford Central Development. For this scenario, the analysis has identified the critical areas of the proposed development that required the implementation of mitigations measures.

- The ”Cumulative Impact”: in this case the assessment has considered the impact of wind on the existing area including the proposed Sandyford Central Development and the adjacent Rockbrook Phase 2 buildings for which a SHD has recently been granted by ABP(Ref.PL06D304405). For this scenario, the Sandyford Central Development has been simulated inclusive of its mitigation measures impact in the locations identified as critical during the ”Proposed Development” scenario.

In summary, as shown in the details of this report, the wind study carried out shows that the development, implemented with the suggested mitigation measures, 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 does not introduce any critical impact on the surrounding areas and on the existing buildings even when considering the adjacent future construction of the Rockbrook Phase 2 development. In particular:

- The wind profile was built using the annual average of meteorology data collected at Dublin Airport Weather Station. In particular, the local wind climate was determined from historical meteorological data recorded 10 m above ground level at Dublin Airport.

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

- From this, a wind speed profile was determined, to be used in the CFD analysis to generate the wind profile around the building in each of the selected directions.

- The results of the simulations have shown that the proposed Sandyford Central Development will produce a quality environment that is attractive and comfortable for pedestrians. The development does not introduce major critical impacts on the existing environment and do not appear to be impacted negatively by the adjacent Rockbrook Phase 2 buildings once constructed, indeed Sandyford Central and Rockbrook Phase 2 have similar heights and massing and are surrounded by further developments with similar characteristics.

- Good shielding is achieved on all critical roads within the development. There are some funnelling effects around both the main roads abutting the Sandyford Central development and some high velocities in the main road on the east side of the development (Carmanhall Road). However, high velocity areas are limited to the part of the roads where the cars pass. Footpaths are successfully shielded by vegetation. The funnelling across the development does not reach critical velocities and would be mitigated by the presence of the trees. These high velocities appear to be already present before construction of Sandyford Central Development and not a consequence of its construction.

- Assessment of the velocities on the terrace of Block D shows that the velocities are always below critical values for the intended use of the terraces and considering its seasonal use (primarily summer/spring).
- The pedestrian comfort assessment, performed accordingly to the Lawson criteria, identified the areas that are suitable for the different pedestrian activities in order to guarantee pedestrian comfort and showed that the entire development is suitable for any activities. Moreover, in terms of distress, no critical conditions were found for "Frail persons or cyclists", neither for members of the "General Public", in the surrounding of the development.
- Balconies are not considered "common pedestrian areas" and do not have a category within the Lawson criteria, however, as it can be seen by the results of flow velocities (streamlines in particular) there are not high accelerations or re-circulation of flow nearby the facades of the development and the balconies appear to be shielded by the main wind direction analysed. Having seen the wind conditions and the location of the balconies and the fact that a solid parapet is used for them as part of the architectural design, it can be anticipated that during the summer months, it will be suitable to use the balconies to stand or sit.
- Entrances are all shown for the height of 1.5m above ground, the flow at this height is within the Lawson category for long term sitting, under the wind conditions and directions simulated.

Therefore, the wind study carried out has shown that, under the assumed wind conditions and the proposed mitigation measures:

- 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 pedestrians), and,
- The development does not introduce any critical impact on the surrounding areas and on the existing buildings.

13.13 Do Nothing Scenario

In order to provide a qualitative and equitable assessment of the proposed development, the 'Do Nothing' Impact considers the proposed development in the context of the likely impacts upon the receiving environment should the proposed development not take place.

Based on statistical wind data related to the existing environment, and the wind microclimate assessment performed, the proposed development introduces no critical or negative wind microclimate conditions unto the existing environments pedestrian path, sidewalks, buildings or environment, therefore, a 'Do Nothing' Impact is regarded as imperceptible.

13.14 Difficulties Encountered

No difficulties were encountered during the assessment of wind microclimate impacts on the proposed Sandyford Central Development or its existing environments.

13.15 Interactions

Wind microclimate interacts with risks to human health. Results of wind microclimate (Distress Criteria) has shown this interaction to be not significant based on wind conditions

prevalent in Dublin and considering the mitigation measures implemented during the design process. Wind microclimate has also been considered in the landscaping strategy for the proposed development.

13.16 References

- Lawson, T.V., 2001, 'Building Aerodynamics', Imperial College Press, Dublin
- Simiu, E., 2011, 'Design of buildings for wind: a guide for ASCE 7-10 Standard users and designers of special structures', 2nd Edition, John Wiley and Sons, Inc., Hoboken, New Jersey, U.S.A.
- Building Aerodynamics, Tom Lawson FREng. Imperial College Press, 2001
- Blocken, B., 2015. Computational Fluid Dynamics for Urban Physics: Importance, scales, possibilities, limitations and ten tips and tricks towards accurate and reliable simulations. Building and Environment.
- Blocken, B., Janssen, W.D. and van Hooff, T., 2012. CFD simulation for pedestrian wind comfort and wind safety in urban areas: General decision framework and case study for the Eindhoven University campus. Environmental Modelling and Software, 30, pp.15–34.
- Franke, J., Hellsten, A., Schlunzen, H., Carissimo, B, Ed. (2007); Best Practice Guidelines for the CFD Simulation of Flows in the Urban Environment, University of Hamburg
- RWDI, Wind Microclimate Guidelines for Development in the City of London