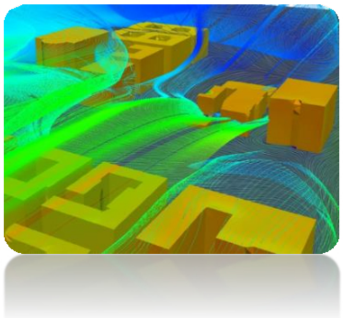 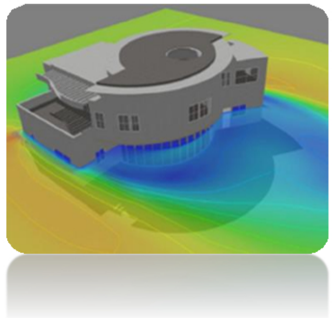 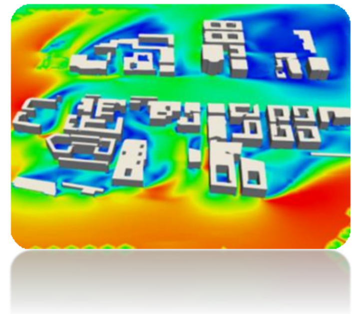

WIND AND MICROCLIMATE MODELLING

Belgard Gardens, Tallaght, Co. Dublin

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

For: Atlas GP Ltd

B-Fluid
Buildings Fluid Dynamics

<table>
<tr><th colspan="3">Document Reference</th></tr>
<tr><td>Project Name</td><td colspan="2">WIND AND MICROCLIMATE MODELLING.
BELGARD GARDENS, TALLAGHT, Co. DUBLIN</td></tr>
<tr><td>Project Ref.</td><td colspan="2">SV_1809087</td></tr>
<tr><td>Site location</td><td colspan="2">Tallaght, Co. Dublin</td></tr>
<tr><td>CFD Study by</td><td colspan="2">B-Fluid Ltd.</td></tr>
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B-Fluid | Wind Modelling

Contents

1. EXECUTIVE SUMMARY

B-Fluid Limited has been commissioned by 'Atlas GP Ltd' to carry out a Wind and Microclimate Modelling for Belgard Gardens Development, Phase 1 and Phase 2, in Tallaght, Co. Dublin. The development of the site will comprise the construction of a large mixed residential project of 438 no. apartments, 403 no. bedspaces and ancillary uses in 5 blocks ranging from 4 – 10 storeys in height (Phase 1 – Units 1 to 3) and c. 1000 units in 12 blocks of 4 – 12 storeys in height (Phase 2 - Units 4 to 9).

Figure 1.1 shows a top view of the development and highlights Phase 1 and Phase 2. The analysis has been carried on for both Phase 1 on its own and Phase 1 together with Phase 2. It has to be noted that Phase 2 does not form part of the subject application, however a cumulative assessment was considered prudent.

Figure 1.1: Top View of Belgard Gardens Development, Phase 1 and Phase 2

The aim of the wind modelling study is to predict the wind patterns around the area proposed, under mean and peaks wind conditions typically occurring in Tallaght.

The assessment will identify areas of concern in terms of critical flows and areas where the pedestrian safety and comfort could be compromised (in accordance with the Lawson Acceptance Criteria) and will suggest mitigation measures that can be implemented.

The results of the wind modelling study will be utilized by Atlas GP Ltd. design team to configure the optimal layout for Belgard Gardens Development, to demonstrate that:

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

The wind modelling study is performed through a Computational Fluid Dynamics (CFD) analysis which simulates the movement of wind within the prescribed area. The simulations are carried out with OpenFoam, using the concept of Large Eddy Simulation (LES).

For the purposes highlighted above, the present study is divided in two parts:

- Part 1: Local Wind Data Statistical Analysis, necessary for the following flow feature assessment.
- Part 2: Wind Microclimate Model of the Site, in order to predict the flow field in terms of pressure and velocity that develops at the Belgard Gardens Development and successively perform a Pedestrian Comfort analysis of the area.

This two parts are summarised in Table 1.1:

ASSESSMENT PARTS	
PART 1	LOCAL WIND DATA STATISTICAL ANALYSIS
PART 2	WIND MICROCLIMATE MODEL OF THE SITE

Table 1.1: Part 1 and Part 2 of Belgard Gardens Wind and Microclimate Assessment Study

For Part 2, two major cases will be modelled. Case 1 carries out a microclimate assessment for Phase 1 only, while Case 2 carries out a cumulative microclimate assessment for Phase 1 and Phase 2. These two cases are illustrated in Table 6.1.

PART 2 CASES	
CASE 1	PHASE 1 MICROCLIMATE ASSESSMENT
CASE 2	PHASE 1 AND PHASE 2 CUMULATIVE MICROCLIMATE ASSESSMENT

Table 1.2: Belgard Gardens Analysed Cases

During Part 2 - Wind Microclimate Model of the Site, for both cases, eight different scenarios will be modelled, in order to take into consideration all the different relevant wind directions. Results in this report are presented for the worst case scenarios. In particular, each of the modelled scenarios are presented below:

1. **Scenario 1 - North Wind**
2. **Scenario 2 - North-East Wind**
3. **Scenario 3 - East Wind**
4. **Scenario 4 - South-East Wind**
5. **Scenario 5 - South Wind**
6. **Scenario 6 - South-West Wind**
7. **Scenario 7 - West Wind**
8. **Scenario 8 - North-West Wind**

The following report describes the wind and microclimate assessment performed and the rational of the methodology and assumptions that B-Fluid Ltd. has adopted for the assessment scenarios. This report aims to outline the CFD (Computational Fluid Dynamics) parameters used to simulate the assessment scenarios and wind development within Belgard Gardens Development and to show results of the simulations carried out.

The CFD study aims 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.

In summary, as shown in the details of this report, the CFD study carried out shows that the development is designed to be a high-quality environment for the scope of use intended of each areas/building (i.e. comfortable and pleasant for potential pedestrian), and does not introduce any critical impact on the surrounding areas and on the existing buildings. In particular:

1. **PART 1 - LOCAL WIND DATA STATISTICAL ANALYSIS SUMMARY:**
   - 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.

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

2. **PART 2 - WIND MICROCLIMATE MODEL OF THE SITE SUMMARY:**
   - The proposed Belgard Gardens Phase 1 development will produce a quality environment that, once landscapind is implemented, is attractive and comfortable for pedestrians. The landscaping plans have been adapted and designed to provide further protection from the wind. Different sizes of trees have been specified in the square, as well as all around the buildings to help disperse the approaching wind and protect the footpaths and the cycling paths. Where higher speed winds have been predicted by the analysis carried out, landscaping has been suggested and implemented in all those areas where pedestrian comfort could be affected.

   - The mitigation implemented achieves good shielding on all critical roads. High velocity areas are limited to the part of the roads where the cars pass. Footpaths and cycling paths are clearly successfully shielded by vegetation.

   - Shielding conditions in the square are pretty good. However, an increase of trees or an increase in the height of them could further improve square conditions, especially for some wind directions. However, the introduction of Phase 2 would shield the square completely.

   - In few areas, the mitigation can be implemented adding some trees or incrementing trees height.

   - The pedestrian comfort assessment, performed on Phase 1 accordingly to the Lawson criteria, identified the areas that are suitable for the different pedestrian activities in order to guarantee pedestrian comfort. Moreover, in terms of distress, some critical conditions were found for “Frail persons or cyclists” in the surrounding of the development only in the west direction. However, the frequency at which these conditions happen are below the critical threshold for distress. These results are summarised in Figures 1.2 to 1.4 and in Table 1.3.

   - Regarding Phase 1 and Phase 2 together, all the critical area have been mitigate by the landscaping performed on Phase 1 only. However, there are still few area that could be improved if some landscaping is implemented on Phase 2 as well.

   - The Tallaght Hospital Ground-Based Helicopter Pad is located 150m to the west of Belgard Garden development site. Belgard Gardens Development can affect and modify wind conditions at Tallaght Hospital Helipad exclusively when the wind flows in East and North-East directions. Results show that the velocity might exceed threshold values in a few small areas. However, prevailing wind direction in Dublin is South-West. Therefore, Belgard Gardens Development Phase 1 has not impact on the Helipad exposure to the prevailing wind conditions. On the East and North-East wind directions the development is actually partially protecting the helipad from the incoming wind. The wake that is causing acceleration of the flow at the helipad is not created by Belgard Garden phase 1 but it is created by the existing building between Phase 1 and the helipad. Therefore, Belgard Gardens Development Phase 1 has not impact on the Helipad exposure to the prevailing wind conditions. However, the introduction of Phase 2 will require the implementation of mitigation measures on the North-East area, this to avoid the creation of high velocity wake of Phase 2 which can extend up to the helipad area. Mitigations will be implemented as part of the Phase 2 proposal.

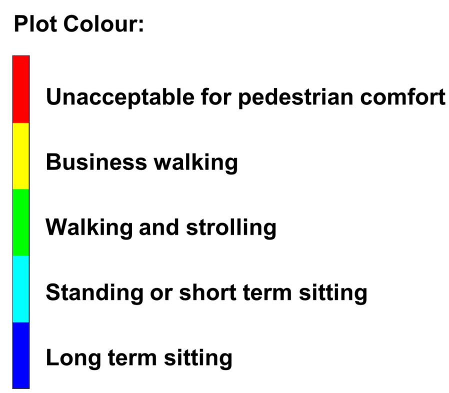


Figure 1.2: Lawson Comfort Categories

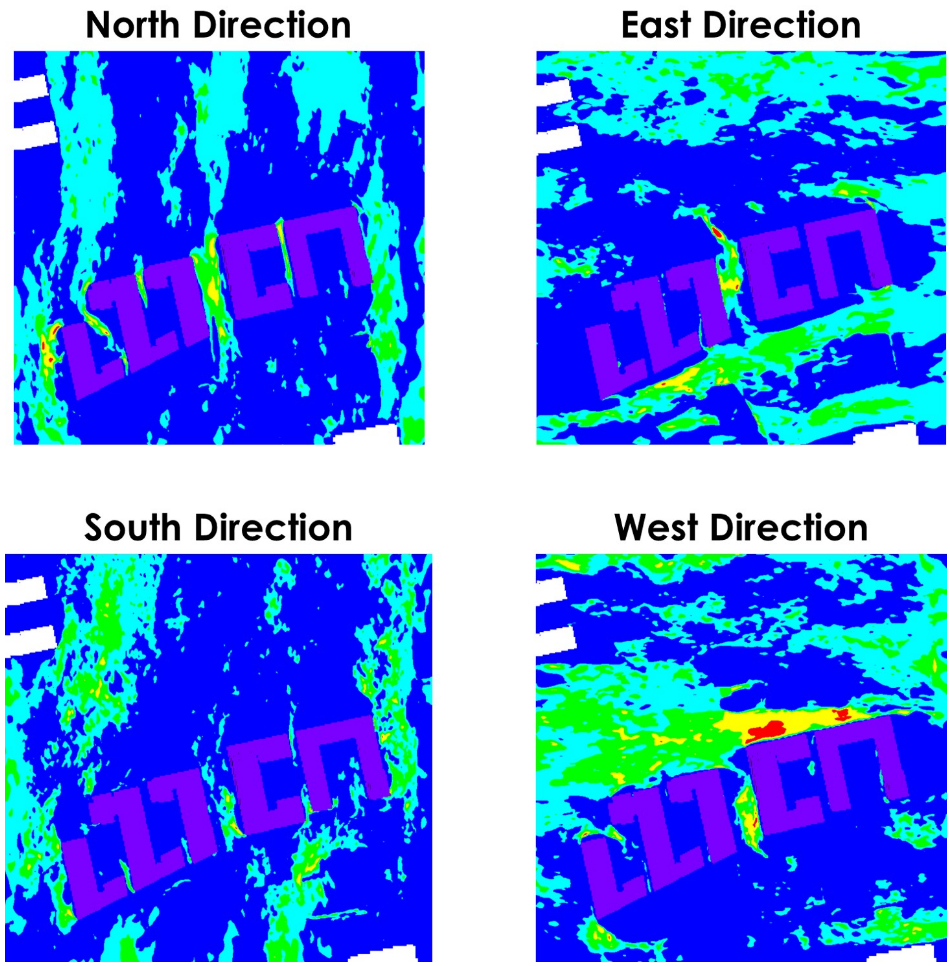


Figure 1.3: Lawson Discomfort Map - Cardinal Directions

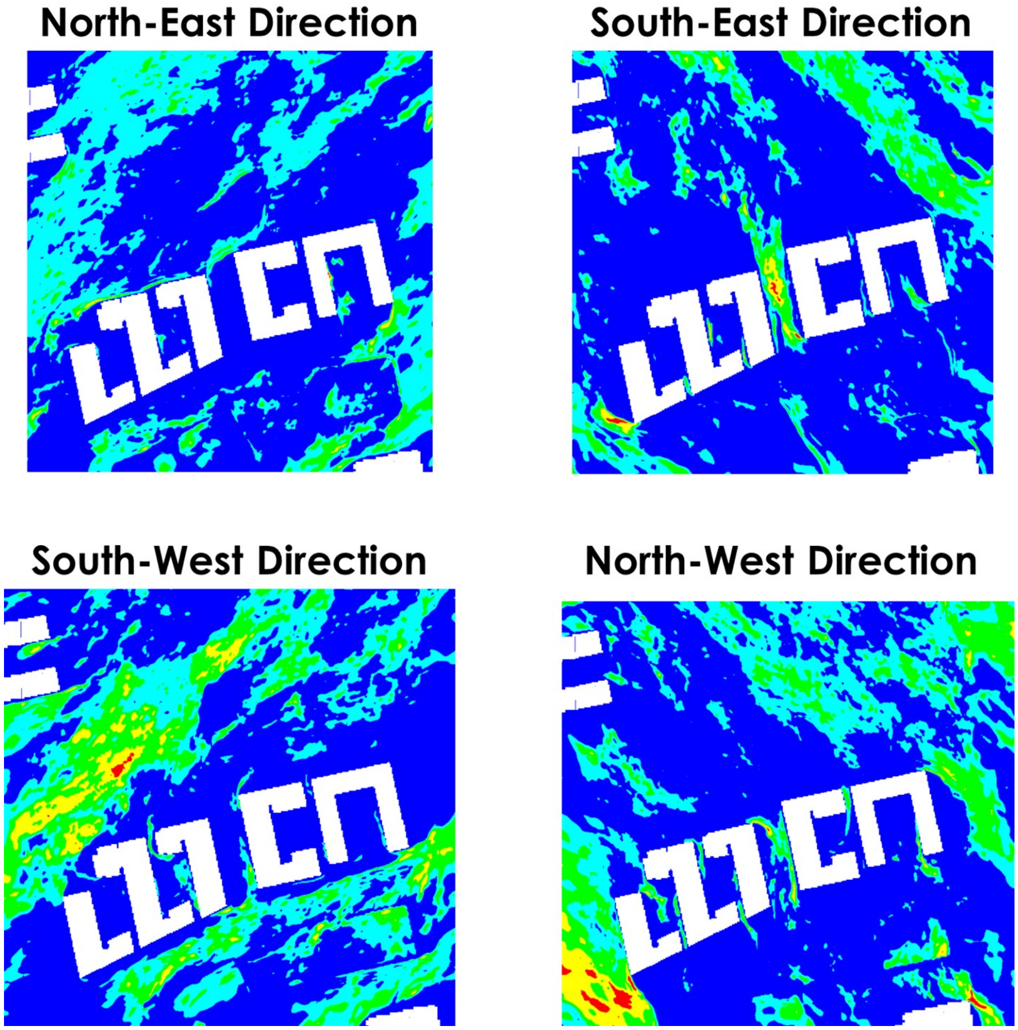


Figure 1.4: Lawson Discomfort Map - Ordinal Directions

Direction	Lawson Criteria	Occurrancy of Criticism	Final Acceptance
N	Always Accepted	–	–
NE	Always Accepted	–	–
E	Critical on some areas	0.7%	Accepted
SE	Critical on some areas	0.8%	Accepted
S	Always Accepted	–	–
SW	Always Accepted	–	–
W	Critical on some areas	3.8%	Accepted
NW	Critical on some areas	1.4%	Accepted

Table 1.3: Summary of Lawson Discomfort Results - Cardinal and Ordinal Directions

2. PROJECT DESCRIPTION

2.1 INTRODUCTION

This technical report presents a wind and microclimate assessment carried out for Belgard Gardens Development, Tallaght, Co. Dublin. The image in Figure 2.1 shows the elevation layout of the development.

Figure 2.1: Elevation View of Belgard Garden Development

The development of the site will comprise the construction of a large mixed residential project of 438 no. apartments, 403 no. bedspaces and ancillary uses in 5 blocks ranging from 4 – 10 storeys in height (Phase 1 – Units 1 to 3) and c. 1000 units in 12 blocks of 4 – 12 storeys in height (Phase 2 - Units 4 to 9).

A wind and microclimate modelling of both Phase 1 on its own and Phase 1 together with Phase 2, 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.

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.

2.2 BUILDING DESCRIPTION

Belgard Gardens Development is a mixed use building containing 438 no. apartments, 403 no. bedspaces and ancillary uses in 5 blocks ranging from 4 – 10 storeys in height (Phase 1 – Units 1 to 3) and c. 1000 units in 12 blocks of 4 – 12 storeys in height (Phase 2 - Units 4 to 9). The image in Figure 2.2 shows the layout of the development.

Figure 2.2: Belgard Gardens Development Layout

2.3 EXTENTS OF ANALYSED AREA

Belgard Gardens Development will be situated in Tallaght, between Belgard Road and Belgared Square North, as shown in Picture 2.3. The modelled area for the wind modelling study comprises a 3km^2 area around the Belgard Gardens Development as represented in Figure 2.4.

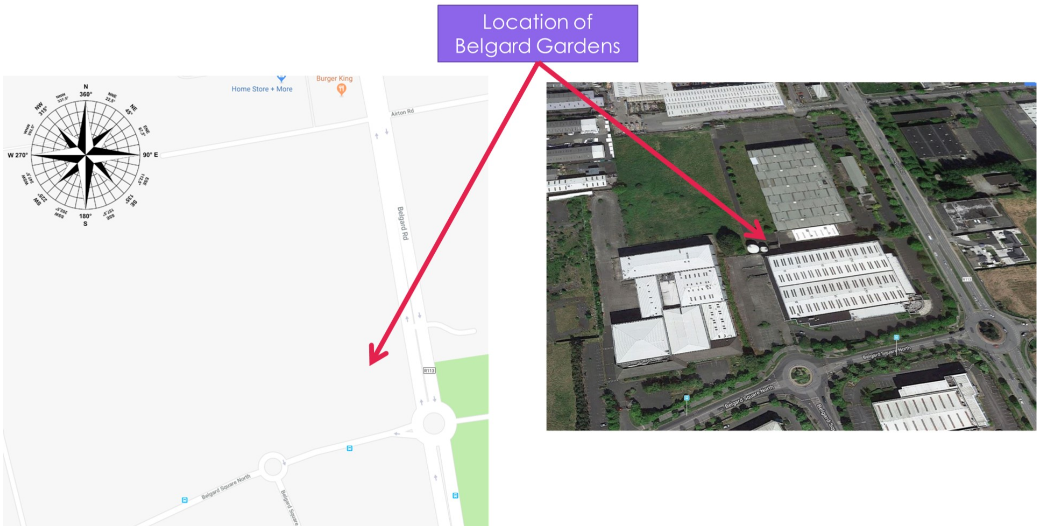


Figure 2.3: Belgard Gardens Actual Site Location

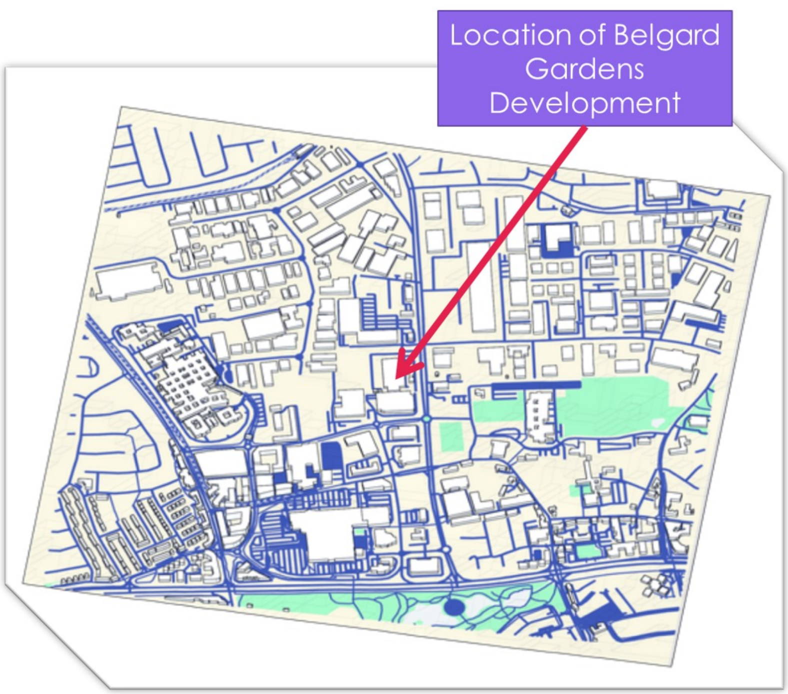


Figure 2.4: Extents of Analysed Area around Belgard Gardens Development

2.4 OBJECTIVE OF THE WIND MODELLING

The CFD wind model is adopted to 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, eight scenarios have been modelled, in order to take into consideration all the different relevant wind directions. Results in this report are presented for the worst case scenarios. In particular, each of the modelled scenarios are presented below:

1. **Scenario 1 - North Wind**
2. **Scenario 2 - North-East Wind**
3. **Scenario 3 - East Wind**
4. **Scenario 4 - South-East Wind**
5. **Scenario 5 - South Wind**
6. **Scenario 6 - South-West Wind**
7. **Scenario 7 - West Wind**
8. **Scenario 8 - North-West Wind**

The details of the design wind adopted are described in the next sections of this report.

2.5 WIND IMPACT ASSESSMENT ON BUILDINGS

2.5.1 PLANETARY BOUNDARY LAYER AND TERRAIN ROUGHNESS

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

Wind speed increases with increasing height above the ground, starting from zero, due to the no-slip condition. In particular, the wind velocity profile is parabolic. Flow near the surface encounters obstacles that reduce the wind speed, and introduce random vertical and horizontal velocity components. This turbulence causes vertical mixing between the air moving horizontally at one level, and the air at those levels immediately above and below it. For this reason, the velocity profile is given by a fluctuating velocity along a mean velocity value. Figure 2.5 shows the wind velocity profile, as described above.

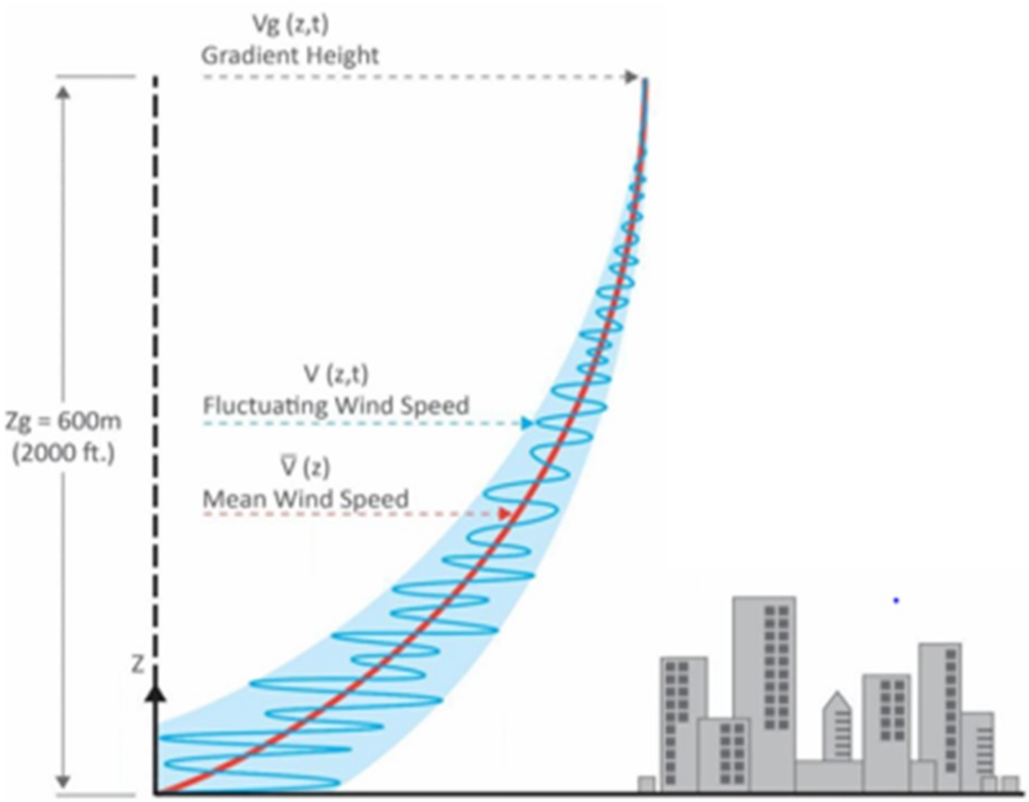


Figure 2.5: Wind Velocity Profile

Two effects influence the shape of the wind speed profile:

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

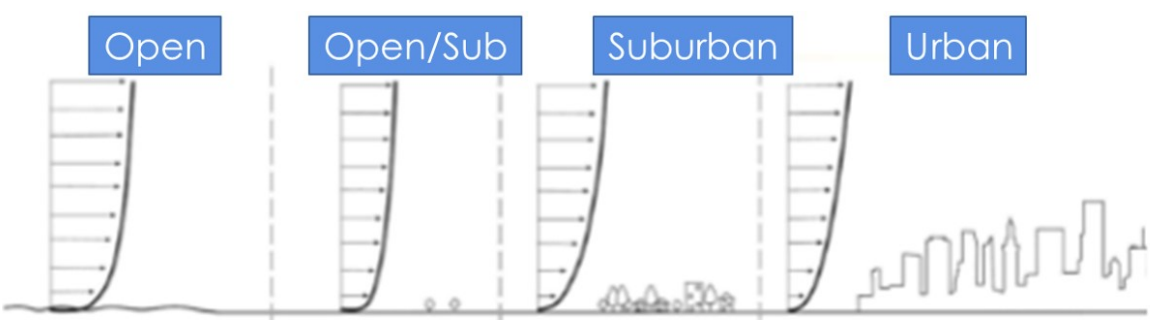


Figure 2.6: Wind Velocity Profile for different terrains

In order to assess the wind conditions in a particular area, it is important to know (Figure 2.7):

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

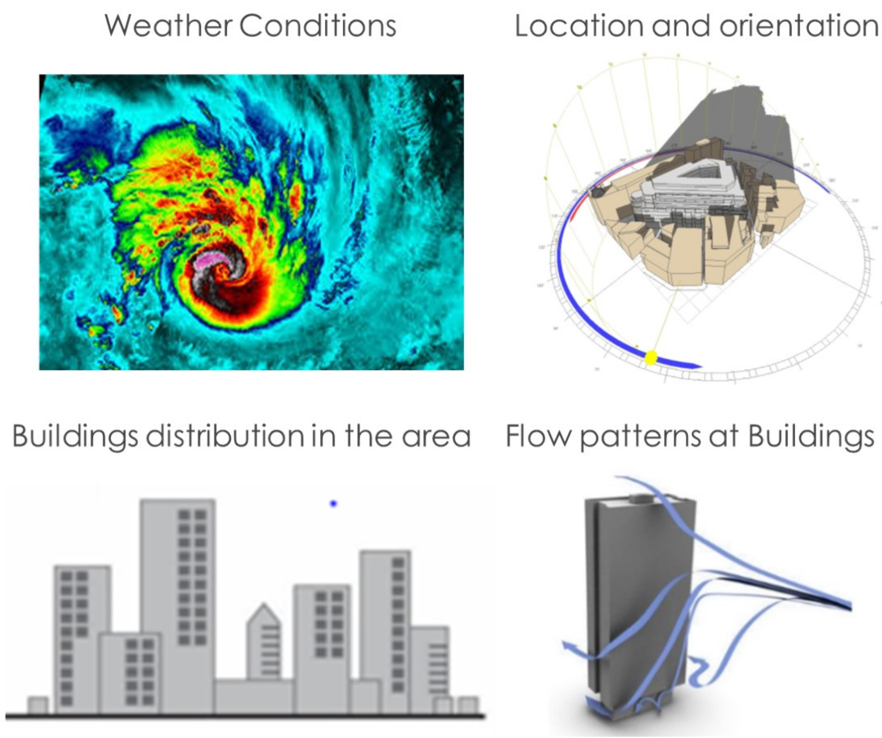


Figure 2.7: Parameters to know for Wind Conditions Assessment

Moreover, it is important to understand key flow features (Figure 2.8):

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

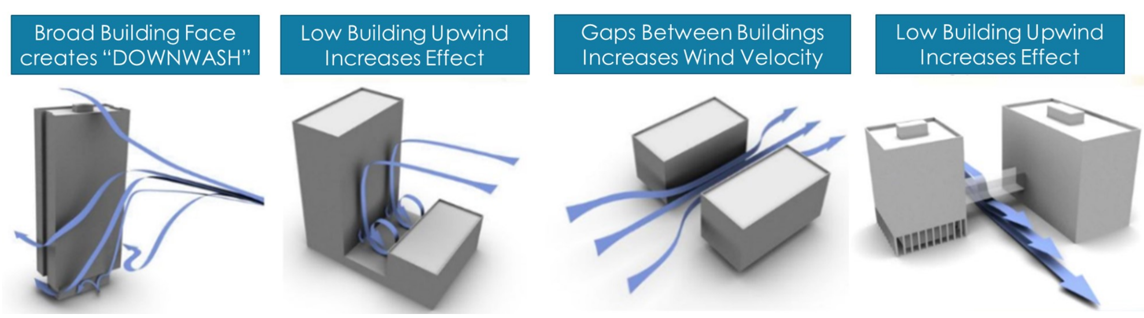


Figure 2.8: Parameters to know for Wind Conditions Assessment

2.6 ACCEPTANCE CRITERIA

2.6.1 PEDESTRIAN COMFORT AND LAWSON CRITERIA

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

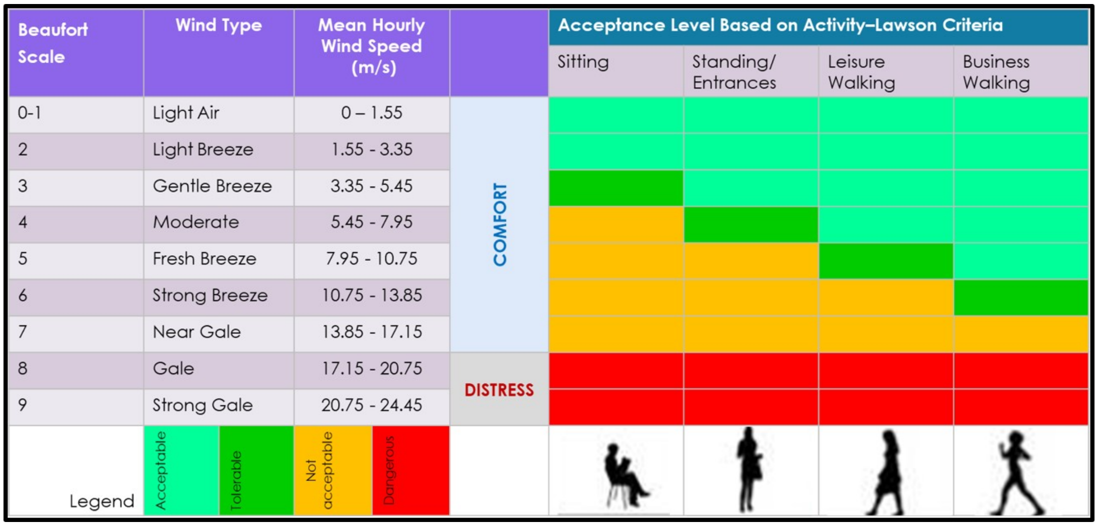
Only gust winds are considered in the safety criterion. These are usually rare events, but deserve special attention in city planning and building design due to their potential impact on pedestrian safety. Gusts cause the majority of cases of annoyance and distress and are assessed in addition to average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

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

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

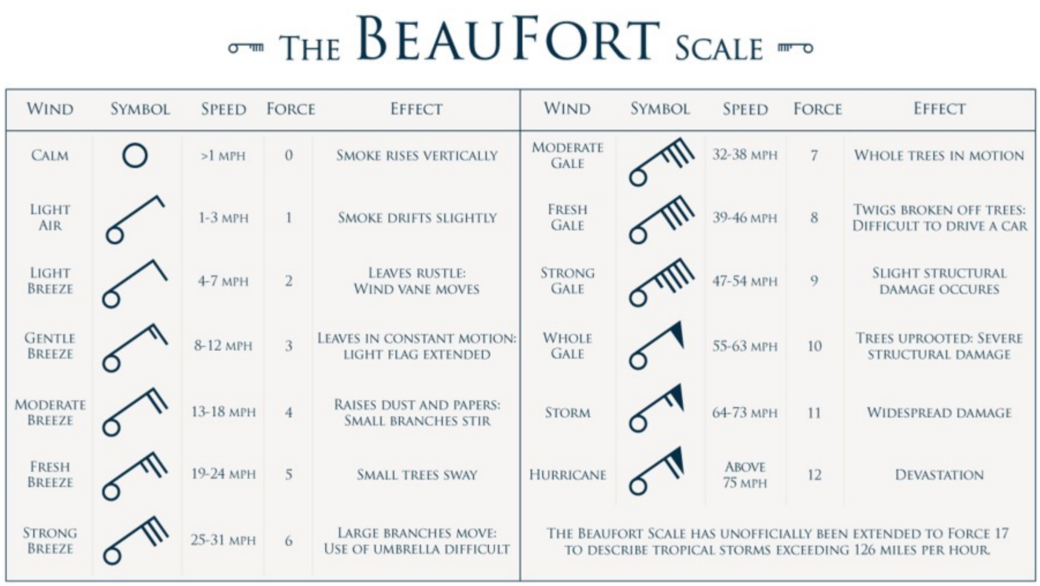
- DISTRESS CRITERIA: Relates to the physical well-being of the individual.
  Onset of distress:
  - ‘Frail Person Or Cyclist’: equivalent to an hourly mean speed of 15 m/s and a gust speed of 28 m/s (62 mph) to be exceeded less often than once a year. This is intended to identify wind conditions which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

The above criteria set out six pedestrian activities and reflect the fact that calm activity requires calm wind conditions, which are summarised by the Lawson scale, shown in Figure 2.9. Lawson scale assesses pedestrian wind comfort in absolute terms and defines the reaction of an average person to the wind. Each wind type is associated to a number, corresponding to the Beaufort scale, which is represented in Figure 2.10. 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 2.9: Lawson Scale



THE BEAUFORT SCALE

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

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

Figure 2.10: BeaufortScale

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

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

A breach of the distress criteria requires a consideration of:

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

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

2.7 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 2.11 and 2.12):

- **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.

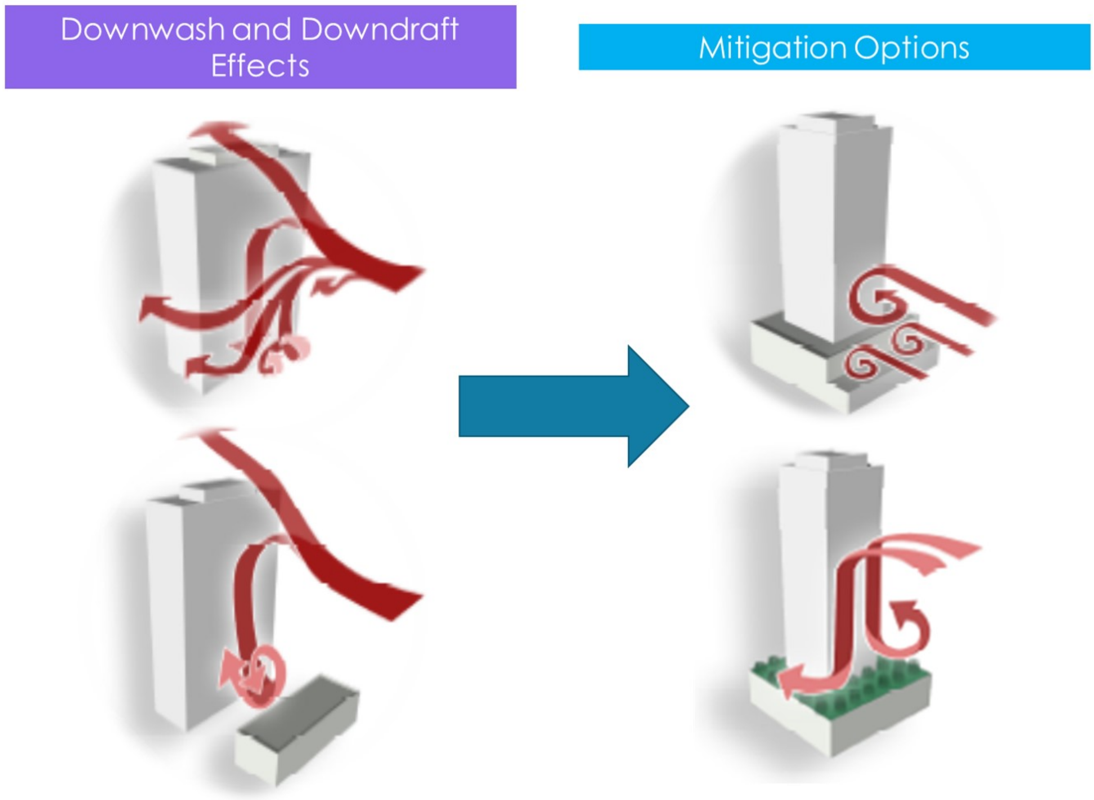


Figure 2.11: Mitigation Measures for Downwash and Downdraft Effects

- **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.

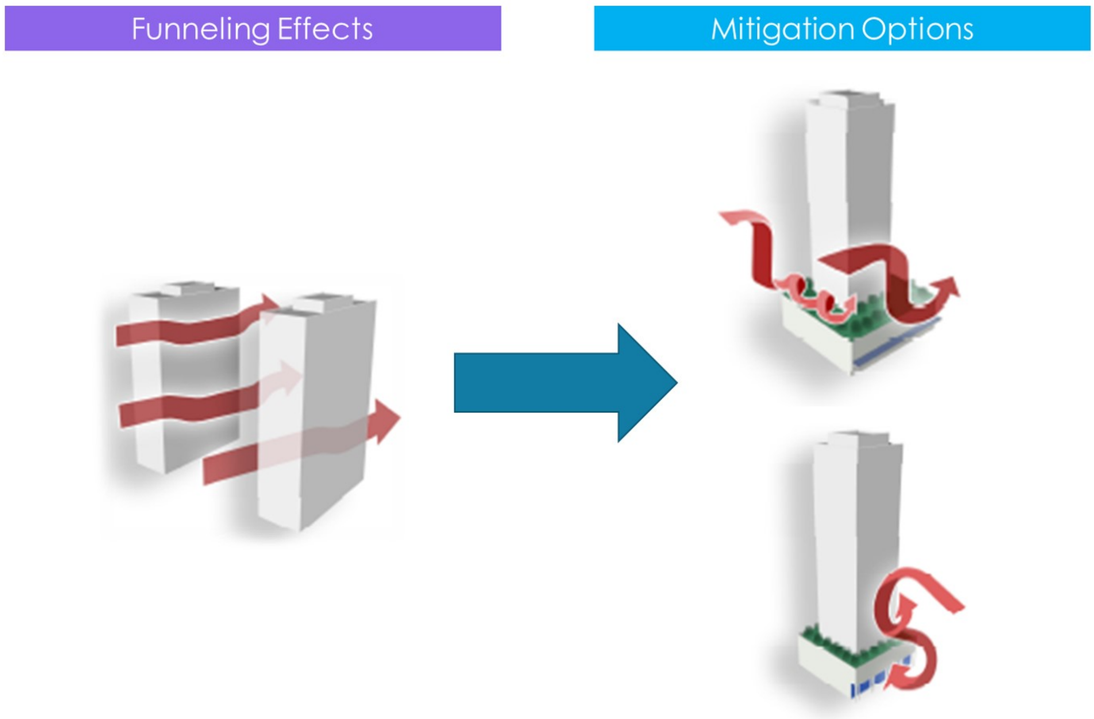
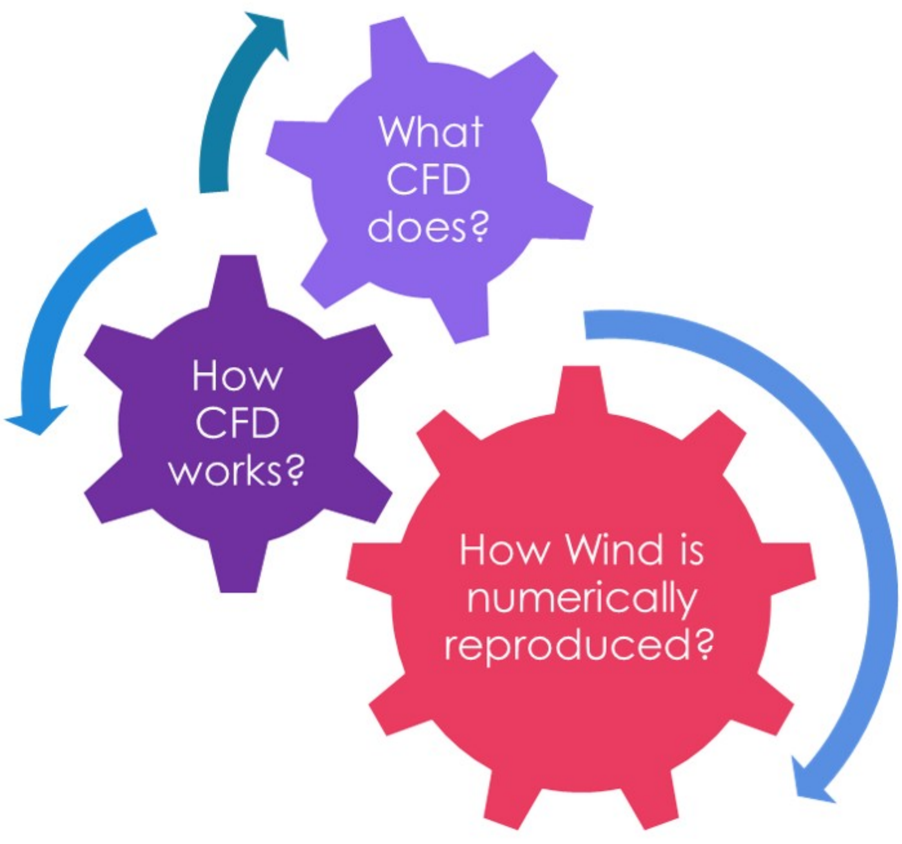


Figure 2.12: Mitigation Measures for Funnelling Effects

3. CFD MODELLING METHOD



3.1 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 3.1. The Navier-Stokes equations, used within CFD analysis, are based entirely on the application of fundamental laws of physics and therefore produce extremely accurate results providing that the scenario modelled is a good representation of reality.

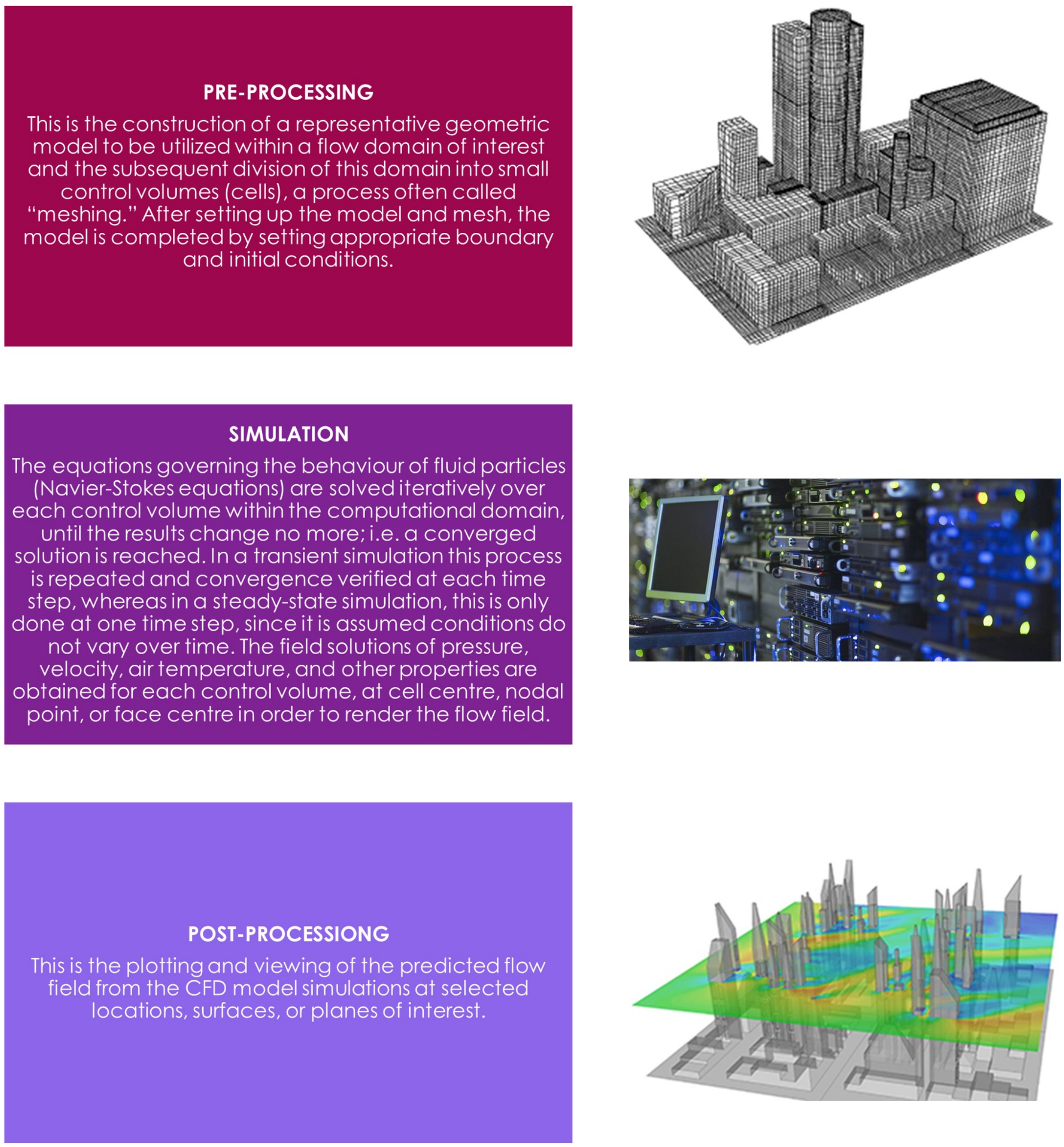


Figure 3.1: CFD Modelling Process Explanation

3.2 OpenFoam SOFTWARE DETAILS

This report employs OpenFoam Code, based on the concept of Large Eddy Simulation (LES) and the post-processing visualisation tool Paraview version 5.5 to investigate fire spread and smoke movement. 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.

3.2.1 NUMERICAL SOLVER

OpenFoam has a selection of solvers available from which the LES model has been selected for this simulation. LES directly solves the mass and momentum equations for the large eddies that comprise most of the fluid's energy. By solving the large eddies directly no error is introduced into the calculation.

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

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

3.3 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 3.1.

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

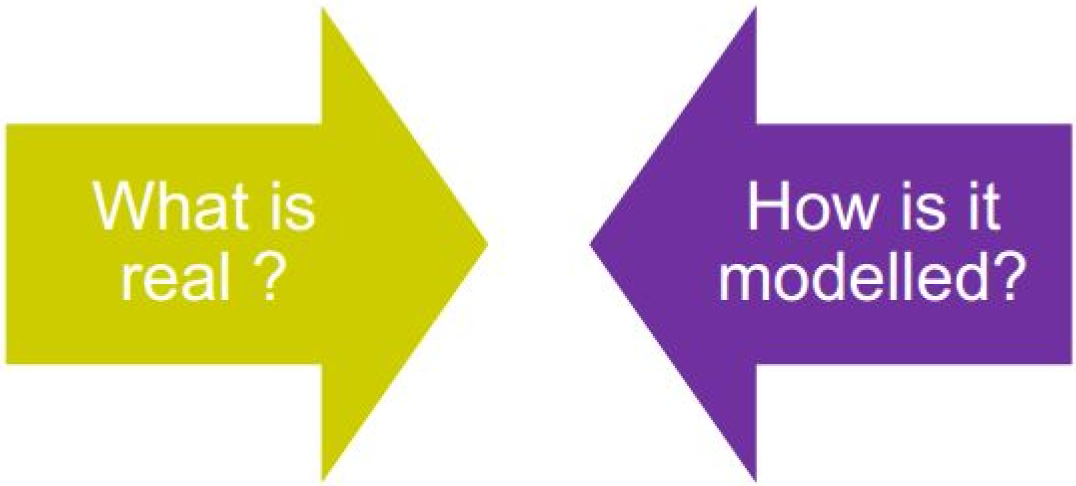
PARAMETERS TO CALCULATE COMPUTATIONAL MESH	
Air Density ρ	$1.2kg/m^3$
Ambient Temperature (T)	$288K(approx.15C^\circ)$
Gravity Acceleration (g)	$9.8m/s^2$
dx	0.1m at the development 0.2m elsewhere
Mesh cells size	0.1 m (ratio 1:1)
Total mesh size	Approx. cells number = approx. 20 million

Table 3.1: Paramenters To Calculate Computational Mesh

3.4 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”.

4. BELGARD GARDENS MODEL DESIGN



4.1 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 the Client and are referenced in Table 4.1.

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.

REFERENCE DRAWINGS	
Drawing Ref. Code	Provided by
Dwg. 18076-3DDB-00-00-M3-Z-0001-03	Atlas GP Ltd.
Dwg. 1722-OMP-M3-Massing (Recesses Pop outs) Phase 01 02 9052018	
Dwg. Model Phase 1 Tree Planting 17.10.18	
Dwg. Model Phase 1 Tree Planting 17.10.18 2017 Version	

Table 4.1: List of Reference Drawings Used For CFD Wind Modelling

4.2 MODELLED GEOMETRY

The model consists of the Belgard Gardens Development which includes Phase 1 and Phase 2. The building consists of a large mixed residential development of 500 units in 5 blocks ranging from 4 – 10 storeys in height (Phase 1 – Units 1 to 3) and c. 1000 units in 12 blocks of 4 – 12 storeys in height (Phase 2 - Units 4 to 9), as shown in Figure 4.1.

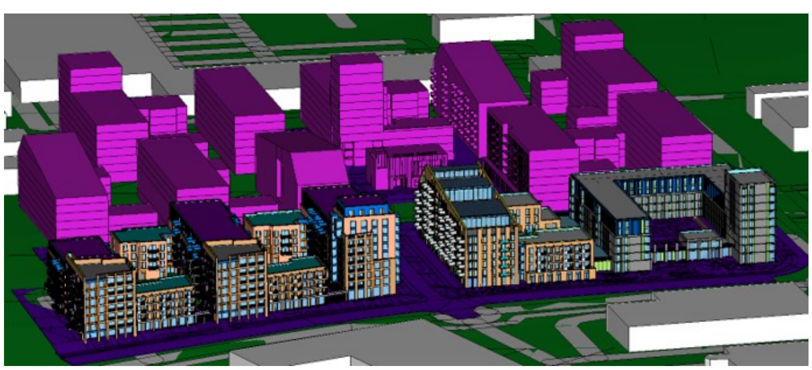


Figure 4.1: Belgard Gardens Development

The overall Belgard Gardens Development dimensions are approximately 275*m* (Width), 335*m* (Length) and the maximum height of the highest roof pitch above the commercial area is approx 50*m*. 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 3km^2 around the Belgard Gardens Development as represented in Figure 4.2. The model layout, dimensions and orientation are outlined in the table below (Table 4.2) and shown in details in the figures that follows (Figure 4.3 and Figure 4.4).

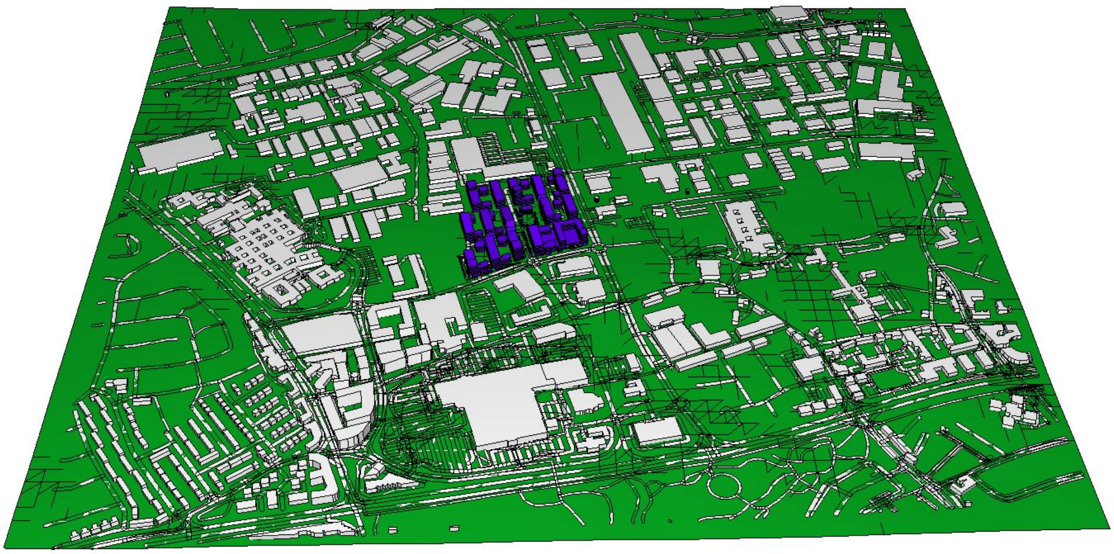


Figure 4.2: Extents of Modelled Area around Belgard Gardens Development

	MODELLED GEOMETRY DIMENSIONS		
	Width	Length	Height
Building	275m approx	335m approx	50m approx
CFD Mesh Domain	1000m approx	1000m approx	100m approx

Table 4.2: Modelled Geometry Dimensions

Figure 4.3: Belgard Gardens Model Generic View

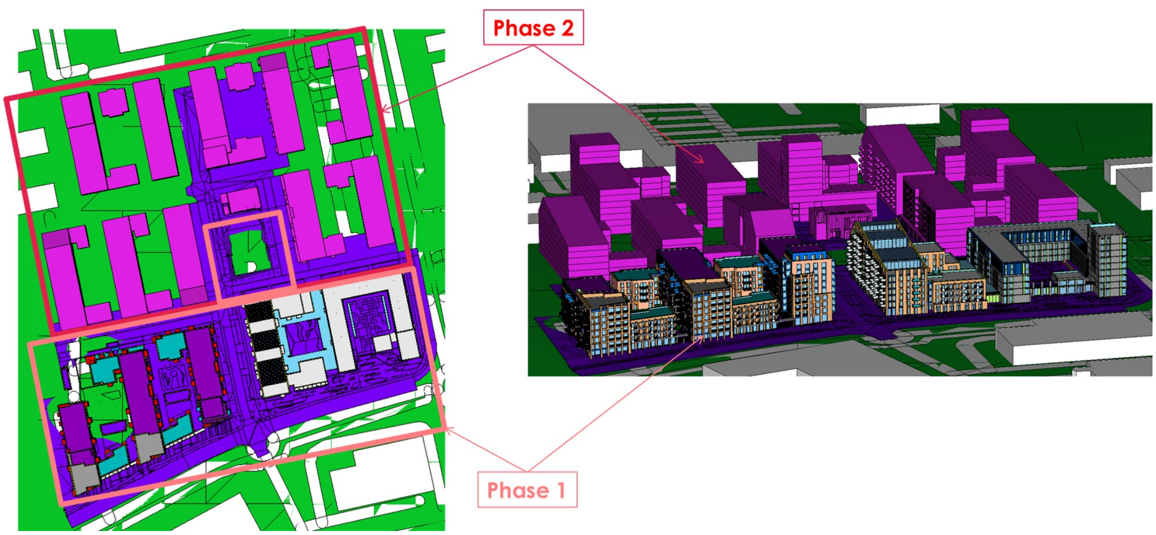


Figure 4.4: Belgard Gardens Model Top View, highlighting Phase 1 and Phase 2

4.2.1 MODELLING OF MITIGATION MEASURES

The mitigation measure that has been used for this project is landscaping using trees, which creating a vorticity, makes it possible to reduce the velocities, thus the wind impact on the building. Smalls particles randomly distributed within an area are normally used in numerical modelling to model trees, as shown in Figure 4.5. These introduce a pressure drop in the model and therefore causes the wind to reduce its speed when passing through the trees, as expected in reality. The CFD plot shown in Figure 4.6 demonstrate this effect.

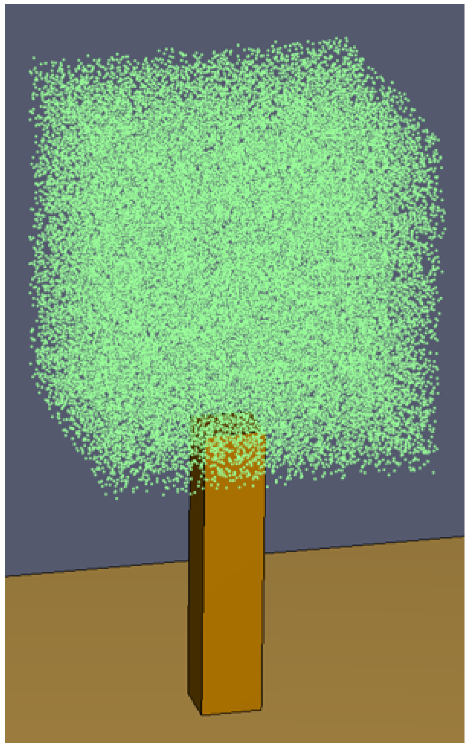


Figure 4.5: Model of a tree in FDS

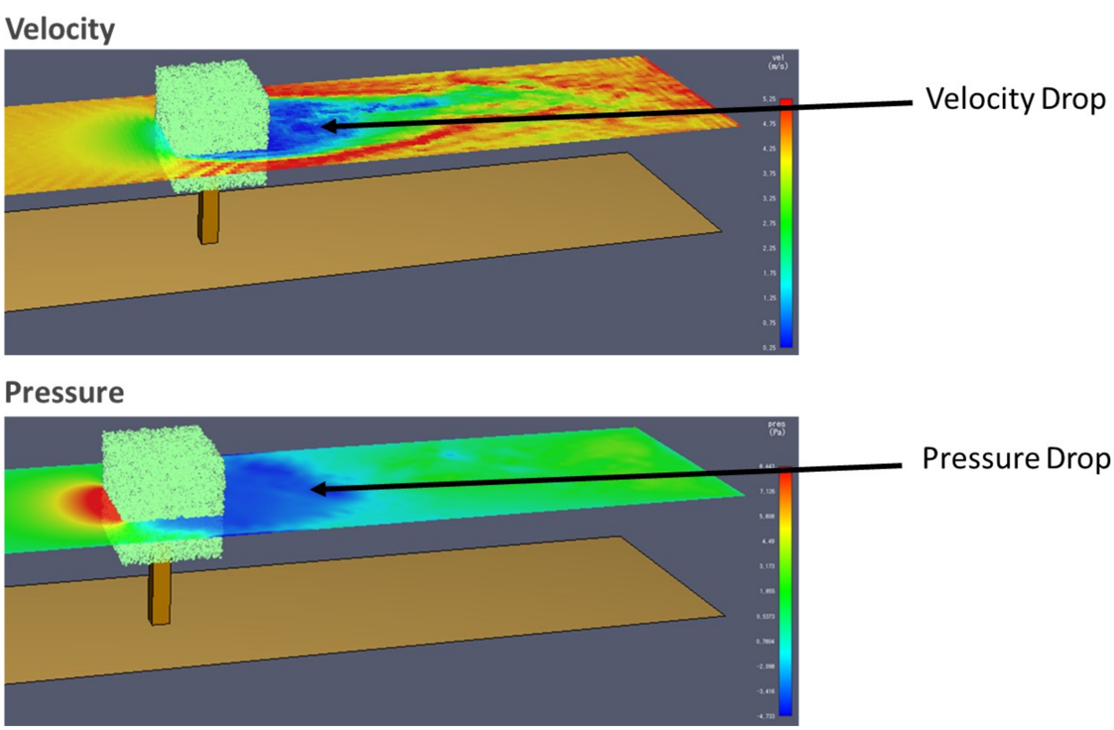
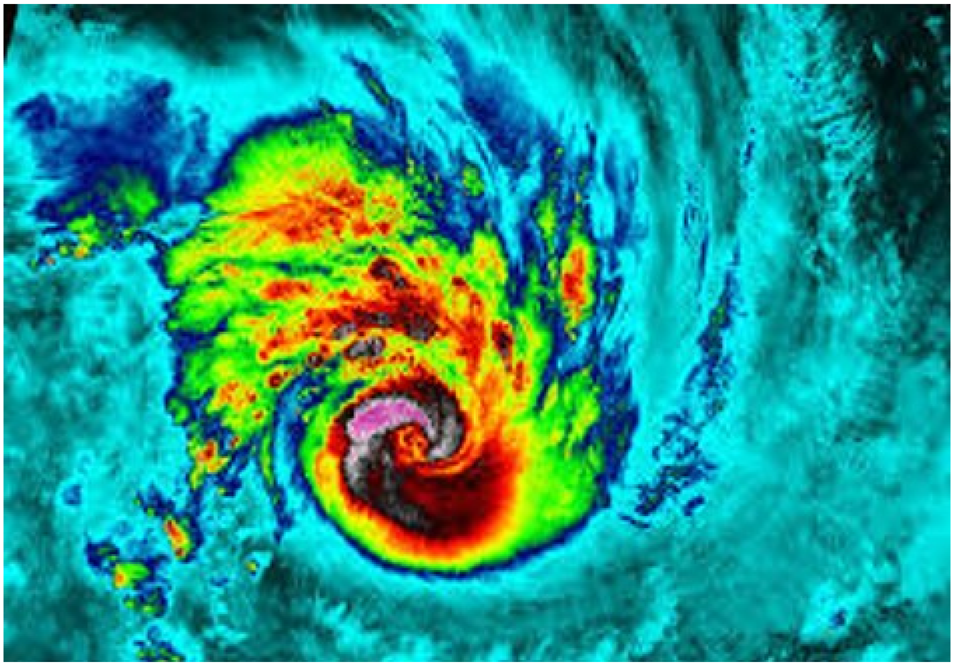


Figure 4.6: Generic Result of Wind Impacting on a Tree

5. PART 1 - WIND DESKTOP STUDY



5.1 WIND FLOW 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 5.1 shows on the map the position of Belgard Gardens Development and the position of Dublin Airport.

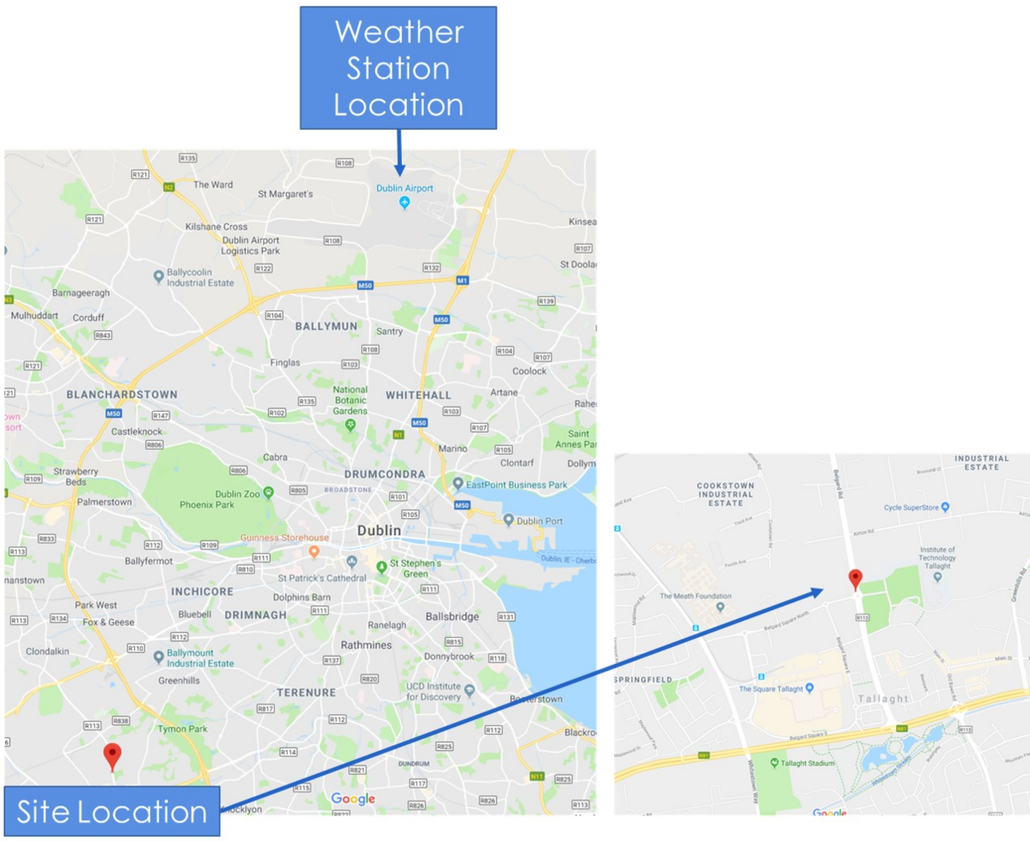


Figure 5.1: Map shwoing the position of Belgard Gardens Development and Dublin Airport

5.2 LOCAL, MAXIMUM AND MEAN WIND CONDITIONS

5.2.1 LOCAL WIND CONDITIONS

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

- The meteorological data associated with the maximum daily wind speeds recorded over a 30 year period between 1985 and 2015 and,
- The mean hourly wind speeds recorded over a 10 year period between 2005 and 2015. The data is recorded at a weather station at the airport, which is located 10m above ground or 71mOD.

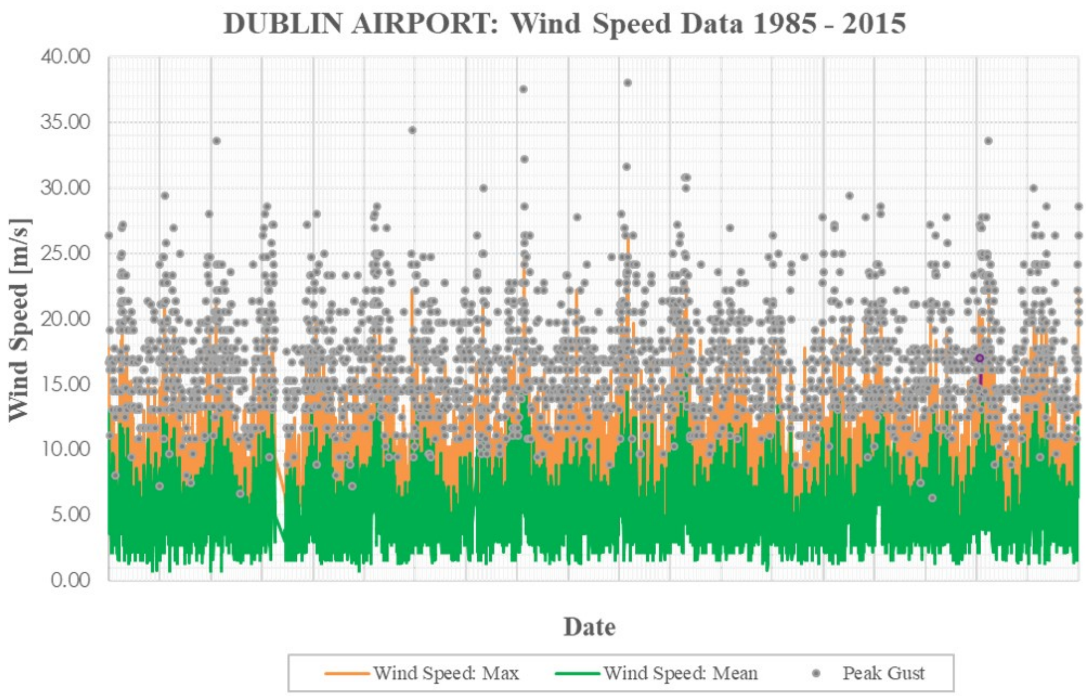


Figure 5.2: Local Wind Conditions

5.2.2 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 Southwest.

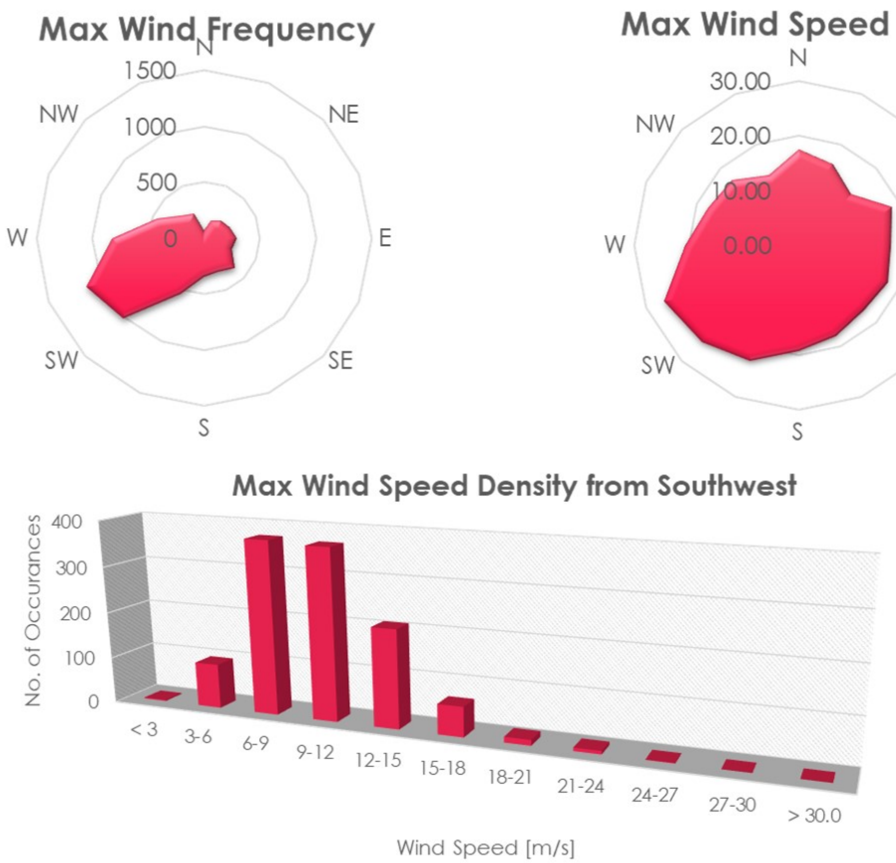


Figure 5.3: Maximum Wind Conditions

5.2.3 MEAN 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 Southwest.

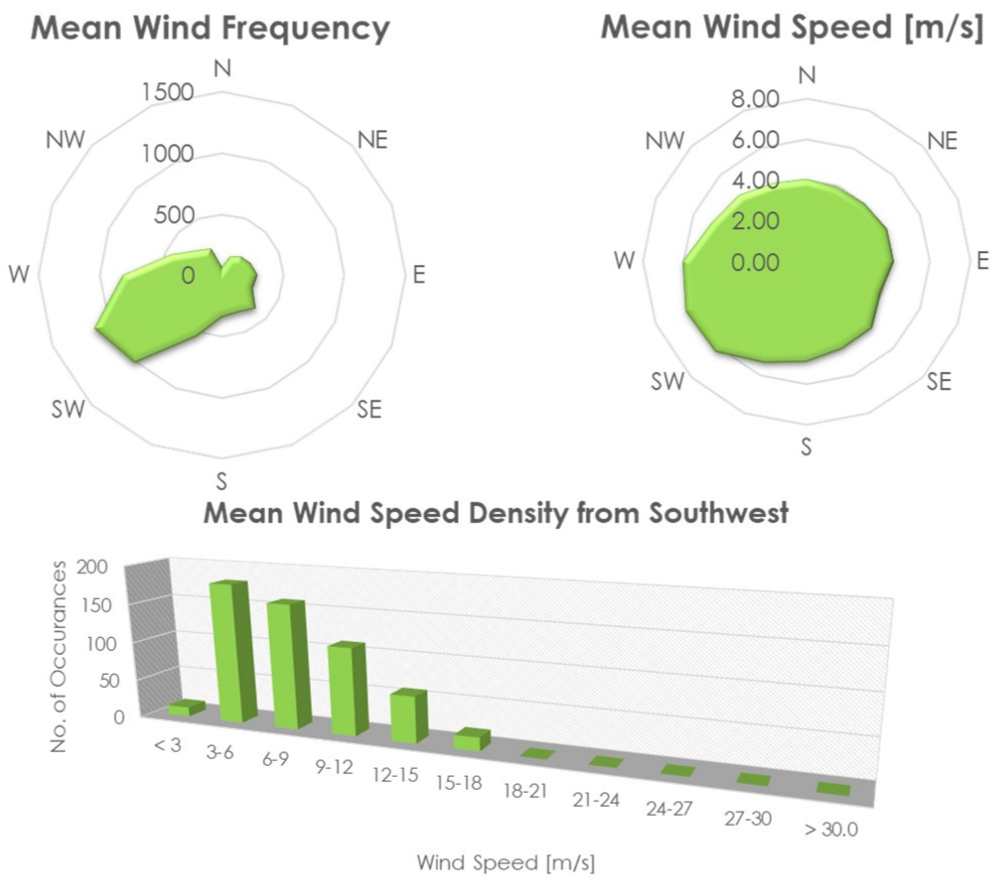


Figure 5.4: Mean Wind Conditions

5.3 LOGARITHMIC WIND PROFILE

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

$$v_2 = v_1 \cdot \frac{ln\frac{h_2}{z_0}}{ln\frac{h_1}{z_0}} \tag{5.1}$$

where:

- v_1 = wind speed measured at the reference height h_1
- h_1 = reference height to measure v_1
- h_2 = height of the wind speed v_2 calculated for the wind profile
- z_0 = 0.4 [m] roughness length selected (see table in Figure 5.5 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 5.5: 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 5.6.

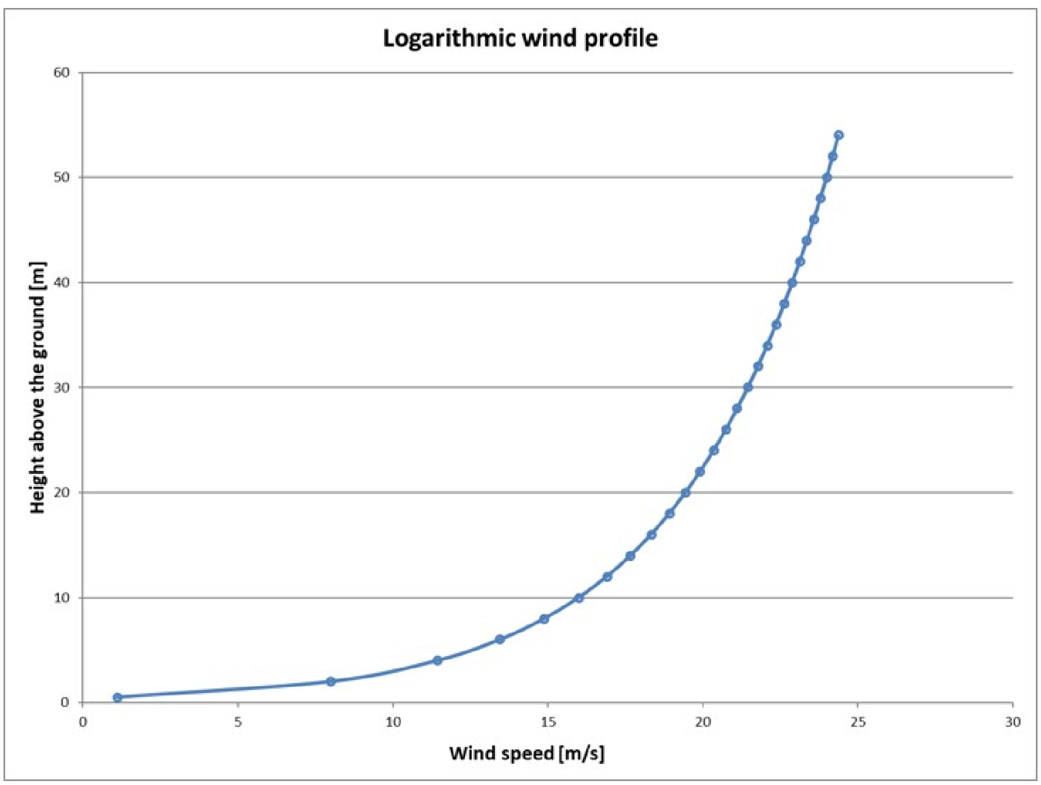
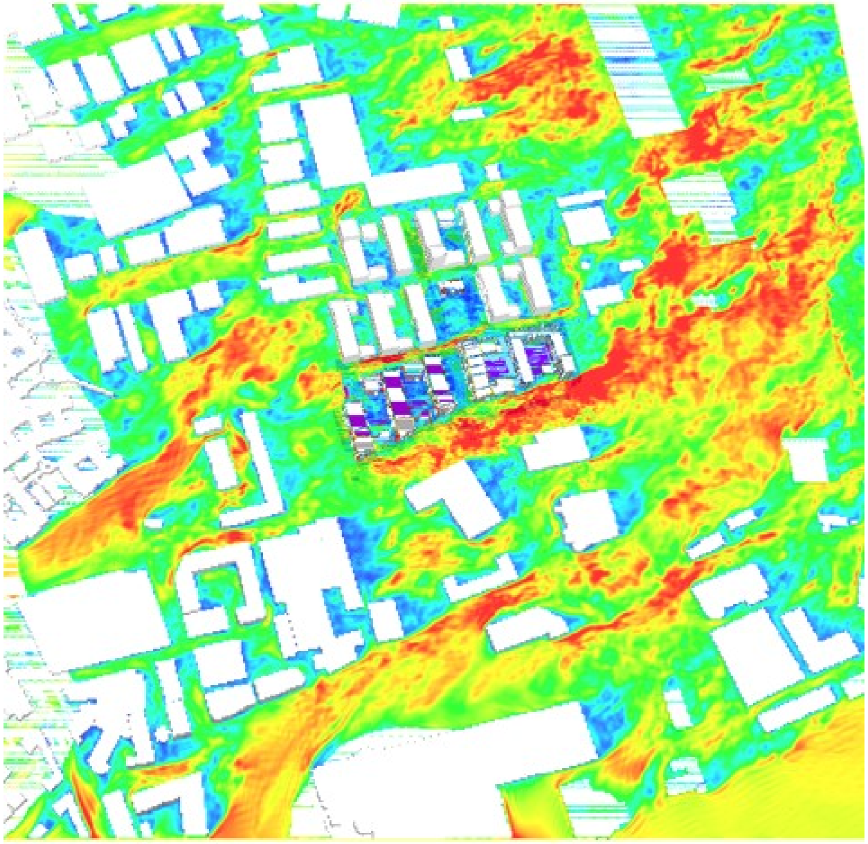


Figure 5.6: Wind profile used in the model

6. PART 2 - ANALYSIS OF CFD RESULTS



6.1 CFD RESULTS

Before presenting an analysis of the CFD results, a summary of CFD model input data used in this project is given in the table shown in Figure 6.1.

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

Figure 6.1: Summary of CFD Model Input Data

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

The 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 in the form of vertical and horizontal slices through Belgard Gardens development. Slices of the following parameters are collected throughout the simulation time and shown for different times:

- Flow Velocity
- Pressure

Figure 6.2 shows an example of the location of a slice in the Z direction, at 1.5m above the ground.

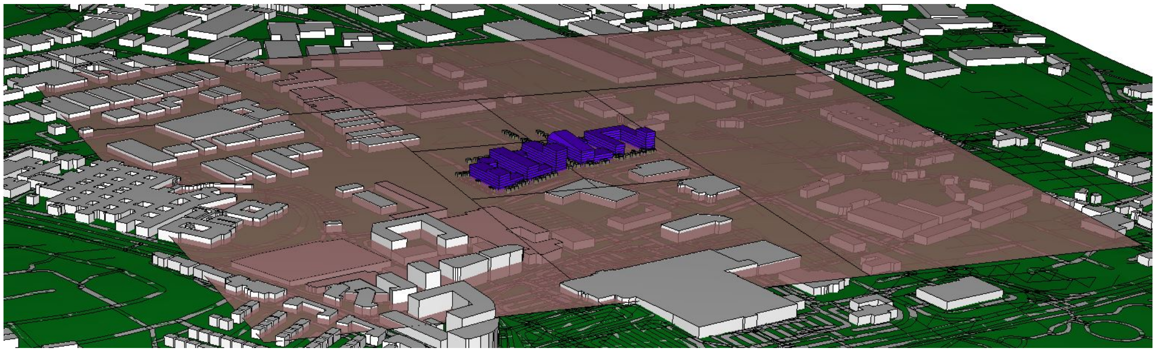


Figure 6.2: Results slice collected at Z=1.5m above the ground

Red colors indicate critical values while blue colors indicate tenable conditions.

In particular, for the CFD Analysis carried out, two major cases have been modelled, as illustrated in Table 6.1.

PART 2 ASSESSMENT CASES	
CASE 1	PHASE 1 MICROCLIMATE ASSESSMENT
CASE 2	PHASE 1 AND PHASE 2 CUMULATIVE MICROCLIMATE ASSESSMENT

Table 6.1: Belgard Gardens Analysed Cases

Section 6.2 presents a detailed assessment of Case 1, Phase 1 Microclimate Assessment.

Section 6.3 shows results of Case 2, Phase 1 and Phase 2 Cumulative Microclimate assessment.

Finally, Section 6.4 shows the impact of Belgard Gardens Development on Tallaght Hospital Ground-Based helicopter pad.

6.2 CASE 1 - PHASE 1 MICROCLIMATE ASSESSMENT

This section aims to predict the wind patterns around the proposed Phase 1 of Belgard Gardens Development, under mean and peaks wind conditions typically occurring in the area, in order to assess the impact of the proposed mitigation measures. A view of the model for Phase 1 only is presented in Figure 6.21.

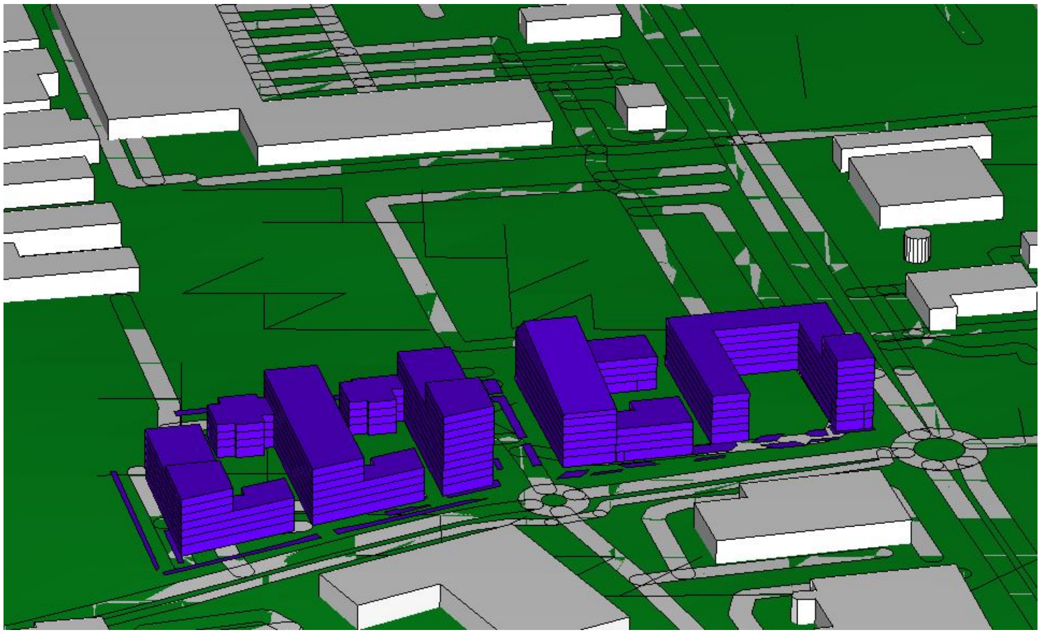


Figure 6.3: Belgard Gardens Phase 1 Model

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 pedestrian comfort assessment, performed on Phase 1 accordingly to the Lawson criteria, identified the areas that are suitable for the different pedestrian activities in order to guarantee pedestrian comfort. Moreover, in terms of distress, some critical conditions were found for “Frail persons or cyclists” in the surrounding of the development only in the west direction. However, the frequency at which these conditions happen are below the critical threshold for distress.

- The mitigation implemented achieves good shielding on all critical roads. High velocity areas are limited to the part of the roads where the cars pass. Footpaths and cycling paths are clearly successfully shielded by vegetation.

- Shielding conditions in the square are pretty good. However, an increase of trees or an increase in the height of them could further improve square conditions, especially for some wind directions. However, the introduction of Phase 2 would shield the square completely.

- In few areas, the mitigation can be implemented adding some trees or incrementing trees height.

- The pedestrian comfort assessment, performed on Phase 1 accordingly to the Lawson criteria, identified the areas that are suitable for the different pedestrian activities activities in order to garantee pedestian comfort. Moreover, in terms of distress, some critical conditions were found for “Frail persons or cyclists” in the surrounding of the development only in the west direction. However, the frequency at which these conditions happen are below the critical threshold for distress.

6.2.1 Flow Velocity Results - Before Landscaping

Results of velocity at slice location of 1.5m above the ground are presented in Figures 6.4 and 6.5 for Cardinal and Ordinal Directions respectively, for wind assessment of Phase 1 of Belgard Gardens Development. The potential high velocity critical area are circled in purple.

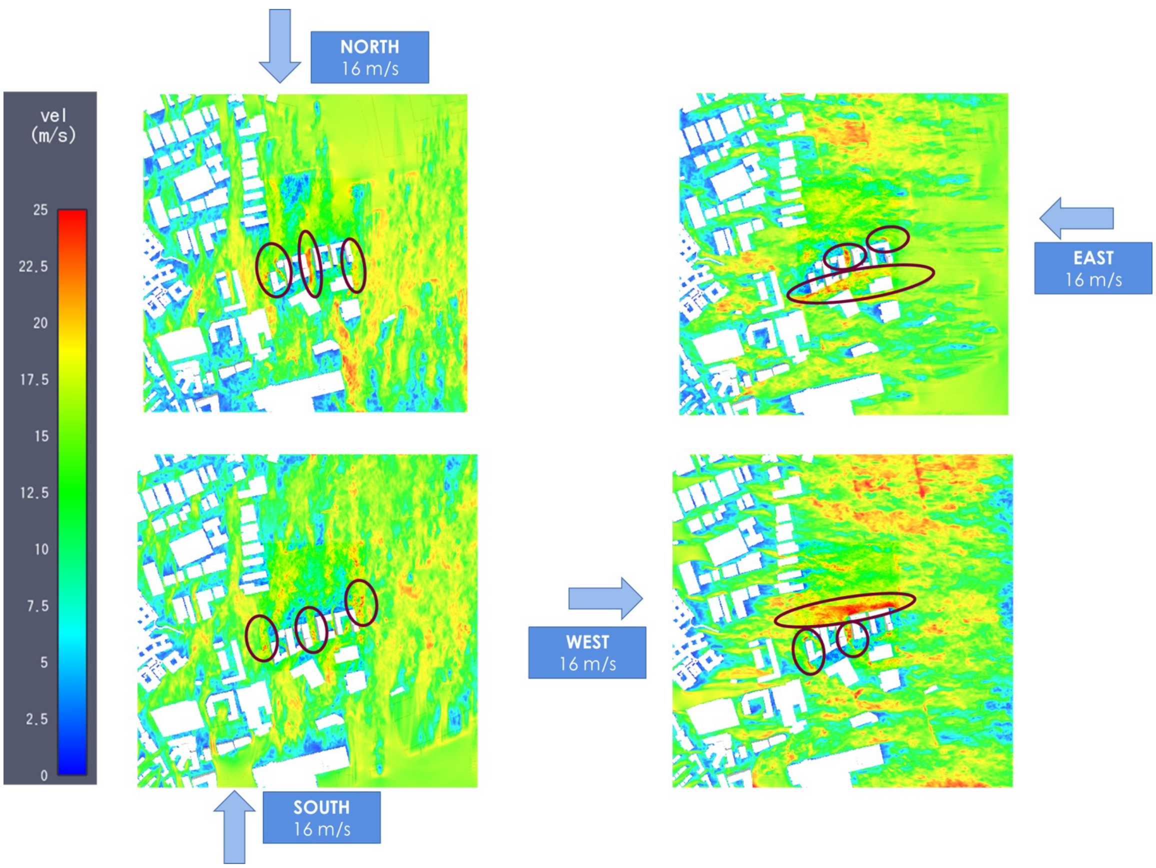


Figure 6.4: Flow Velocity Results at Z=1.5m above the ground, before landscaping - Cardinal Directions - Phase 1

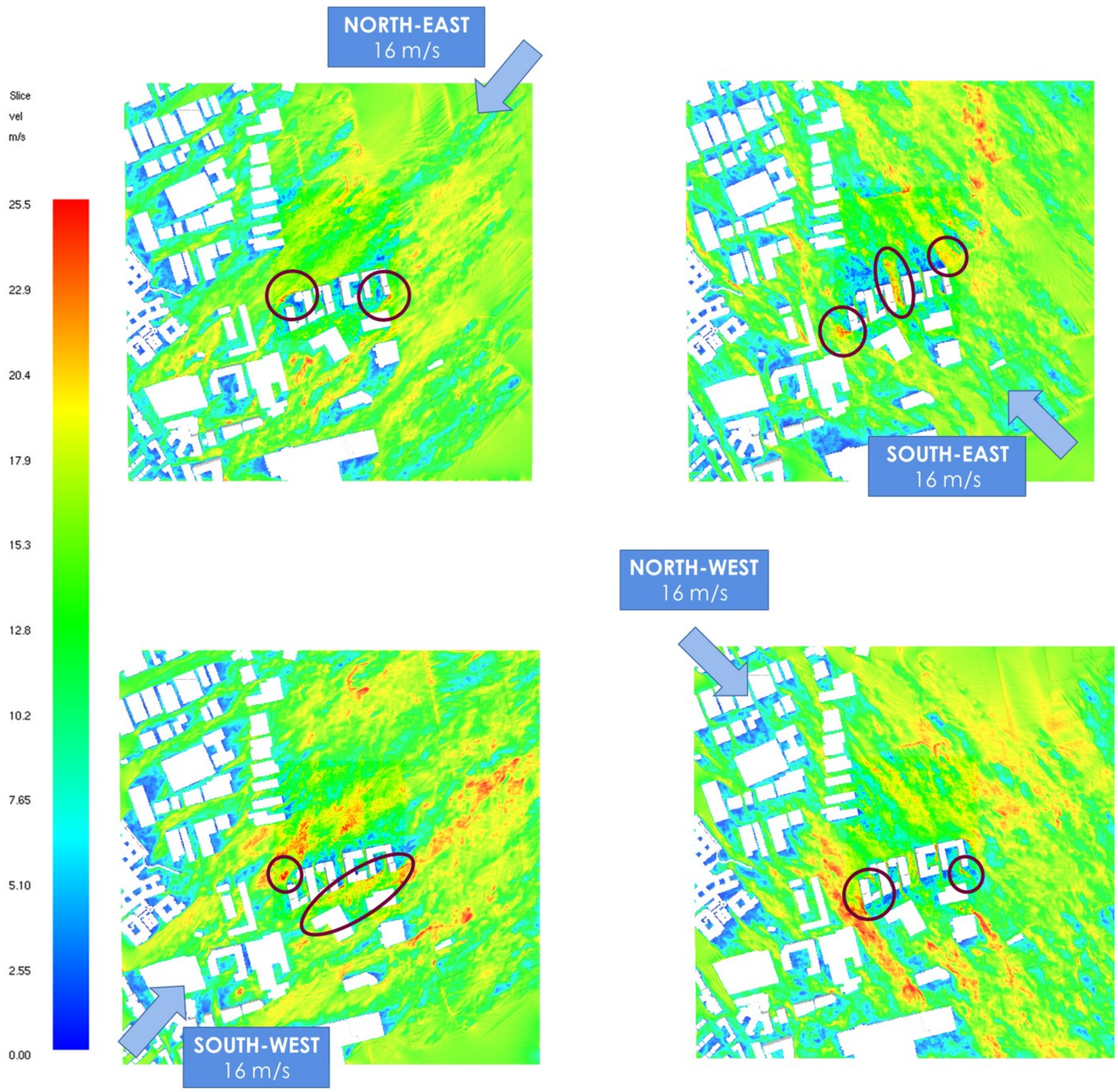


Figure 6.5: Flow Velocity Results at Z=1.5m above the ground, before landscaping - Ordinal Directions - Phase 1

6.2.2 Proposed Mitigation Measures

Landscaping with trees is suggested all around the development, in order to mitigate the impact of the wind around the buildings and protect the footpaths and the cycle paths, as well as the square and areas where is is possible to sit. In this way it is possible to target all the above critical high velocity areas. Figure 6.6 shows a drawing of the model with mitigation measures implemented, while Figure 6.3 shows the corresponding CFD model.

Figure 6.6: Belgard Gardens Phase 1 with Mitigation Measures

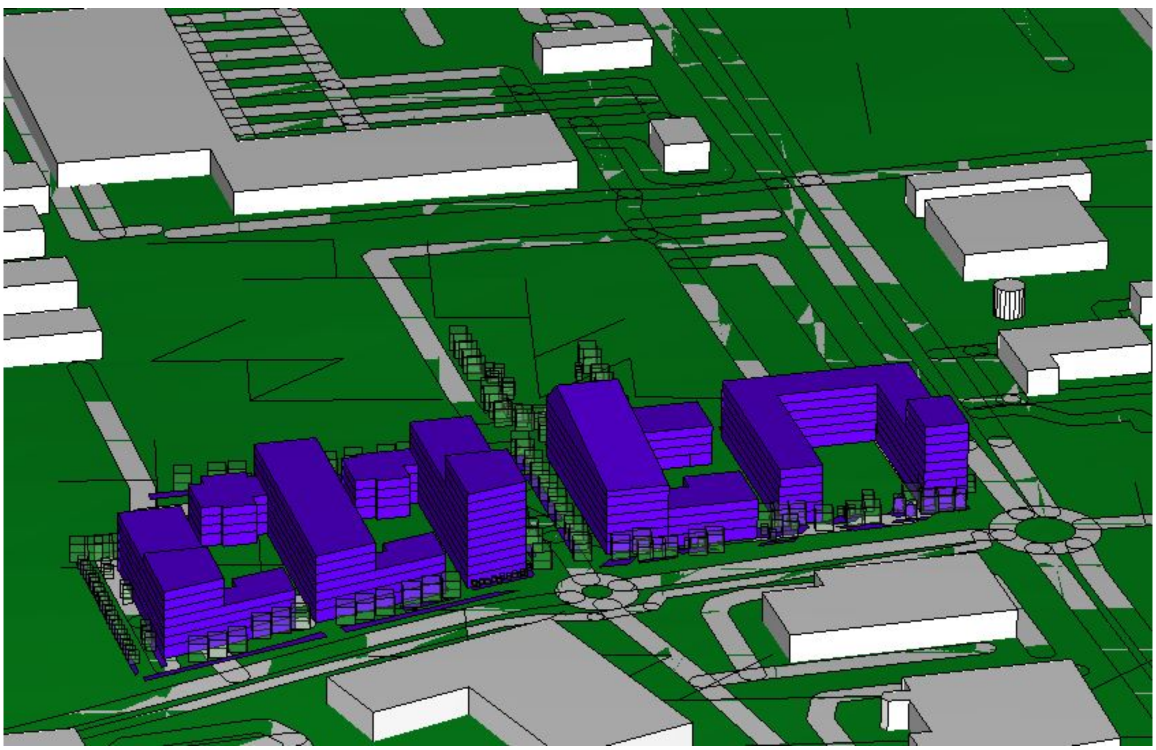


Figure 6.7: Belgard Gardens Phase 1 Model with Mitigation Measures

6.2.3 Flow Velocity Results - Effect of Landscaping

Results of velocity at slice location of 1.5m above the ground are presented in Figures 6.8 and 6.9 for Cardinal and Ordinal Directions respectively, for wind assessment of Phase 1 of Belgard Gardens Development, after landscaping.

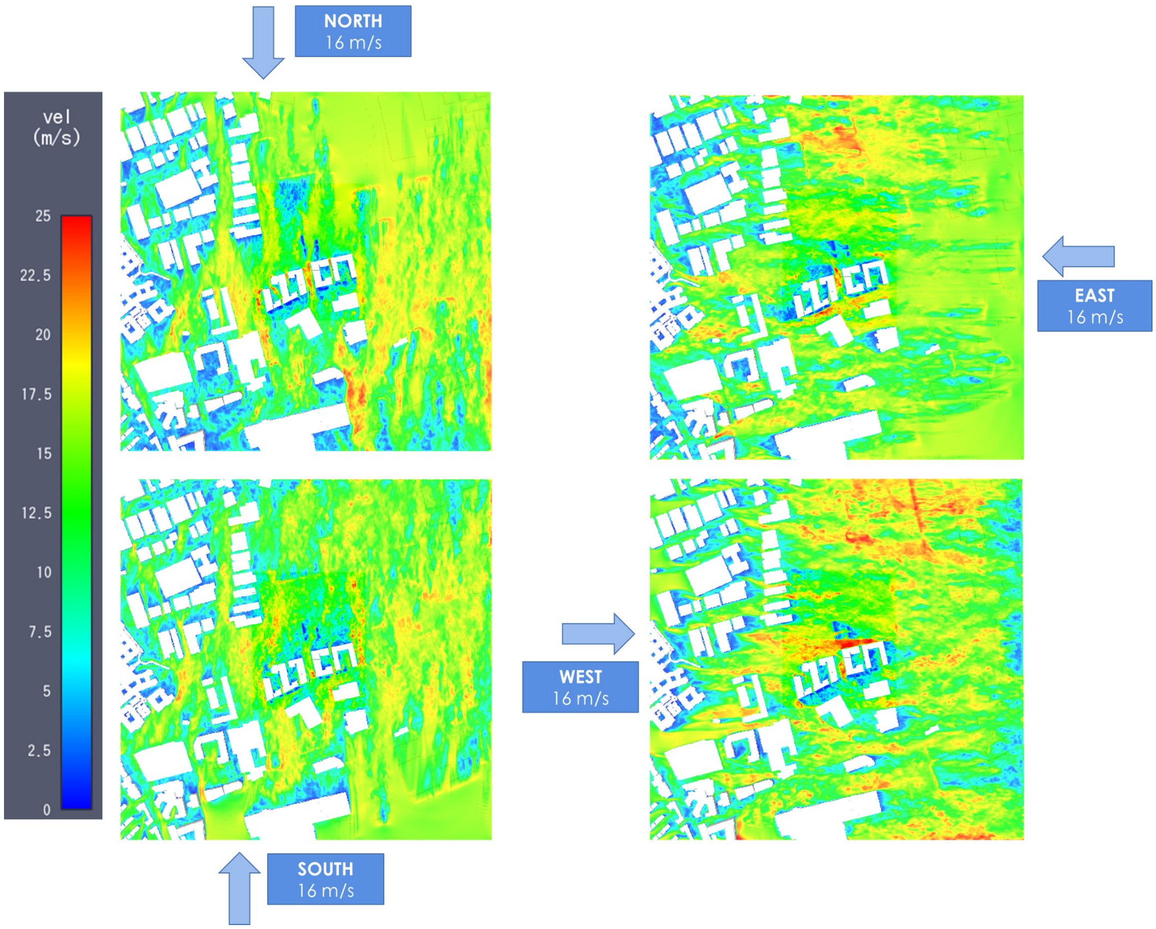


Figure 6.8: Flow Velocity Results at Z=1.5m above the ground, after landscaping - Cardinal Directions - Phase 1

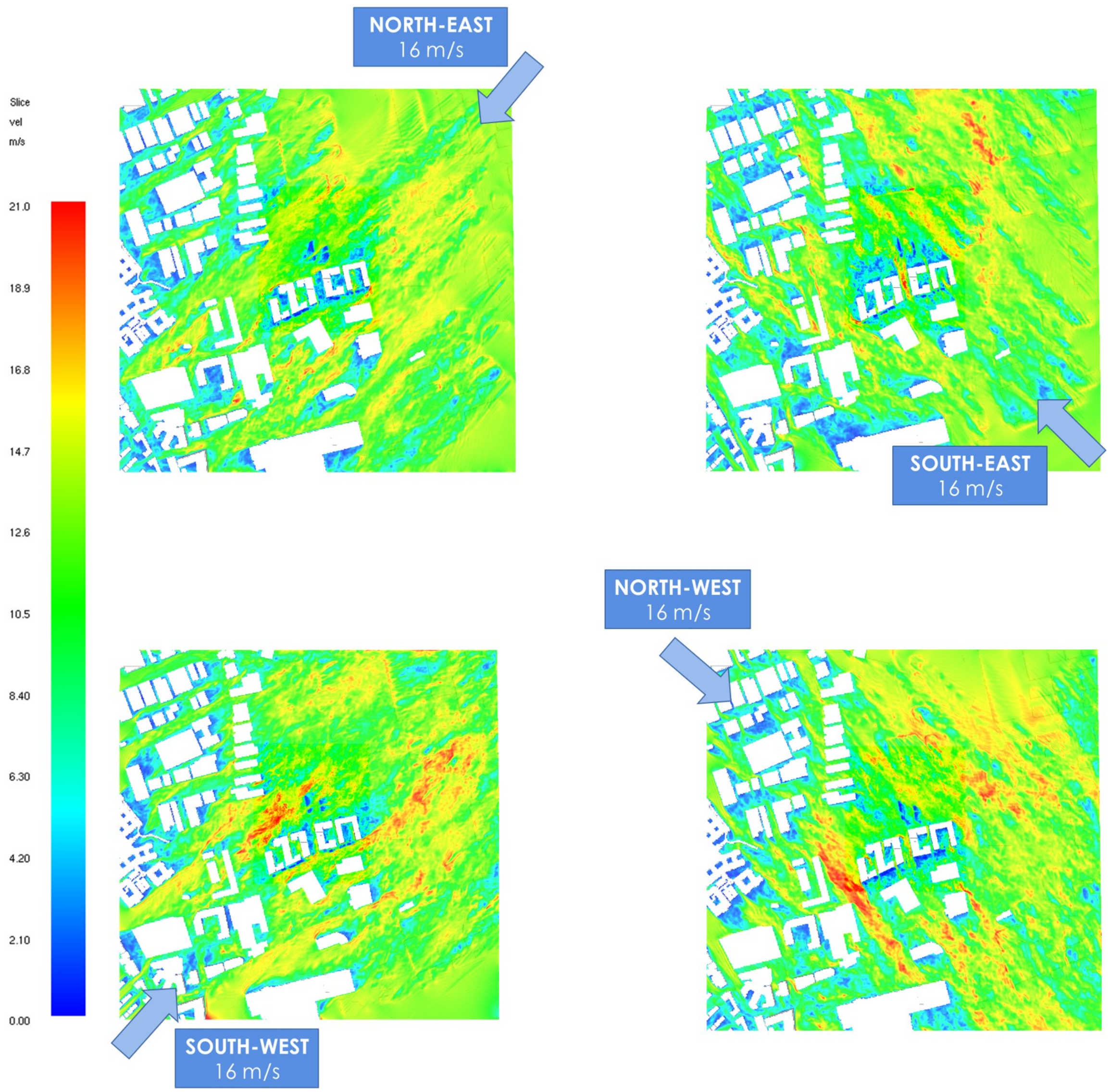


Figure 6.9: Flow Velocity Results at Z=1.5m above the ground, after landscaping - Ordinal Directions - Phase 1

To better highlight the effect of the implemented landscaping, Results of velocity at slice location of 1.5m above the ground are presented in Figures 6.10 and 6.11 for Cardinal and Ordinal Directions respectively, for wind assessment of Phase 1 of Belgard Gardens Development, after landscaping, supported with a schematic analysis of the effect of landscaping, in order to highlight the effect of the mitigation measure implemented.

Each Figure represent a scheme in which the effects of the mitigation are highlighted and the areas that still require some attentions are reported. In particular, these results show that:

- The mitigation implemented achieves good shielding on all critical roads. High velocity areas are limited to the part of the roads where the cars pass. Footpaths and cycling paths are clearly successfully shielded by vegetation.

- Shielding conditions in the square are pretty good. However, an increase of trees or an increase in the height of them could further improve square conditions, especially for some wind directions.
- In few areas, the mitigation can be implemented adding some trees or incrementing trees height. These areas are shown in Figure 6.12.

Moreover, it is important to keep in mind that South-West Direction is the prevailing direction in Dublin so best shielding conditions should be achieved for this direction.

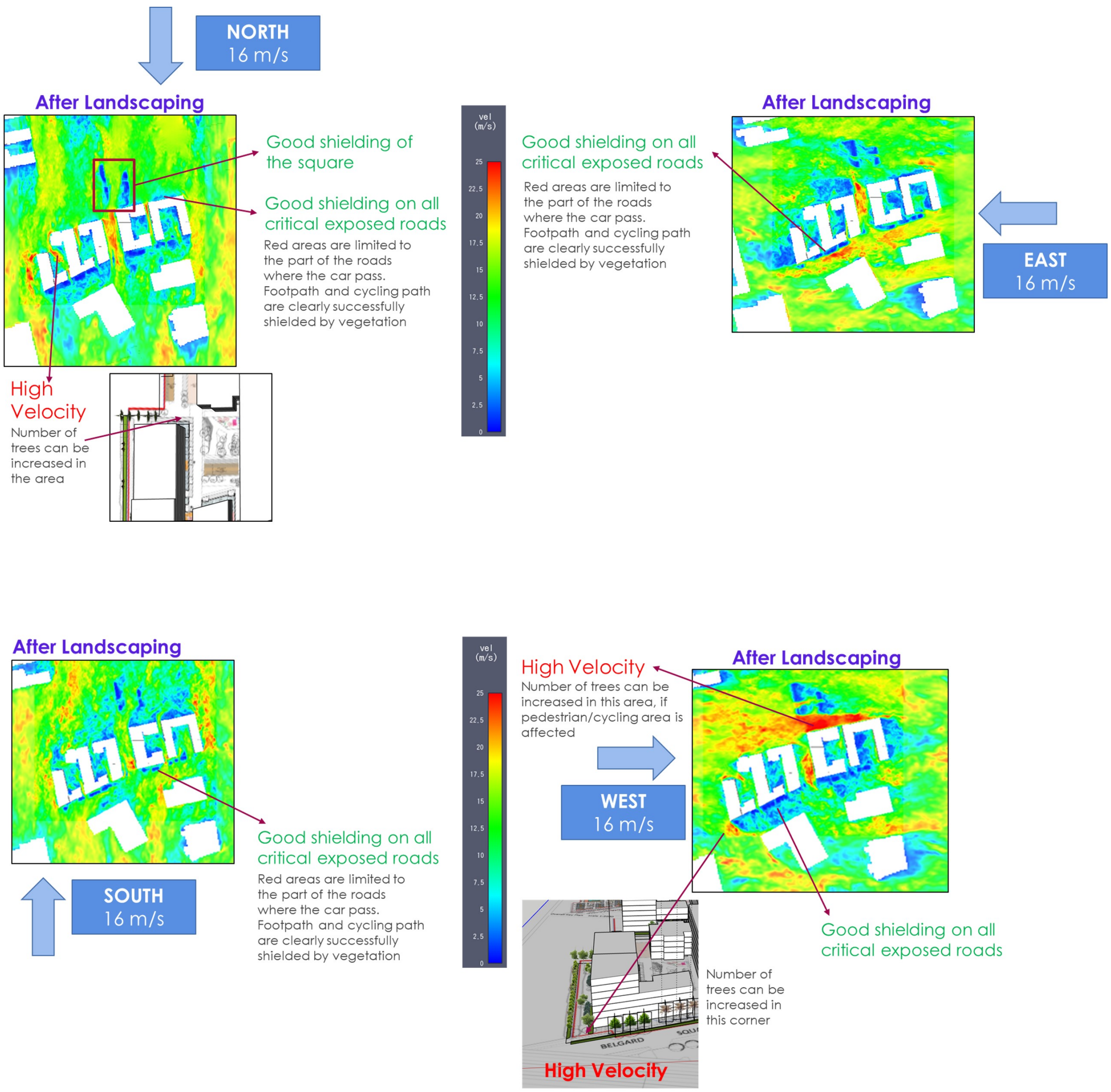


Figure 6.10: Effect of Landscaping - Flow Velocity Results at Z=1.5m above the ground, after Landscaping - Cardinal Directions - Phase 1

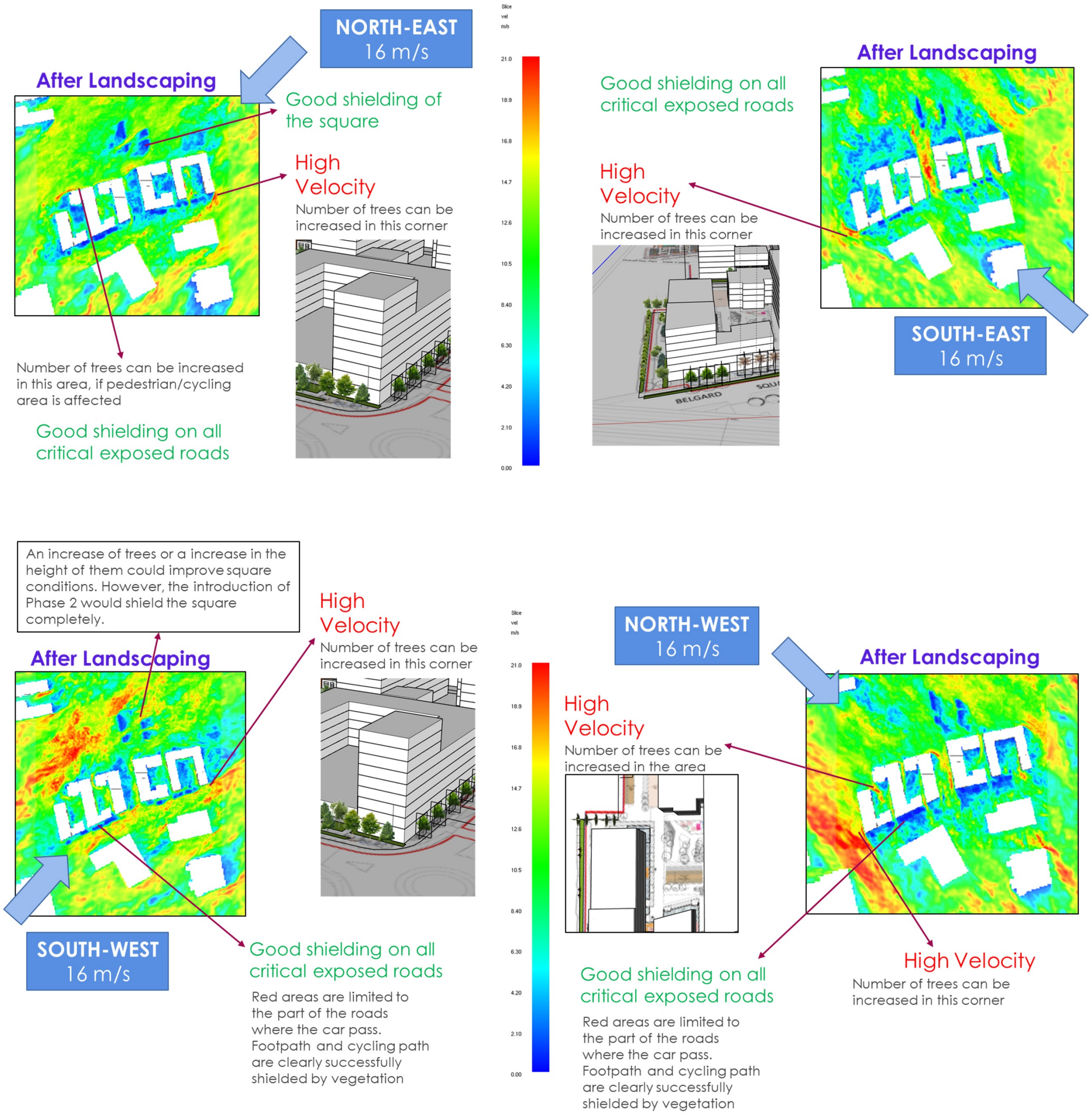


Figure 6.11: Effect of Landscaping - Flow Velocity Results at Z=1.5m above the ground, after Landscaping - Ordinal Directions - Phase 1

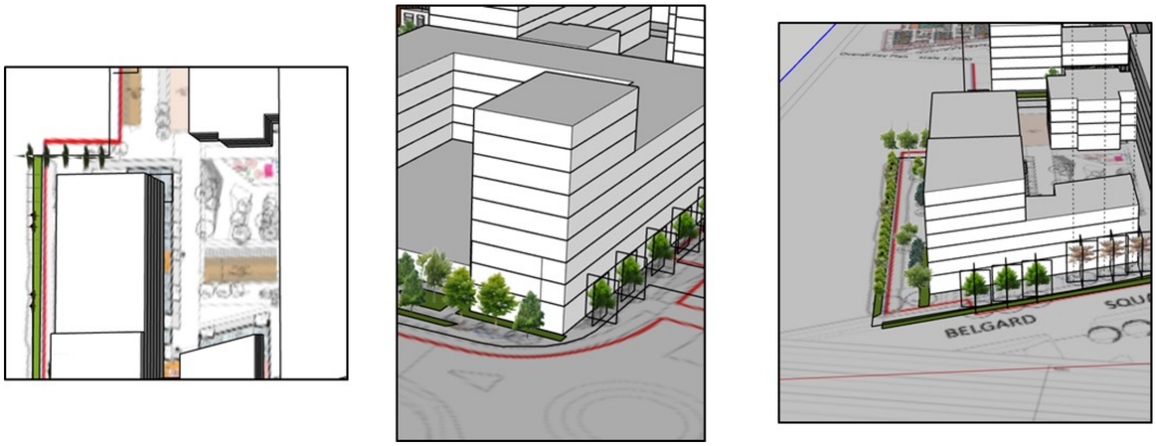


Figure 6.12: Areas where the mitigation can be implemented adding some trees or incrementing trees height

6.2.4 Pedestrian Comfort Assessment

This section aims to identify areas of Belgard Garden Phase 1 and Phase 2 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

Figurse 6.14 and 6.15 below shows Lawson comfort categories over the area around Belgard Garden Development, respectively for the cardinal and the ordinal directions. The scale used is set out in Figure 6.13. As it can be seen, depending on the wind direction, the general wind conditions range from “suitable for long term sitting” to “suitable for walking and strolling” and really rarely are only suitable for “business walking” or “unaccettable for pedestrian comfort”.

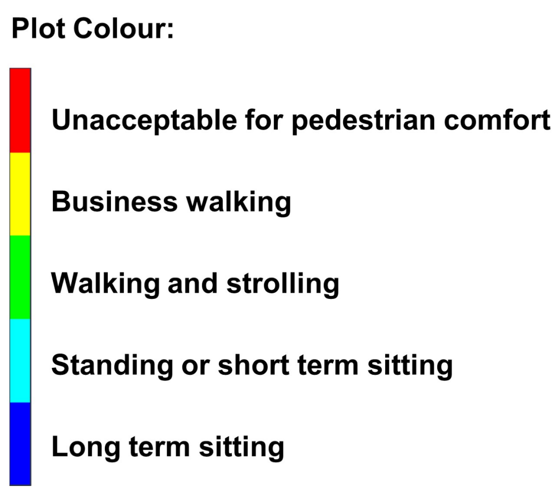


Figure 6.13: Lawson Comfort Categories

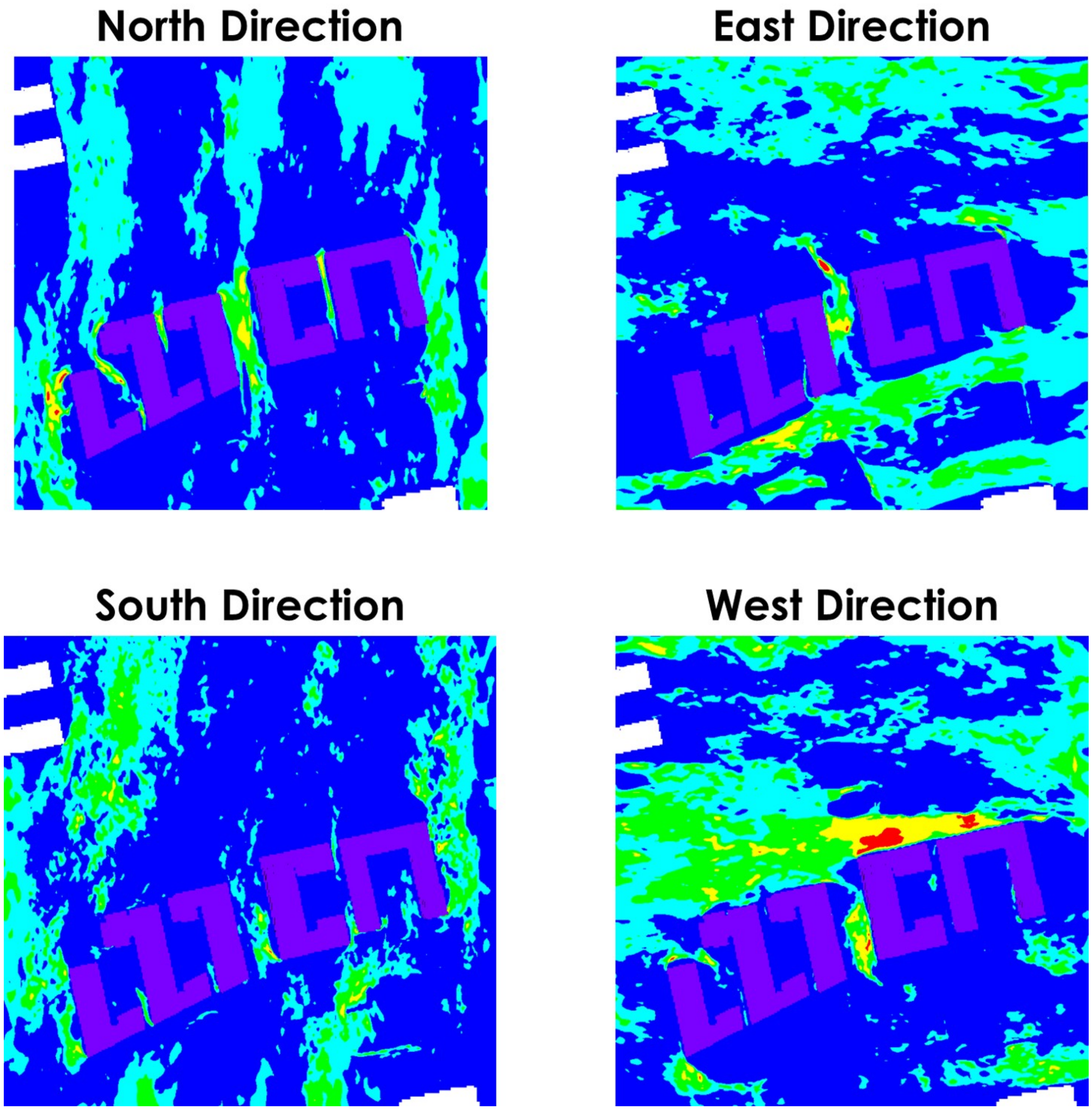


Figure 6.14: Lawson Discomfort Map - Cardinal Directions

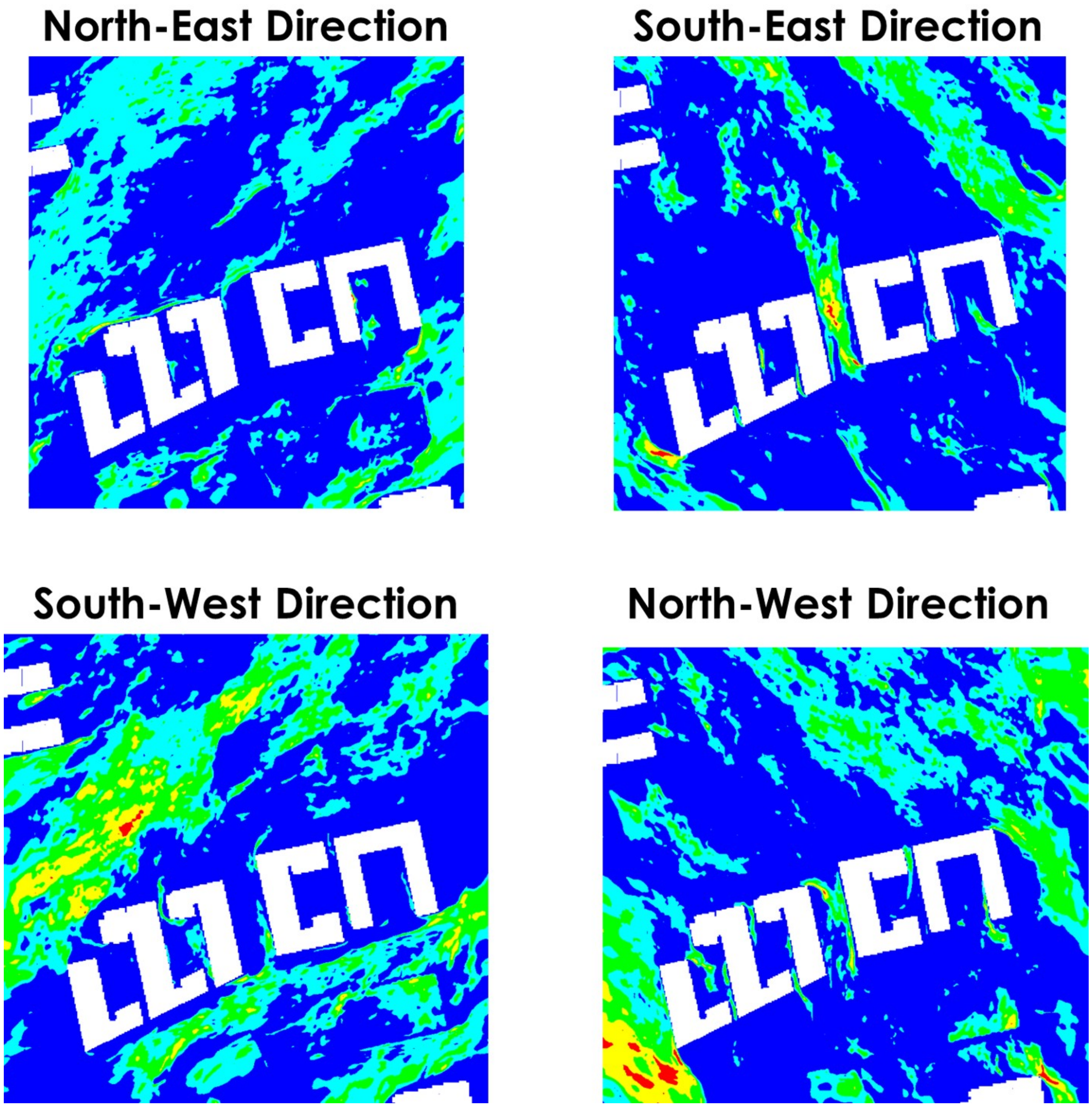


Figure 6.15: Lawson Discomfort Map - Ordinal Directions

The results shown in the previous map show that there are some critical areas when the wind is blowing from East, South-East, West and North-West. However, these criticisms must be related to their occurrencies, as it must be noted that, 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.

For this purpose, the probabilities that the wind is blowing towards a certain direction have been calculated and are presented in the following wind rose:

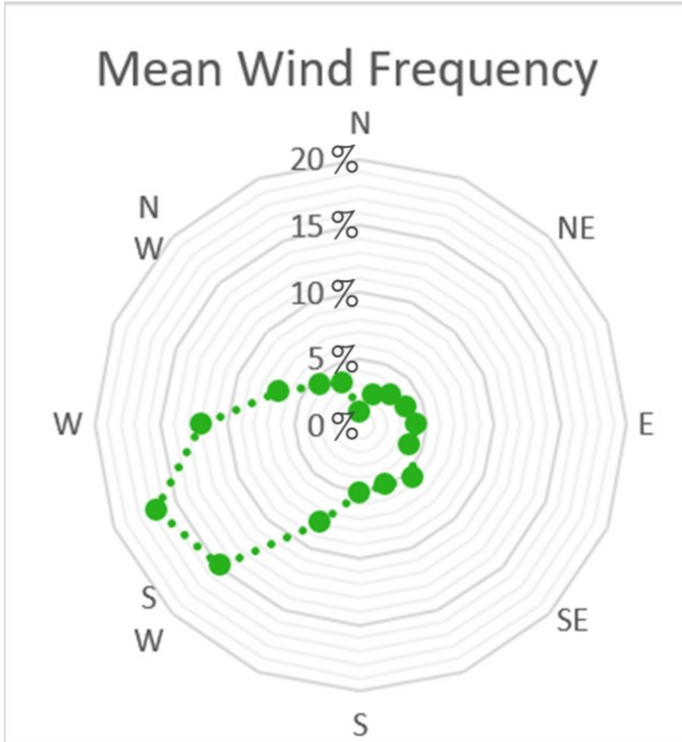


Figure 6.16: Frequency of Wind Direction

The wind rose shows that, for example, the wind from SW is occurring for the 15% of the time.

Thus, after having combined the Lawson discomfort maps obtained and wind probabilities for criticisms, final results show that the discomfort criteria is satisfied as the critical areas previously noticed have an occurrancy below the acceptance limit of 5 %. This results are further summarised in the following table:

Direction	Lawson Criteria	Occurrancy of Criticism	Final Acceptance
N	Always Accepted	–	–
NE	Always Accepted	–	–
E	Critical on some areas	0.7%	Accepted
SE	Critical on some areas	0.8%	Accepted
S	Always Accepted	–	–
SW	Always Accepted	–	–
W	Critical on some areas	3.8%	Accepted
NW	Critical on some areas	1.4%	Accepted

Table 6.2: Summary of Lawson Discomfort Results - Cardinal and Ordinal Directions

Distress Criteria

In addition to 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 6.17 shows the hourly wind gust rose for Dublin, from 1985 to 2015. This will be necessary to assess how many hours per year on average the velocity exceed the threshold values.

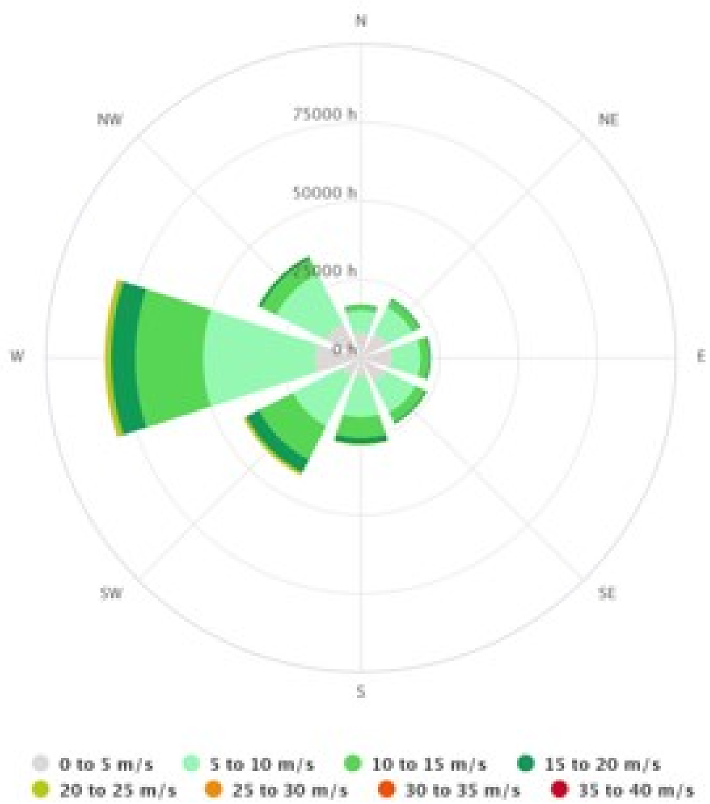


Figure 6.17: Hourly Dublin Wind Gust Rose

The criteria for distress for a frail person or cyclist is 15m/s wind occurring at low level 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 6.18), it is possible to see how a gust velocity of 15m/s is exceed at pedestrian level only in the West direction, for a total of 5 hours over 30 years.

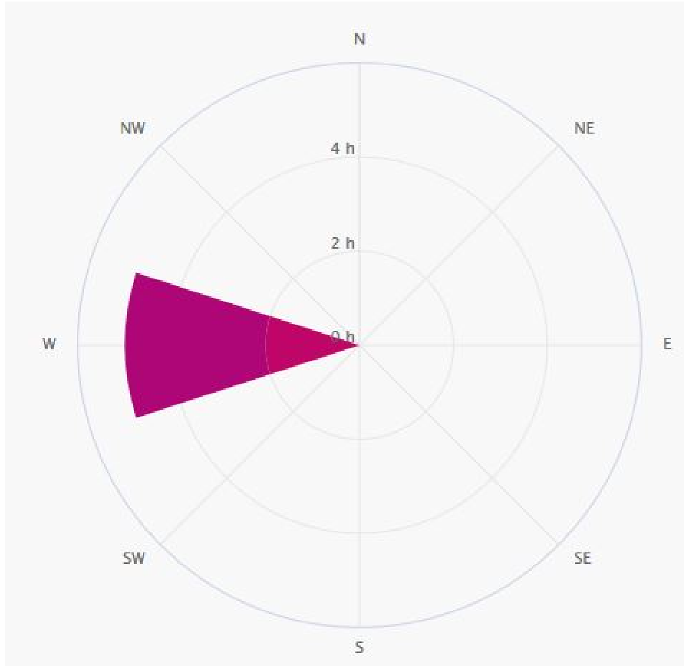


Figure 6.18: Hourly Dublin Wind Gust Rose - Cumulative hourse when the velocity is above 15m/s

Figure 6.19 below shows the areas around Belgard Gardens Development where the measured velocity is above 15 m/s in the west direction. Figure 6.20 shows the scale used in this case. However, this is not considered to be a critical situation in terms of distress as in average the occurrency is below the threshold value of 2 hours per year.

Figure 6.19: Lawson Distress Map - Frail Person or Cyclist - West Direction

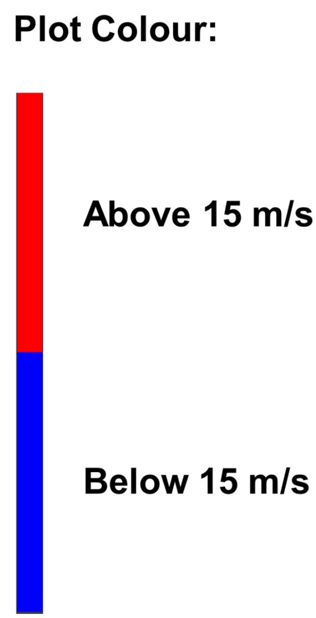


Figure 6.20: Lawson Distress Categories - Frail Person or Cyclist

The criteria for distress for a member of the general population is 20m/s wind occurring at low level for more than two hours per year. In this case, a gust velocity of 20m/s is never exceed at pedestrian level for more than 2 hours per year. Therefore there are not distress conditions for the general public.

6.3 CASE 2 - PHASE 1 AND 2 MICROCLIMATE ASSESSMENT

This section aims to predict the wind patterns around the proposed Phase 1 and Phase 2 of Belgard Gardens Development, under mean and peaks wind conditions typically occurring in the area, in order to identify areas of concern in terms of critical flows. A view of the model for Phase 1 only is presented in Figure 6.2.

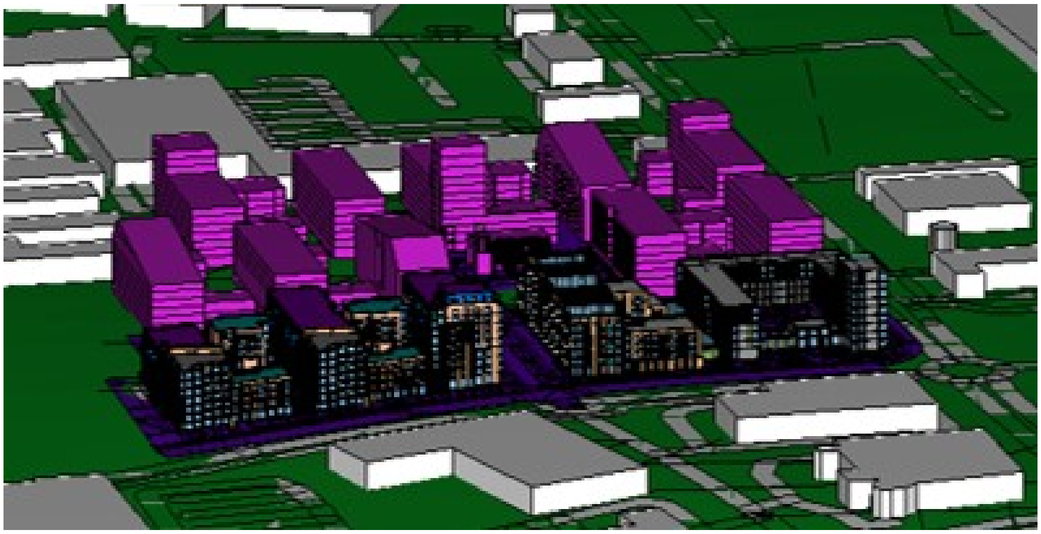


Figure 6.21: Belgard Gardens Phase 1 and Phase 2 Model

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:

- All the critical area have been mitigate by the landscaping performed on Phase 1 only. However, there are still few area that could be improved if some landscaping is implemented on Phase 2 as well.

6.3.1 Flow Velocity Results

Results of velocity at slice location of 1.5m above the ground are presented in Figures 6.22 and 6.23 for Cardinal and Ordinal Directions respectively, for wind assessment of Phase 1 and Phase 2 of Belgard Gardens Development. The potential high velocity critical area are circled in purple.

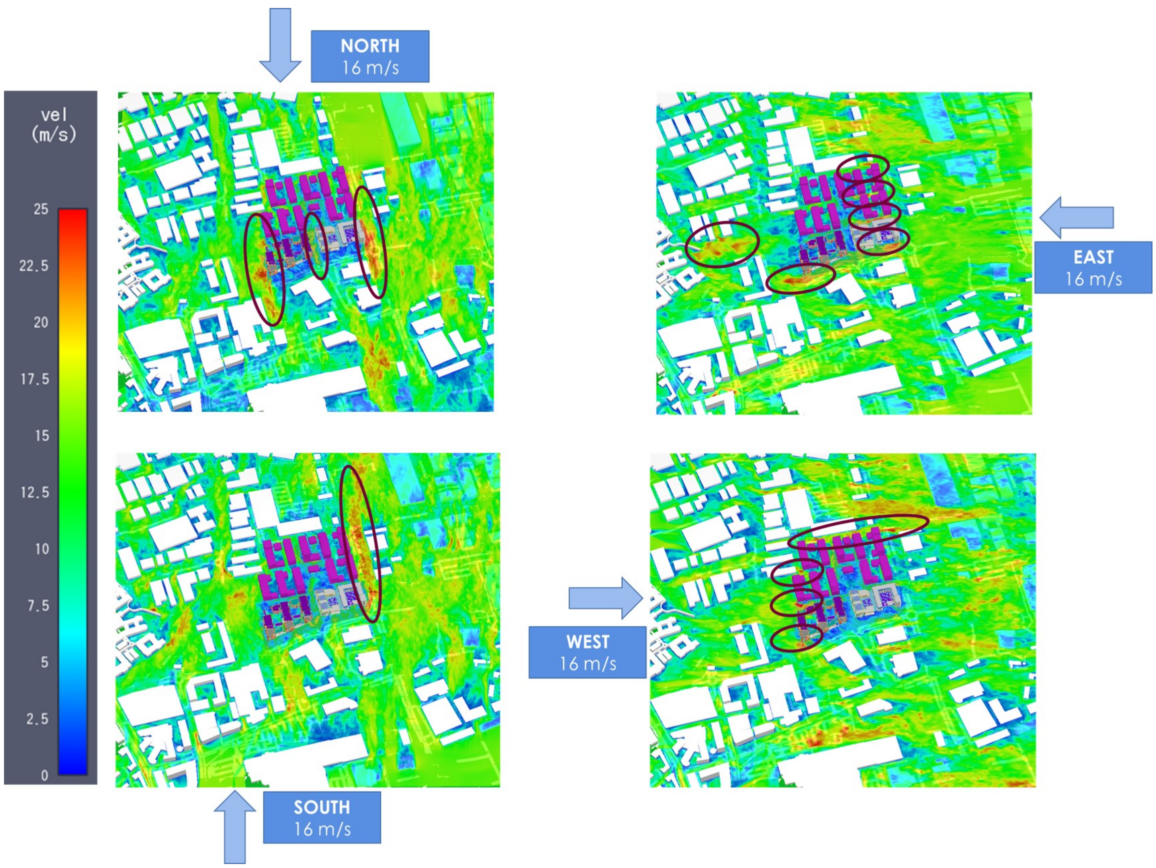


Figure 6.22: Flow Velocity Results at Z=1.5m above the ground - Cardinal Directions - Phase 1 and Phase 2

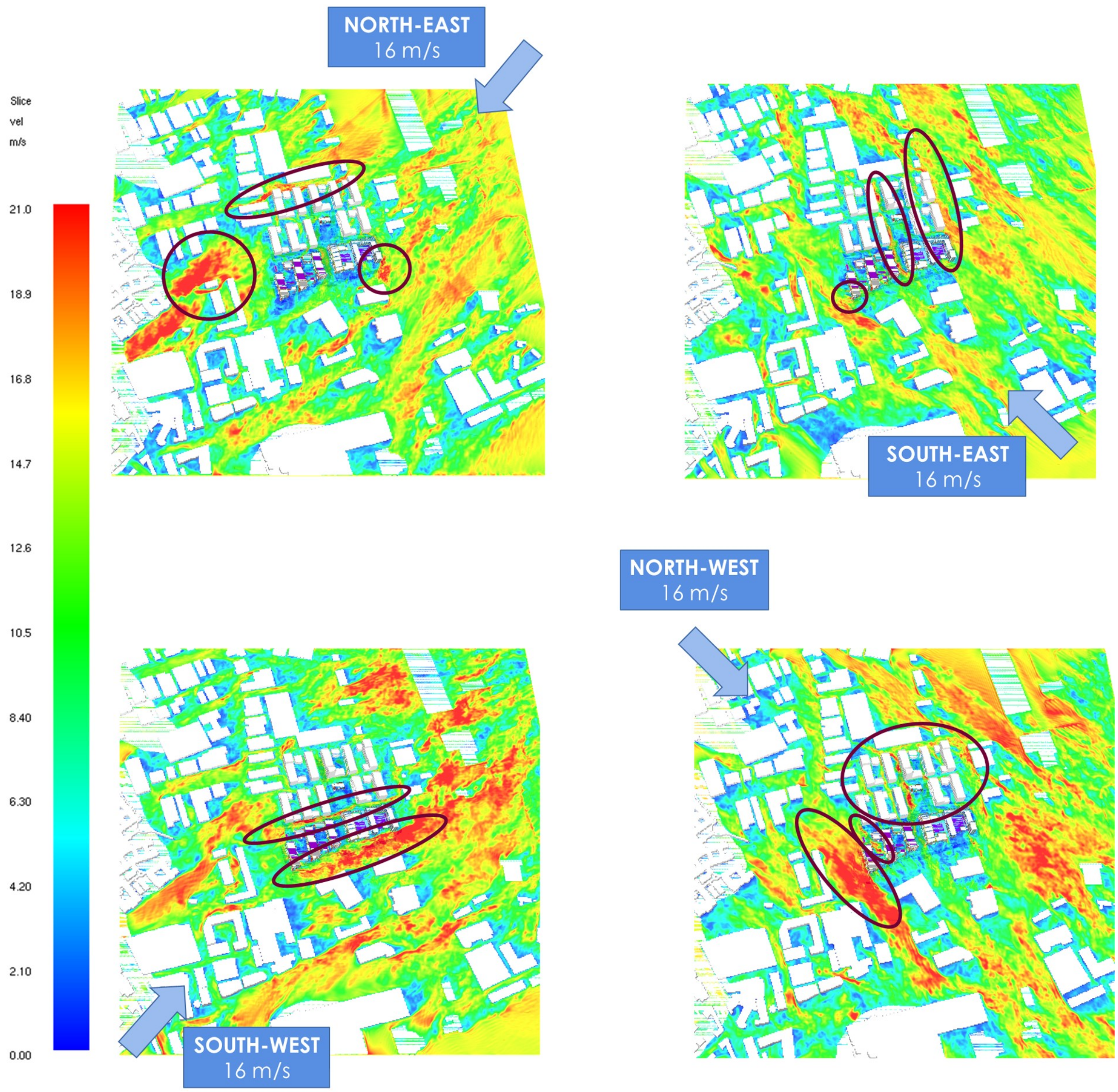


Figure 6.23: Flow Velocity Results at Z=1.5m above the ground - Ordinal Directions - Phase 1 and Phase 2

6.3.2 Flow Velocity Results - Critical Zones

Results of critical velocity above 20m/s at slice location of 1.5m above the ground are presented in Figures 6.24 and 6.25 for Cardinal and Ordinal Directions respectively, for wind assessment of Phase 1 and Phase 2 of Belgard Gardens Development.

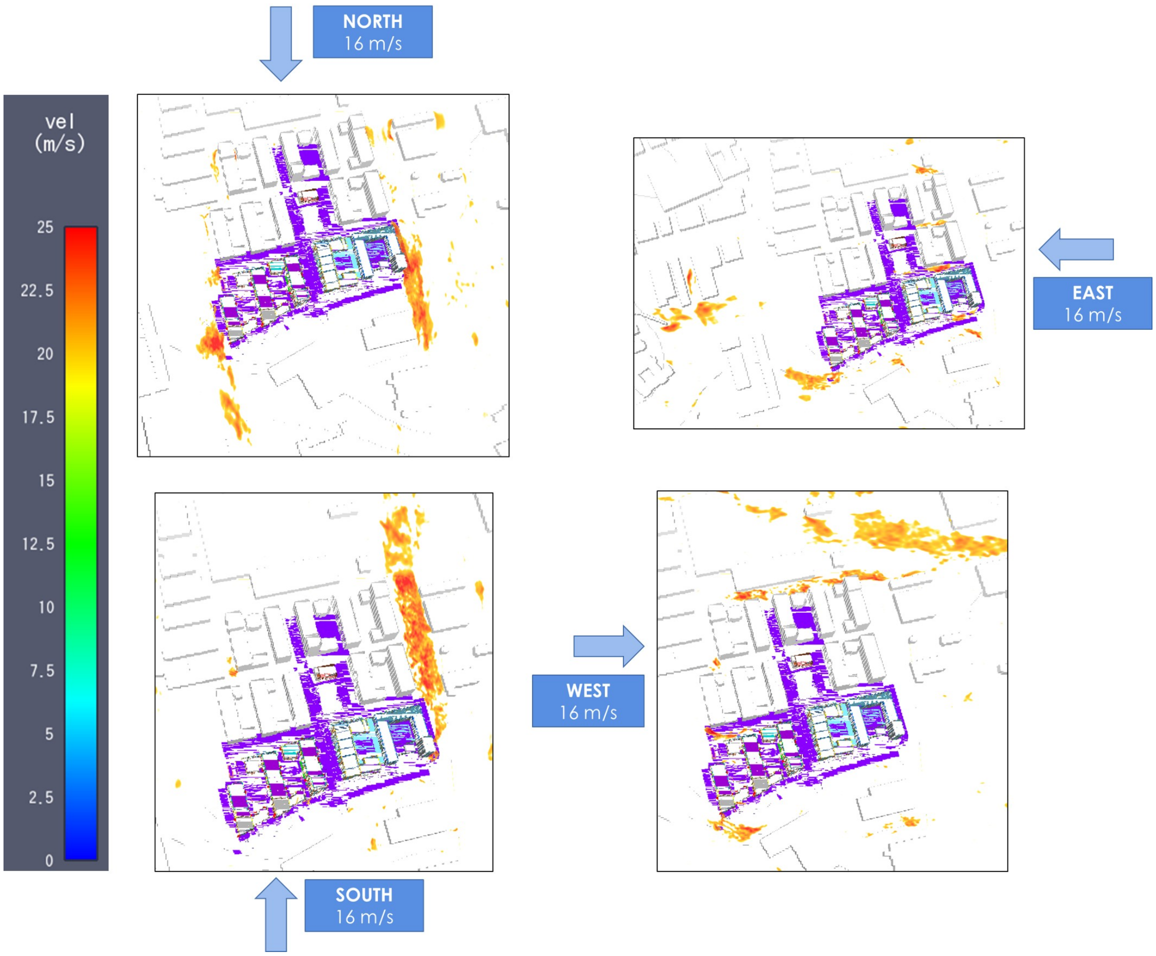


Figure 6.24: Critical Flow Velocity Results above 20 m/s at Z=1.5m above the ground - Cardinal Directions - Phase 1 and Phase 2

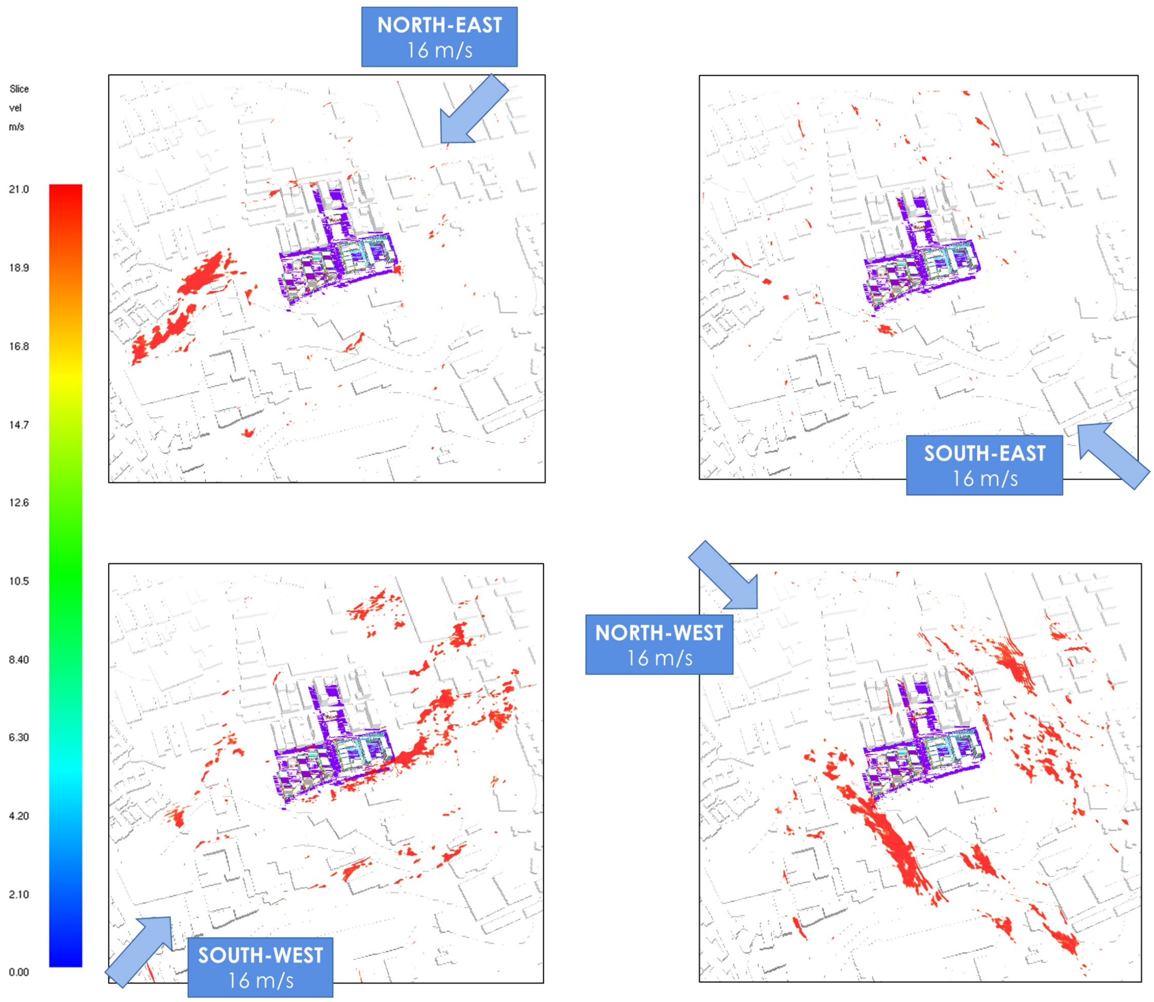


Figure 6.25: Critical Flow Velocity Results above 20 m/s at Z=1.5m above the ground - Ordinal Directions - Phase 1 and Phase 2

6.3.3 Remaining Areas To Mitigate for Phase 2

All the above critical area have been mitigate by the landscaping performed on Phase 1 only. However, there are still few area that could be improved if some landscaping is implemented on Phase 2 as well. In particular, there is an area behind Phase 2 that might require landscaping. However, this requires a detailed assessment in case Phase 2 would be actually implemented.

6.4 IMPACT ON TALLAGHT HOSPITAL HELICOPTER PAD

The Tallaght Hospital Ground-Based Helicopter Pad is located 150m to the west of our Tallaght development site, as shown in Figure 6.26. This section aims to evaluate if Belgard Garden Development has an impact on the operation of the helipad as part of the change the microclimate that are created as part of the current development.

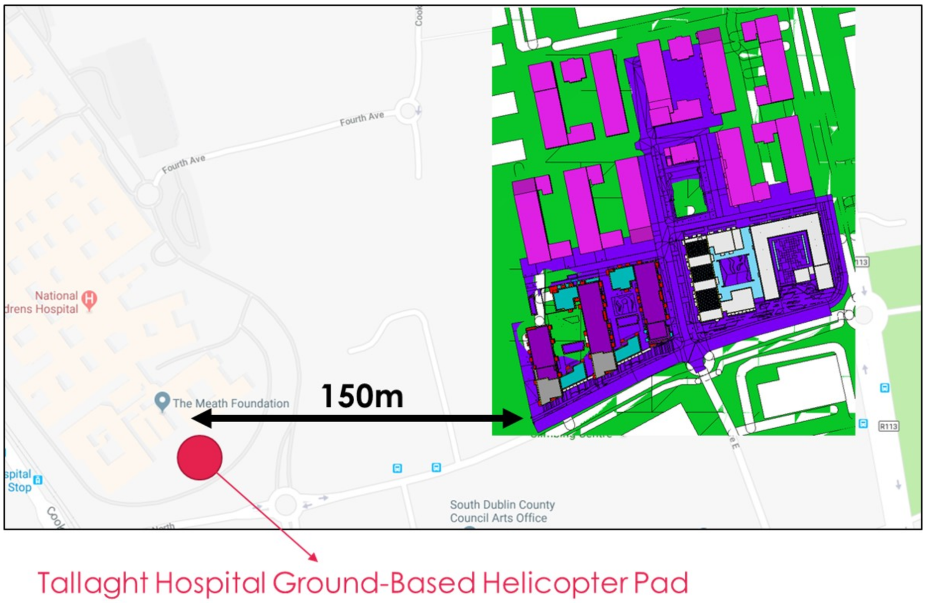


Figure 6.26: Location of Tallaght Hospital Ground-Based Helicopter Pad in respect to Belgard Gardens Development

6.4.1 WIND SPEED RESTRICTIONS

Wind speed restrictions for helicopters take off/landing depend on wind direction, helicopter model, weight class of the helicopter and the degree of turbulence associated with the wind.

FAA indicate that, if the helicopter flight manual or the helicopter operator's policy does not set lower limits, the following shall be used [Ref. "Interagency Helicopter Operations Guide - June 2009 Chapter 6"]. These limits may be further restricted at the discretion of the Pilot or other air operations personnel. Limitations are as follows:

1. Flight Above 500' AGL - Flights more than 500 feet from the surface are allowed in winds up to 50 knots for all types of helicopters.

2. Flight Below 500' AGL
   - Type 1 (Heavy) And Type 2 (Medium) Helicopters - Steady winds shall not exceed 40 knots (approx. 20.6 m/s), or a maximum gust spread of 15 knots (approx. 7.8 m/s).
   - Type 3 (Light) Helicopters - Steady winds shall not exceed 30 knots (approx. 15.5 m/s), or a maximum gust spread of 15 knots (approx. 7.8 m/s).

6.4.2 IMPACT OF PHASE 1 ONLY

Belgard Gardens Development can affect and modify wind conditions at Tallaght Hospital Helipad exclusively when the wind flows in East and North-East directions. Results for these two conditions are reported in Figure 6.27.

As it is possible to see from the results, in both cases, the velocity might exceed 15.5 m/s - 20.6 m/s in few small areas and might exceed 7.8 m/s in the full area. However, prevailing wind direction in Dublin is South-West. Therefore, Belgard Gardens Development Phase 1 has not impact on the Helipad exposure to the prevailing wind conditions.

On the East and North-East wind directions the development is actually partially protecting the helipad from the incoming wind. The wake that is causing acceleration of the flow at the helipad is not created by Belgard Garden phase 1 but it is created by the existing building between Phase 1 and the helipad.

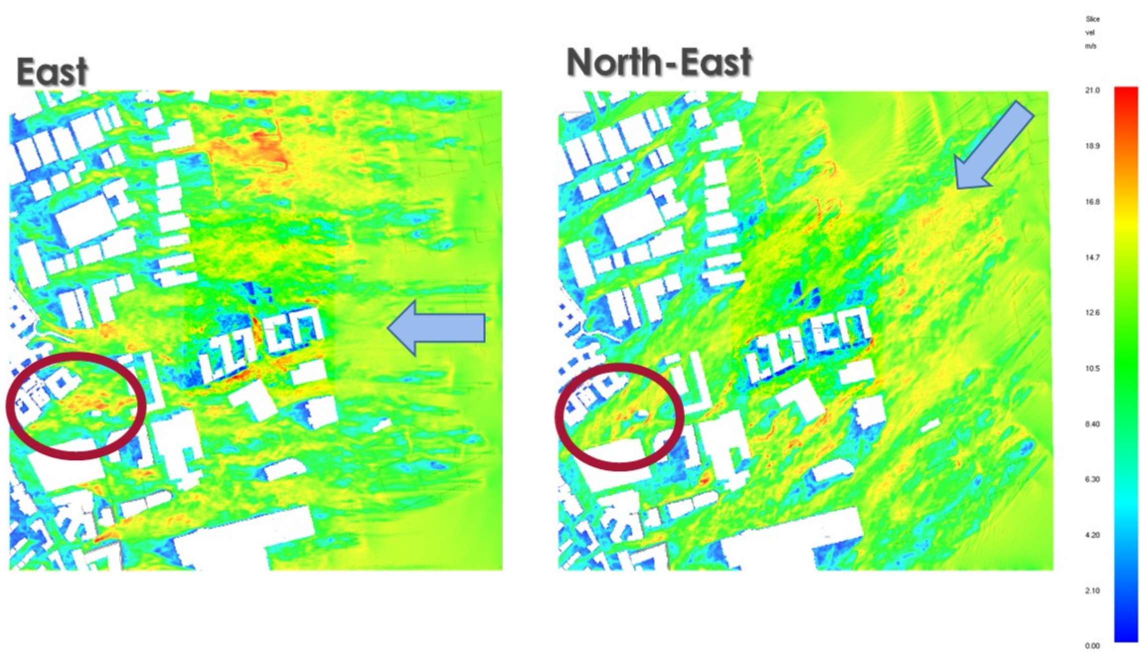


Figure 6.27: Impact of Belgard Gardens Development Phase 1 on Tallaght Hospital Helicopter Pad

6.4.3 IMPACT OF PHASE 1 AND PHASE 2

The introduction of Phase 2 will require the implementation of mitigation measures on the North-East area, this to avoid the creation of high velocity wake of Phase 2 which can extend up to the helipad area, as can be assessed in the results presented in Figure 6.28. Looking at the results from Phase 1 only, and assuming that Phase 2 will be similar in terms of generic features, it is expected that a similar landscaping to Phase 1 will help to mitigate the wind impact on Phase 2. These mitigation measures are being implemented into the Phase 2 proposal and are not impacted or constrained by this Phase 1 planning application. Moreover, the north-east direction is not predominant in Dublin, therefore the impact is likely to be completely solved once landscaping is implemented.

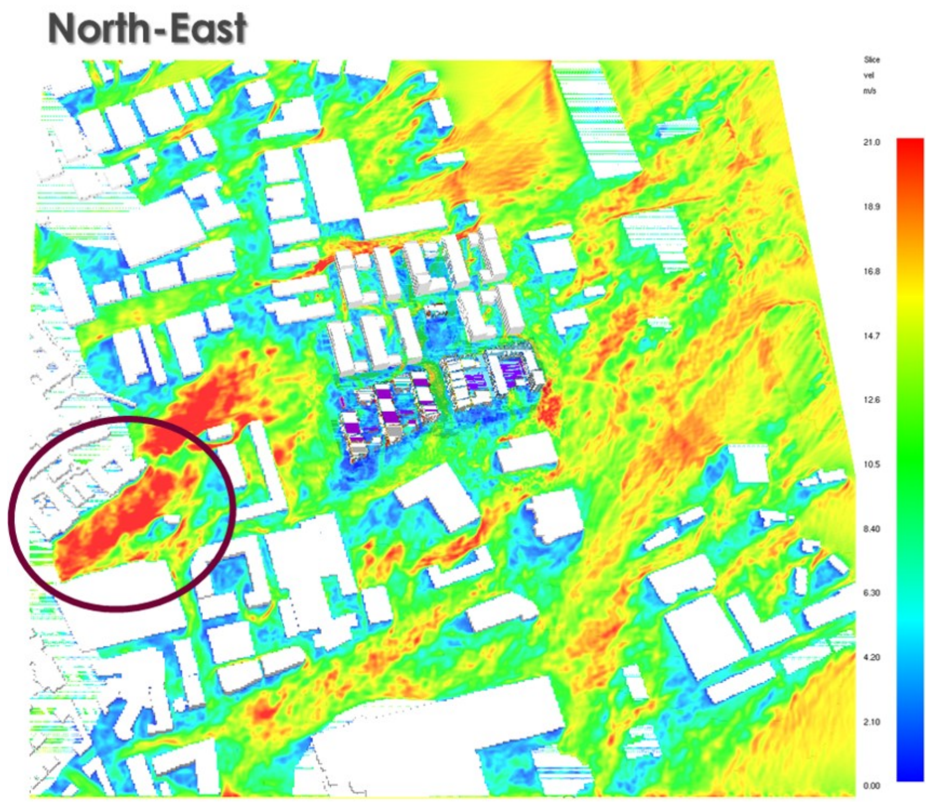
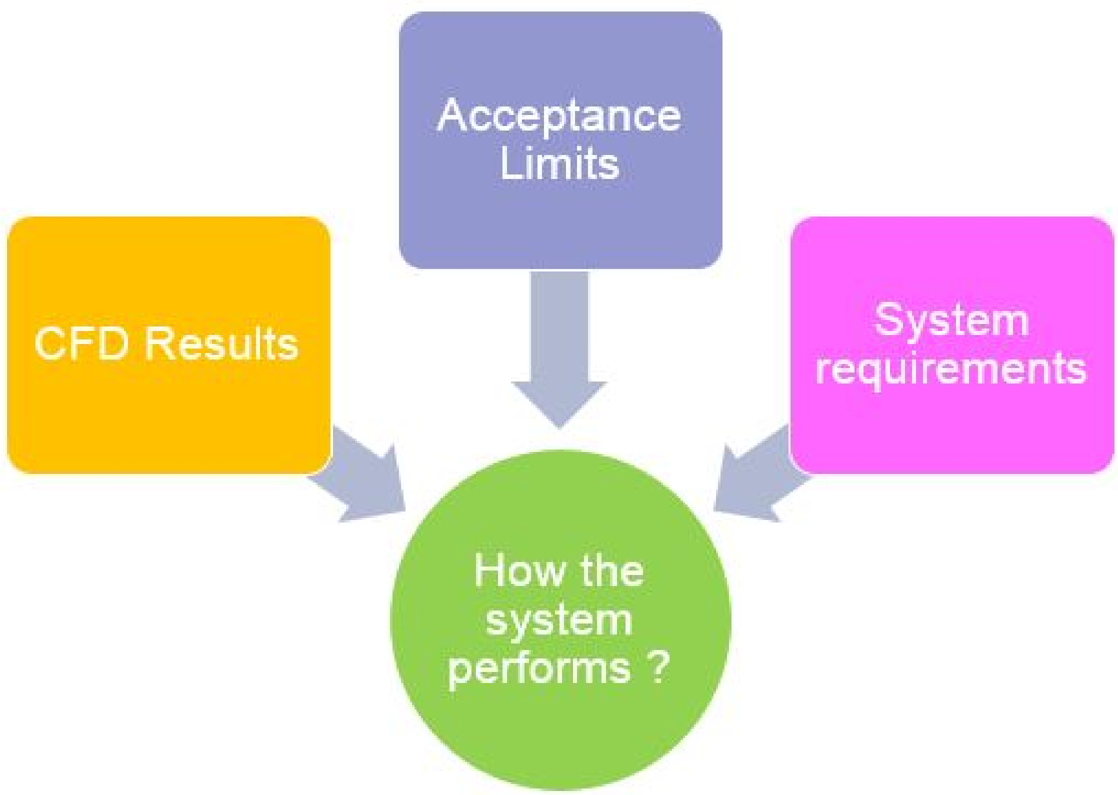


Figure 6.28: Impact of Belgard Gardens Development Phase 1 and Phase 2 on Tallaght Hospital Helicopter Pad

7. CONCLUSIONS



7.1 CONCLUSIONS and COMMENTS ON CFD STUDY

This report has presented the CFD modelling assumptions and results of the Wind and Microclimate Modelling of Belgard Gardens Development, Tallaght, Co. Dublin. This CFD model has been carried out to predict the wind patterns around the area proposed, under mean and peaks wind conditions typically occurring in the area.

The assessment identified areas of concern in terms of critical flows and areas where the pedestrian safety and comfort could be compromised (in accordance with the Lawson Acceptance Criteria) and suggested mitigation measures to be implemented.

For this analysis two parts are carried out. Part 1 carried out a local wind data statistical analysis. Part 2 performed a wind microclimate model of the site. For this Part, two major cases have been modelled. Case 1 carried out a microclimate assessment for Phase 1 only, while Case 2 carried out a cumulative microclimate assessment for Phase 1 and Phase 2.

For Part 1, results show:

- The wind profile that 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.

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

For Part 2, the results indicate that:

- The proposed Belgard Gardens Phase 1 development will produce a quality environment that, once the landscapind is implemented, is attractive and comfortable for pedestrians. The landscaping plans have been adapted and designed to provide further protection from the wind. Different sizes of trees have been specified in the square, as well as all around the buildings to help disperse the approaching wind and protect the footpaths and the cycling paths. At the corners, where higher speed winds are more prevalent, more landscaping is suggested.

- The mitigation implemented achieves good shielding on all critical roads. High velocity areas are limited to the part of the roads where the cars pass. Footpaths and cycling paths are clearly successfully shielded by vegetation.

- Shielding conditions in the square are pretty good. However, an increase of trees or an increase in the height of them could further improve square conditions, especially for some wind directions. However, the introduction of Phase 2 would shield the square completely.

- In few areas, the mitigation can be implemented adding some trees or incrementing trees height.

- The pedestrian comfort assessment, performed on Phase 1 accordingly to the Lawson criteria, identified the areas that are suitable for the different pedestrian activities in order to guarantee pedestrian comfort. Moreover, in terms of distress, some critical conditions were found for "Frail persons or cyclists" in the surrounding of the development only in the west direction. However, the frequency at which these conditions happen are below the critical threshold for distress.

- Regarding Phase 1 and Phase 2 together, all the critical area have been mitigate by the landscaping performed on Phase 1 only. However, there are still few area that could be improved if some landscaping is implemented on Phase 2 as well.

- Regarding the impact of Belgard Garden Development on Tallaght Hospital Ground-Based Helicopter Pad:

  - The Tallaght Hospital Ground-Based Helicopter Pad is located 150m to the west of Belgard Garden development site. Belgard Gardens Development can affect and modify wind conditions at Tallaght Hospital Helipad exclusively when the wind flows in East and North-East directions.

  - Results show that the velocity might exceed threshold values in a few small areas. However, prevailing wind direction in Dublin is South-West. Therefore, Belgard Gardens Development Phase 1 has not impact on the Helipad exposure to the prevailing wind conditions.

  - On the East and North-East wind directions the development is actually partially protecting the helipad from the incoming wind. The wake that is causing acceleration of the flow at the helipad is not created by Belgard Garden phase 1 but it is created by the existing building between Phase 1 and the helipad. Therefore, Belgard Gardens Development Phase 1 has not impact on the Helipad exposure to the prevailing wind conditions.

  - However, the introduction of Phase 2 will require the implementation of mitigation measures on the North-East area, this to avoid the creation of high velocity wake of Phase 2 which can extend up to the helipad area. Mitigations will be implemented as part of the Phase 2 proposal.

Therefore, the CFD study carried out has shown that, under the assumed wind condition 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 pedestrian), and,

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

8. BIBLIOGRAPHY

- Lawson, T.V., 2001, ‘Building Aerodynamics’, Imperial College Press, London
- 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
- Interagency Helicopter Operations Guide - June 2009 Chapter 6
- 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