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Pedestrian Wind Comfort Study

Rosemount Development

Project No. W340
5th August 2022

Pedestrian Wind Comfort Study

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NOTICE

DOCUMENT CONTROL & HISTORY

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EXECUTIVE SUMMARY

This report outlines the predicted climatic wind conditions experienced within and surrounding the proposed Rosemount development located at Northern Cross, Malahide Road, Dublin 17.

A conscious effort was made by the design team during the design stages to mitigate the risk of localised increased wind speed conditions due to the proposed development. The introduction of mitigation measures such as the courtyard location, building line, inset balconies, as well as the strategic location of extensive landscaping, all assist in reducing the potential development of local increased wind speed and the negative impact on local climatic conditions.

Based on the CFD modelling results, the proposed development will be a comfortable environment for occupants. Certain areas have been highlighted as being potentially uncomfortable for a limited period of time. However, these concerns have been largely addressed through the incorporation of landscaping and trellis/windbreak structures which will mitigate excessive wind speeds in these areas.

Overall, the proposed development will be a high-quality, comfortable environment for occupants throughout the year.

PEDESTRIAN WIND COMFORT REPORT

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1. INTRODUCTION

The intention of this report is to outline the predicted climatic wind conditions experienced within and surrounding the proposed development located at Northern Cross, Malahide Road, Dublin 17.

The proposed method for compliance validation is via the industry best practice standard for pedestrian comfort (Lawson Criteria). The Lawson Criteria sets acceptable levels of wind speed and velocity for various human activities.

Given the specific location of the building and recorded metrological data available for the area, and standard interpolation calculation procedures, it is possible to predict the expected wind speeds and their annual occurrence.

2. PROPOSED DEVELOPMENT

The proposed Rosemount SHD development shall consist of:

• Demolition of existing c. 3,315 sq.m, 3 storey office building on site and existing ancillary facilities and the construction of a single mixed-use block (Block A) of up to 9 storeys (over basement), consisting of a 4-sided structure based around a central courtyard area.

• c. 1,050.8 sq.m. of office space at ground floor level with own door access and associated infrastructure including staff kitchen, meeting rooms and designated car parking (7 spaces) at basement level.

• A café unit of c. 143.7 sq.m at ground floor level with own door access to the south and east, accessed via proposed public open space.

• 176 no. residential units from 1st to 8th floor level comprising 72 no. 1 bed units (41%), 57 no. 2 bed units (32%) and 47 no. 3 bed units (27%) [each with private amenity space in the form of balcony or terrace], with separate access to the proposed commercial uses at ground floor level.

• c. 1,846 sq. m. of communal open space at ground floor, first floor podium, 4th floor and 7th floor level, and public open space of c. 1,577 sq.m. at ground floor level, including a public courtyard area located to the southeast of the proposed block.

• Resident amenity and support services are proposed at ground floor level to include a cinema room, post room, games room, co-working spaces, gym and concierge services.

• 134 no. car parking spaces, 7 of which are accessible, and 6 no. motorcycle parking spaces, located at basement level and accessed by a vehicular ramp via Mayne River Avenue to the west (with a vehicular set down areas fronting Mayne River Avenue), in addition to 2 no. car club spaces at the southern boundary.

• 424 no. bicycle parking spaces, 416 of which at ground floor and at surface level and 8 no. spaces at basement level.

• All associated vehicular and pedestrian access routes (including links to the adjoining site to the north), external communal play facilities, E.S.B substation, Meter rooms, foul and surface water drainage, hard and soft landscaping, lighting, plant at basement level, bin stores, PV panels and green roof, telecommunications infrastructure all associated and ancillary site works.

The application contains a statement setting out how the proposal will be consistent with the objectives of the relevant development plan and local area plan. The application contains a statement indicating why permission should be granted for the proposed development, having regard to a consideration specified in section 37(2)(b) of the Planning and Development Act, 2000, as amended, notwithstanding that the proposed development materially contravenes a relevant development plan or local area plan other than in relation to the zoning of the land.

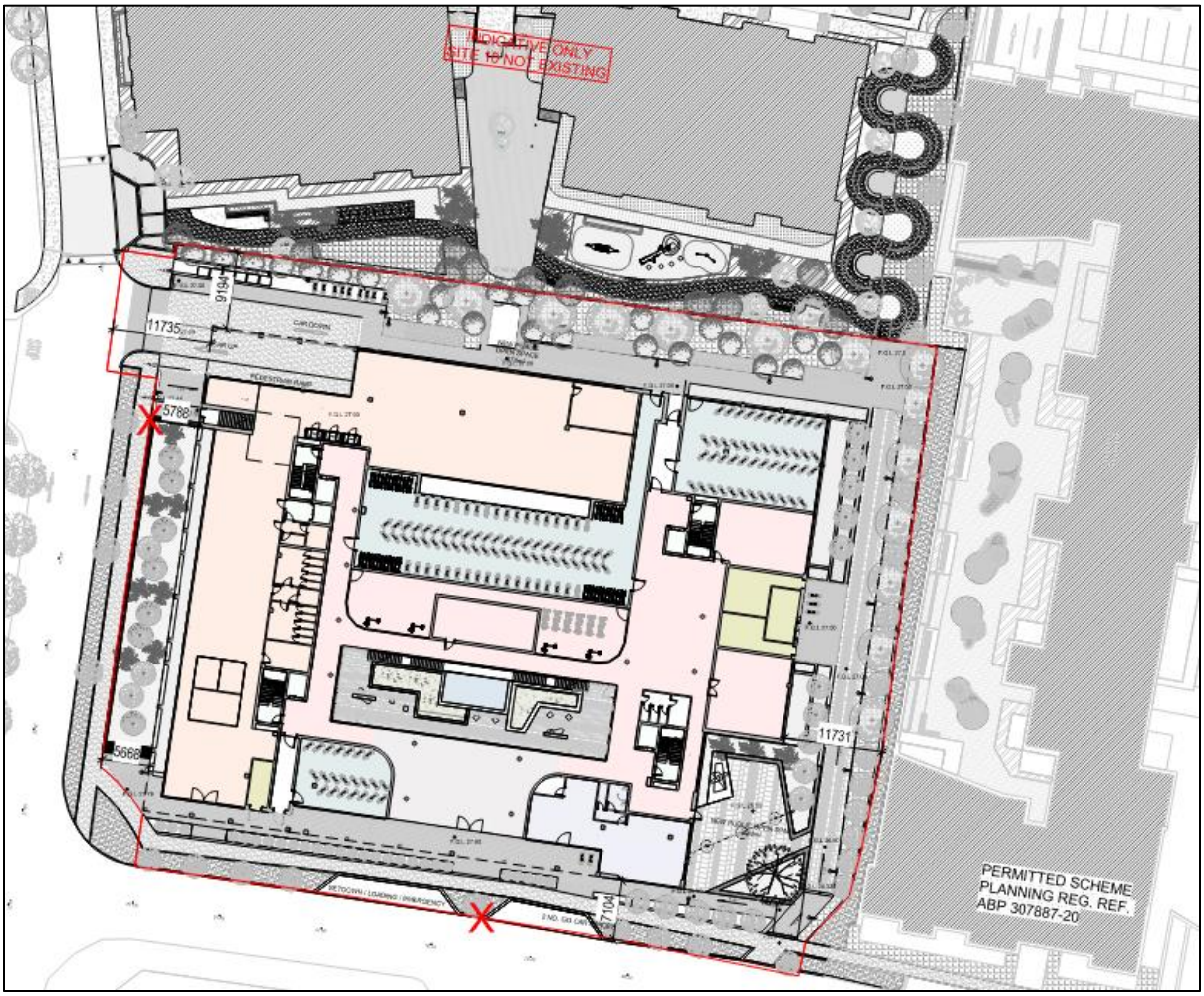


Figure 1 – Proposed Site Plan

3. PEDESTRIAN COMFORT COMPLIANCE

The Lawson criteria gives guidance to quantify the effect of wind velocity on pedestrian comfort and safety. The Lawson recommended guidance indicates that for the comfort and safety assessment of the wind environment, it is not only the velocity of wind that is considered but also the frequency of occurrence of these velocities. The frequency of occurrences is used here as an indicator of the likely duration of certain wind speeds. The Lawson criteria indicates that the threshold mean hourly wind speed for each pedestrian activity should not be exceeded for more than 5% of the time to maintain pedestrian comfort.

Pedestrian activity	Threshold mean hourly wind speed not to be exceeded for more than 5% of the time [m/s]
Business Walking	10
Leisurely Walking	8
Standing or Short Term Sitting	6
Long Term Sitting	4

Table 1: Lawson Criteria for Pedestrian Comfort

4. ASSESSMENT METHODOLOGY

The methodology adopted for the study combines the use of Computational Fluid Dynamics (CFD) to predict air flow patterns and wind velocities around the proposed development, the use of wind data from the nearest suitable meteorological station and the recommended comfort and safety standards (The Lawson Criteria).

The study considered the following factors:

- The effect of the geometry, height and massing of the proposed development and existing surroundings on local wind speed and direction;
- The wind speed as a function of the local environment such as topography, ground roughness and nearby obstacles (buildings, bridges, etc.);
- The effects of site location (open field, inner city, etc.);
- Orientation of the buildings relative to the prevailing wind direction; and
- The pedestrian activity to be expected (long term sitting, standing or short term sitting, leisure and business walking).

The wind analysis focuses on the potential variation of the wind velocities from the reference wind data due to the proposed development.

4.1. EXTENT OF CFD STUDY AREA

The extent of the built area that is represented in the computational domain is dependent on the influence of the features on the region of interest which includes the site and its nearby surroundings. The analytical CFD model analyses the proposed development with the extent of the buildings included in the study area illustrated in Figure 2.

The analytical CFD model is assessed against the full Lawson Criteria to identify the pedestrian comfort and safety conditions surrounding the development.

The analytical CFD model has been constructed based on the information provided below:

- Drawings received from Plus Architecture;
- Topographical survey drawings of surrounding buildings;
- Available aerial photographic data via Google Maps;
- Meteorological wind data for Dublin Airport.

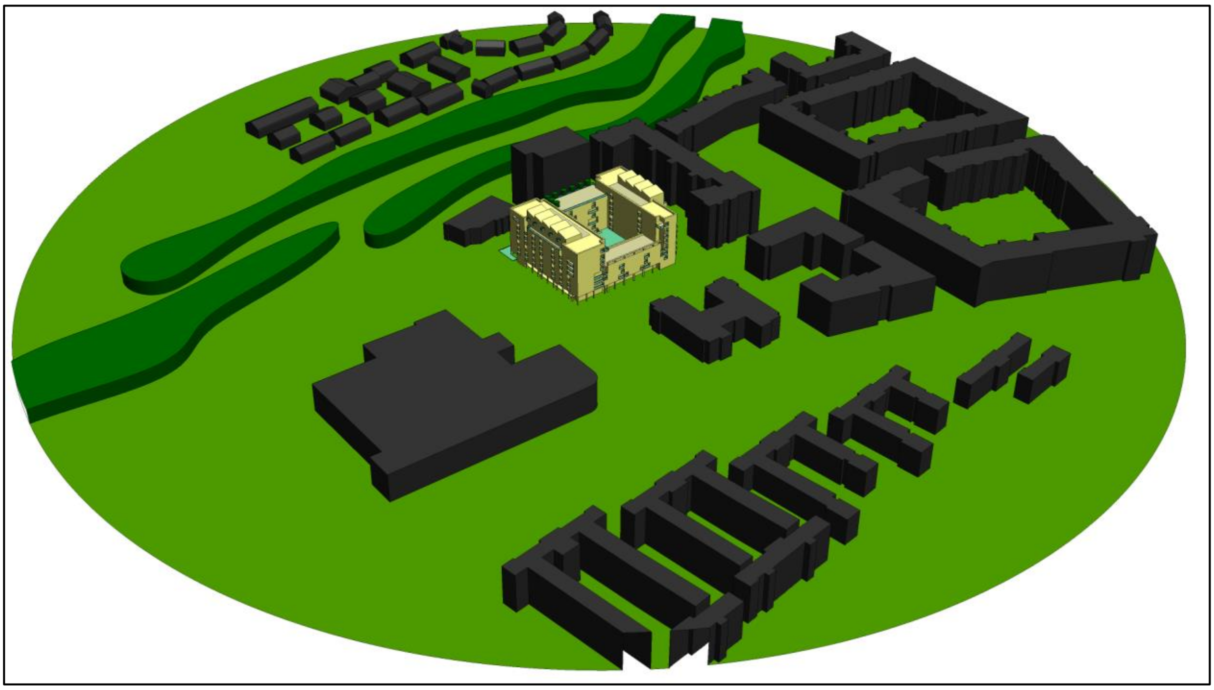


Figure 2: Extent of CFD Study Area

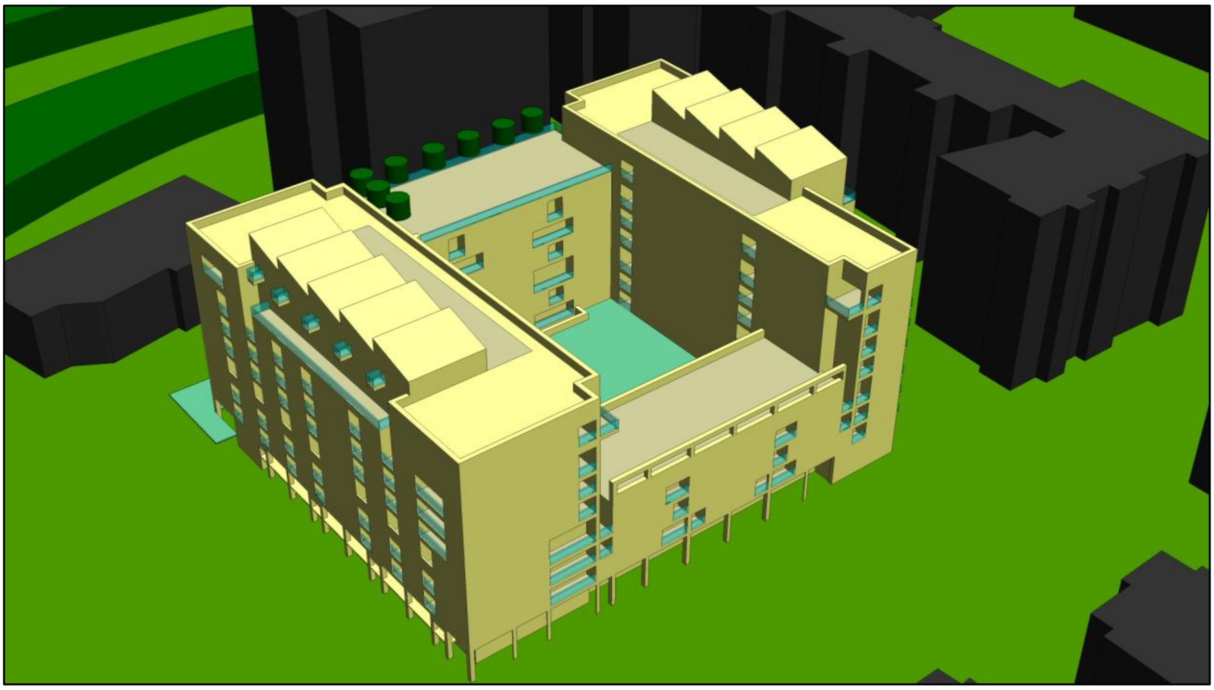


Figure 3: Rendering of CFD Model

4.2. WIND CLIMATE

The wind climate analysis is based on the wind data obtained from the Dublin Airport weather station which incorporates hourly wind data over a 30-year period (1989 until 2019). Figure 3 illustrates the percentage of hours per wind direction over a period of 30 years for 12 no. wind directions.

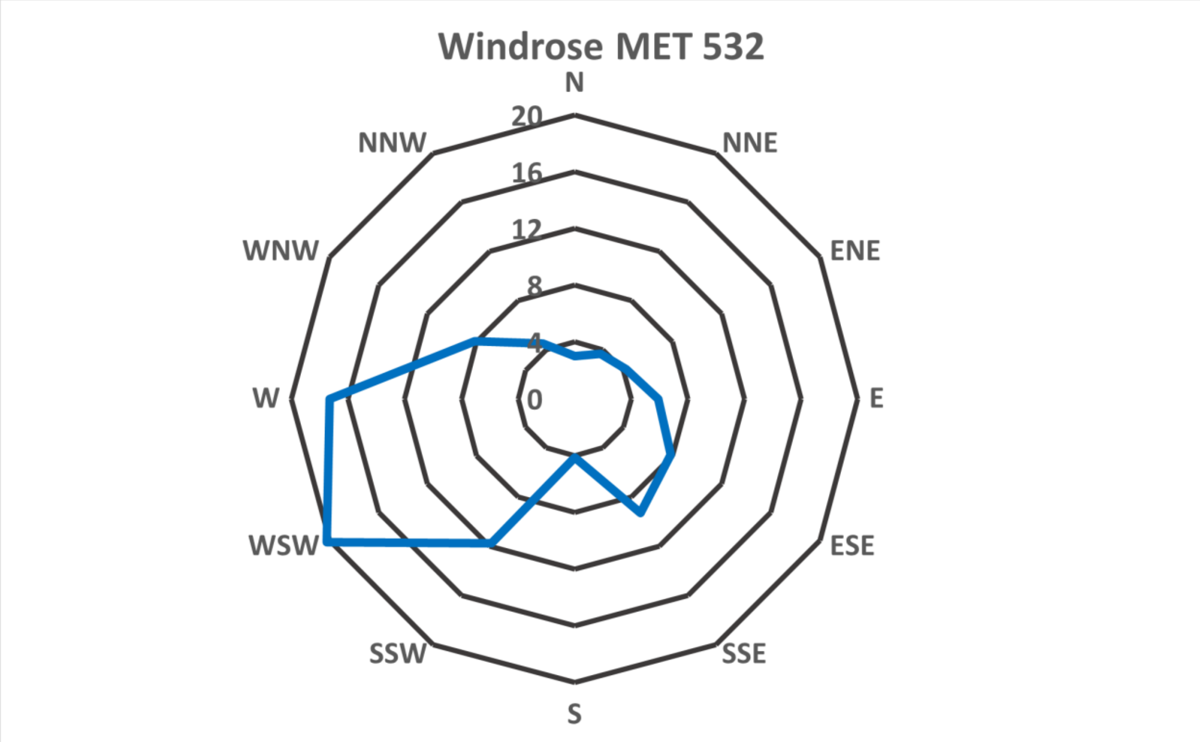


Figure 3: Percentage of Hours per Wind Direction over 30 years

The hourly wind data is the basis for the wind climate analysis. The number of hours that wind occurs from a given wind direction and velocity influences the local wind climate. The CFD simulation is used to calculate the wind-factor (local wind velocity relative to reference wind velocity). The wind-factor is a measure to calculate the number of hours that a given threshold wind velocity is exceeded based on statistical wind data. The yearly average frequency of a wind velocity occurrence per wind direction is outlined in Table 2.

Wind dir.	N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	n/a
	0	30	60	90	120	150	180	210	240	270	300	330	Still
Speed [m/s]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]	[hrs]
0-1	24	19	12	23	31	26	16	17	23	30	30	26	43
1-2	52	41	25	53	74	64	34	47	63	70	63	49	0
2-3	51	54	50	87	122	108	51	94	130	143	102	63	0
3-4	43	48	67	92	132	121	49	124	191	194	133	66	0
4-5	32	45	66	75	109	121	43	140	224	219	121	62	0
5-6	24	38	51	53	85	107	42	148	234	211	94	47	0
6-7	16	30	37	37	57	84	38	130	228	169	63	33	0
7-8	10	21	24	25	36	60	30	111	195	134	41	24	0
8-9	6	11	17	18	22	41	22	85	159	105	25	14	0
9-10	4	7	11	12	12	27	17	59	121	80	14	7	0
10-11	2	4	4	8	9	16	11	39	82	56	7	3	0
11-12	1	3	2	5	5	10	6	23	52	36	5	1	0
12-13	0	2	1	2	2	5	3	13	32	21	2	1	0
13-14	0	0	0	1	2	3	1	8	18	11	1	0	0
14-15	0	0	0	1	1	1	0	5	11	6	1	0	0
15-16	0	0	0	1	0	1	0	2	6	4	0	0	0
16-17	0	0	0	0	0	0	0	1	2	2	0	0	0
17-18	0	0	0	0	0	0	0	0	1	1	0	0	0
18-19	0	0	0	0	0	0	0	0	1	1	0	0	0
19-20	0	0	0	0	0	0	0	0	1	1	0	0	0

Table 2: Frequency of Wind Velocity Occurrence per Wind Direction

4.3. WIND PROFILE

A rectangular computational domain was created to simulate the effect of the atmospheric boundary layer surrounding the region of interest. The extents of the computational domain are illustrated in Figure 4, where H is the height of the highest tower within the proposed development.

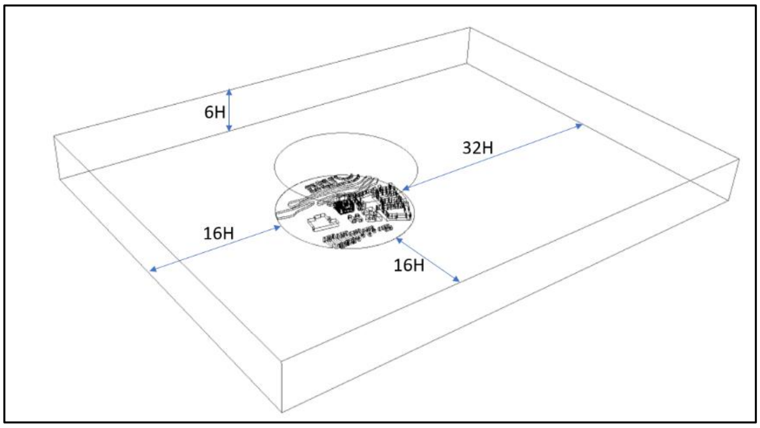


Figure 4: Computational Domain Surrounding the Region of Interest

An atmospheric boundary layer wind profile (v_{wind}) is applied to the boundaries of the computational model. To incorporate the effect of small height differences and small objects at street level, which are not explicitly included in the model, a roughness has been applied to the ground surface of the detailed CFD model. For the wind profile a roughness length (z_0) of 0.4 m has been estimated.

Based on the reference velocity, reference height, and roughness length, a wind profile can be defined. The wind profile v_{wind} is defined as follows.

$$v_{wind} = v_{ref} \cdot \left(\frac{\ln\left(\frac{z}{z_0}\right)}{\ln\left(\frac{z_{ref}}{z_0}\right)} \right)$$

Where

v_{wind}	Wind velocity	[m/s]
v_{ref}	Reference velocity	[m/s]
z	Height above the ground	[m]
z_0	Roughness length	[m]
z_{ref}	Reference height	[m]

4.4. WIND FACTOR

The CFD simulations are used to calculate the wind factor. The wind factor is a factor which indicates if the wind speed is locally increased (wind factor > 1.0) or decreased (wind factor < 1.0) due to buildings (or other geometry), relative to the applied reference wind speed at 10m height. The wind factor is independent of the magnitude of the reference wind speed at 10m height, making the obtained wind factor valid for all wind speeds in a specific wind direction range. Hence, one simulation can be applied per wind direction covering all wind speeds in this direction.

To explain the wind factor in more detail, the wind factor results for the 0-degree wind direction (i.e. North) are illustrated in Figure 5. The wind factor arrows that are coloured green, cyan or dark blue indicate that the local wind speed has been reduced (wind factor < 1.0), while wind factor arrows which are coloured light green/yellow indicate the local wind speed has increased (wind factor > 1.0). Using the wind factors, the quantity of hours that a wind speed is exceeded can be calculated (per wind direction) which is then used to assess compliance against the Lawson Criteria.
The wind factor results for all 12 no. wind directions are included in Appendix A.

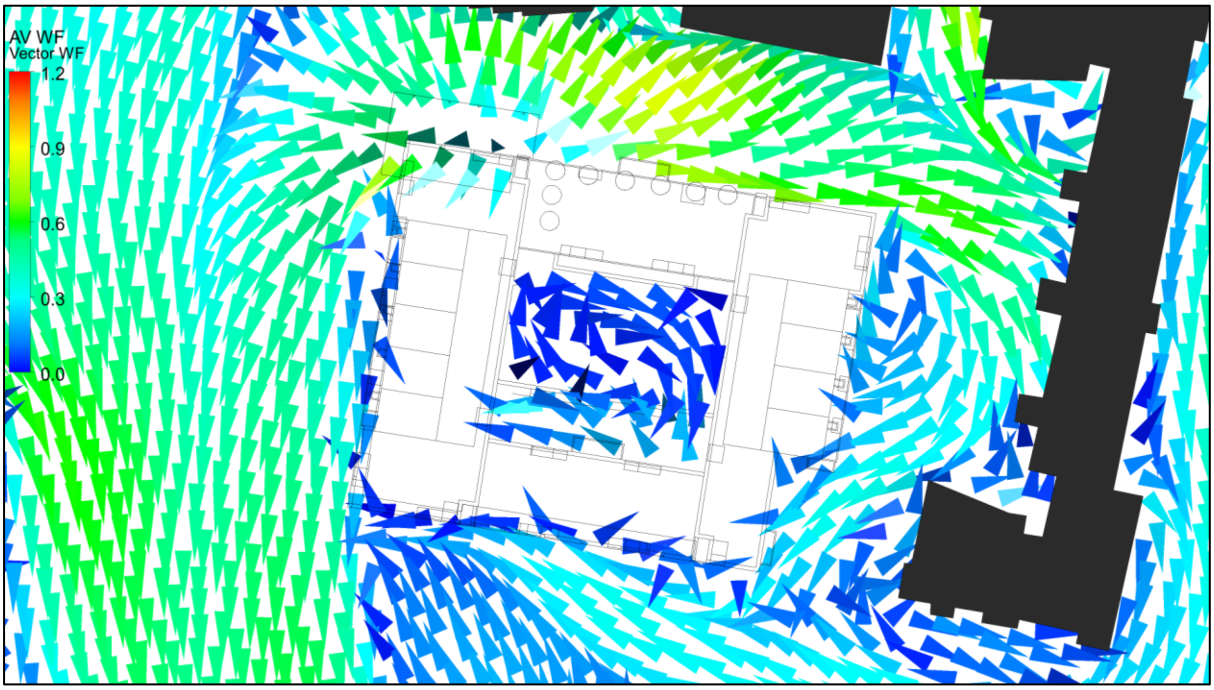


Figure 4: Wind Factor – 0 Degree (N) Wind Orientation

4.5. CFD MODELLING

The CFD simulation has been performed using the software package ANSYS CFX version 2020. This software package can be used for a large range of applications and has been extensively validated.

A full 3D CFD model of the proposed development and surrounding buildings was created and split into a large number of control volumes or cells. The standard equations for fluid motion and energy transport are applied to each cell. The equations are then solved using numerical techniques. The CFD settings used for the analysis are summarised in Table 3.

CFD settings	Description
Grid type	Hybrid, mixture of tetrahedrons, pyramids and prisms
Cell size	Dynamic, ranging from 0.025 up to 2 m at the building surfaces and streets, growing to 10 m in the volume
Number of cells	28.4 million
Simulation type	Steady state
Convergence	$< 1 \cdot 10^{-4}$
Simulation time	1500 s
Fluid	Air fixed properties
Turbulence model	RANS, RNG Kappa-Epsilon model
Walls	Smooth, no slip
Wind volume	Profile for velocity and turbulence
Roughness	Volumetric sources for momentum and turbulence
Vegetation	Volumetric loss coefficient

Table 3: Summary of CFD Model Settings

5. ASSUMPTIONS AND LIMITATIONS

Computational Fluid Dynamic (CFD) is a widely recognised method for modelling airflow problems and as computer power develops, it increasingly improves its applicability. However, there are some limitations with CFD in relation to the modelling of wind environments. The method uses mean hourly wind values and presents a limitation to capture gusts.

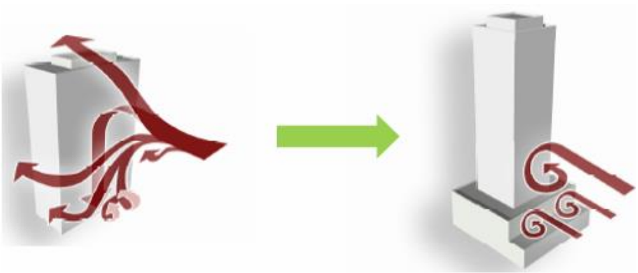
The Lawson criteria for pedestrian comfort focus on the effect of wind and do not factor in other environmental variables such as air temperature, solar radiation and relative humidity. However, overlaying all these factors would be a complex process and Lawson’s simplified method presents the best available methodology for anticipating wind effects in the built environment.

The buildings were modelled as blocks, i.e. with smooth surfaces and sharp corners, which is generally sufficient detail to represent buildings in airflow modelling. This assumption is industry accepted as further detail to the model such as the window reveals and façade texture would add an impractical and unnecessary complexity to the model without adding greater quality results. Landscaping features such as pergolas and trellis structures were not modelled within the simulation as they would provide an extra level of complexity to an otherwise large CFD model. Furthermore, a very limited number of trees and hedges were modelled locally to prove their impact on mitigating wind speeds. Incorporating all balconies, trees and hedges would be impractical on a model this size.

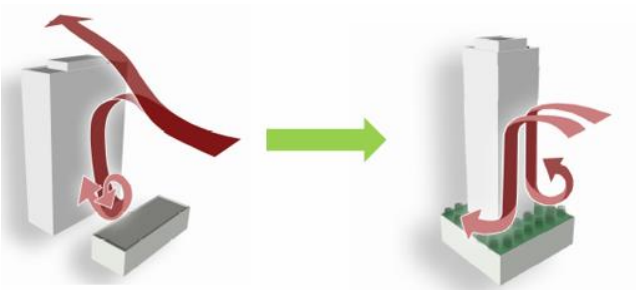
6. WIND MITIGATION MEASURES

The following are common strategies to mitigate excessive wind speeds associated with building developments[1].

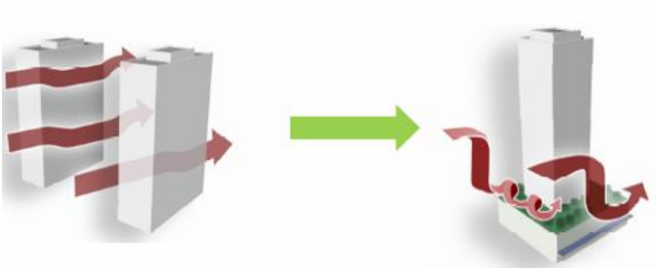
- When wind hits the windward face of a building, the building deflects the wind downwards (downwashing), causing accelerated wind speeds at pedestrian level and around the corners of the building. By introducing a base building or podium, the downward wind flow can be deflected, resulting in a reduction of wind speed at pedestrian level.



- When the leeward face of a low building faces the windward face of a tall building, it causes an increase in the downward wind flow. By landscaping the base building roof, wind speeds can be further reduced.



- Wind speed is accelerated when wind is funneled between two buildings. A horizontal canopy on the windward face of a base building can improve pedestrian comfort conditions.



[1] *Pedestrian Wind Comfort and Safety Studies,* (City of Mississauga, 2014).

The following specific mitigation measures have been incorporated into the proposed design to prevent excessive wind speeds.

6.1. COURTYARD LOCATION

The large central courtyard within the centre of the development at ground level (shown in Figure 5) has been strategically located as it is sheltered from the predominant south-west wind direction by the proposed development resulting in a comfortable environment for pedestrians using the space.

Figure 5: Wind Mitigation Measure – Courtyard Location

6.2. INSET BALCONIES

Balconies within the development are inset balconies as highlighted in red in Figure 6 below. Inset balconies offer increased wind protection for people utilising the balcony spaces.

Figure 6: Wind Mitigation Measure – Inset Balconies

6.3. LANDSCAPING

The landscaping has been strategically designed to mitigate increased wind speeds and to provide shelter for pedestrians at street level, in the central courtyard and on the rooftop terrace areas. The landscaping design incorporates covered and sheltered seating, hedge and raised planters as wind breakers, sheltered seating pockets, and pergola structures to act as wind mitigation measures.

The proposed landscaping design is illustrated in Figure 7. Trees are to be planted close to primary entrance ways and along the streetscape, mitigating excessive wind speeds and providing shelter for pedestrians at street level. The use of trees and low-level shrubs all assist in the localised reduction of wind speed. Within the central courtyard and rooftop terrace areas, the landscaping design incorporates hedge and raised planters as wind breakers, sheltered seating pockets, and pergola structures to act as wind mitigation measures. Additional wind mitigation measures such as additional landscaping and potential restructuring of the pergola will be introduced on the Northwest corner of the site to further reduce the wind speeds currently observed.

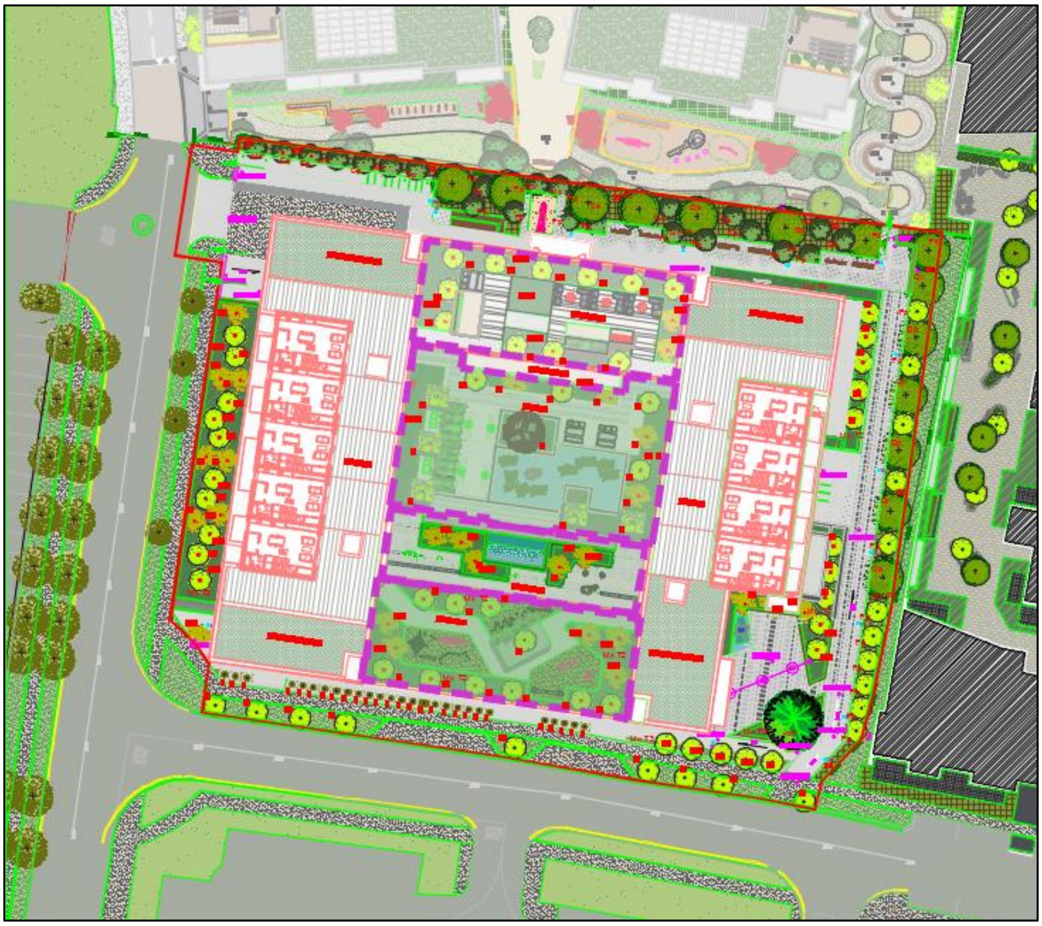


Figure 7: Wind Mitigation Measure – Landscaping Design (All Levels)

7. PEDESTRIAN COMFORT RESULTS

The number of hours for all wind directions are summed to calculate the total number of hours that a given pedestrian activity class exceeds the 5% yearly threshold with the results presented in Figure 8.

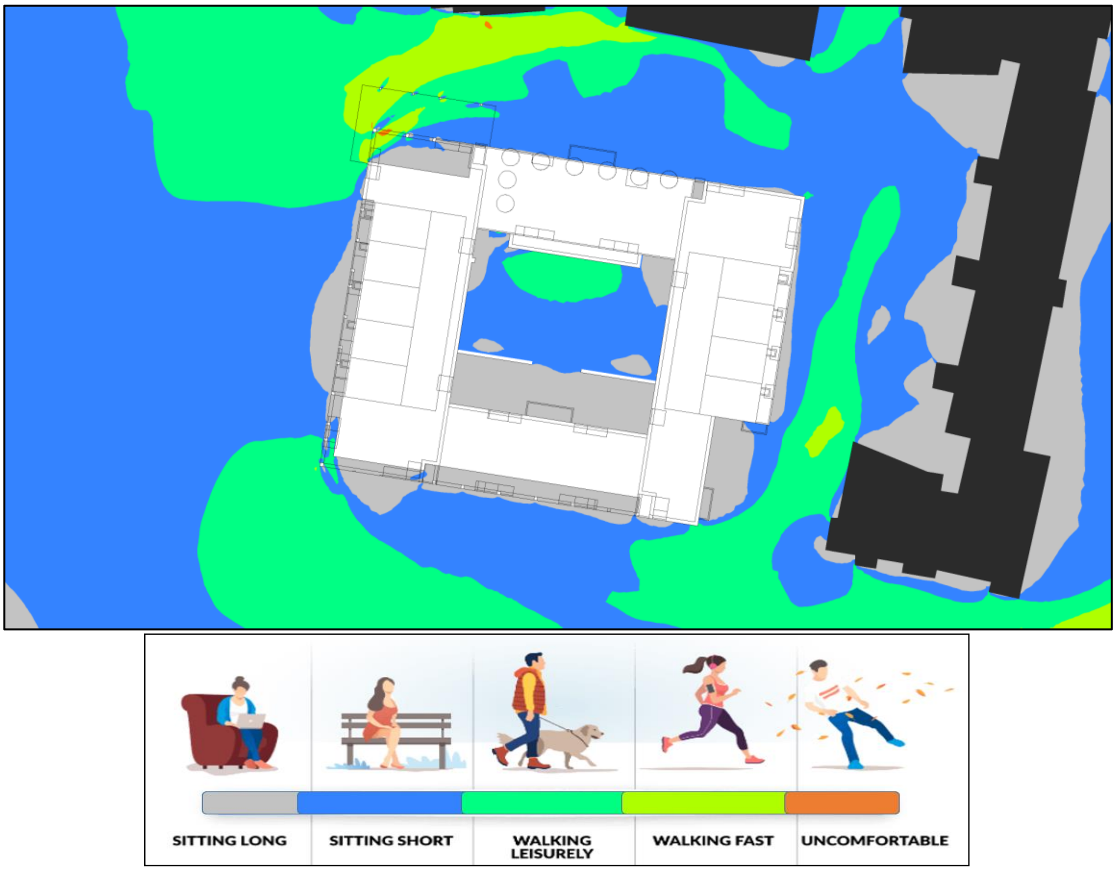


Figure 8: Pedestrian Wind Comfort Results

The results of the simulations are explained as follows:

- **Northwest Corner of Site:** The CFD results show that the majority of the classes are exceeded, however, as outlined within the limitations section of this report, mitigation measures such as a potentially expanded pergola and additional landscaping will be implemented to ensure a further reduction in wind speeds is observed.

- **Top Floor Terraces:** Trellises/Wind Break structures will be added on the East and West top floor terraces to ensure comfort for occupants.

- **Inset Balconies:** All private balconies comply with the "Long Term Sitting" class resulting in a very comfortable environment for occupants year-round.

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Following on from the above summary, it should also be noted that a pedestrian activity class is only a statistical assessment of the local wind climate. When a region does not meet a certain criterion (e.g. sitting), this does not mean that one can never do this activity in this region. It only means that for more than 5% of the time per year the wind speed for this activity is exceeded. The remaining time of the year this activity is possible. For this reason, the percentage of time that "Standing or Short Term Sitting" is comfortable is illustrated in Figure 9. It is evident from this image that "Standing or Short Term Sitting" is comfortable for more than 90% of the year on the vast majority of rooftop and podium levels, with certain areas at the street level being less comfortable. However, as outlined above, some additional landscaping features such as pergolas, small trees and hedging were not modelled due to the complexity they would add to the CFD model. The landscaping design will ensure the areas that exceed the pedestrian classes will be comfortable spaces and will mitigate excessive wind speeds.

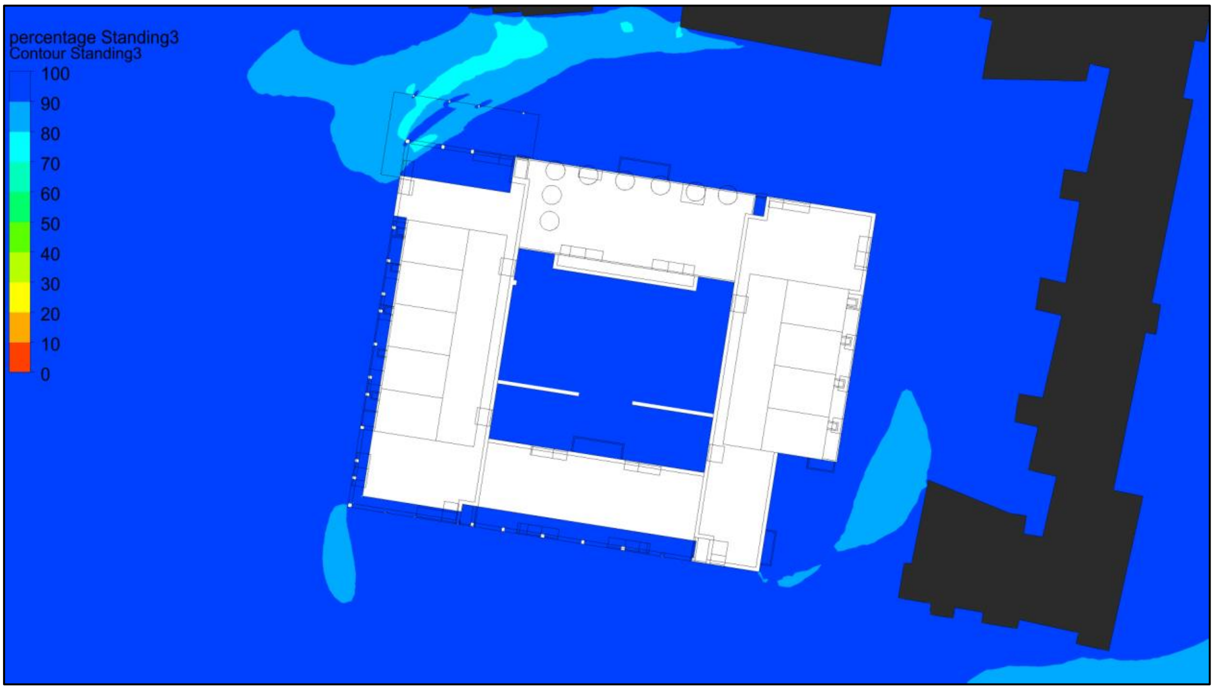
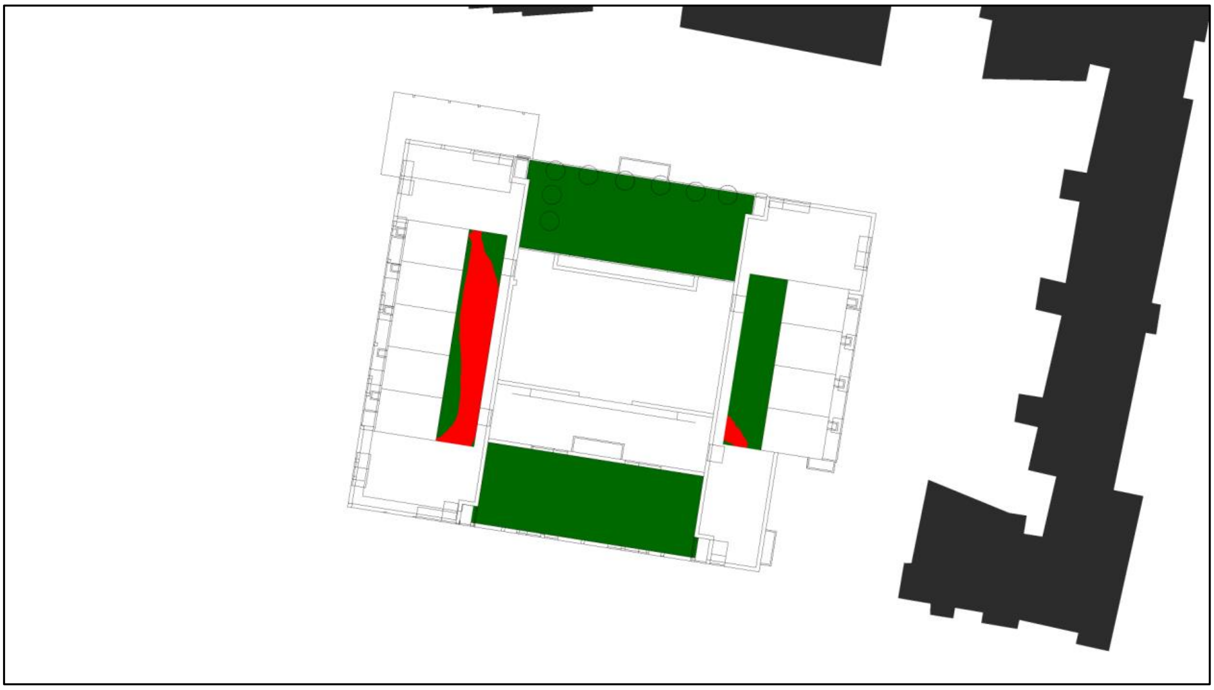


Figure 9: Percentage of Time per Year that Standing or Short-Term Sitting is Comfortable

Finally, the wind speed threshold for a certain pedestrian class is only meant to provide guidance on where to locate certain areas where a certain type of activity is expected to be performed. In practice, the experience of the outdoor climate depends on more than just wind speed. Other factors such as clothing, air temperature, solar irradiation, age and relative humidity must also be considered.

Terraces and Private Balconies Safety:

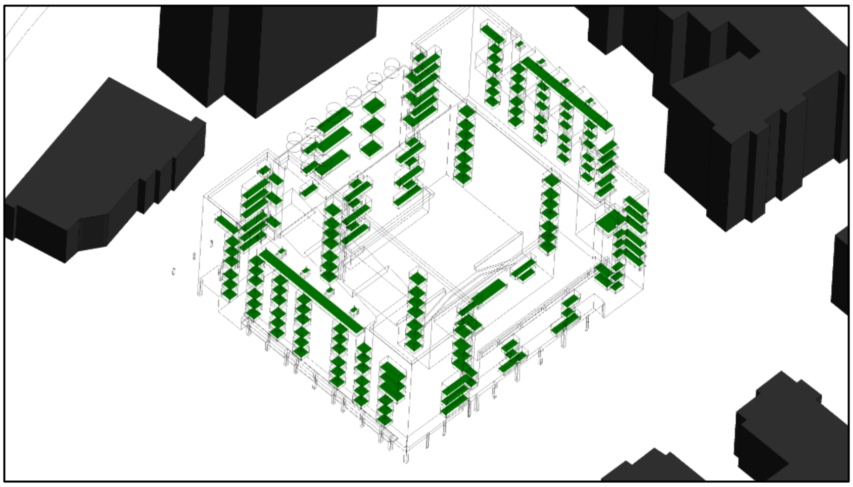
As private balconies are not considered common pedestrian areas, they have not been assessed against the typical comfort classes for pedestrian comfort. However, they have been assessed based on the safety criteria with the most stringent condition being considered, i.e. “sensitive” (refer to Table 2). Terraces have also been assessed against the safety criteria in addition to the typical comfort classes for pedestrian comfort. Based on the sensitive class, certain terraces and all private balconies are currently considered safe as illustrated in Figures 10 and 11.



Safe
Unsafe

Figure 10 - Pedestrian Wind Comfort Results Frail Pedestrian – Terraces

As shown in Figure 10, terraces on the West and one area on the East Terraces are currently not compliant with the safety criteria. To mitigate this, Trellis/Wind Break structures will be implemented in these areas.



Safe
Unsafe

Figure 11 - Pedestrian Wind Comfort Results Frail Pedestrian – Private Balconies

As shown in Figure 11, all private balconies are currently compliant with the safety criteria.

8. CONCLUSION

This report outlines the predicted climatic wind conditions experienced within and surrounding the proposed Rosemount development located at Northern Cross, Malahide Road, Dublin 17.

As part of this assessment, the industry accepted standard of the Lawson Criteria was utilised. The Lawson Criteria gives guidance to quantify the effect of wind velocity on pedestrian comfort and safety. The wind climate analysis is based on the wind data obtained from the Dublin Airport weather station which incorporates hourly wind data over a 30-year period (1989 until 2019).

A conscious effort was made by the design team during the design stages to mitigate the risk of localised increased wind speed conditions due to the proposed development. The introduction of mitigation measures such as the courtyard location, building line, inset balconies, trellis/wind break structures , as well as the strategic location of extensive landscaping, all assist in reducing the potential development of local increased wind speed and the negative impact on local climatic conditions.

Based on the CFD modelling results, the proposed development will be a comfortable environment for occupants. Certain areas have been highlighted as being potentially uncomfortable for a limited period of time, however, these concerns have been largely addressed through the incorporation of landscaping which will mitigate excessive wind speeds in these areas.

Overall, the proposed development will be a high-quality, comfortable environment for occupants throughout the year.

APPENDIX A – CFD SIMULATION RESULTS

The CFD wind factor results included in this section are for all 12 No. wind directions as referenced within the body of the report. The wind directions referenced in the wind rose below correspond to the wind directions referenced in the CFD results.

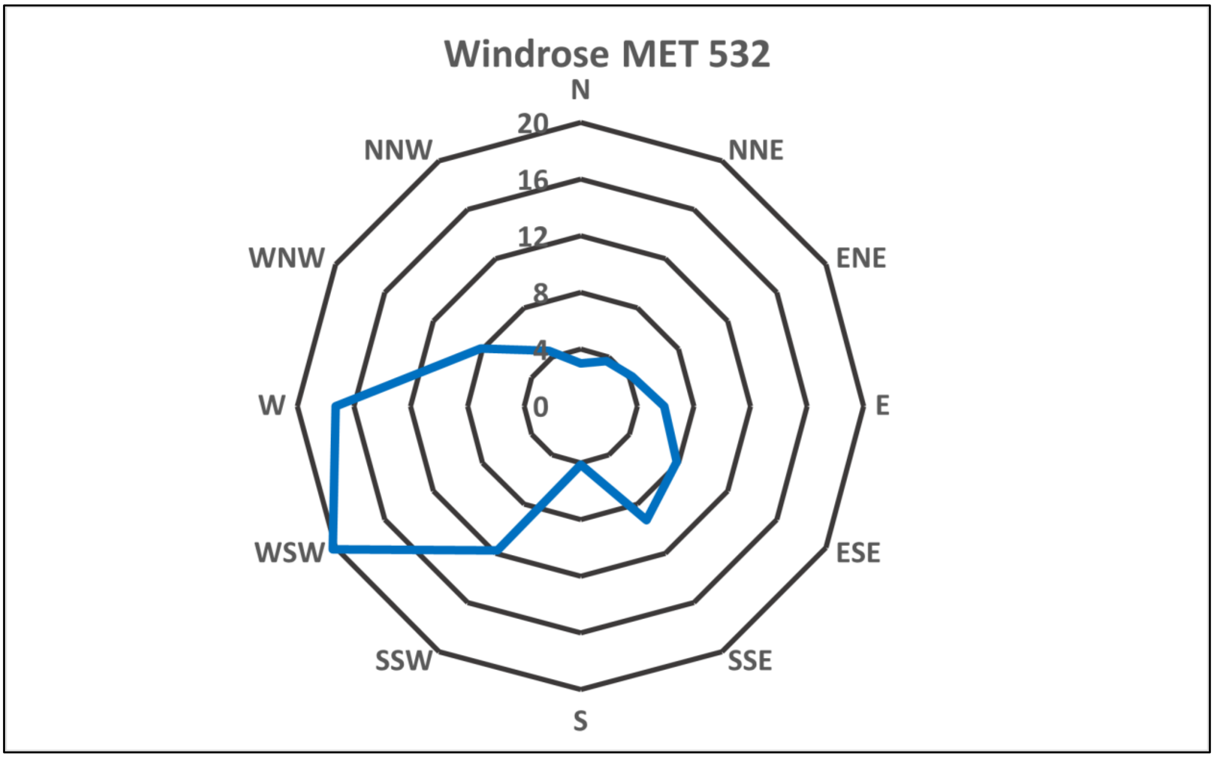


Figure 12: Dublin Airport Wind Rose Data (1989 – 2019)

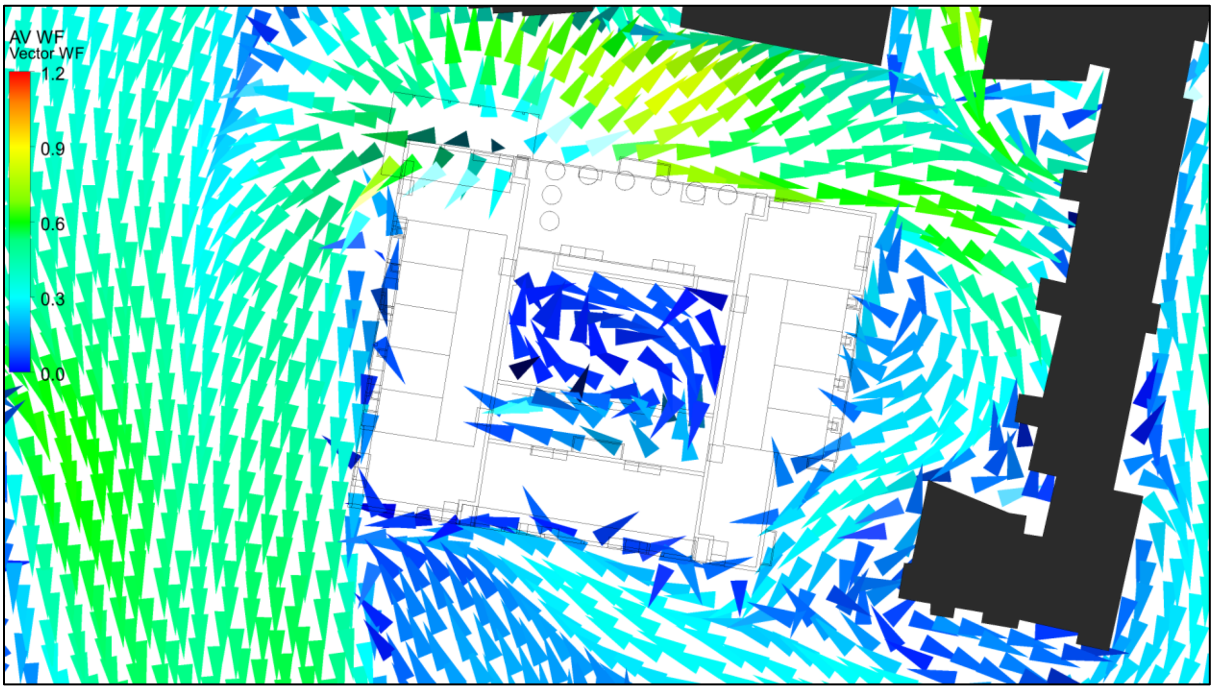


Figure 13: Wind Factor – 0 Degree (N) Wind Direction

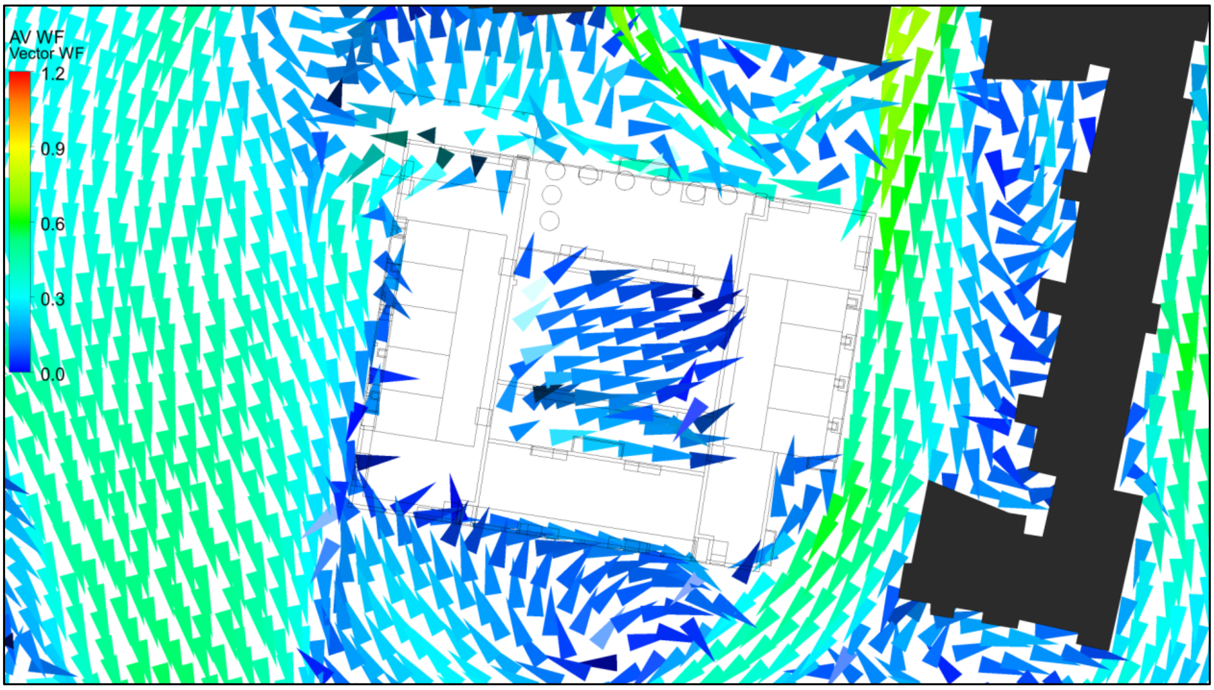


Figure 14: Wind Factor – 30 Degree (NNE) Wind Direction

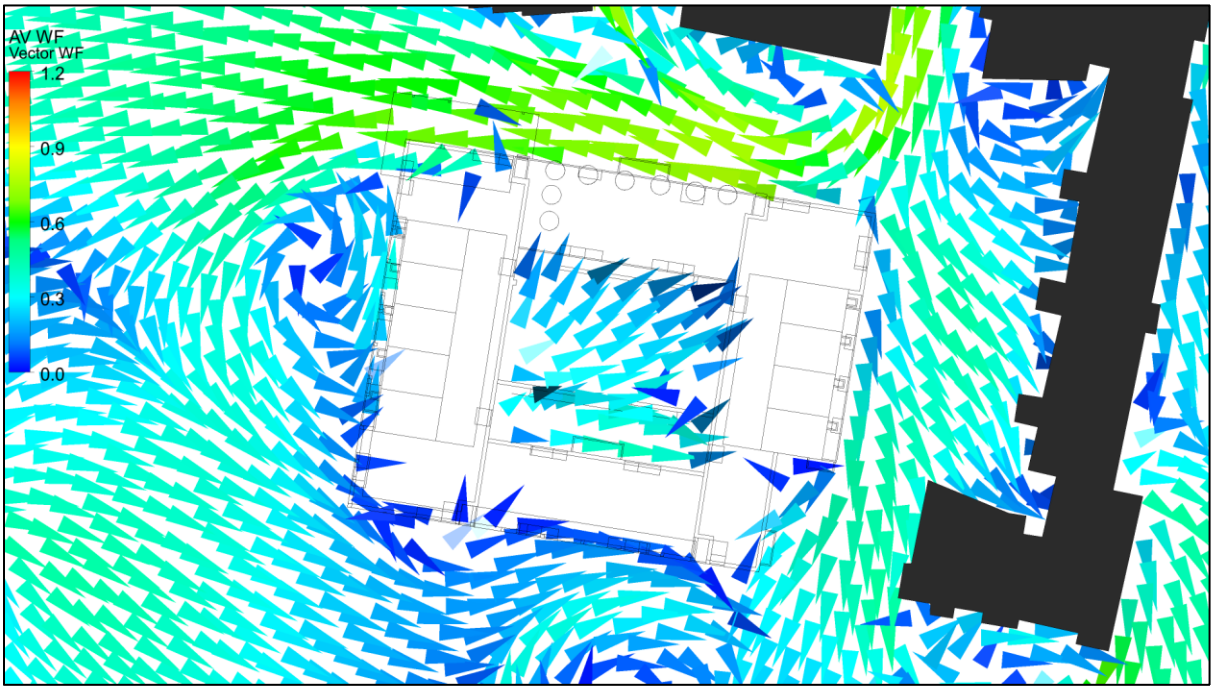


Figure 15: Wind Factor – 60 Degree (ENE) Wind Direction

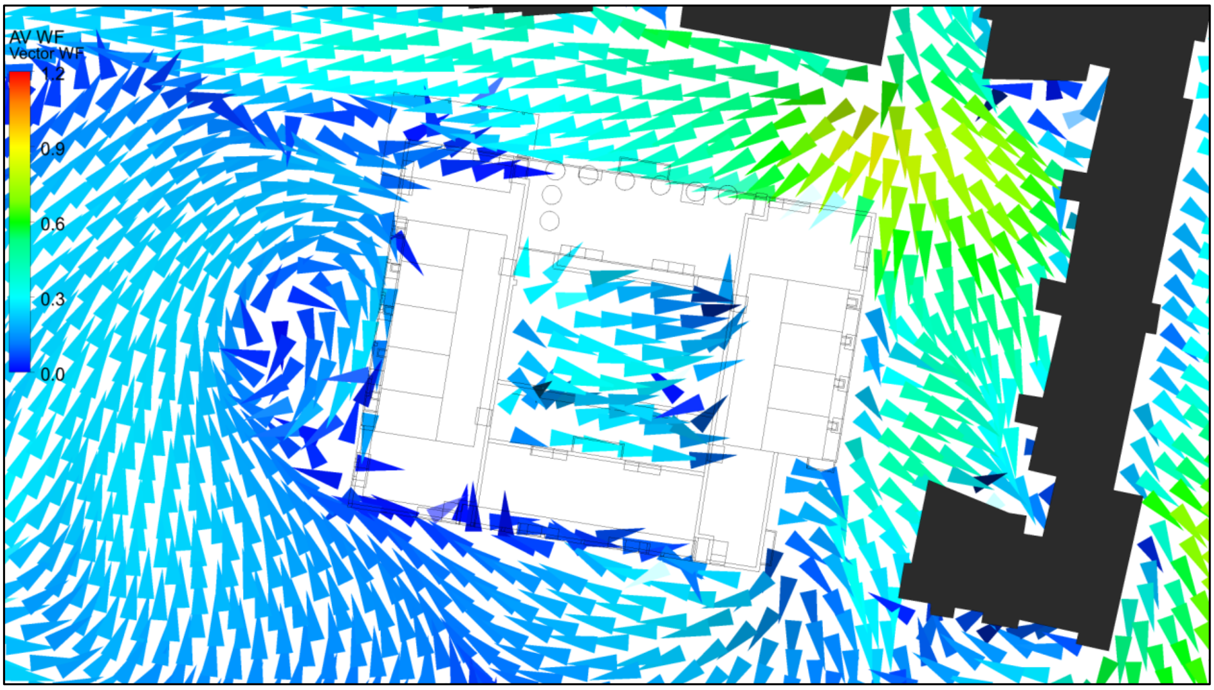


Figure 16: Wind Factor – 90 Degree (E) Wind Direction

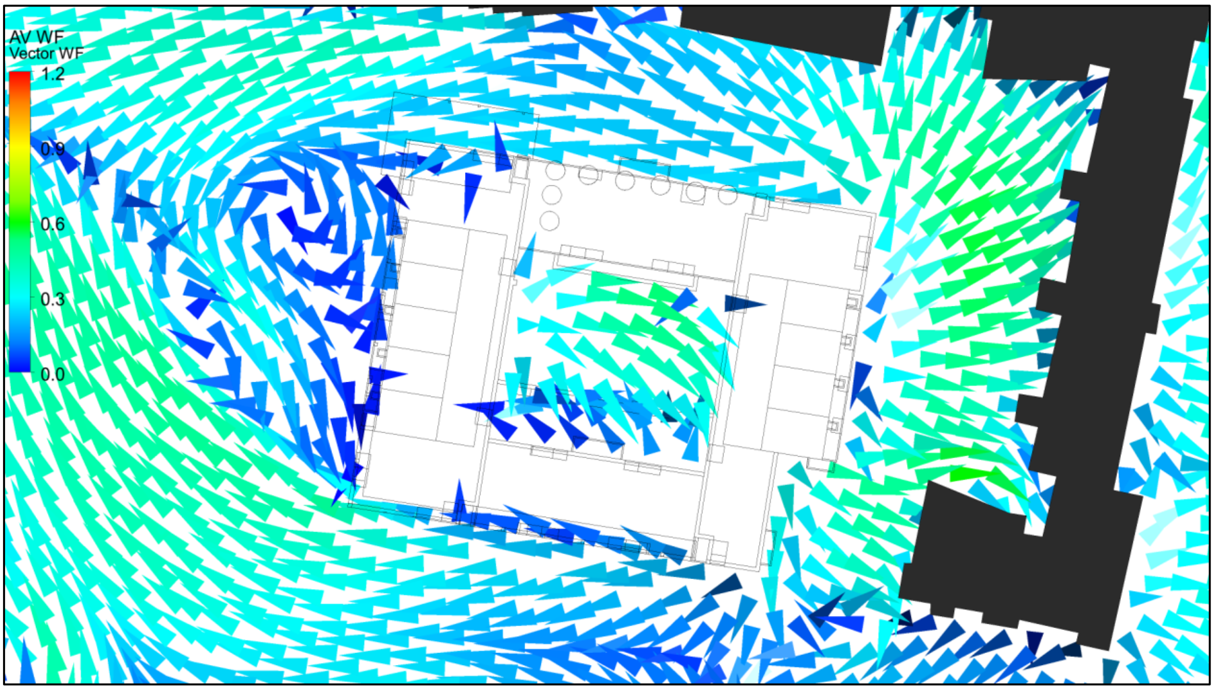


Figure 17: Wind Factor – 120 Degree (ESE) Wind Direction

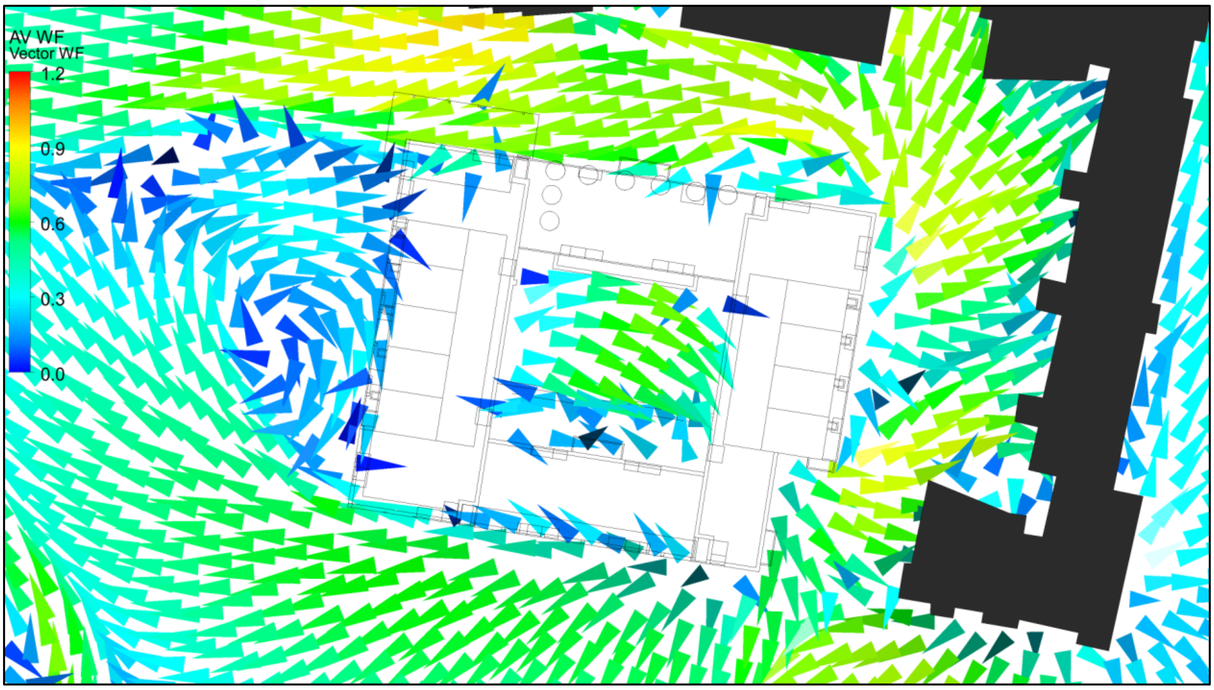


Figure 18: Wind Factor – 150 Degree (SSE) Wind Direction

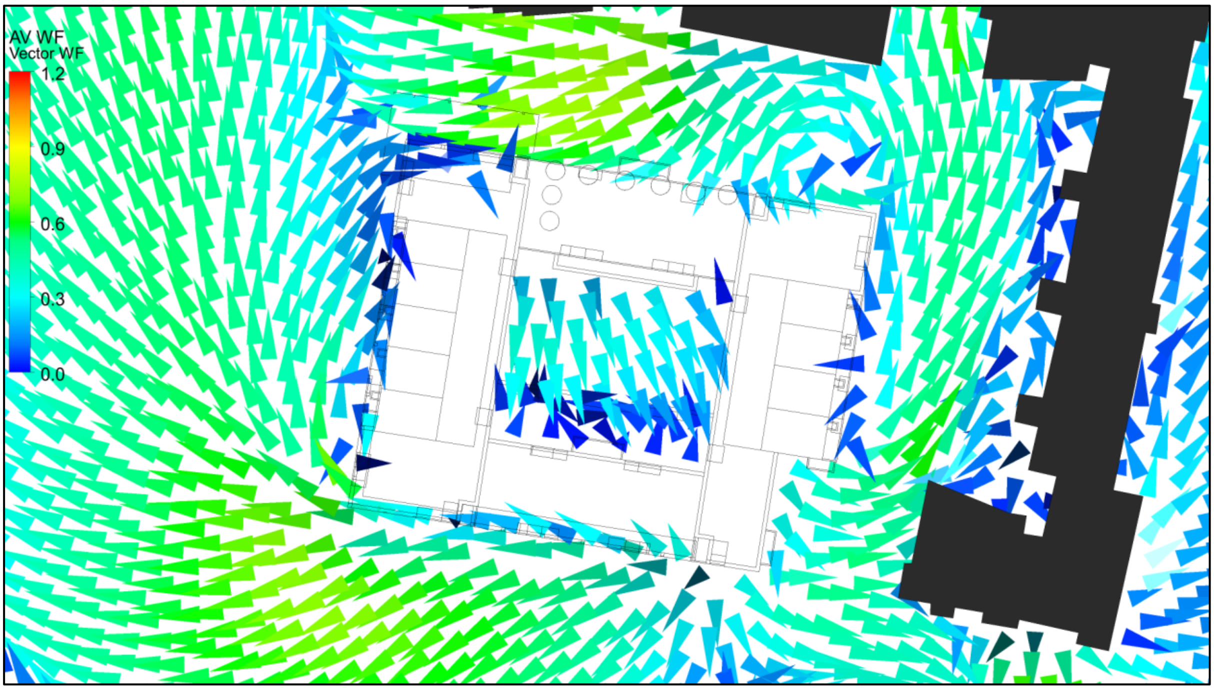


Figure 19: Wind Factor – 180 Degree (S) Wind Direction

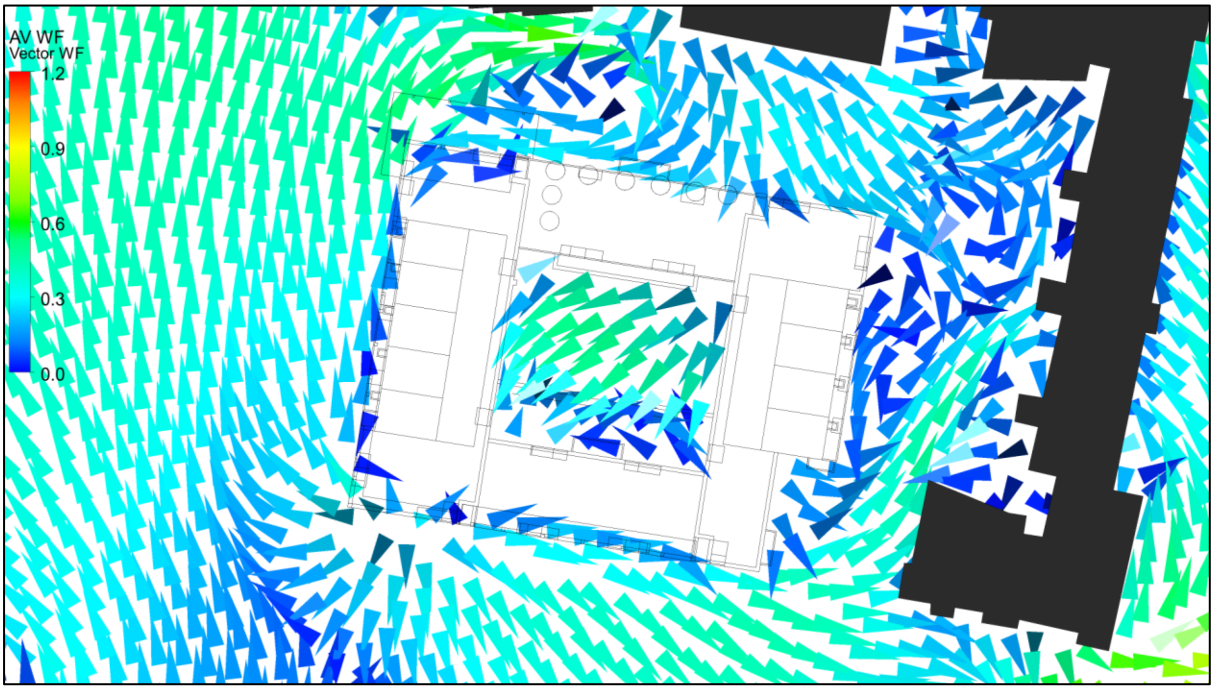


Figure 20: Wind Factor – 210 Degree (SSW) Wind Direction

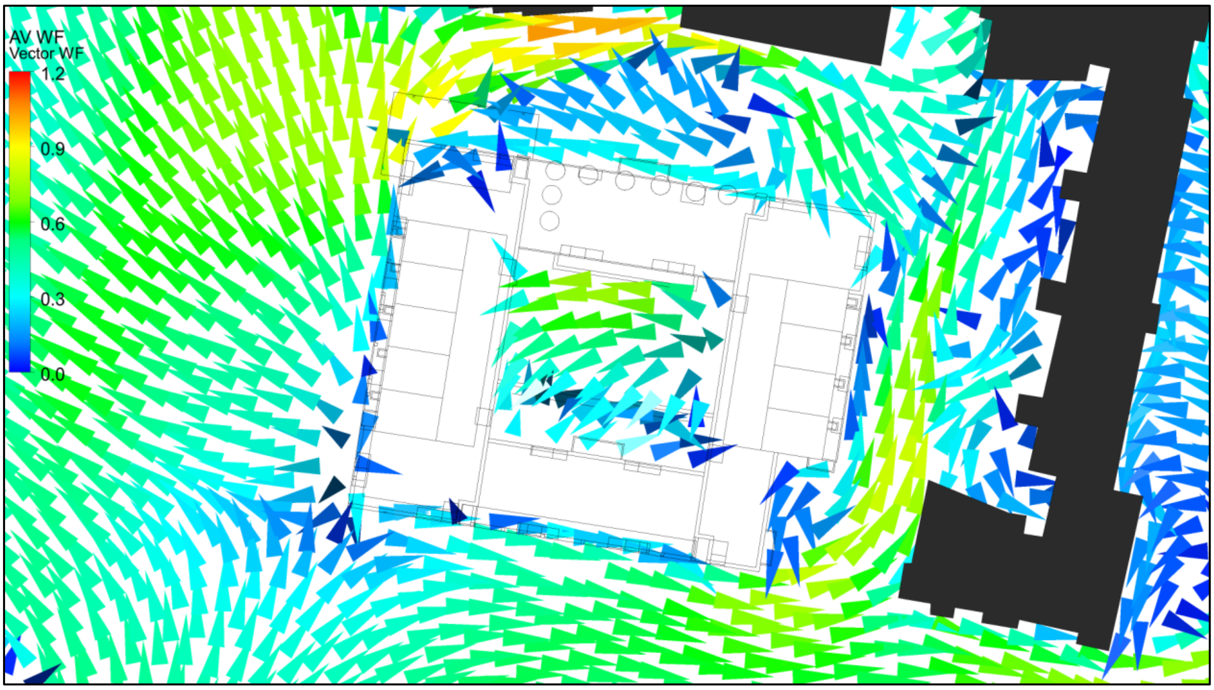


Figure 21: Wind Factor – 240 Degree (WSW) Wind Direction

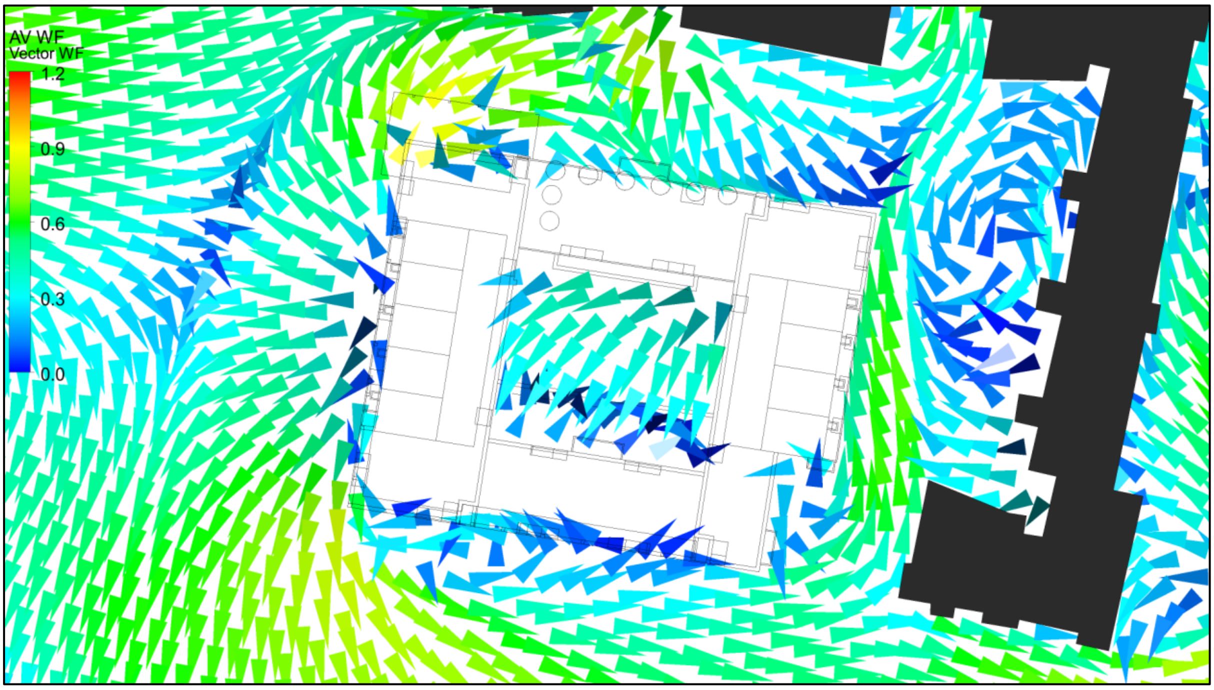


Figure 22: Wind Factor – 270 Degree (W) Wind Direction

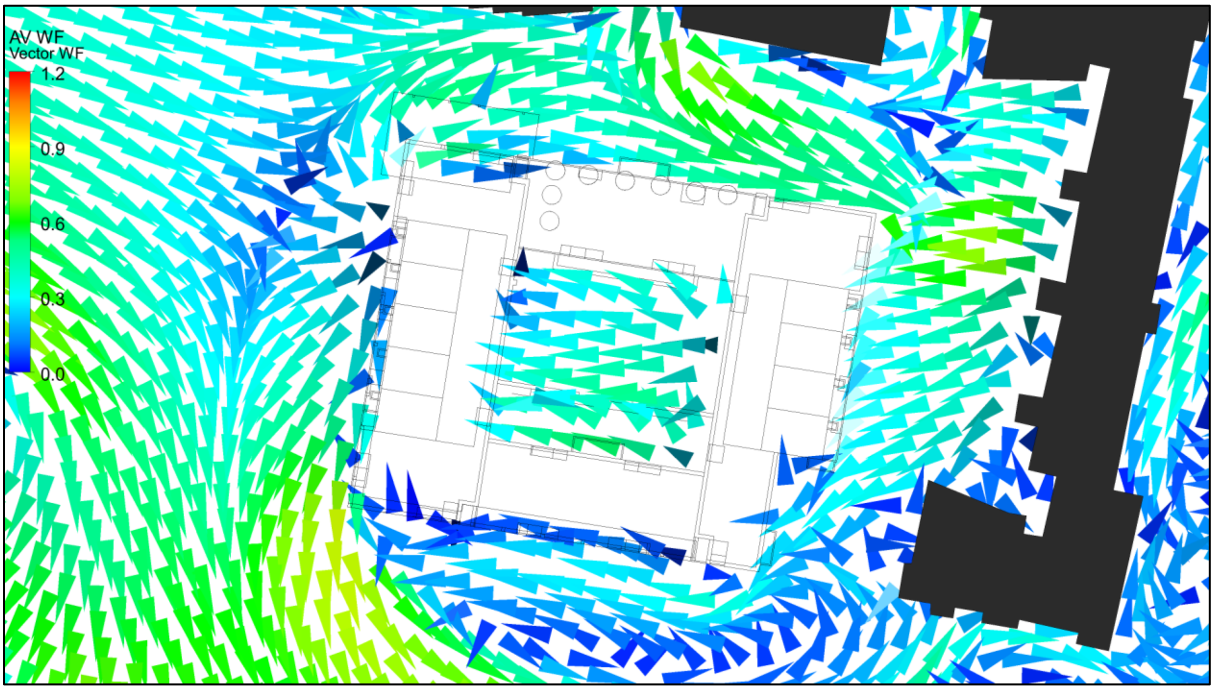


Figure 23: Wind Factor – 300 Degree (WNW) Wind Direction

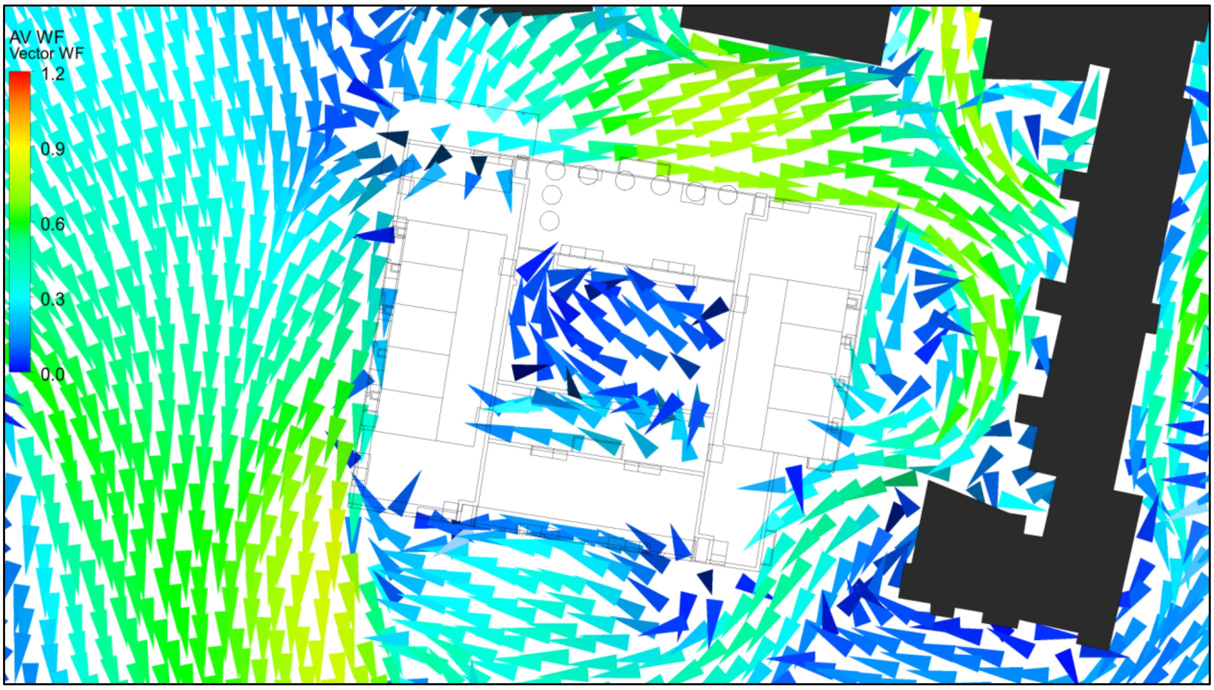


Figure 24: Wind Factor – 330 Degree (NNW) Wind Direction

OCSC

O'CONNOR | SUTTON | CRONIN

Multidisciplinary
Consulting Engineers

9 Prussia Street
Dublin 7
Ireland

T | +353 (0)1 8682000
F | +353 (0)1 8682100
W | www.ocsc.ie