Health Infrastructure

Sydney Children's Hospital Stage 1 and Children's Comprehensive Cancer Centre (SCH1/CCCC)

Environmental Wind Assessment

Wind

Revision 03 | 21 April 2021

Job number 274965

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Document verification

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Executive summary

Arup have been commissioned by Health Infrastructure to provide a quantitative wind impact assessment of the proposed development, the Sydney Children's Hospital Stage 1 and Children's Comprehensive Cancer Centre (SCH1/CCCC), on the pedestrian level wind conditions for comfort and safety in and around the site.

Three configurations were assessed:

- existing, hereafter referred to as 'existing conditions' including the Integrated Acute Services Building currently under construction to the south of the site,
- proposed SCH1/CCCC development, hereafter referred to as 'proposed development', and
- inclusion of the proposed future, neighbouring UNSW HTH building, hereafter referred to as the 'future development'.

Wind conditions are a function of the flow around all surroundings rather than individual buildings. The inclusion of large buildings generally has an impact on the wind environment making some areas windier and others calmer depending on the incident wind direction.

From a pedestrian safety perspective, all locations pass the safety conditions in the existing and proposed conditions. In the future conditions, some localised areas exceed the safety criterion. These are concentrated in the middle of Botany Street away from pedestrian footpaths, and on the raised area between the IASB and the UNSW HTH building, where a solid balustrade (recommended to be 1.8 m high at the corner section) would provide local amelioration to pedestrians.

In terms of pedestrian comfort, with the inclusion of the proposed and future buildings, the wind conditions around the site are generally classified as suitable for pedestrian standing and walking with areas suitable for pedestrian sitting, and smaller localised areas exceeding the walking criterion.

The inclusion of the SCH1/CCCC ameliorates the exceedances of the walking criterion around the north-west corner of the IASB, by transferring them to the north-west of the site south in the proposed UNSW HTH site to the south of the pedestrian pavement along High Street. These conditions are ameliorated with the inclusion of the proposed UNSW HTH building. The wind conditions on all pedestrian accessways in the surrounding streets meet the walking criteria and are therefore considered suitable for the intended use of the space. The wind conditions at all the recessed entries are calm and suitable for the intended use.

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1 Introduction

Health Infrastructure (HI) NSW have engaged Arup to provide a quantitative environmental wind assessment for the proposed SCH1/CCCC development. This report outlines the assessment and recommendations relating to the pedestrian wind comfort and safety on the ground level in and around the site.

Three configurations were assessed:

- existing, hereafter referred to as 'existing conditions' including the Integrated Acute Services Building currently under construction to the south of the site,
- proposed SCH1/CCCC development, hereafter referred to as 'proposed development', and
- inclusion of the proposed future, neighbouring UNSW HTH building, hereafter referred to as the 'future development'.

The purpose of this Report is to support the State Significant Development Application (SSDA) for the SCH1/CCCC at Randwick Hospital Campus (the project). This report responds to item 4, Environmental Amenity, of the Secretary's Environmental Assessment Requirements (SEARs) issued 2 December 2020 for (SSDA) 10831778.

The Randwick Health and Education Precinct (RHEP) is one of the most comprehensive health innovation districts in Australia. While healthcare at RHEP has been evolving for over 160 years, the last five years has seen a strengthening of collaboration amongst a wide range of organisations in the precinct, including with government, universities and community.

The project seeks to strengthen the precinct as a world-class centre for health, research, and education, driving cutting edge, compassionate and holistic healthcare and wellness programs for the local community and other residents of NSW. The project will deliver brand new, state-of-the-art paediatric health, medical research and education facilities and will assist to transform paediatric services and a key step in realising the vision for the RHEP.

1.1 Project background

The project scope includes construction and operation of a new proposed 9 storey building plus 2 basement levels and a plant room to provide:

- a new Emergency Department,
- a new Intensive Care Unit,
- Short Stay Unit,
- day and inpatient CCCC oncology units,
- ambulance access, parking, back of house, and loading dock services,
- integration with the Prince of Wales and IASB, both currently under construction,

- integration with the proposed UNSW HTH which is a proposed facility being developed for education, training, and research, and
- public domain and associated landscaping.

The project is located on the south-west corner of High Street and Hospital Road, Randwick, Figure 1.

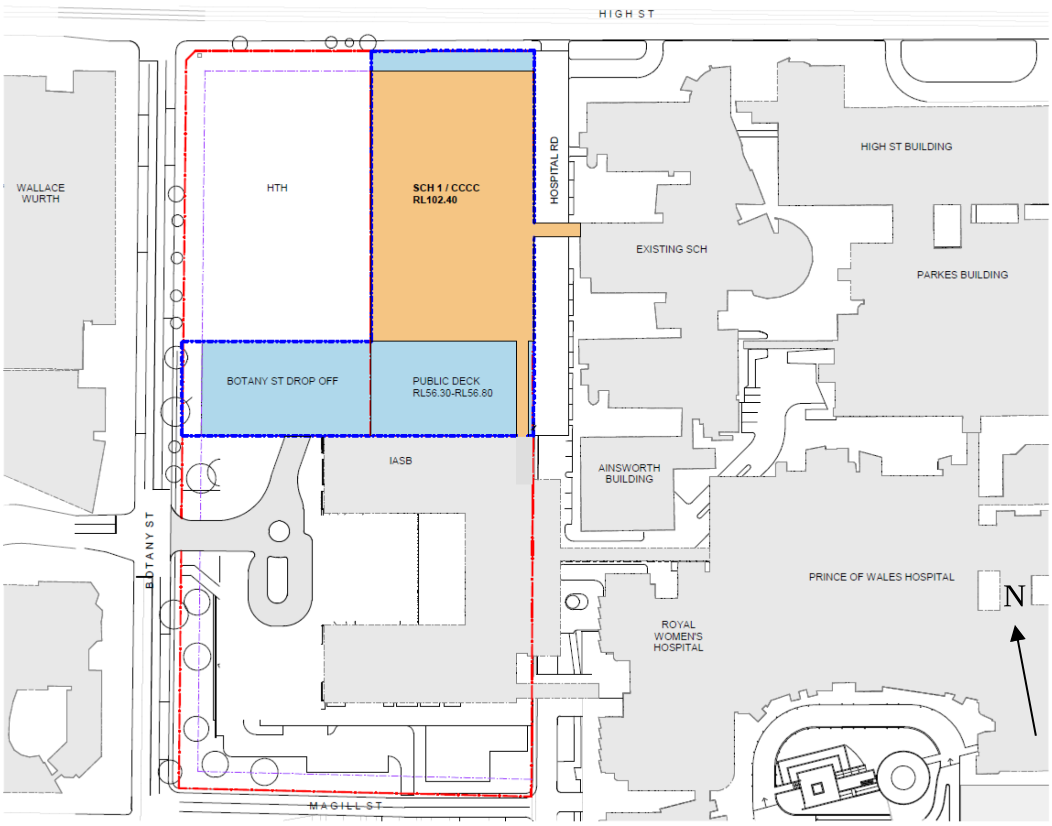

Figure 1: Indicative site plan

2 Site Description and location

The site is located approximately 6 km to the south of the Sydney Central Business District (CBD), within the Randwick Local Government Area (LGA). It is located approximately 6 km to the north-east of Sydney Airport. Figure 2 provides a context map of the site.

The site is surrounded by low-rise domestic dwellings to the north and south and medium-rise buildings to the east and west. The topography surrounding the site is essentially flat from a wind perspective dropping slightly to the south and west.

The proposed development is located on the north-east corner of the block bounded by Hospital Road, and High, Botany, and Magill Streets, Figure 3. The proposed development is located to the north of the Integrated Acute Services Building (IASB) currently under construction.

The proposed development consists of nine proposed above-ground levels with two basement levels, rising to approximately 50 m above ground level. The building is irregular in shape in the form of a U-shape open to the west, Figure 3.

At ground level, an undercroft is proposed on the north, west, and south sides. From Level 5, the building tapers back on the west aspect (in the 'U') and subsequently on the northern and southern aspects from Level 6, creating podium setbacks (approx. max. 6.7 m for western aspect and 8.6 m for northern and southern aspects). Bridge connections to the existing SCH over Hospital Road at Level 2 and at Level 1 to the IASB are proposed. There will be a bridge connection to the proposed UNSW HTH building from the south-west corner.

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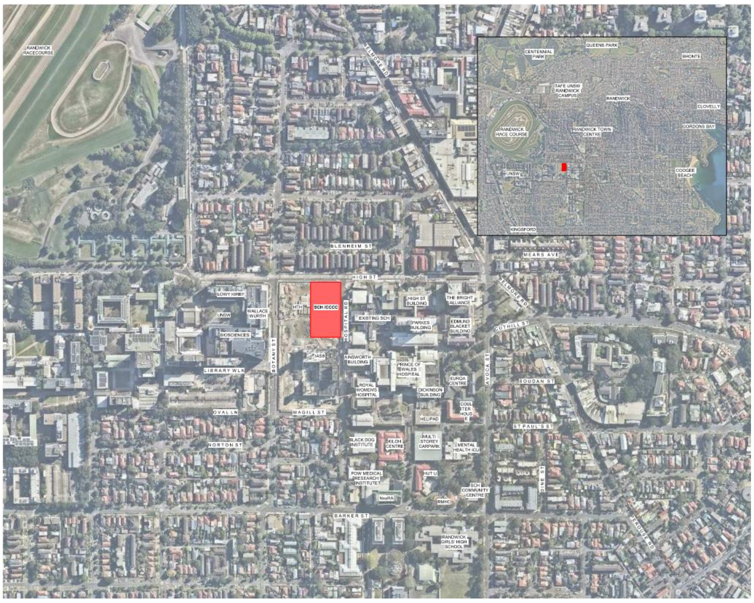

Figure 2: Site aerial (Source: Billard Leece Partnership)

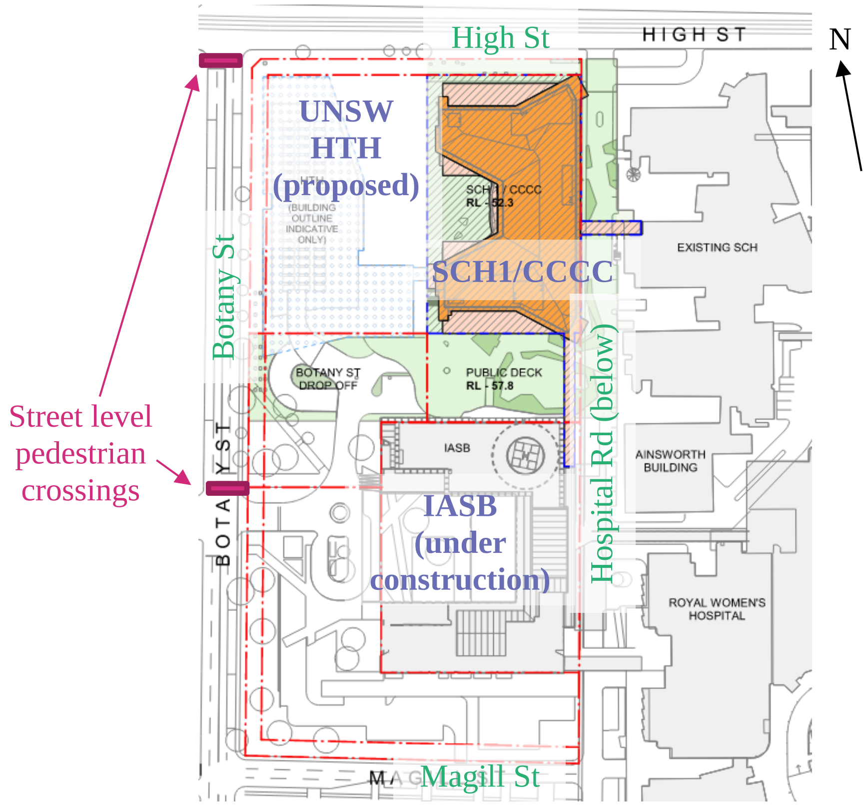

Figure 3: Site plan

3 Secretary's Environmental Assessment Requirements (SEARs)

DPIE has issued SEARs for the proposed development. This report has been prepared having regard to the relevant SEARs as referenced in Table 1.

Table 1: Applicable SEAR

SEAR	Comment / Reference
4. Environmental Amenity: *Provide a wind impact assessment, including a wind tunnel study, prepared by a suitably qualified person that considers the impact of the proposed development having regard to the surrounding development and pedestrian amenity and comfort.*	This report addresses the requirements providing a quantitative wind impact assessment prepared by a suitable qualified person. Quantification has used benchmarked numerical modelling techniques instead of physical (wind-tunnel) modelling as this allows investigation of the wind climate across the entire modelled volume rather than at discrete locations.

4 Local wind climate

The wind frequency and direction information measured by the Bureau of Meteorology anemometer at a standard height of 10 m at Sydney Airport from 1995 to 2017, between hours of 6 am and 10 pm when the hospital will be more trafficked and the winds are stronger, have been used in this analysis, Figure 4.

The Sydney Airport anemometer is located about 7 km to the south-west of the site. The arms of the wind rose point in the direction from where the wind is coming from. The directional wind speeds measured here are considered representative of the wind conditions at the site.

It is evident from Figure 4 that strong prevailing winds are organised into three main groups centred about the north-east, south, and west directions.

Strong summer winds occur mainly from the north-east and south quadrant. Winds from the south are associated with large synoptic frontal systems and generally provide the strongest gusts during summer. North-east winds often improve thermal comfort on hot summer days.

Winter and early spring strong winds typically occur from the west quadrants. West quadrant winds provide the strongest winds affecting the area throughout the year and tend to be associated with large scale synoptic events that can be hot or cold depending on inland conditions.

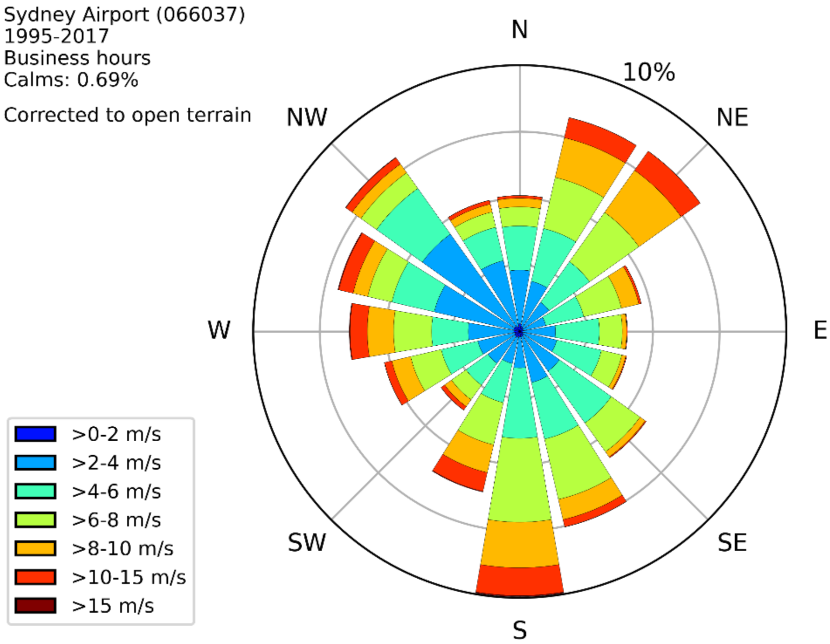

Figure 4: Wind rose showing probability of time of wind direction and speed

The measured mean wind speed is about 5 m/s, and the 5% exceedance mean wind speed is 9.5 m/s.

A general description on flow patterns around buildings is given in Appendix 2.

5 Specific wind controls

Wind comfort is generally measured in terms of wind speed and rate of change of wind speed, where higher wind speeds and gradients are considered less comfortable. Air speed has a large impact on thermal comfort and are generally welcome during hot summer conditions. This assessment is focused on wind speed in terms of mechanical comfort.

There are no specific defined wind controls applicable to this project. The criterion used for the study are used internationally and based on the work of Lawson (1990), described in Figure 19 and Table 2.

Table 2: Pedestrian comfort criteria for various activities

Comfort (max. of mean or GEM wind speed exceeded 5% of the time)	
<2 m/s	Dining
2-4 m/s	Sitting
4-6 m/s	Standing
6-8 m/s	Walking
8-10 m/s	Objective walking or cycling
>10 m/s	Uncomfortable
Safety (max. of mean or GEM wind speed exceeded 0.022% of the time)	
<15 m/s	General access
<20 m/s	Able-bodied people (less mobile or cyclists not expected)

Transferring the 5% exceedance wind speed measured at 10 m in open country terrain, to pedestrian level in suburban conditions similar to the site, would result in a wind speed of about 6 m/s, which would be on the boundary of the classification between pedestrian standing and walking. This is considered representative of the known wind conditions in this area.

6 Computational Fluid Dynamics (CFD) assessment

6.1 Methodology and modelling

The numerical CFD simulations were conducted for the proposed development using steady-state Reynolds-Averaged Navier-Stokes (RANS) method. The urban context including surrounding buildings within a radius of 500 m around the site was explicitly modelled, Figure 5 and Figure 6. Topography surrounding the site is included in the model. The context is placed in a much larger domain based on best practice guideline for the CFD simulation of flows in urban environment, Figure 7.

A computational mesh was constructed comprising of approximately 25 million hexahedral elements, Figure 8. The grid resolution is finest around the proposed building where greater resolution is required. The computational mesh size increases with distance from the regions of most interest. Other mesh sizing controls including varying the level of mesh refinement were used to more accurately capture the effects of important surrounding buildings from an aerodynamic perspective. Mesh sensitivity study was conducted to reduce the effect of mesh size on the solution.

The effect of terrain outside the 1.2 km diameter urban context was implicitly modelled using rough wall functions reproducing the roughness characteristics corresponding to suburban, Terrain Category 3 (TC3) as defined in Standards Australia (2011). The wind speed and turbulence profiles corresponding to TC3 were employed at the inlet boundary. Simulations were conducted for 16 wind directions at 22.5° increments.

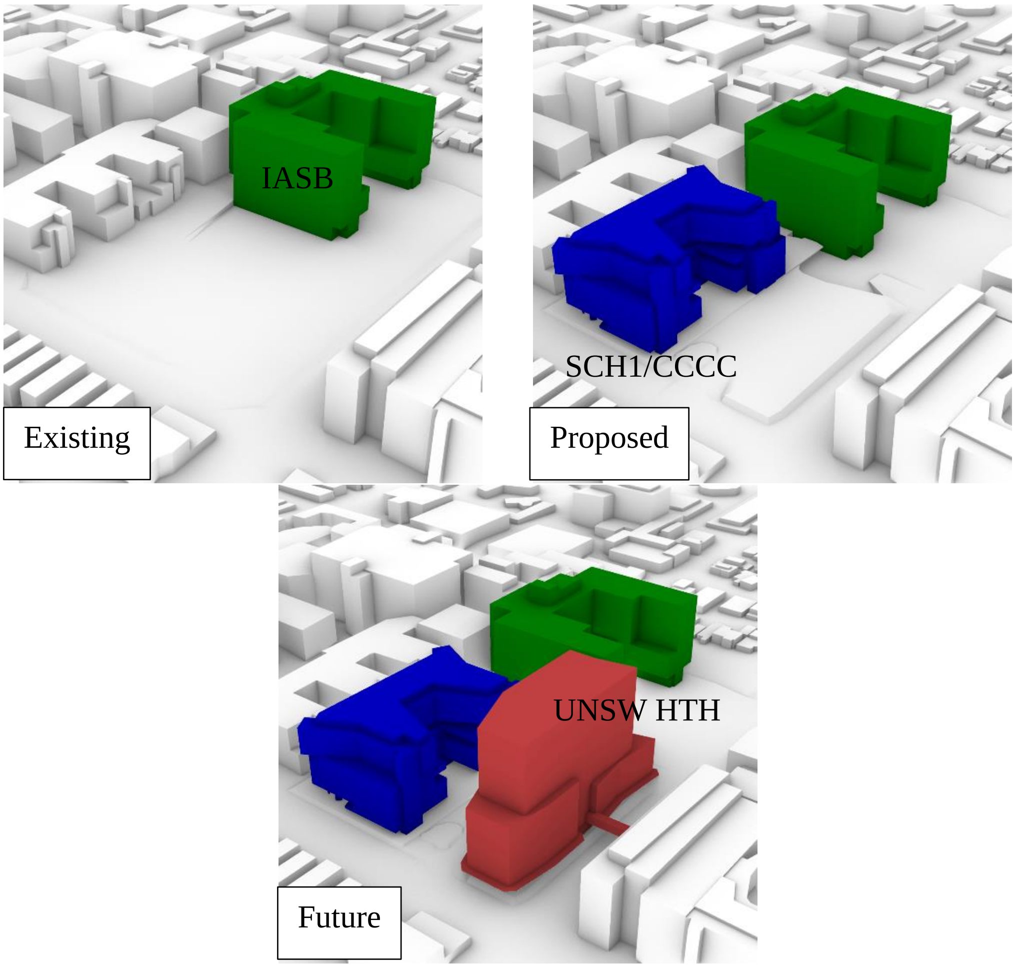

Figure 5: 3d models for the various configurations, viewed from the north-west

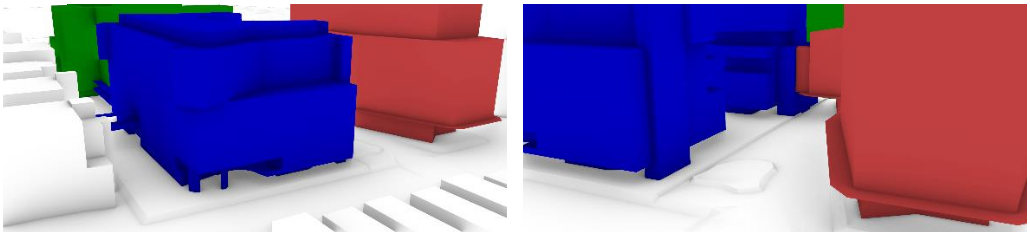

Figure 6: Close-up view from north-east (L), and from north-west(R)

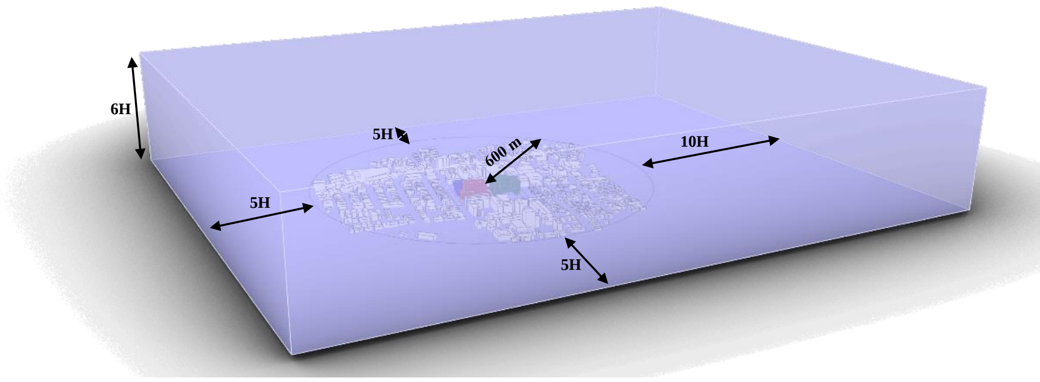

Figure 7: Simulation domain (dimensions in metres; 'H' represents subject building height)

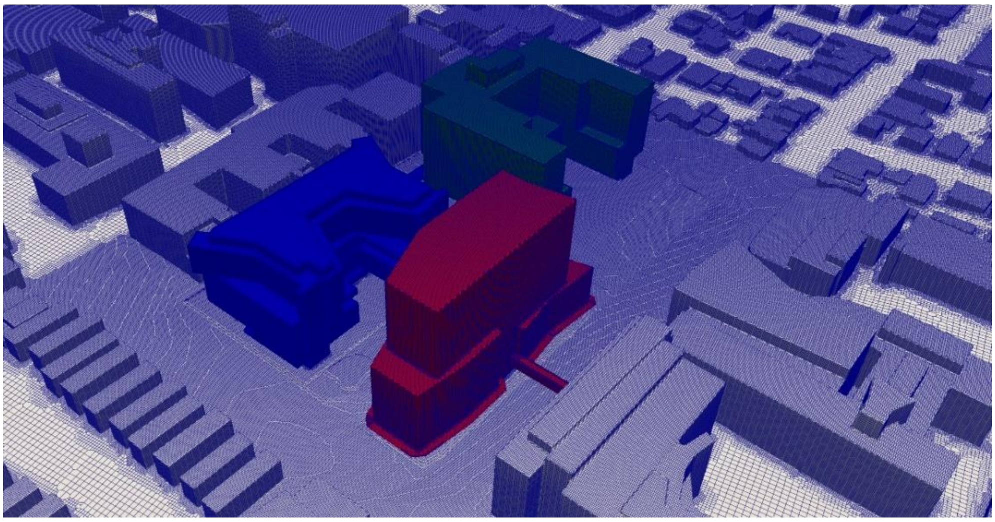

Figure 8: Mesh strategy and grid resolution in future configuration

The CFD setup followed the best practices and guidelines for simulating flow in urban environments (Franke, 2011). Probes at different locations around the site and parameter residuals were used to monitor the convergence of the results and ensure the solution reached a steady state solution.

6.2 Wind conditions on ground level

Contour maps of wind speed ratio at pedestrian level at pedestrian height of 1.5 m above the local ground level for 16 wind directions are presented in Appendix 1. The extension of the assessed area around the site is aligned with guidelines for pedestrian wind effects criteria, AWES (2014). The wind speeds over the entire surface are integrated with the local wind climate data presented in Section 4 for assessment against the Lawson criteria for pedestrian comfort and safety. For assessment against the criteria, the Gust Equivalent Mean (GEM) is calculated based on measured turbulent kinetic energy. Considering isotropic turbulence, standard deviation of wind speed can be calculated using:

$$\sigma = (2/3k)^{0.5}$$

where k is turbulent kinetic energy. Using mean wind speed and standard deviation, GEM can be determined based the equation in Appendix 3. The maximum of GEM and mean wind speed is statistically analysed to provide the comfort classification based on 5% of the time exceedance and indicative safety rating based on 0.022% of time in accordance with the Lawson wind criteria. Contour maps showing the directionally integrated safety and comfort classifications are presented in Figure 10 and Figure 11 respectively.

It is evident from Figure 10 that the wind speed exceeding 0.022% of time during business hours increases with the inclusion of the additional larger buildings. With the inclusion of SCH1/CCCC, the wind conditions at all locations pass the safety criterion. The inclusion of the larger proposed UNSW HTH building causes minor exceedances of the safety criterion:

- in the middle of Botany Street to the south, for winds from the north-west, Appendix 1. This is not considered to be an issue as the existing and proposed street level crossings are at the intersection of High Street and Botany Street and further south, at the intersection at the Gate 11, Figure 3. These locations are remote from the strongest wind conditions on Botany Street,
- locally under the south-west undercroft of the proposed UNSW HTH building, caused by the specific design of the proposed UNSW HTH building, and
- locally at the perimeter of the elevated walkway between IASB and SCH1/CCCC for winds from the south-west quadrant being funnelled between the buildings. Pedestrians would be unlikely to be close to the perimeter during strong wind events. The form of the perimeter balustrade, not included in the model, would have a beneficial impact on the local wind conditions if it were solid. It is recommended that a solid balustrade of 1.8 m high around the corner section is incorporated, Figure 9.

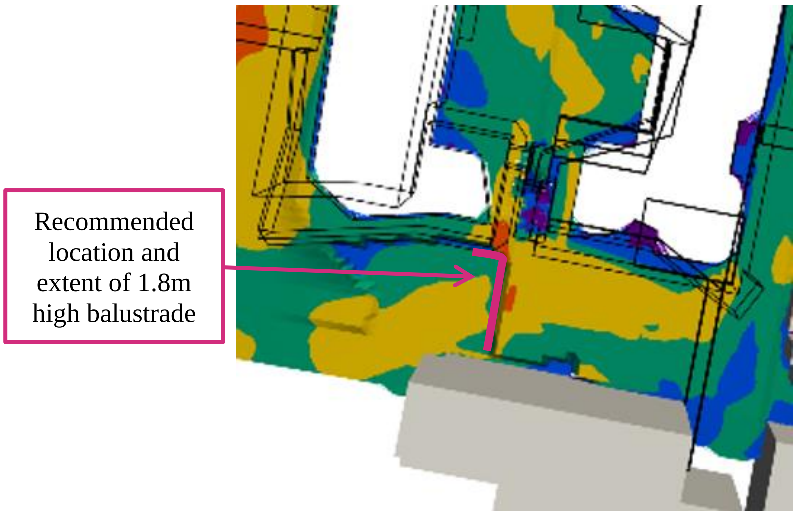

Figure 9: Recommended location and extent of 1.8 m high balustrade

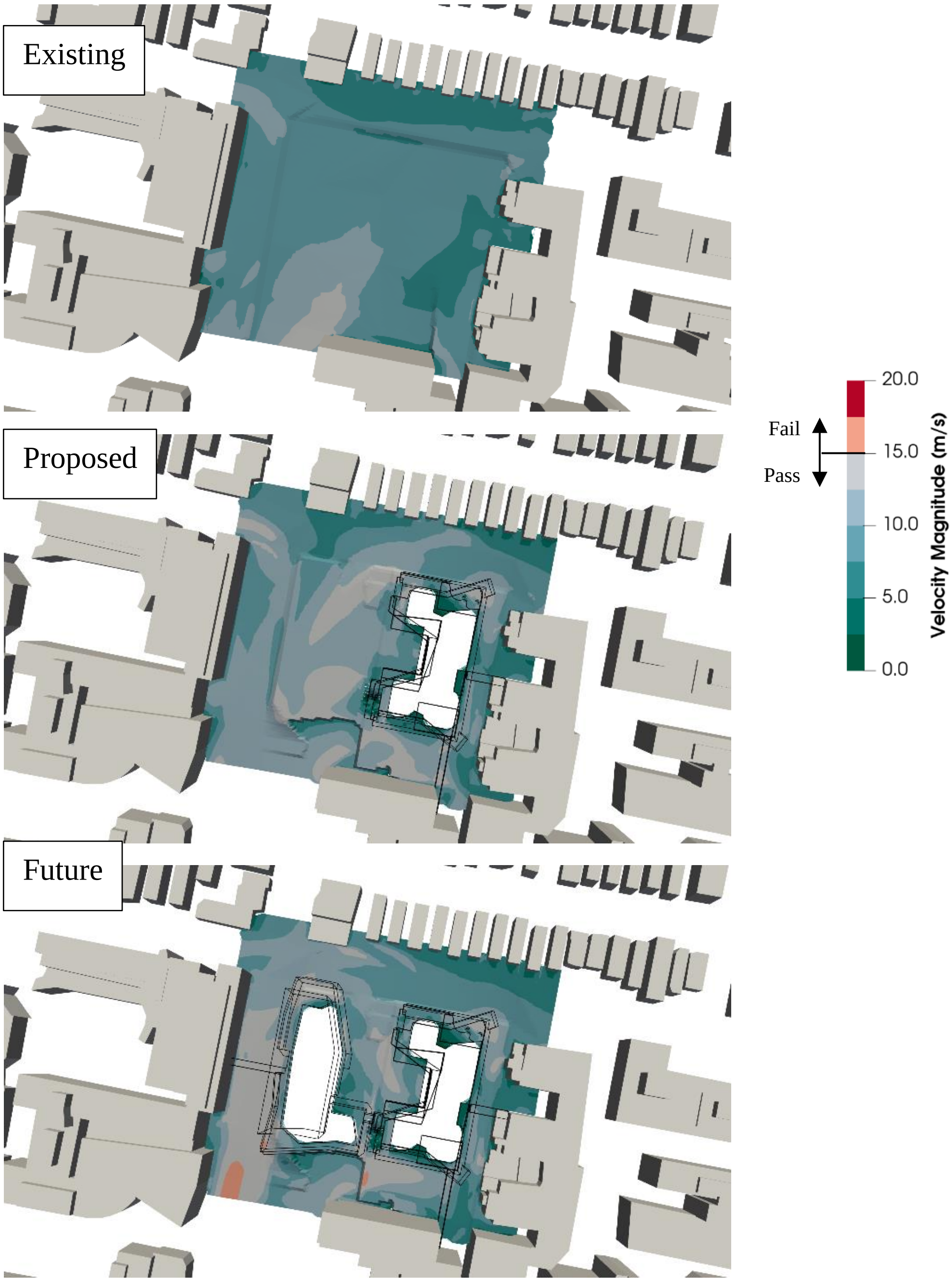

Figure 10: Classification of wind safety at 1.5 m above local ground level

The contour map of wind comfort classification is presented in Figure 11. The directional results have been integrated with the wind climate and colour coded to match the criteria classification categories.

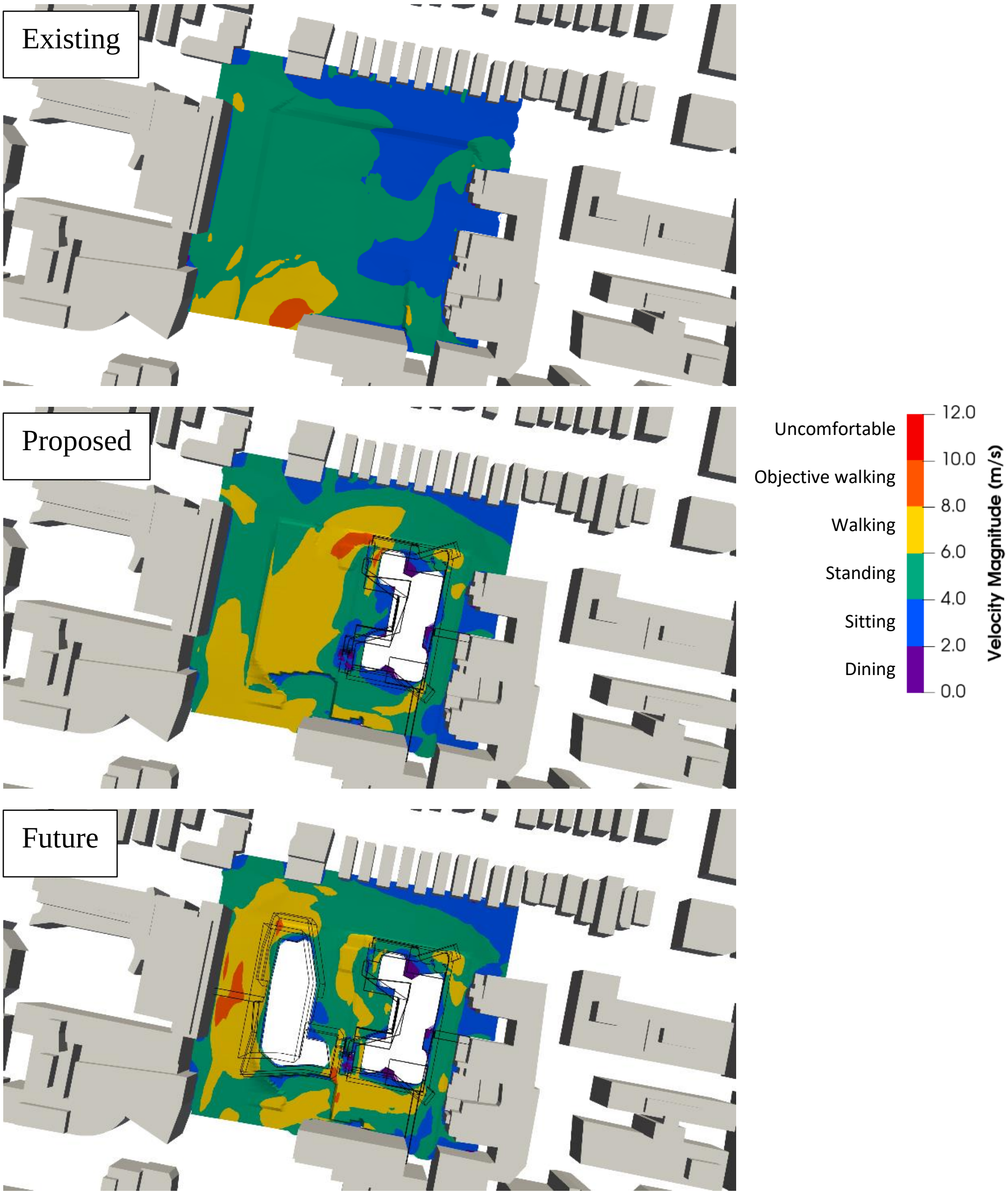

Figure 11: Classification of wind comfort at 1.5 m above local ground level

In the existing configuration, it is evident from Figure 11 that the wind conditions across the site are generally classified as suitable for sitting and standing activities, with walking conditions experienced around the exposed corners of the taller Wallace Wurth Building and IASB. There is a zone of exceedance of the walking criterion around the north-west corner of the IASB primarily caused by winds from the north-east and west quadrants.

The inclusion of the proposed SCH1/CCCC next to the neighbouring large buildings, increases the compound massing hence causes a general increase in the wind speed in the local surrounding area, with most areas being classified as suitable for pedestrian standing and walking. These conditions are suitable for the intended use of the spaces. The wind conditions at the recessed entries to the building are calmer, classified as suitable for pedestrian sitting. The wind conditions exceeding the walking criterion around the north-west corner of the IASB in the existing configuration are mitigated with the inclusion of the SCH1/CCCC and transferred to north-west corner of the SCH1/CCCC. The size of the area exceeding the walking classification is reduced due to the local architectural geometry. These conditions occur for winds from the north-east and extend across the proposed UNSW HTH site south of the pedestrian accessible area. There is a small area exceeding the walking classification under the west colonnade. This could be ameliorated by blocking the flow under the colonnade along the north and west sides.

With the inclusion of the future proposed UNSW HTH building, the general wind conditions across the site tend to improve slightly, particularly in the courtyard area between the buildings. The majority of areas are classified as suitable for pedestrian standing and walking. Local calmer areas are experienced close to the building articulations.

Windier conditions are experienced around the perimeter of the compound shape and between the building where pressure driven flow is experienced. Areas exceeding the walking criterion are in the middle Botany Street under and close to the link bridge to the Wallace Wurth building. Small localised exceedance areas are experienced under the north-west corner of the proposed UNSW HTH building, close to the edge of the raised perimeter section between the IASB and SCH1/CCCC, and in the laneway under the building to the south-west of the SCH1/CCC and the proposed UNSW HTH. These areas are small and would result in a localised windy area. These flows are pressure driven and would result regardless of the building form, the benefit of the design is the tapered nature of the form, which localises the wind conditions rather than having a constant wind speed through a long laneway of similar width. Potential amelioration strategies include vertical barriers or kinetic artwork through the laneway space. However, the 1.8 m balustrade will mitigate wind conditions for winds from the south-west in this area.

6.3 Summary

Arup have provided a quantitative assessment of the impact of the proposed development on pedestrian wind comfort and safety in and around the site using Computation Fluid Dynamics (CFD).

Three configurations were assessed:

- 'existing', including the Integrated Acute Services Building currently under construction to the south of the site,
- 'proposed' SCH1/CCCC development, and
- 'future', with the inclusion of the proposed future, neighbouring UNSW HTH building.

Surrounding buildings within the radius of 500 m around the site were explicitly modelled, meshed and solved for 16 wind directions at 22.5° increments. A mesh sensitivity study was conducted to minimize the effect of cell size on the final result. Inlet boundary condition were modelled to a wind profile corresponding to Terrain Category 3 in Standards Australia (2011) and an appropriate atmospheric rough wall function is applied. The directional CFD results were integrated with historic wind climate data to obtain classification of all areas with respect to Lawson pedestrian safety and comfort criteria.

Wind conditions are governed by the overall geometry rather than individual buildings. From a pedestrian safety perspective, all locations pass the safety conditions in the existing and proposed conditions. In the future conditions, there are some localised areas exceeding the safety criterion. These are concentrated in the middle of Botany Street away from pedestrian footpaths, and on the raised area between the IASB and the UNSW HTH building, where a solid balustrade would provide local amelioration to pedestrians. It is recommended that a solid balustrade of 1.8 m high around the corner section is incorporated, Figure 9.

With the inclusion of SCH 1/CCCC, the wind conditions in the raised area improve. The location of any pedestrian crossing across Botany Street should be cognisant of the strong wind conditions remote from the pavements. This is not expected to be an issue as the existing and proposed street level crossings are at the intersection of High Street and Botany Street and further south, at the intersection at the Gate 11, Figure 3. These locations are remote from the strongest wind conditions on Botany Street.

In terms of pedestrian comfort, the results show that increasing the building massing slightly increases the wind speed in the surrounding area. With the additional proposed and future buildings, the wind conditions around the site are generally classified as suitable for pedestrian standing and walking with areas suitable for pedestrian sitting, and smaller localised areas exceeding the walking criterion.

The inclusion of the proposed SCH1/CCCC ameliorates the exceedances of the walking criterion around the north-west corner of the IASB, by transferring them to the north-west of the site. These conditions are ameliorated with the inclusion of the proposed UNSW HTH building. All pedestrian accessways along the surrounding streets meet the walking criteria and are therefore considered suitable for the intended use of the space. The wind conditions at all the recessed entries are calm and suitable for the intended use.

7 Summary of mitigation measures

The impact of wind has been discussed with the architect throughout the design process, therefore most mitigation measures have already been considered and coordinated into the design, such as the U-shape building form, enclosed ground floor with recessed entries, and the elevated setbacks above ground level.

Further liaison with the design team will be undertaken during the next phase of the development to incorporate further mitigation strategies as appropriate in relation to the north-west colonnade when only the SCH1/CCCC building is constructed. This could be ameliorated by partially blocking the colonnade along the north and west faces with the inclusion of a facia or balustrade, the inclusion of landscaping to the north, and/or hanging artwork under the colonnade.

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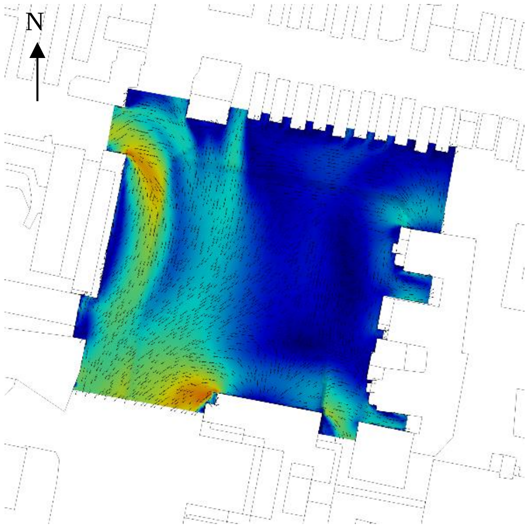
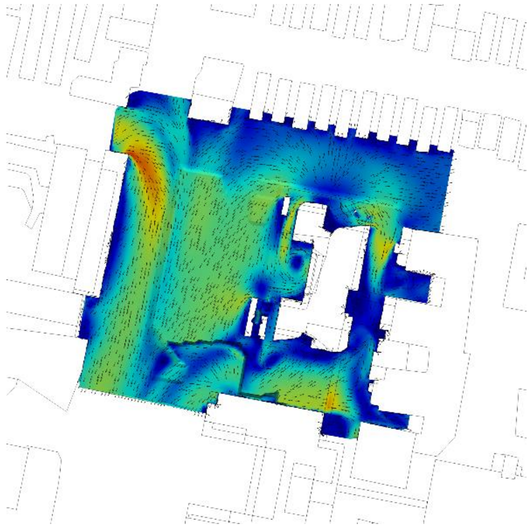
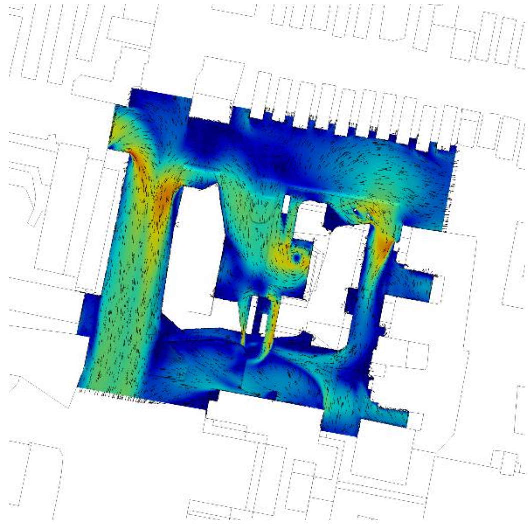
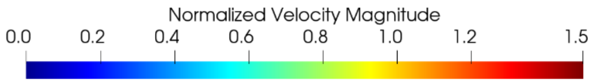
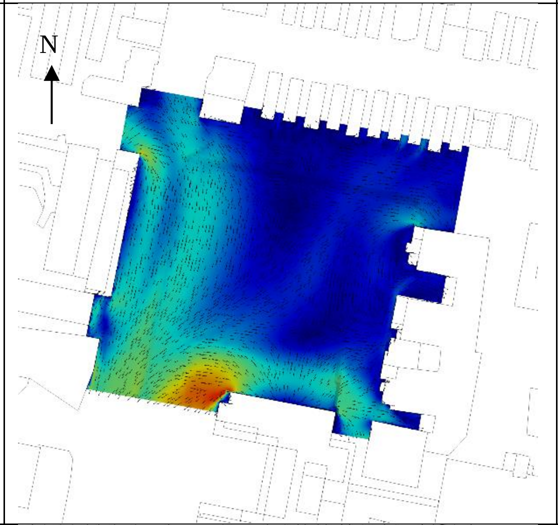
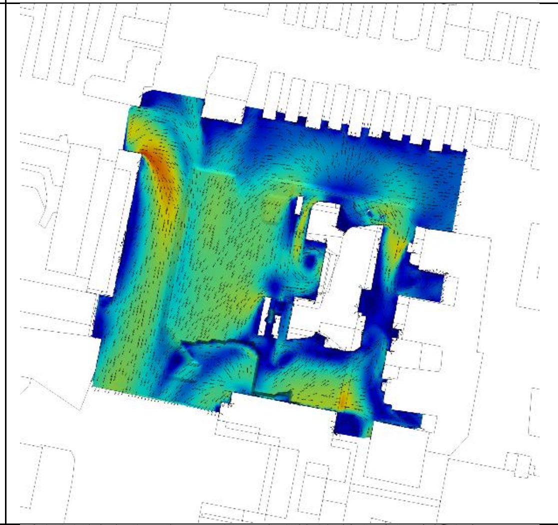
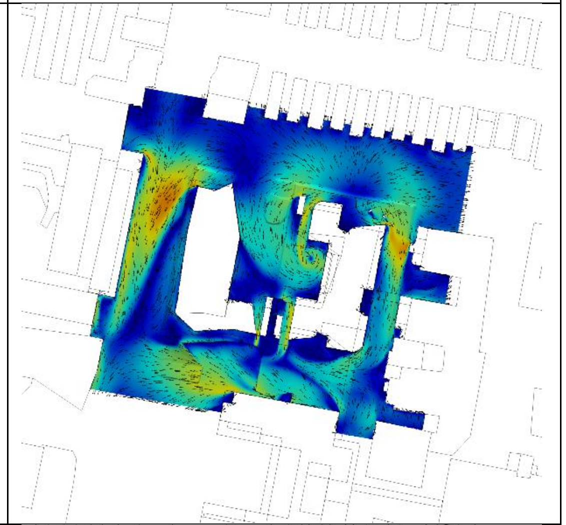
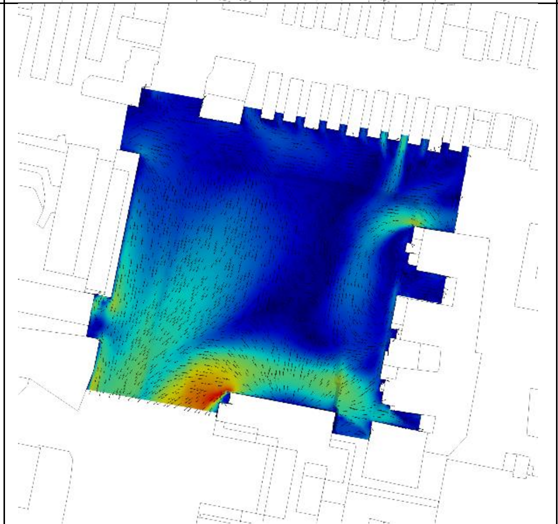
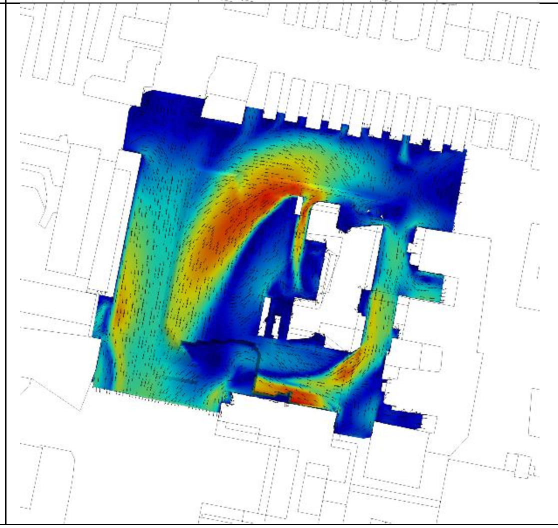
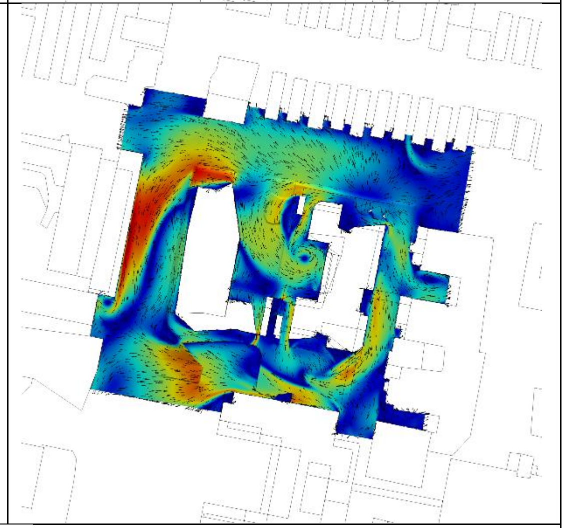
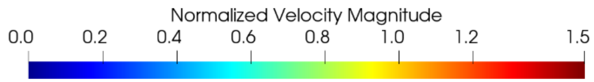
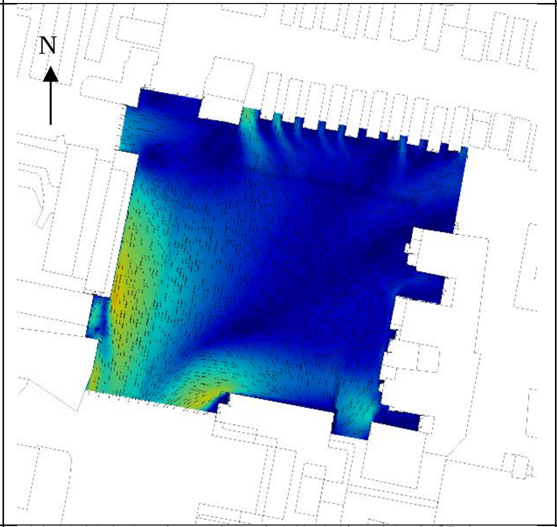
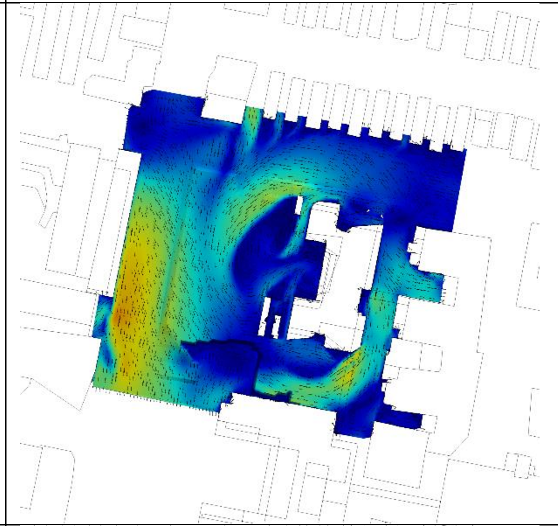
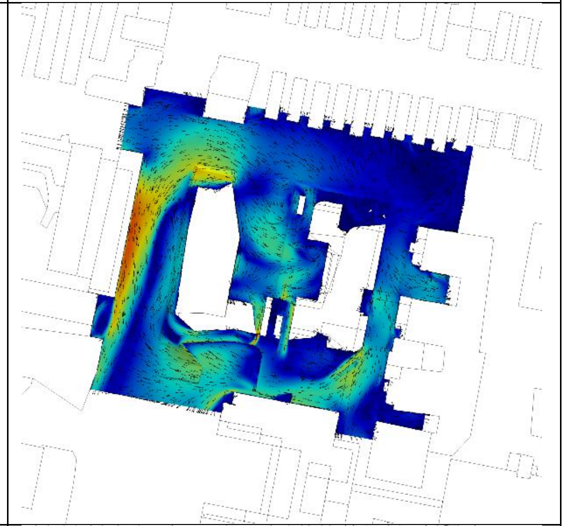
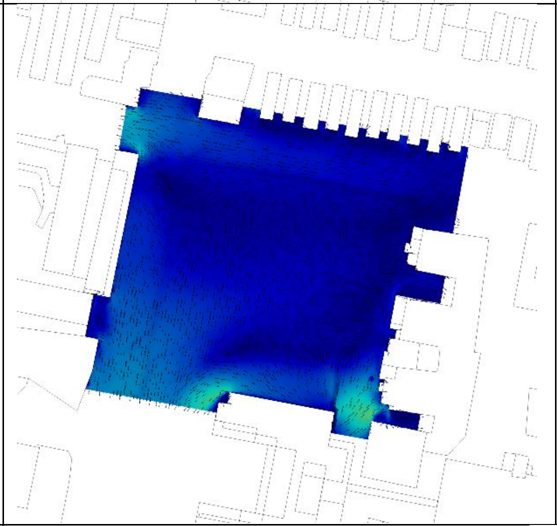
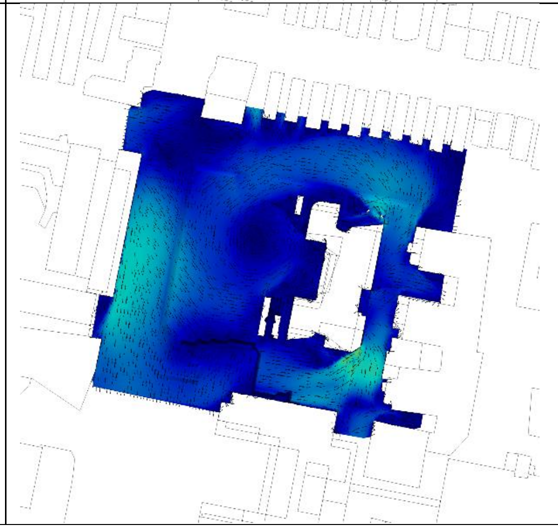
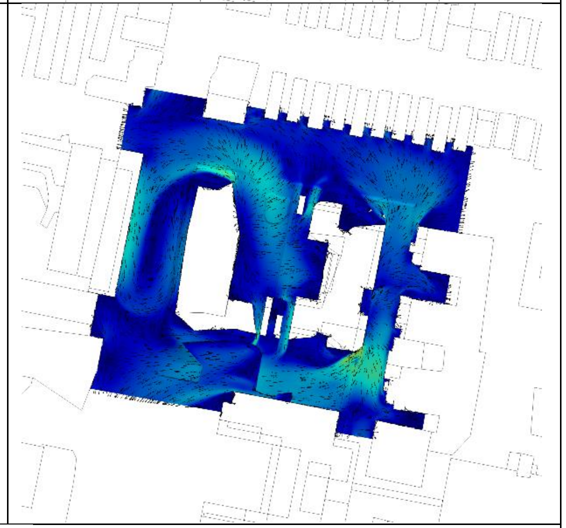
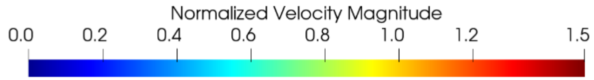
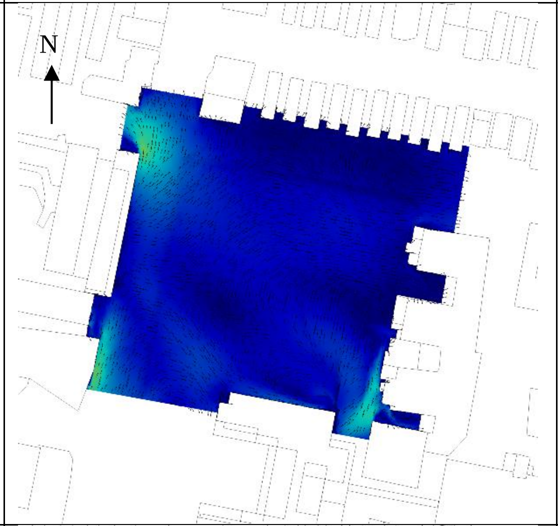
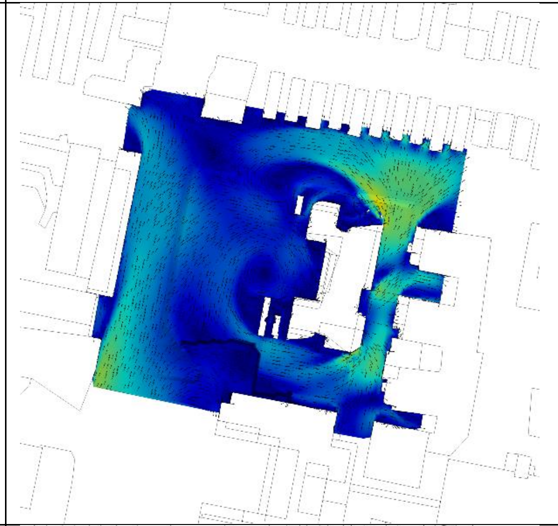
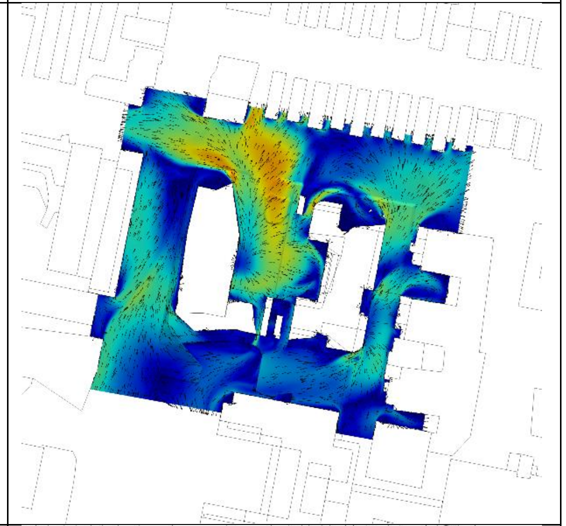
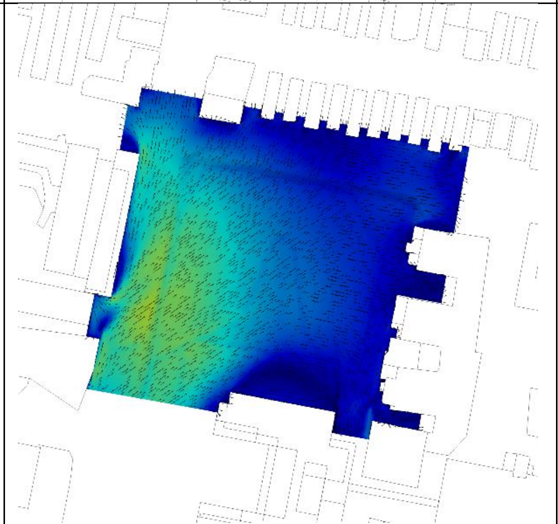
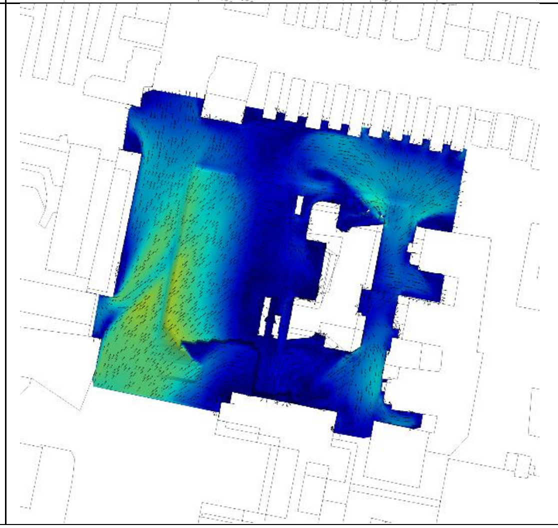
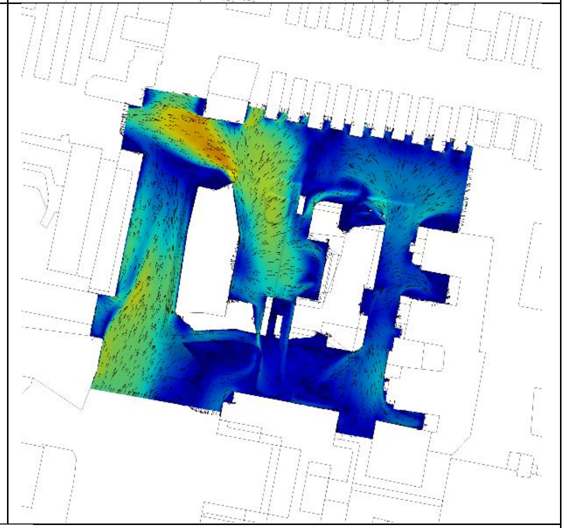
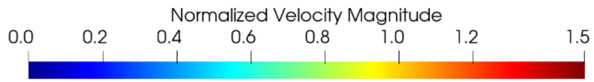
Appendix 1. Directional results at pedestrian level

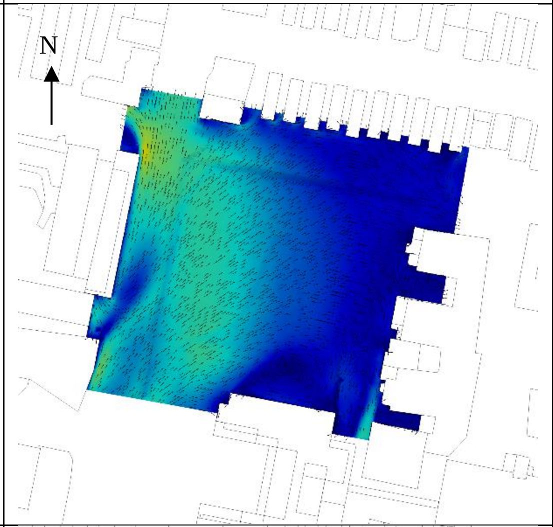
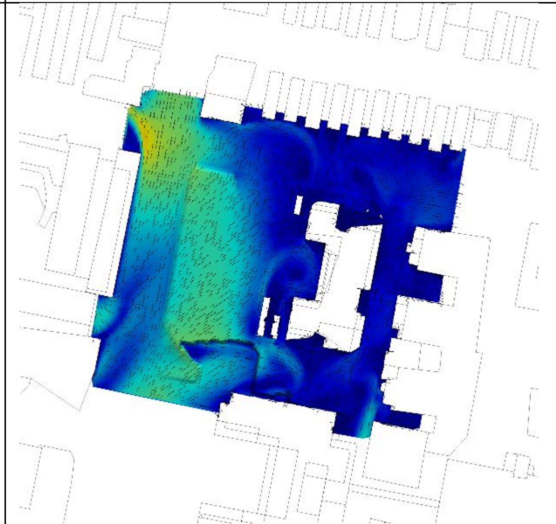
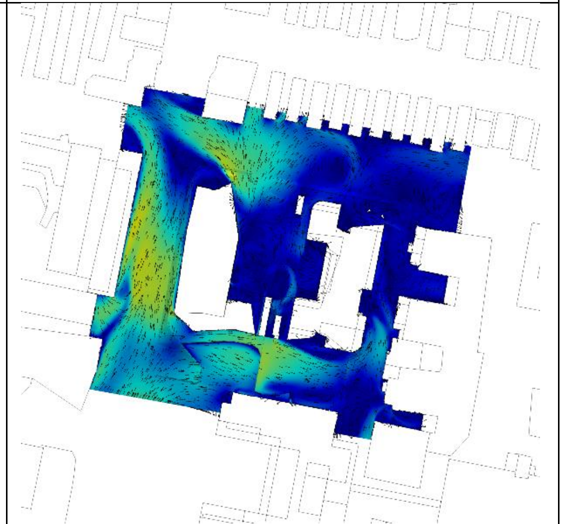
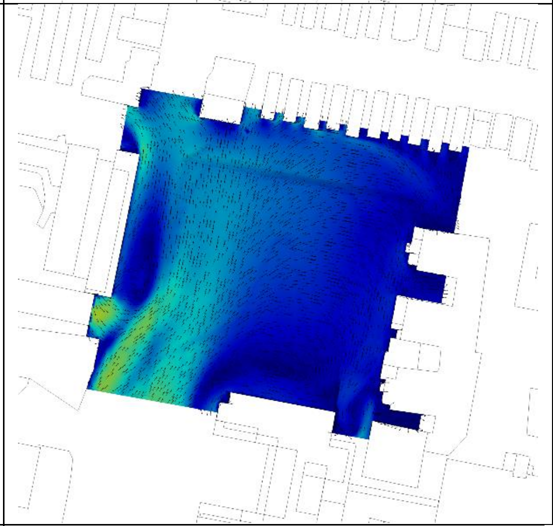
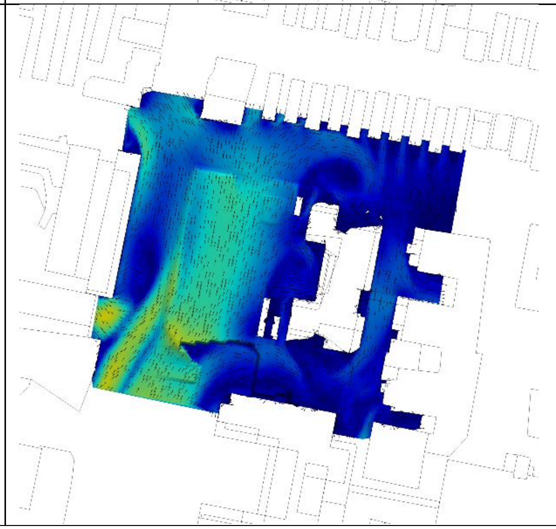
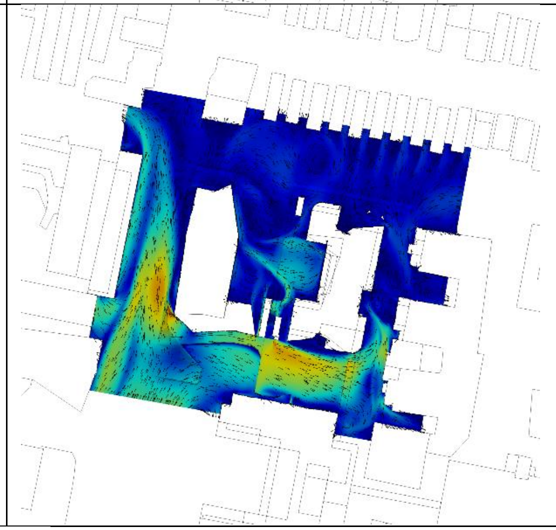
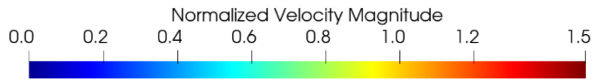
The coloured contour map of mean wind speed ratio 1.5 m above the ground for different wind directions are presented below. The wind speed ratio is calculated as the local wind speed to the reference undisturbed incident mean wind speed at 10 m in suburbia region (TC3). These directional CFD results were integrated with local wind climate data to provide wind speeds occurring 0.022% and 5% of time per annum from all directions for safety (Figure 10) and comfort (Figure 11) respectively.

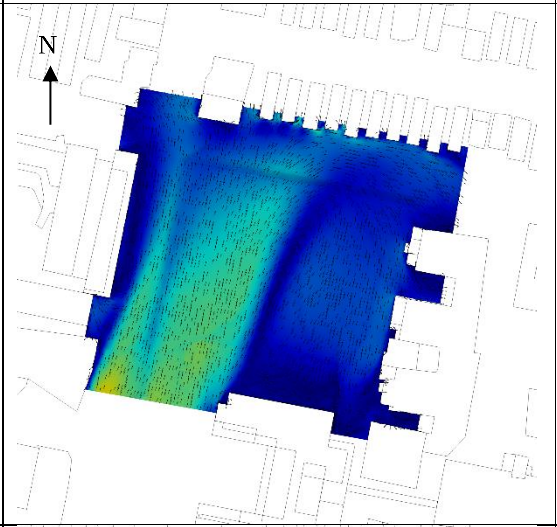
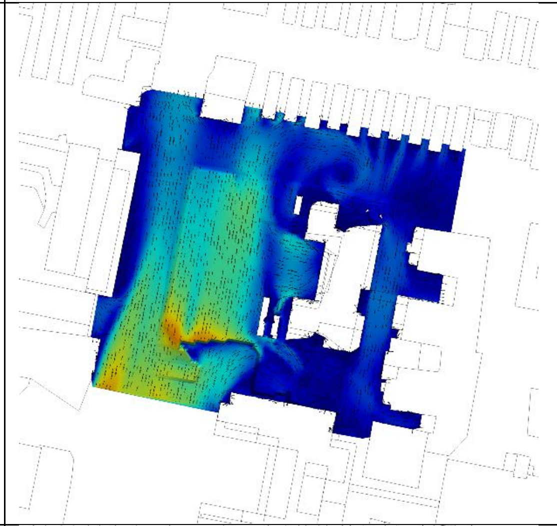
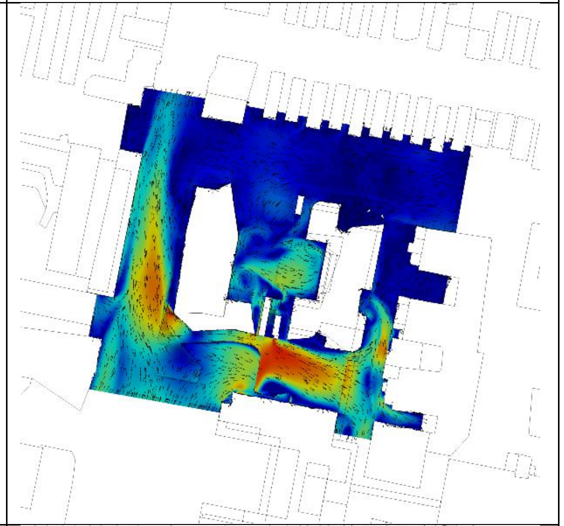
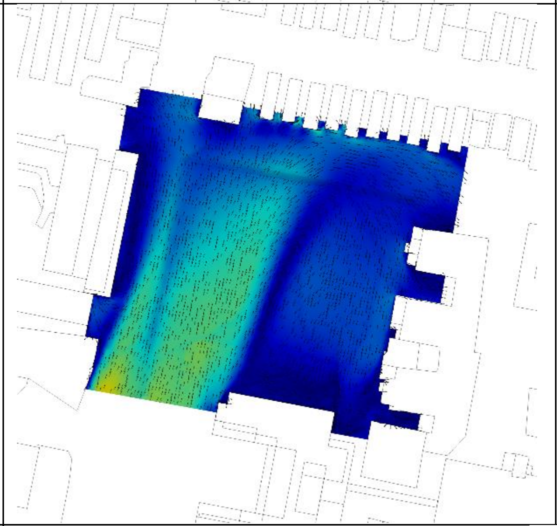
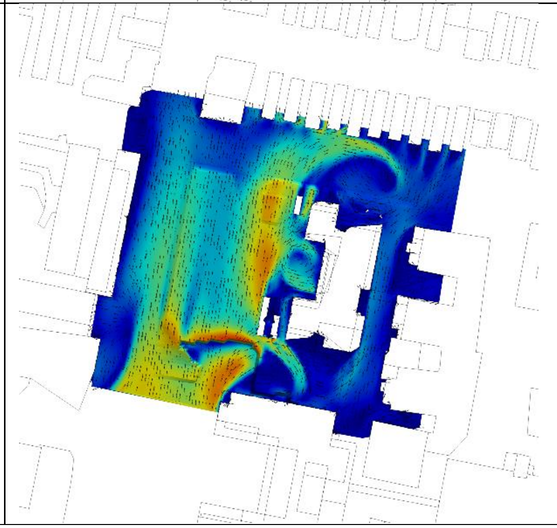
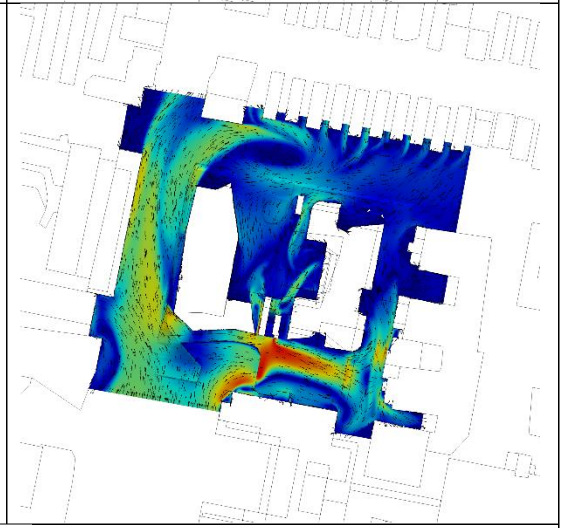
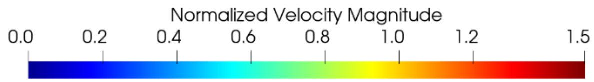
Wind direction	**Existing condition**	**Proposed development**	**Future development**
0° ↓			
			

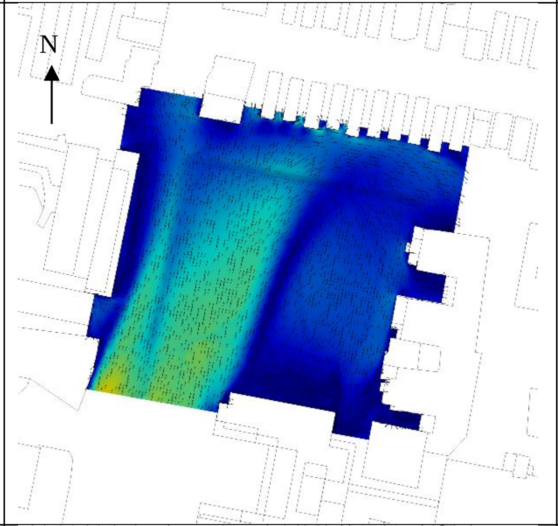
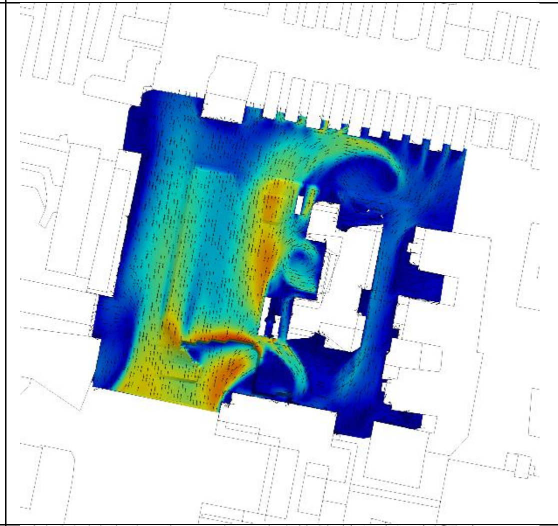
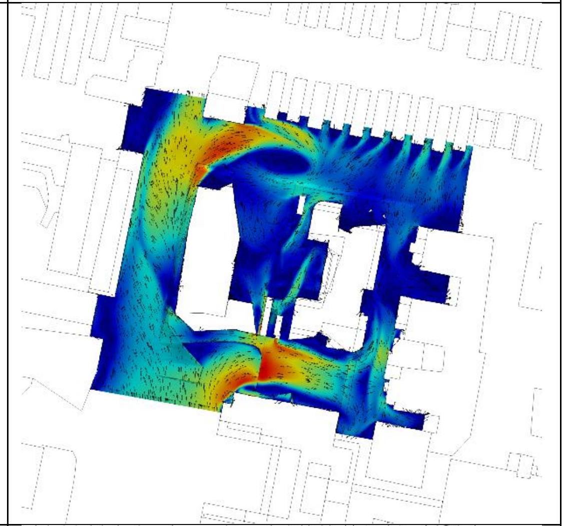
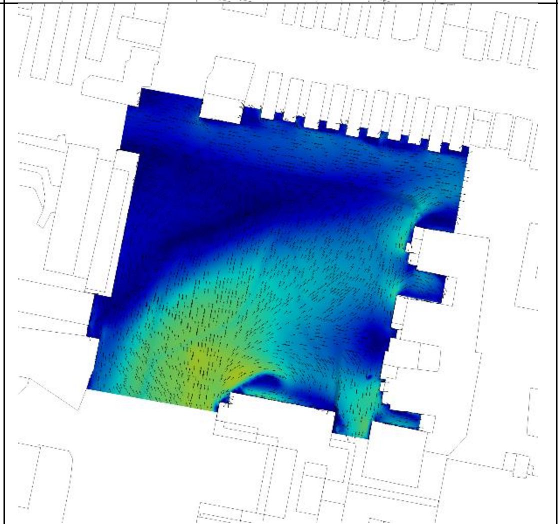
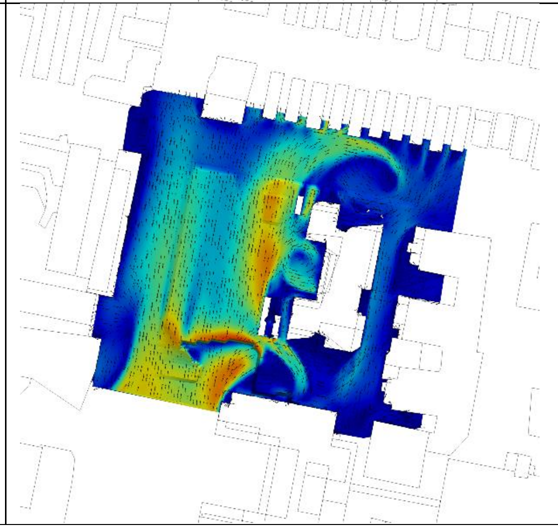
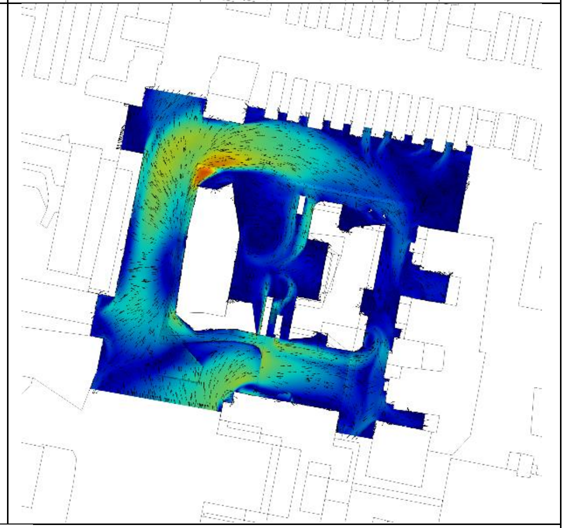
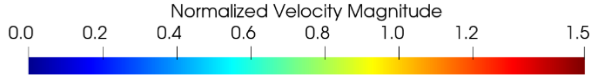
Wind direction	Existing condition	Proposed development	Future development
22.5º			
45º			
			

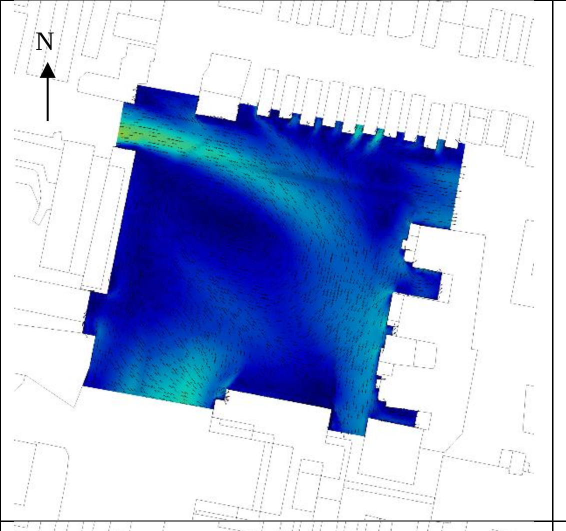
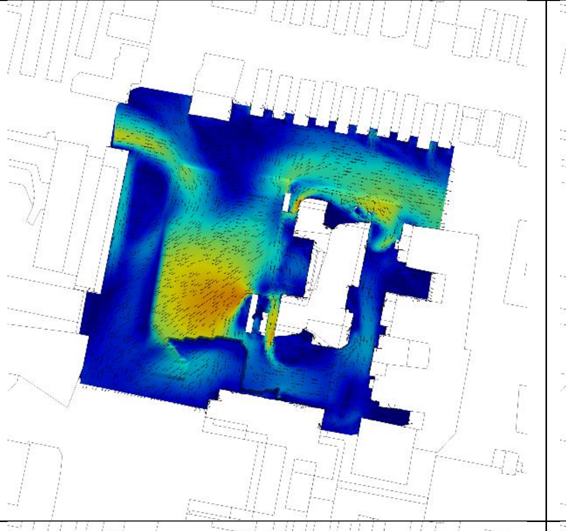
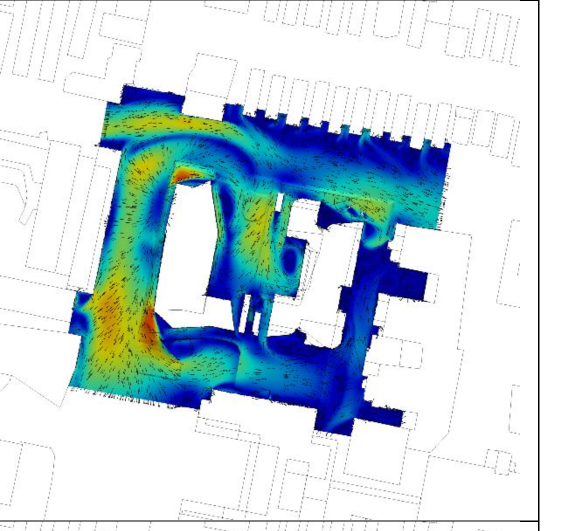
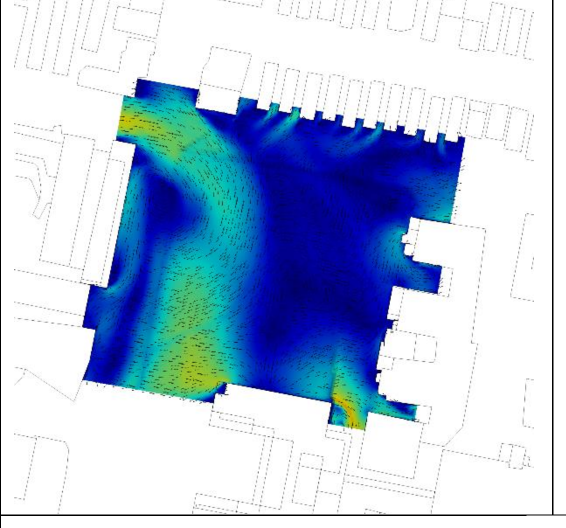
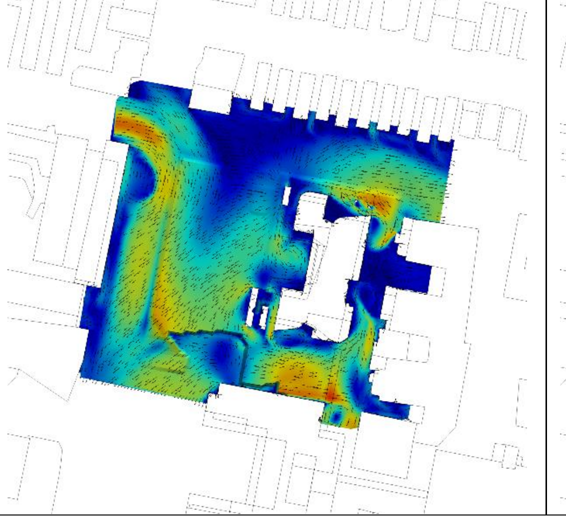
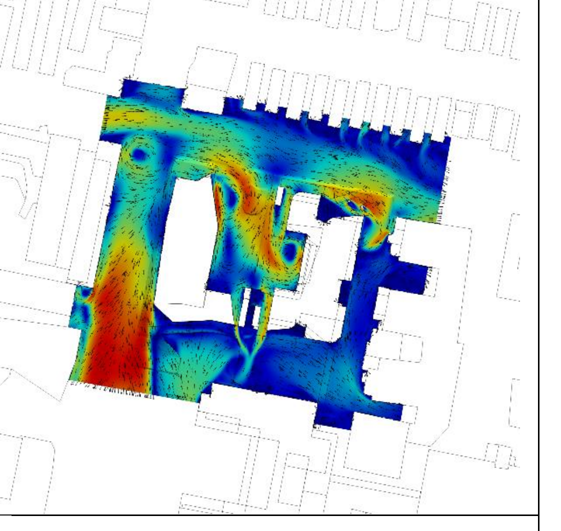
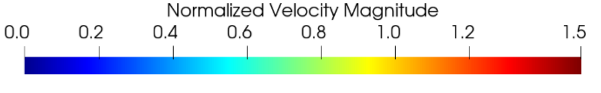
Wind direction	Existing condition	Proposed development	Future development
67.5º			
90º			
			

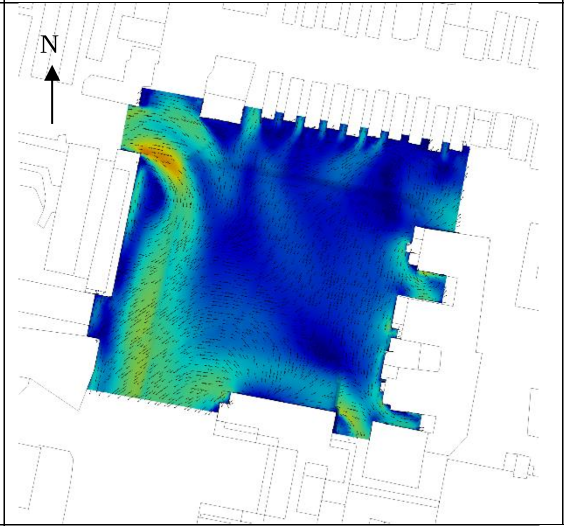
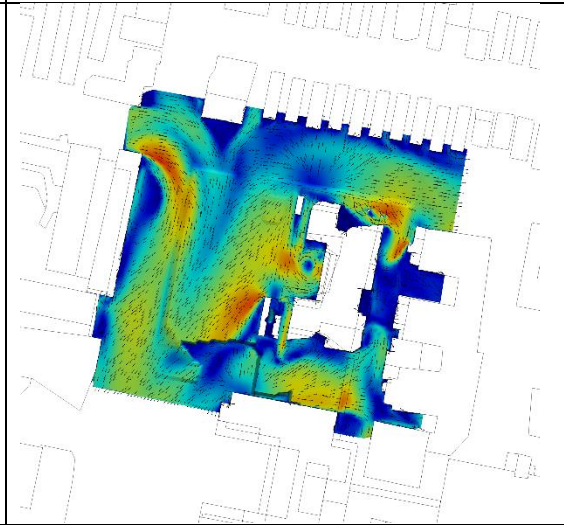
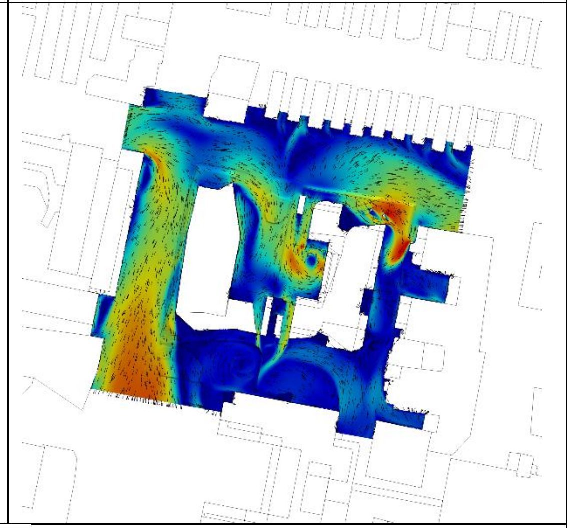
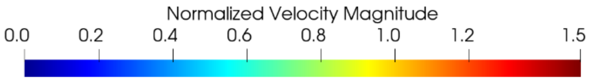
Wind direction	Existing condition	Proposed development	Future development
112.5º			
135º			
			

Wind direction	Existing condition	Proposed development	Future development
157.5º			
180º			
			

Wind direction	Existing condition	Proposed development	Future development
202.5º			
225º			
			

Wind direction	Existing condition	Proposed development	Future development
247.5º			
270º			
			

Wind direction	Existing condition	Proposed development	Future development
292.5º ↘			
315º ↘			
			

Wind direction	Existing condition	Proposed development	Future development
337.5º			
			

Appendix 2. Wind flow mechanisms

An urban environment generates a complex wind flow pattern around closely spaced structures, hence it is exceptionally difficult to generalise the flow mechanisms and impact of specific buildings as the flow is generated by the entire surrounds. However, it is best to start with an understanding of the basic flow mechanisms around an isolated structure.

Isolated building

When the wind hits an isolated building, the wind is decelerated on the windward face generating an area of high pressure, Figure 12, with the highest pressure at the stagnation point at about two thirds of the height of the building. The higher pressure bubble extends a distance from the building face of about half the building height or width, whichever is lower. The flow is then accelerated down and around the windward corners to areas of lower pressure, Figure 12. This flow mechanism is called **downwash** and causes the windiest conditions at ground level on the windward corners and along the sides of the building.

Rounding the building corners or chamfering the edges reduces downwash by encouraging the flow to go around the building at higher levels. However, concave curving of the windward face can increase the amount of downwash. Depending on the orientation and isolation of the building, uncomfortable downwash can be experienced on buildings of greater than about 6 storeys.

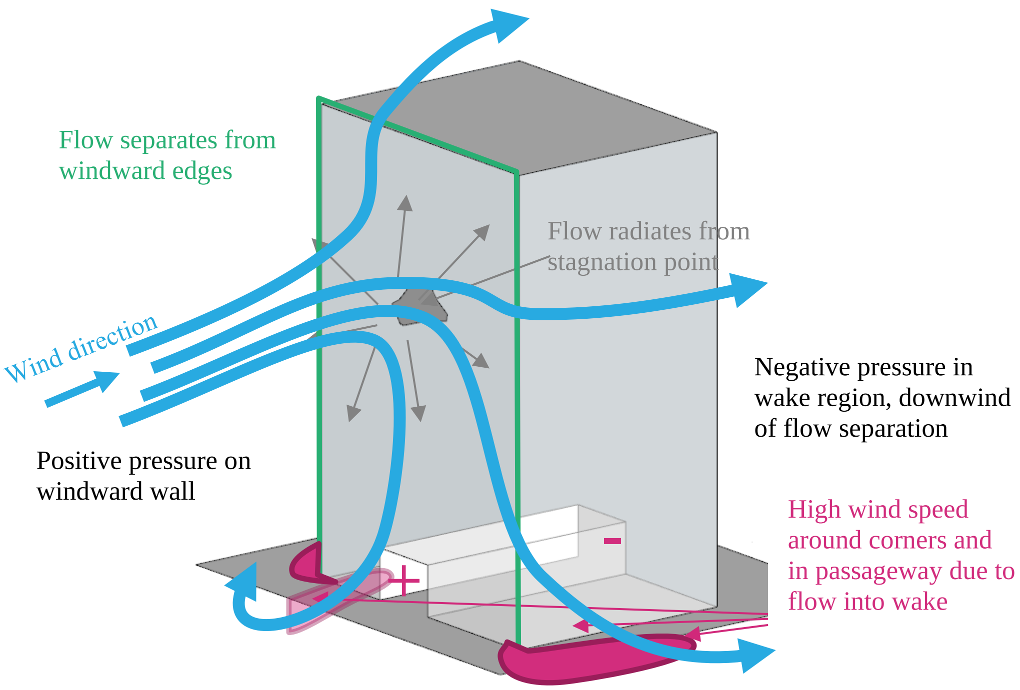


Figure 12: Schematic wind flow around tall isolated building

Techniques to mitigate the effects of downwash winds at ground level include the provision of horizontal elements, the most effective being a podium to divert the downward flow away from pavements and building entrances, but this will generate windy conditions on the podium roof, Figure 11. Generally, the lower the podium roof and deeper the setback from the podium edge to the tower improves the ground level wind conditions. The provision of an 8 m setback on an isolated building is generally sufficient to improve ground level conditions, but is highly dependent on the building isolation, orientation to prevailing wind directions, shape and width of the building, and any plan form changes at higher level.

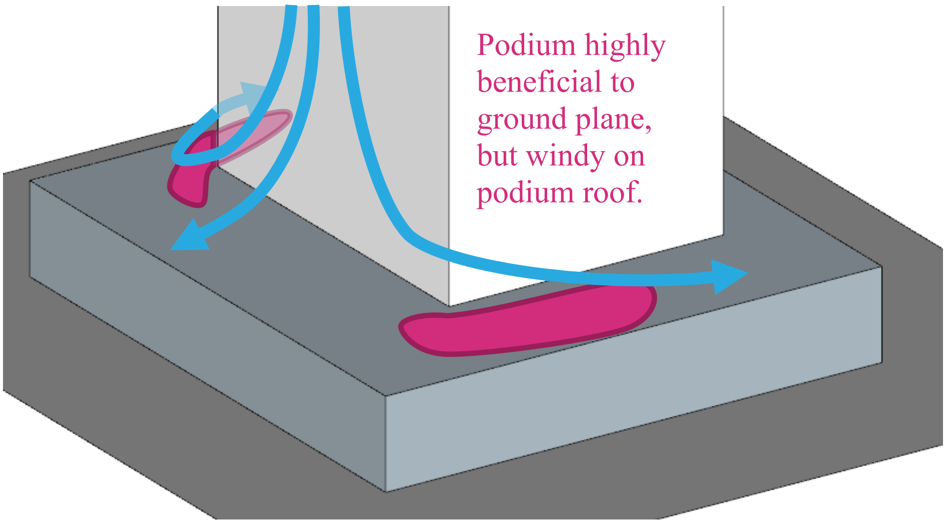


Figure 13: Schematic flow pattern around building with podium

Awnings along street frontages perform a similar function as a podium, and generally the larger the horizontal projection from the façade, the more effective it will be in diverting downwash flow, Figure 14. Awnings become less effective if they are not continuous along the entire façade, or on wide buildings as the positive pressure bubble extends beyond the awning resulting in horizontal flow under the awning.

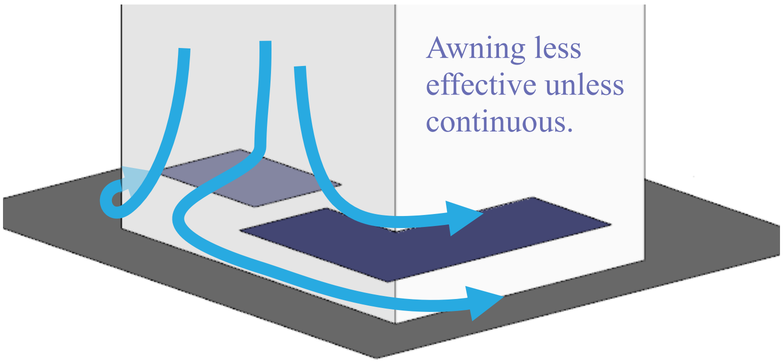


Figure 14: Schematic flow pattern around building with awning

It should be noted that colonnades at the base of a building with no podium generally create augmented windy conditions at the corners due to an increase in the pressure differential, Figure 15. Similarly, open through-site links through a building cause wind issues as the environment tries to equilibrate the pressure generated at the entrances to the link, Figure 12. If the link is blocked, wind conditions will be calm unless there is a flow path through the building, Figure 16. This area is in a region of high pressure and therefore the is the potential for internal flow issues. A ground level recessed corner has a similar effect as an undercroft, resulting in windier conditions, Figure 16.

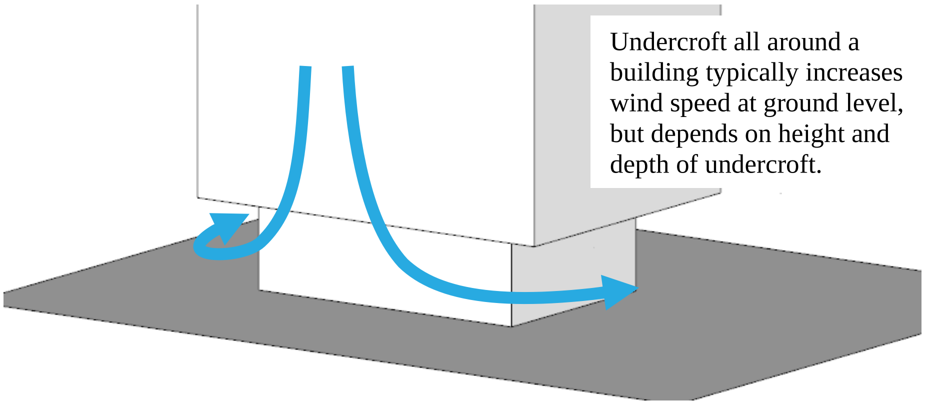


Figure 15: Schematic of flow patterns around isolated building with undercroft

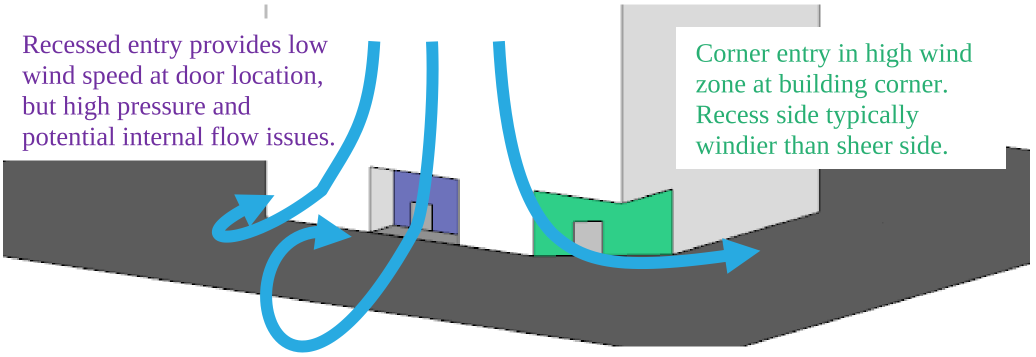


Figure 16: Schematic of flow patterns around isolated building with ground articulation

Multiple buildings

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 17. If the building is taller, more of the wind impacting on the exposed section of the building is likely to be drawn to ground level by the increase in height of the stagnation point, and the additional negative pressure induced at the base. If the upwind buildings are of similar height then the pressure around the building will be more uniform hence downwash is typically reduced with the flow passing over the buildings.

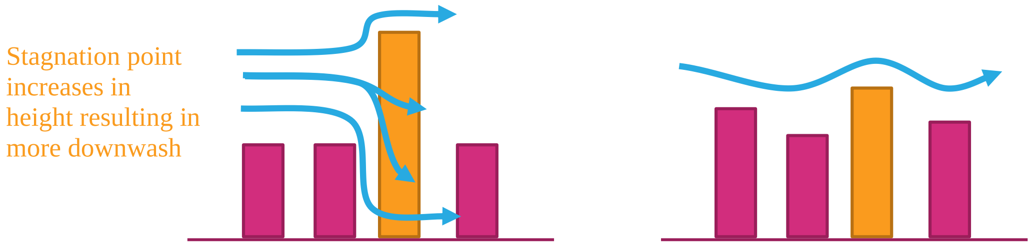


Figure 17: Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 18.

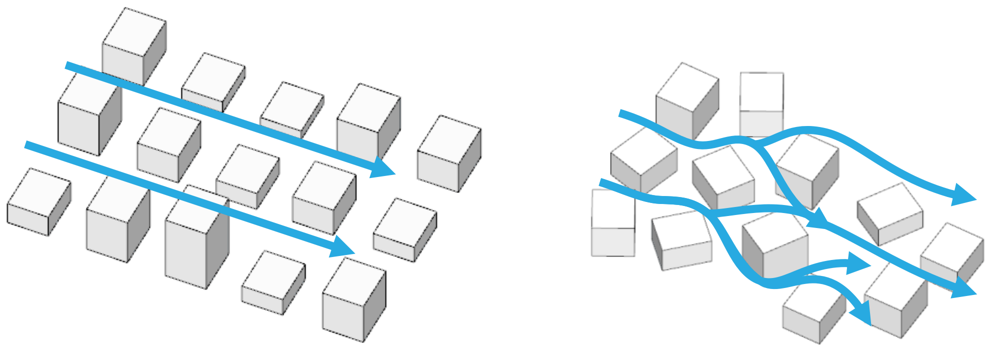


Figure 18: Schematic of flow patterns through a grid and random street layout

Channelling occurs when the wind is accelerated between two buildings, or along straight streets with buildings on either side, Figure 18(L), particularly on the edge of built-up areas where the approaching flow is diverted around the city massing and channelled along the fringe by a relatively continuous wall of building facades. This is generally the primary mechanism driving the wind conditions for this perimeter of a built-up area, particularly on corners, which are exposed to multiple wind directions. The perimeter edge zone in a built-up area is typically about two blocks deep. Downwash is more important flow mechanism for the edge zone of a built-up area with buildings of similar height.

As the city expands, the central section of the city typically becomes calmer, particularly if the grid pattern of the streets is discontinued, Figure 18(R). When buildings are located on the corner of a central city block, the geometry becomes slightly more important with respect to the local wind environment.

Appendix 3. Wind speed criteria

General discussion

Primary controls that are used in the assessment of how wind affects pedestrians are the wind speed, and rate of change of wind speed. A description of the effect of a specific wind speed on pedestrians is provided in Table 3. It should be noted that the turbulence, or rate of change of wind speed, will affect human response to wind and the descriptions are more associated with response to mean wind speed.

Table 3. Summary of wind effects on pedestrians

Description	Speed (m/s)	Effects
Calm, light air	0–2	Human perception to wind speed at about 0.2 m/s. Napkins blown away and newspapers flutter at about 1 m/s.
Light breeze	2–3	Wind felt on face. Light clothing disturbed. Cappuccino froth blown off at about 2.5 m/s.
Gentle breeze	3–5	Wind extends light flag. Hair is disturbed. Clothing flaps.
Moderate breeze	5–8	Raises dust, dry soil. Hair disarranged. Sand on beach saltates at about 5 m/s. Full paper coffee cup blown over at about 5.5 m/s.
Fresh breeze	8–11	Force felt on body. Limit of agreeable wind on land. Umbrellas used with difficulty. Wind sock fully extended at about 8 m/s.
Strong breeze	11–14	Hair blown straight. Difficult to walk steadily. Wind noise on ears unpleasant. Windborne snow above head height (blizzard).
Near gale	14–17	Inconvenience felt when walking.
Gale	17–21	Generally impedes progress. Difficulty with balance in gusts.
Strong gale	21–24	People blown over by gusts.

Local wind effects can be assessed with respect to a number of environmental wind speed criteria established by various researchers. These have all generally been developed around a 3 s gust, or 1 hour mean wind speed. During strong events, a pedestrian would react to a significantly shorter duration gust than a 3 s, and historic weather data is normally presented as a 10 minute mean.

Despite the apparent differences in numerical values and assumptions made in their development, it has been found that when these are compared on a probabilistic basis, there is some agreement between the various criteria. However, a number of studies have shown that over a wider range of flow conditions, such as smooth flow across water bodies, to turbulent flow in city centres, there is less general agreement among. The downside of these criteria is that they have seldom been benchmarked, or confirmed through long-term measurements in the field, particularly for comfort conditions. The wind criteria were all developed in temperate climates and are unfortunately not the only environmental factor that affects pedestrian comfort.

For assessing the effects of wind on pedestrians, neither the random peak gust wind speed (3 s or otherwise), nor the mean wind speed in isolation are adequate. The gust wind speed gives a measure of the extreme nature of the wind, but the mean wind speed indicates the longer duration impact on pedestrians. The extreme gust wind speed is considered to be suitable for safety considerations, but not necessarily for serviceability comfort issues such as outdoor dining. This is because the instantaneous gust velocity does not always correlate well with mean wind speed, and is not necessarily representative of the parent distribution. Hence, the perceived 'windiness' of a location can either be dictated by strong steady flows, or gusty turbulent flow with a smaller mean wind speed.

To measure the effect of turbulent wind conditions on pedestrians, a statistical procedure is required to combine the effects of both mean and gust. This has been conducted by various researchers to develop an equivalent mean wind speed to represent the perceived effect of a gust event. This is called the 'gust equivalent mean' or 'effective wind speed' and the relationship between the mean and 3 s gust wind speed is defined within the criteria, but two typical conversions are:

$$\mathrm{U_{GEM}} = \frac{(\mathrm{U_{mean}} + 3 \cdot \sigma_\mathrm{u})}{1.85} \text{ and } \mathrm{U_{GEM}} = \frac{1.3 \cdot (\mathrm{U_{mean}} + 2 \cdot \sigma_\mathrm{u})}{1.85}$$

It is evident that a standard description of the relationship between the mean and impact of the gust would vary considerably depending on the approach turbulence, and use of the space.

A comparison between the mean and 3 s gust wind speed criteria from a probabilistic basis are presented in Figure 19 and Figure 21. The grey lines are typical results from modelling and show how the various criteria would classify a single location. City of Auckland has control mechanisms for accessing usability of spaces from a wind perspective as illustrated in Figure 19 with definitions of the intended use of the space categories defined in Figure 20.

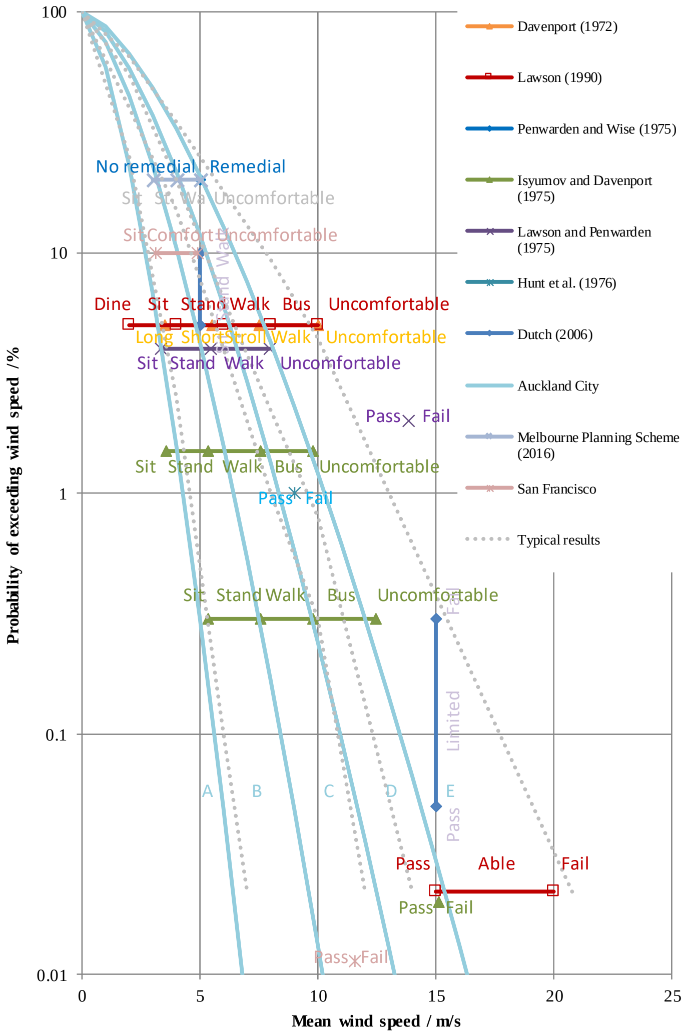


Figure 19: Probabilistic comparison between wind criteria based on mean wind speed

Category A	Areas of pedestrian use or adjacent dwellings containing significant formal elements and features intended to encourage longer term recreational or relaxation use i.e. public open space and adjacent outdoor living space
Category B	Areas of pedestrian use or adjacent dwellings containing minor elements and features intended to encourage short term recreation or relaxation, including adjacent private residential properties
Category C	Areas of formed footpath or open space pedestrian linkages, used primarily for pedestrian transit and devoid of significant or repeated recreational or relaxational features, such as footpaths not covered in categories A or B above
Category D	Areas of road, carriage way, or vehicular routes, used primarily for vehicular transit and open storage, such as roads generally where devoid of any features or form which would include the spaces in categories A - C above.
Category E	Category E represents conditions which are dangerous to the elderly and infants and of considerable cumulative discomfort to others, including residents in adjacent sites. Category E

Figure 20: Auckland Utility Plan (2016) wind categories

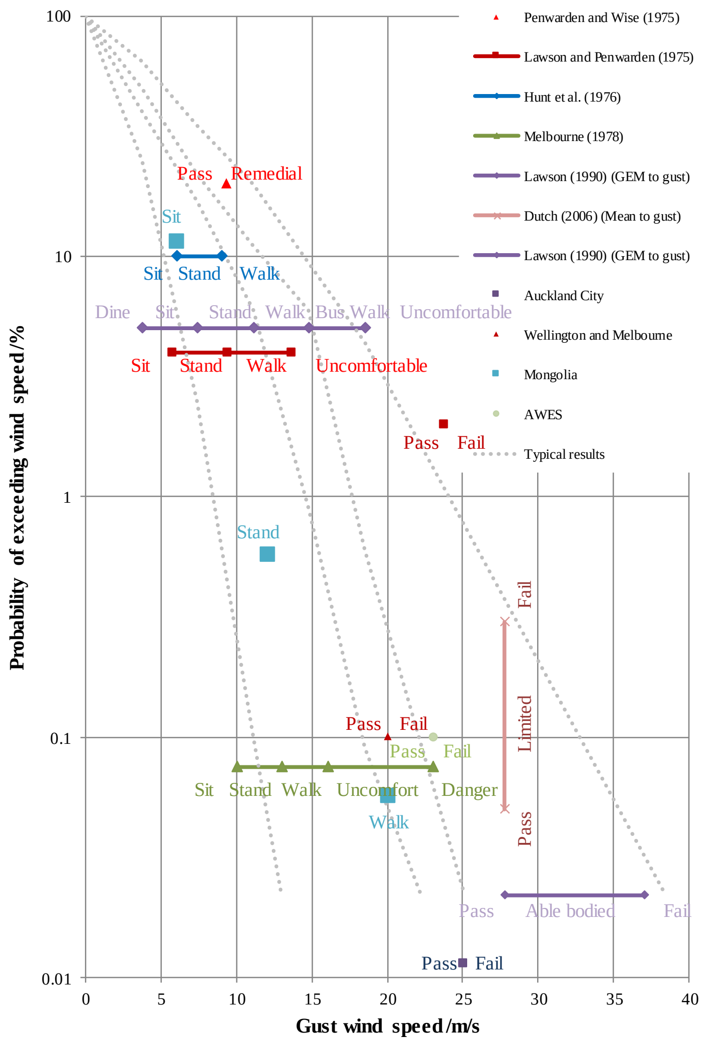


Figure 21: Probabilistic comparison between wind criteria based on 3 s gust wind speed

Appendix 4. Reference documents

In preparing the assessment, the following documents, received on 8 December 2020, have been referenced to understand the building massing and features.

- SCH CCCC SEARS Request FINAL_9NOV .pdf
- SCH1-AR-DG-SSD002[A] - LOCATION PLAN - AERIAL PHOTOGRAPH.pdf
- SCH1-AR-DG-SSD003[A] - SITE PLAN - EXISTING.pdf
- SCH1-AR-DG-SSD005[A] - SITE PLAN - PROPOSED.pdf
- SCH1-AR-DG-SSD010[A] - PROPOSED PLAN - LEVEL B2.pdf
- SCH1-AR-DG-SSD011[A] - PROPOSED PLAN - LEVEL B1.pdf
- SCH1-AR-DG-SSD012[A] - PROPOSED PLAN - LEVEL 00.pdf
- SCH1-AR-DG-SSD013[A] - PROPOSED PLAN - LEVEL 01.pdf
- SCH1-AR-DG-SSD014[A] - PROPOSED PLAN - LEVEL 02.pdf
- SCH1-AR-DG-SSD015[A] - PROPOSED PLAN - LEVEL 03.pdf
- SCH1-AR-DG-SSD016[A] - PROPOSED PLAN - LEVEL 04.pdf
- SCH1-AR-DG-SSD017[A] - PROPOSED PLAN - LEVEL 05.pdf
- SCH1-AR-DG-SSD018[A] - PROPOSED PLAN - LEVEL 06.pdf
- SCH1-AR-DG-SSD019[A] - PROPOSED PLAN - LEVEL 07.pdf
- SCH1-AR-DG-SSD020[A] - PROPOSED PLAN - LEVEL 08.pdf
- SCH1-AR-DG-SSD021[A] - PROPOSED PLAN - LEVEL 09.pdf
- SCH1-AR-DG-SSD022[A] - PROPOSED PLAN - LEVEL 10 - ROOF.pdf
- SCH1-AR-DG-SSD030[A] - ELEVATION - SHEET 01.pdf
- SCH1-AR-DG-SSD031[A] - ELEVATION - SHEET 02.pdf
- SCH1-AR-DG-SSD035[A] - SECTION - SHEET 01.pdf
- SCH1-AR-DG-SSD036[A] - SECTION - SHEET 02.pdf