University of New South Wales

Health Translation Hub (HTH)

Environmental Wind Assessment

Wind

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Executive summary

Arup have been commissioned by the University of New South Wales to provide a quantitative wind impact assessment of the proposed development, the UNSW Health Translation Hub (UNSW HTH), on the pedestrian level wind conditions for comfort and safety in and around the site.

Arup have provided quantitative advice for the impact of the proposed development on the pedestrian level wind comfort in three configurations:

- existing, hereafter referred to as ‘existing conditions’ including the Integrated Acute Services Building (IASB) currently under construction to the south-east of the site,
- proposed UNSW HTH development, hereafter referred to as ‘proposed development’, and
- inclusion of the proposed future, neighbouring Sydney Children’s Hospital, Comprehensive Children’s Cancer Centre (SCH Stage 1 and the CCCC) building, hereafter referred to as the ‘future development’.

Wind conditions are 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 condition. In the proposed and 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. With the inclusion of SCH Stage 1 and the CCCC the wind conditions in the raised area improve.

In terms of pedestrian comfort, the results show that increasing the building massing generally increases the wind speed in the surrounding area. In the proposed and future building configurations, 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 UNSW HTH changes the shape of the walking criterion exceedance area around the north-west corner of the IASB, meaning that a smaller area would be created during winds from a specific direction, but would occur in different areas during different incident wind directions. The conditions in this area are further ameliorated with the inclusion of the SCH Stage 1 and the CCCC 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 the recessed entries are suitable for the intended use. The use of solid balustrades around the entire development would improve the local wind conditions for safety and comfort.

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1 Introduction and description of proposed development

University of New South Wales (UNSW) have engaged Arup to provide a quantitative environmental wind assessment for the proposed UNSW Health Translation Hub (UNSW HTH) development. This report outlines the assessment and recommendations relating to 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 (IASB) currently under construction to the south-east of the site,
- proposed UNSW HTH development, hereafter referred to as 'proposed development', and
- inclusion of the proposed future, neighbouring Sydney Children's Hospital, Comprehensive Children's Cancer Centre (SCH Stage 1 and the CCCC) building, hereafter referred to as the 'future development'.

This report supports a State Significant Development Application (SSDA) for the proposed UNSW Health Translation Hub (UNSW HTH) at the Randwick Hospitals Campus (RHC), which is submitted to the Department of Planning, Industry and Environment (DPIE) pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (the Act). Health Infrastructure on behalf of Health Administration Corporation (HAC) is the applicant for the UNSW HTH, which will be delivered with the University of New South Wales (UNSW).

The UNSW HTH forms an extension of the existing and proposed hospital facilities at the RHC, providing a specialist health-related research and education facility on the Campus.

The UNSW HTH project will bring together educational and medical researchers, clinicians, educators, industry partners and public health officials to drive excellence, and support the rapid translation of research, innovation, and education into improved patient care.

1.1 Description of proposed development

The SSDA seeks approval for:

- Relevant site preparation, excavation and enabling works.
- Construction and use of a new, 15-storey building accommodating research and health education uses, comprising:
  - One basement level; and
  - A total GFA of 35,600 m^2, including health-related research, education and administrative floor space.

  - Pedestrian link bridges connecting the UNSW Kensington campus to the RHC, via the Wallace Wurth building to the UNSW HTH and through to the SCH Stage 1 and the CCCC
- Landscaping and public domain works, including the creation of over 2,500 m² of new publicly accessible open space within the eastern portion of the site, sitting between the UNSW HTH and the SCH Stage 1 and the CCCC redevelopment.
- Stratum subdivision.
- Services and utilities augmentation as required.

1.2 Operation and function of the UNSW HTH

The UNSW HTH will be an expansion of the RHC to accommodate new health related education, research, and administrative facilities. It will include:

- Purpose-built spaces for health educators and researchers to work alongside clinicians.
- Floor plates for health translation research focused work with physical connections to the SCH Stage 1 and the CCCC and wider RHC.
- Dedicated facilities for the CCCC directly linking the UNSW HTH with the SCH Stage 1 and the CCCC.
- An education hub, including education and training rooms allowing hospital staff to educate and train UNSW medical students.
- Facilities for education, training, research, seminars, and industry events.
- Clinical schools for the Women's and Children's Health, Psychiatry and Prince of Wales Hospital.
- Ambulatory care clinics including in neurosciences, public and population health.
- Supporting facilities including retail premises.

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 1 provides a regional context map of the site showing its location in relation to the Sydney CBD and surrounding centres.

This block sits in between the existing Randwick Hospitals Campus and the UNSW Kensington Campus, and directly adjacent to the CBD and South East Light Rail service which runs along High Street, Figure 2. The site of the proposed UNSW HTH has an area of 8,897 m^2.

The site has been subject to some site preparation and early works associated with the broader development of the block. Adjacent to the site, along the High Street and Botany Road frontages, runs a 6 m wide stormwater and sewage easement.

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-west corner of the block bounded by Hospital Road, and High, Botany, and Magill Streets, Figure 3. The proposed development is located to the north-west of the 11-storey Integrated Acute Services Building (IASB) currently under construction.

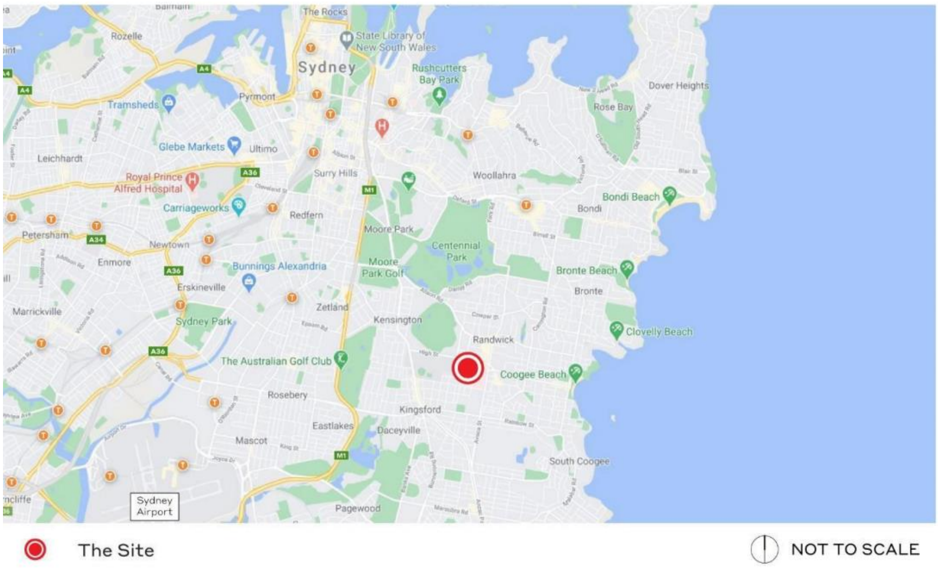

Figure 1: Site context (Source: Google maps and Ethos Urban)

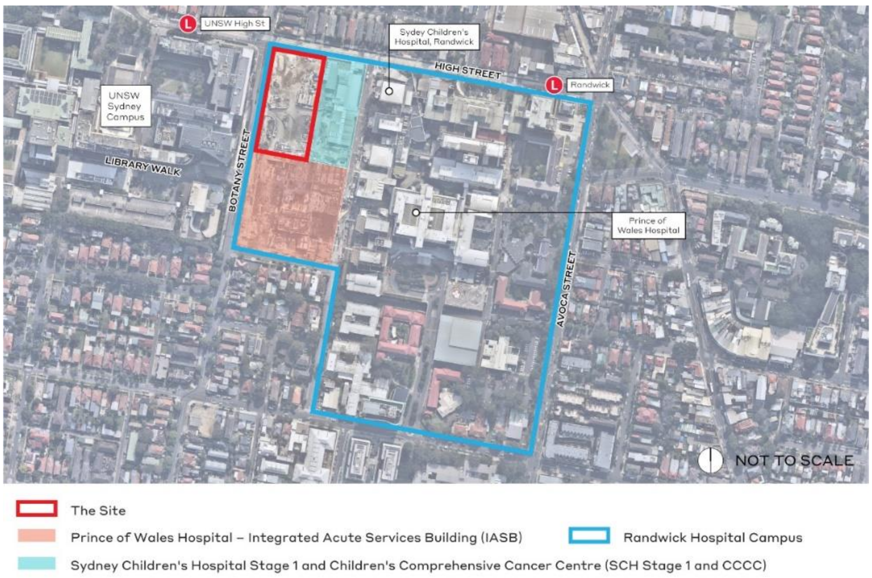

Figure 2: Site aerial (Source: Nearmaps and Ethos Urban)

The proposed development consists of 15 levels plus a basement level and rises approximately 69 m above ground level. The buildings is of irregular floor plan, and is articulated with height with building setbacks of about 10, 3, 12, and 4 m from the podium edge to the north, east, south, and west respectively, Figure 4. At ground level, undercroft are proposed around the north-east, and south-west corners, with an awning wrapping around the building. There is a public accessway between the UNSW HTH building and the SCH Stage 1 and the CCCC building to the south-east corner of the site.

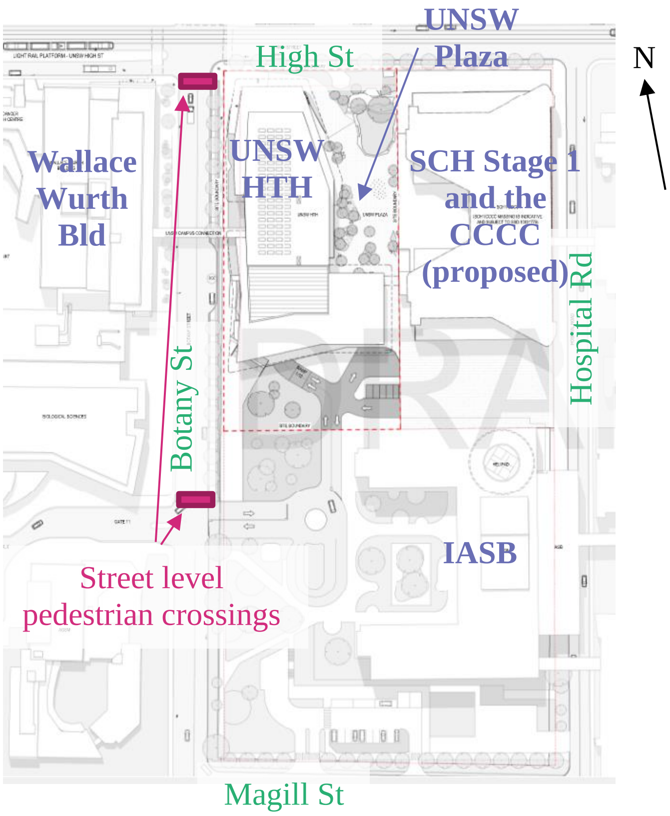

Figure 3: Site plan

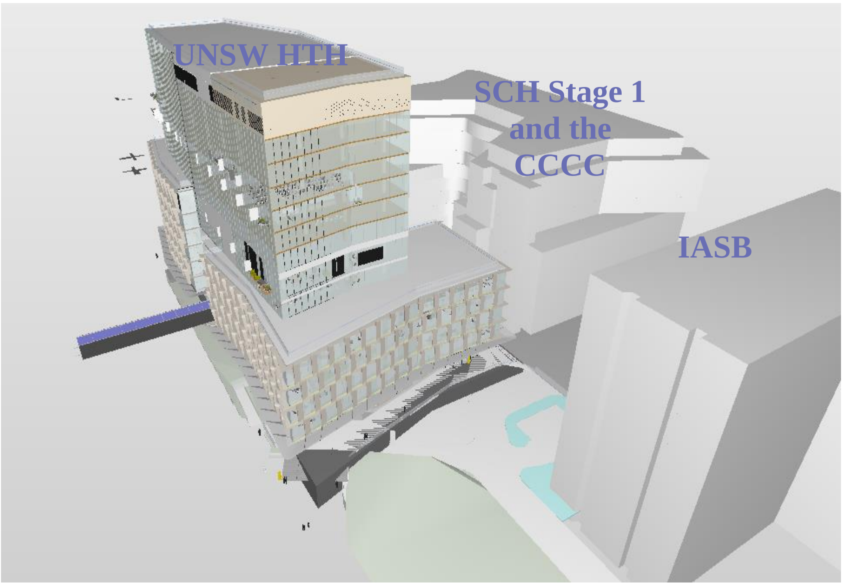

Figure 4: View of the UNSW HTH building from the south-west

3 Secretary's Environmental Assessment Requirements (SEARs)

Department of Planning, Industry and Environment has issued Secretary's Environmental Assessment Requirements (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 5. 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 5 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.

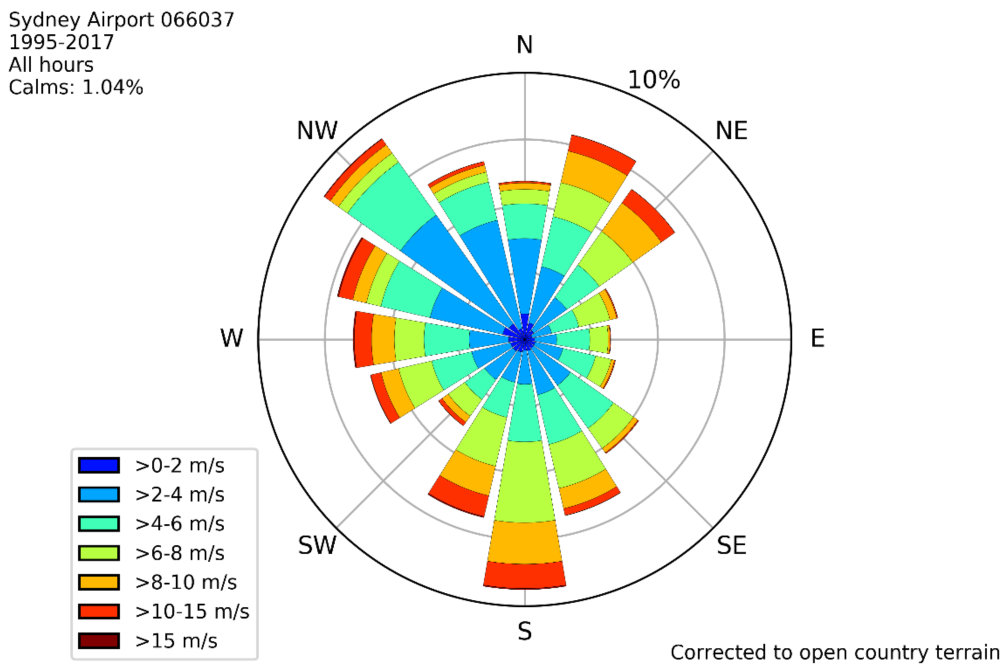

Figure 5: Wind rose showing probability of time of wind direction and speed

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 have been many wind comfort criteria proposed, and a general discussion is presented in Appendix 3. 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 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 600 m around the site was explicitly modelled, Figure 6 and Figure 7. 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 8.

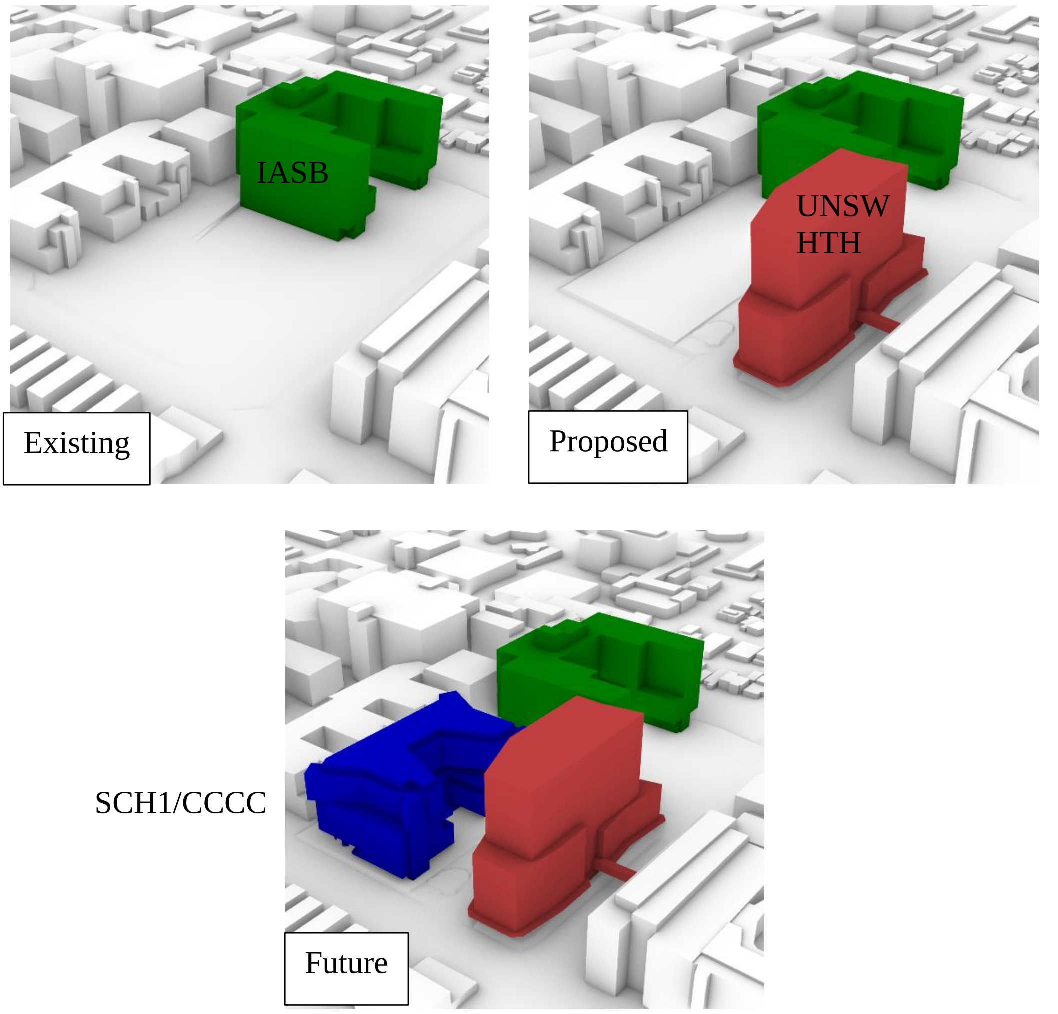

Figure 6: 3d models for the various configurations, view from the north-west

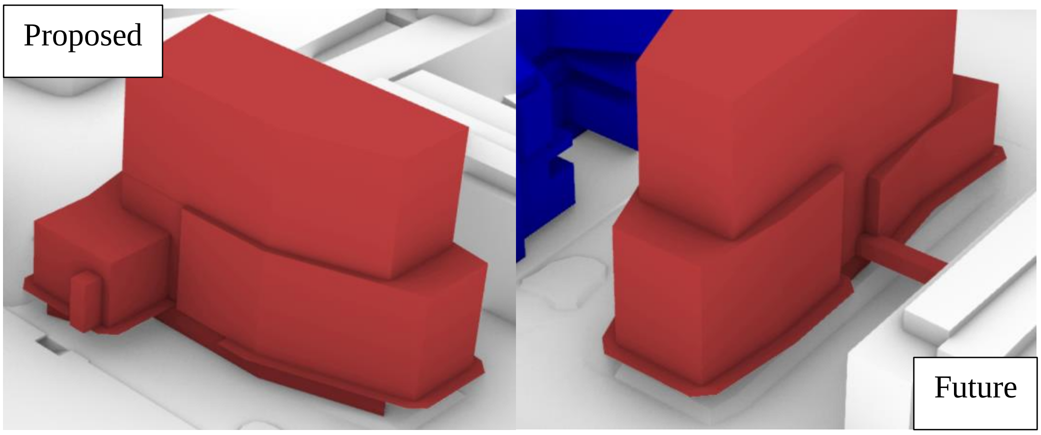

Figure 7: Close-up views of the model from the north-east (L) and north-west (R)

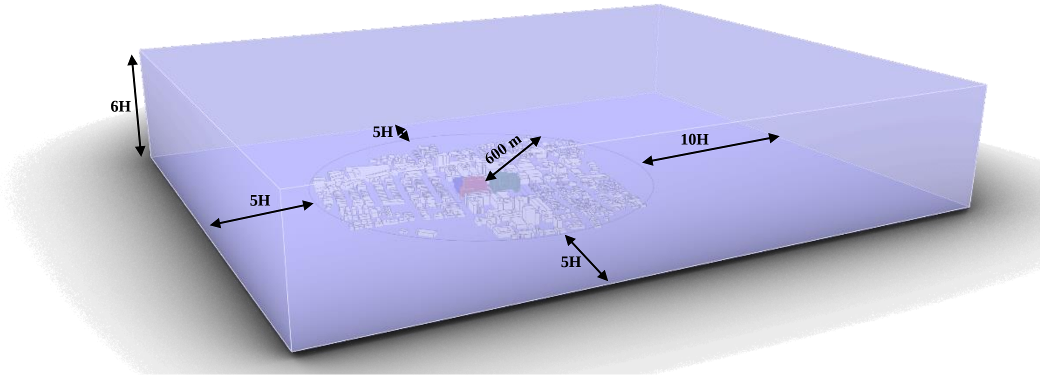

Figure 8: Simulation domain (dimensions in metres)

A computational mesh was constructed comprising of approximately 25 million hexahedral elements, Figure 9. 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. A mesh sensitivity study was conducted to reduce the effect of mesh size on the solution.

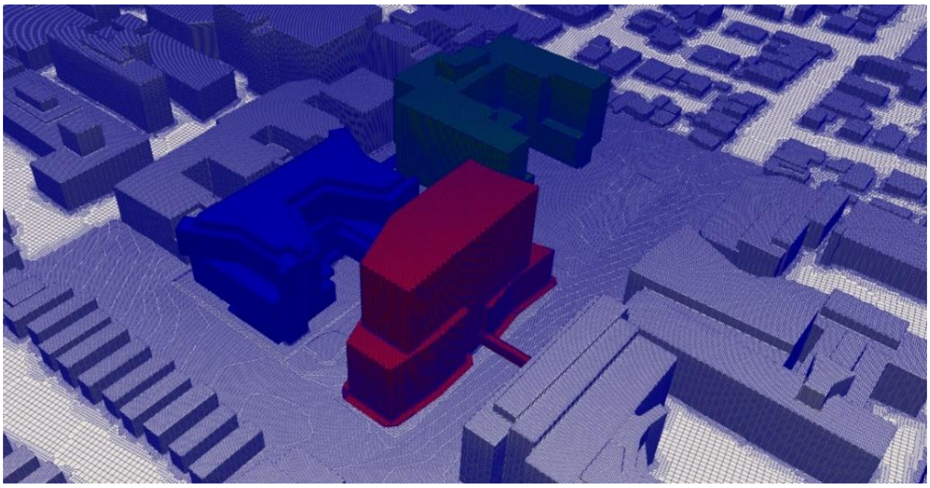

Figure 9: Mesh strategy and grid resolution in future configuration

The effect of terrain outside the 1 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.

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 Figure 10. 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 would 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 site safety, and comfort classification based on 0.022% and 5% of the time exceedance respectively 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.

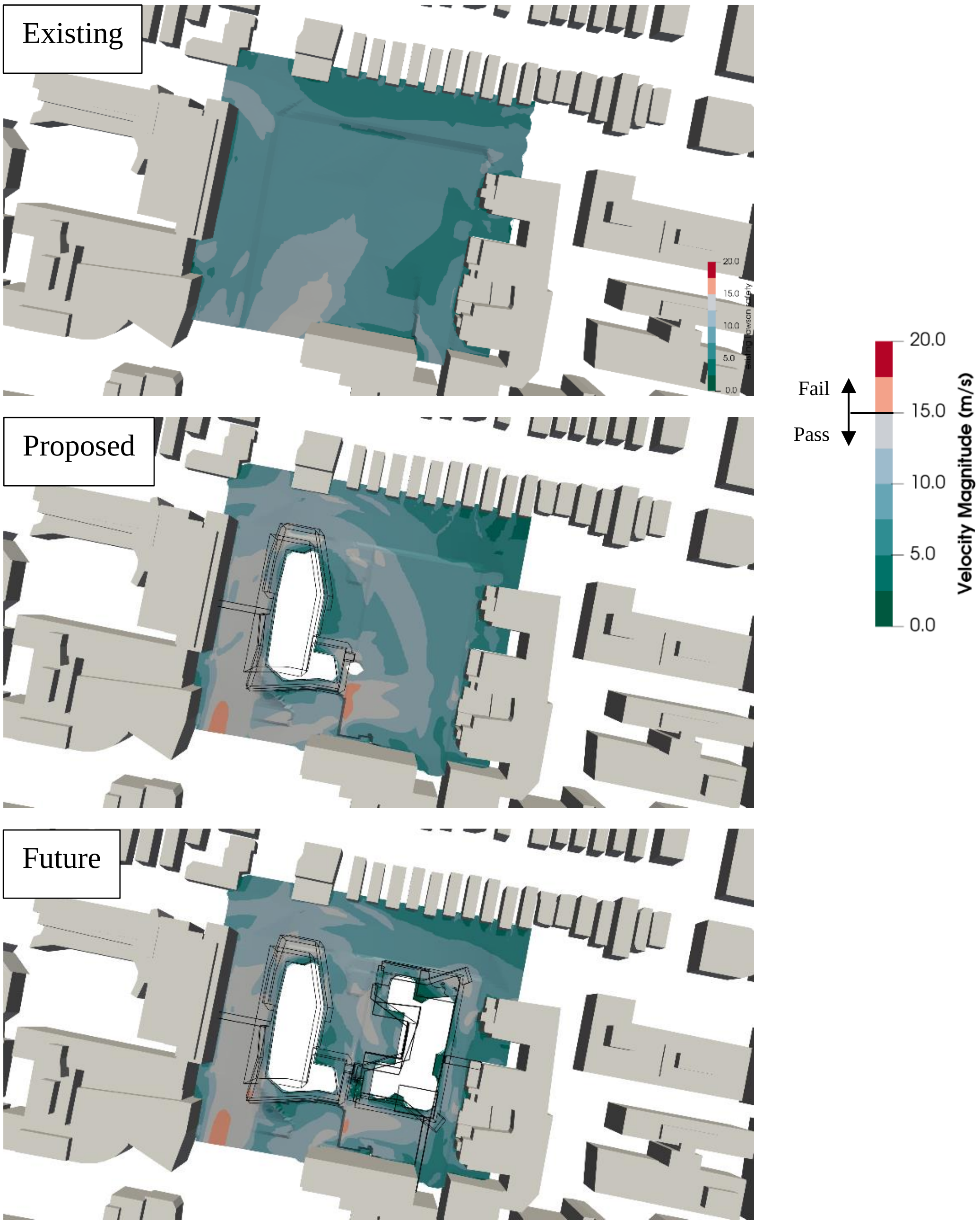

Figure 10: Classification of wind safety at 1.5 m above local ground level for the existing conditions (T), proposed development (M) and future development (B).

It is evident from Figure 10 that all locations pass the safety criterion in the existing configuration. With the inclusion of larger buildings, the wind speed exceeding 0.022% of time generally increases during business hours. The wind conditions at ground level are based on the impact of the compound building geometry. With the inclusion of the proposed UNSW HTH, the spacing between the Wallace Wurth and IASB buildings generates zones of faster flow for prevailing wind directions. The inclusion of the taller UNSW HTH building causes minor exceedances of the safety criterion:

1. in the middle of Botany Street to the south of the site. This is caused by winds from the north-west inducing downwash to the south, and channelling flow for winds from the north-east, Appendix 1. Pedestrians access would be along the

pavement and not in this area, so is not considered an issue. A pedestrian crossing should not be included in this area,

2. locally at the perimeter of the elevated walkway between IASB and UNSW HTH for winds from the north-east and south-west quadrants being funnelled between the buildings. The perimeter balustrade was not included in the model, and if solid would have a beneficial impact on the local wind conditions. Alternatively a secondary vertical screen could be used to ameliorate the wind conditions in this area.

The inclusion of the SCH Stage 1 and the CCCC increases the massing of the compound building form, which changes the flow patterns through the site making some areas windier and calmer depending on the incident wind direction. The impact of the geometry changes on the safety conditions are:

1. The exceedance to the south of the site along Botany Street is slightly larger in size compared with the proposed configuration. The exceedance is dominated by winds from the north-west quadrant and the increased massing directs slightly more flow along Botany Street. The exceedance area remains in the middle of the road, remote from pedestrian access.

2. The increase in massing blocks winds from the north-east and hence reduces the size of the exceedance zone around the perimeter of the elevated walkway between IASB, UNSW HTH, and SCH Stage 1 and the CCCC. The final configuration is exposed to 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 perimeter balustrade was not included in the model, and if solid would have a beneficial impact on the local wind conditions.

3. There is a new minor exceedance locally under the south-west undercroft of UNSW HTH building. This is caused by more flow being directed along Botany Street during winds from the north-west as described in 1. The flow around this corner would be horizontal. It would be recommended to include solid balustrades to the stair accessing the south-west entrances, and around the perimeter of the elevated terrace area to provide local amelioration to pedestrians.

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.

It is evident from Figure 11 that in the existing configuration, the wind conditions across the site are generally classified as suitable for sitting and standing type 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 accelerating around the corners of the building massing.

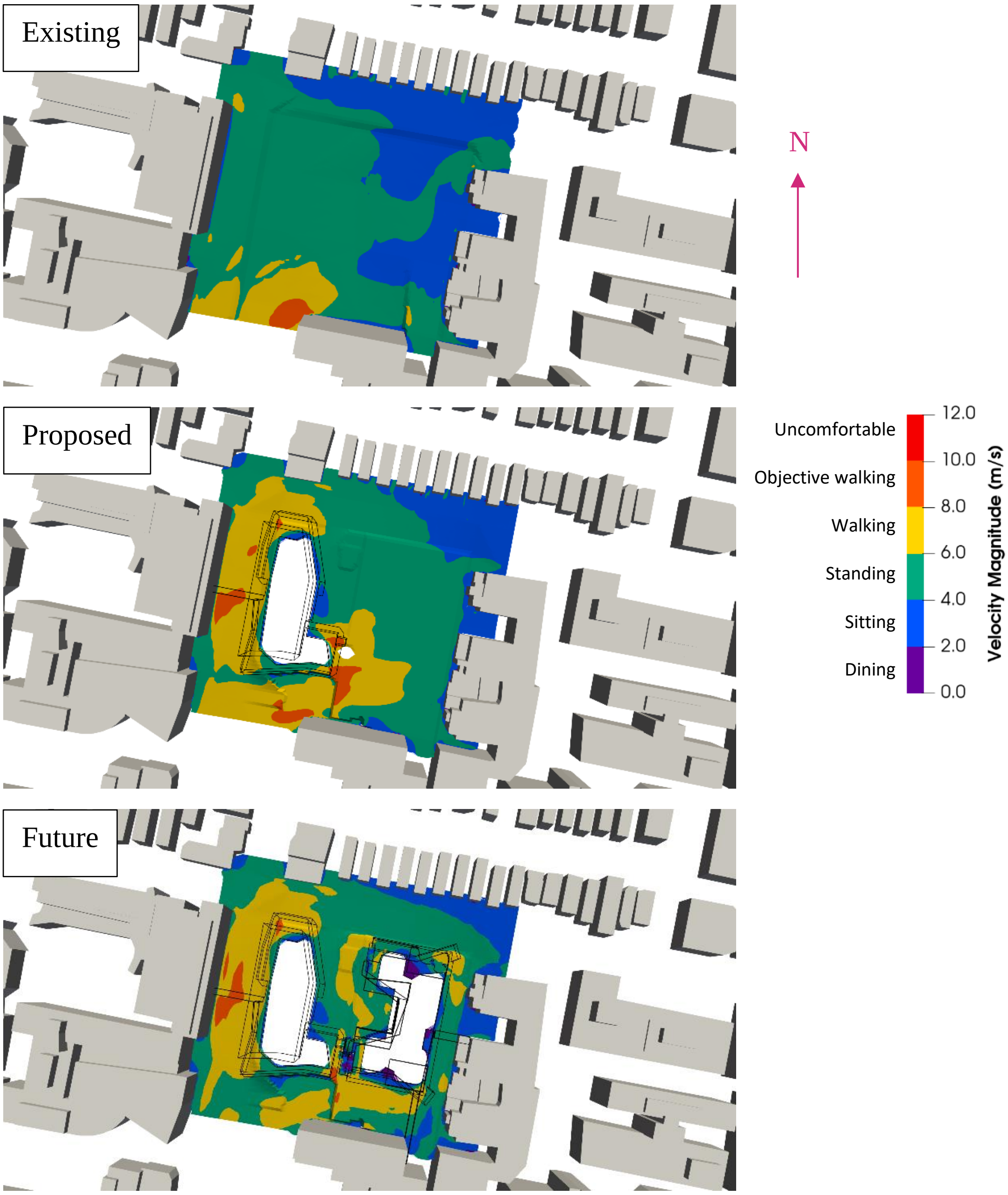

Figure 11. Classification of wind comfort at 1.5 m above local ground level for the existing conditions (T), proposed development (M) and future development (B).

The inclusion of UNSW HTH 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 entries to the building are generally calmer, being classified as suitable for pedestrian sitting or standing. The wind conditions in the UNSW Plaza area are generally relatively calm, in particular, close to the east façade. Local amelioration such as permanent or temporary vertical barriers may be required in outdoor eating areas.

The wind conditions exceeding the walking criterion in the existing configuration around the north-west corner of the IASB are distributed over more areas with the inclusion of the UNSW HTH. This is caused by the flow being channelled between the two large buildings for the two prevailing wind directions from the north-east and south-west. The wind conditions on the upper section would benefit with the inclusion of a solid balustrade providing a calm accessway to pedestrians.

In the proposed configuration, the exceedances of the walking criterion to the north-west of the site are very small in spatial extent hence only marginally exceed the criterion. These exceedances are caused by downwash flow accelerating through the undercroft for winds from the north-east and south-west quadrants. Similar to the south-west corner a solid balustrade would offer local protection too pedestrians. The exceedance in the vicinity of the footbridge over Botany Street is caused by winds accelerating under the elevated massing for winds from the north-east and north-west and is located in the middle of the street remote from pedestrian accessways. A pedestrian crossing at street level should not be considered in this area.

With the inclusion of the future SCH Stage 1 and the CCCC building, the general wind conditions across the site tend to improve slightly in the windy areas to the south-east of the UNSW HTH building due to blockage for winds from the north-east, and get windier along Botany Street, and in the centre of the UNSW Plaza due to change in flow pattern for winds from the north-east and south-west directing more flow around the outside of the compound massing. The majority of areas are classified as suitable for pedestrian standing and walking. Local calmer areas are experienced at the main entry to the north-west of the site, and close to the building in the UNSW Plaza.

In the future configuration, windier conditions are experienced around the perimeter of the compound shape and between the buildings where pressure driven flow is experienced. The area exceeding the walking criterion along Botany Street has increased in size compared with the proposed configuration, but has centralised towards the middle of the street where pedestrians would not be expected to be walking. The small localised area under the north-west corner of the UNSW HTH building remains. The area close to the edge of the raised perimeter section between the IASB, UNSW HTH, and SCH Stage 1 and the CCCC, has significantly decreased in size. These areas are small and would result in a localised windy area, which would be expected to be ameliorated with solid balustrades or taller porous wayfinding elements to block the horizontal flow. The flow through the laneway between the UNSW HTH and SCH Stage 1 and the CCCC buildings is pressure driven and would exist regardless of the building form on buildings of this massing. The benefit of the design is the tapered nature of the form, which localises the strong wind conditions rather than having a constant fast wind speed along the entire laneway of similar width. The inclusion of staggered vertical barriers or kinetic artwork through this laneway space would ameliorate the local wind conditions.

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).

Modelling was conducted for the existing conditions and for the proposed and future developments with surrounding buildings included within a 600 m radius around the site. The three configurations 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 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 condition. In the proposed and 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. With the inclusion of SCH Stage 1 and the 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 generally increases the wind speed in the surrounding area. In the proposed and future building configurations, 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 UNSW HTH changes the shape of the walking criterion exceedance area around the north-west corner of the IASB, meaning that a smaller area would be created during winds from a specific direction, but would occur in different areas during different incident wind directions. The conditions in this area are further ameliorated with the inclusion of the SCH Stage 1 and the CCCC 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 the recessed entries are suitable for the intended use. The use of solid balustrades around the entire development would improve the local wind conditions for safety and comfort.

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 L-shape podium form, and building setbacks above ground level. The only pedestrian areas of slight concern are on the raised area between UNSW HTH and SCH Stage 1 and the CCCC to the south-east, and under the colonnades to the north-west and south-west of the site. These small areas could be ameliorated with the inclusion of solid balustrades. With the future SCH Stage 1 and the CCCC building there is a small localised zone in the laneway between the two buildings exceeding the walking comfort criterion. The wind conditions in this area could be ameliorated with the inclusion of staggered vertical porous wayfinding barriers or kinetic artwork.

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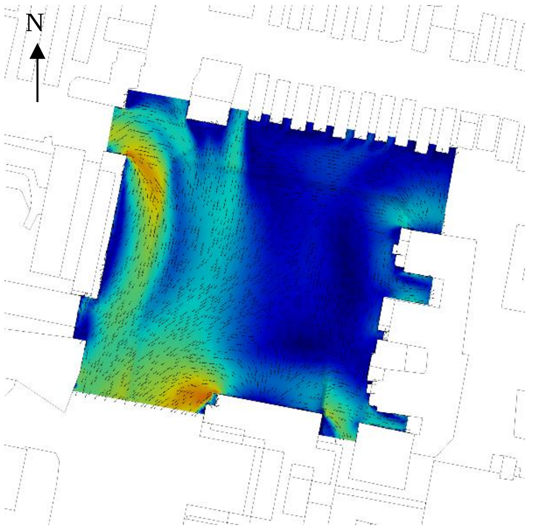
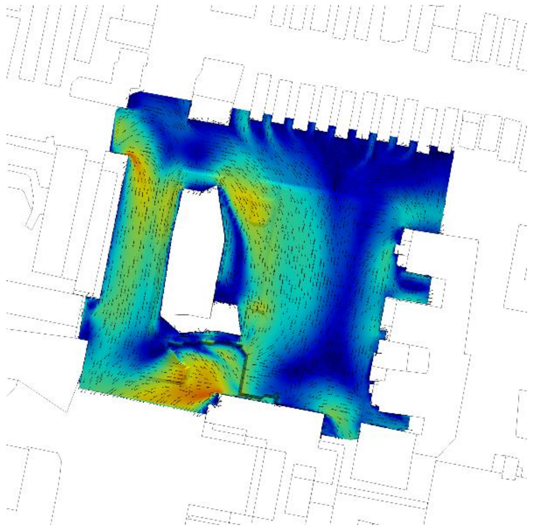
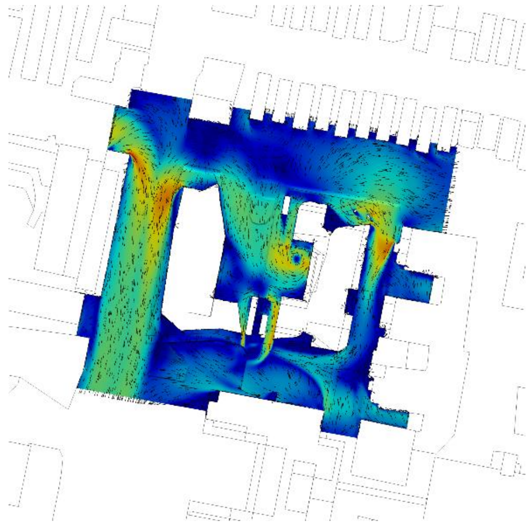
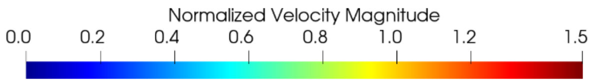
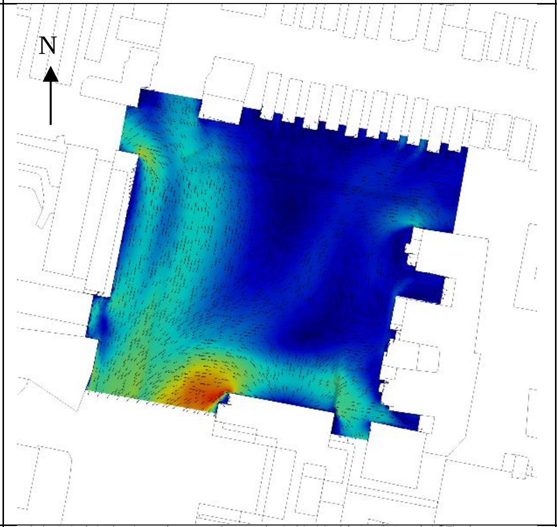
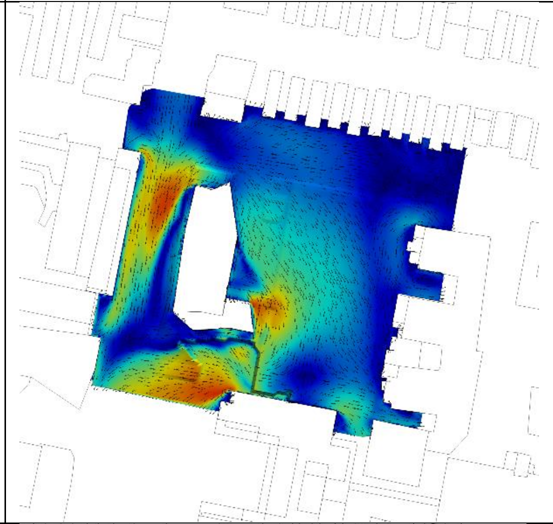
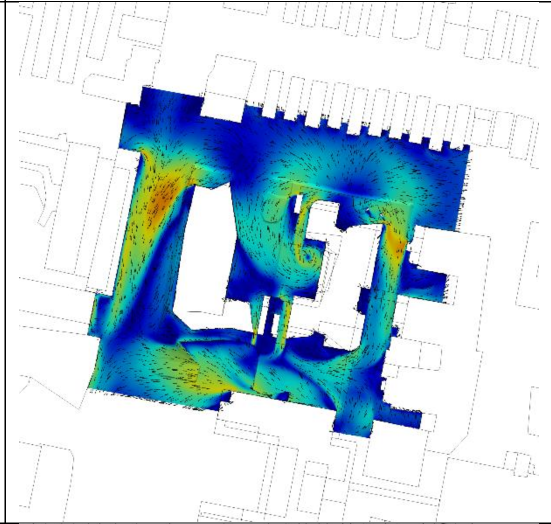
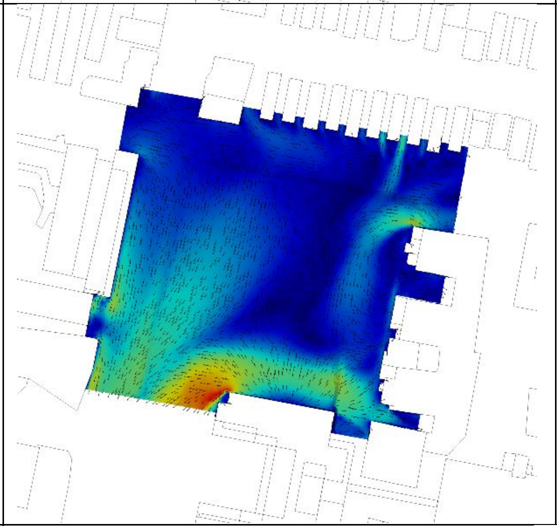
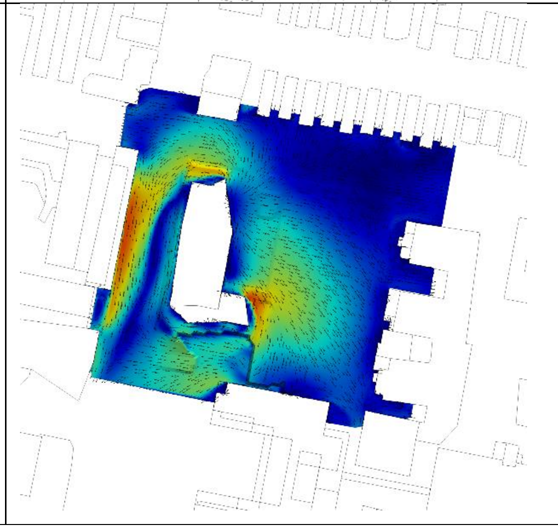
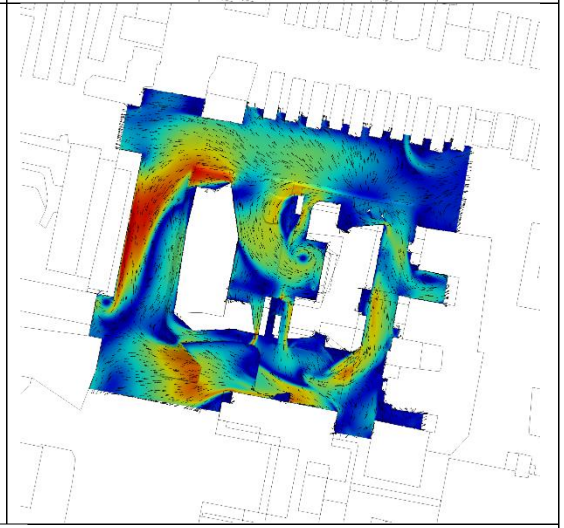
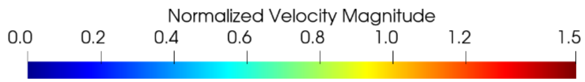
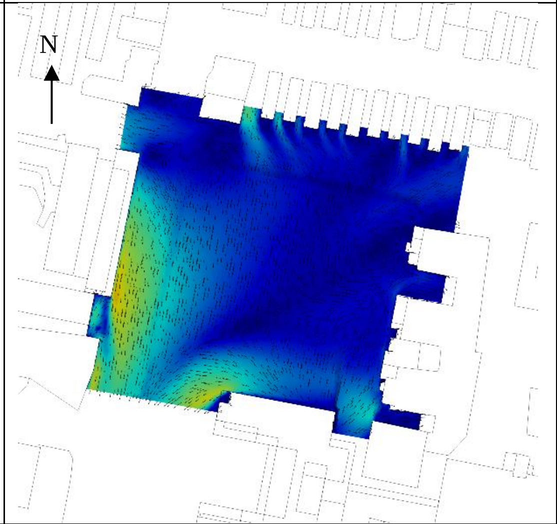
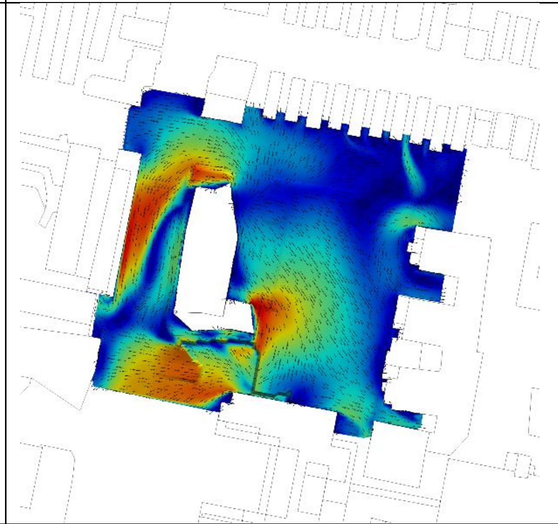
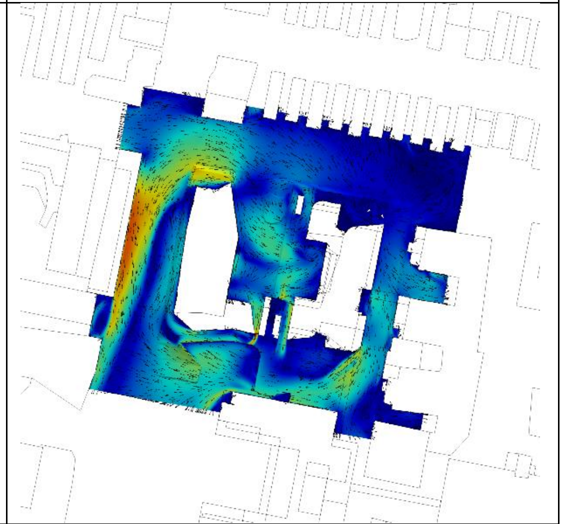
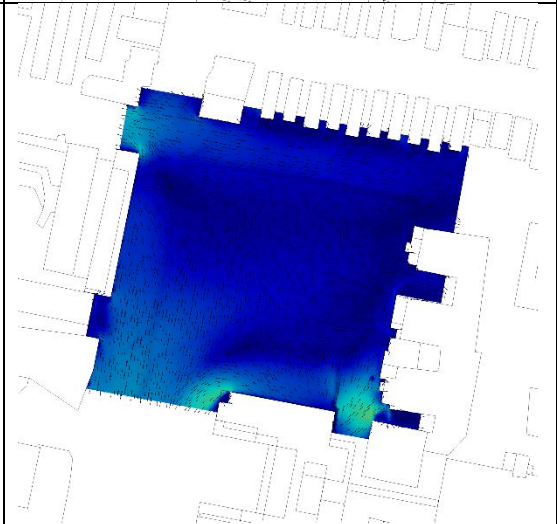
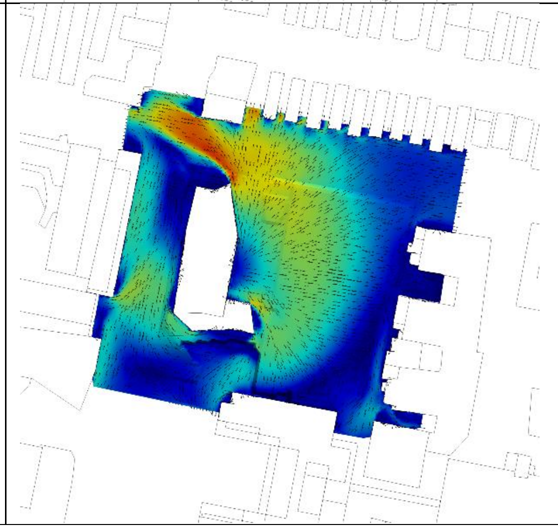
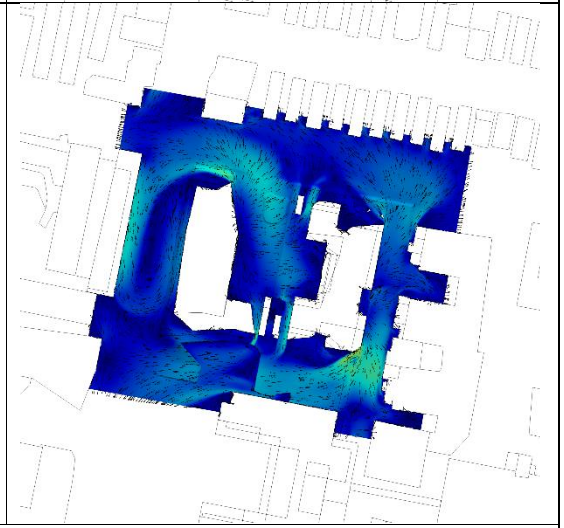
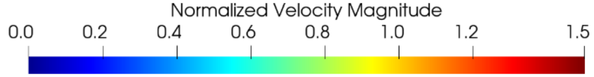
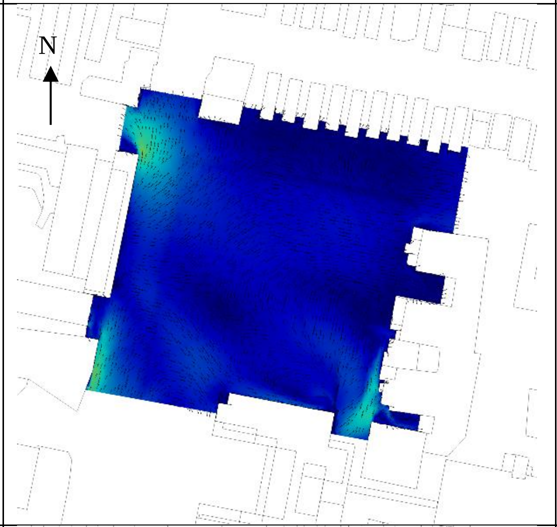
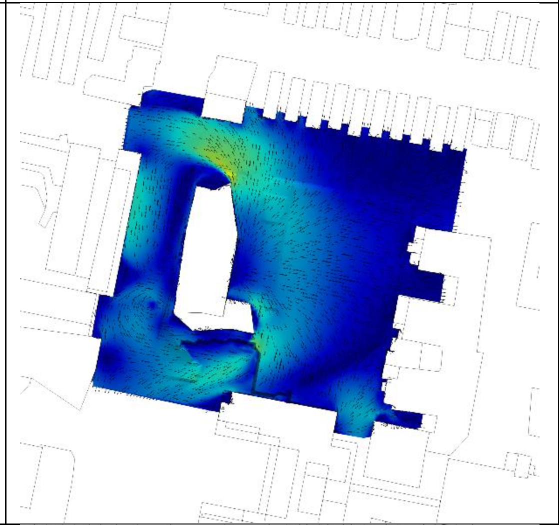
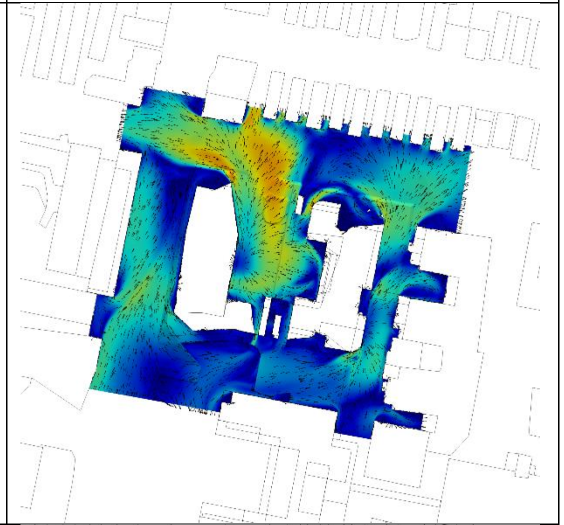
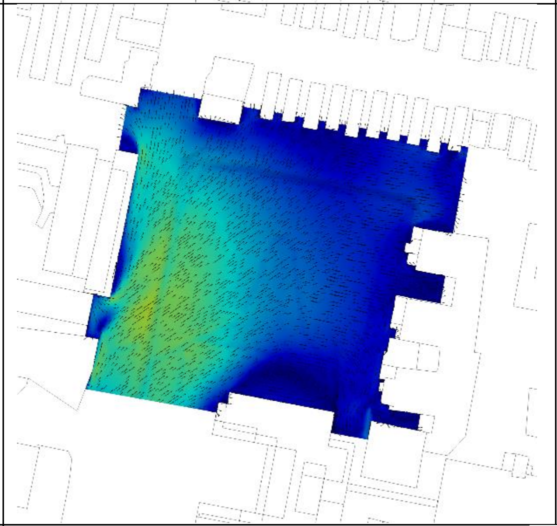
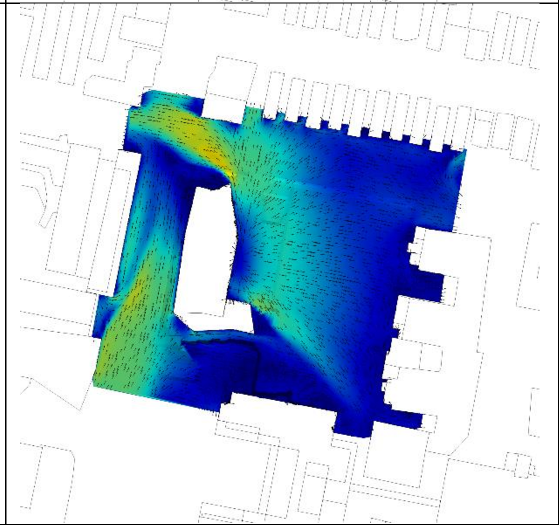
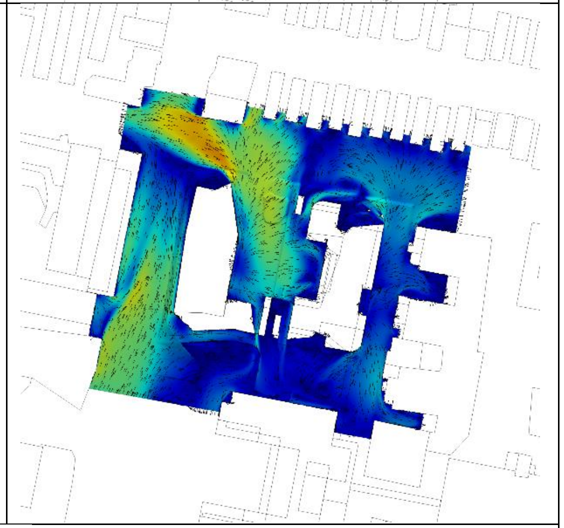
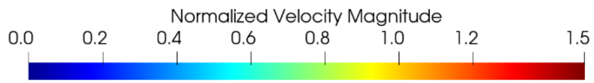
Appendix 1. Directional results at pedestrian level

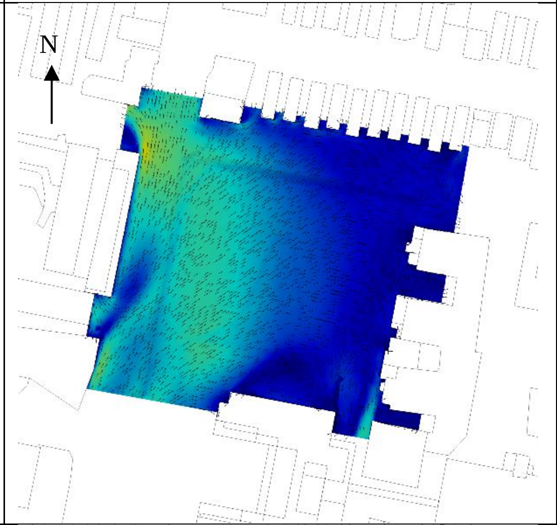
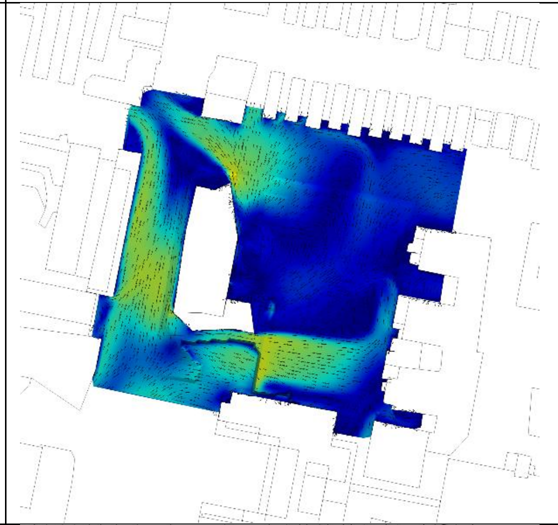
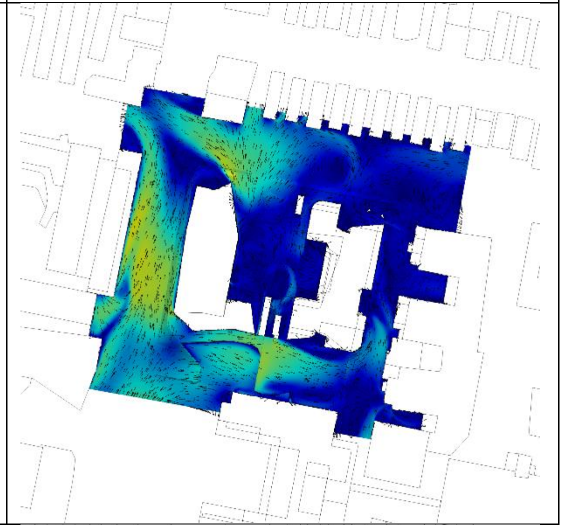
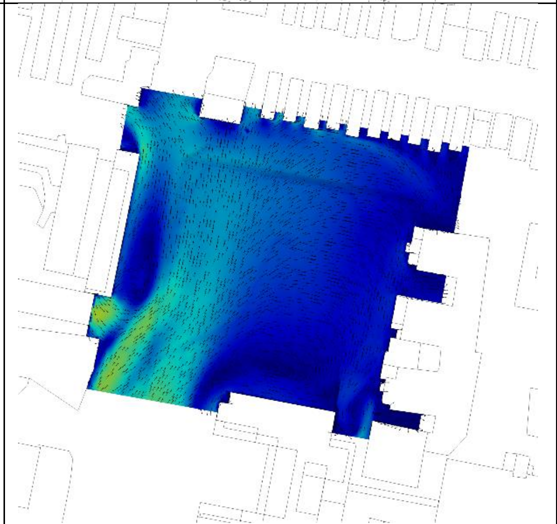
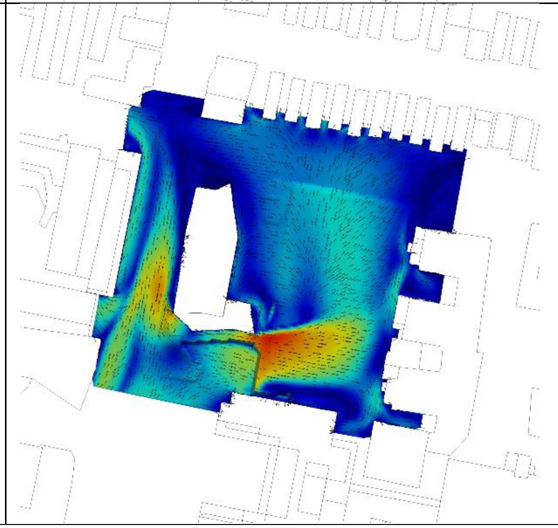
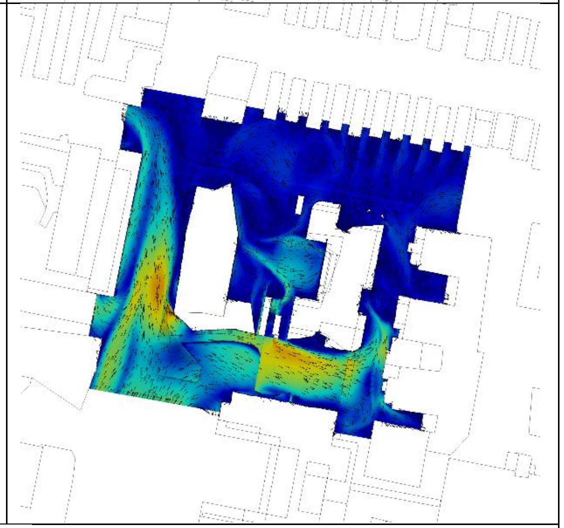
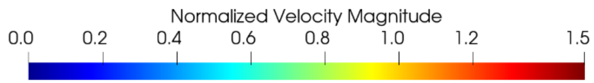
The coloured contour map of mean wind speed ratio 1.5 m above the ground for different wind directions are presented below. The wind speed ratio is calculated as the local wind speed to the reference undisturbed mean wind speed of 4 m/s at 10 m in suburbia region (TC3). These directional CFD results 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.

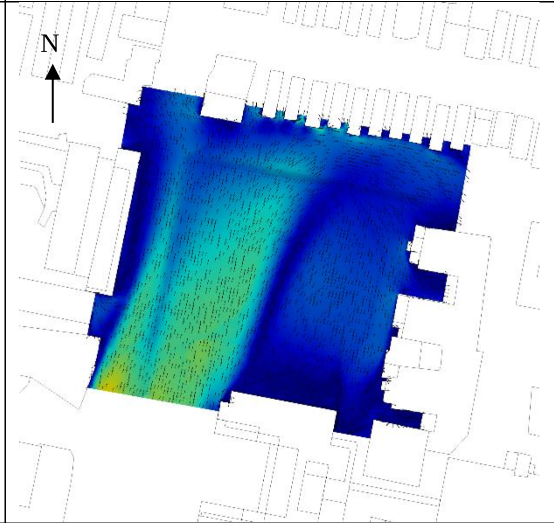
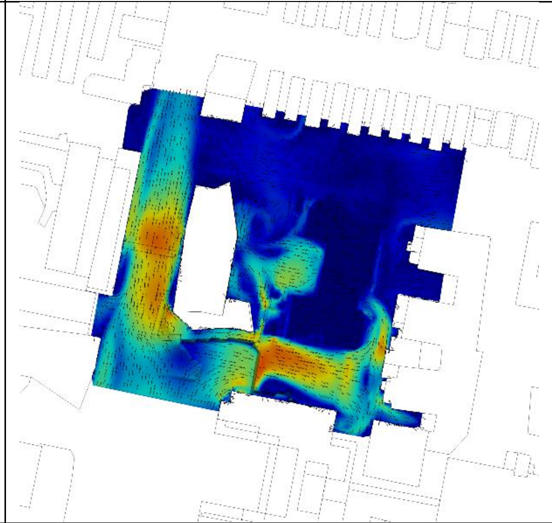
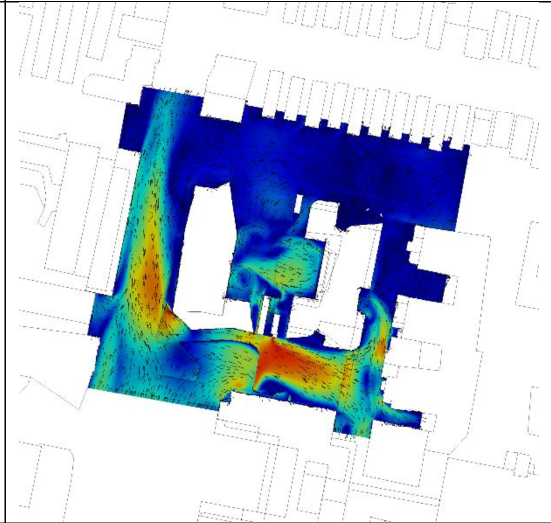
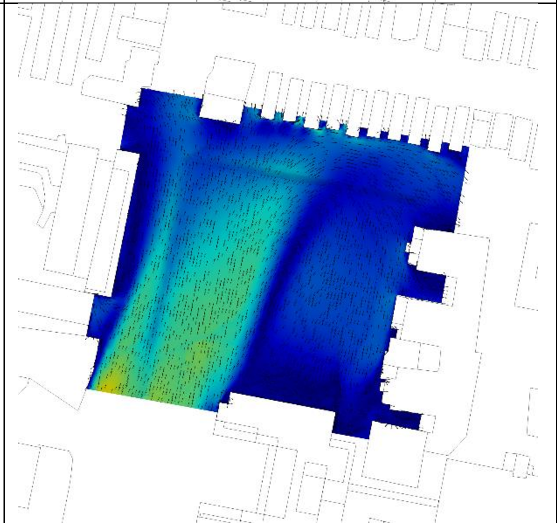
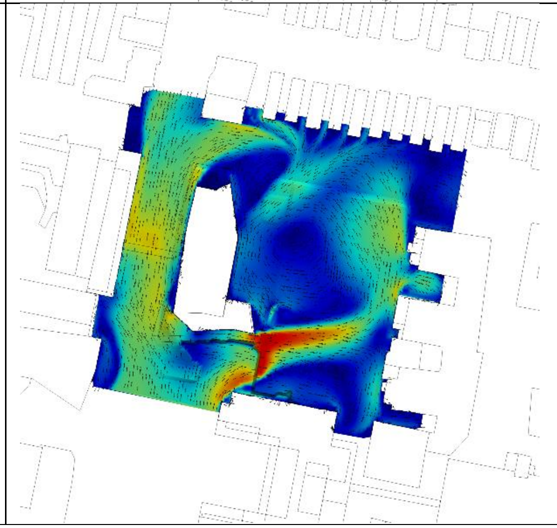
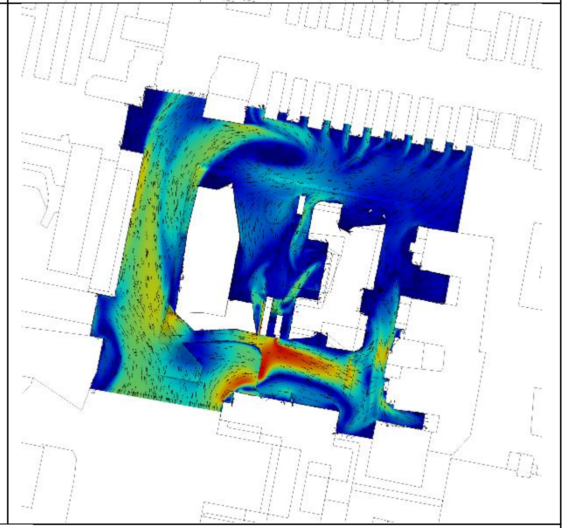
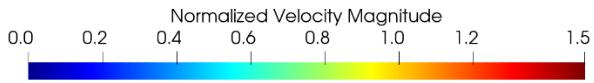
Wind direction	**Existing condition**	**Proposed development**	**Future development**
0º ↓			
			

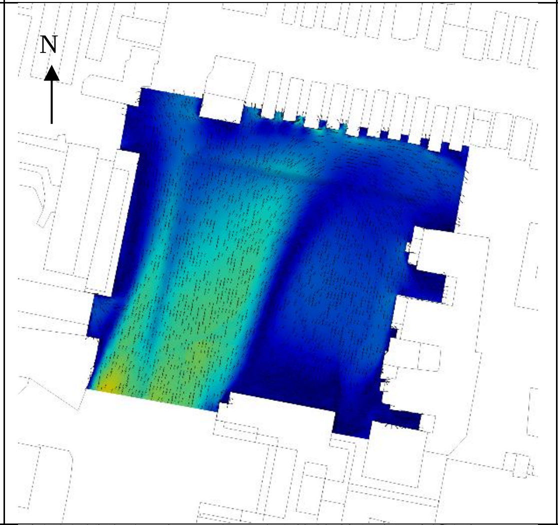
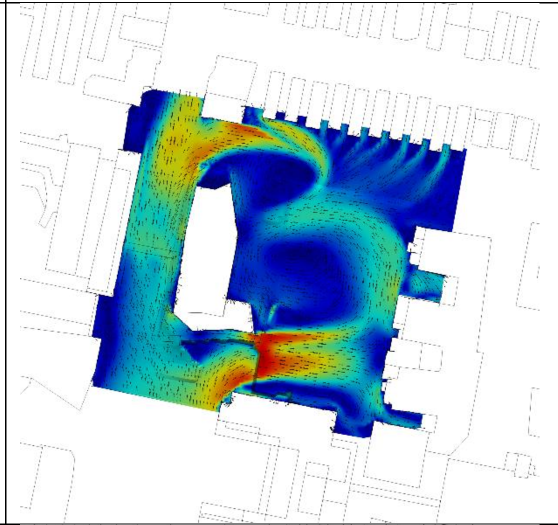
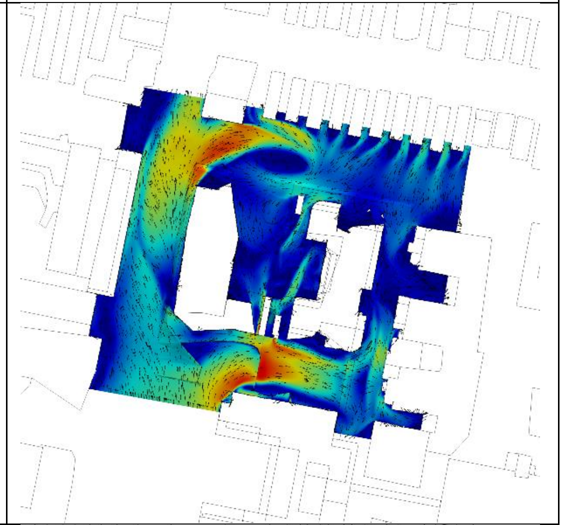
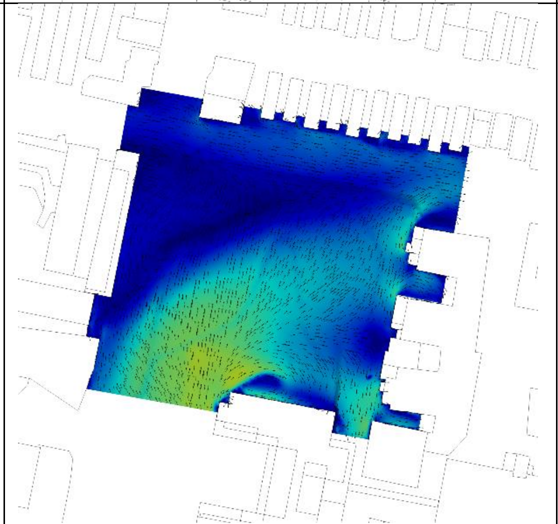
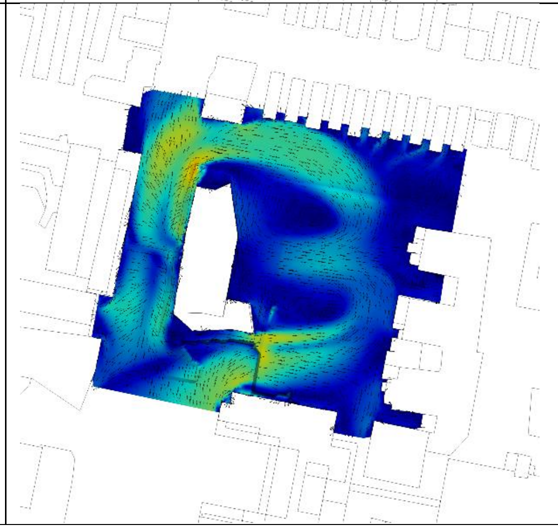
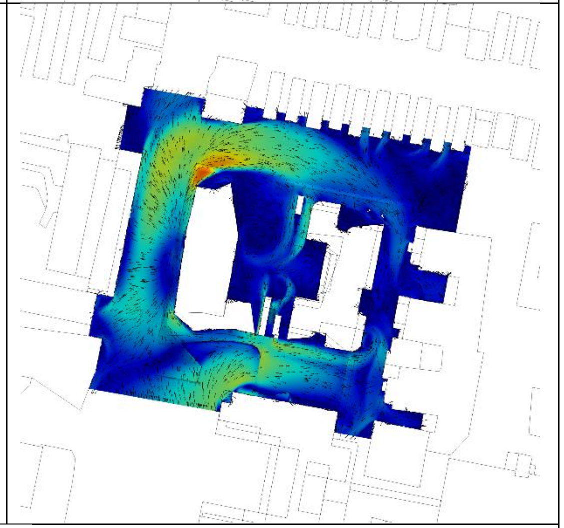
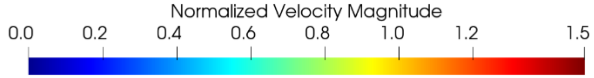
Wind direction	**Existing condition**	**Proposed development**	**Future development**
22.5º			
45º			
			

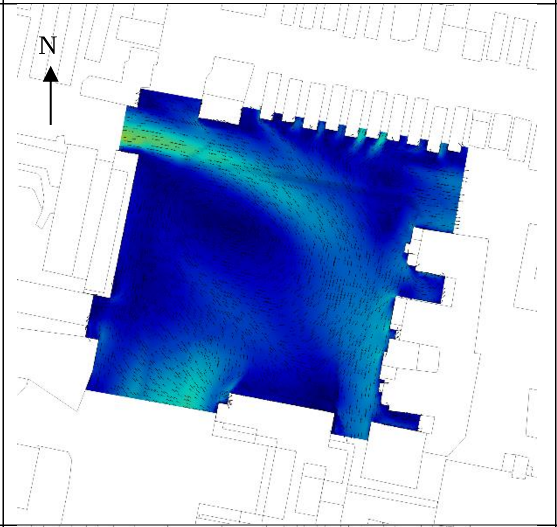
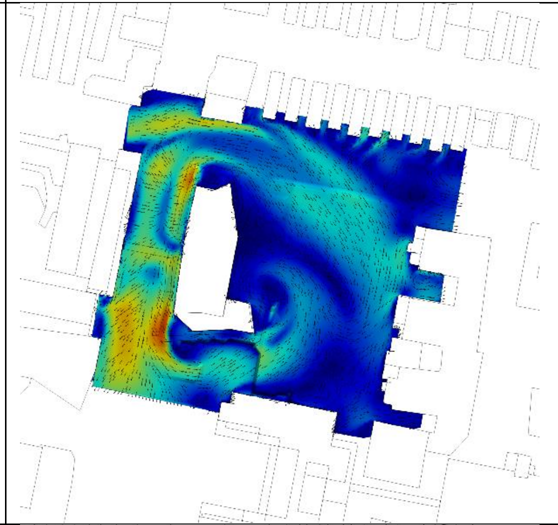
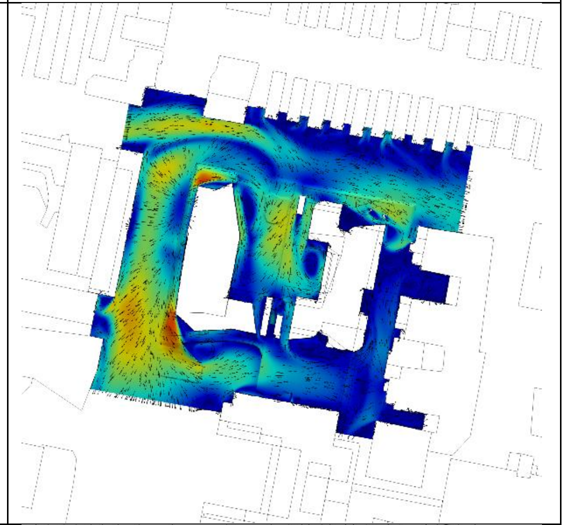
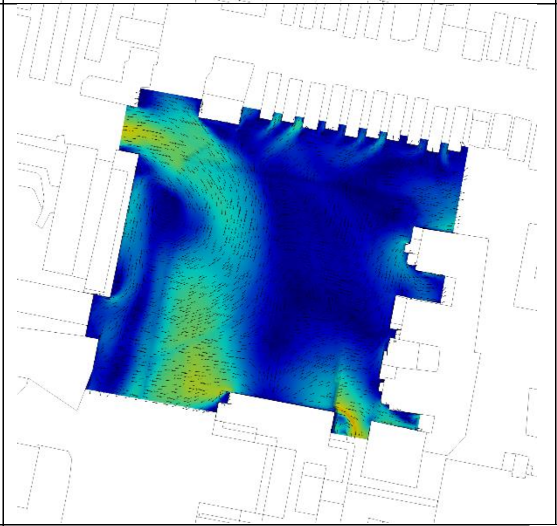
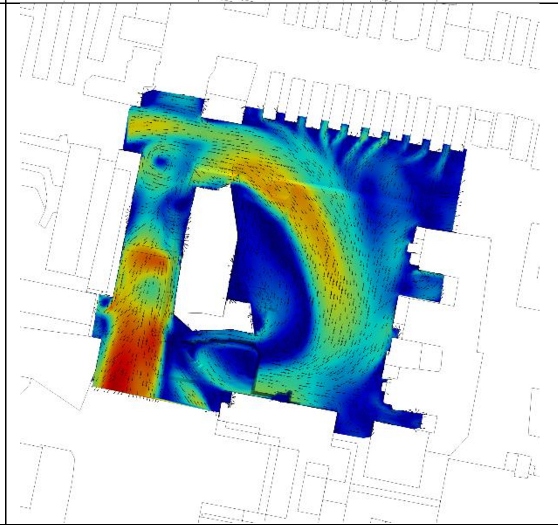
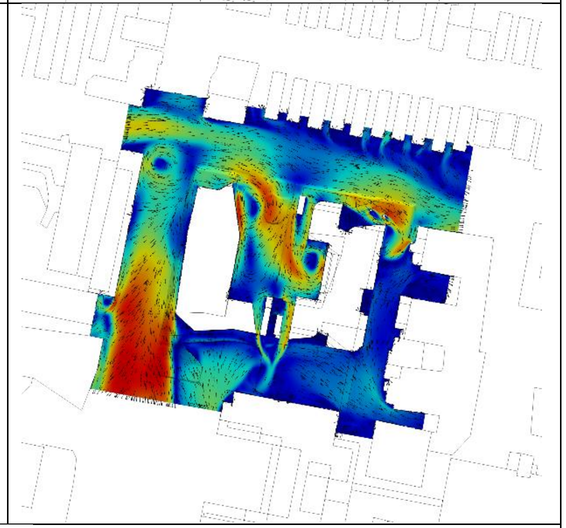
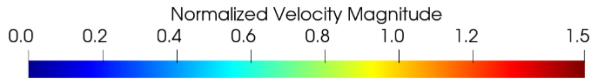
Wind direction	Existing condition	Proposed development	Future development
67.5º ↙			
90º ←			
			

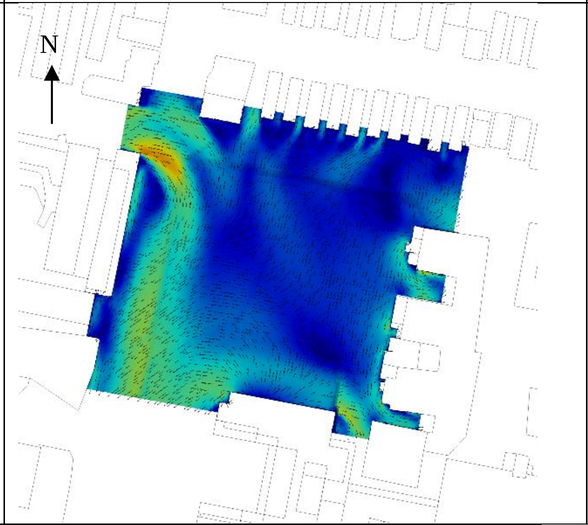
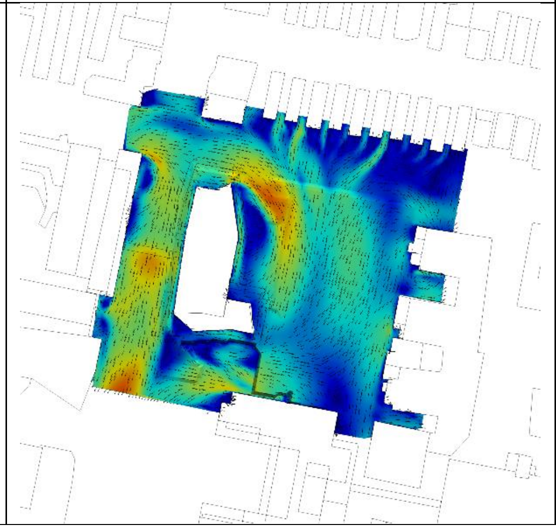
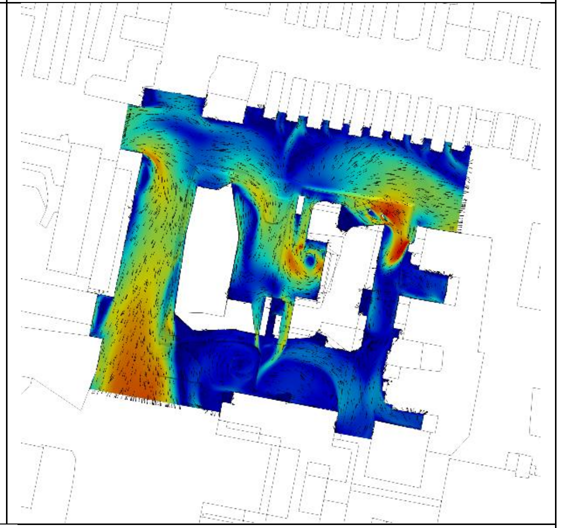
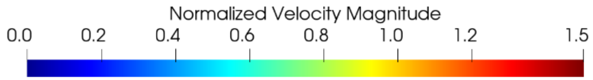
Wind direction	Existing condition	Proposed development	Future development
112.5º ↖			
135º ↖			
			

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.

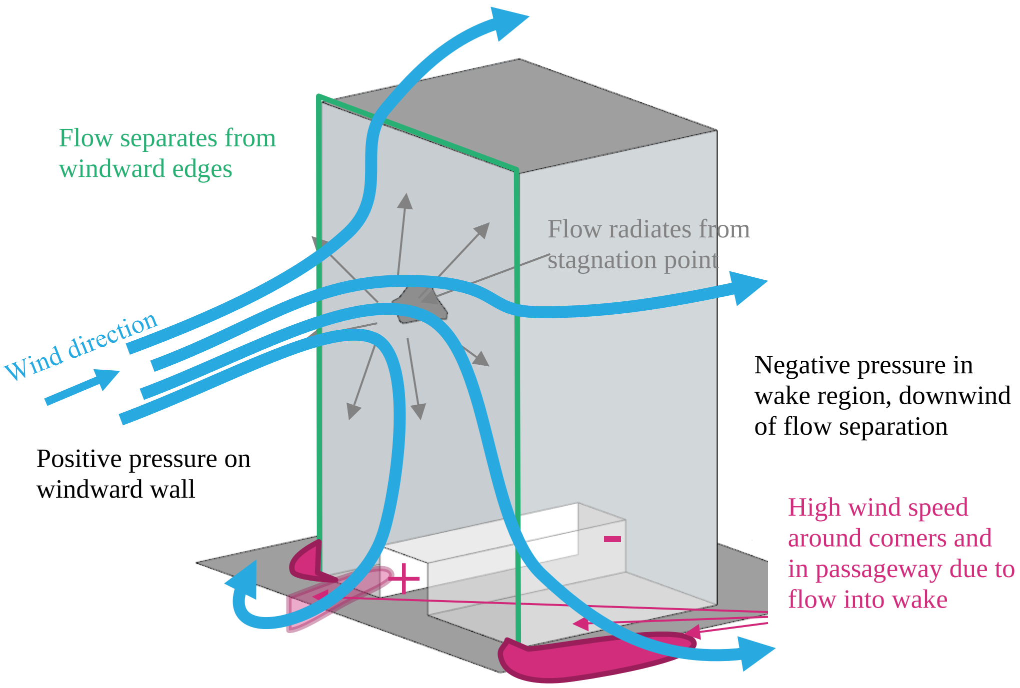


Figure 12. Schematic wind flow around tall isolated building

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.

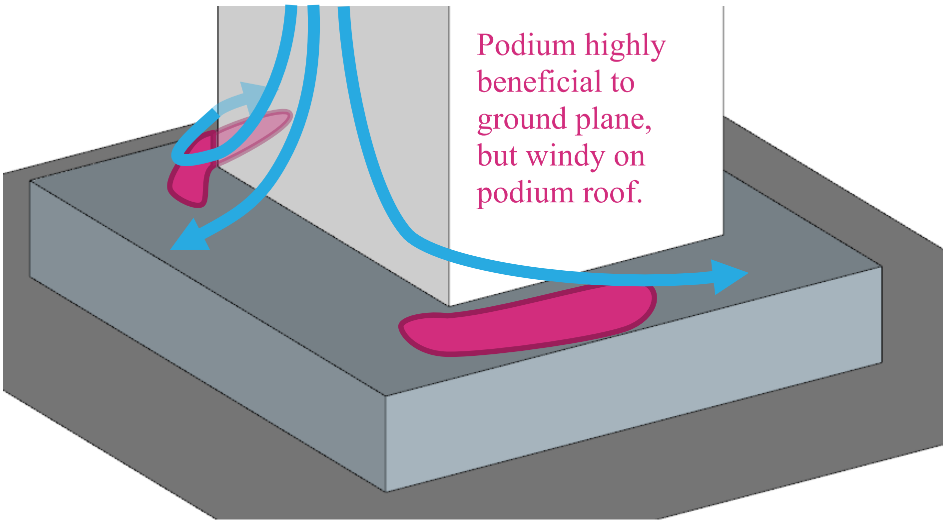


Figure 13. Schematic flow pattern around building with podium

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.

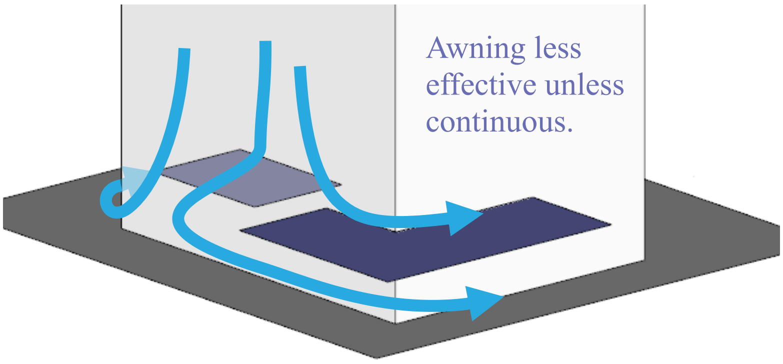


Figure 14. Schematic flow pattern around building with awning

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.

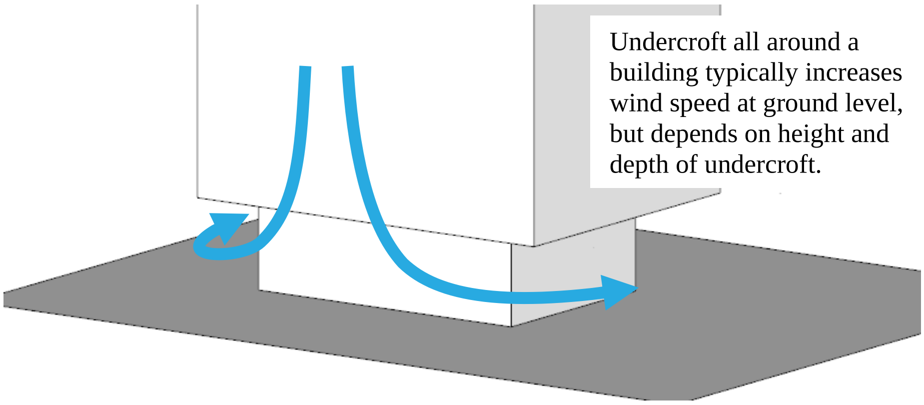


Figure 15. Schematic of flow patterns around isolated building with undercroft

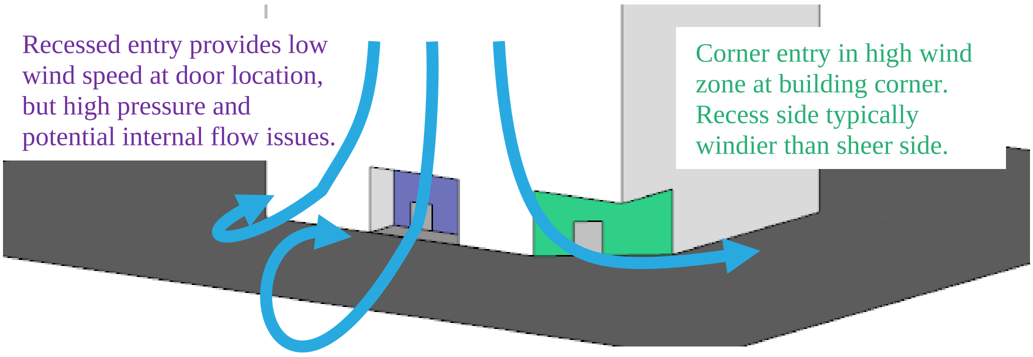


Figure 16. Schematic of flow patterns around isolated building with ground articulation

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.

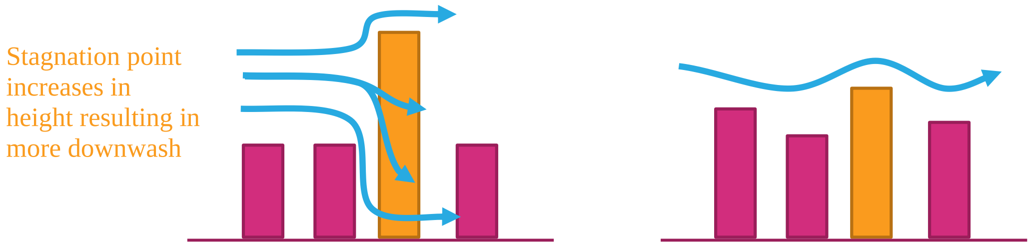


Figure 17. Schematic of flow pattern interference from surrounding buildings

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.

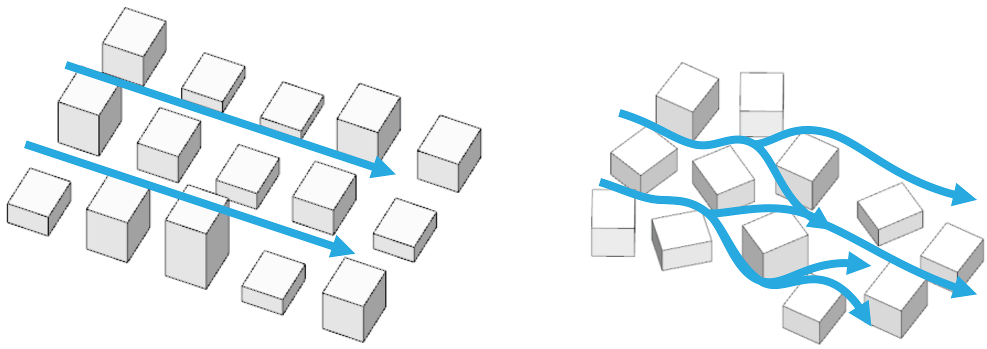


Figure 18. Schematic of flow patterns through a grid and random street layout

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:

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

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.

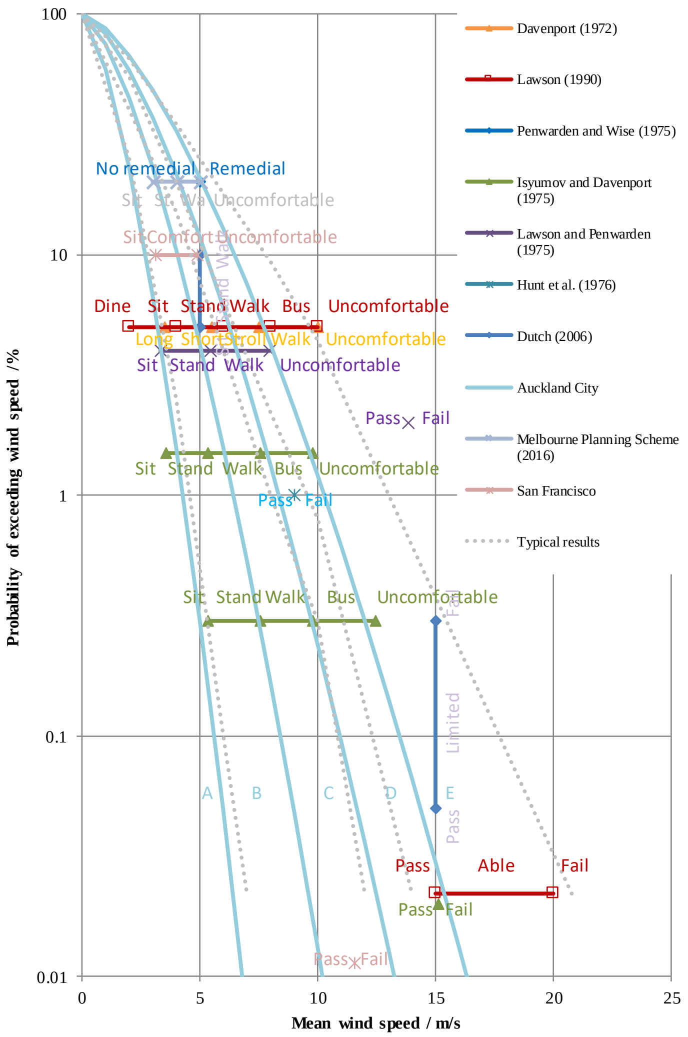


Figure 19. Probabilistic comparison between wind criteria based on mean wind speed

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

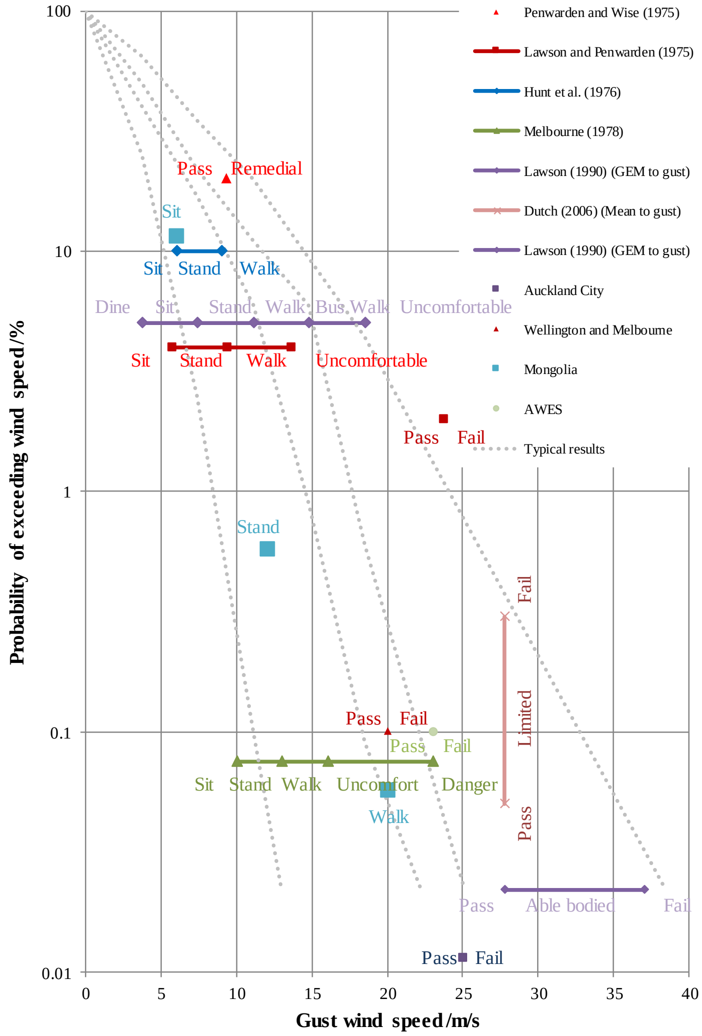


Figure 21. Probabilistic comparison between wind criteria based on 3 s gust wind speed

Appendix 4. Reference documents

In preparing the assessment, the following documents have been referenced to understand the building massing and features.

201204_UNSW Health Translation Hub_Draft SSDA Architectural Set.pdf

201214_UNSW HTH_3D Model_Architectus.ifc