Thirdi Crows Nest Lot B Pty Ltd

Crows Nest OSD Site B

Environmental Wind Assessment Report

Reference: Report

Revision 02 | 23 September 2024

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Job number 298160-00

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Executive Summary

Arup have been commissioned to prepare a quantitative environmental wind impact assessment for the proposed Crows Nest Over Station Development (OSD) Site B, on the pedestrian level wind conditions for comfort and safety in and around the site. This report specifically responds to the Secretary's Environmental Assessment Requirements (SEARs) for Environmental Amenity, Pedestrian Wind Environment Assessment.

The wind conditions in and around the site have been quantified through computational fluid dynamics (CFD) modelling in the existing and proposed configurations. This qualitative report presents the current design, with a comparison to the results of the CFD modelling, which was completed by Arup in October 2023 (Appendix A.1).

The site is exposed to the prevailing winds from the north-east, south-east, and north-west, which impact the local wind conditions at the site. The results illustrate the combined impact of Sites A-C and the associated impacts on the local wind environment.

Ground Level

At ground level, through qualitative review, the proposed changes in geometry since the quantitative modelling was completed were found to be minimal from a wind perspective and would be expected to have a negligible impact at the ground level in terms of pedestrian wind comfort and safety. Quantitative numerical modelling (CFD) of the current design would be expected to produce similar results to the previous quantitative modelling completed by Arup in October 2023 (Appendix A.1). These results found that at ground level, all locations pass the safety criterion in the existing and proposed configurations. From a comfort perspective, the majority of locations meet the walking criterion used for the study. There are minor exceedances of the comfort criterion along Pacific Highway in non-pedestrian areas, and along Hume Street, with areas of objective walking predicted. These small areas of higher wind speeds are the combined impact of Sites A-C channelling the wind along Hume Street and wind mitigation strategies would need to be holistically considered across the three sites. For Site B, the proposed street planting would be considered effective to help mitigate pedestrian wind conditions along the Hume Street frontage.

Elevated locations

At elevated locations, through qualitative review, the various changes (inclusion of wintergardens for some apartments and revised design, including layout, location, solid balustrades and/or incorporation of blade walls) are expected to improve conditions on the apartment balconies across Levels 7 to 20, compared to the reported quantitative results (Appendix A.1). All apartment balconies across Levels 7 to 20 are expected to meet the safety criterion, and be suitable for sitting or standing from a wind comfort perspective. Aside from the key layout changes for the penthouse terraces, the rooftop terrace conditions are expected to be similar to those of the quantitative modelling, where all areas met the safety criterion, and wind comfort conditions at the majority of locations are suitable for sitting, with some areas suitable for standing, due to the high level of articulation and shielding. The southern end of the terrace is more classified for walking for the southern penthouse terrace and southern communal area, including the southern area of the pool terrace.

It is important to note that the elevated locations are all privately accessible and these spaces can be used and/or managed as required.

Corridors

The key changes for the communal corridors include closing off the north-east corridor opening (adjacent to lifts; only 2.5% openability) and reducing the openability of the other openings to 50%, with the addition of automated, operable louvres on the inner side of the planter. These changes are expected to improve conditions significantly compared to the quantitative results in Appendix A.1, especially adjacent to the lifts, with the additional option that conditions can be managed with the operable louvres as required to fully close the corridors during extreme conditions.

Summary

The wind conditions around the proposed site are windier than existing conditions, due to the exposure of the site, and combined impact of Sites A-C on local wind conditions. Through qualitative review of the current design compared to design on which the quantitative modelling was based, the majority of locations are considered suitable for the intended use of the space and all locations will be suitable for their intended use subject to the mitigation measures proposed, Table 1.

Table 1: Summary of mitigation measures

Location	Mitigation measures for pedestrian wind comfort
Ground Level	Proposed street planting along Hume Street frontage.
Apartment balconies	A combination of wintergardens for some apartments, solid balustrades, incorporation of blade walls, inset balconies, removal of wraparound balconies. These spaces are privately accessible and can be used and/or managed as required.
Roof terrace	Sectioned areas to the southern portion of the roof terrace (communal area) to provide additional protection from predominantly horizontal winds. A total height of at least 1.8 m high, including landscaping (with at least 75% solidity for landscaping) recommended for perimeters of the southern, communal area of the roof terrace and southern penthouse terrace. These spaces are privately accessible and can be used and/or managed as required.
Corridors	• Closing off the north-east corridor opening (adjacent to lifts; only 2.5% openability) • Reducing openability of other openings to 50%, with the addition of automated, operable louvres on the inner side of the planters to enable fully closing the corridors during extreme conditions

Contents

Tables

Figures

Appendices

1. Introduction

Arup have been engaged to provide a quantitative pedestrian level wind assessment for the Stage 2 State Significant Development Application (SSDA) for the proposed Crows Nest OSD Site B, application number SSD-61400212. The wind conditions in and around the site have been quantified through CFD modelling in the existing and proposed configurations. This qualitative report presents the current design, with a comparison to the results of the CFD modelling, which was completed in October 2023 (Appendix A.1).

2. Secretary's Environmental Assessment Requirements (SEARs)

The Department of Planning 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 2.

Table 2: Applicable SEAR

SEAR	Comment / Reference
5. Environmental Amenity: *Pedestrian Wind Environment Assessment* ▪ *Demonstrate the current wind environment and how the building will impact this* ▪ *Include comfort level assessment of both ground plane and any external spaces that may be used or accessible.*	This report, including Appendix A.1, addresses the requirements to provide 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.

3. Development summary

Crows Nest OSD - Site B is a 14-storey tower above the Crows Nest Metro Station.

The site area is 1872 m^2. The concept approval includes a maximum height to the top of the service zone of RL 158 m and includes a maximum residential FSR of 13,000 m^2.

The Metro Station is comprised of 3 levels:

- **Ground Level - Hume Street** includes the OSD tower lobby, retail, and back of house spaces.
- **Level 01** includes a retail mezzanine, back of house, and a loading dock which is used for OSD garbage collection and is a future easement for rail authority access.
- **Level 02** contains plant rooms for the metro station.

The OSD car parking levels are located on level 5 and 6. These are naturally ventilated with 27 car spaces on level 5 and 28 car spaces on level 6. There is a total of 55 spaces.

Apartments are located from level 7 to 18. Level 19 and 20 contain penthouses.

A roof terrace on level 21 includes communal gardens and pools, as well as private penthouse terraces.

Level 7-8: 10 apartments per floor

Level 9-18: 11 apartments per floor

Level 19: 8 apartments (5 x two storey)

Level 20: 3 apartments

Total number of apartments: 130

Level 7-16: Winter garden apartments

Level 17-18: Balcony apartments

Level 19-20: Penthouses with balconies

Level 21: Rooftop with pools and outdoor kitchens

Updates to mechanical plant rooms include:

- Larger fire pump room and DAS in the basement level.
- 1x substation and reconfigured ground level. Now including main electrical switchroom and a concierge.
- Large fire water storage tank on level 1.
- 94 Condenser units located on car park levels 5 & 6.
- 28 condensers on the rooftop in an open air plant room, condensers above a larger hot water plant room.
- 8 apartments have condensers on their balconies.

4. Wind assessment

4.1 Local wind climate

Weather data recorded at a standard height of 10 m at Sydney Airport have been used in this analysis, Figure 1. The arms of the wind rose point in the direction from where the wind is coming from. The anemometer is located about 15 km to the south of the site. The directional wind speeds measured here are considered representative of the wind conditions at the site.

It is evident from Figure 1 that strong prevailing winds are organised into three main groups which centre at about the north-east, south, and west quadrants.

Strong summer winds occur mainly from the south quadrant and the north-east. Winds from the south are associated with large synoptic frontal systems and generally provide the strongest gusts during summer. Moderate intensity winds from the north-east tend to bring cooling relief on hot summer afternoons typically lasting from noon to dusk. These are small-scale temperature driven effects; the larger the temperature differential between land and sea, the stronger the wind.

Winter and early spring strong winds typically occur from the south-west, and 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.

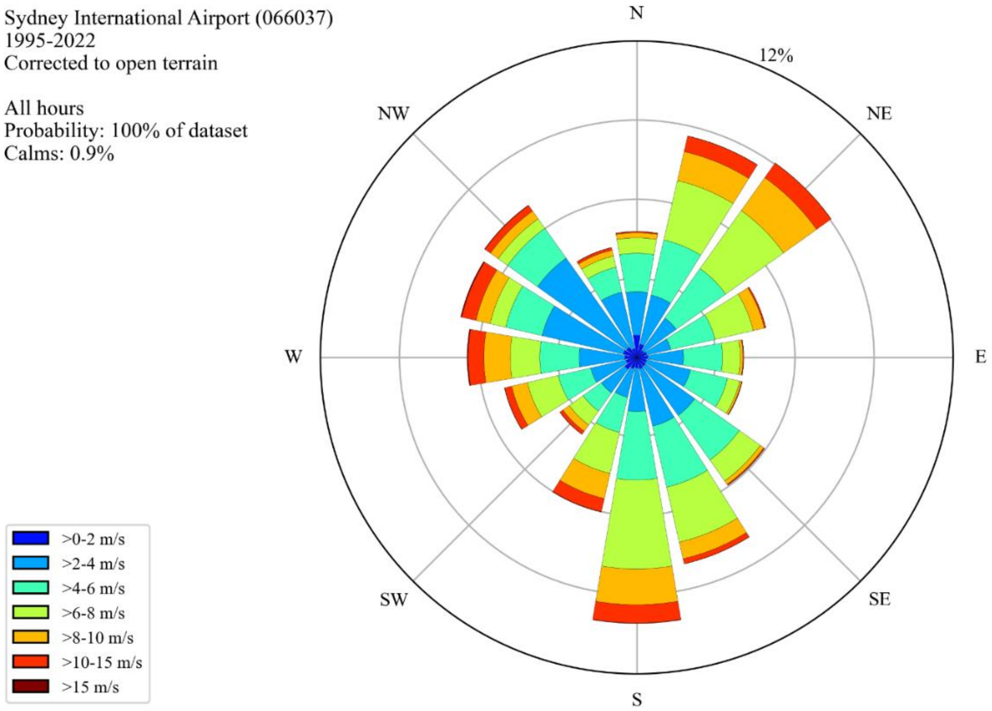

Figure 1: Wind rose showing probability of time of wind direction and speed (10 minute mean)

4.2 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.

The SSDA has no wind assessment criteria. The criteria used in this study are based on those in the North Sydney Council DCP (2013), which specifies that wind speeds along public streets, and in public spaces, should not exceed 13 m/s. It is not stated whether this wind speed is a gust or mean, as such it is assumed to correspond to a 3-second gust after the work of Melbourne (1978), and would relate to a ‘pedestrian standing’ type classification. The work of Melbourne (1978) is based on the peak 3 s gust occurring in an hour from any direction, with a probability of exceedance of 0.1%.

To combat the limited information associated with the North Sydney Council DCP (2013), the wind assessment criteria used in this study is based on Melbourne (1978), which includes additional recreational activity categories as defined in Table 3.

Table 3: Pedestrian comfort and safety criteria for various activities based on the work of Melbourne (1978)

Comfort & Safety (3 s gust wind speed in an hour exceeded for 0.1% of the time)	
<10 m/s	● Sitting
10-13 m/s	● Standing
13-16 m/s	● Walking
16-23 m/s	● Objective walking
>23 m/s	● Unsafe

There are not many locations within Sydney that would satisfy the level of wind amenity proposed in the North Sydney Council DCP (pedestrian standing) without some form of shielding. This study instead proposes the pedestrian ‘walking’ criterion to be a more appropriate comfort classification for publicly accessible spaces.

4.3 Site description

Crows Nest Site B is located at the north-western corner of the block bounded by Pacific Highway, Hume Street, Willoughby Road, and Clarke Lane, Figure 2. The proposed project comprises a new residential development with supporting retail and commercial as part of the OSD.

Figure 2: Site location (source: Google Earth 2023)

Council requirements stipulate that wind impact assessments '*assess the existing and proposed wind environment including the cumulative impact of existing and proposed tower developments adjoining and nearby the site'*. Two configurations were assessed: existing, and proposed. The proposed configuration includes the adjacent Sites A and C, Figure 2.

The site is surrounded by low- to medium-rise developments, with more substantial developments to the north-west in St. Leonards. The site rises along the Pacific Highway by about 5 m elevation from Hume Street to the south, Figure 5, which was included in the model, as well as all surrounding topography.

The proposed development consists of 19 storeys, including a 3-storey podium and 16-storey tower, with a total height of approximately 66.5 m above Hume Street, Figure 3 to Figure 6. A carpark is included on Levels 5 and 6.

The proposed development is prismatic in shape, with an articulated façade, Figure 8 to Figure 13. Levels 7-20 are residential levels, with a rooftop terrace (including swimming pools) on Level 21.

4.4 Comparative assessment

A qualitative, comparative assessment has been undertaken to compare the design changes between the following:

- drawings issued by Woods Bagot (dated 25 August 2023), on which the pedestrian wind modelling (computational fluid dynamics, CFD) and Arup Environmental Wind Assessment Report (dated 26 June 2024; refer to Appendix A.1) were based (in combination with the 3d architectural model issued on 22 August 2023), and
- current SSDA Architectural set, issued by Woods Bagot on 31 July 2024.

This qualitative review considers and discusses the impact of the proposed changes to the development on the pedestrian level wind climate in and around the site compared with the design used for quantification of the wind climate through numerical modelling as reported in Arup (Appendix A.1).

The key changes from a wind perspective, compared to the design that was modelled for the quantitative pedestrian wind assessment (Appendix A.1), are summarised as follows and marked-up in Figure 3 to Figure 14:

- No significant changes at ground levels, aside from internal layouts and removal of awnings on Hume Street, Figure 8
- Level 2 – some changes to the tower footprint on the podium, Figure 9

- Levels 7-8 – additional opening to south-west corridor to match upper levels, Figure 10
- Upper levels - third corridor opening to south-west removed to match other levels, Figure 12
- Changes to balcony locations and positioning across Levels 7 to 20, Figure 10 to Figure 12
- Changes to the rooftop terrace layout, in particular penthouse terraces, Figure 13
- Design of the corridor openings more refined with:
  - North-east opening (adjacent to lift shafts) mostly closed-off (2.5% openability), Figure 14 (L); previously modelled as 100% openability
  - Other openings 50% openability, Figure 14 (M); previously modelled as 100% openability
  - Automated, operable louvres located on the inner side of all openings, Figure 14 (R)

Figure 3: North-east Clarke Lane elevation – previous design (L), current design (R)

Figure 4: South-east elevation: previous design (L), current design (R)

Figure 5: South-west Pacific Hwy elevation – previous design (L), current design (R)

Figure 6: North-west elevation: previous design (L), current design (R)

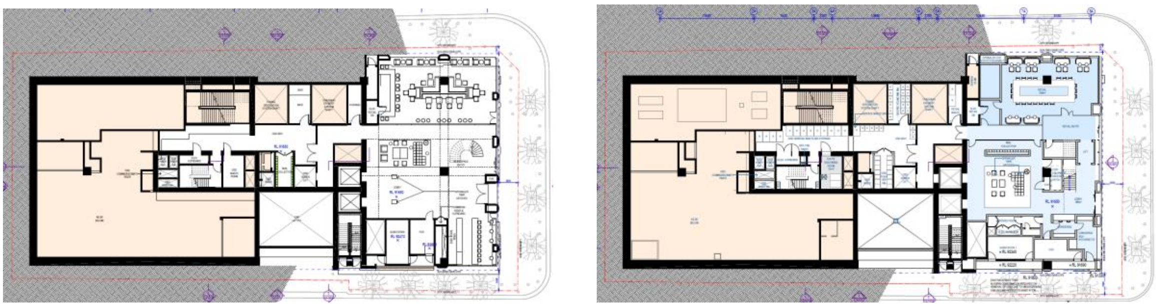

Figure 7: Ground level plan: previous design (L), current design (R)

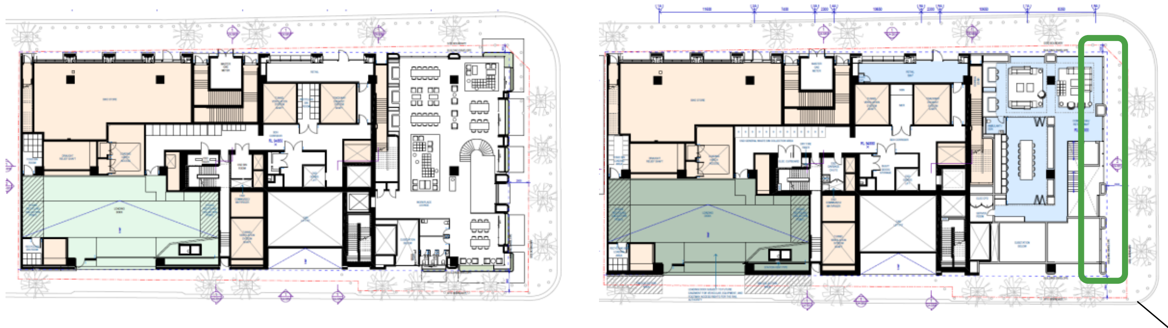

Figure 8: Upper ground level plan: previous design (L), current design (R)

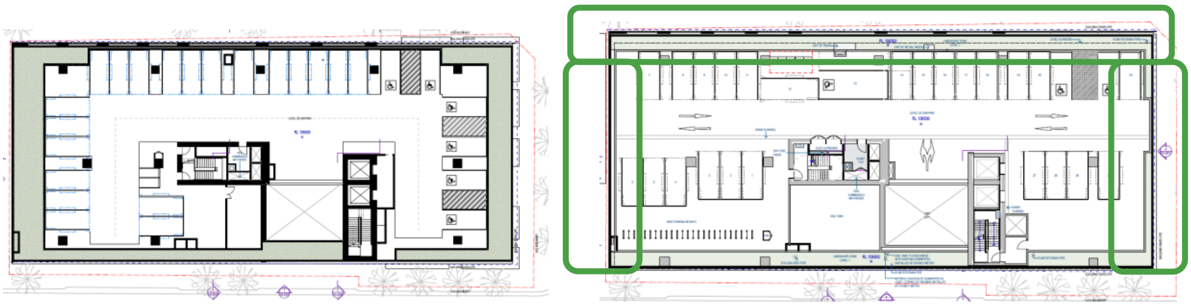

Figure 9: Level 5 - previous design (L, previously Level 2), current design (R)

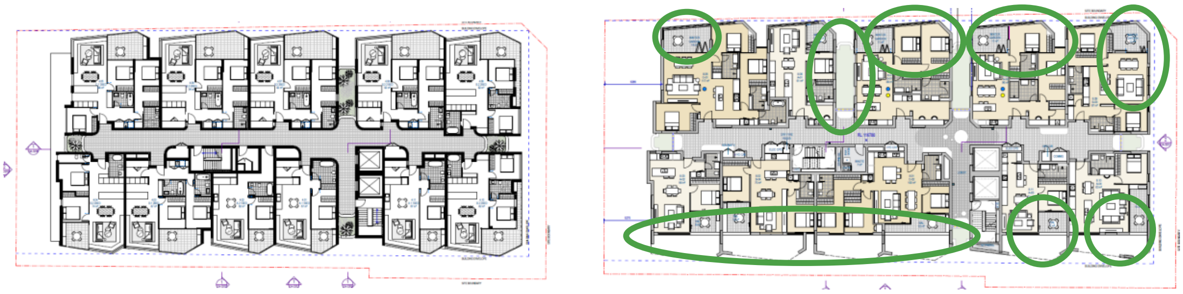

Figure 10: Level 8 - previous design (L, previously Levels 4-7), current design (R)

Figure 11: Tower plan (typical Levels 9-16) - previous design (L, previously Levels 8-11), current design (R)

Figure 12: Tower plan (typical Levels 17-18) - previous design (L, previously Levels 12-14), current design (R)

Figure 13: Roof terrace - previous design (L), current design (R)

Figure 14: Corridor openings (Levels 7+) – operable louvre locations (L), openable area (M), operable louvres inside of planters (R)

4.5 Results and discussion

Through qualitative review, the proposed changes to the development have been compared with the design used for quantification of the wind climate through numerical modelling as reported by Arup (Appendix A.1) to assess expected impacts on the pedestrian level wind comfort and safety conditions.

It is evident from Figure 3 to Figure 13 that the previous and current designs are very similar from an overall massing perspective when considering the wind effects. The main differences are the changes to the tower articulation with the modifications to various balconies and the rooftop terrace, and refinement to the design of the corridor openings. There are no major changes at the lower levels, including ground level/upper ground level. The overall tower height and general massing are the same from a wind perspective.

4.5.1 Ground plane

The proposed changes in geometry are minimal from a wind perspective and would be expected to have a negligible impact at the ground level in terms of pedestrian wind comfort and safety. As discussed in the quantitative report by Arup (Appendix A.1), the flow along Hume Street at ground level is governed by the combined of Sites A-C and strategies to mitigate the expected wind conditions cannot solely be achieved through individual sites. The removal of the awnings along Hume Street is not expected to have a significant impact.

Quantitative numerical modelling (CFD) of the current design would be expected to produce similar results to the previous modelling, completed by Arup in October 2023 (Appendix A.1). For ease of reference, the quantitative results are reproduced in Figure 15**Error! Reference source not found.**, with contour maps showing the safety and comfort classifications at ground level.

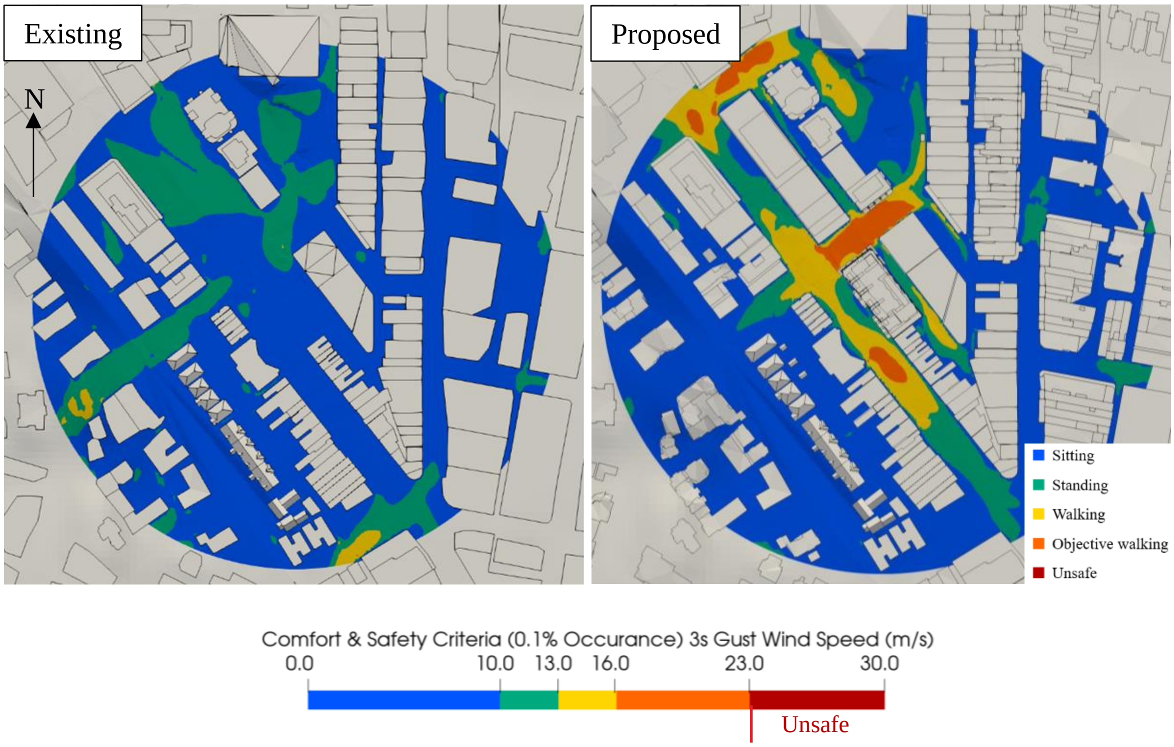

Figure 15: Quantitative results (reproduced from quantitative report, Appendix A.1) - classification of wind comfort and safety at 1.5 m above local ground level for the existing (L) and proposed (R) configurations.

The quantitative assessment found that at ground level, all locations pass the safety criterion in the existing and proposed configurations. From a comfort perspective, the majority of locations meet the walking criterion used for the study. There are minor exceedances of the comfort criterion along Pacific Highway in non-pedestrian areas, and along Hume Street, with areas of objective walking predicted. As discussed in the quantitative report (Appendix A.1, Section 3.5.1), due to the compressed accelerated flow between the buildings and the lack of landscaping in the model, the results presented along the surrounding streets are considered conservative. The wind conditions along Hume Street are the result of the combined impact of the buildings on Sites A-C. Strategies to mitigate the expected wind conditions cannot be solely achieved through individual sites. For Site B, there are no proposed outdoor seating areas and the pedestrian areas around the site are for the most part, therefore, transitory zones, in which case objective walking is applicable. The proposed trees along Hume Street, Figure 7 (R), would be effective to help improve the wind conditions along the Hume Street frontage. Please refer to Appendix A.1, Section 3.5.1 for further discussion.

4.5.2 Elevated locations

There are various changes to the apartment balconies and rooftop terrace, including:

- the balcony to the south-east corner apartment now being inset, as opposed to being located on the corner
- the balcony to the south corner apartment now being located on the corner, as opposed to being inset
- changing L-shaped balconies at the north and north-west corners to rectangular form, which would improve wind conditions
- the conversion of balconies to wintergardens across many of the apartments for Levels 7 to 16
- solid blade walls with returns, which will provide more protected spaces from prevailing winds
- modified locations for some of the apartments, slightly changing the articulation of the overall façade
- modified layout of the rooftop terrace

Overall, these changes are expected to improve conditions on the apartment balconies across Levels 7 to 20. Considering that the balconies were modelled without balustrades (worst case scenario) in the quantitative modelling, the inclusion of wintergardens for some of the apartments and revised design of balconies (layout, location, solid balustrades and/or incorporation of blade walls) is expected to improve local wind conditions, compared to the quantitative modelling. All apartment balconies across Levels 7 to 20 are expected to meet the safety criterion, and be suitable for sitting or standing from a wind comfort perspective. Aside from the key layout changes for the penthouse terraces, the rooftop terrace conditions are expected to be similar to those of the quantitative modelling, where all areas met the safety criterion, and wind comfort conditions at the majority of locations are suitable for sitting, with some areas suitable for standing, due to the high level of articulation and shielding. The southern end of the terrace is more classified for walking for the southern penthouse terrace and southern communal area, including the southern area of the pool terrace.

Please refer to Appendix A.1, Section 3.5.2 for further discussion for elevated locations.

It is important to note that the elevated locations are all privately accessible and these spaces can be used and/or managed as required.

4.5.3 Corridors

The key changes for the communal corridors include closing off the north-east corridor opening (adjacent to lifts; only 2.5% openability) and reducing the openability of the other openings to 50%, with the addition of automated, operable louvres on the inner side of the planter. These changes are expected to improve conditions significantly compared to the quantitative results in Appendix A.1, especially adjacent to the lifts, with the additional option that conditions can be managed with the operable louvres as required to fully close the corridors during extreme conditions.

5. Declaration

I, Lauren Boysen, confirm that all available information relevant to the assessment of the proposed development is contained in this report (and Appendix) and that the information contained in this report is neither false nor misleading.

Lauren Boys

Senior Wind Engineer

MIEAust CPEng NER | BAeroEng(Hons) BA

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Appendix A

A.1 Arup Quantitative Environmental Wind Assessment Report (June 2024)

Thirdi Crows Nest Lot B Pty Ltd

Crows Nest OSD Site B

Environmental Wind Assessment Report

Reference: Report

Revision 01 | 26 June 2024

Job number 298160-00

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			Prepared by	**Checked by**	**Approved by**
		Name	Lauren Boysen	Graeme Wood	Graeme Wood
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		Description	Minor revisions to Fig 2 and Fig 6 (naming of adjacent sites) and associated text, based on stakeholder comments		
			Prepared by	**Checked by**	**Approved by**
		Name	Lauren Boysen	-	
		Filename			
		Description			
			Prepared by	**Checked by**	**Approved by**
		Name			

Issue Document Verification with Document ☑

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This report details the wind conditions around the site. Numerical modelling (Computational Fluid Dynamics, CFD) was conducted by Arup in the existing and proposed configurations. Arup analysed the CFD results comparing the results with the Melbourne (1978) comfort and safety criteria, which are the basis for the North Sydney Council criteria, to provide greater interpretation of the wind conditions.

The site is exposed to the prevailing winds from the north-east, south-east, and north-west, which impact the local wind conditions at the site. The results illustrate the combined impact of Sites A-C and the associated impacts on the local wind environment.

At ground level, all locations pass the safety criterion in the existing and proposed configurations. From a comfort perspective, the majority of locations meet the walking criterion used for the study. There are minor exceedances of the comfort criterion along Pacific Highway in non-pedestrian areas, and along Hume Street, with areas of objective walking predicted. These small areas of higher wind speeds are the combined impact of Sites A-C channelling the wind along Hume Street and wind mitigation strategies would need to be holistically considered across the three sites. For Site B, the proposed street planting would be considered effective to help mitigate pedestrian wind conditions along the Hume Street frontage.

At elevated locations, all locations pass the safety criterion, with the exception of one very localised area of the western corner balcony on Level 12, which would be mitigated by the inclusion of a solid balustrade, which was not included in the modelling.

Areas of objective walking were predicted in the open corridors, based on the Level 12 analysis, both in landscaped and circulation areas, including apartment entries, lift lobby and fire stair access. It is strongly recommended to include operable openings so that wind conditions (and wind driven rain) can be managed appropriately. The southern portion of the Level 17 roof terrace is expected to experience areas of walking, with some localised areas of objective walking. Flow at this level will be predominantly horizontal and therefore, vertical mitigation strategies would be most effective (e.g. screens, landscaping, solid balustrades, etc). It is important to note that the wind comfort criterion is based on a 0.1 percent of the time gust wind speed occurring in an hour, and the elevated locations are all privately accessible locations and during high wind events, people are unlikely to use these spaces and/or they can be managed as required.

The wind conditions around the proposed site are windier than existing conditions, due to the exposure of the site, and combined impact of Sites A-C on local wind conditions. The majority of locations are considered suitable for the intended use of the space.

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Tables

Figures

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Table 1: Applicable SEAR

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3. Wind assessment

3.1 Local wind climate

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Strong summer winds occur mainly from the south quadrant and the north-east. Winds from the south are associated with large synoptic frontal systems and generally provide the strongest gusts during summer. Moderate intensity winds from the north-east tend to bring cooling relief on hot summer afternoons typically lasting from noon to dusk. These are small-scale temperature driven effects; the larger the temperature differential between land and sea, the stronger the wind.

Winter and early spring strong winds typically occur from the south-west, and 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.

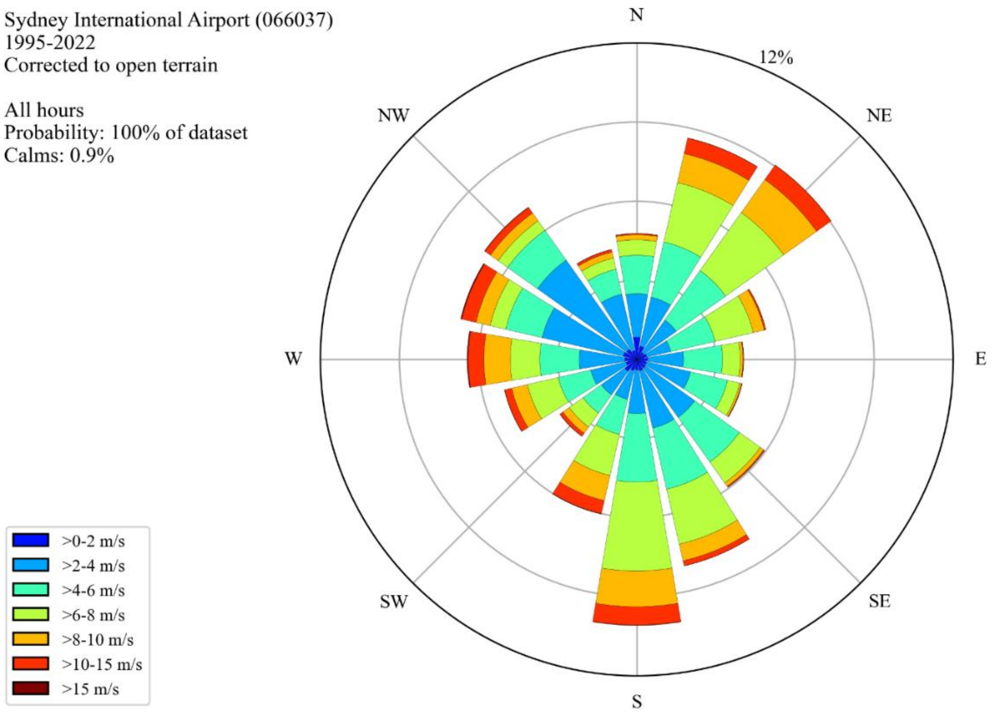


Figure 1: Wind rose showing probability of time of wind direction and speed (10 minute mean)

A general description of flow patterns around buildings is given in Appendix A.1

3.2 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.

The SSDA has no wind assessment criteria. The criteria used in this study are based on those in the North Sydney Council DCP (2013), which specifies that wind speeds along public streets, and in public spaces, should not exceed 13 m/s. It is not stated whether this wind speed is a gust or mean, as such it is assumed to correspond to a 3-second gust after the work of Melbourne (1978), and would relate to a ‘pedestrian standing’ type classification. The work of Melbourne (1978) is based on the peak 3 s gust occurring in an hour from any direction, with a probability of exceedance of 0.1%.

To combat the limited information associated with the North Sydney Council DCP (2013), the wind assessment criteria used in this study is based on Melbourne (1978), which includes additional recreational activity categories as defined in Table 2.

Table 2: Pedestrian comfort and safety criteria for various activities based on the work of Melbourne (1978)

Comfort & Safety (3 s gust wind speed in an hour exceeded for 0.1% of the time)	
<10 m/s	● Sitting
10-13 m/s	● Standing
13-16 m/s	● Walking
16-23 m/s	● Objective walking
>23 m/s	● Unsafe

There are not many locations within Sydney that would satisfy the level of wind amenity proposed in the North Sydney Council DCP (pedestrian standing) without some form of shielding. This study instead proposes the pedestrian ‘walking’ criterion to be a more appropriate comfort classification for publicly accessible spaces.

3.3 Site description

Crows Nest Site B is located at the north-western corner of the block bounded by Pacific Highway, Hume Street, Willoughby Road, and Clarke Lane, Figure 2. The proposed project comprises a new residential development with supporting retail and commercial as part of the OSD.

Figure 2: Site location (source: Google Earth 2023)

Council requirements stipulate that wind impact assessments '*assess the existing and proposed wind environment including the cumulative impact of existing and proposed tower developments adjoining and nearby the site*'. Two configurations were assessed: existing, and proposed. The proposed configuration includes the adjacent Sites A and C, Figure 2.

The site is surrounded by low- to medium-rise developments, with more substantial developments to the north-west in St. Leonards. The site rises along the Pacific Highway by about 5 m elevation from Hume Street to the south, Figure 3, which has been included in the model, as well all surrounding topography.

The proposed development consists of 19 storeys, including a 3 storey podium and 16 storey tower, with a total height of approximately 66.5 m above Hume Street, Figure 3 and Figure 4. A carpark is included on Levels 2 and 3.

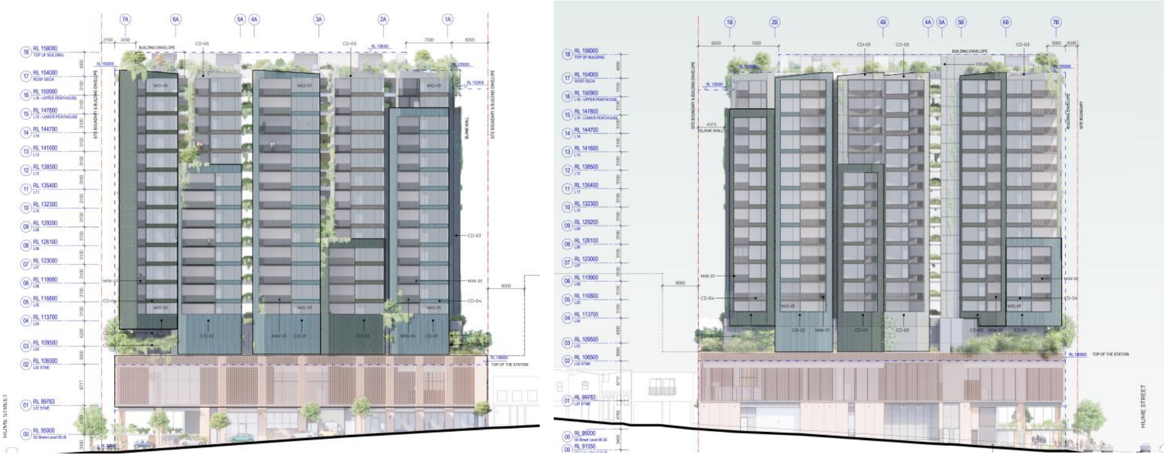
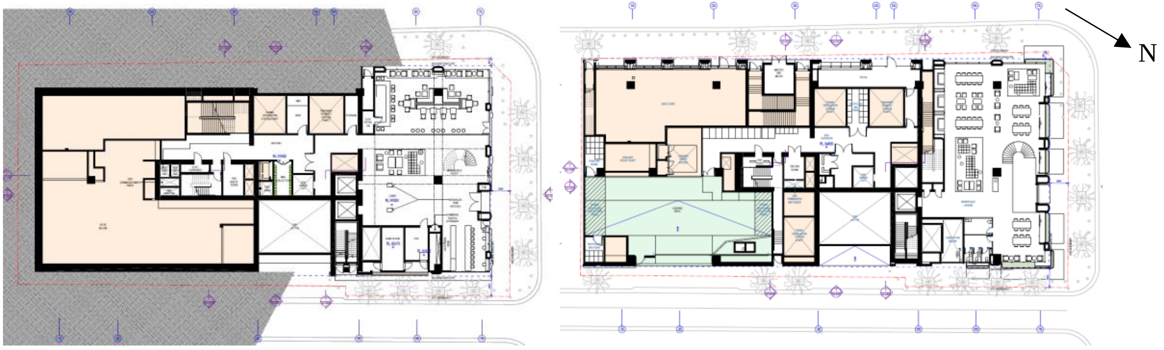


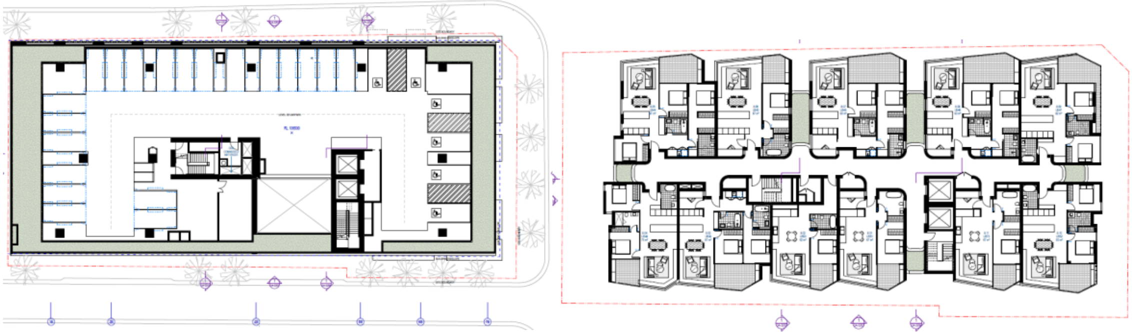
Figure 3: South-west Pacific Hwy elevation (L), North-east Clarke Lane elevation ®

The proposed development is prismatic in shape, with an articulated façade, Figure 5. Levels 4-16 are residential levels, with a rooftop terrace (including swimming pools) on Level 17.

Figure 4: North elevation (L), South elevation (R)


Ground Level – Hume Street

Upper Ground Level


Level 2

Typical Mid Levels (L08-L11)


Lower Penthouse (L15)

Roof Level

Figure 5: Various floor plans

3.4 CFD methodology and modelling

The development of the 3d model for modelling was based on the 3d model received by Woods Bagot on 22 August 2023.

The numerical CFD simulations were conducted for the proposed development using steady-state Reynolds-Averaged Navier-Stokes (RANS) method. Modelling was completed for both existing and proposed configurations, Figure 6, with the proposed configuration including adjacent sites A and C. The urban context including surrounding buildings within a radius of 500 m around the site was explicitly modelled, Figure 7, with topography surrounding the site included in the model. As the testing is primarily to assess for pedestrian safety, no landscaping elements have been included in the model as they cannot be relied on in an extreme event, but would improve comfort conditions. The rooftop terrace and balconies on three representative levels were modelled, Figure 8. The context is placed in a much larger domain based on best practice guideline for the CFD simulation of flows in urban environment, Figure 9.

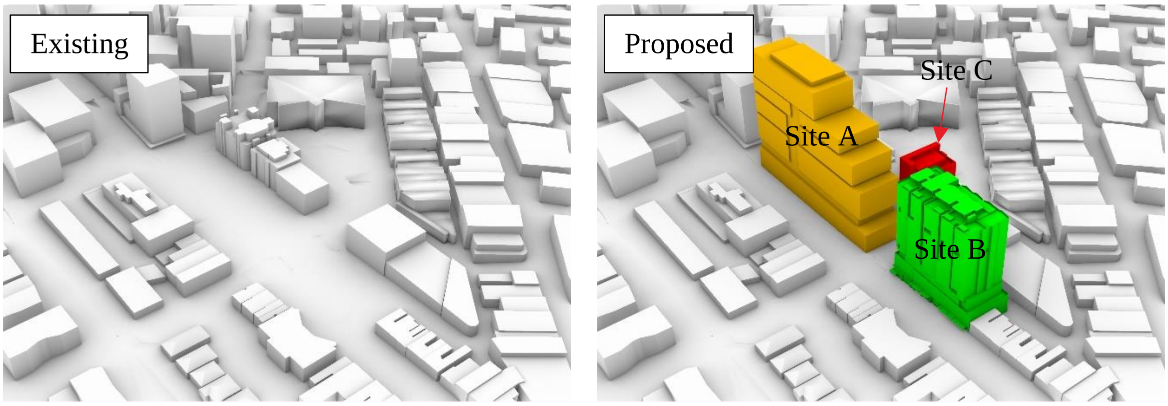


Figure 6: 3d models for the various configurations, view from the south

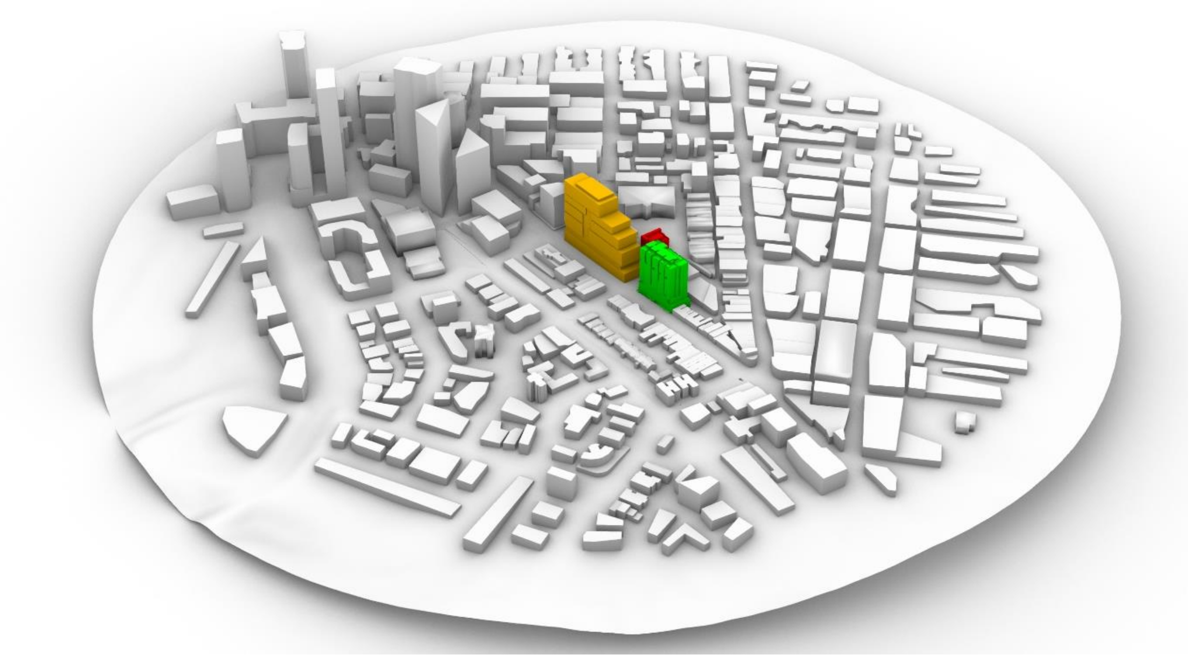


Figure 7: Urban context including and the surrounding buildings and topography; view from the south

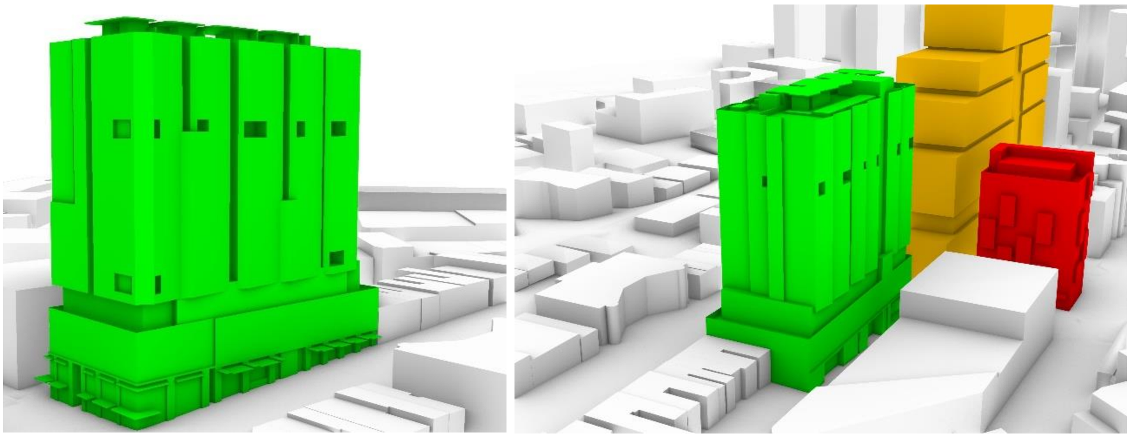


Figure 8: Close-up views of the model from the west (L) and east (R)

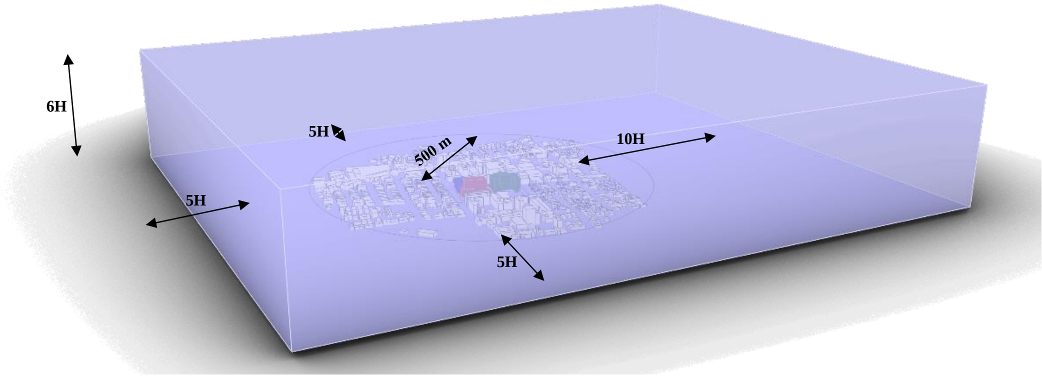


Figure 9: Typical simulation domain (dimensions in metres)

A computational mesh was constructed comprising of approximately 28 million hexahedral elements, Figure 10. 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.

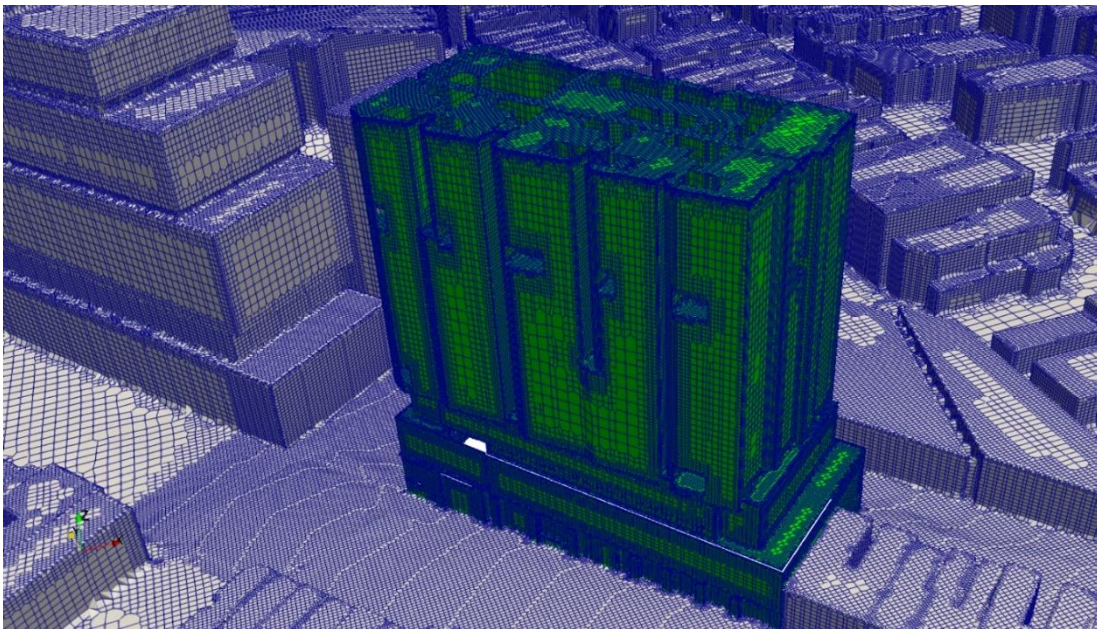


Figure 10: Mesh strategy and grid resolution in future configuration

The effect of terrain outside the 1 km diameter urban context was implicitly modelled using rough wall functions reproducing the surface roughness characteristics corresponding to suburbia, Terrain Category 3 (TC3) as defined in Standards Australia (2011) for all directions. 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.

3.5 Results and discussion

Pedestrian wind comfort and safety results are presented in the following sections for both ground plane and elevated areas. Wind speed measurements were taken at a height of 1.5 m above ground level for 16 wind directions. The directional wind tunnel results were combined with the wind climate data detailed in Section 3.1 and the Melbourne wind criteria for comfort and safety as detailed in Section 3.2. Directional results on the ground plane are presented in Appendix A.3.

3.5.1 Ground plane

Summary contour maps of wind speed ratio at height of 1.5 m above the local ground level for the integrated probability of 0.1% of the time are presented in Figure 11. The extension of the assessed area around the site is aligned with guidelines for pedestrian wind effects criteria, AWES (2014). The local wind speeds are integrated with the local wind climate data presented in Section 3.1 for assessment against the Melbourne criteria for pedestrian comfort and safety. For assessment against the criteria, the 3 s gust is estimated based on measured turbulent kinetic energy using:

$$\mathrm{U}_{3\ s\ gust} = \mathrm{U}_{10\ \mathrm{minute\ mean}} + 2.5 \cdot \sigma_{\mathrm{u}}$$

where considering isotropic turbulence, standard deviation of wind speed would can be calculated using:

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

where k is turbulent kinetic energy. The peak factor of 2.5 is appropriate for open approaches, as the flow is accelerated around buildings the relationship changes and the estimated gust wind speed would be conservative as the turbulence is reduced. Conversely in low-wind areas, the turbulence increases and the results would be slightly non-conservative.

Contour maps showing the safety and comfort classifications are presented in Figure 11.

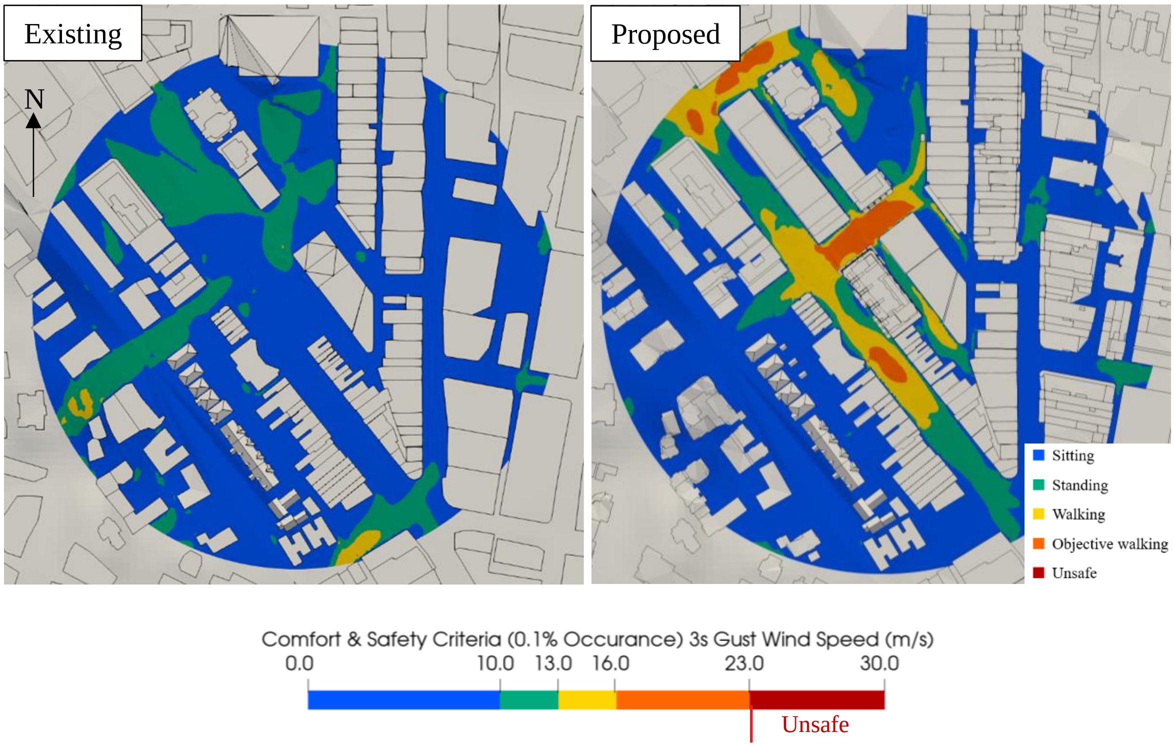


Figure 11: Classification of wind comfort and safety at 1.5 m above local ground level for the existing (L) and proposed (R) configurations.

In general, windier conditions are measured in the proposed configuration, which includes the combined impact of Sites A-C; this is to be expected given the sites are taller than their immediate surrounds and exposed to winds from the north-east, south and west, bringing the upper level winds to ground level. The combined impact of the proposed Sites A-C channels flow along Hume Street for winds from the north-east and south-west quadrants, with additional strong wind along the Pacific Highway for winds from the west of the site.

It is evident from Figure 11 that all locations pass the safety criterion in the existing and proposed configurations without the inclusion of any landscaping.

In terms of pedestrian comfort, the majority of locations along Hume Street in the proposed configuration are classified as suitable for objective walking, with some locations immediately adjacent to the site being suitable for walking, Figure 12. As noted above, due to the compressed accelerated flow between the buildings and the lack of landscaping in the model, the results presented herein along the surrounding streets are considered conservative. The wind conditions along Hume Street are the result of the combined impact of the buildings on Sites A-C. Strategies to mitigate the expected wind conditions cannot be solely achieved through individual sites. For Site B, there are no proposed outdoor seating areas and the pedestrian areas around the site are for the most part, therefore, transitory zones, in which case objective walking is applicable. The proposed trees along Hume Street, Figure 4 and Figure 5, would be effective to help improve the wind conditions along the Hume Street frontage.

The majority of pedestrian locations along the Pacific Highway are classified as suitable for walking or better. Some areas, confined to the middle of the road remote from pedestrian crossings, are classified as suitable for objective walking. Pedestrian areas to the south of the site on the Pacific Highway are classified as suitable for standing, Figure 12. These conditions are considered appropriate for the intended uses.

Conditions in Clarke Lane are mainly classified as suitable for standing along the site, with some areas of walking further to the south, Figure 12.

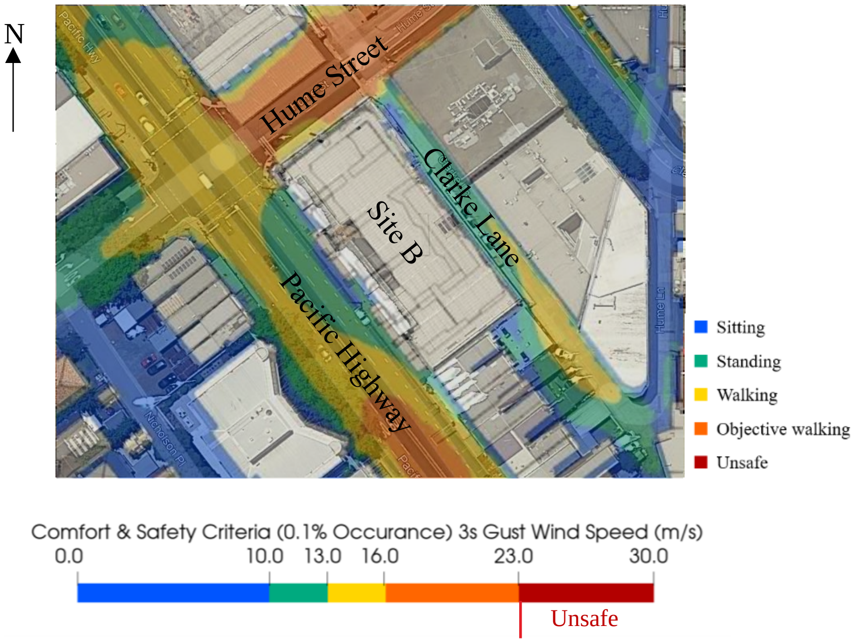


Figure 12: Classification of wind comfort and safety at 1.5 m above local ground level for the proposed configuration, focused on Site B and overlaid on Google Earth image

3.5.2 Elevated locations

A number of elevated areas were modelled, Figure 13, including:

- Level 2 podium wrap around balcony
- Level 4 representative balconies (corner and inset)
- Level 12 open corridor and balconies
- Level 17 roof terrace

Figure 13: Elevated areas modelled (view from south)

The results for the terraces are presented in Figure 14 to Figure 17. The Level 2 and 17 terraces were modelled with a solid balustrade (approximately 1.5 m for Level 2 and approximately 1.0 m for Level 17, as per the 3d model provided). The balconies on Levels 4 and 12 were modelled with open balustrades, only blade walls as per the design. No landscaping was included in the model.

Wind conditions on the elevated terraces are generally windier than ground level, due to their greater exposure to the incident prevailing winds and in protecting the ground plane from downwash from the tower portion of the building. It is important to note that as these are privately accessible locations, during high wind events people are unlikely to use these spaces and/or they can be managed appropriately.

It is evident that all locations pass the safety criterion except for one localised portion of the Level 17 western corner balcony, Figure 16. Nevertheless, given this balcony was modelled without a balustrade, this is not considered to be a concern. It does, however, highlight the tendency for winds to be accelerated across the balcony behind the blade wall. High, solid balustrades (at least 1.5 m) are recommended to mitigate this issue and provide a suitable area for use for the majority of time.

From a comfort perspective, the Level 2 terrace, Figure 14, experiences a range of conditions from sitting in the middle of the facades to objective walking around the southern corners. This is expected at podium level as it is working to protect the ground plane. The majority of locations are classified as pedestrian walking or better. This terrace was modelled for completeness, but does not appear to be accessible, hence the areas of objective walking are not a concern.

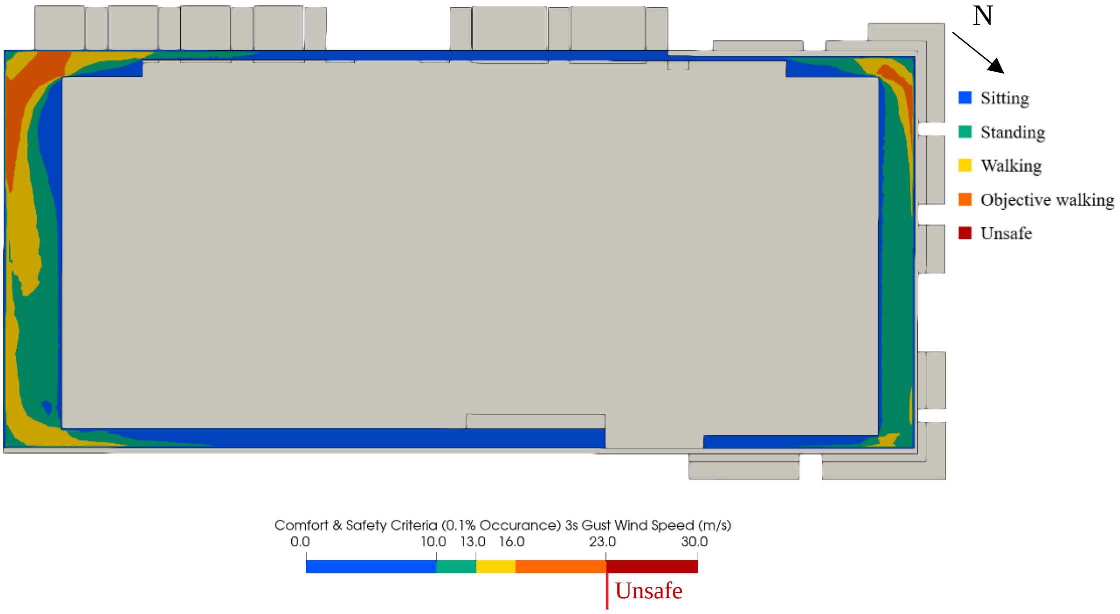


Figure 14: Classification of wind comfort and safety at 1.5 m above floor level for Level 2 balcony

The Level 4 and 12 inset balconies are classified as suitable for sitting, Figure 15 and Figure 16. The exceptions are the western corner balconies on both levels, which are expected to experience a range of conditions. As previously discussed, these balconies were modelled without a solid balustrade and therefore, high, solid balustrades (at least 1.5 m) are recommended to mitigate these conditions.

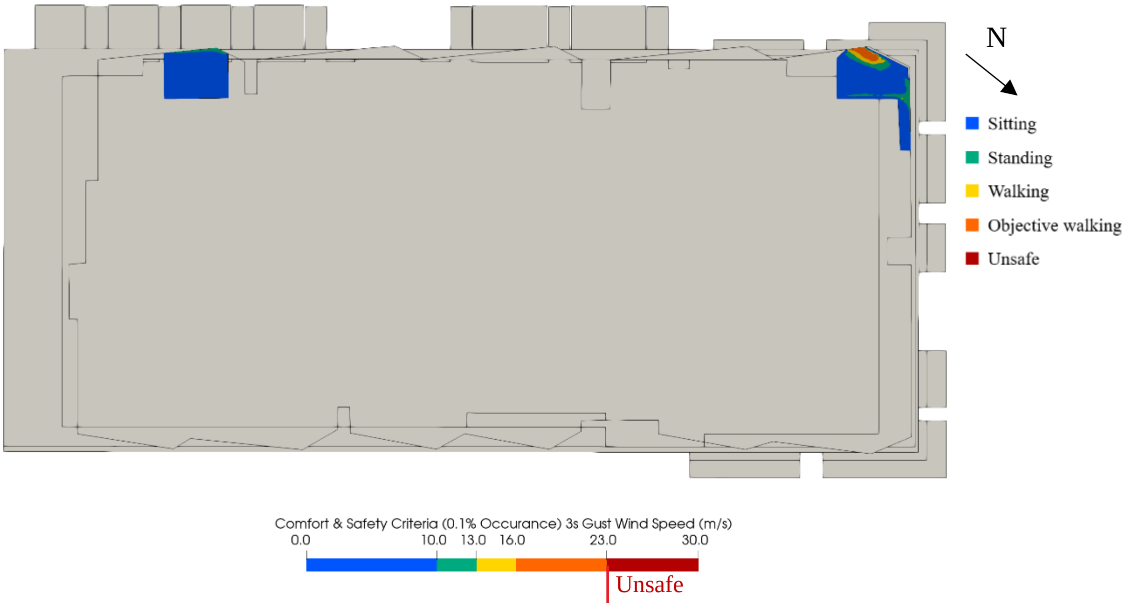


Figure 15: Classification of wind comfort and safety at 1.5 m above floor level for Level 4 representative balconies

The Level 12 open corridor, Figure 16, is expected to experience a range of comfort conditions, ranging from sitting through to objective walking. The areas predicted to experience objective walking conditions are generally located within landscaping zones for the south-western facing openings. The region of objective walking for the north-eastern opening does include the lift lobby and fire stairs. The region of objective walking for the north-western opening is co-located with entries to the northern apartments. It is strongly recommended to include operable openings at the ends of the corridors to enable appropriate control of the wind and wind driven rain conditions.

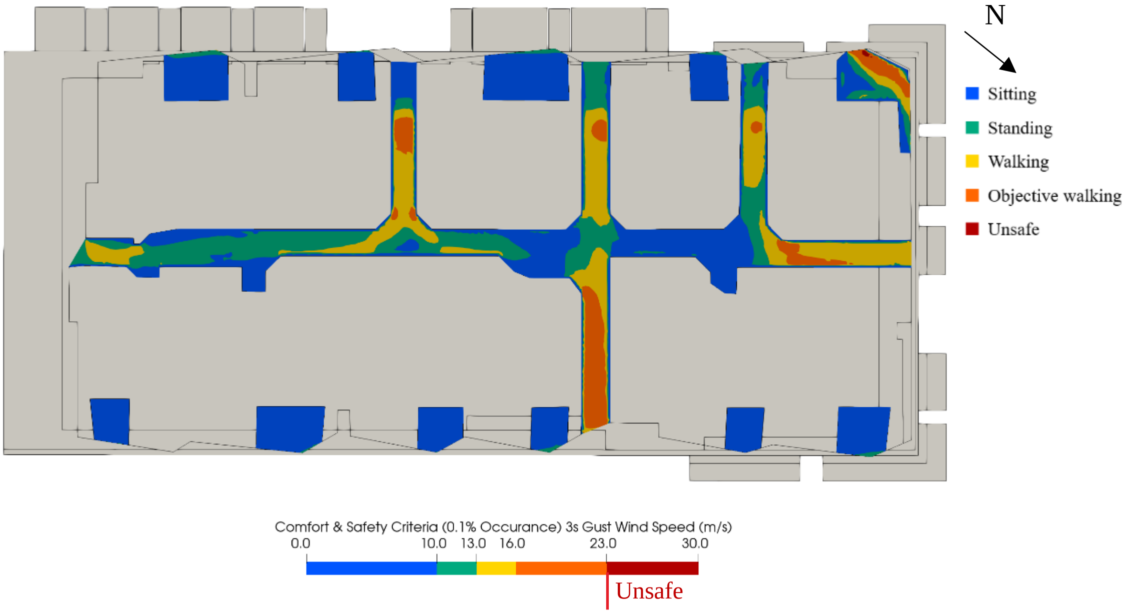


Figure 16: Classification of wind comfort and safety at 1.5 m above floor level for Level 12 open corridor and balconies

The majority of locations on the Level 17 roof terrace, Figure 17, are predicted to experience conditions suitable for sitting, with some areas suitable for standing, due to the high level of articulation and shielding. The southern end of the terrace is more classified for walking for the southern penthouse terrace and southern communal area, including the southern area of the pool terrace. At roof level, winds are predominantly horizontal and therefore, vertical screening is most effective for wind mitigation. This can take the form of high, balustrades with a minimum solidity of 75%, at least 1.8 m tall, landscaping and screens. An effective strategy is to create smaller, sectioned areas that are protected.

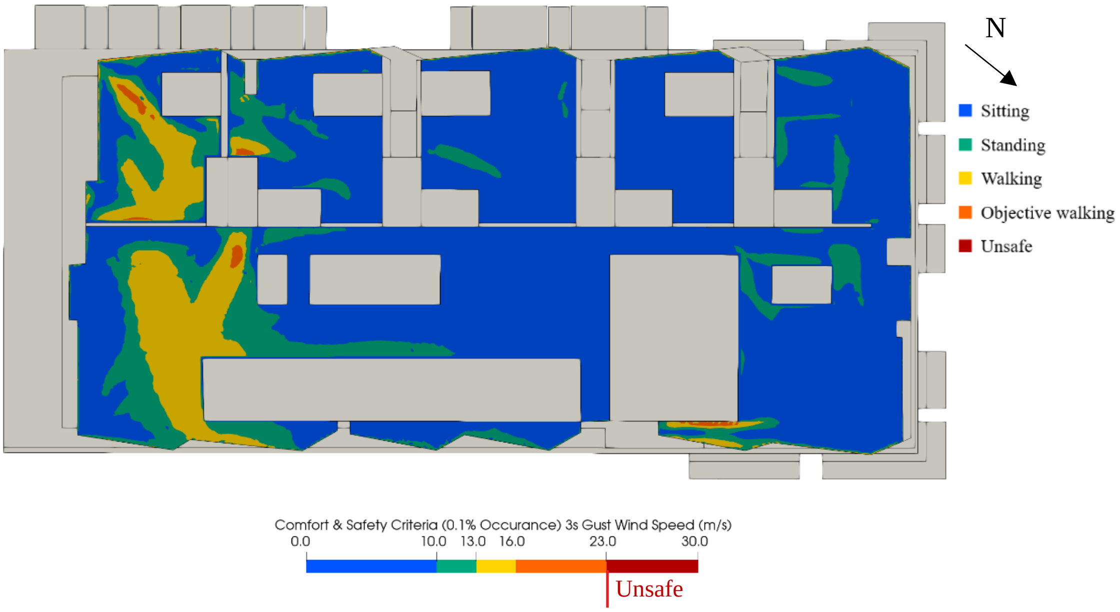


Figure 17: Classification of wind comfort and safety at 1.5 m above floor level for Level 17 roof terrace

3.5.3 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 CFD.

Modelling was conducted for existing and proposed configurations with surrounding buildings included within a 500 m radius around the site. The two 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 the Melbourne (1978) pedestrian safety and comfort criteria.

At ground level, all locations pass the safety criterion in the existing and proposed configurations without landscaping.

From a comfort perspective, the majority of pedestrian locations meet the walking criterion used for the study. There are areas classified as suitable for objective walking on the vehicular carriageways along Hume Street and the Pacific Highway in the proposed configuration. These areas of objective walking are limited to non-pedestrian (road) areas along Pacific Highway and are less of a concern. Pedestrian areas along Hume Street, and into the intersection with Pacific Highway, are expected to experience objective walking conditions, including along the site frontage to Hume Street and across the road (Site A frontage). These areas of higher wind speeds are the combined impact of Sites A-C channelling the wind along Hume Street and wind mitigation strategies would need to be holistically considered across the three sites. For Site B, there are no proposed outdoor seating areas and the pedestrian areas around the site are for the most part, therefore, transitory zones, in which case objective walking is applicable. The proposed trees along Hume Street would be effective to mitigate the conditions along Hume Street. The results presented herein are considered conservative.

At the elevated locations, all locations pass the safety criterion, with the exception of a localised area on Level 12 of the western corner balcony. This balcony was modelled without a balustrade, hence is not expected to be a concern and a high balustrade with minimum solidity of 75% and height of at least 1.5 m is recommended to mitigate this issue.

From a comfort perspective within the site, the main issues to consider are the management of the open corridors and the southern portion of the Level 17 roof terrace. These issues are internal and not publicly accessible.

Areas of objective walking are predicted in the open corridors, based on the Level 12 analysis, both in landscaped areas and circulation areas, including apartment entries, lift lobby, and fire stair access. It is strongly recommended to include operable openings to the ends of the corridors to manage the internal wind and wind driven rain conditions.

The southern portion of the Level 17 roof terrace is expected to experience areas of walking, with some localised areas of objective walking. Flow at this level will be predominantly horizontal and therefore, vertical mitigation strategies will be most effective (e.g. screens, landscaping, solid balustrades, etc).

It is important to note that the elevated locations are all privately accessible and during high wind events, people are unlikely to use these spaces and/or they can be managed as required.

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A.1 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 18, 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 18. 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.

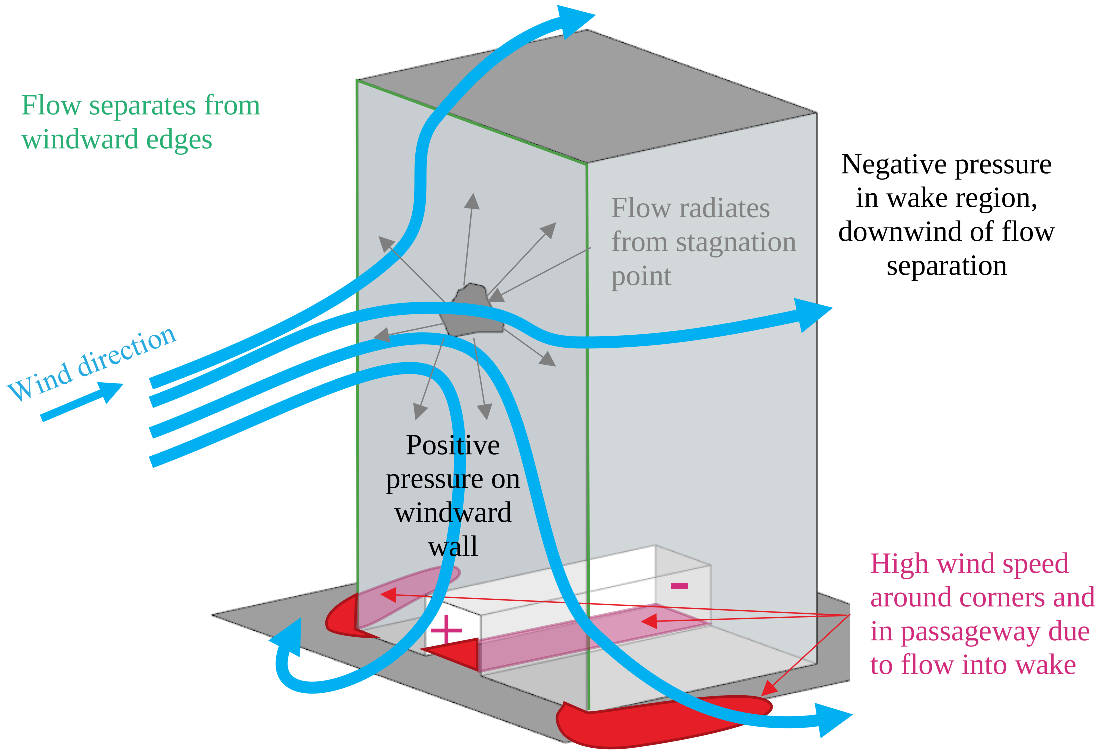


Figure 18: Schematic wind flow around tall isolated building

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 19. 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.

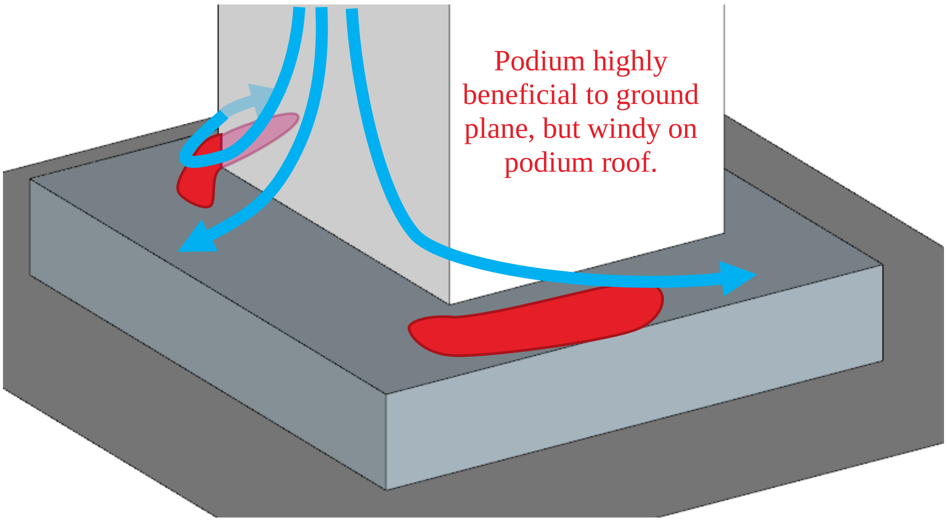


Figure 19: Schematic flow pattern around building with podium

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 20. 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.

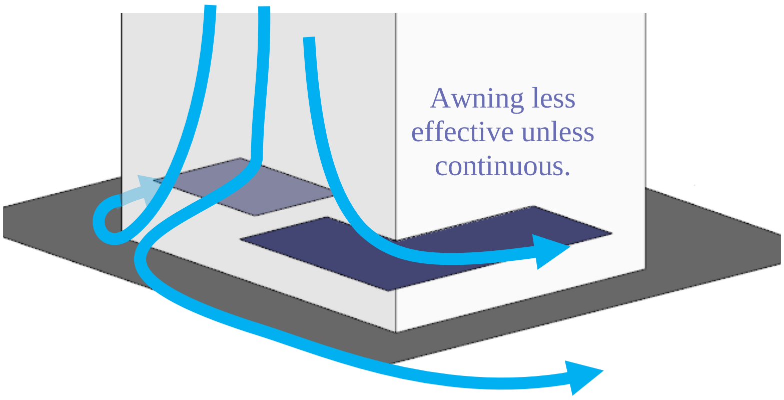


Figure 20: Schematic flow pattern around building with podium

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 21. Similarly, open through-site links through a building cause wind issues as the pressure tries to equilibrate between the entrances to the link causing strong flow, Figure 18. If the link is blocked, wind conditions will be relatively calm, Figure 22. This area is in a region of high pressure and therefore there is the potential for internal flow issues. A ground level recessed corner has a similar effect as an undercroft, resulting in windier conditions, Figure 22.

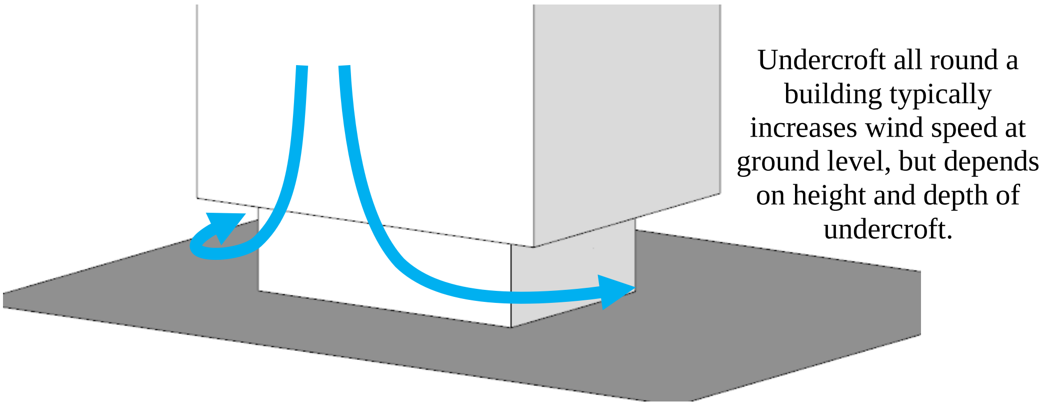


Figure 21: Schematic of flow patterns around isolated building with undercroft

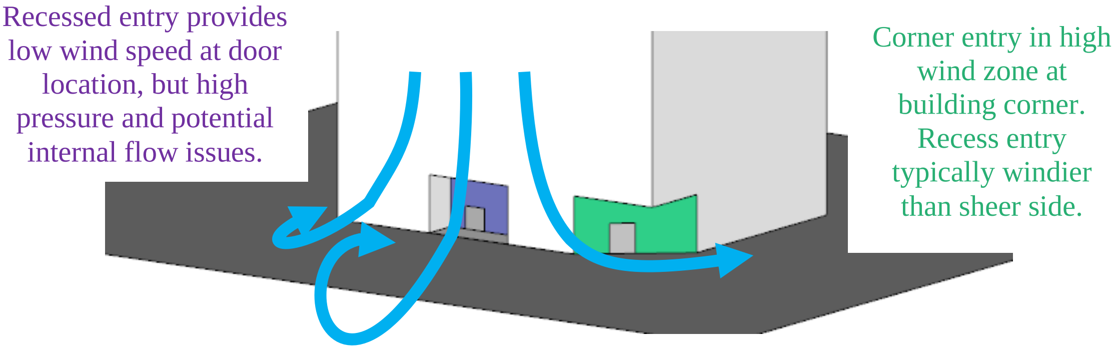


Figure 22: Schematic of flow patterns around isolated building with ground articulation

Multiple building

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 23. 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.

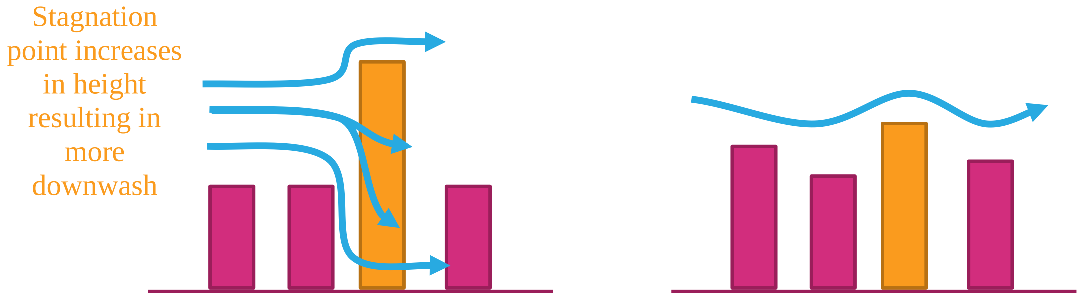


Figure 23: Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 24.

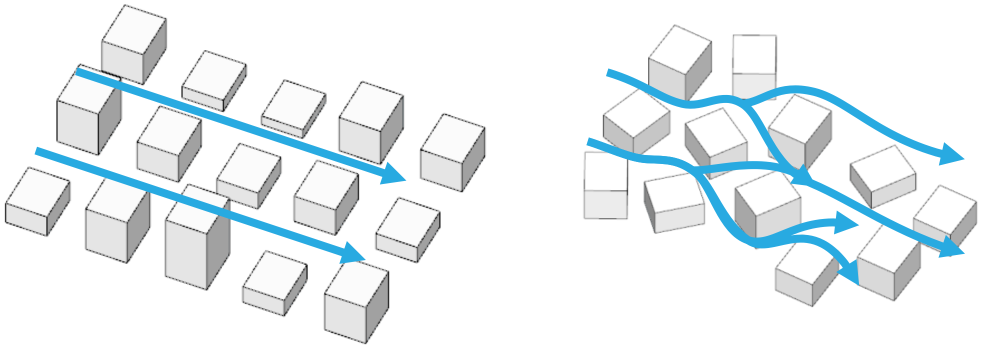


Figure 24 Schematic of flow patterns through a grid and random street layout

On the fringe of a city, the compound shape of neighbouring buildings instigates the flow pattern through the city. The overall massing causes an obstruction to the flow causing a slowing of the incident flow and increasing the windward pressure. Pressure driven flow is produced between the buildings, Figure 25. The vertical component in pressure driven flow is lower than downwash flow.

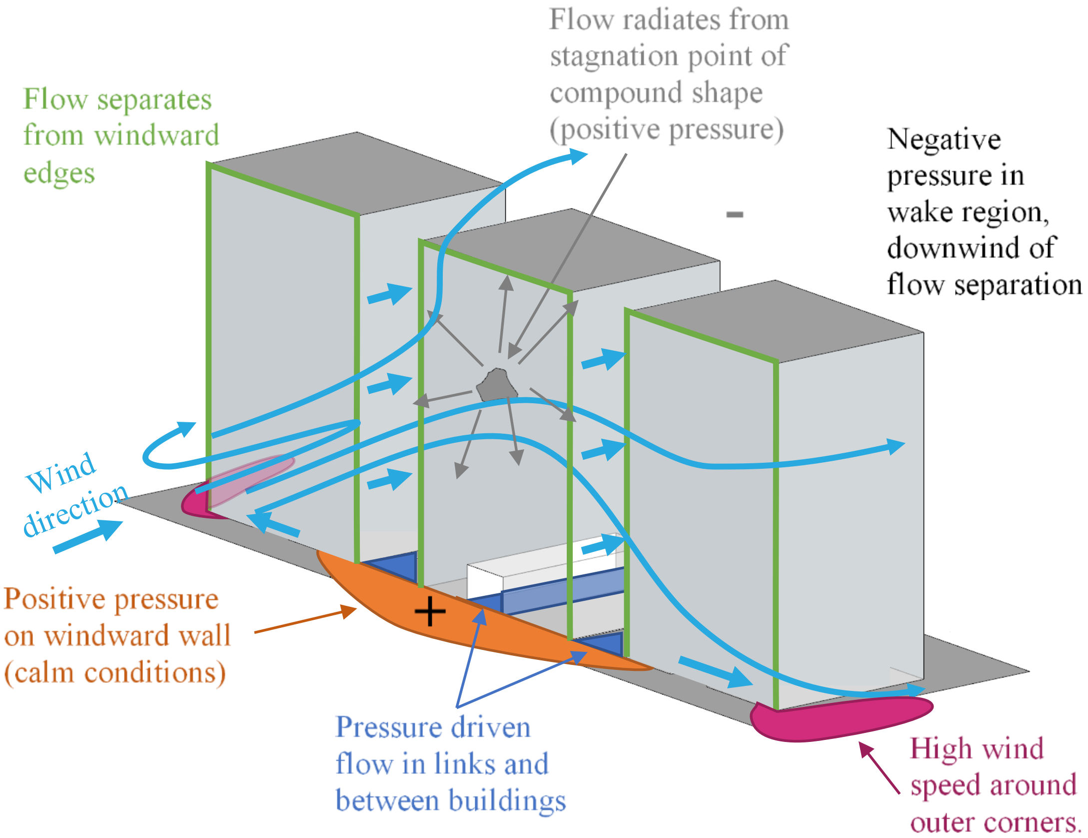


Figure 25: General flow pattern around multiple buildings

Channelling is instigated when pressure driven flow accelerates between two buildings, and continues along straight streets with buildings on either side, Figure 24(L). This occurs on the edge of large built-up areas where the approaching flow is diverted around the overall massing and channelled along the fringe by a relatively continuous wall of building facades. This is generally the primary mechanism producing strong wind conditions on the perimeter of a built-up area, particularly on corners, which can be exposed to multiple prevailing 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 24(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.

Single barriers and screens

The wind flow pattern over a vertical barrier is illustrated in Figure 26, showing there will be recirculation zones near the windward wall and in the immediate lee of the barrier. The typical extent of these recirculation zones relative to the height of the barrier, h, is illustrated in Figure 26. These regions are not fixed but fluctuate in time. The mean wind speed in the wake areas drops significantly compared with the incident flow. With increasing distance from the barrier the flow pattern will resort to the undisturbed state. Typically the mean velocity and turbulence intensity at barrier height would be expected to be within 10% of the free stream conditions at 10 times the height of the structure downwind from the barrier.

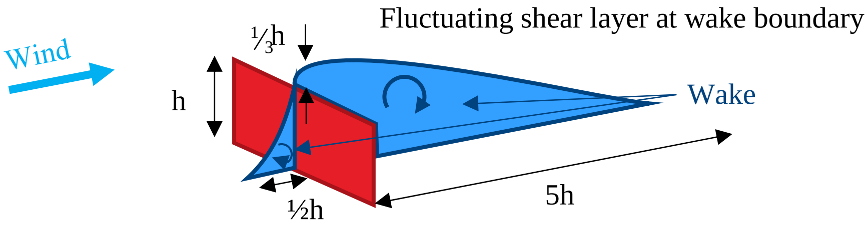


Figure 26: Sketch of the flow pattern over an isolated structure

A.2 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:

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

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 27 and Figure 29. 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 27 with definitions of the intended use of the space categories defined in Figure 28.

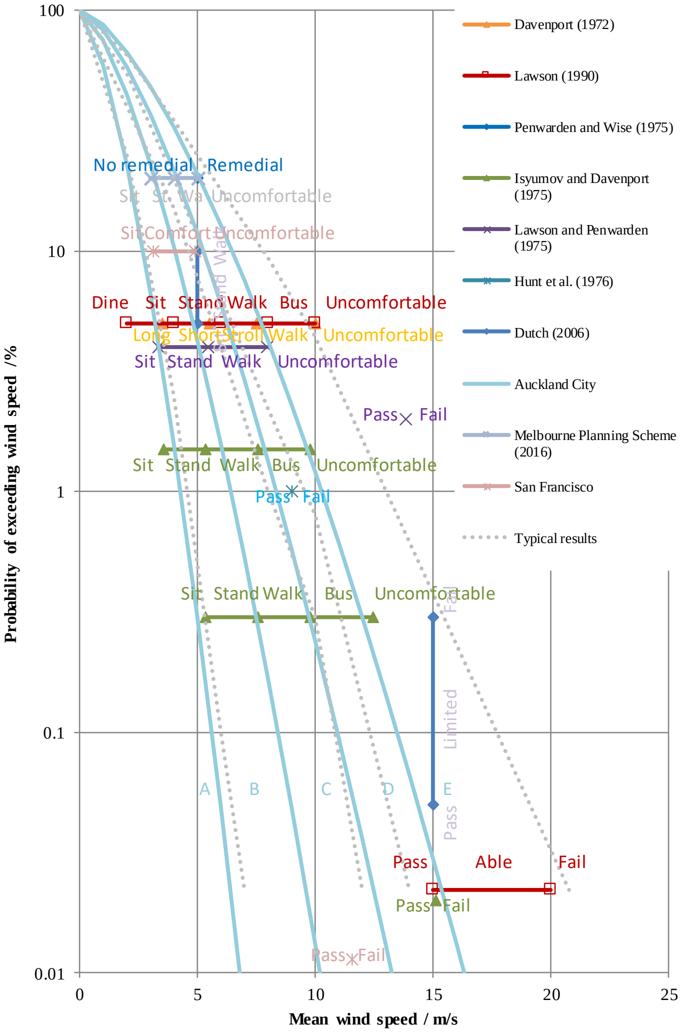
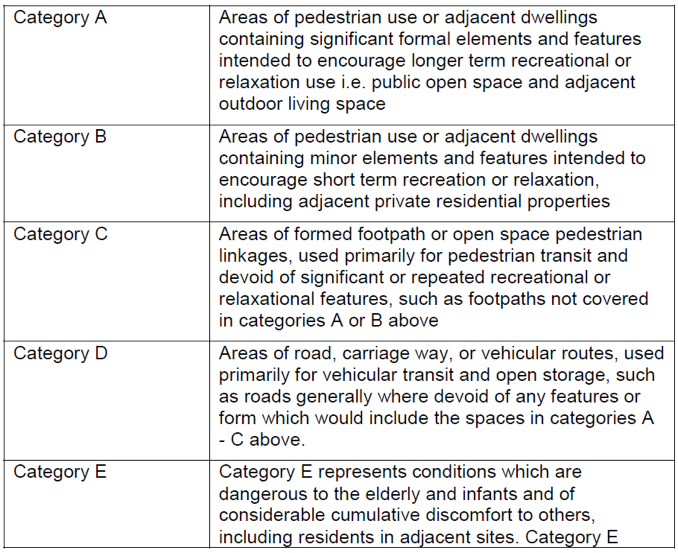


Figure 27. Probabilistic comparison between wind criteria based on mean wind speed



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 28. Auckland Utility Plan (2016) wind categories

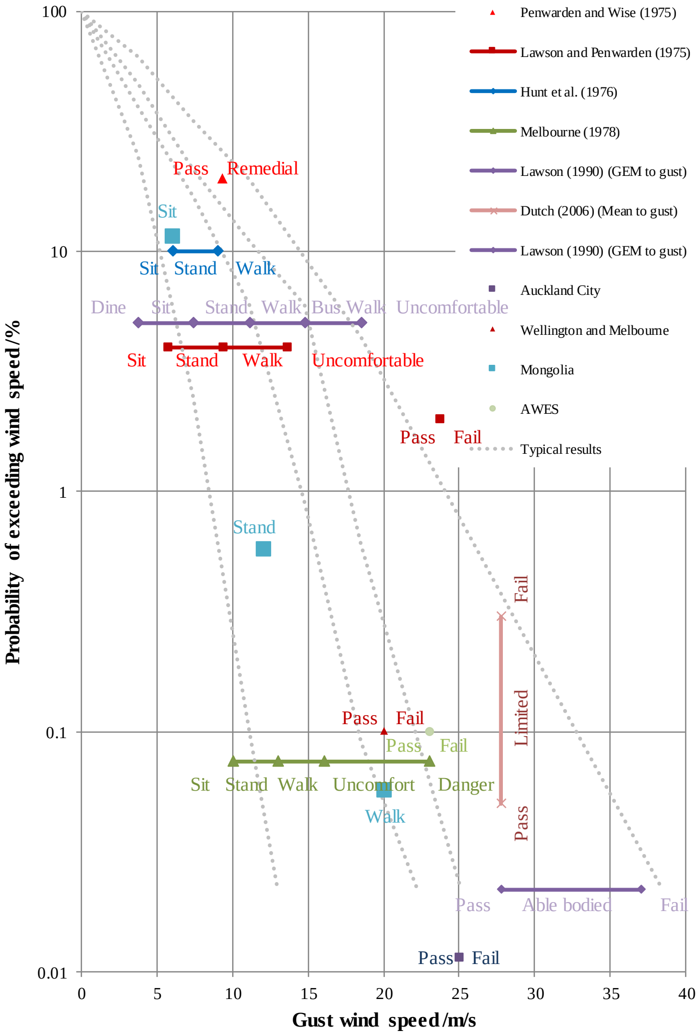
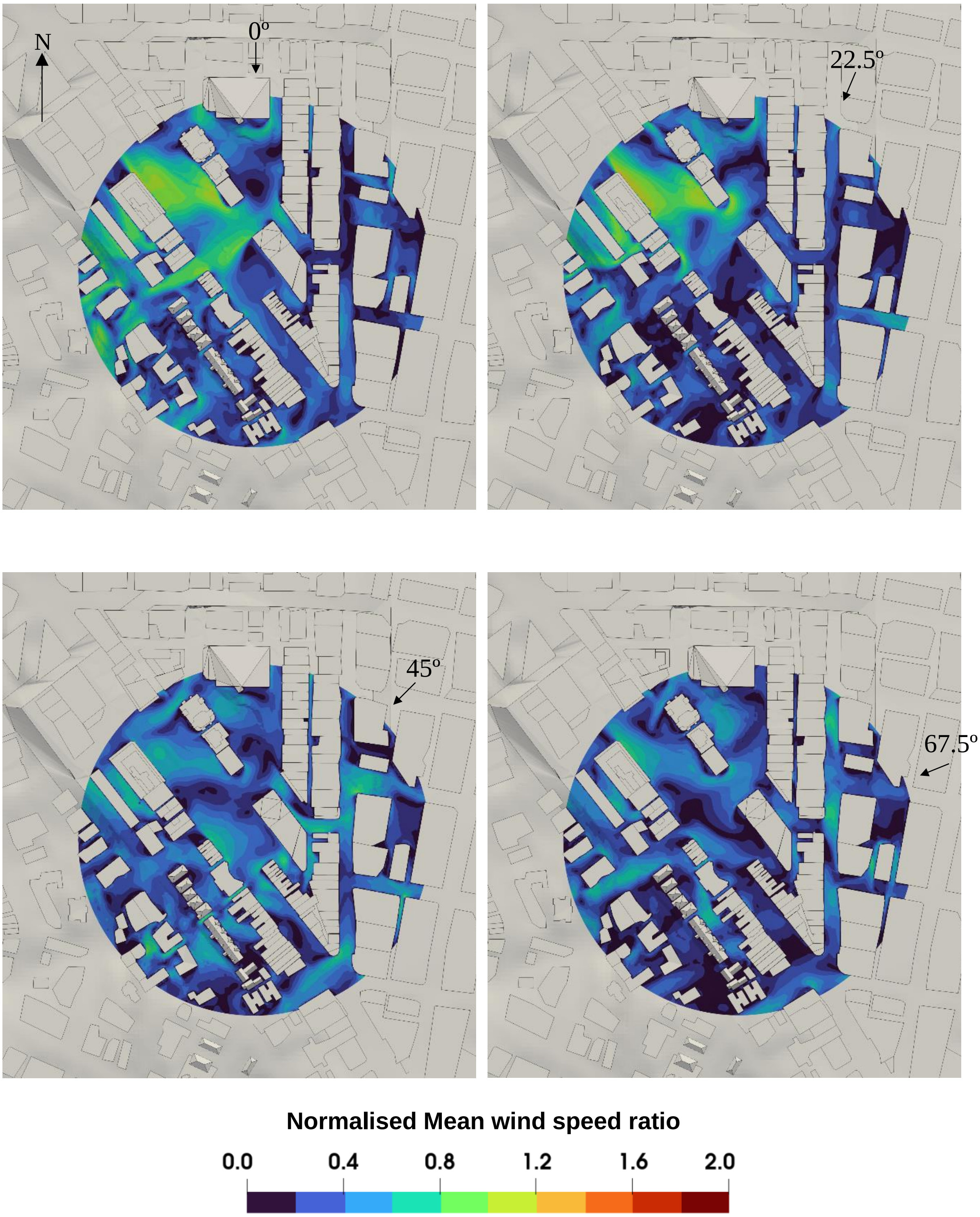
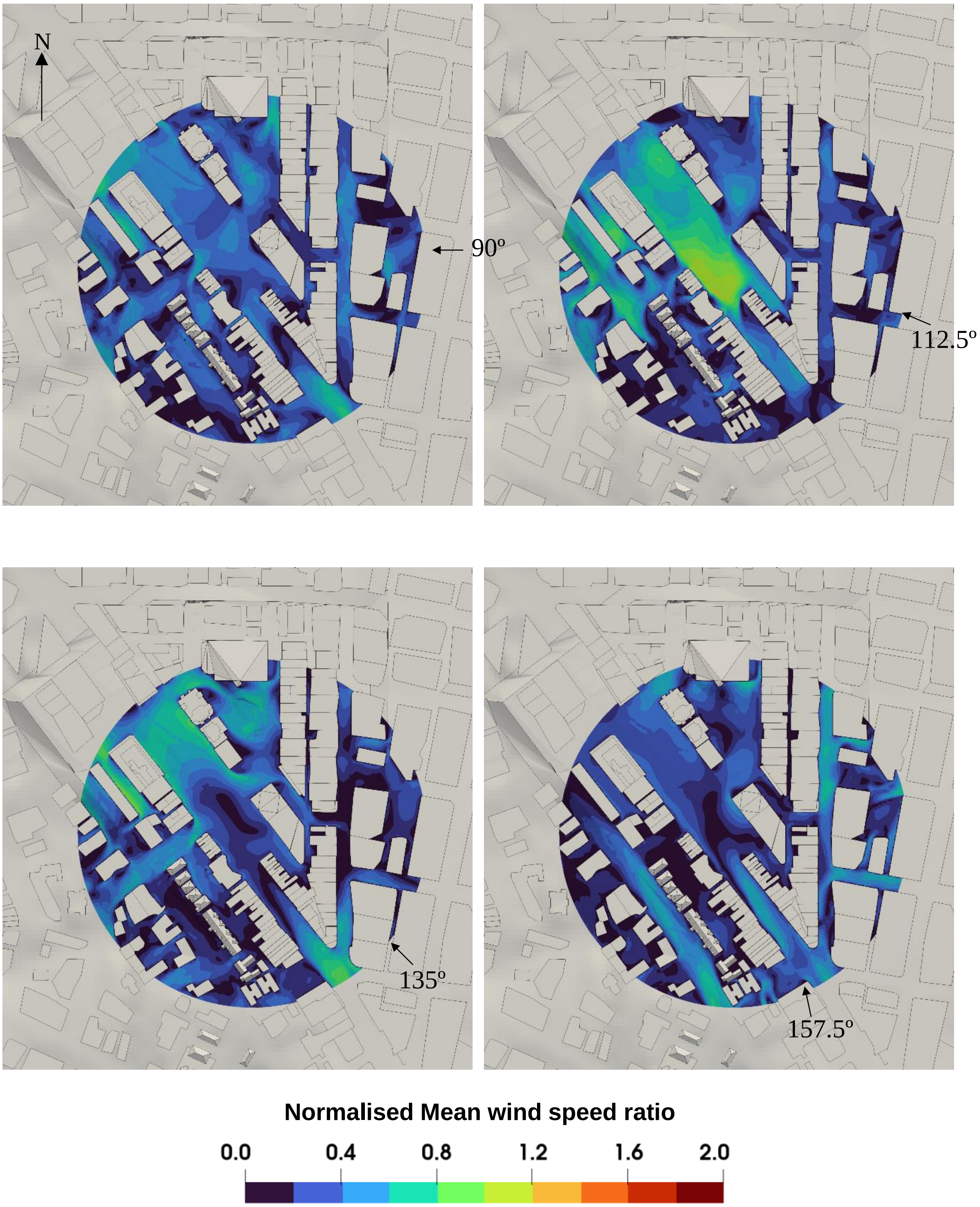


Figure 29. Probabilistic comparison between wind criteria based on 3 s gust wind speed

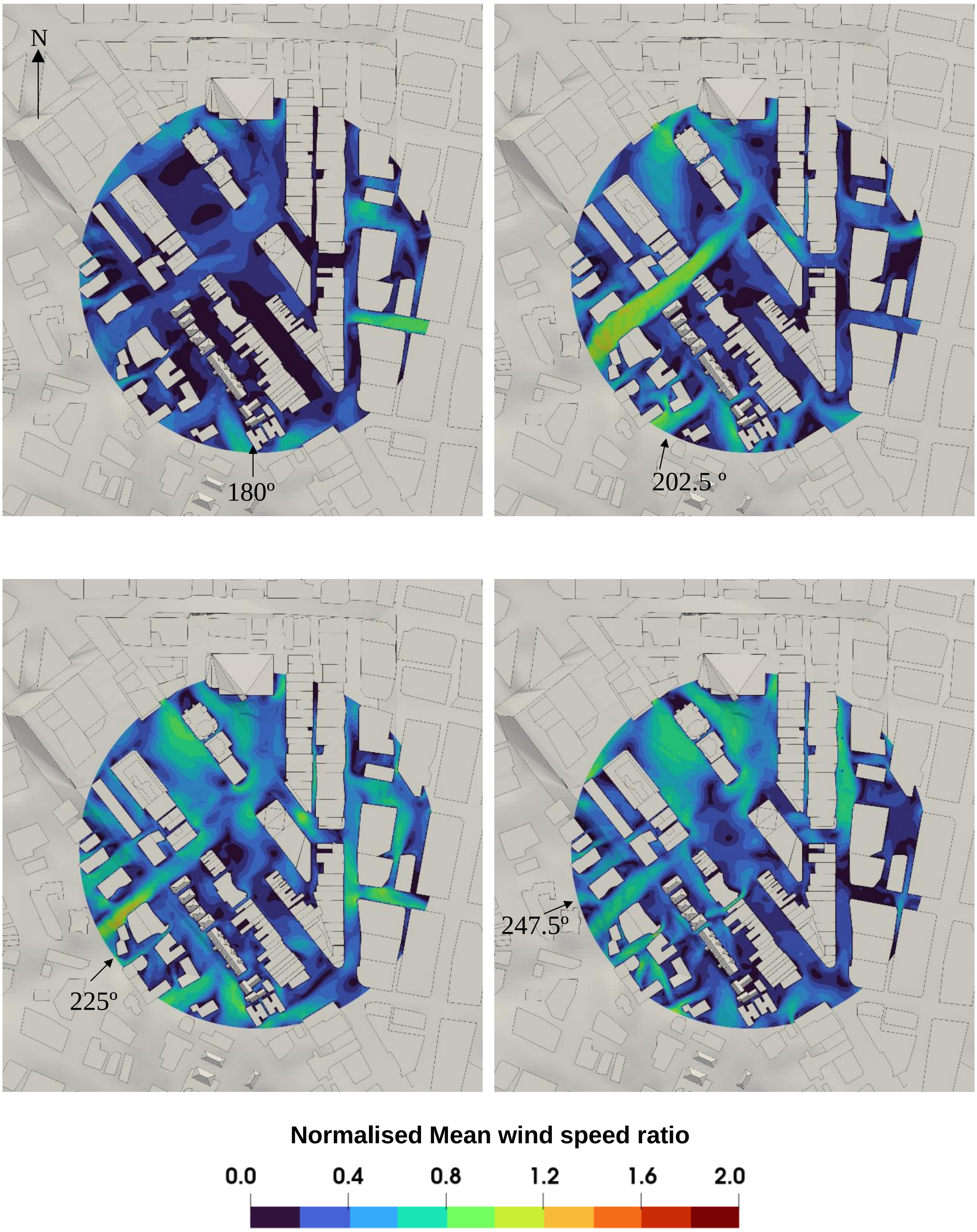
A.3 Directional results at pedestrian level

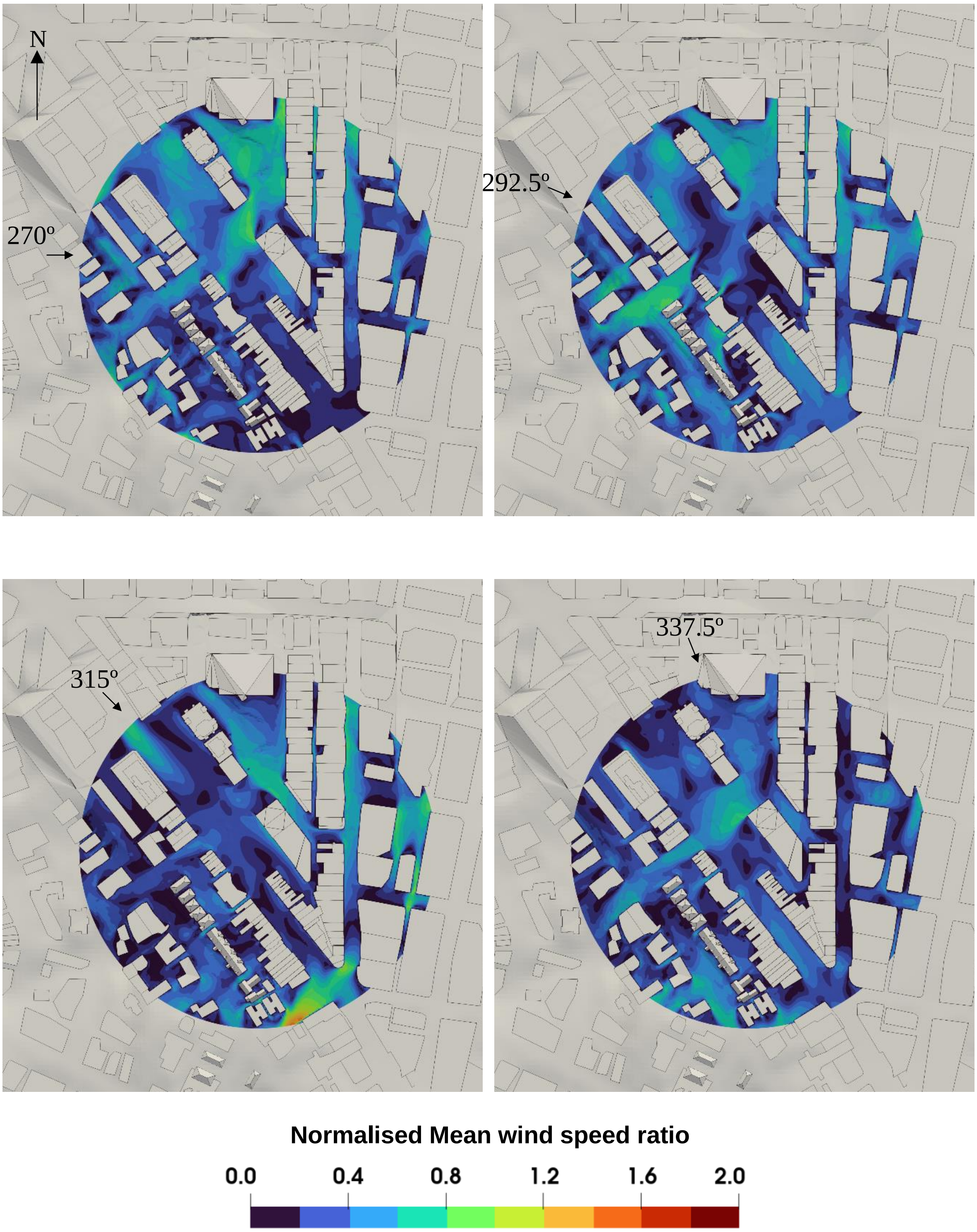
Existing



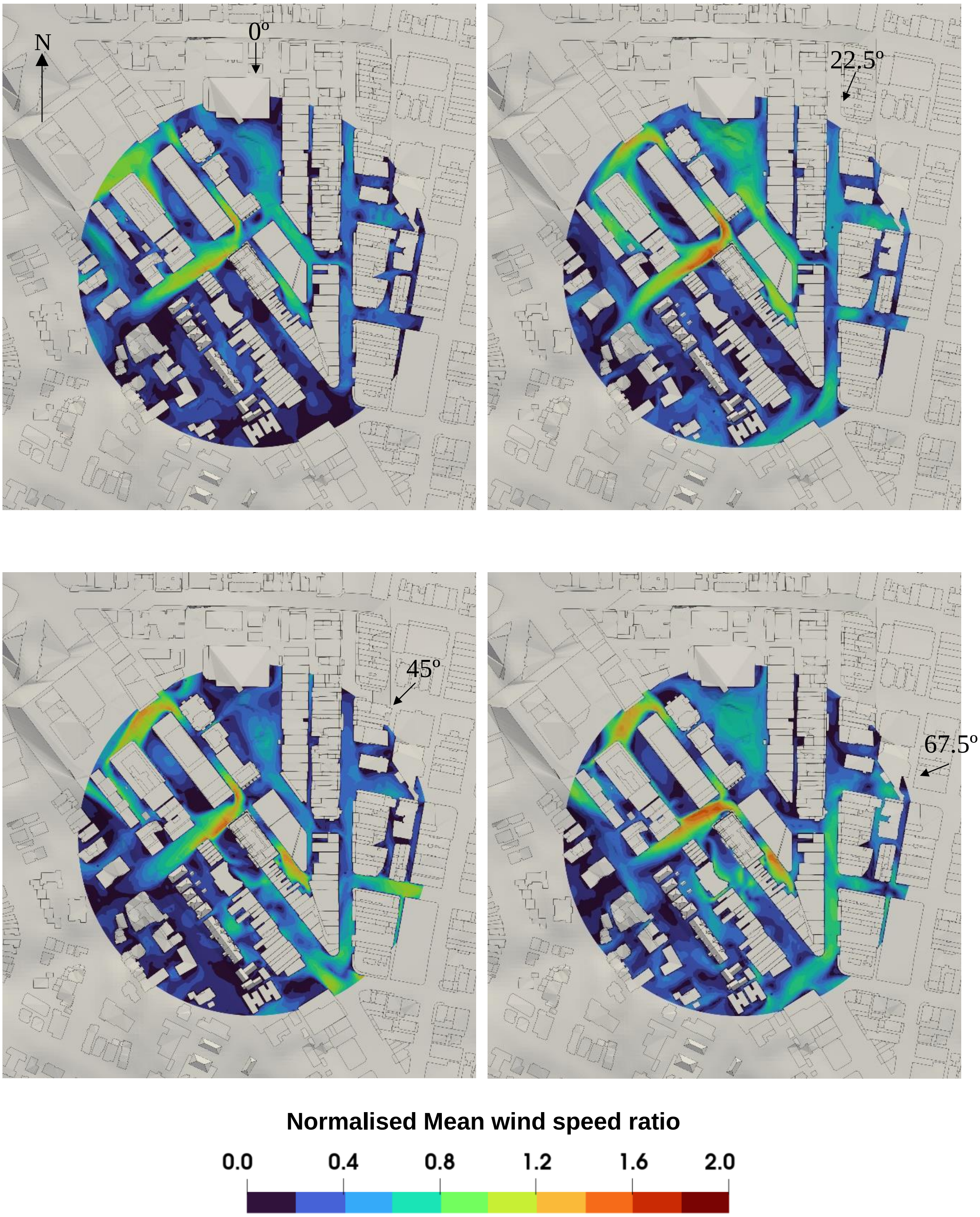


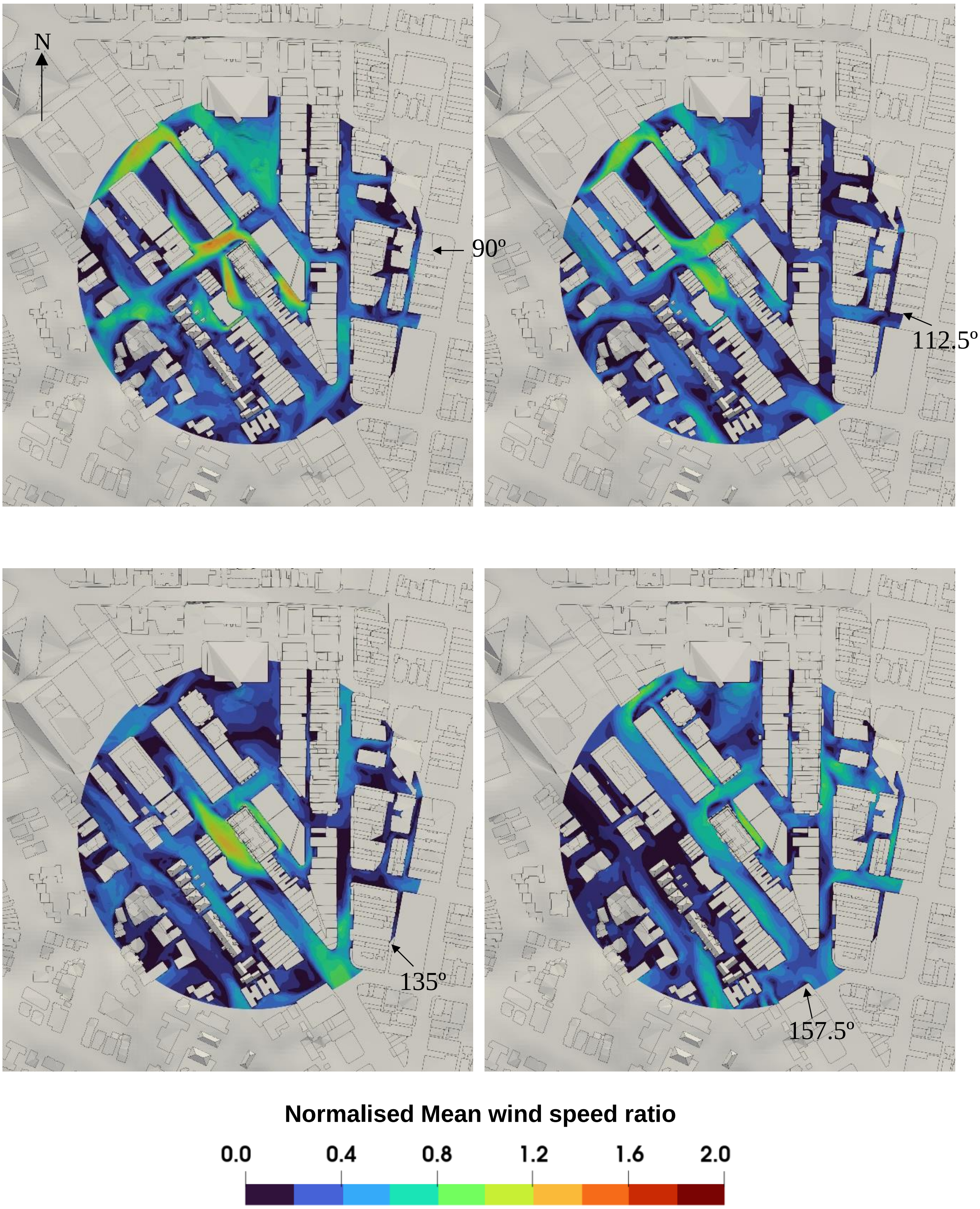
N
90º
112.5º
135º
157.5º
Normalised Mean wind speed ratio
0.0
0.4
0.8
1.2
1.6
2.0

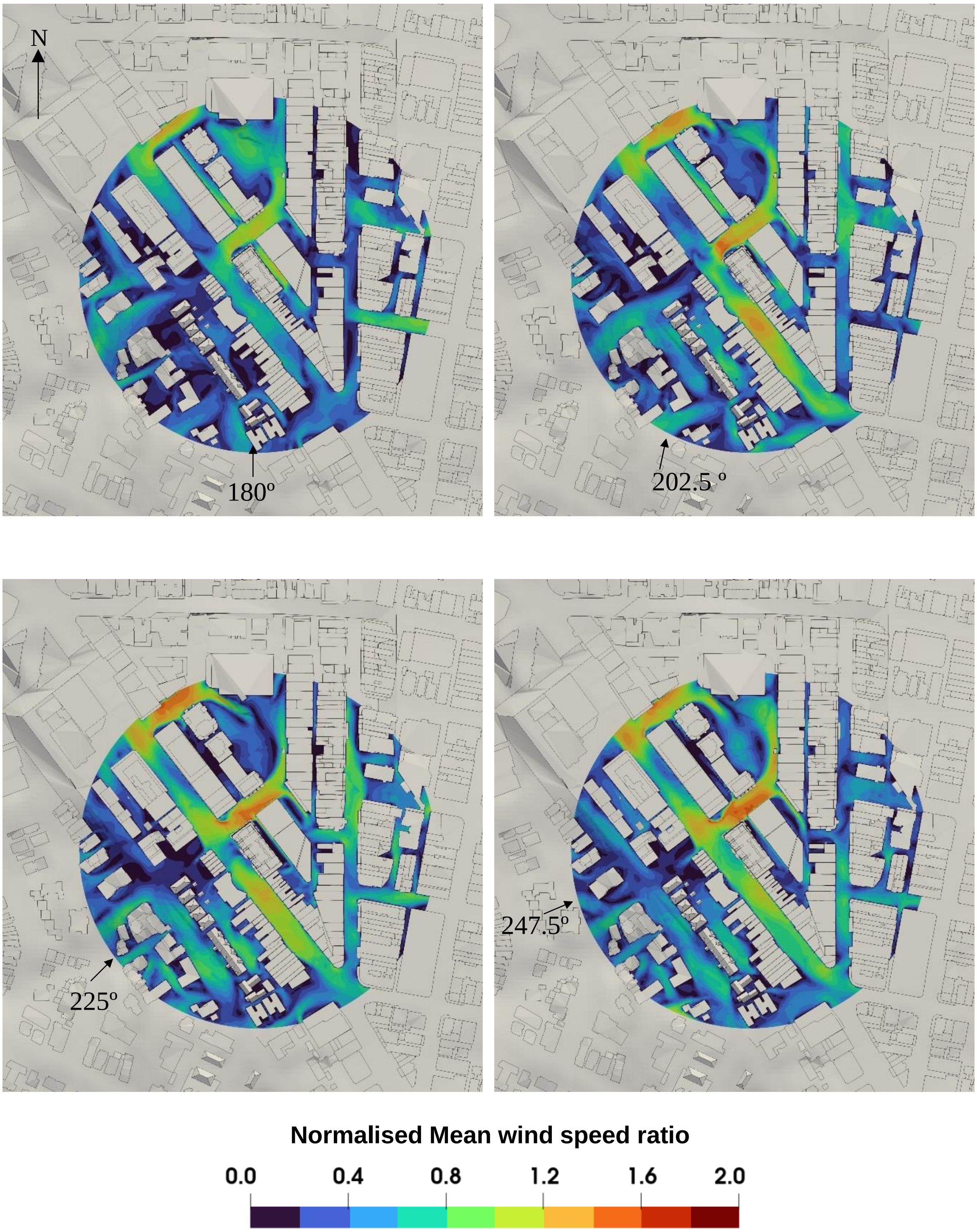

N
180º
202.5 º
225º
247.5º
Normalised Mean wind speed ratio
0.0
0.4
0.8
1.2
1.6
2.0

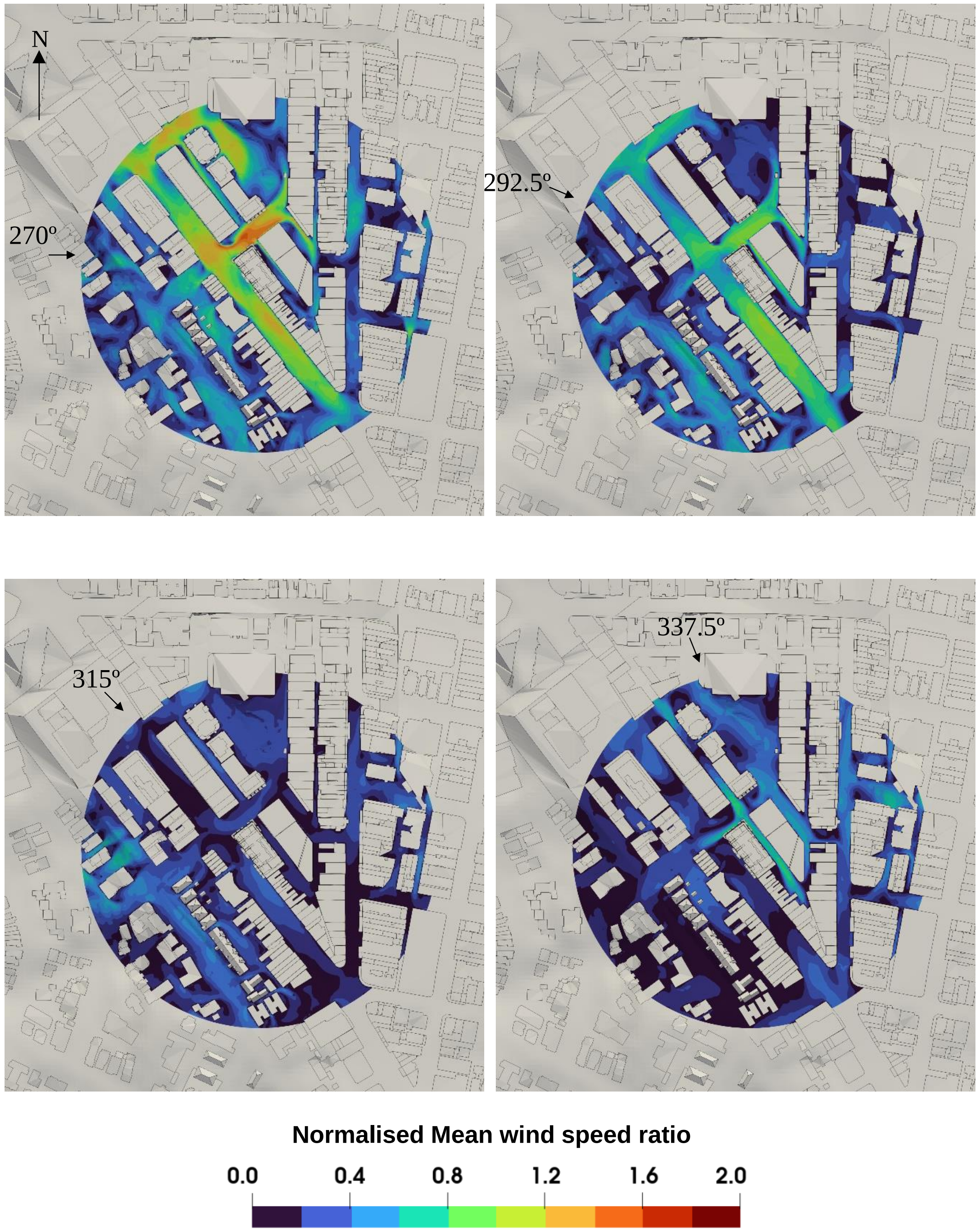

N
270º
292.5º
315º
337.5º
Normalised Mean wind speed ratio
0.0
0.4
0.8
1.2
1.6
2.0

Proposed


N
0°
22.5°
45°
67.5°
Normalised Mean wind speed ratio
0.0
0.4
0.8
1.2
1.6
2.0


N
90º
112.5º
135º
157.5º
Normalised Mean wind speed ratio
0.0
0.4
0.8
1.2
1.6
2.0


N
180º
202.5 º
225º
247.5º
Normalised Mean wind speed ratio
0.0
0.4
0.8
1.2
1.6
2.0


N
270º
292.5º
315º
337.5º
Normalised Mean wind speed ratio
0.0
0.4
0.8
1.2
1.6
2.0