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APPENDIX Z

Environmental Wind Assessment

Arup

Infrastructure NSW

Sydney Football Stadium (SFS) Redevelopment Project

Environmental Wind Assessment

2019-05-01 Sydney Football Stadium - Environmental Wind Assessment - Issue03

Issue 04 | 28 May 2019

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Executive Summary

This report provides a summary of the impact of the proposed design of the Sydney Football Stadium (SFS) Redevelopment Project on pedestrian wind comfort around the site, with a comparison to former SFS conditions for precedence. All test locations are well below the safety criterion.

Not all test locations for the proposed stadium configuration meet the City of Sydney criterion. However, the former SFS configuration (Allianz Stadium) was also measured to experience uncomfortable wind conditions that are above the City of Sydney criterion at various locations. For a number of the proposed locations, the current existing conditions were also measured to experience more uncomfortable wind conditions.

It should be noted that the precinct is generally only highly occupied on game days, where the dense number of pedestrians offers local wind protection called the penguin-effect, particularly in high-trafficked areas. As such, there are a limited number of days in the year when the predicted comfort conditions for certain locations would be a concern. Further to this, part of the precinct is inaccessible to the general public on non-game days, which includes some of the test locations that do not meet the relevant City of Sydney criterion. It is important to note that the main entries at the northern end of the stadium (Locations 21 and 24, Figure 5) meet the City of Sydney criterion. Location 28, to the west of the stadium, another main pedestrian access point from the carpark, also meets the criterion.

Consideration has also been given to the broader precinct, with a number of test locations along Moore Park Road and Driver Avenue, covering key intersections that people would regularly access. All of these locations meet the City of Sydney non-active frontage criterion and are similar to the former SFS conditions. Locations further from the stadium would be less affected. Beyond a distance of about twice the stadium height from the perimeter of the stadium façade, the wind conditions and associated classification level would not be expected to be significantly affected by the stadium massing, as evidenced from the wind-tunnel test results. Locations in Moore Park and pedestrian circulation approaches to the stadium would therefore be unaffected by the revised stadium design.

In light of the outlined results in terms of magnitude and similarity to the former SFS design, the pedestrian level wind conditions at the proposed site are deemed to sufficiently meet the intent of the City of Sydney criterion with consideration of the applicability of the criteria to stadium design. Although not all test locations meet the non-active frontage comfort criterion, in general, wind conditions are expected to be similar to the former SFS conditions with some areas becoming windier and others calmer. Additionally, the main key entry points meet the non-active frontage comfort criterion. The fact that for the majority of the year the precinct will have a low occupation (i.e. outside of events) and events are controlled including during extreme weather conditions, further substantiates the argument that the proposed design is appropriate from a pedestrian level wind perspective.

During non-event days there will be areas of calm around the precinct allowing activation of the space.

The proposed design, combined with the results presented in this report, is deemed to meet the Assessment Objectives, as outlined in Section 3, including Condition C58, the mitigation measures, and also the SEARs.

Contents

Appendices

1 Introduction

Infrastructure NSW have engaged Arup to provide a quantitative environmental wind assessment for the Sydney Football Stadium (SFS) Redevelopment Project. This report outlines the wind tunnel testing study conducted on the precinct in the former SFS, and proposed configurations, and presents the results related to pedestrian wind comfort and safety on the ground level in and surrounding the development.

The objective of this report is to form part of the Development Application and responds accordingly to the various conditions, mitigation measures and Secretary's Environmental Assessment Requirements (SEARs).

Wind tunnel testing was conducted on 25/26 March at the MEL Consultants facility. An environmental wind study was completed in accordance with AWES (2019) to assess the impact of the proposed development on pedestrian level wind conditions for comfort and safety in and around the site. The base results have been analysed and compared with the City of Sydney wind assessment criteria.

2 Project Overview

2.1 Introduction

This report supports a State Significant Development (SSD) Development Application (DA) for the redevelopment of the Sydney Football Stadium, which is submitted to the Minister for Planning pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The redevelopment is being conducted in stages comprising the following planning applications:

- **Stage 1** – Concept Proposal for the stadium envelope and supporting retail and functional uses as well as development consent for the carrying out of early works, including demolition of the existing facility and associated structures.
- **Stage 2** – detailed design, construction and operation of the stadium and supporting business, retail and functional uses.

Development consent was granted for the Concept Proposal and detailed approval to carry out early works and demolition (SSD 18_9249) by the Minister for Planning on 6 December 2018.

This report relates to the Stage 2 application and considers the detailed design, construction and operation of the new Sydney Football Stadium pursuant to the approved Concept Proposal.

Infrastructure NSW is the proponent of the Stage 2 DA.

2.2 Background

The Sydney Football Stadium (SFS) is a significant component of the sports facilities that comprise the Sydney Cricket and Sports Ground. Completed in 1988, the SFS has hosted numerous sporting events in its 30 years of operation for a number of sporting codes including football (soccer), rugby league and rugby union as well as occasional music concerts.

The NSW Stadia Strategy 2012 provides a vision for the future of stadia within NSW, prioritising investment to achieve the optimal mix of venues to meet community needs and to ensure a vibrant sports and event environment in NSW. A key action of the strategy included development of master plans for Tier 1 stadia and their precincts covering transport, integrated ticketing, spectator experience, facilities for players, media, corporate and restaurant and entertainment provision. SFS is one of three Tier 1 stadia within NSW, the others being Stadium Australia (Olympic Park) and the Sydney Cricket Ground.

In order to qualify for Tier 1 status, a stadium is required to include:

- Seating capacity greater than 40,000;
- Regularly host international sporting events;
- Offer extensive corporate facilities, including suites, open-air corporate boxes and other function/dining facilities; and
- Be the home ground for sporting teams playing in national competitions.

On 6 December 2018, development consent was granted for the Concept Proposal and Early Works/ Demolition stage of the SFS redevelopment (SSD 18_9249). This consent permitted the completion of demolition works on the site and established the planning and development framework through which to assess this subsequent Stage 2 application. Specifically, State Significant Development Consent SSD 18_9249 encompassed:

1. A Concept Proposal for:
    - A maximum building envelope for the stadium with capacity for 45,000 seats (55,000 patrons in concert mode) and 1,500 staff.
    - Urban Design Guidelines and a Design Excellence Strategy to guide the detailed design of the stadium at Stage 2.
    - General functional parameters for the design and operation of the new stadium, including:
        - Range of general admission seating, members areas, premium box/terrace, function/lounge and corporate suite options;
        - Administration offices;
        - New roof with 100% drip-line coverage of all permanent seating;
        - Flood lighting, stadium video screens and other ancillary fittings;
        - Food and beverage offerings;
        - Facilities for team, media, administration and amenity such as changing rooms, media rooms and stadium; and
        - Provision for ancillary uses within the stadium and surrounds.
    - Principles and strategies for transport and access arrangements.
    - Indicative staging of the development.

2. Detailed consent for the following works:
    - The demolition of the existing SFS and ancillary structures, including the existing Sheridan, Roosters, Waratahs and Cricket NSW buildings down to existing slab level.

- Site and construction management, including use of the existing MP1 car park for construction staging, management and waste processing, and provisions for temporary pedestrian and vehicular access management.
- The protection and retention of Tree 125 (Moreton Bay Fig adjacent to Moore Park Road) and Tree 231-238 cluster (Hills Weeping Fig and others near Paddington Lane) and all existing street trees located outside of the site boundary, with the removal of all other vegetation within the proposed future building footprint.
- Works to make the site suitable for the construction of the new stadium (subject to this separate Stage 2 application).

2.3 Site Description

The site is located at 40-44 Driver Avenue, Moore Park within the Sydney Cricket Ground Precinct. It is bound by Moore Park Road to the north, Paddington Lane to the east, the existing SCG stadium to the south and Driver Avenue to the west. The site is located within the City of Sydney local government area.

The site is legally described as Part Lots 1528 and 1530 in Deposited Plan 752011 and Lot 1 in Deposited Plan 205794. The site is Crown Land, with the SCSGT designated as the sole trustee under the *Sydney Cricket and Sports Ground Act 1978*. The site is wholly contained within designated land controlled by the Sydney SCSGT under Schedule 2A of the *Sydney Cricket and Sports Ground Act 1978*.

In a broader context, the site is largely surrounded by Centennial and Moore Parks, the Fox Studios and Entertainment Quarter precincts and the residential suburb of Paddington. Located approximately 3km from the Sydney CBD and approximately 2km from Central Station, the site is connected to Sydney’s transport network through existing bus routes and will benefit from a dedicated stop on the soon to be completed Sydney CBD and South East Light Rail.

The locational context of the Site is shown in Figure 1, whilst the site boundaries and existing site features are shown in Figure 2**.**

Figure 1: Regional site context

Figure 2: Site area and local context

2.4 Overview of Proposed Development

The application represents the next phase in the SFS redevelopment. It seeks consent for the detailed design, construction and operation of the new stadium as 'Stage 2' of the redevelopment, which includes:

- Construction of a new stadium with up to 45,000 seats (55,000 capacity in concert-mode), including playing pitch, grandstands, sports and stadium administration areas, food and drink kiosks, corporate facilities, and all other aspects of a modern stadium;
- Operation and use of the stadium and surrounding site area for a range of sporting and entertainment events;
- Vehicular and pedestrian access and circulation arrangements, including excavation to deliver a partial basement level for storage, internal loading and servicing at the playing pitch level;
- Reinstatement of the MP1 car park following the completion of construction, including enhanced vehicle rejection facilities and direct vehicular connection to the new stadium basement level;
- Public domain improvements within the site boundary, including hard and soft landscaping, to deliver a range of publicly accessible, event and operational areas;
- Provision of new pedestrian and cycling facilities within the site;
- Signage, including building identification signage, business identification signage and a wayfinding signage strategy; and
- Extension and augmentation of physical infrastructure/ utilities for the development within the site.

The proposed development is consistent with the approved Concept Proposal pursuant to State Significant Development Consent SSD 9249.

3 Assessment Objectives

The objective of this report is to form part of the Development Application and responds accordingly to the various conditions, mitigation measures, and Secretary's Environmental Assessment Requirements (SEARs). These are outlined in the following sections.

3.1 Conditions

Condition C58 is applicable to the wind assessment:

"The future development application must include detailed assessment of the wind impacts due to the future development including impacts on surrounding public areas within the site and offsite, road reserves and Moore Park. The impact assessment must include quantitative data to assess the potential impact and proposed appropriate management and mitigation measures."

3.2 Mitigation Measures

This report responds to the Wind Impact mitigation measure, CP-WI1:

"A Pedestrian Wind Environment Study, including wind tunnel testing, is to be prepared based upon detailed stadium design and submitted with Stage 2 Development Application."

3.3 SEARs

The Department of Planning and Environment have issued Secretary's Environmental Assessment Requirements (SEARs) to the applicant for the preparation of an Environmental Impact Statement for the proposed development. This report has been prepared having regard to the SEARs as follows:

SEAR	Where addressed in report
Provide a wind assessment of the detailed design including a wind tunnel study.	Appendix A5
Assess amenity impacts including solar access, acoustic impacts, visual privacy, overshadowing and wind impacts to assess any potential impacts on residential and other land uses.	Wind aspects discussed in this report
Provide a Wind Effects Report based on the conclusions and recommendations in the preliminary Wind Considerations for Stadium Design prepared by Arup dated 27 April 2018 (SSD 9249).	This report
The report is to be prepared by a suitably qualified engineer and is to:	Dr. Graeme Wood, Arup, (PhD, BEng) Ms. Lauren Boysen (BAeroEng) Dr. Michael Eaddy, MEL Consultants (PhD, ME, BE)
be based on wind tunnel testing, which compares and analyses the current wind conditions and the wind conditions created by the proposed stadium and any other ancillary buildings;	Wind tunnel testing report in Appendix A5
report the impacts of wind on the pedestrian environment at the footpath level within the site and the public domain; and	Section 4 of this report
Assess the potential wind impacts on the ground level environment having regard to Section 3.2.6 (wind effects) of Sydney Development Control Plan 2012 (Sydney DCP).	Section 4.3 of this report

4 Wind Assessment

4.1 Modelling

Wind tunnel testing was conducted in two configurations: former SFS (Allianz Stadium), and proposed stadium design. Mitigation measures in the form of mature trees were also tested at some locations for pedestrian comfort in the proposed configuration. Photographs of the wind tunnel testing models are included in Figure 3 and Appendix A3.

The wind tunnel testing programme conducted by MEL Consultants was in accordance with the requirements of AWES (2019), and is considered appropriate for this investigation. Appropriate wind profiles and test locations were used in the testing in accordance with Standards Australia (2011), and AWES (2014). For the proposed configuration, measurements were taken at 33 points at pedestrian level in and around the site as shown in Figure 5. For the former SFS configuration, measurements were taken at 8 points at pedestrian level, Figure 6. The former SFS configuration was tested for comparative purposes and therefore, only key locations needed to be tested. Testing at all locations was conducted at 22.5° wind direction intervals.

Arup have subsequently reviewed the wind tunnel testing results. Arup have analysed the base results with Sydney Airport climate data, for years 1995 to 2017, Appendix A1. The results presented in the body of the report are based on Arup's analysis.

Figure 3: Photograph of the wind tunnel model for the proposed configuration

4.2 Wind Assessment Criteria

The current City of Sydney (2012) DCP specifies wind effects not to exceed 10 m/s for active frontages, and 16 m/s for all other streets, Figure 4. There are few locations in Sydney that would meet the 'active frontage' criterion without significant shielding to improve the wind conditions. With reference to the City of Sydney active frontage map, Figure 4, the SFS is zoned as non-active frontages and therefore, the 16 m/s criterion applies.

Figure 4: Active frontage map from City of Sydney DCP, with the approximate SFS site marked in purple

From personal communications with Council, this reference wind speed is a once per annum gust wind speed as per the wind criteria in City of Sydney 2004 DCP, but is meant to be interpreted as a comfort level criterion to promote outdoor activities and is not intended to be used as a distress requirement. The once per annum gust wind speed criterion used in the City of Sydney (2012) DCP is based on the work of Melbourne (1978), Table 1, which is for the probability of the 3 s gust occurring in an hour of data for 0.1% of the time for any wind direction, or two peak storm events in a year. The 10 m/s level is classified as generally acceptable for pedestrian sitting, and the 16 m/s for pedestrian walking. The Melbourne criteria give the ‘once per annum gust wind speed’, and uses this as an estimator of the general wind conditions at a site. A more detailed discussion on wind criteria are presented in Appendix A2. The City of Sydney (2012) DCP criteria are considered more relevant for well-frequented streetscapes rather than open locations where people will frequent when a range of environmental conditions meet their intended needs.

Table 1: Summary of wind effects on pedestrians based on MEL Consultants criteria

‘Annual’ maximum 3 s gust wind speed	Result on perceived pedestrian comfort
> 23 m/s	**Unsafe** (frail pedestrians knocked over)
< 23 m/s	**Unacceptable** for comfort
< 20 m/s	**Waterfront** locations / fast walking
< 16 m/s	Acceptable for **walking** (steady steps for most pedestrians)
< 13 m/s	Acceptable for **standing** (window shopping, vehicle drop-off, queuing)
< 10 m/s	Acceptable for **sitting** (outdoor café, gardens, park benches)

4.3 Results Discussion

Results for the proposed and former SFS designs are presented in Figure 5 and Figure 6 respectively. These figures show the test locations and whether the wind conditions would meet the City of Sydney non-active frontage criterion. Table 2 summarises the results for each test location in terms of the predicted comfort category for former SFS and proposed configurations, including the mitigation strategies that were tested for some locations; the comfort category shown represents the highest directional annual maximum 3 s gust wind speed at each location.

Results for the former SFS configuration (in equivalent locations) enable a direct comparison between the former and proposed configurations to further inform whether predicted wind conditions are changing significantly. This direct comparison is considered appropriate as the primary use of the space around the stadium is not changing and it is understood that the wind conditions around the former SFS design were considered appropriate for the use of the space. This is important for identifying the necessity for amelioration strategies.

The majority of test locations meet the City of Sydney non-active frontage criterion (walking) for both the proposed and former SFS configurations. The test locations that are currently not meeting the criterion (locations 40, 42, and 44) are generally located close to the building façade, on the corners of the stadium, and on the eastern and western sides where the prevailing winds are accelerated along the facades. All test locations are well below the safety criterion.

In the proposed configuration, nine test locations are above the City of Sydney non-active frontage criterion, however of these nine locations, two (Locations 18 and 29) are either on or just over the 16 m/s threshold. For a number of the proposed Locations 9, 21, 28, and 31 (Figure 7), the former SFS configuration experiences more uncomfortable wind conditions.

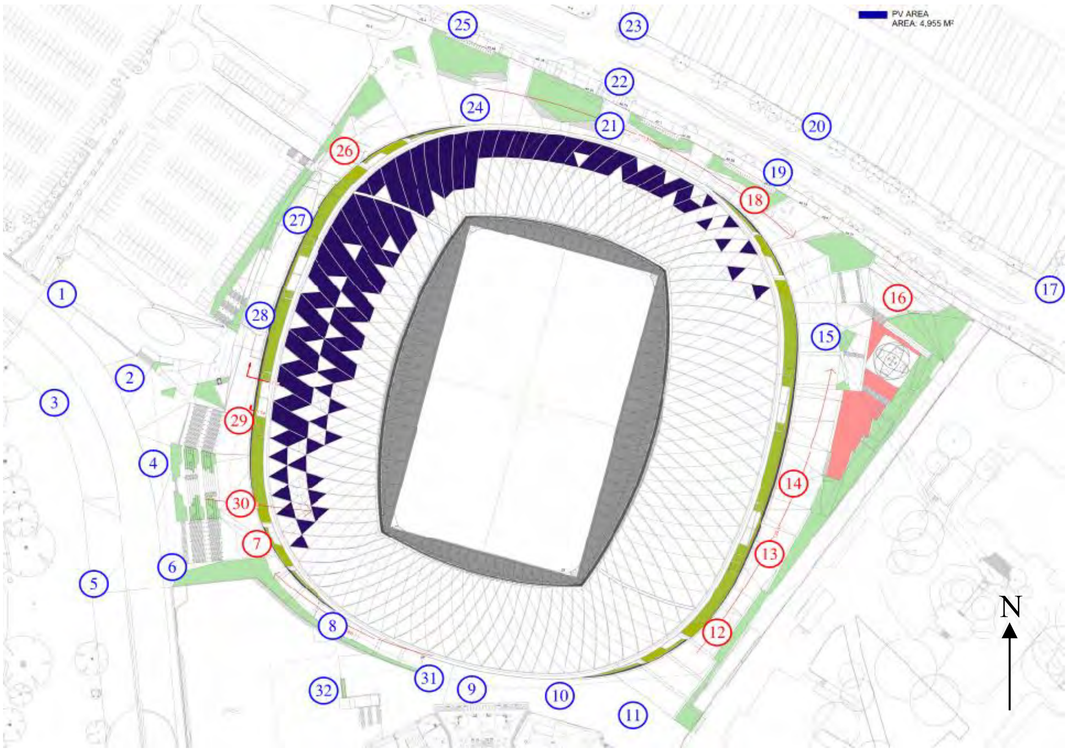

Figure 5: Proposed configuration: test locations mark-up on site plan – red text indicates locations that are not meeting the City of Sydney criterion.

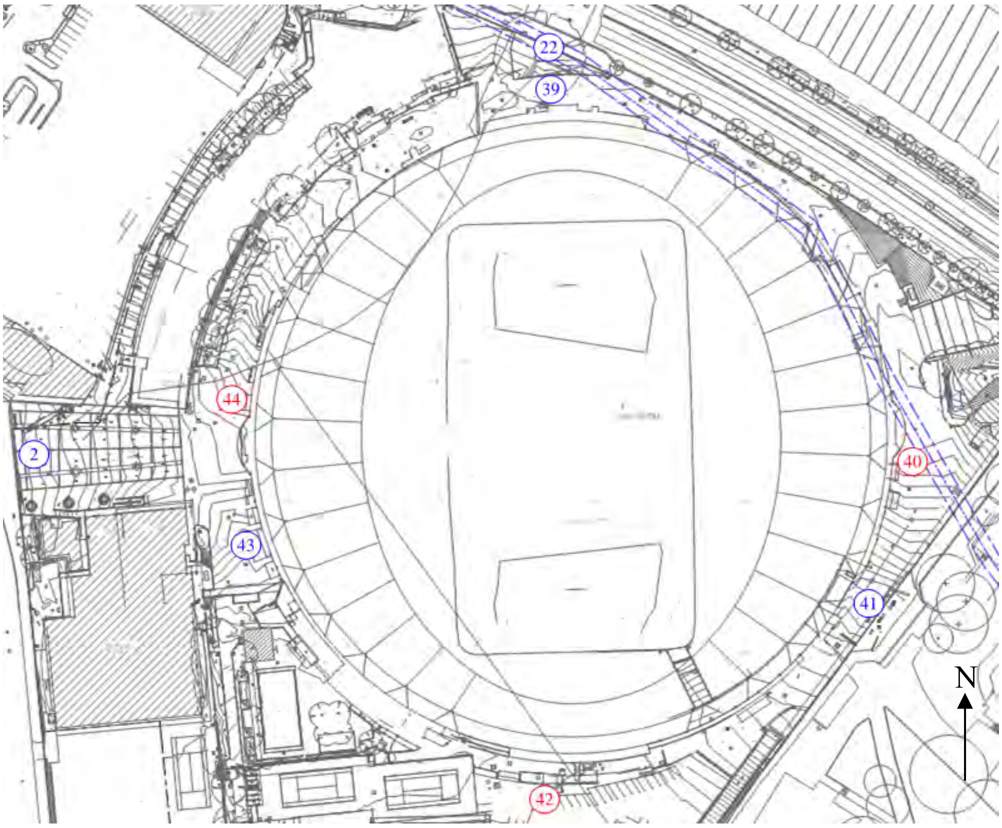

Figure 6: Former SFS configuration (Allianz Stadium): test locations mark-up on site plan – red text indicates locations that are not meeting the City of Sydney criterion.

Table 2: Results Summary Table

Description / Test Location		Target	Wind tunnel results						
			Former SFS design			Proposed design		Mitigation	
		DCP 2012 criteria, 0.1% exceedance wind speed (m/s)	Equiv. test location	DCP 2012 criteria, 0.1% exceedance wind speed (m/s)	Meet Target? Y(es)/N(o)	DCP 2012 criteria, 0.1% exceedance wind speed (m/s)	Meet Target? Y(es)/N(o)	DCP 2012 criteria, 0.1% exceedance wind speed (m/s)	Meet Target? Y(es)/N(o)
Ground Plane	1	< 16				14.3	Y		
	2	< 16	2	12.1	Y	13.2	Y		
	3	< 16				13.4	Y		
	4	< 16				12.9	Y		
	5	< 16				12.9	Y		
	6	< 16				13.9	Y		
	7	< 16				18.9	N		
	8	< 16				11.5	Y		
	9	< 16	42	17.1	N	14.4	Y		
	10	< 16				14.8	Y		
	11	< 16				15.3	Y		
	12	< 16	41	14.1	Y	17.3	N		
	13	< 16				17.2	N		
	14	< 16	40	17.1	N	17.8	N	14.9	Y (trees)
	15	< 16				14.2	Y		
	16	< 16				16.6	N		
	17	< 16				8.7	Y		
	18	< 16				16.0	N		
	19	< 16				13.9	Y		
	20	< 16				13.4	Y		
	21	< 16	39	15.1	Y	13.9	Y		
	22	< 16	22	12.9	Y	13.5	Y		
	23	< 16				13.5	Y		
	24	< 16				13.9	Y		
	25	< 16				15.9	Y		
	26	< 16				18.5	N	17.4	N (trees)
	27	< 16				14.9	Y		
	28	< 16	44	17.6	N	15.4	Y		
	29	< 16	43	15.7	Y	16.4	N		
	30	< 16				18.5	N		
	31	< 16	42	17.1	N	13.3	Y		
	32	< 16				12.8	Y		

Melbourne Criteria

Annual Maximum 3 s gust speed	Result on perceived pedestrian comfort
≥ 23 m/s	**Unsafe** (frail pedestrians knocked over)
< 23 m/s	**Unacceptable**
<20 m/s	Acceptable for **Waterfront** locations
< 16 m/s	Acceptable for **walking** (steady steps for most pedestrians)
< 13 m/s	Acceptable for **standing** (window shopping, vehicle drop-off, queuing)
< 10 m/s	Acceptable for **sitting** (outdoor café, gardens, park benches)

Figure 7 shows a comparison between two equivalent locations (for example, Location 42 for the former SFS configuration and Location 9 for the proposed configuration). The various pedestrian comfort criteria thresholds are overlaid. It can be see that except for one wind direction, the predicted conditions for the proposed design have improved compared with the former SFS configuration for all wind directions. All wind directions are also comfortably below the City of Sydney criterion for the proposed configuration.

Figure 7: Comparison of predicted wind conditions at equivalent locations

It is worth mentioning that the precinct is generally only highly occupied on game days where the dense number of pedestrians offers local wind protection called the penguin-effect, particularly in high-trafficked areas. As such, there are a limited number of days in the year when the predicted comfort conditions for certain locations would be a concern. In addition, on exceptionally strong forecast wind days, the game may be cancelled for weather reasons. No unsafe conditions were measured on the precinct. The general limited occupation of the precinct on non-game days, and limited pedestrian access to the south and east provides further context in regard to the necessity for all locations to meet the City of Sydney criteria at all locations.

The proposed main entries at the northern end of the stadium are located at location 21 and 24 (Fig Tree Place), Figure 5, both of which meet the City of Sydney criterion. Location 28 is another key pedestrian access point for people coming from the carpark; this location also meets the criterion. Location 16 (Busby's Corner) does not meet the City of Sydney criterion, but only just exceeds the 16 m/s threshold at 16.6 m/s. The criterion is only exceeded for one wind direction (NNE), which is a prevailing wind direction for Sydney during summer. There are three locations that exceed the criterion on the east side of the stadium (12, 13 and 14). However, it is understood the area around the stadium between approximately Locations 8 to 13 is inaccessible by the public on non-game days and during certain events.

As indicated in Table 2, basic mitigation strategies for pedestrian comfort (trees) were tested for two test locations, being Locations 14 and 26. For Location 14, trees were effective in meeting the City of Sydney non-active frontage criterion.

Wind conditions at Location 26, at the narrowest point between the stadium and the existing Rugby AU building exceeded the City of Sydney non-active frontage criterion. The inclusion of trees in this location improved the wind conditions. To further improve the wind conditions in this area, additional small-scale vertical screening such as trees, walls, or small wayfinding structures to the immediate south of the narrowest sections would be recommended.

Consideration has also been given to the broader precinct, with a number of test locations along Moore Park Road and Driver Avenue, covering key intersections that people would be using as part of pedestrian access. All these locations meet the City of Sydney criterion and are similar to the former SFS conditions. Locations further from the stadium would be less affected. Beyond a distance of about twice the stadium height from the perimeter of the stadium façade, the wind conditions and associated classification level would not be expected to be significantly affected by the stadium massing, as evidenced from the wind-tunnel test results. Locations in Moore Park and pedestrian circulation approaches to the stadium would therefore be unaffected by the revised stadium design.

Regardless of the incident wind direction, close to the stadium on non-event days, there will be relatively calm wind conditions somewhere on the precinct allowing the potential for greater activation of the space. As with all large open activation precincts, event management will have to be cognisant of the environmental conditions and plan the location of events accordingly.

In light of the outlined results in terms of magnitude and similarity to the former SFS design, it is considered that the pedestrian level wind conditions at the proposed site are deemed to sufficiently meet the intent of the City of Sydney non-active frontage criterion. Although not all test locations meet the comfort criterion, in general, wind conditions are expected to be similar to the former SFS conditions with some areas becoming windier and others calmer. A number of the comfort criterion exceedances are minor with the greater exceedances in inaccessible areas, or of low-pedestrian traffic except during events.

Locations at the stadium main entrances meet the appropriate comfort criterion. The fact that for the majority of the year the precinct has limited use, with a large proportion inaccessible by the public, further substantiates that the proposed design is appropriate from a pedestrian level wind perspective.

All test locations are well below the safety criterion.

5 Summary

Arup have provided a summary of the impact of the proposed design on pedestrian level wind comfort in and around the site, with comparison to former SFS conditions. The wind conditions around both stadia are similar indicating that the wind conditions would be expected to be similar with specific areas becoming windier and others calmer. The relevant wind comfort criteria classification used in and around such a stadium would be different to a general heavily-trafficked area, but the safety criterion is immutable. All locations are well below the safety criterion.

In the proposed configuration, the majority of location passed the City of Sydney, non-active frontage criterion with exceedances measured at 9 test locations. Two of these points are either on, or just over, the 16 m/s threshold, and another 4 are to the east of the stadium in generally inaccessible low-trafficked areas. The remaining points, at the south-west corner and the narrowest point between the stadium and the existing Rugby AU building, have a similar wind climate to the former SFS conditions. However, to improve the wind conditions at these locations, local treatments with small vertical elements such as trees, walls, or small wayfinding structures that are too small to include in the wind tunnel study for this submission would be expected to improve the wind conditions.

It should be noted that the precinct is generally only highly occupied on game days where the high density of people offers collective wind protection. In addition, on non-game days part of the precinct is inaccessible to the general public, which includes some of the test locations exceeding the City of Sydney non-active frontage criterion. The proposed main entries at the northern end of the stadium are located at Locations 21 and 24 (Fig Tree Place), Figure 5, both of which meet the City of Sydney non-active frontage criterion. Location 28 is another key pedestrian access point for people coming from the carpark; this location also meets the criterion. Location 16 (Busby's Corner) does not meet the City of Sydney criterion, but only just exceeds the 16 m/s threshold at 16.6 m/s. The criterion is only exceeded for one wind direction (NNE), which is a prevailing wind direction for Sydney during summer.

Consideration has also been given to the broader precinct, with a number of test locations along Moore Park Road and Driver Avenue, covering key intersections that people would be using as part of pedestrian access and impacted by the stadium. All of these locations meet the City of Sydney non-active frontage criterion.

In light of the outlined results, the pedestrian level wind conditions at the proposed site are deemed to sufficiently meet the intent of the City of Sydney criterion with consideration of the applicability of the criteria to stadium design. Although not all test locations meet the non-active frontage comfort criterion, in general, wind conditions are expected to be similar to the former SFS conditions with some areas becoming windier and others calmer. All test locations are well below the safety criterion.

Locations at the stadium main entrances meet the appropriate comfort criterion. The fact that for the majority of the year the precinct will not be extensively occupied or trafficked further substantiates that the proposed design is appropriate from a pedestrian level wind perspective.

During non-event days there will be areas of calm around the precinct allowing activation of the space.

The proposed design, combined with the results presented in this report, is deemed to meet the Assessment Objectives, as outlined in Section 3, including Condition C58, the mitigation measures, and also the SEARs.

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Appendix A

A1 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 have been used in this analysis, Figure 8. The arms of the wind rose point in the direction from where the wind is coming from. The anemometer is located about 8 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 8 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 and north-east quadrants. 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-scales 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.

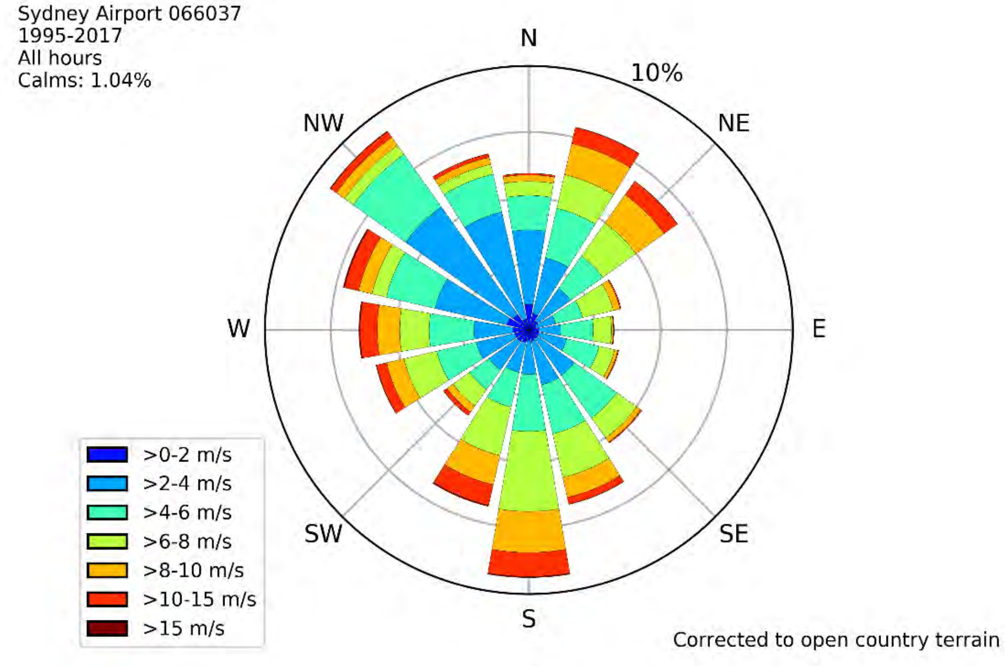

Figure 8: Wind rose showing probability of time of wind direction and speed

A2 Wind Speed Criteria

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

Table 3 Summary of wind effects on pedestrians

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

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

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

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

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

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

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

A comparison between the mean and 3 s gust wind speed criteria from a probabilistic basis are presented in Figure 9 and Figure 11. 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 9 with definitions of the intended use of the space categories defined in Figure 10.

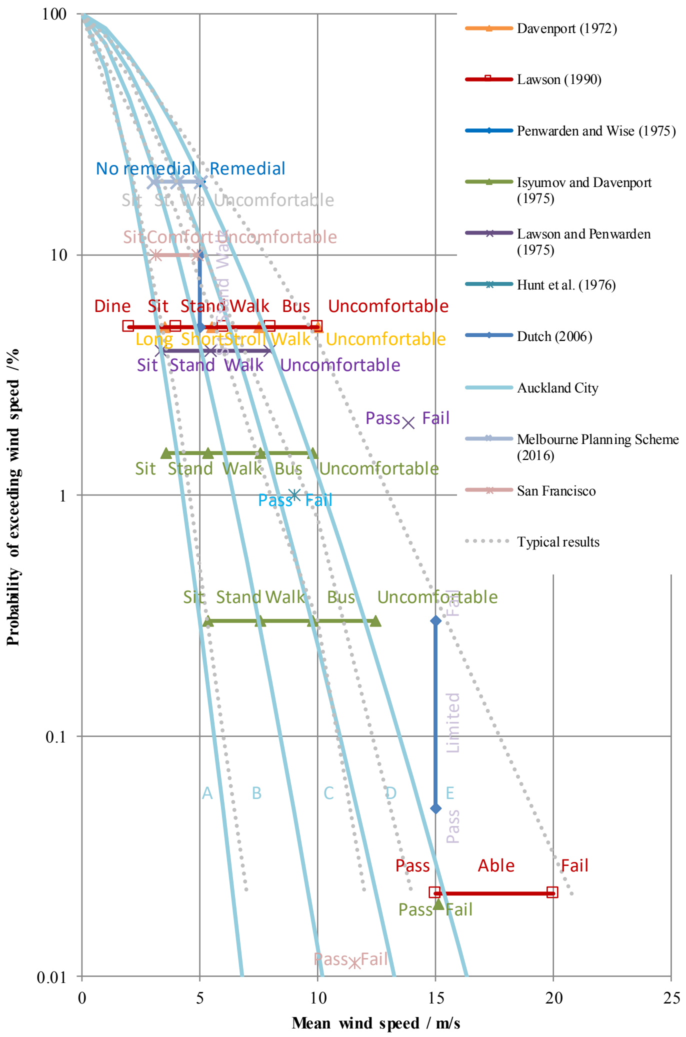

Figure 9: Probabilistic comparison between wind criteria based on mean wind speed

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 10: Auckland Utility Plan (2016) wind categories

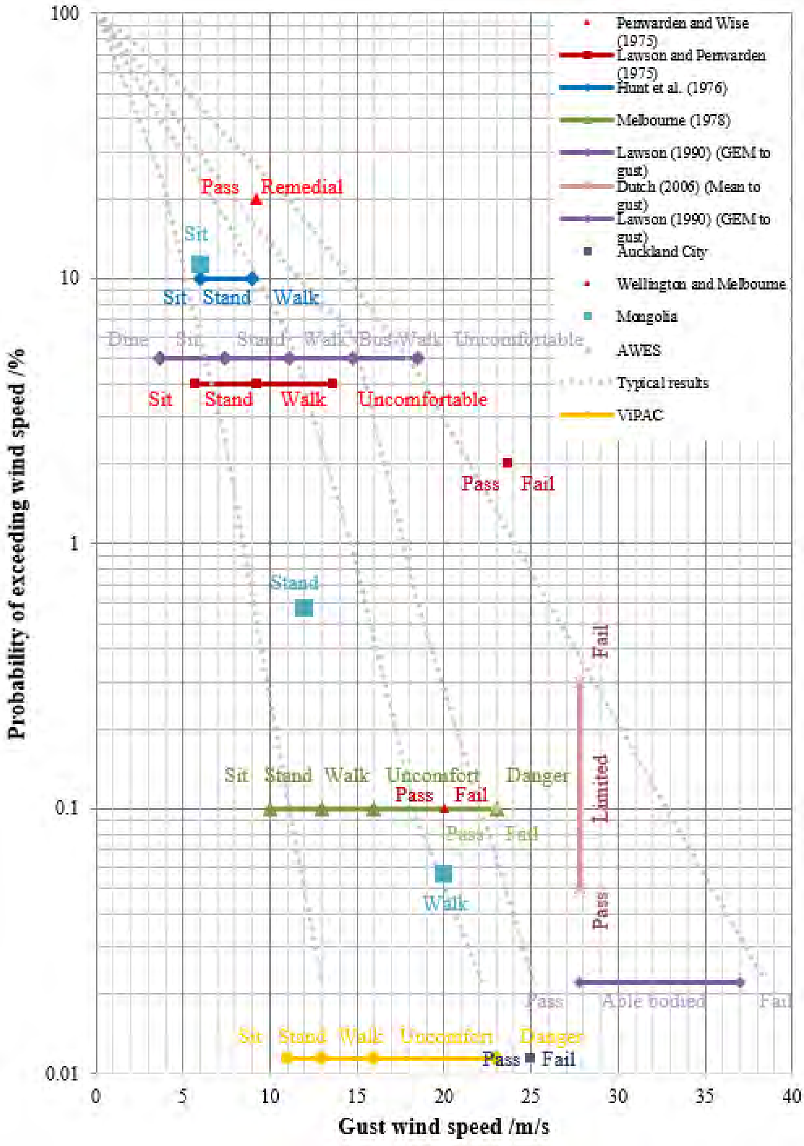

Figure 11: Probabilistic comparison between wind criteria based on 3 s gust wind speed

A3 Photographs of Tested Models

Figure 12: Wind tunnel model: proposed configuration

Figure 13: Wind tunnel model: former SFS configuration

A4 Reference Documents

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

Date Received	Filename
11/02/2019	A01.01_COVERSHEET_A.pdf
11/02/2019	A01.02_NOTES&LEGENDS_A.pdf
11/02/2019	A11.01_EXISTINGPRECINCTSITEPLAN_A.pdf
11/02/2019	A11.02_LOCATIONPLAN_A.pdf
11/02/2019	A11.03_EXISTINGSITESURVEY_A.pdf
11/02/2019	A11.04_DEMOLITIONPLAN_A.pdf
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11/02/2019	A11.06_EXISTINGSERVICESPLAN_A.pdf
11/02/2019	A11.07_SITEPLAN_A.pdf
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11/02/2019	A11.09_SECTIONANDELEVATIONKEYPLAN_A.pdf
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11/02/2019	A97.RD.01_ROOMDATASHEETS_A.pdf
11/02/2019	A99.AR.01_DESIGNREPORT_A.pdf
11/02/2019	A99.SE.01_STRUCTURALENGINEERINGSCHEMEDESIGNREPORT_A.pdf
11/02/2019	ASK124_FACADECLADDINGZONES_A.pdf
11/02/2019	ASK125_ILLUSTRATIVEEXTERNALFINISHESSCHEDULE_A.pdf
11/02/2019	ASK126_FACADEINTENTSECTIONS-INTERIM_A.pdf
11/02/2019	BRIEF_SFSRPROJECTBRIEF_C.pdf

A5 Wind Tunnel Testing Report – MEL Consultants

ENVIRONMENTAL WIND SPEED MEASUREMENTS ON A WIND TUNNEL MODEL OF THE SYDNEY FOOTBALL STADIUM DEVELOPMENT, SYDNEY

By

A. Loie

and

M. Eaddy

SUMMARY

Wind tunnel tests have been conducted on a 1/400 scale model of the Sydney Football Stadium Development, Sydney. The model of the Development within surrounding buildings was tested in a simulated upstream boundary layer of the natural wind to determine likely environmental wind conditions. These wind conditions have been related to the freestream mean wind speed at a reference height of 300m and compared with criteria developed for the Sydney region as a function of wind direction.

The wind conditions for the Proposed Configuration were shown to exceed the walking comfort criterion at most locations around the proposed stadium with the exception of some locations to the north and south of the stadium.

The wind conditions for the Proposed Configuration along Driver Avenue have been shown to achieve the walking criterion for all wind directions. The wind conditions for the Proposed Configuration along Moore Park Road have been shown to generally achieve the walking criterion for all wind directions with the exception of locations to the north-west of the proposed stadium and to the east of the proposed stadium.

In comparison, it was shown that the wind conditions for a number of locations around the existing Allianz Stadium were also above the walking criterion.

Report 37-19-WT-ENV-00

April 2019

SYDNEY FOOTBALL STADIUM DEVELOPMENT, SYDNEY
ENVIRONMENTAL WIND TUNNEL MODELLING

MEL CONSULTANTS REPORT NO: **37-19-WT-ENV-00**

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CONTENTS

1. INTRODUCTION

The proposed Sydney Football Stadium Development will be a new stadium built on the site of the currently under-demolition Allianz Stadium, with Driver Avenue to the west and Moore Park Road to the north (refer to Figure 1). The Sydney Football Stadium Development site is immediately surrounded for all wind directions by a mixture of commercial and residential buildings, parks and the Sydney Cricket Ground to the south.

Figure 1: View of the surrounding area of the Sydney Football Stadium Development site.

A wind tunnel model study was commissioned by ARUP to provide environmental wind conditions around the Proposed Development and, if required, to develop further wind-break features to achieve conditions satisfying the recommended environmental wind criteria. These tests were carried out in the MEL Consultants 400kW Boundary Layer Wind Tunnel during March, 2019.

2. ENVIRONMENTAL WIND CRITERIA

The advancement of wind tunnel testing techniques, using large boundary layer flows to simulate the natural wind, has facilitated the prediction of wind speeds likely to be induced around a Development. To assess whether the predicted wind conditions are likely to be acceptable or not, some form of criteria are required. A discussion of criteria for environmental wind conditions has been made in a paper by Melbourne, Reference 1. This paper notes that it is the forces caused by the peak gust wind speeds and associated gradients which people feel most and criteria have been stated in terms of gust wind speeds. The probabilistic inference of these criteria in relation to hourly mean wind speeds and frequency of occurrence is discussed. The basic criteria can be summarised as follows:

In main public access-ways wind conditions are considered

(a) unacceptable if the peak gust speed during the hourly mean with a probability of exceedence of 0.1% in any 22.5^o wind direction sector exceeds 23ms^{-1} (the gust wind speed at which people begin to get blown over);

(b) generally acceptable for walking in waterfront locations if the peak gust speed during the hourly mean with a probability of exceedence of 0.1% in any 22.5^o wind direction sector does not exceed 20 ms^{-1} (which results in 75% of the wind pressure of a 23 ms^{-1} gust).

(c) generally acceptable for walking in urban and suburban areas if the peak gust speed during the hourly mean with a probability of exceedence of 0.1% in any 22.5^o wind direction sector does not exceed 16 ms^{-1} (which results in half the wind pressure of a 23 ms^{-1} gust).

For more recreational activities wind conditions are considered

(d) generally acceptable for stationary short exposure activities (window shopping, standing or sitting in plazas) if the peak gust speed during the hourly mean with a probability of exceedence of 0.1% in any 22.5^o wind direction sector does not exceed 13 ms^{-1};

(e) generally acceptable for stationary, long exposure activities (outdoor restaurants, theatres) if the peak gust speed during the hourly mean with a probability of exceedence of 0.1% in any 22.5^o wind direction sector does not exceed 10 ms^{-1}.

The probability of exceedence of 0.1% relates approximately to the annual maximum mean wind speed occurrence for each wind direction sector. These criteria can be developed in terms of hourly mean wind speed versus frequency of occurrence as shown in References 1 and 2.

For the purpose of comparison, or integrating with local wind data, it is necessary to be able to relate the local velocity measurement to a reference velocity well clear of the influence of buildings. Because the wind force is related to wind velocity squared, it is often more convenient to express criteria in terms of velocity ratio squared, or velocity pressure ratio as this becomes. To this end, two velocity pressure ratios referenced to conditions at 300m height (as a convenient reference) are defined as,

mean velocity pressure ratio $\left|\frac{\bar{V}_{local}}{\bar{V}_{300m}}\right|^2$

and

peak velocity pressure ratio $\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$

where the peak velocity is the 3-second mean maximum gust wind speed in full scale conditions.

For wind conditions in Sydney these criteria can be expressed in terms of velocity pressure ratios, calculated from hourly mean wind speed data as per the methodology given in Reference 1.

The criteria in terms of peak velocity pressure ratios are illustrated in Figure 2 and appear in subsequent figures to enable immediate assessment of the wind conditions as measured on the model.

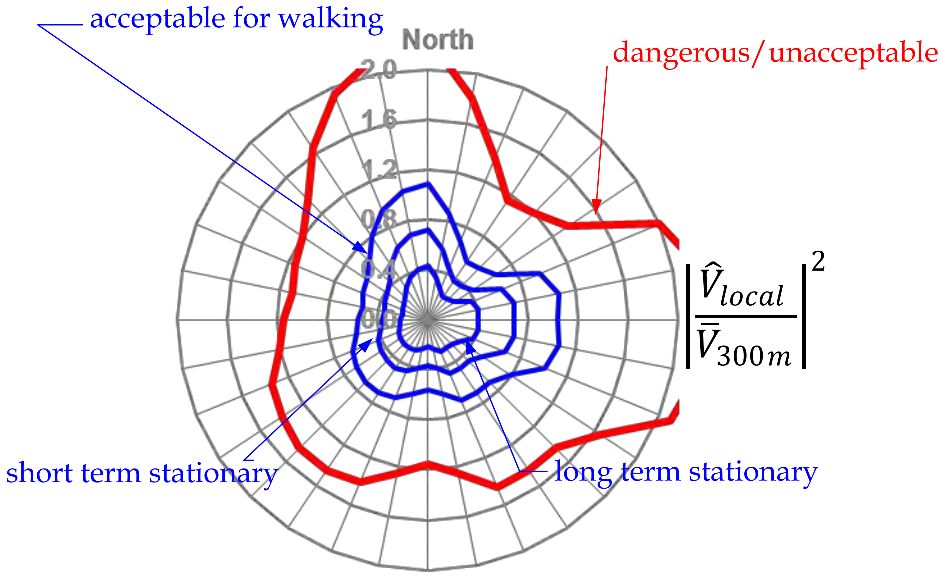


Figure 2 - Environmental wind criteria for the Sydney region expressed in terms of peak velocity pressure ratios

The velocity pressure ratio values considered as unacceptable in Figure 2 are equivalent to conditions which have existed in some areas in Australian capital cities where people have been blown over by the wind. The velocity pressure ratios considered as acceptable for walking in urban and suburban areas are equivalent to conditions existing at corners in these areas before high rise development commenced.

3. MODEL AND EXPERIMENTAL TECHNIQUES

A 1/400 scale model of the Sydney Football Stadium Development was constructed from digital information provided by Cox Architecture received up to February, 2019.

The 1/400 scale model of the Sydney Football Stadium Development was inserted into a proximity model with significant surrounding buildings out to a minimum radius of 300m. The building model was tested in a model of the natural wind generated by flow over roughness elements augmented by vorticity generators at the beginning of the wind tunnel working section. The basic natural wind model was for flow over suburban terrain, the characteristics of which are given in Figure 3. The surrounding wind tunnel model modified the approach wind model for the presence of the surrounding buildings.

The techniques used to investigate the environmental wind conditions and the method of determining the local criteria are given in detail in Reference 2. In these tests measurements in the Development areas are inside separated regions and peak velocity squared ratios were required to make conclusions about likely wind conditions. In summary, measurements were made of the peak gust wind velocity with a hot wire anemometer at various stations and expressed as a squared ratio with the mean wind velocity at a scaled reference height of 300m. This gives the peak velocity squared ratio

$$\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$$

as defined in Section 2. This peak velocity squared ratio can then be compared with the velocity squared ratio criteria for Sydney given in Figure 2. Wind tunnel velocity measurements were made for the an equivalent 1 hour period in full scale and filtered to provide an equivalent full scale 3 second gust wind speed. Photographs of the model as tested in the wind tunnel are shown in Figures 4 and 5.

4. DISCUSSION OF RESULTS

Velocity measurements were made at various locations around the Sydney Football Stadium Development for different wind directions at 22.5° intervals. The results of these measurements are presented on polar diagrams against a background plot of the various criteria for each Test Location as a function of wind direction. The Test Locations are shown in Figures 6a, 6b, 6c, 6d and 6e for locations around the existing stadium as well as the proposed development.

The Proposed Configuration, for the Sydney Football Stadium Development is as outlined in the digital information provided by Cox Architecture received up to February, 2019. The Proposed Configuration included proposed landscaping features around the concourse.

The Existing Configuration comprised the existing surrounding buildings and the current Allianz Stadium, which is currently being decommissioned.

Wind mitigation strategies for the ground level around the proposed stadium are shown in Figures 6b, 6c and 6d. The mitigation strategies for the ground level include the following:

1. Mature, 4 – 6m high trees with 4 - 5m wide canopies and 70% - 80% solidity ratios.

The following Sections detail the results for the various areas tested.

4.1 Summary of Discussion (Figures 7, 8 and 9)

To assist with the assessment of the wind conditions, summaries of the highest wind conditions at all Test Locations, ground, podium, and balconies have been summarised in the following figures

- Figure 7 Existing Configuration (Allianz Stadium)
- Figure 8a Proposed Configuration – north-west of stadium
- Figure 8b Proposed Configuration – north-east of stadium
- Figure 8c Proposed Configuration – south-east of stadium
- Figure 8d Proposed Configuration – south-west of stadium
- Figure 9a Proposed Configuration including mitigation strategies – north-west of stadium
- Figure 9b Proposed Configuration including mitigation strategies – north-east of stadium
- Figure 9c Proposed Configuration including mitigation strategies – south-east of stadium

The summaries are for all wind directions (i.e. 0°→ 360°) and different colours have been used to represent the wind criteria achieved at the respective Test Locations.

4.2 North of Stadium (Figures 10 to 11)

The wind conditions at the northern and north-west entrances to the proposed stadium (Test Locations 21 and 24) have been shown to be either on or within the criterion for walking comfort for all wind directions.

The wind conditions at the north-east of the proposed stadium (Test Location 18) have been shown to be above the walking criterion for the north-west wind direction and within the walking criterion for the remaining wind directions.

The wind conditions between the proposed stadium and the existing building to the north-west (Test Locations 26 and 26A) have been shown to exceed the walking comfort criterion for south to west winds with the remaining wind directions shown to achieve the walking comfort criterion. It was seen via flow visualisation that the winds from these critical wind directions were being funnelled and accelerated through the gap between the existing building and the proposed stadium. It was shown that adding trees along the concourse (Trees A and Trees B) improved the wind conditions for the critical wind directions but still not to the level of achieving the walking criterion.

In comparison, the existing wind conditions to the north of the Allianz Stadium (Test Location 39) were shown to be above the walking criterion for some westerly winds with the wind conditions for the remaining wind directions achieving the walking criterion.

4.3 West of Stadium (Figure 12)

The wind conditions along the west side of the proposed stadium (Test Locations 27 - 30) have been shown to be above the walking criterion for north-north-east and north-east wind directions for Test Location 27, and most westerly winds for Test Locations 28 – 30 and either on or within the walking criterion for the remaining wind directions.

In comparison, the existing wind conditions to the west of the Allianz Stadium (Test Locations 43 and 44) were shown to be above the walking criterion for westerly winds with the wind conditions for the remaining wind directions achieving the walking criterion.

4.4 South of Stadium (Figures 13 and 14)

The wind conditions near the south-west entrance to the proposed stadium (Test Location 7) have been shown to be above the criterion for walking comfort for southerly and westerly wind directions and either on or within the walking criterion for all remaining wind directions.

Along the south of the proposed stadium (Test Location 8, 9, 31 and 32) wind conditions were shown to be either on or within the walking criterion for all wind directions.

The wind conditions near the south-east of the proposed stadium (Test Locations 10 and 11) have been shown to above the walking criterion for winds from the west and south-east (Test Location 10) and from the north-east (Test Location 11). It has been shown that having trees along the south of the proposed stadium (Trees D) that the wind conditions at Test Location 10 could be improved to achieve the walking criterion for all wind directions.

In comparison, the existing wind conditions to the south of the Allianz Stadium (Test Location 42) were shown to be above the walking criterion for westerly and south-easterly winds with the wind conditions for the remaining wind directions achieving the walking criterion.

4.5 East of Stadium (Figure 15)

The wind conditions along the east of the proposed stadium (Test Locations 12 – 15) have been shown to be well above the criterion for walking comfort for some north-easterly wind directions and for the south-south-east wind direction for Test Location 14. For Test Locations 13 and 14 the wind conditions for most southerly wind directions were also above the walking criterion. All remaining wind directions for Test Locations 12 -15 were shown to be either on or within the walking criterion. It as shown that having trees along the east of the proposed stadium (Trees C) wind conditions at Test Location 14 improved to meet the walking criterion for all wind directions with the exception of the north-east wind direction, which still exceeded the walking criterion.

In comparison, the existing wind conditions to the east of the Allianz Stadium (Test Locations 40 and 41) were shown to be above the walking criterion for some north-easterly winds (both Test Locations 40 and 41) and for some southerly wind directions for Test Location 40. The wind conditions for the remaining wind directions were shown to achieve the walking criterion.

4.6 Moore Park Road (Figures 16 and 17)

The wind conditions along Moore Park Road (Test Locations 16 – 17, 19 – 20, 22 – 23, and 25) have been shown to generally achieve the walking criterion for all wind directions. The exceptions are at Test Location 16 for winds from the north-east, north-north-east and north-west wind directions, and at Test Location 25 for westerly winds.

In comparison, the existing wind conditions on Moore Park Road to the north of the Allianz Stadium (Test Location 22) were shown to be achieve the walking criterion for all wind directions.

4.7 Driver Avenue (Figures 18 and 19)

The wind conditions along Driver Avenue (Test Locations 1 – 6) have been shown to achieve the walking criterion for all wind directions for the Proposed Configuration.

In comparison, the existing wind conditions on Driver Avenue to the west of the Allianz Stadium (Test Location 2) were shown to be achieve the walking criterion for all wind directions.

5. CONCLUSIONS

Wind tunnel tests have been conducted on a 1/400 scale model of the Sydney Football Stadium Development, Sydney. The model of the Development within surrounding buildings was tested in a simulated upstream boundary layer of the natural wind to determine likely environmental wind conditions. These wind conditions have been related to the freestream mean wind speed at a reference height of 300m and compared with criteria developed for the Sydney region as a function of wind direction.

The wind conditions for the Proposed Configuration were shown to exceed the walking comfort criterion at most locations around the proposed stadium with the exception of some locations to the north and south of the stadium

The wind conditions for the Proposed Configuration along Driver Avenue have been shown to achieve the walking criterion for all wind directions. The wind conditions for the Proposed Configuration along Moore Park Road have been shown to generally achieve the walking criterion for all wind directions with the exception of locations to the north-west of the proposed stadium and to the east of the proposed stadium.

In comparison, it was shown that the wind conditions for a number of locations around the existing Allianz Stadium were also above the walking criterion.

A. Loie

MEL CONSULTANTS

April 2019

REFERENCES

1. W. H. Melbourne, Criteria for environmental wind conditions, Journal of Industrial Aerodynamics, Volume 3, 1978, pp. 241-249
2. W. H. Melbourne, Wind environment studies in Australia, Journal of Industrial Aerodynamics, Volume 3, 1978, pp. 201-214

FIGURES

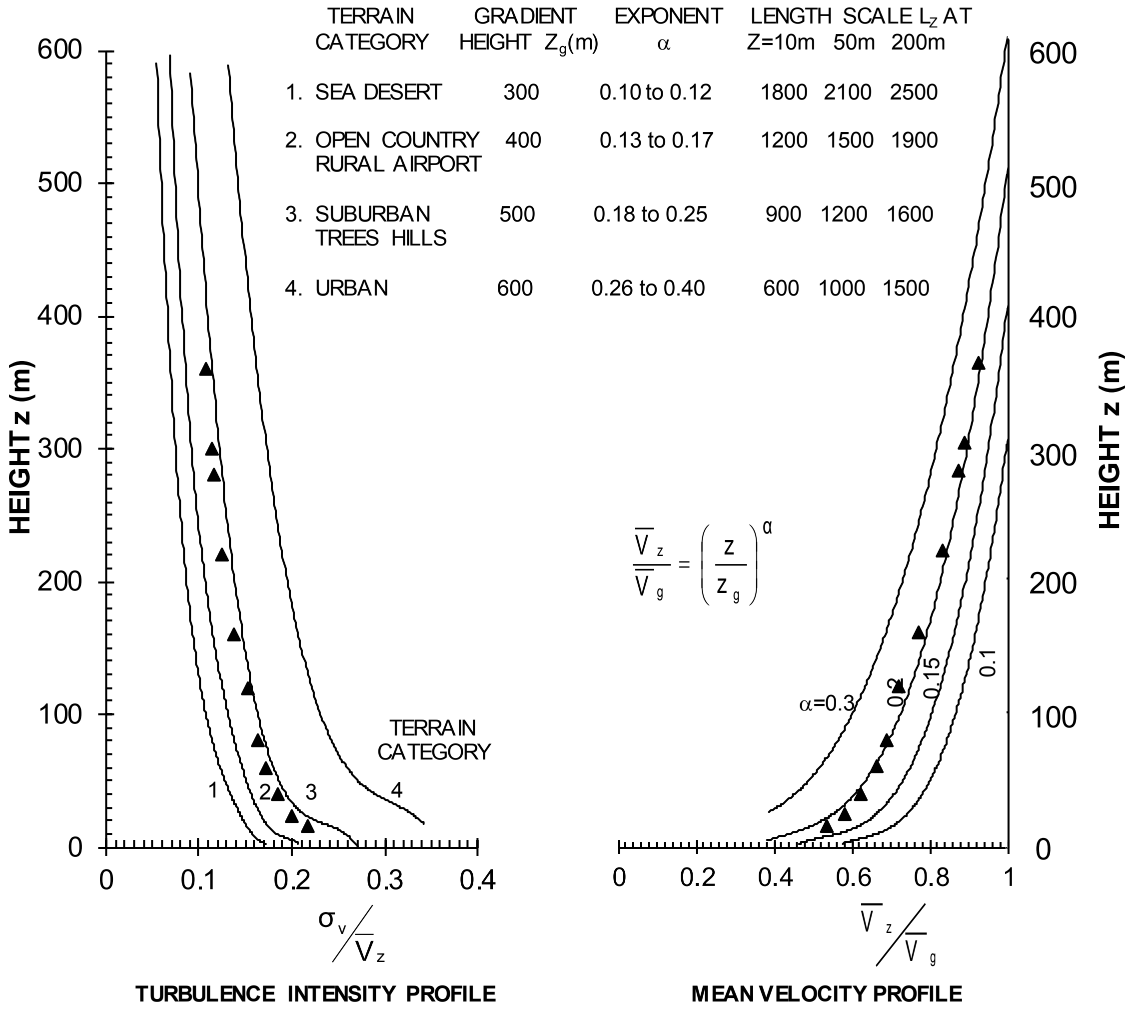


Figure 3 – 1/400 scale Terrain Category 3 boundary layer turbulence intensity and mean velocity profiles and spectra in the MEL Consultants Boundary Layer Wind Tunnel 4.8m x 2.4m working section, scaled to full scale dimensions

Figure 4 – View from the north-east of the 1/400 scale model of the Sydney Football Stadium Development in the wind tunnel.

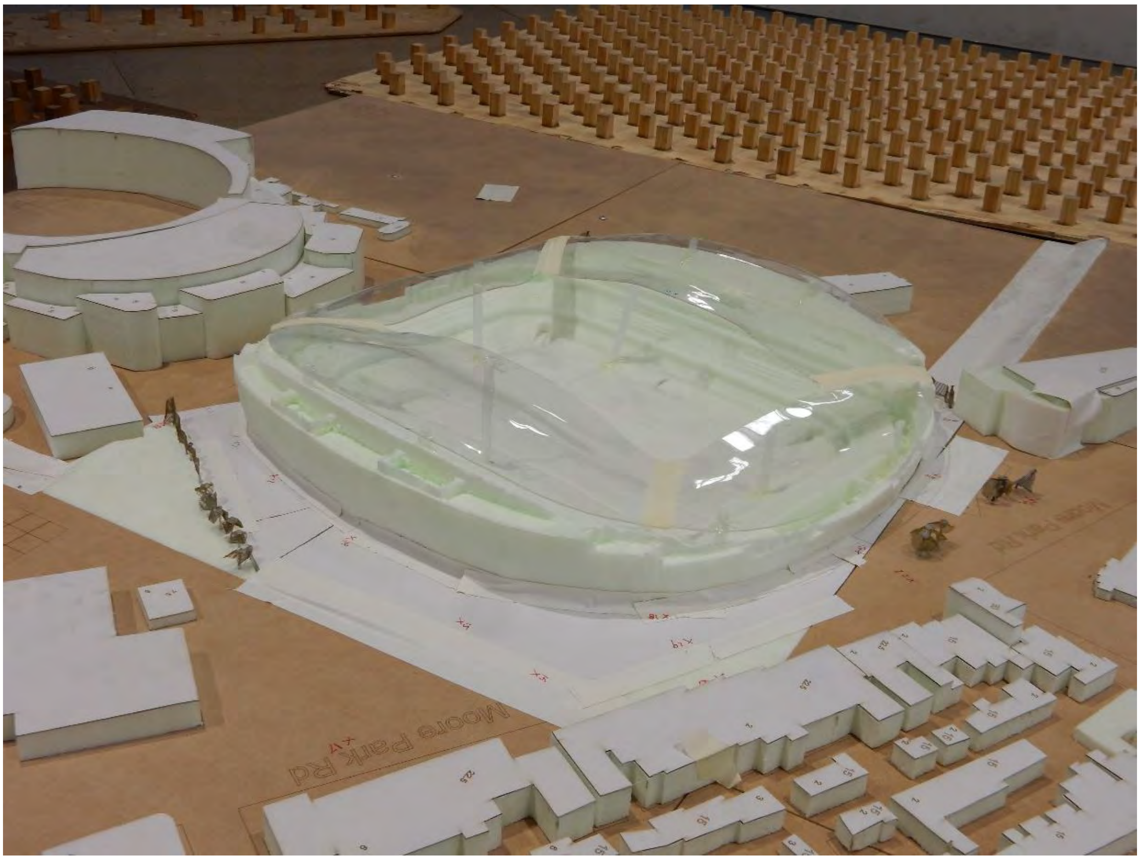


Figure 5 – Close-up view from the north-east of the 1/400 scale model of the Sydney Football Stadium Development in the wind tunnel.

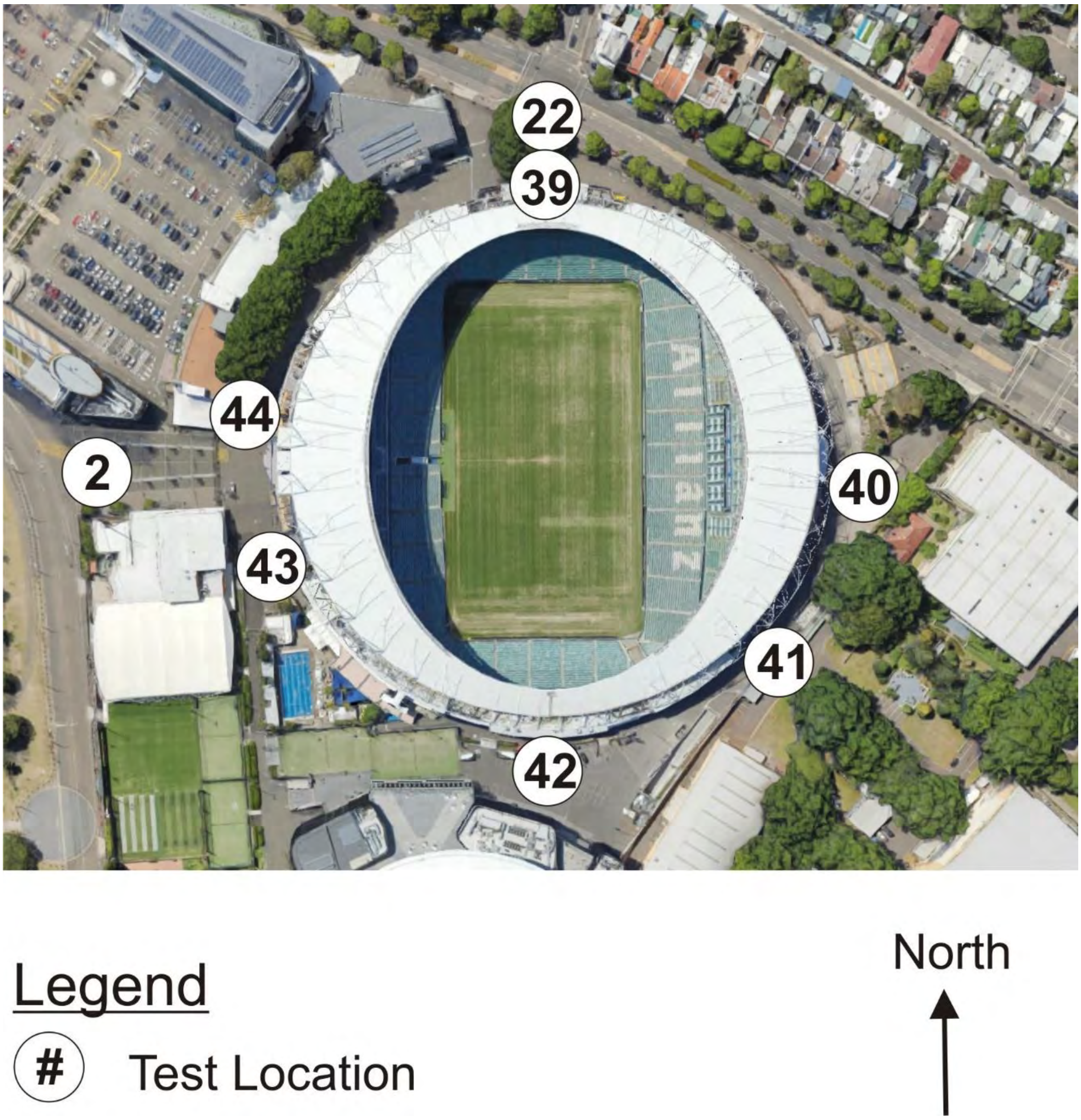


Figure 6a - Ground Level Test Locations around the existing Allianz Stadium.

Figure 6b - Test Locations around the north-west of the proposed Sydney Football Stadium Development for the Proposed Configuration.

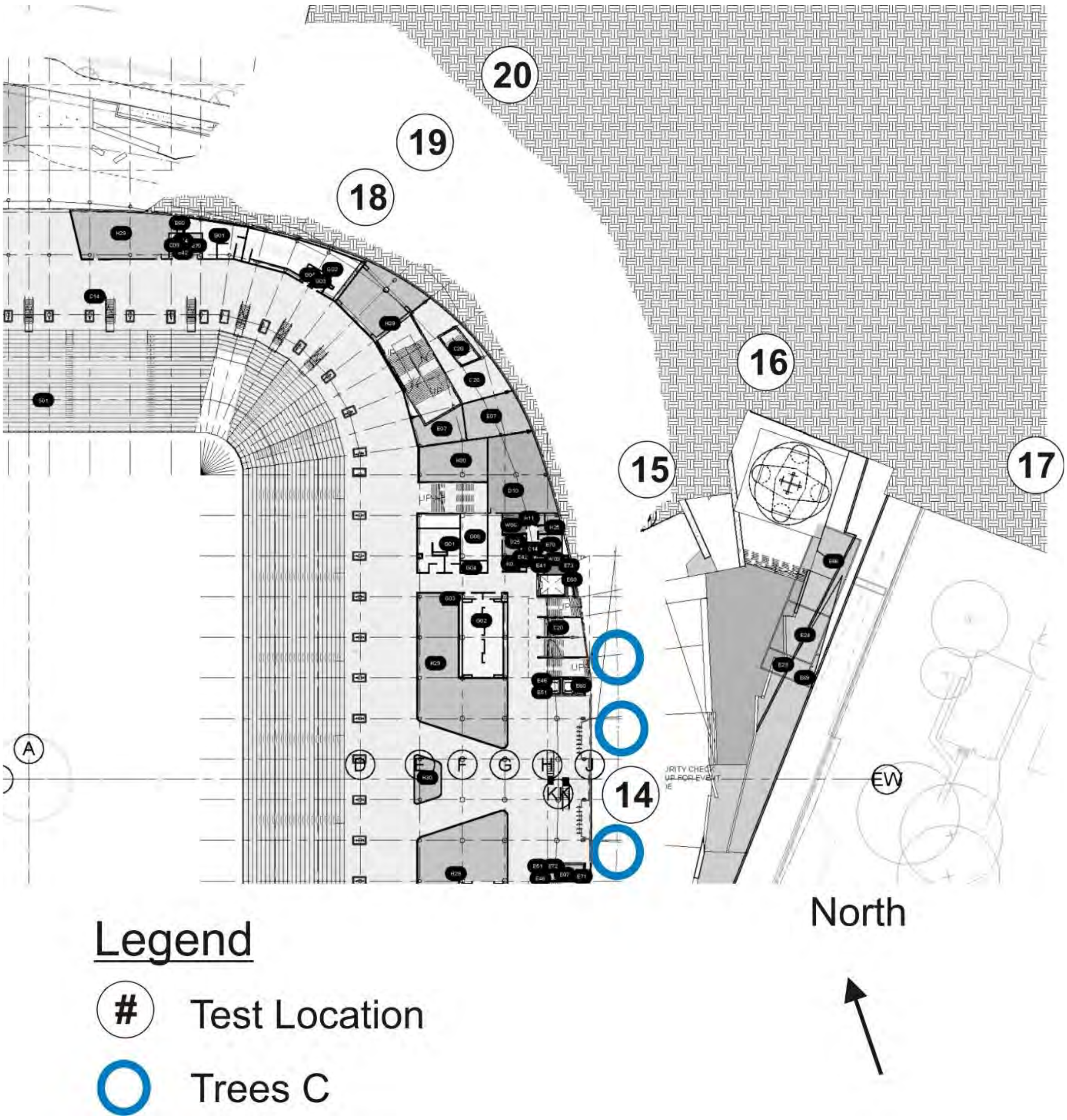


Figure 6c - Test Locations around the north-east of the proposed Sydney Football Stadium Development for the Proposed Configuration

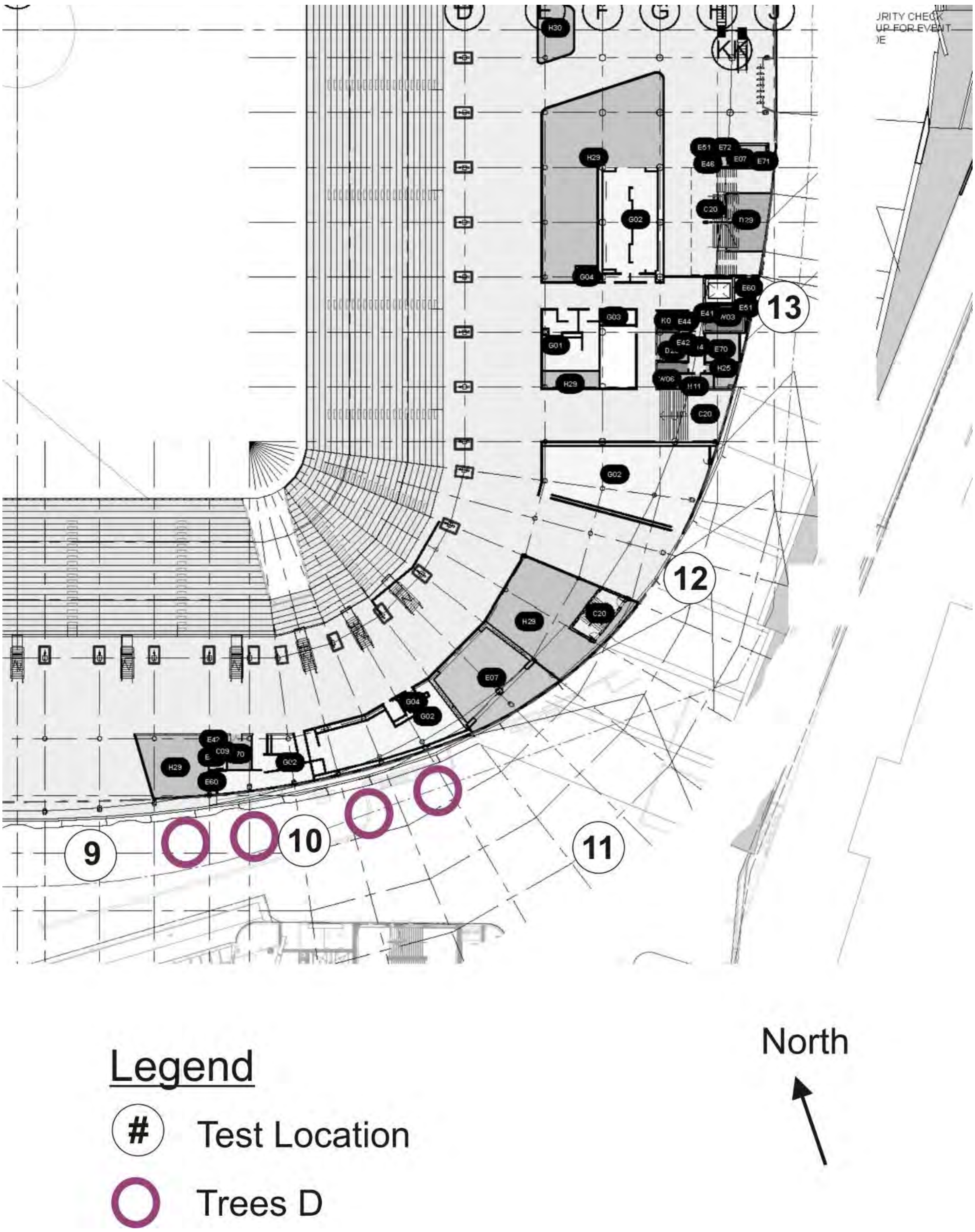


Figure 6d - Test Locations around the north-east of the proposed Sydney Football Stadium Development for the Proposed Configuration

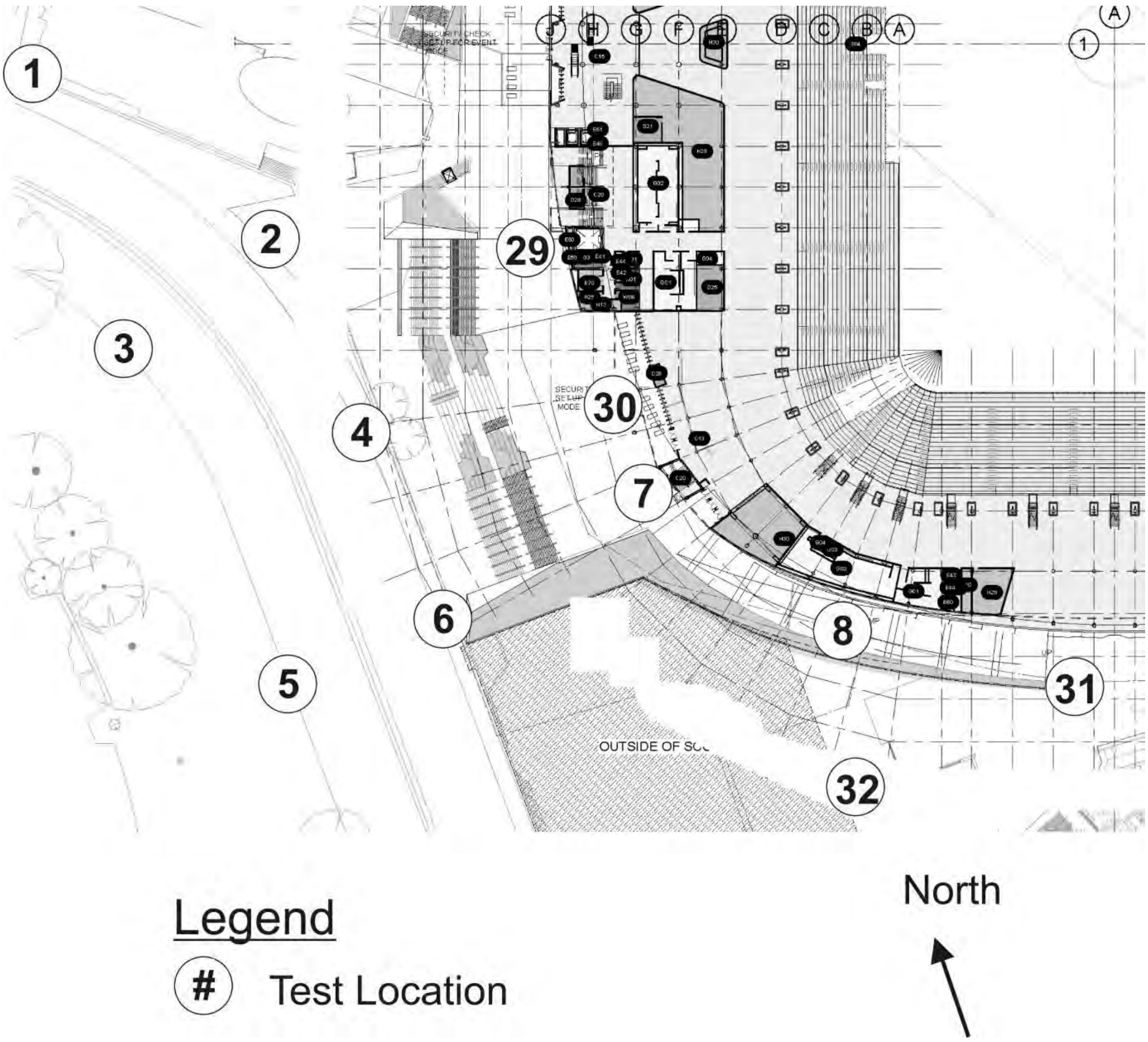


Figure 6e - Test Locations around the north-east of the proposed Sydney Football Stadium Development for the Proposed Configuration

Figure 7 - Summary of wind conditions around the existing Allianz Stadium for 360° of wind direction

Figure 8a – Summary of wind conditions around the north-west of the proposed Sydney Football Stadium Development for 360° of wind direction.

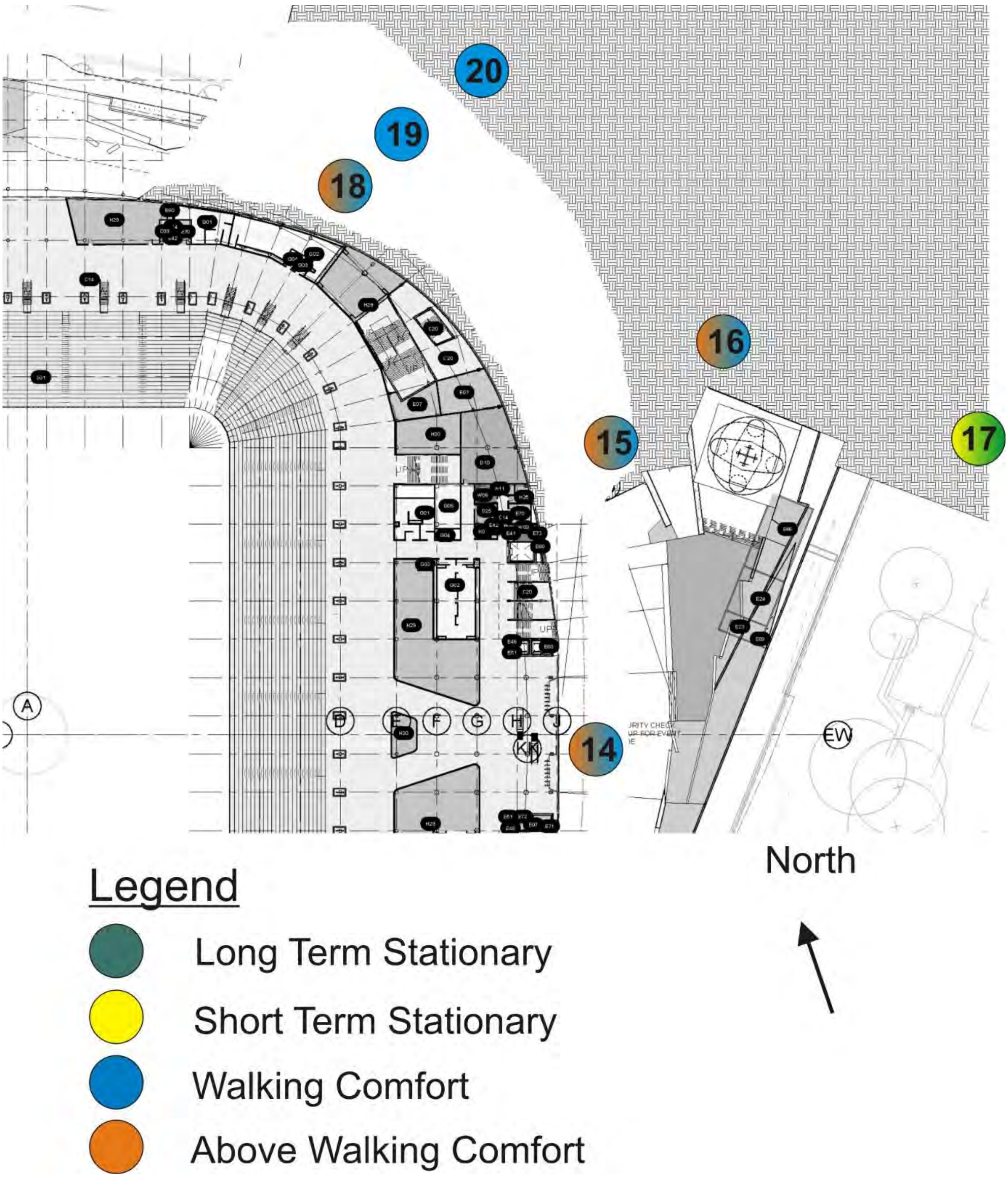


Figure 8b – Summary of wind conditions around the north-east of the proposed Sydney Football Stadium Development for 360° of wind direction.

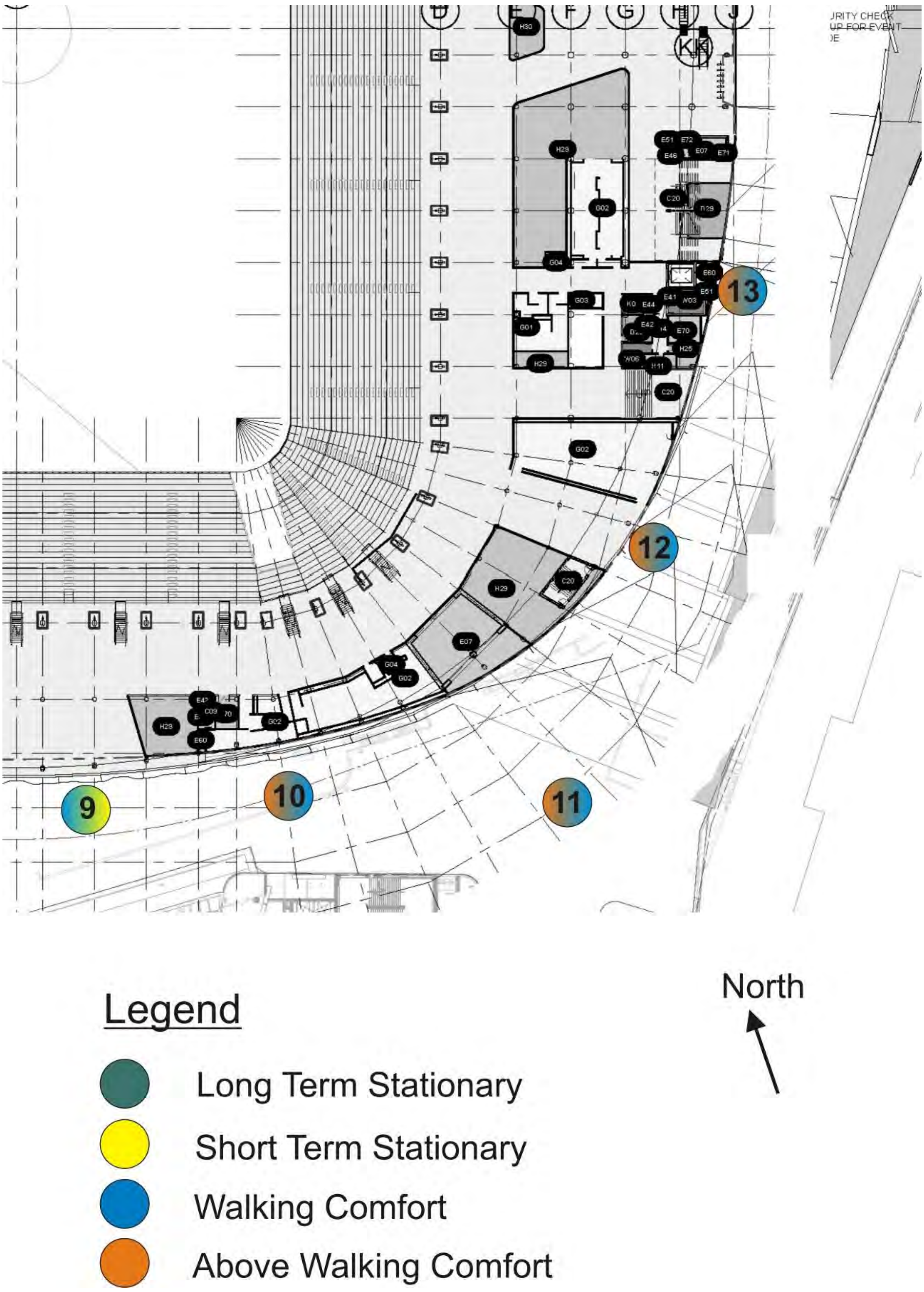


Figure 8c – Summary of wind conditions around the south-east of the proposed Sydney Football Stadium Development for 360° of wind direction.

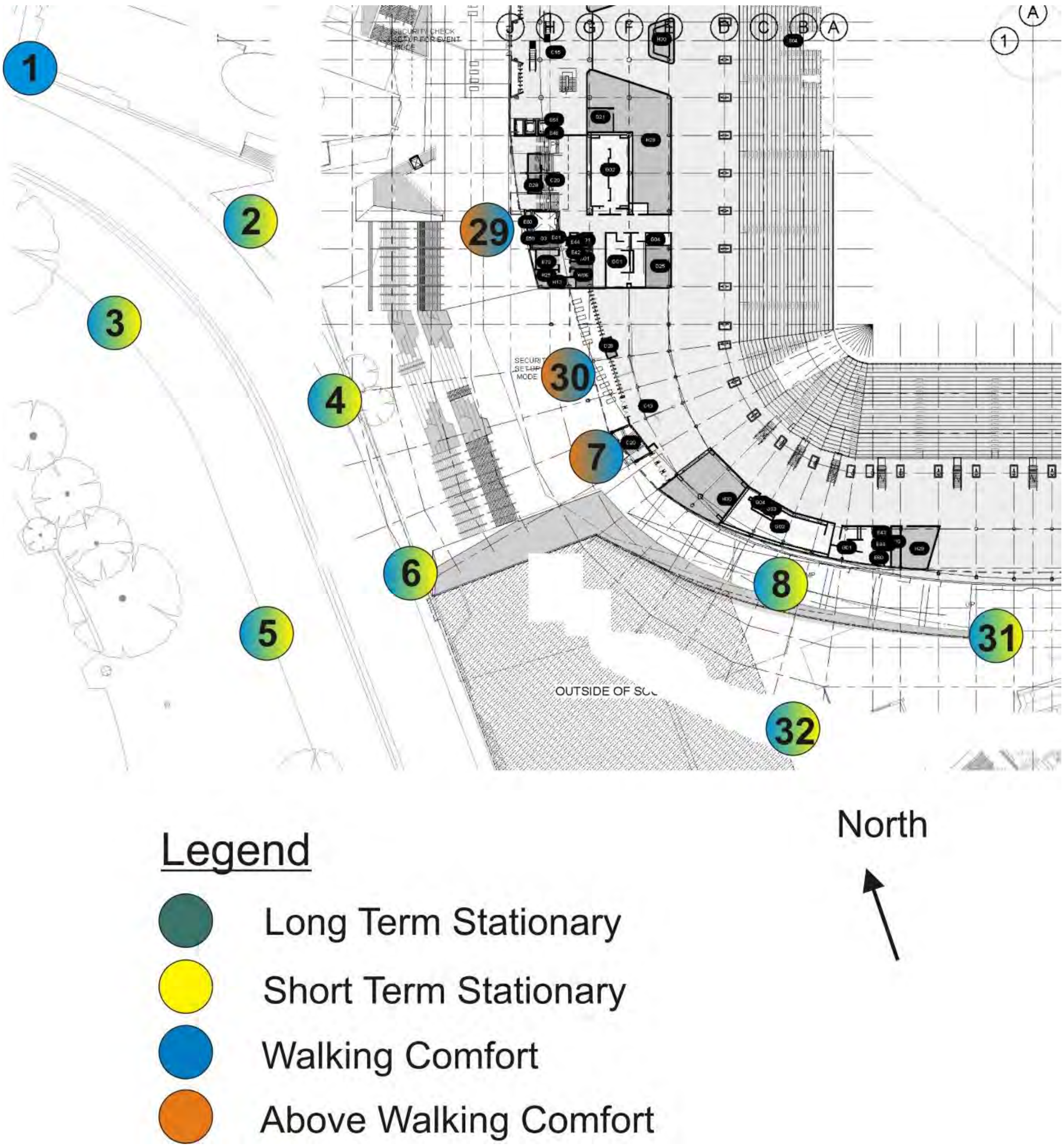


Figure 8d – Summary of wind conditions around the south-west of the proposed Sydney Football Stadium Development for 360° of wind direction.

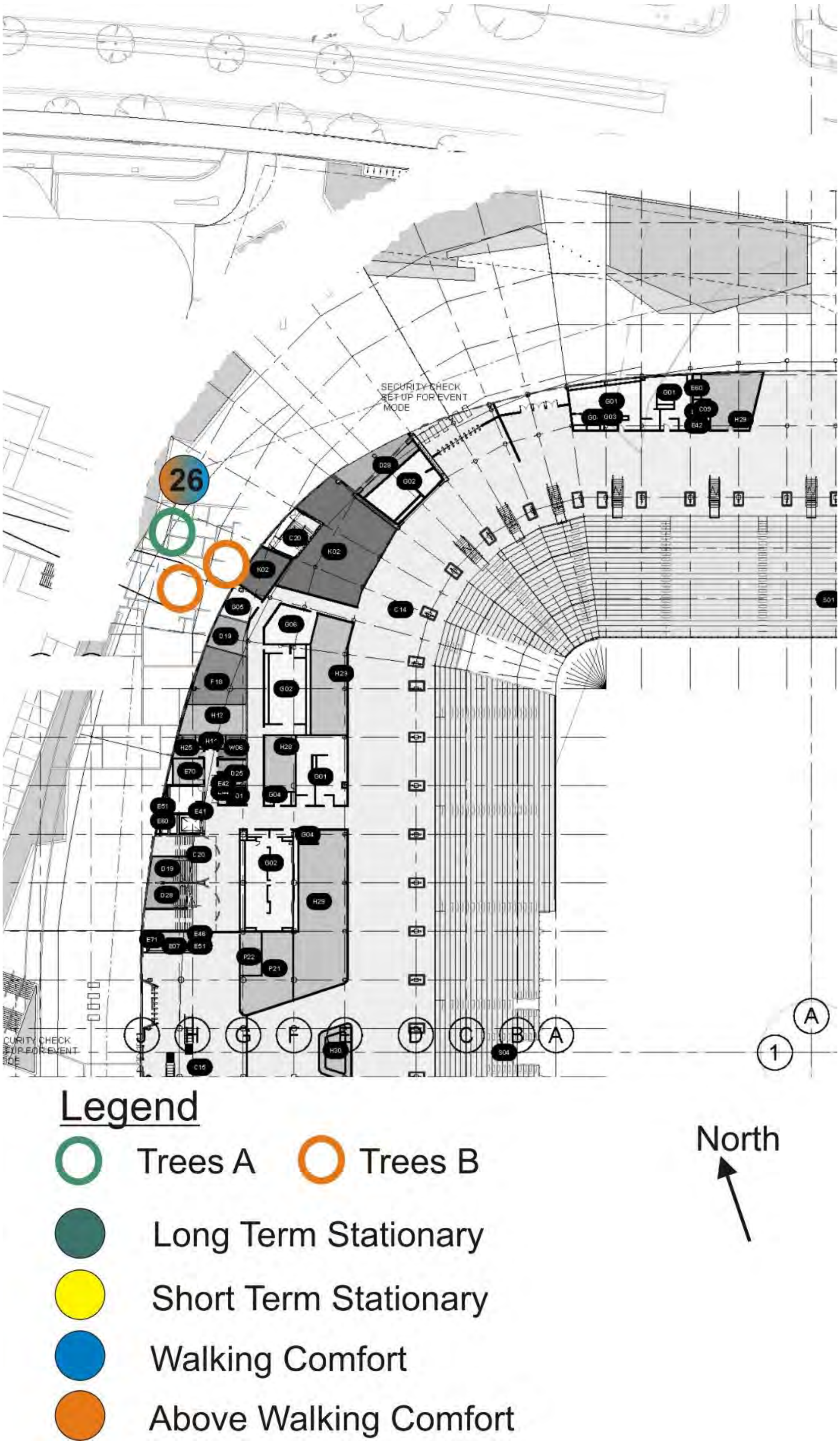


Figure 9a – Summary of wind conditions around the north-west of the proposed Sydney Football Stadium Development with wind mitigation strategies for 360° of wind direction.

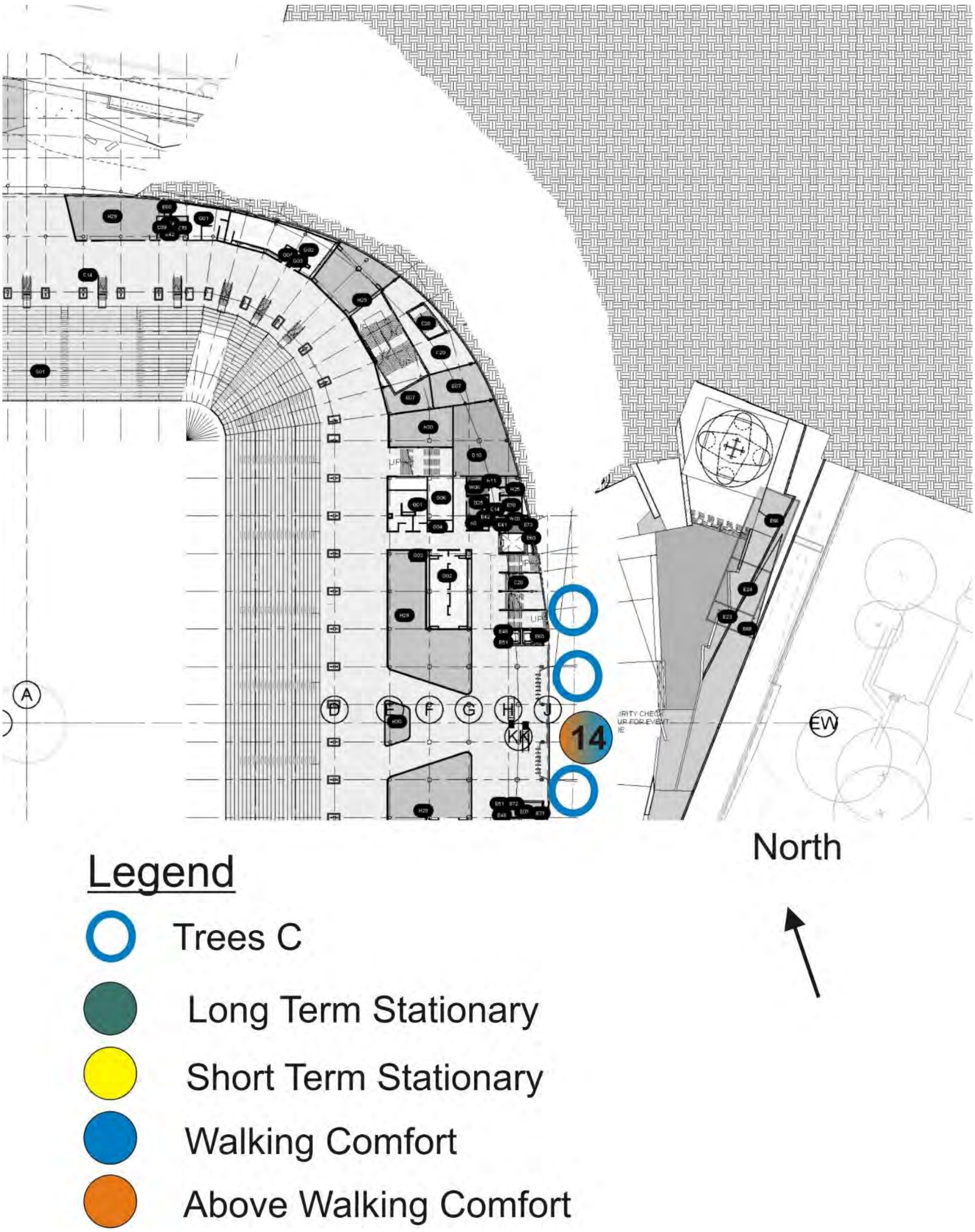


Figure 9b – Summary of wind conditions around the north-east of the proposed Sydney Football Stadium Development with wind mitigation strategies for 360° of wind direction.

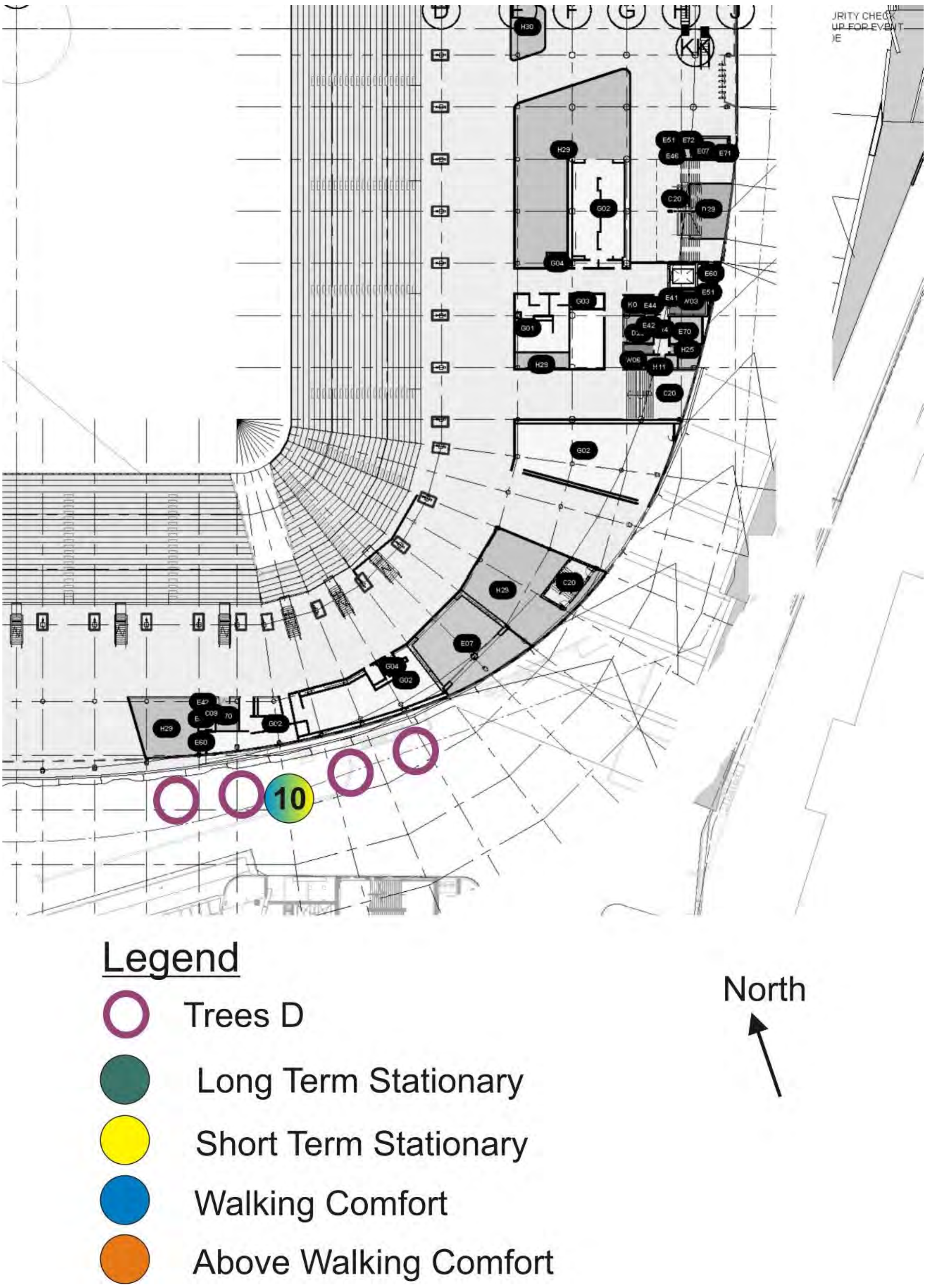
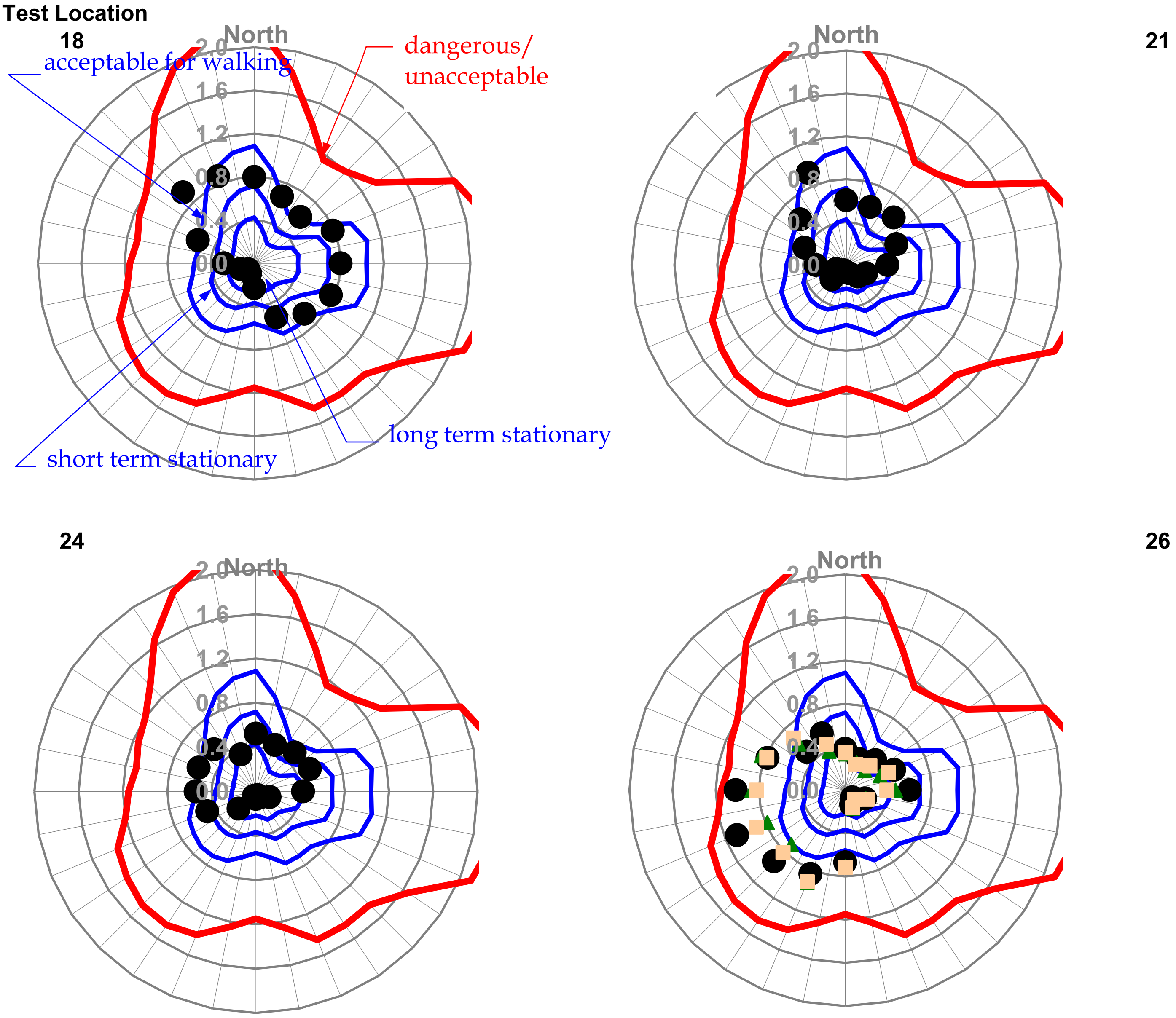


Figure 9c – Summary of wind conditions around the south-east of the proposed Sydney Football Stadium Development with wind mitigation strategies for 360° of wind direction.

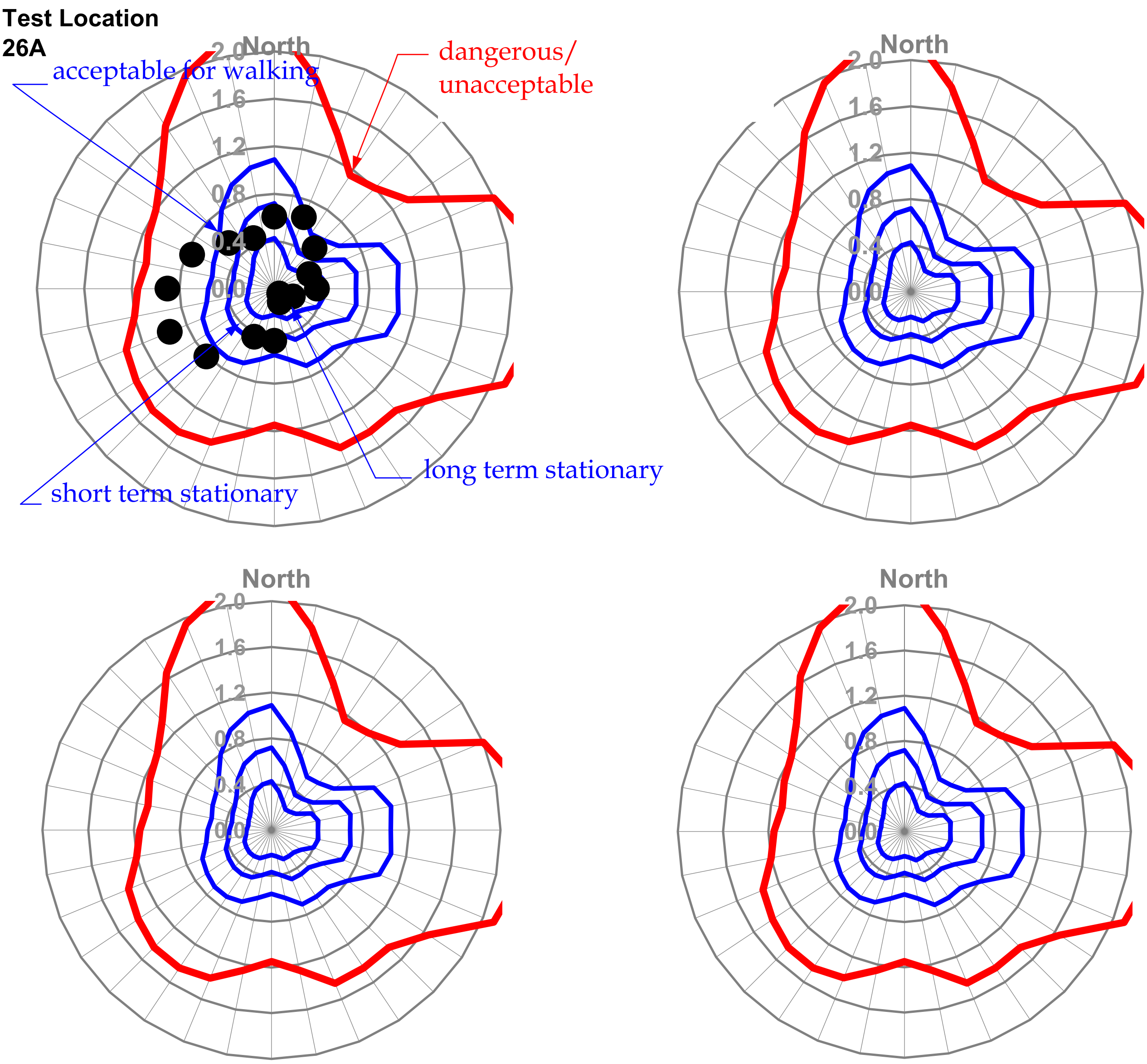


Peak velocity squared ratio $\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$ *as a function of wind direction*

Basic Configuration ●

Basic Configuration with Trees A and B ▲
Basic Configuration with Trees A ■

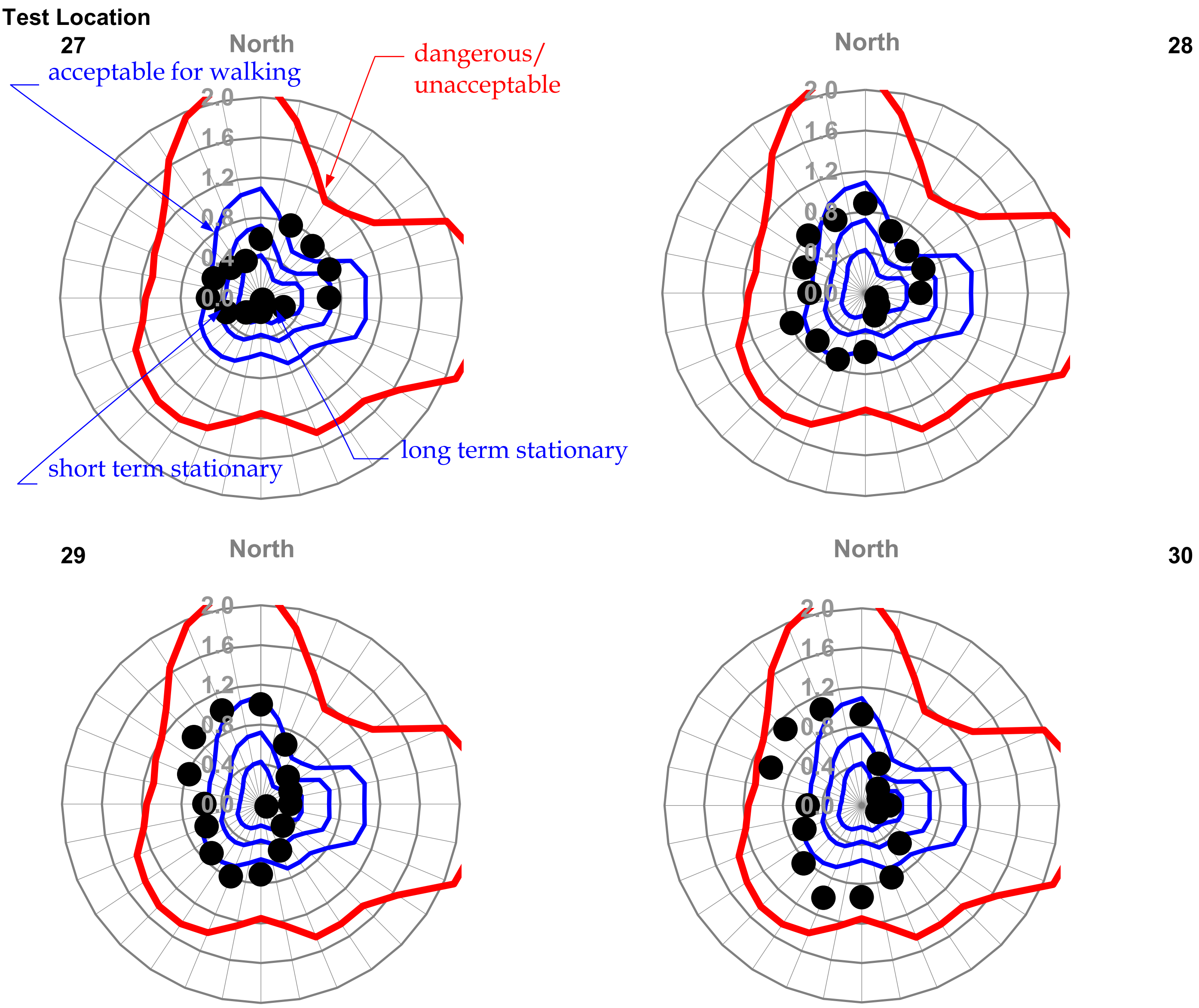
Figure 10 - North of Stadium



$$\textit{Peak velocity squared ratio} \left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2 \textit{as a function of wind direction}$$

Basic Configuration ●

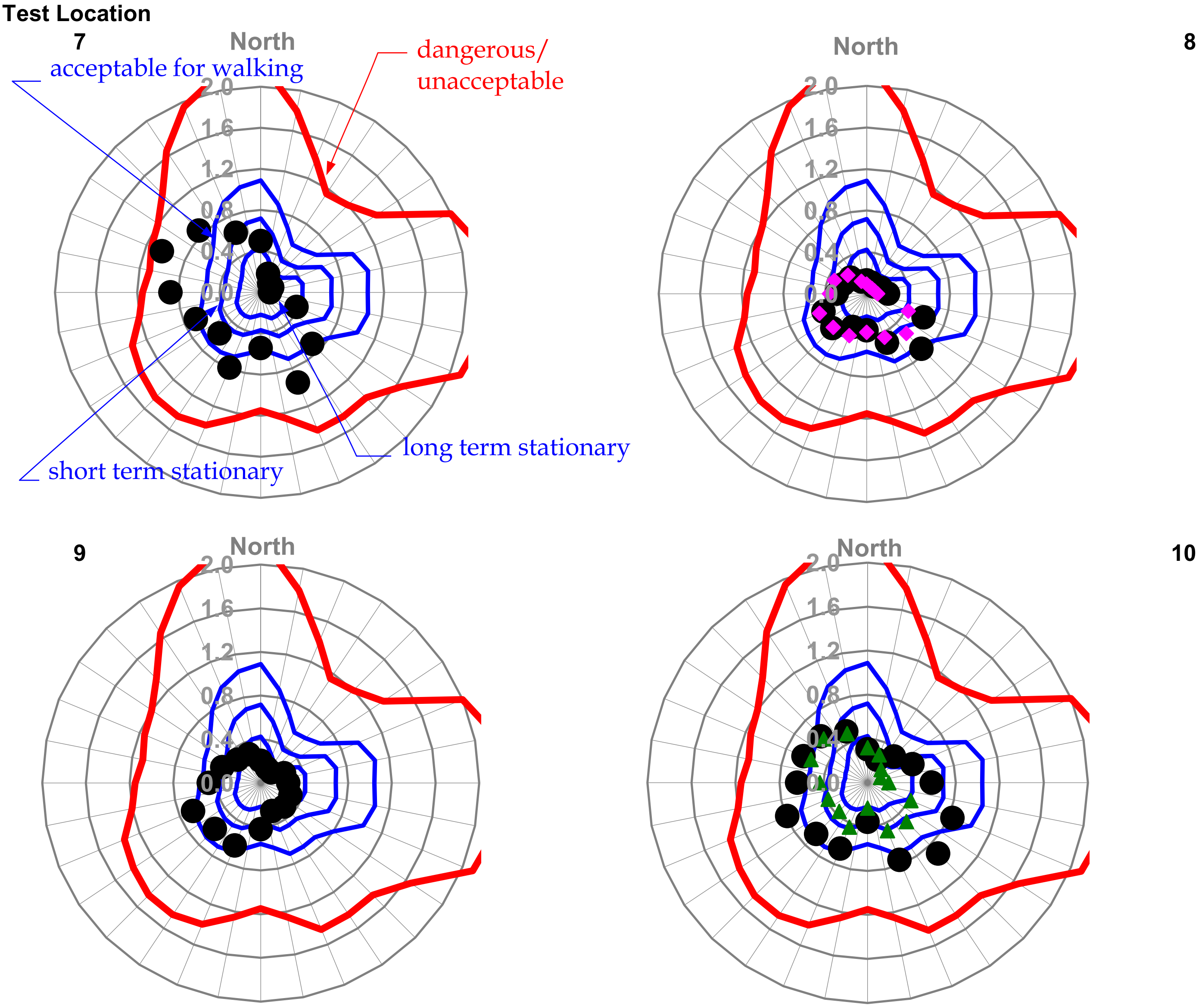
Figure 11 - North of Stadium



Peak velocity squared ratio $\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$ *as a function of wind direction*

Basic Configuration	●

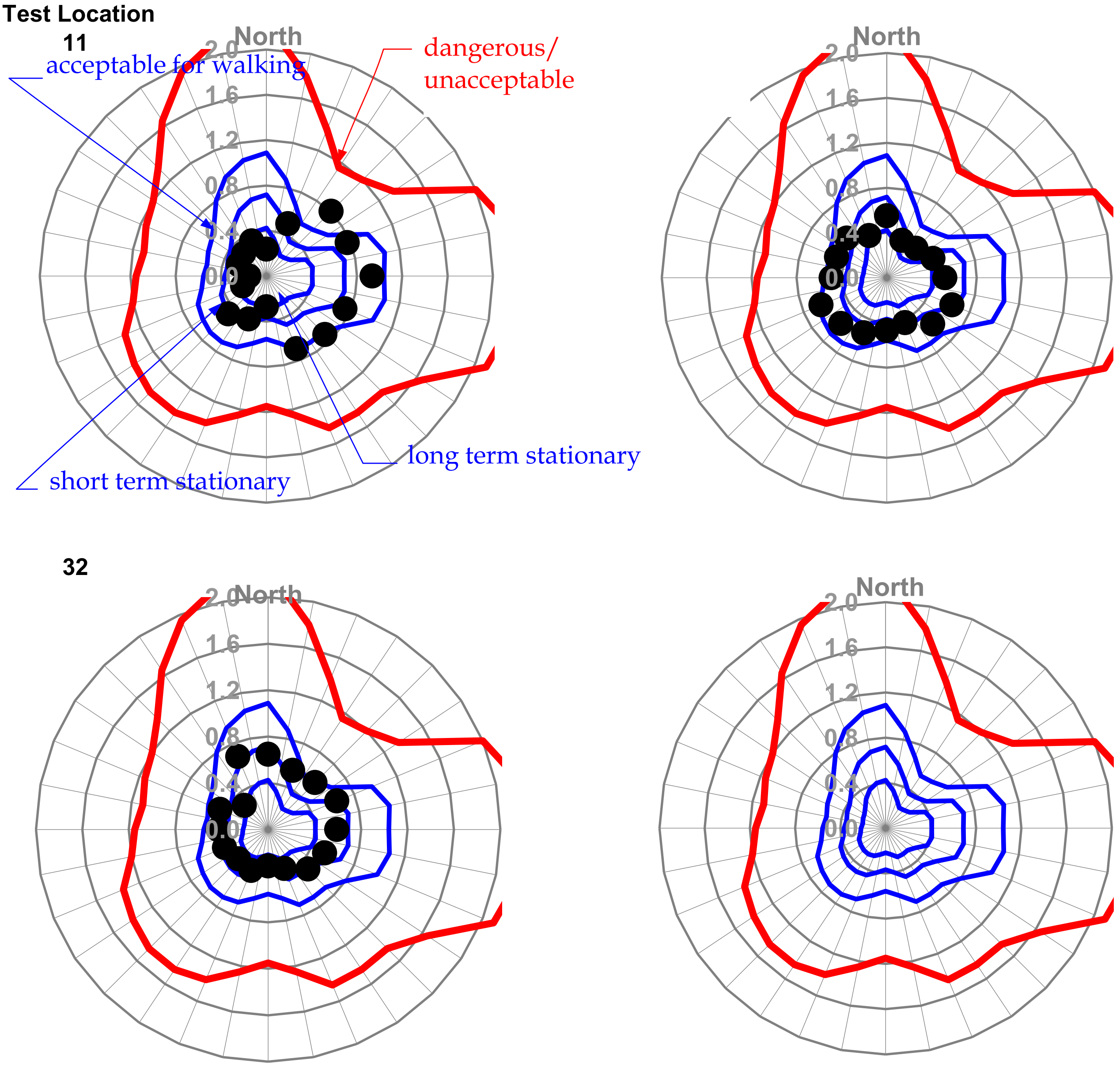
Figure 12 - West of Stadium



$$\textit{Peak velocity squared ratio} \left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2 \textit{as a function of wind direction}$$

Basic Configuration	●
Basic Configuration with Trees D	▲

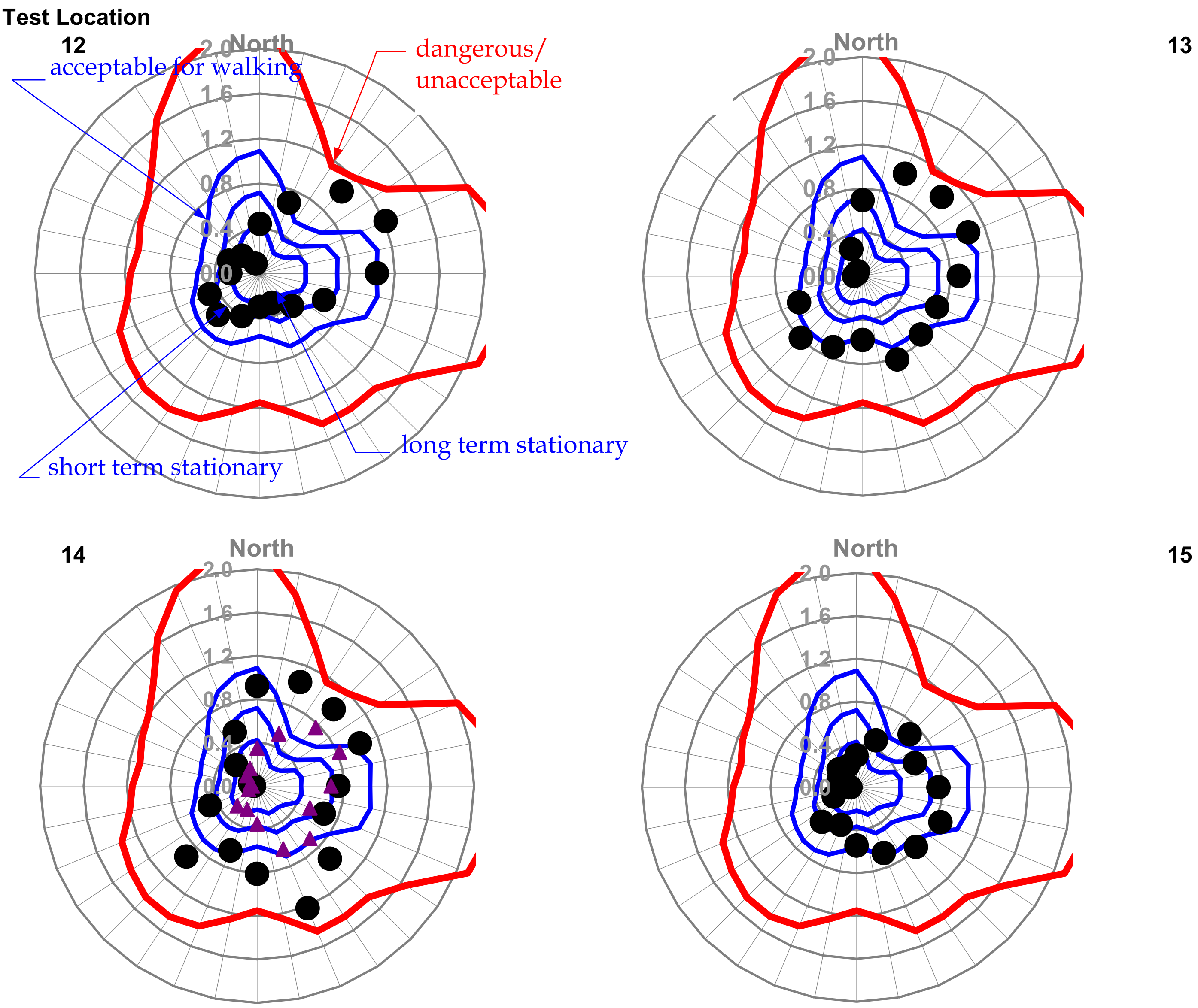
Figure 13 - South of Stadium



Peak velocity squared ratio $\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$ *as a function of wind direction*

Basic Configuration ●

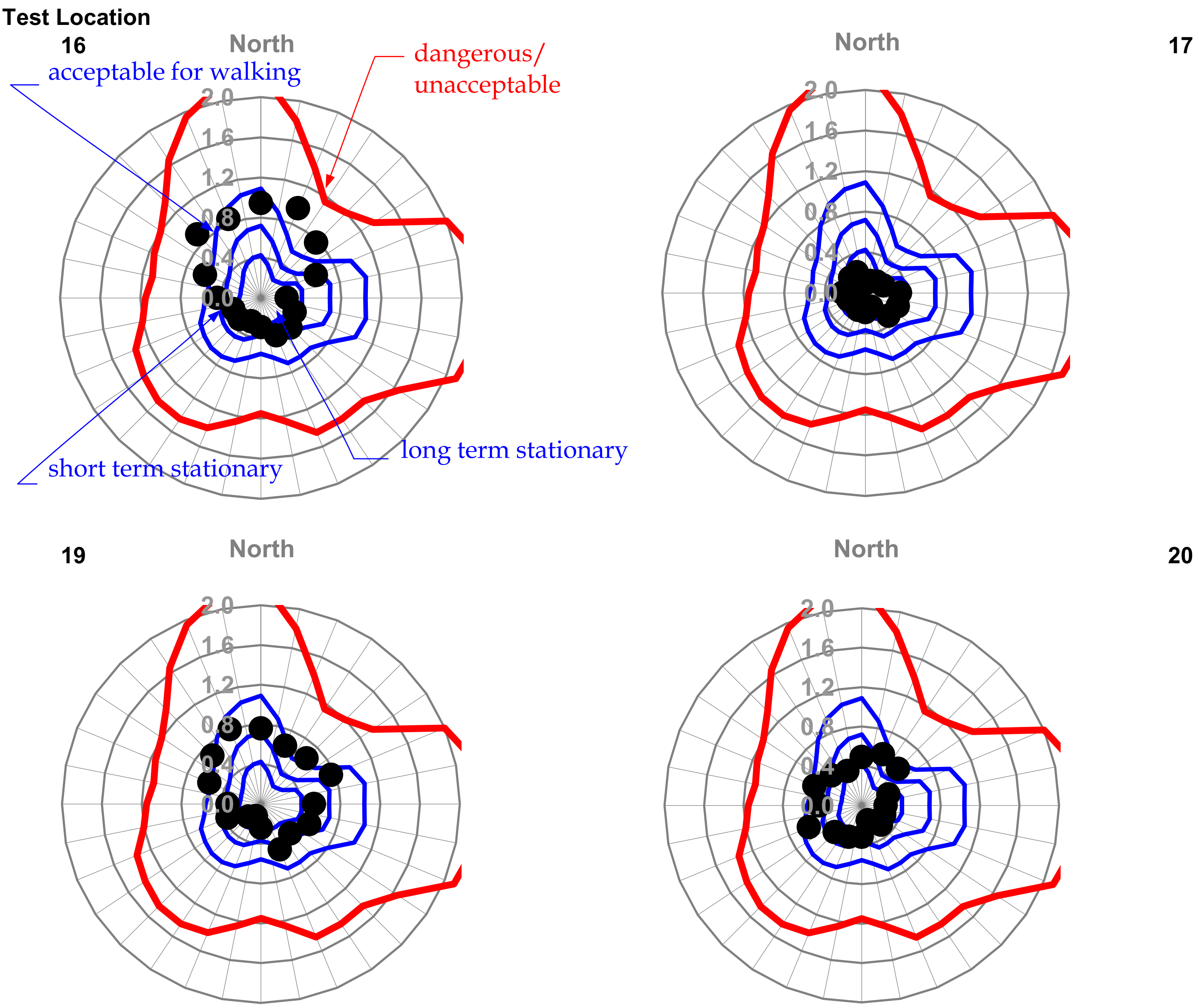
Figure 14 - South of Stadium (continued)



$$Peak\ velocity\ squared\ ratio \left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2 \ as\ a\ function\ of\ wind\ direction$$

Basic Configuration	●
Basic with Tree group C	▲

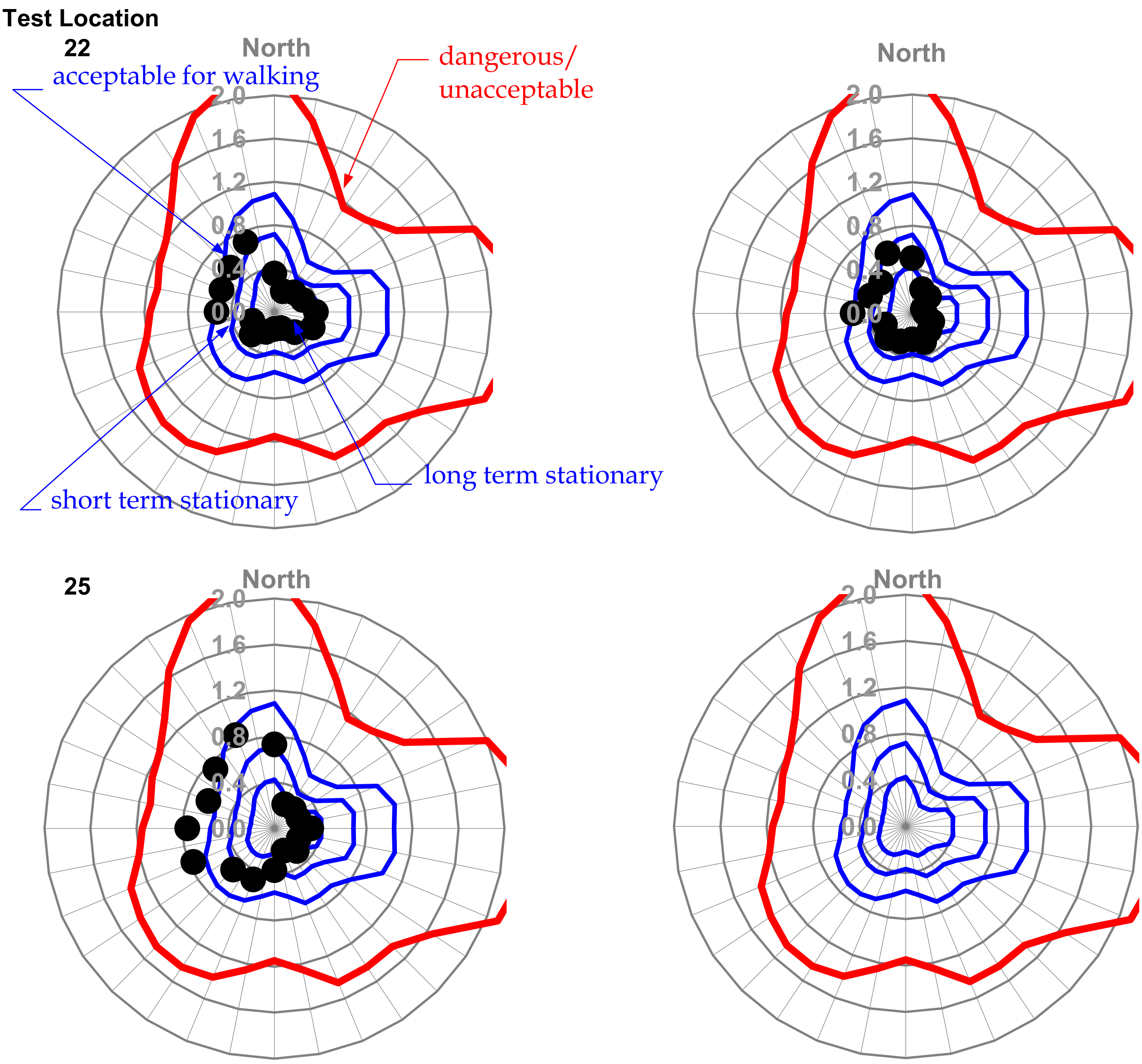
Figure 15 - East of Stadium



Peak velocity squared ratio $\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$ *as a function of wind direction*

Basic Configuration ●

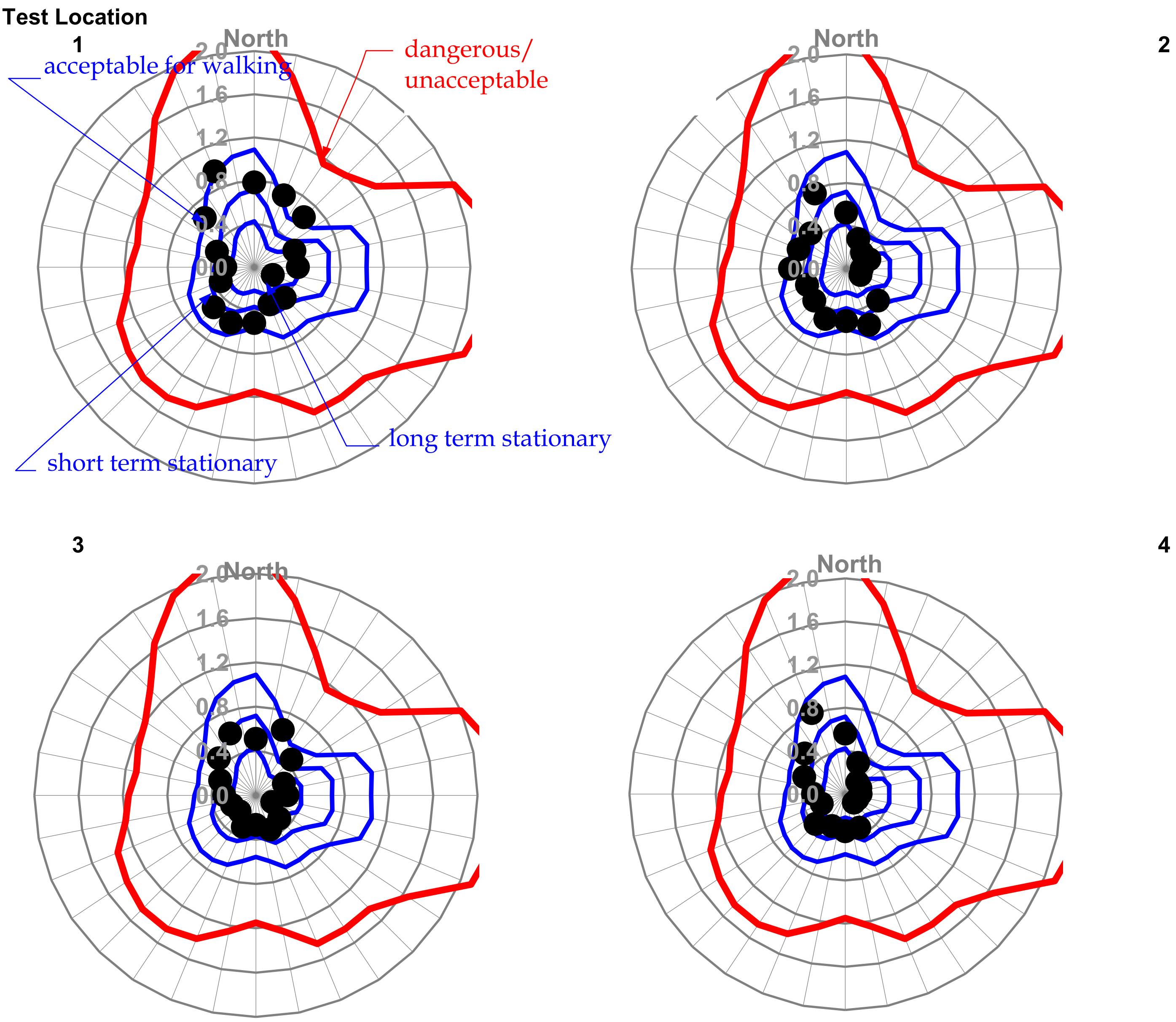
Figure 16 - Moore Park Road



Peak velocity squared ratio $\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$ *as a function of wind direction*

Basic Configuration ●

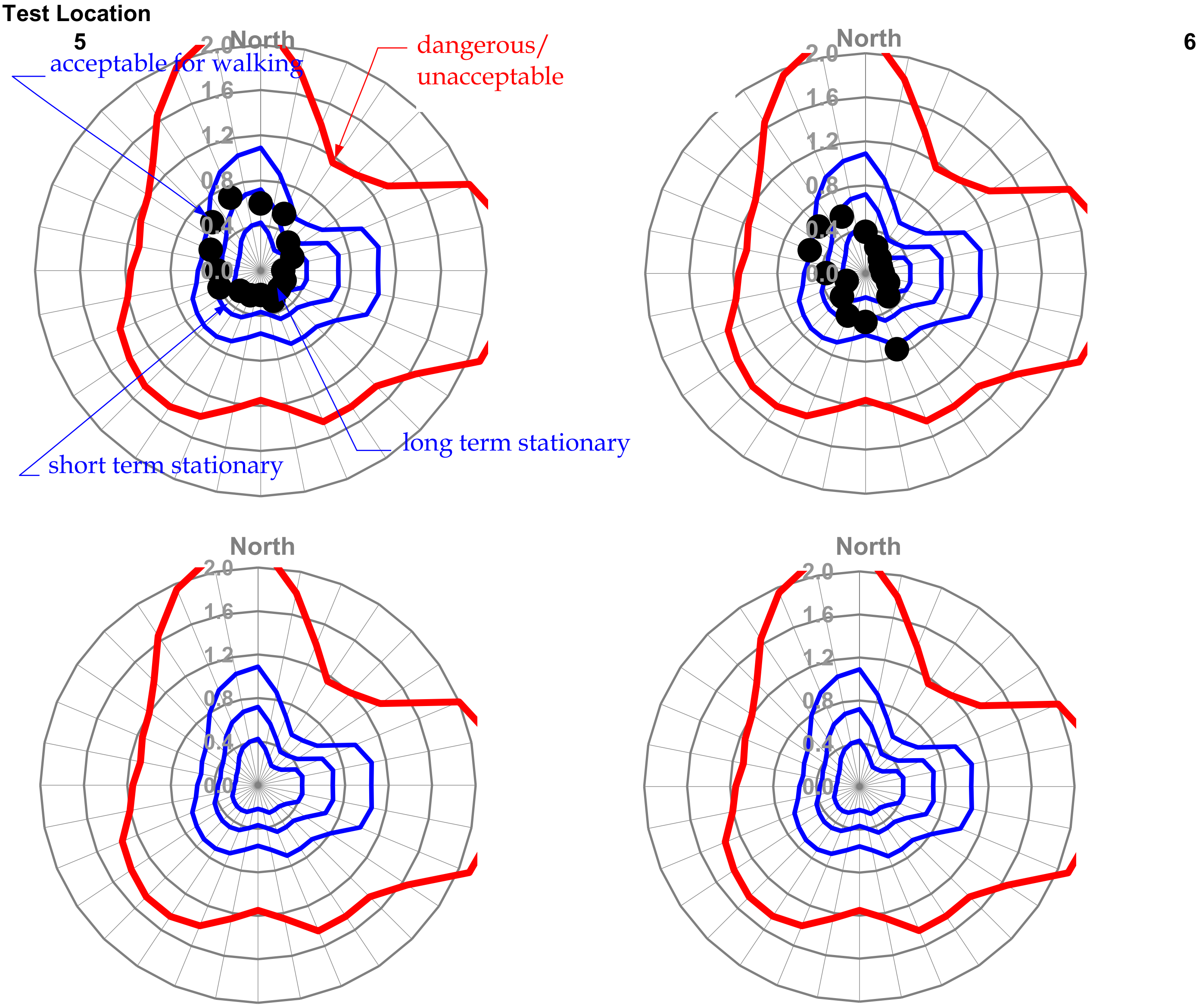
Figure 17 - Moore Park Road (continued)



Peak velocity squared ratio $\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$ *as a function of wind direction*

Basic Configuration ●

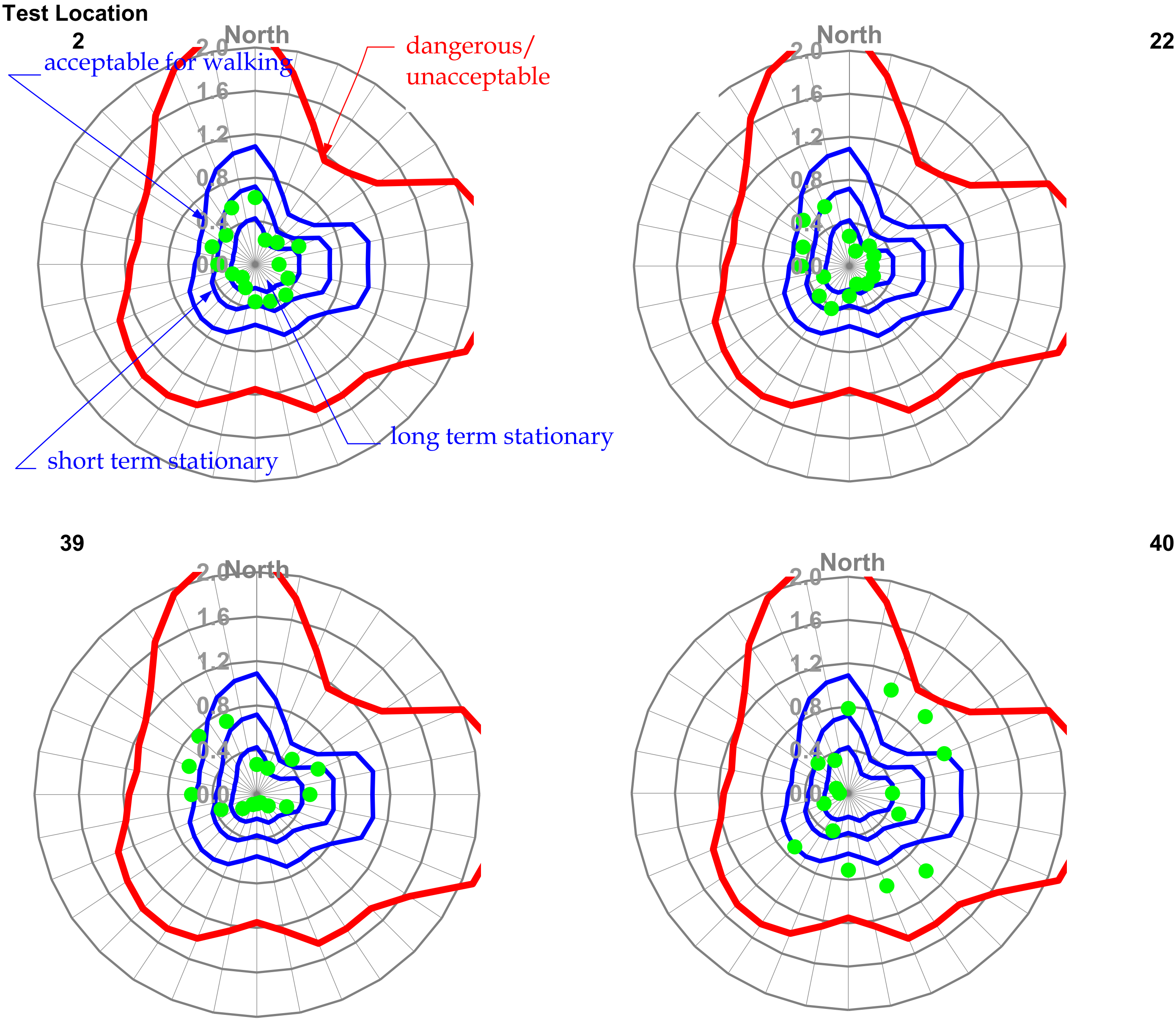
Figure 18 - Driver Avenue



Peak velocity squared ratio $\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$ *as a function of wind direction*

Basic Configuration ●

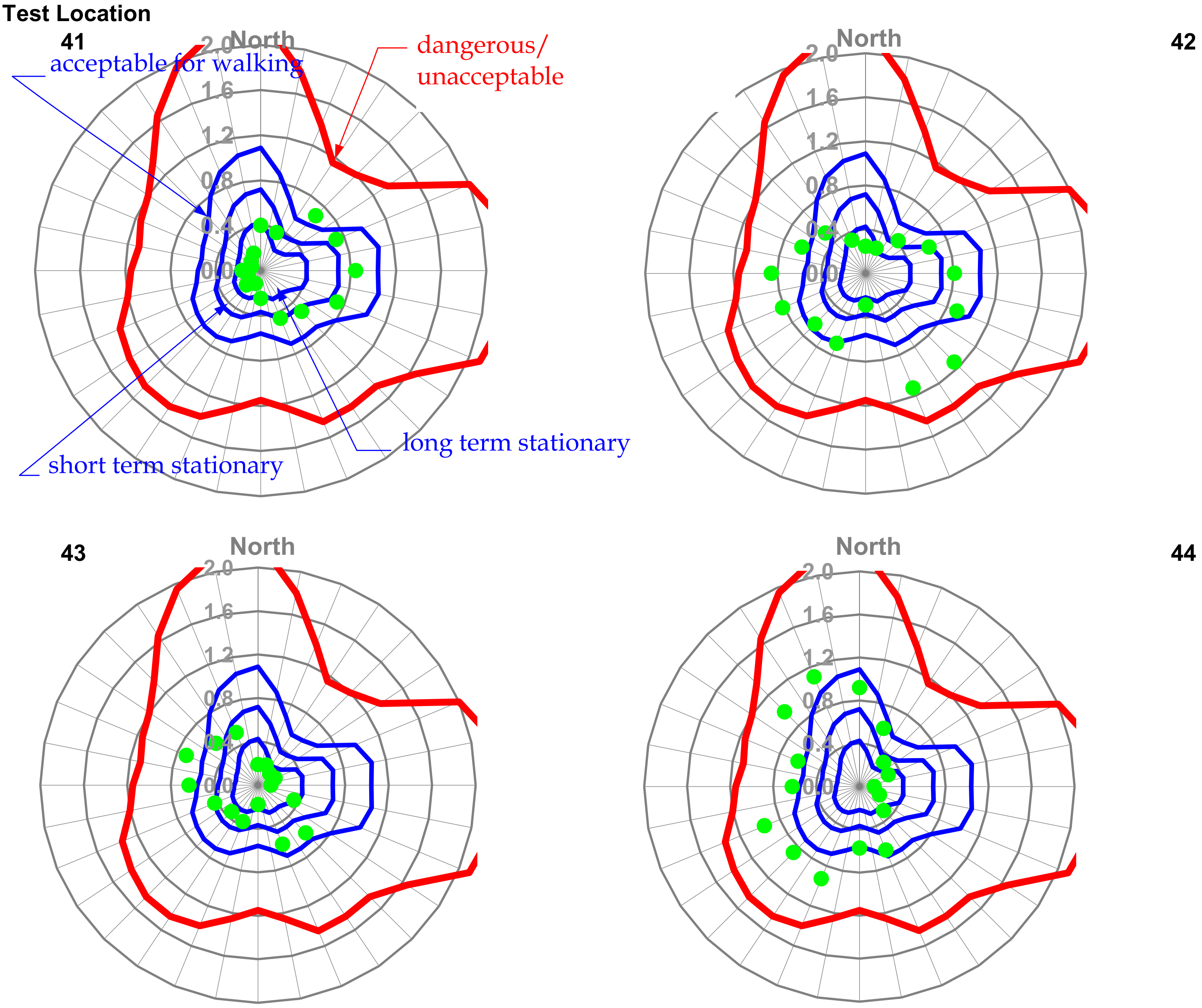
Figure 19 - Driver Avenue (continued)



Peak velocity squared ratio $\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$ *as a function of wind direction*

Existing Configuration

Figure 20 - Around the existing Allianz Stadium



Peak velocity squared ratio $\left|\frac{\hat{V}_{local}}{\bar{V}_{300m}}\right|^2$ *as a function of wind direction*

Existing Configuration

Figure 21 - Around the existing Allianz Stadium (continued)