Appendix D
Wind Study

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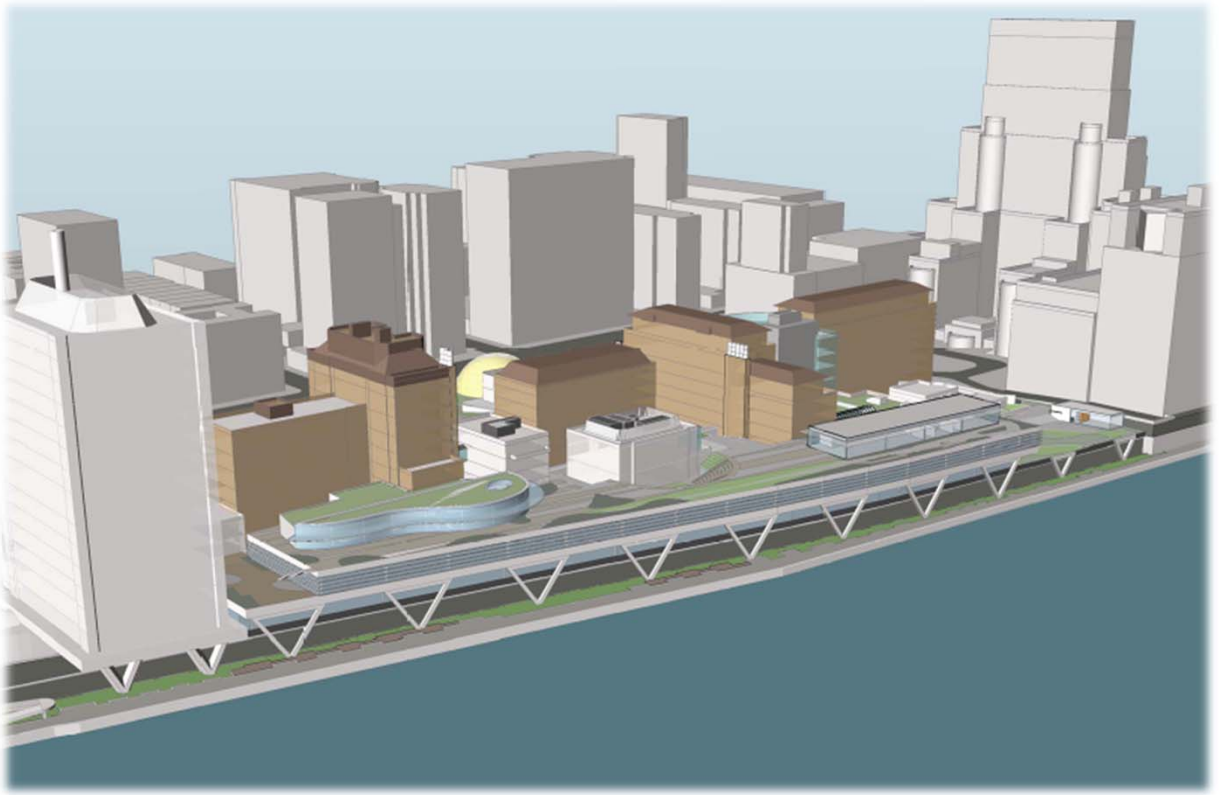


Date: January 29, 2013

To: Mr. Fred Wilmers
Rafael Viñoly Architects

Re: **Pedestrian Wind Study**
New Laboratory Building
Rockefeller University, New York
Novus Project # 12-0179

Novus Team:

Senior Specialist:	Bill F. Waechter, C.E.T.
Principal / Specialist:	Jason Slusarczyk, P.Eng.
Scientist:	Jenny Vesely, B. Eng., EIT

1.0 INTRODUCTION

Novus Environmental Inc. (Novus) was retained by Rafael Viñoly Architects to conduct a Pedestrian Wind Study for the new laboratory building planned for construction at Rockefeller University in New York, New York.

1.1 Nature of the Existing Subject Lands

The subject property is located at 1230 York Avenue between E68th Street and E64th Street. The existing on-site buildings in the study area include a mix of low and mid-rise buildings that range in height from one to 15 storeys. An aerial view of the project site and nearby buildings is provided in **Figure 1**.

1.2 Proposed Development

The proposed development incorporates a 2-storey laboratory overbuild of FDR Drive in the area shown in Figure 1. The overall roof of the overbuild is a landscaped park and includes an amphitheater, a cafeteria pavilion and an office pavilion on top of the overbuild. Some building highlights include:

- The overbuild of FDR Drive extends from the Research Building to E68th Street.
- Landscaped platforms are incorporated at the north and south ends.
- An amphitheater is incorporated into the overbuild along the east façade of Welch Hall.

A perspective rendering of the overbuild roof is shown in **Figure 2**. A view of the existing and proposed site conditions is included in **Figure 3**.

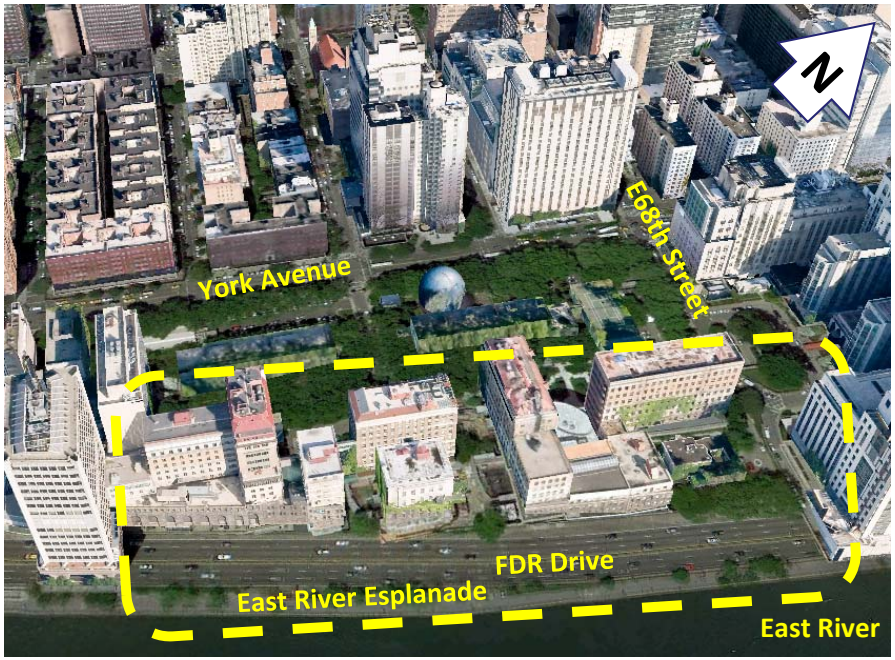


Figure 1: Project Study Area - Rockefeller University
Aerial Image from Google Earth (June 2, 2011)

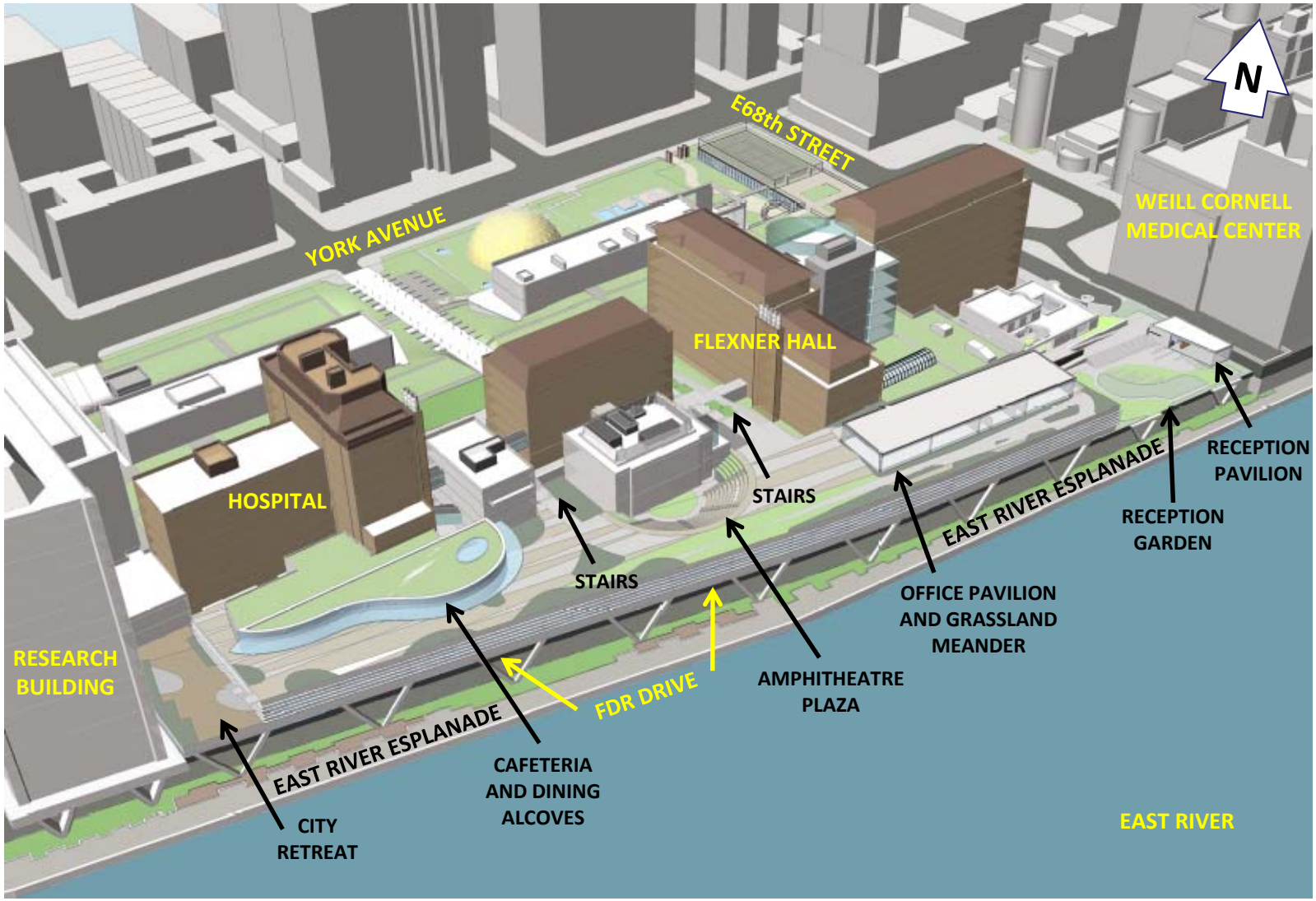


Figure 2: Site Orientation – Wind Comfort Areas of Interest in Black Text

Figure 3: Proposed New Laboratory Overbuild

1.3 Nature of the Surroundings

A site visit was conducted by Novus personnel on October 17, 2012.

The site is located on the university campus' east edge, facing the East River, and extends over FDR Drive as an overbuild. The overbuild runs between the Rockefeller Medical Building, to the south, and the Weill Cornell Medical Center to the north.

The land drops by several floors from the elevation of the main campus area along York Street, to the level of FDR Drive and the East River Esplanade. Surrounding buildings to the north are typically 10 to 20-storeys high, or more. The East River is situated less than 100 feet to the east and is present from the northeast through to the south. The shore of Roosevelt Island is located 800 feet to the east. Buildings to the south are on the order of 15 to 30-storeys. From southwest through west to the northwest, the nearby surroundings are comprised of buildings that range from about 6-storeys to 20-storeys, with several being taller. The "edge" of high-rise buildings in Mid-town East is situated about 2000 feet to the south through approximately west.

An aerial view of the development site and surroundings is shown in **Figure 4**, and includes an overlay of the limits of the wind tunnel model area.

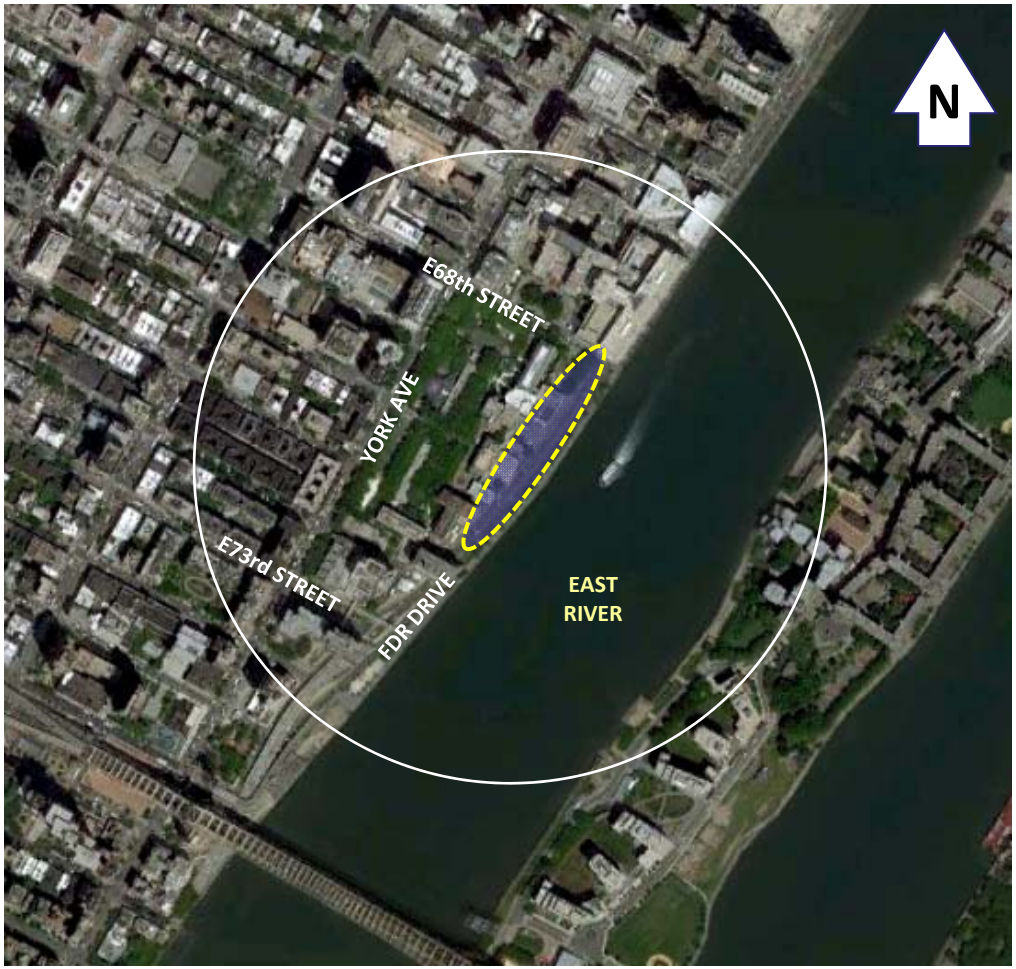


Figure 4: Rockefeller University New Lab Site and Limits of Wind Tunnel Model *(White Circle)*
Aerial Image from Google Earth

2.0 APPROACH

2.1 Scale Model

A 1:250 scale model of the Rockefeller University site and surroundings was constructed based on:

- Drawing information received from the project team on Oct 11, 2012;
- Referral to aerial images (Google Earth and Bing Maps); and,
- A site visit conducted by Novus on Oct 17, 2012.

The proximity model of the surrounding area was built in block form for a radius of approximately 1250 feet from the site center. The structures surrounding the site will influence wind characteristics and therefore existing buildings and those under construction were included in the model. Grade differences in the study area were also incorporated into the model. Existing and proposed landscaping on and around the development property were not modeled, in order to identify local wind conditions attributed to the built form alone. In general, good landscaping coverage will improve wind comfort levels during the summer, and also in the winter should coniferous trees be present or proposed.

Photographs of the wind tunnel model showing the extent of the modelled area for the proposed site configurations are shown in **Figures 5 and 6**.

2.2 Wind Tunnel

Wind tunnel tests were conducted in the Alan G. Davenport Wind Engineering Group Boundary-Layer Wind Tunnel Laboratory at the University of Western Ontario, London, Ontario. The upstream test section of the wind tunnel included generic roughness blocks and turbulence-generating spires to modify the wind flow approaching the model. These features develop characteristics of the wind flow that are similar to the actual site. The test model was rotated on a turn-table to simulate different wind directions with the upstream terrain being changed as appropriate to reflect the various upwind conditions encountered around the site.

The test model was equipped with 81 omni-directional probes to record wind speed at the pedestrian-level (5 ft). The orientation of the model was adjusted in 10° intervals on the turn-table to permit measurement of wind speed at each probe location for 36 wind angles. The wind tunnel data were then combined with the wind climate model for this region to predict the occurrence of wind speeds in the pedestrian realm and to compare against wind criteria for comfort and safety.

Figures 7, 8 and 9 shows the sensor probe locations tested.

Figure 5: Wind Tunnel Model - View From South

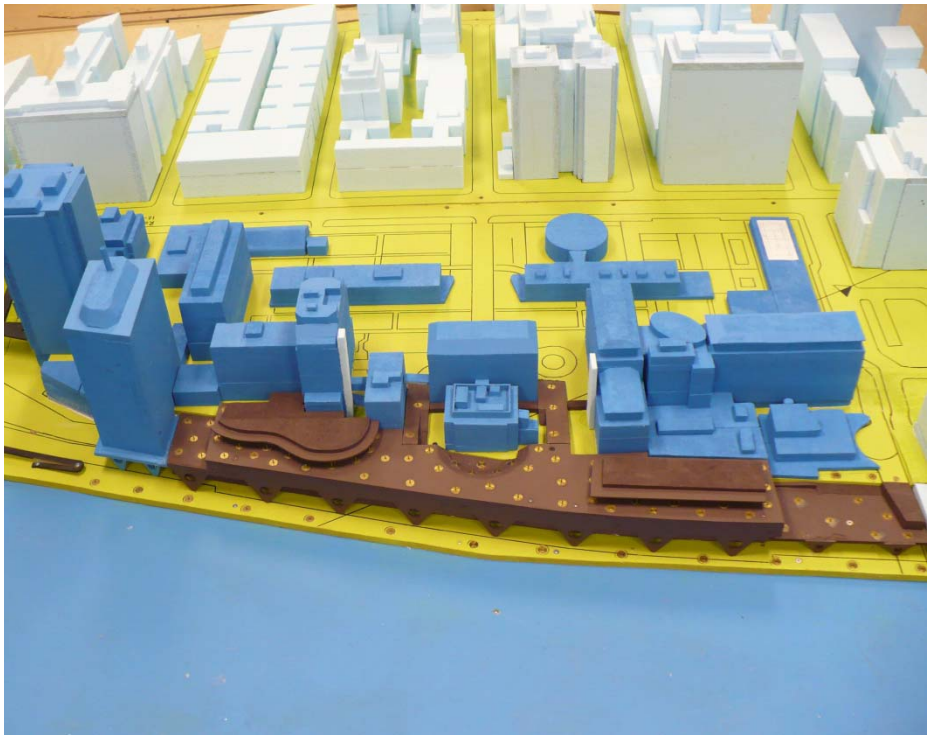


Figure 6: Wind Tunnel Model - View From Southeast

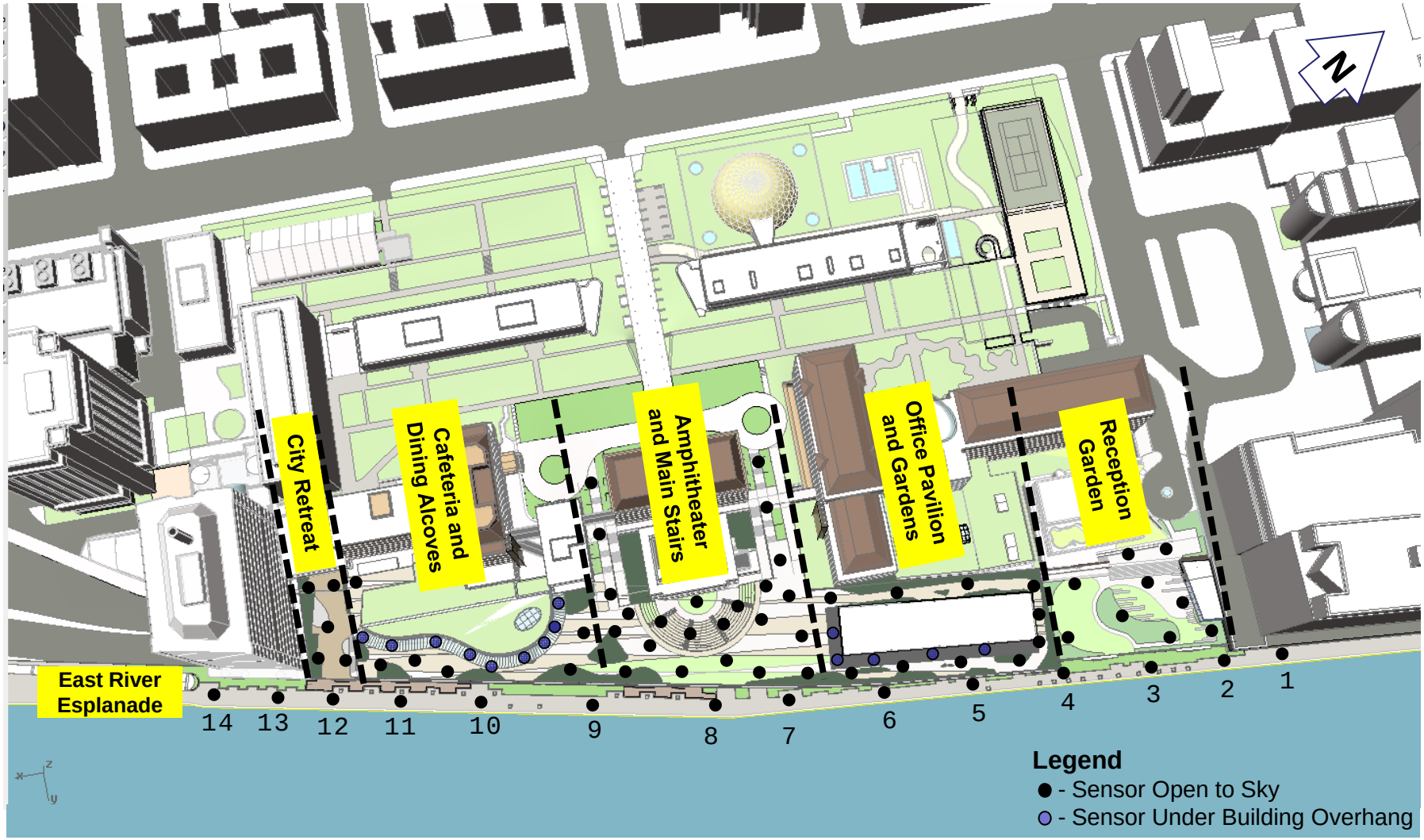


Figure 7: Map of Wind Sensor Locations – East River Esplanade

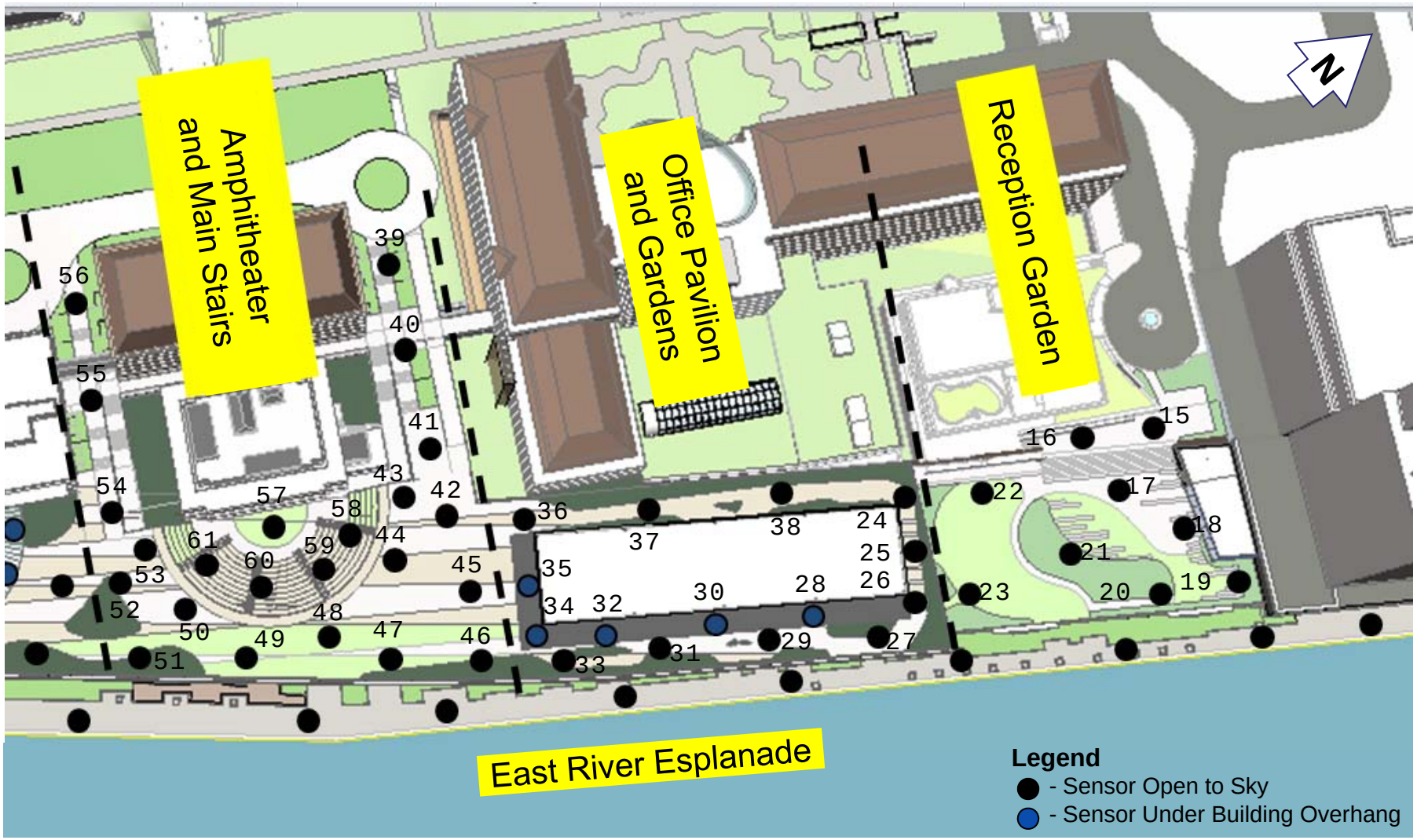


Figure 8: Map of Wind Sensor Locations – North Area of Site

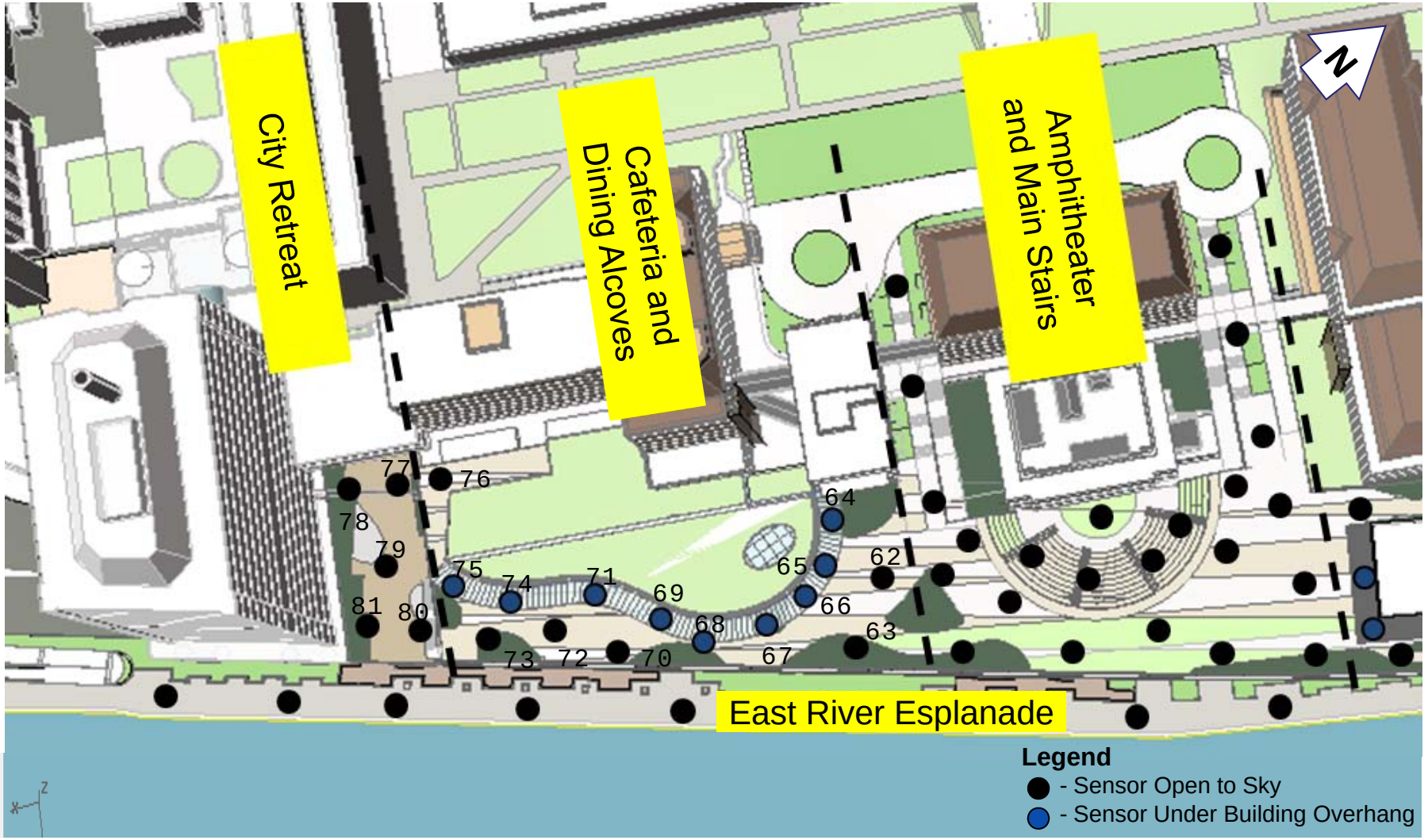


Figure 9: Map of Wind Sensor Locations - South Area of Site

2.3 Wind Climate

Wind data recorded at LaGuardia, Newark and JFK Airports for the period of 1964 – 2008 were obtained and analysed to create a blended wind climate model for the four seasons. Annual and seasonal wind frequency distribution diagrams ("wind roses") are shown in **Figure 10**. These diagrams illustrate the percentage of time that wind blows from 36 compass directions. Of main interest are the longest peaks that identify the most frequently occurring wind directions. The annual wind rose indicates that wind approaching from the northwest and south are most prevalent. The four seasonal wind roses readily show how the most prevalent winds shift direction during the year.

The directions from which stronger winds (e.g., > 20 mph) approach are also of interest as they have the highest potential of creating problematic wind conditions, depending upon the building configurations and site exposure. The wind roses in **Figure 10** also identify the directional frequency of these stronger winds, as indicated in the figure's legend colour key. On an annual basis, strong winds occur most frequently from the northwest and west directions. All wind speeds and directions were included in the wind climate model.

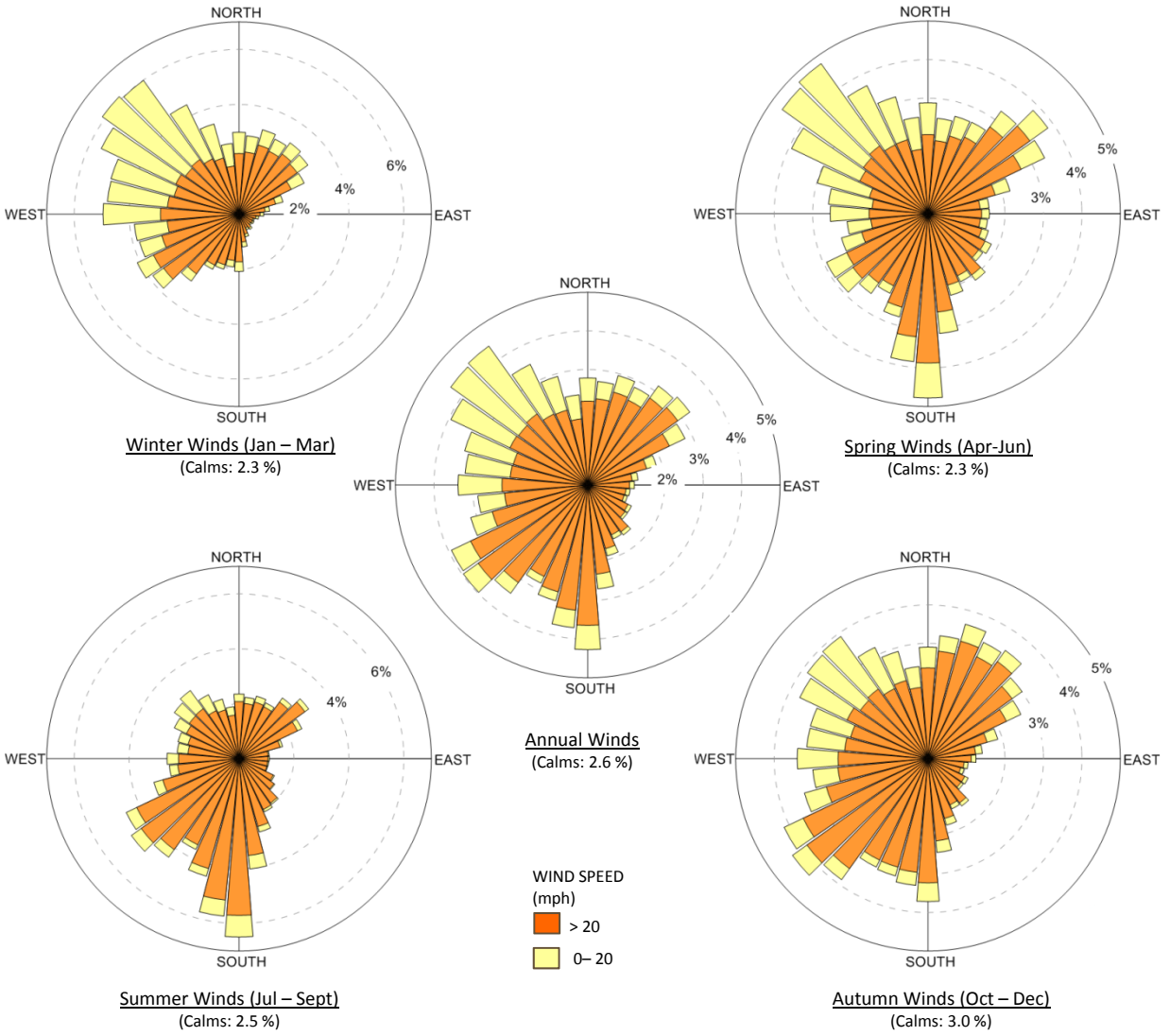


Figure 10: Season Wind Roses for Blended Data of LaGuardia, Newark and JFK Airports (1964 – 2008)

3.0 PEDESTRIAN WIND CRITERIA

The wind comfort conditions are discussed in terms of being acceptable for certain pedestrian activities and are based on wind force. Pedestrian activity, wind chill, clothing, humidity and exposure to direct sun, for example, can all affect pedestrian (thermal) comfort; however, these influences are not considered in wind force criteria.

The criteria for wind comfort and safety used in this assessment are based on those developed at the Boundary Layer Wind Tunnel Laboratory of the University of Western Ontario, together with building officials in London England. They are based broadly on the Beaufort scale and on previous criteria that were originally developed by Davenport. The criteria are used by the Alan G. Davenport Wind Engineering Group Boundary-Layer Wind Tunnel Laboratory for pedestrian wind study projects located around the globe. A detailed description of the criteria and history of its development is contained in the references.

The comfort criteria, which are based on certain predicted hourly mean wind speeds being exceeded 5% of the time, are summarized in the table. Very roughly, this is equivalent to wind speeds greater than those desired occurring for approximately 8 hours per week.

The criterion for wind safety in the table is based on hourly mean wind speeds that are exceeded 0.1% of the time (approximately nine hours per year). When more than three, 3-hour events are predicted to exceed the Fair-Weather Area criterion on an annual basis, wind mitigation measures are then advised, especially for frequently accessed areas.

Activity	**Comfort Ranges for Mean Wind Speed Exceeded 5% of the Time**		**Description of Wind Effects**
Sitting	0 to 9 mph	0 to 4 m/s	• Light wind felt on face • Leaves rustle
Standing	0 to 13 mph	0 to 6 m/s	• Hair is disturbed, clothing flaps • Light leaves and twigs in motion • Wind extends lightweight flag
Leisurely Walking	0 to 18 mph	0 to 8 m/s	• Moderate, raises dust, loose paper • Hair disarranged • Small branches move
Fast Walking	0 to 22 mph	0 to 10 m/s	• Force of wind felt on body • Trees in leaf begin to move • Limit of agreeable wind on land

Activity	**Safety Criterion Mean Wind Speed Exceeded 3 Times per Year *(3x3hr)***		**Description of Wind Effects**
Any [1]	45 mph	20 m/s	• Difficult to walk straight • Wind noise on ears unpleasant

Notes:
[1] Equivalent to the "Fair Weather Location" criterion of UWO's Criteria, which applies to frequently accessed areas.

4.0 RESULTS

The analysis of wind comfort was undertaken for all four seasons in this study. The study results for the seasonal extremes of summer and winter are discussed in this report. Where there is an interest in comfort conditions predicted for the shoulder seasons of spring and autumn, the comfort results in **Appendix A** can also be reviewed.

The major areas of the overbuild are identified in black text in the site orientation plan of Figure 2. The wind comfort conditions are presented in graph form and immediately follow a discussion of the results for each major area of the overbuild.

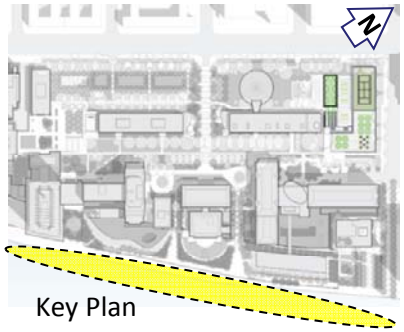
The safety criterion was predicted to be met at all locations tested.

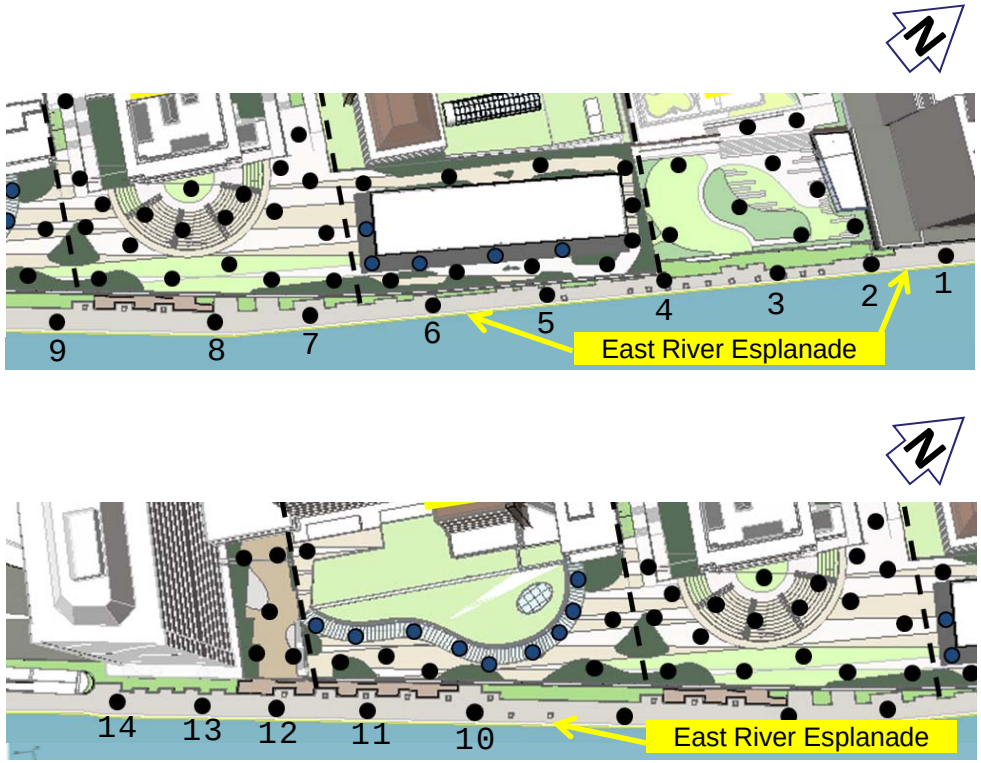
Figure 11: Wind Tunnel Test Model Views from South

4.1 East River Esplanade
(Locations 1 to 14 shown in Figure 12)

The East River Esplanade is a public amenity space along the East River that incorporates benches and other seating areas. The Esplanade is also a pedestrian thoroughfare and bicycle route. For seating areas, wind comfort conditions rated for sitting would be desirable during the summer season.

The predicted wind comfort conditions for the summer and winter seasons are presented in **Figures 14 and 15**, respectively. During both the summer and winter seasons, wind conditions were rated suitable for sitting at all 14 locations on the Esplanade, which is ideal for the intended use. The wind comfort criterion assesses wind force and not thermal comfort, thus issues such as sun/shade, temperature, humidity, etc. are not considered. The low wind activity would suggest that shade would be welcomed by pedestrians sitting along the Esplanade to improve their overall "thermal comfort".





Legend
- ● - Sensor Open to Sky
- ● - Sensor Under Building Overhang

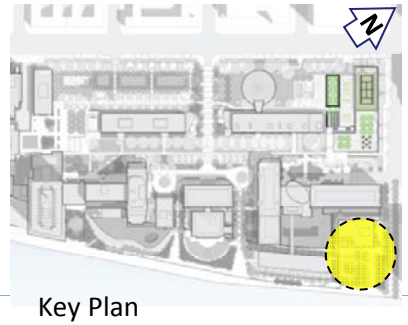
Figure 12: Wind Sensor Locations - East River Esplanade

4.2 Reception Garden
(Locations 15 to 23 shown in Figure 13)

The Reception Garden is an amenity space intended for social events and sedentary activities where wind comfort conditions suitable for sitting would be preferred throughout the summer.

The predicted wind comfort conditions for the summer and winter seasons are illustrated in **Figures 14 and 15**, respectively. The gardens are well protected by the surrounding buildings as the wind comfort levels throughout the year were found to be suitable for sitting. These conditions are satisfactory for the intended use.

The wind tunnel results indicated that when northeasterly winds occur, increased wind activity will be most noticeable in the vicinity of Locations 15, 16 and 22. This is a result of the wind being deflected downward by the tall building adjacent the overbuild. These infrequent conditions can affect planned outdoor functions, but the wind comfort levels are satisfactory overall.



Key Plan

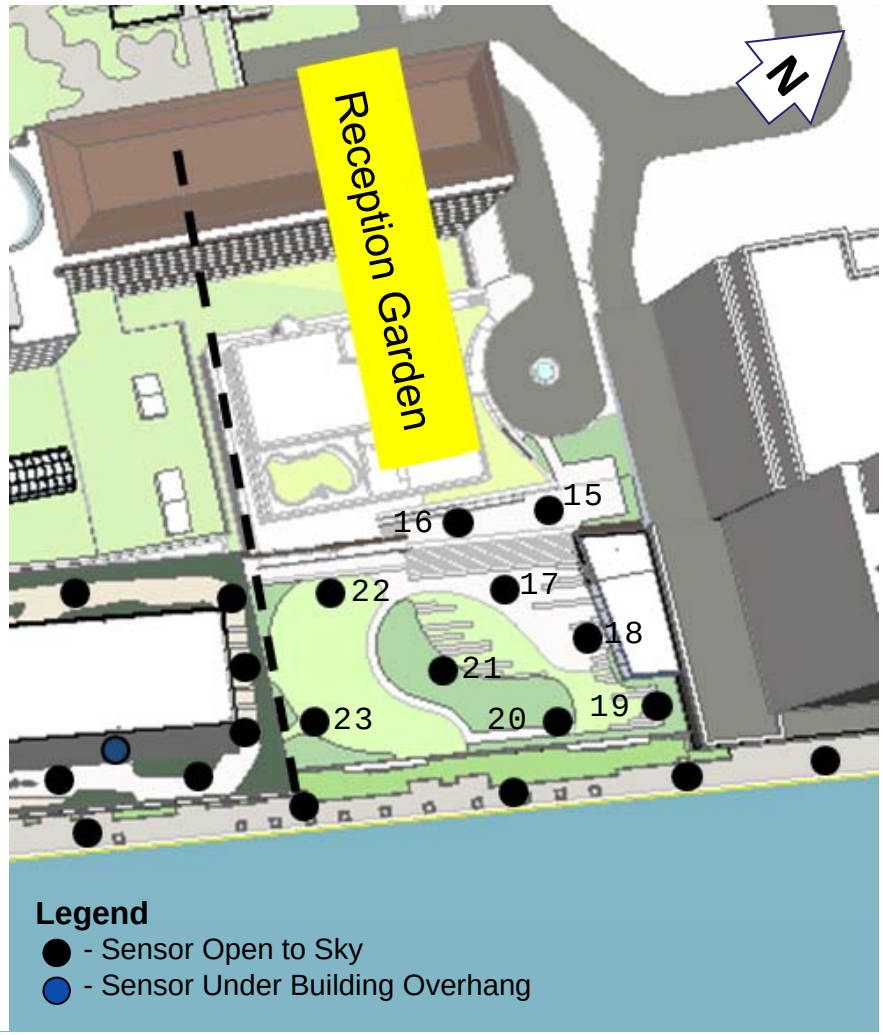


Figure 13: Wind Sensor Locations - Reception Garden Area

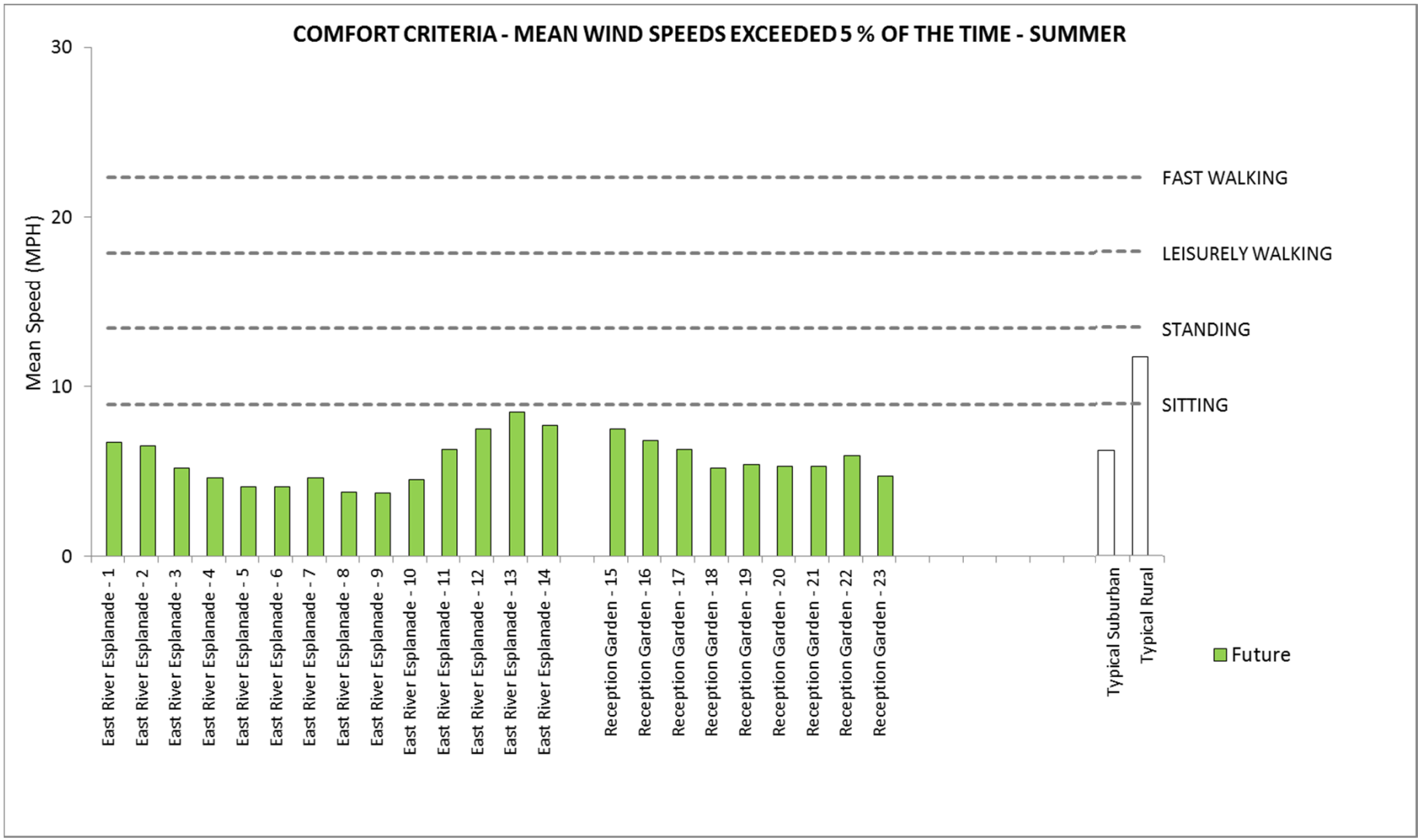


Figure 14: Wind Comfort Results for East River Esplanade and Reception Garden - Summer

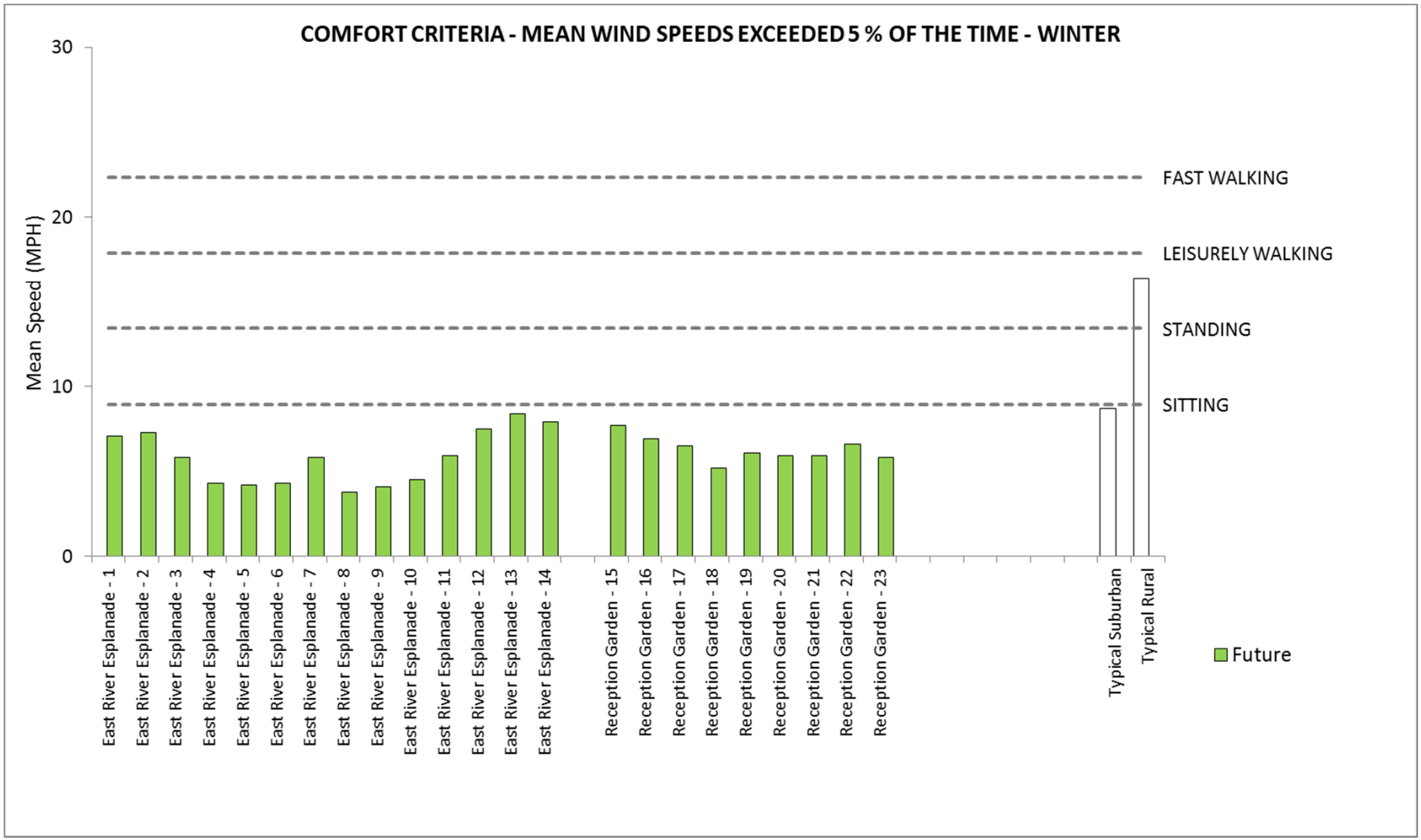
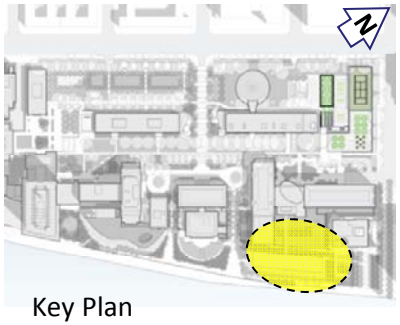


Figure 15: Wind Comfort Results for East River Esplanade and Reception Garden - Winter

4.3 Office Pavilion Area and Gardens
(Locations 24 to 38 shown in Figure 16)

Wind comfort levels suitable for standing at main entrances and suitable for walking on sidewalks are preferred year-round. For the surrounding gardens, wind comfort suitable for sitting or standing would be desirable in the summer.

The predicted wind comfort conditions for the summer and winter seasons are presented in **Figures 17 and 18**, respectively. In all test areas around the Office Pavilion and the (Meandering) gardens, the wind comfort levels were rated suitable for sitting during both summer and winter seasons. The predicted wind comfort conditions are satisfactory.



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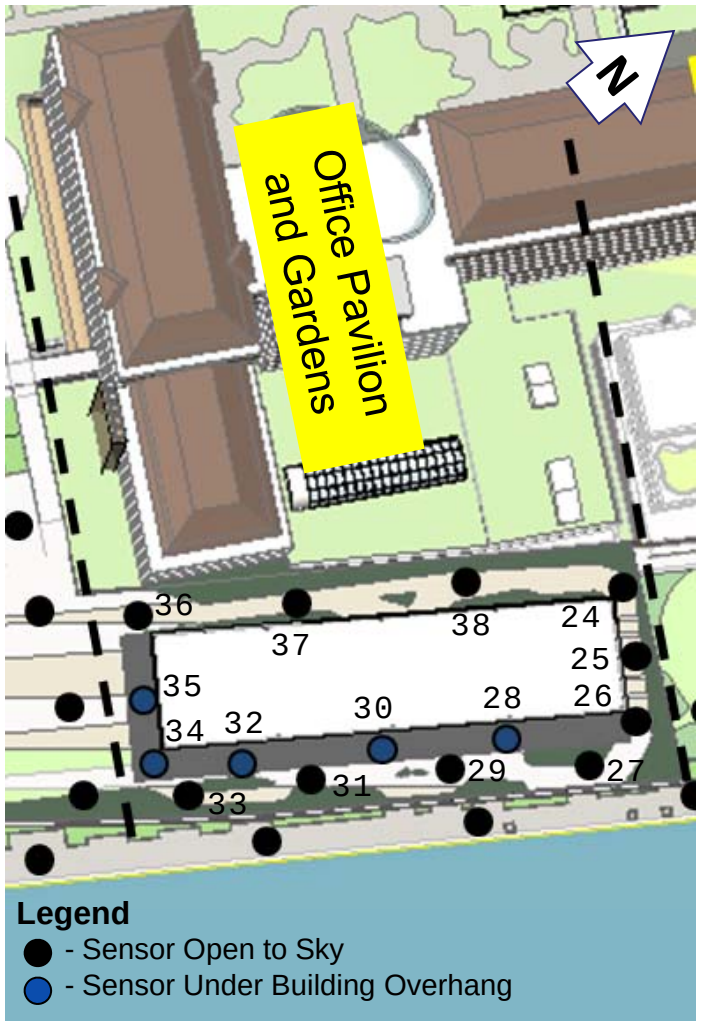


Figure 16: Wind Sensor Locations - Office Pavilion Area

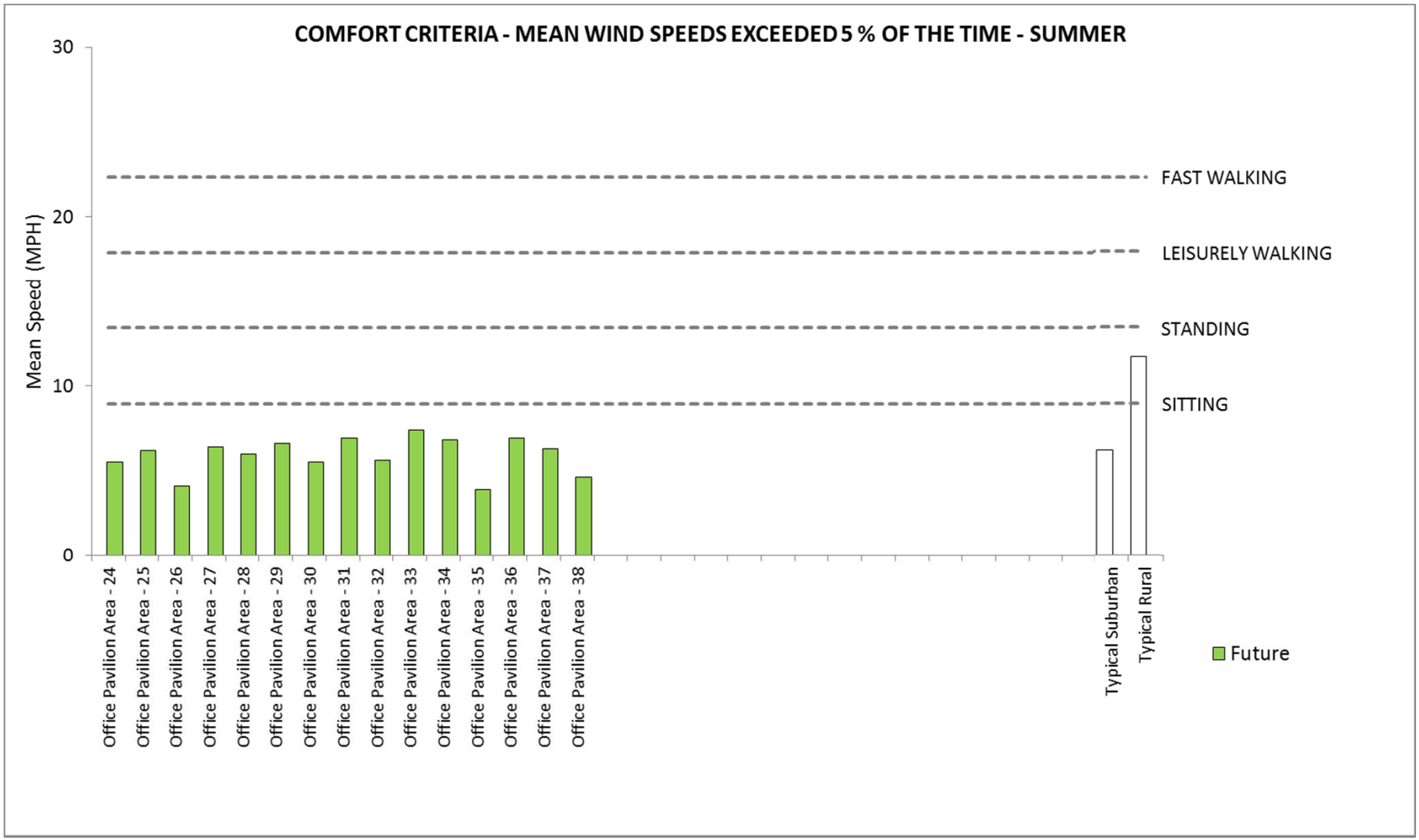


Figure 17: Wind Comfort Results for Office Pavilion Area - Summer

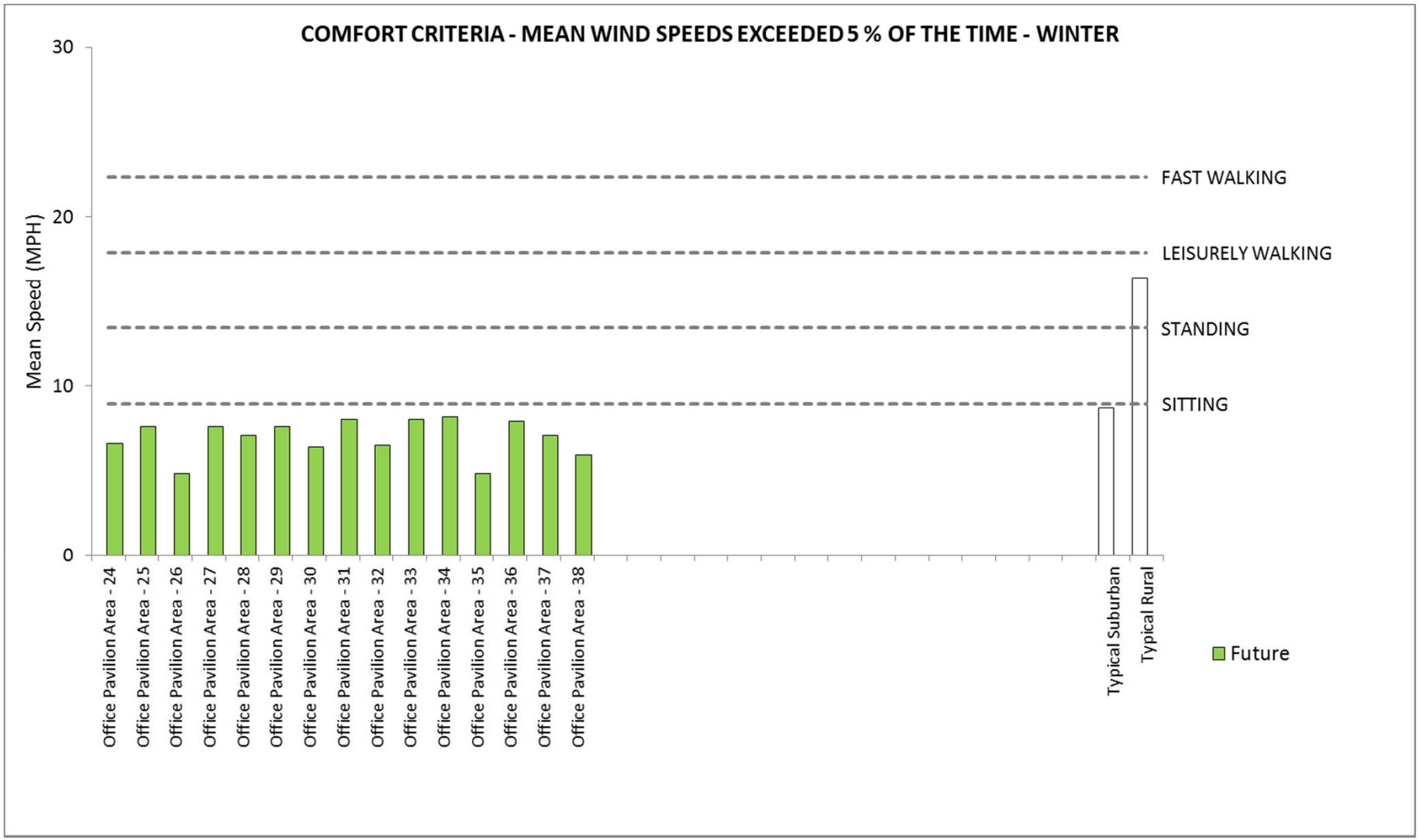
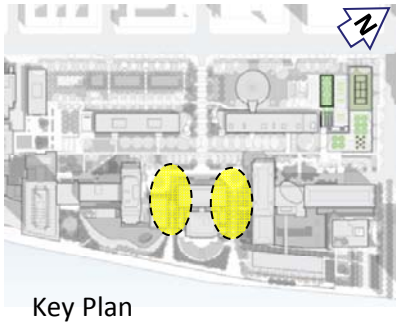


Figure 18: Wind Comfort Results for Office Pavilion Area - Winter

4.4 Access Stairs – Flexner Hall & Nurse's Residence
(Locations 39 to 41 and 54 to 56 shown in Figure 19)

The access stairs connecting the main campus area to the overbuild are mainly a pedestrian thoroughfare. Wind comfort levels suitable for walking would be desired throughout the year.

The predicted wind comfort conditions for the summer and winter seasons are illustrated in **Figures 21 and 22**, respectively. During the summer, wind activity rated suitable for sitting was predicted. In the winter, the wind conditions ranged from suitable for sitting to standing. The slightly higher level of wind activity most notably at Locations 40 and 55 is due to the funneling of east and southeast winds, respectively, between the adjacent buildings. These conditions are suitable for the area throughout the year.



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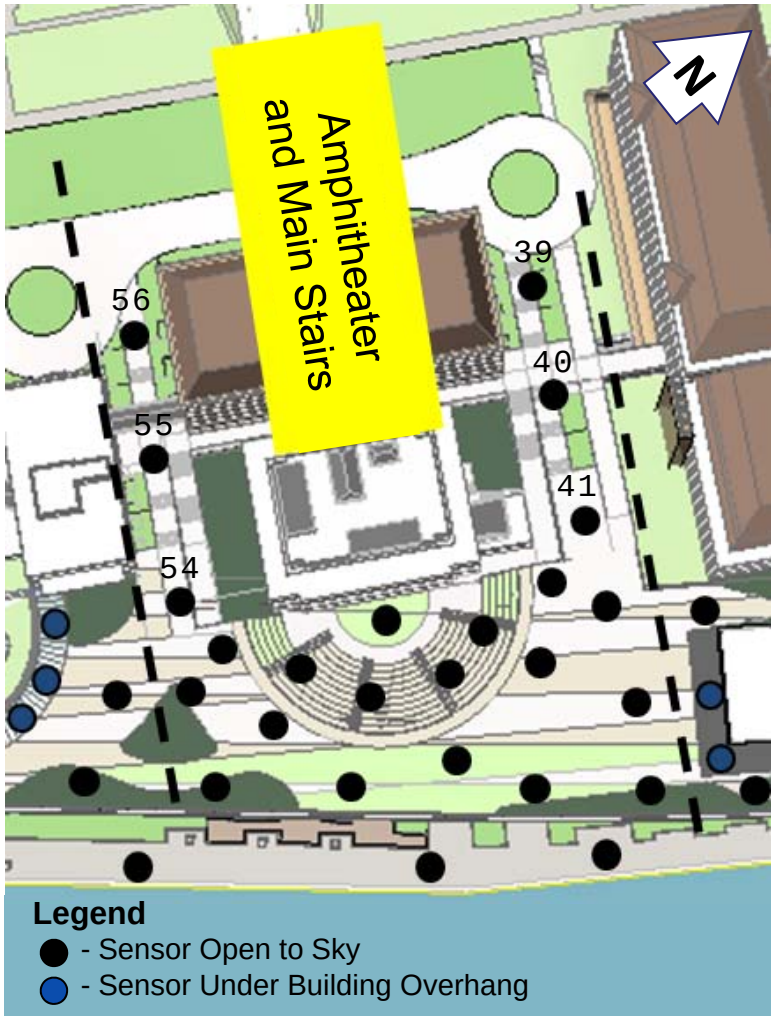


Figure 19: Wind Sensor Locations - Access Stairs Area

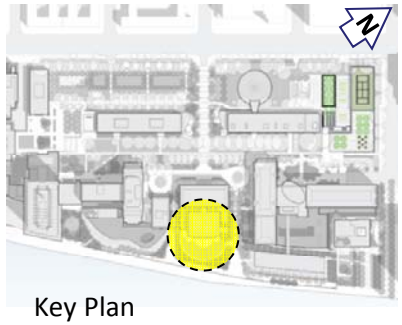
4.5 Amphitheatre Plaza and Amphitheatre

(Locations 42 to 53 and 57 to 61 shown in Figure 20)

The Amphitheater will be used for activities where people must be comfortable to sit for an extended period during the summer. For the surrounding plaza, summertime winds comfortable for sitting or standing would be appropriate.

Predicted wind comfort conditions for the summer and winter seasons are shown in **Figures 21 and 22**, respectively. The wind activity for this entire area was rated as comfortable for sitting during the summer and winter seasons, which is ideal. It is likely that during hot, sunny days it may become too hot for people to sit in full sun to be comfortable as the wind activity will be light. Without the benefit of a cooling breeze, the use of shade devices (e.g., trees, trellis/canopies, etc.) in the landscape plan should be considered.

In terms of wind (force) comfort, the wind conditions in the Amphitheatre and surrounding area are satisfactory for the intended use.



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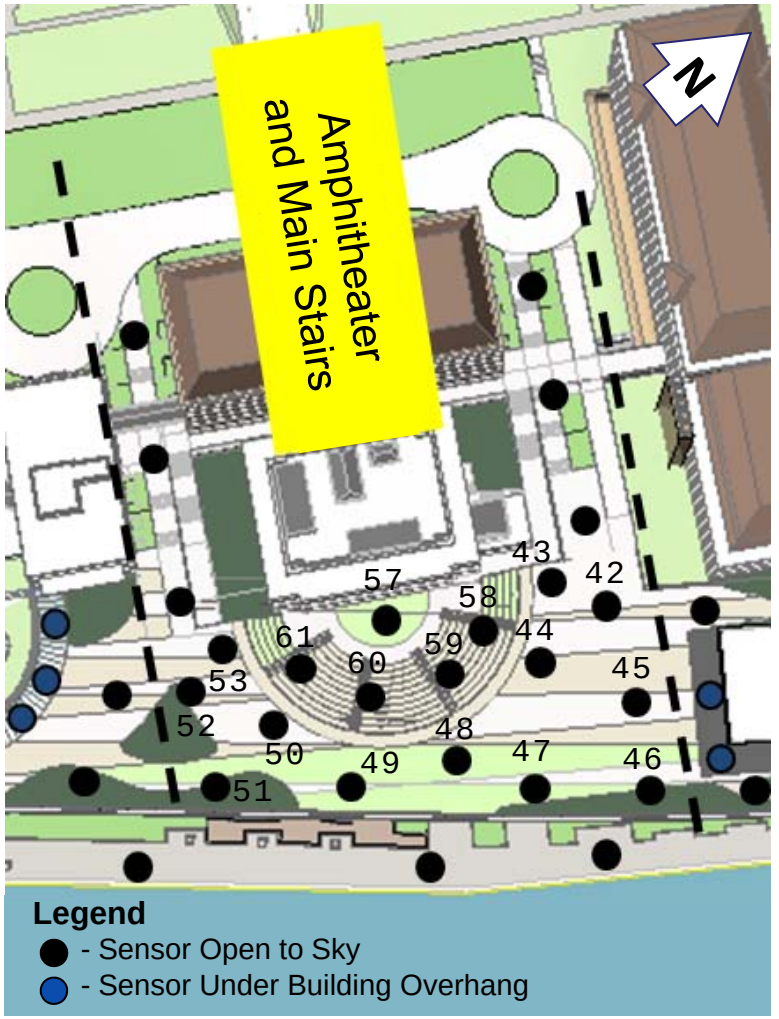


Figure 20: Wind Sensor Locations - Amphitheater Plaza Area

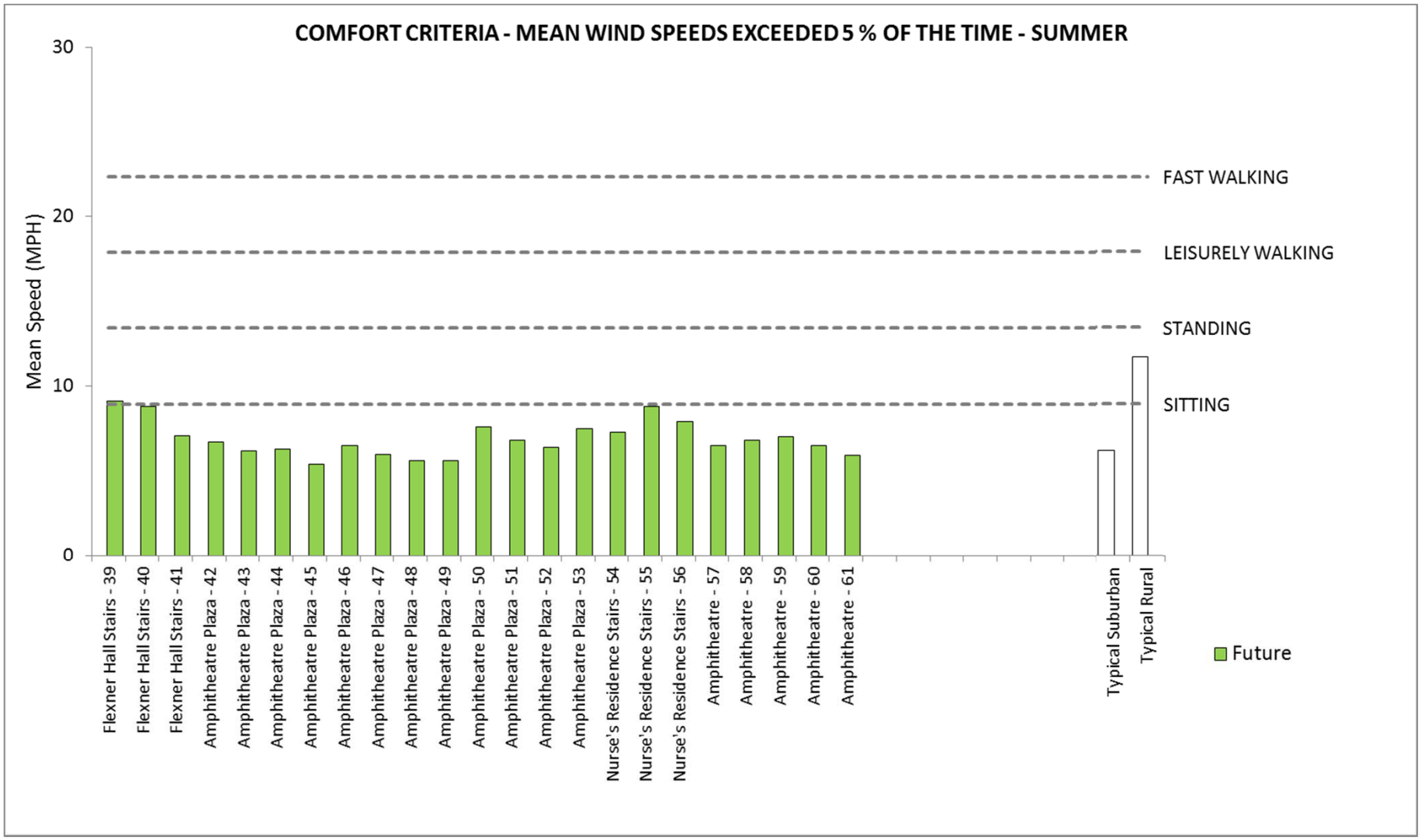


Figure 21: Wind Comfort Results for Stairs and Amphitheatre Plaza - Summer

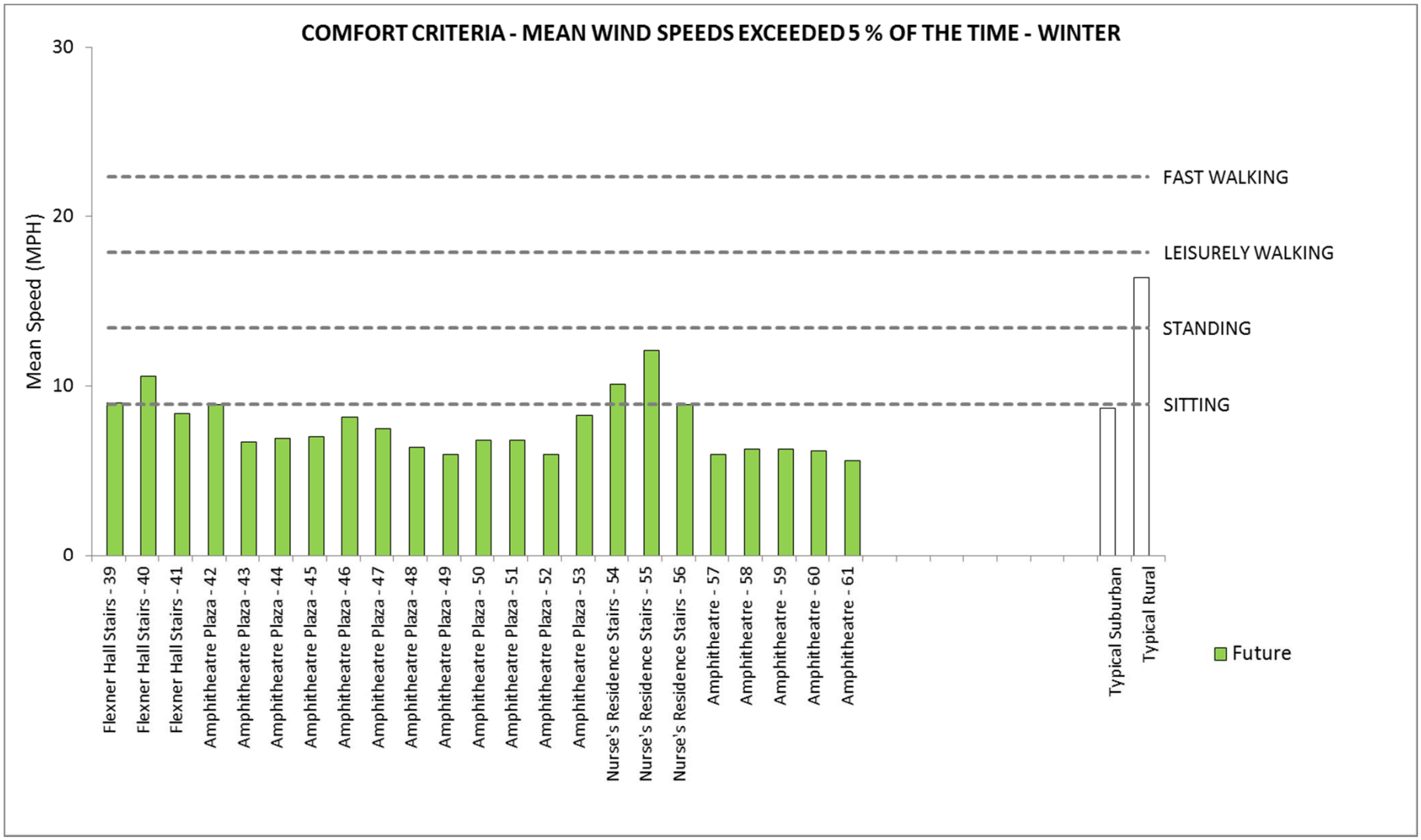


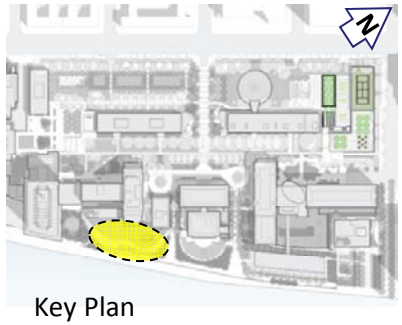
Figure 22: Wind Comfort Results for Stairs and Amphitheatre Plaza - Winter

4.6 Cafeteria and Dining Alcoves
(Locations 62 to 76 shown in Figure 23)

The primary pedestrian activity around the Cafeteria and Dining Alcoves will be sitting. Conditions suitable for sitting are therefore desired during the summer, whereas winds suitable for standing or sitting would be appropriate for non-dining areas.

The predicted wind comfort levels for the summer and winter seasons, respectively, are plotted in **Figures 25 and 26**. Winds comfortable for sitting were predicted in the summer at all locations except 63 and 67, where wind conditions were marginally above and rated suitable for standing. Although wintertime use is expected to be minimal, wind conditions were rated suitable for sitting at all locations. Overall, the wind conditions are appropriate for the area.

Tests were conducted in the absence of landscaping in order to identify wind conditions induced by the buildings alone. The addition of landscaping such as shrubs and hedges, etc. would reduce wind activity. This effect may be undesirable on hot and sunny summer days.



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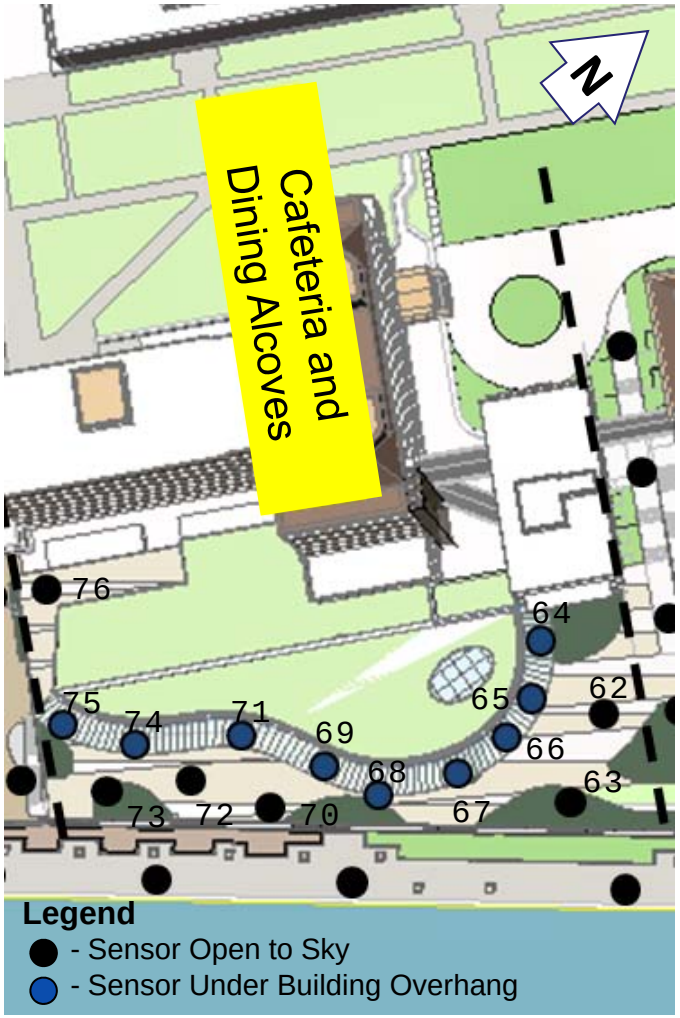


Figure 23: Wind Sensor Locations - Cafeteria and Dining Alcoves Area

4.7 City Retreat

(Locations 77 to 81 shown in Figure 24)

The use of the City Retreat as a seating amenity area suggests that wind comfort levels rated as sitting or standing would be preferred.

The predicted wind comfort conditions during the summer and winter seasons, respectively, for this area are shown in **Figures 25 and 26**. During the summer the wind comfort levels were rated as suitable for sitting and standing in this secluded area. Wintertime conditions were for the most part suitable for sitting with conditions at Location 79 being marginally above. The predicted level of wind activity meets the planned use of the amenity space through a majority of the year.

Key Plan

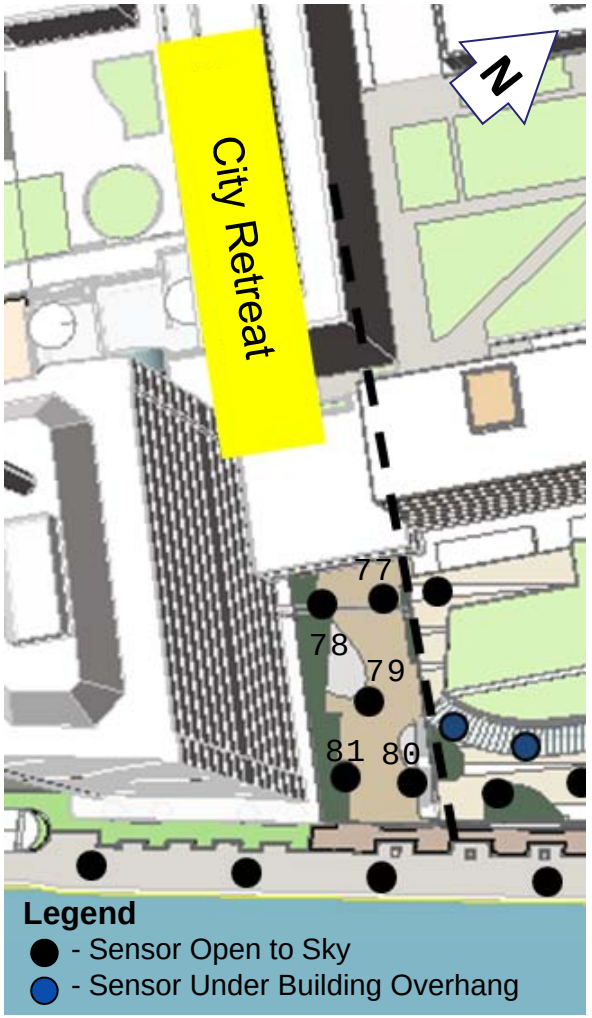


Figure 24: Wind Sensor Locations - City Retreat Area

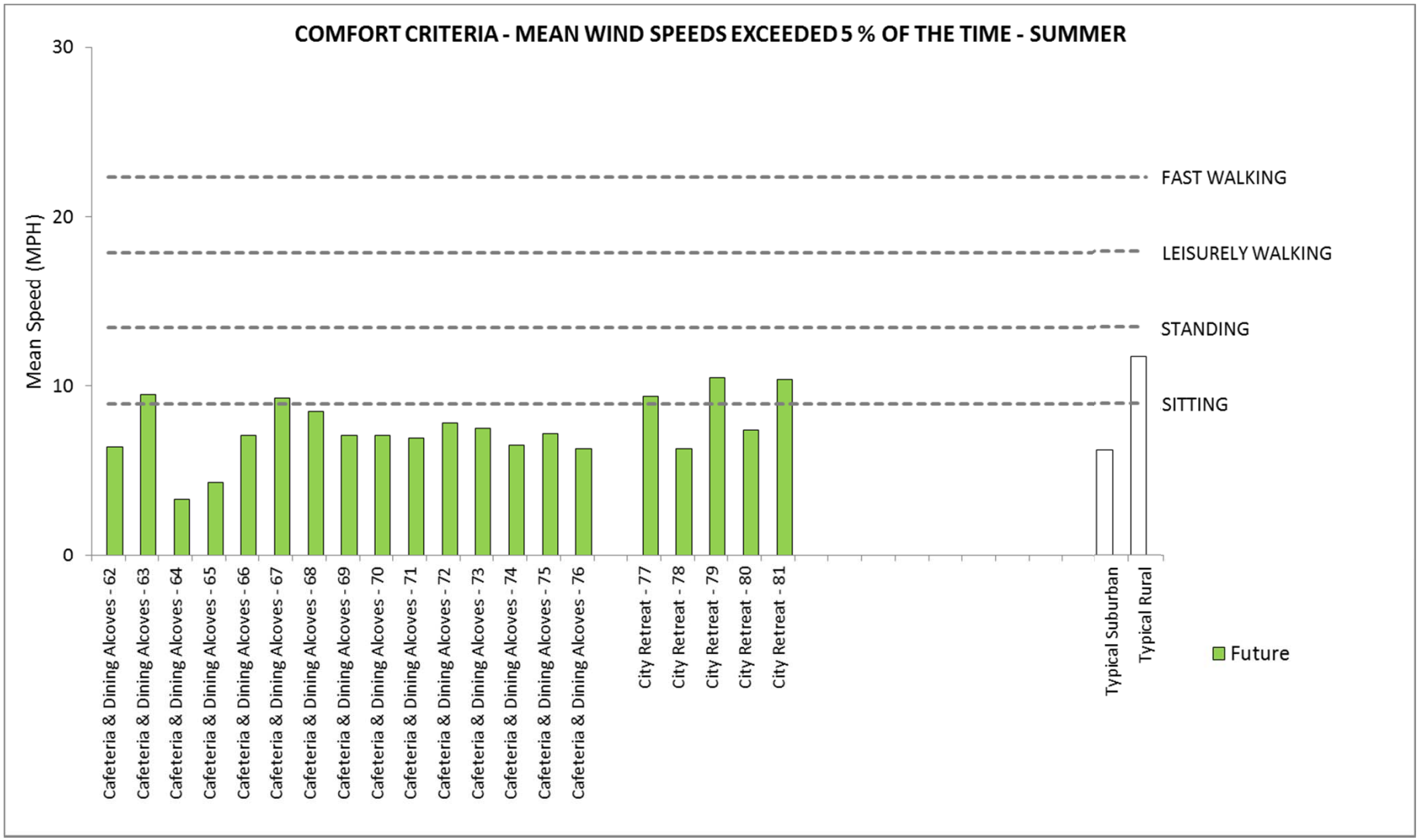


Figure 25: Wind Comfort Results for Cafeteria & Dining Alcoves and City Retreat - Summer

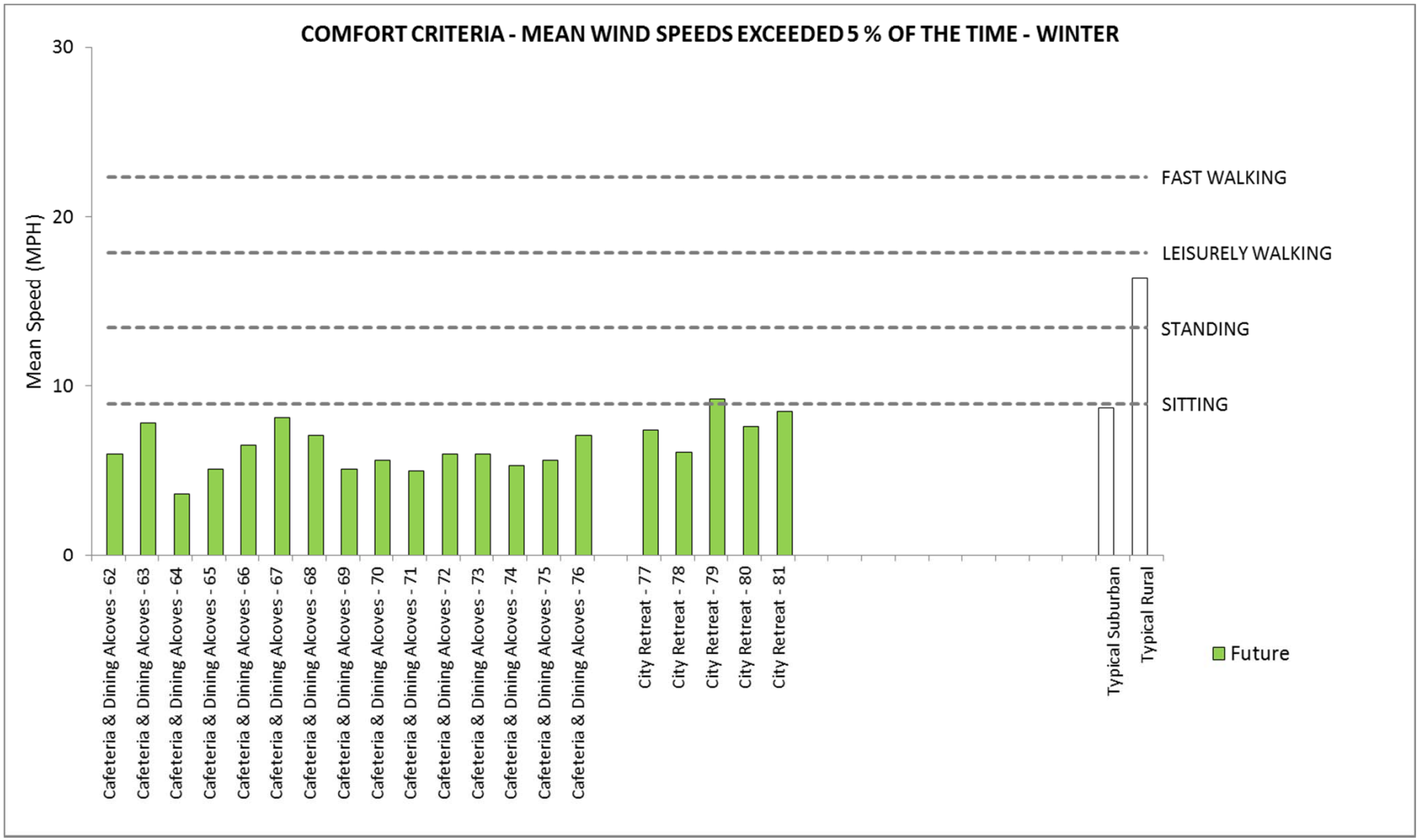


Figure 26: Wind Comfort Results for Cafeteria & Dining Alcoves and City Retreat - Winter

5.0 MICROCLIMATE CONSIDERATIONS FOR OUTDOOR SPACE PLANNING

The focus of this study was on wind speed (force), but various other factors also influence a person's comfort and their overall enjoyment of outdoor spaces. This is especially relevant in areas intended for extended periods of use. Climate parameters, such as direct sun exposure, temperature, humidity, plus clothing or activity (i.e., metabolic rate) are other issues that contribute to a person's thermal comfort.

The site orientation is such that many of the outdoor amenity spaces will be exposed to direct sunlight in the summer through to midday. The graph of temperatures **(Figure 27)** indicates an average maximum daily temperature of 85F in the summer. Most patrons of the Amphitheater, for example, will require shade in order to be "thermally" comfortable. Light color surface treatments can also help reduce thermal discomfort, but may add to glare discomfort. Increased use of grass in lieu of hard paving materials can improve upon local cooling on the overbuild.

Other influences, such as wind driven rain, are seldom considered when planning outdoor amenity areas and building overhangs and canopies. Two wind roses for LaGuardia Airport **(Figure 28)** present the frequency distribution of wind by direction during the summer. However, the wind rose on the right shows the dominant directions when rainfall occurs simultaneously. The strongest winds with rainfall events occur most frequently from the east-northeast. Data analysis such as these can help guide the planning of building overhangs and protective canopies.

The above examples introduce other considerations beyond wind force alone, that can guide the design of outdoor amenity spaces that will enhance the overall enjoyment of pedestrians.

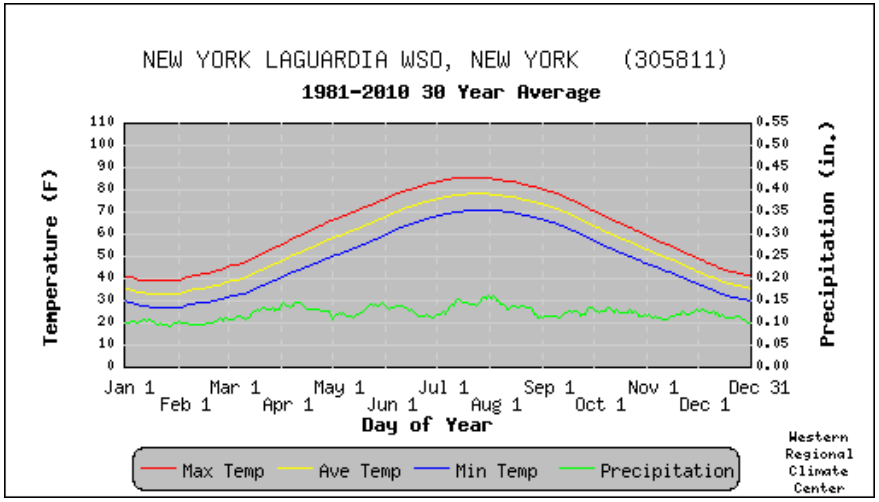
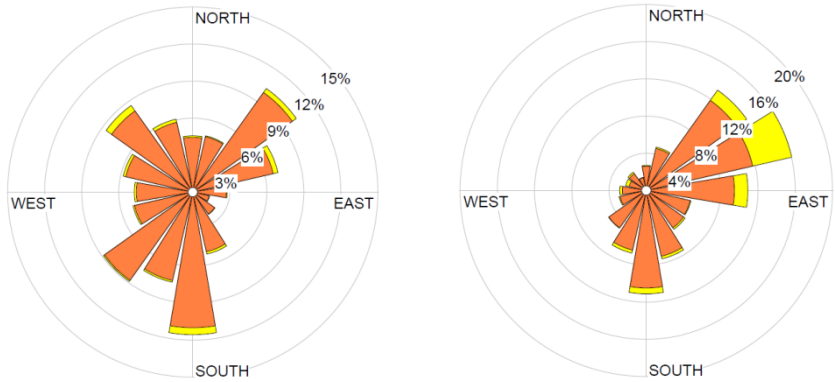


Figure 27: LaGuardia AP - Monthly Temperatures



Wind Without Rain

Wind With Rain

Figure 28: LaGuardia AP - Summer Winds and Rain Events

6.0 CONCLUSIONS AND RECOMMENDATIONS

The pedestrian wind comfort conditions predicted for the proposed new laboratory building at Rockefeller University have been assessed through wind tunnel testing techniques. Based on the results of our study, the following conclusions have been reached:

- The wind safety criterion were met at all locations tested on the laboratory building overbuild and also along the East River Esplanade.
- Summer and winter wind comfort conditions along the East River Esplanade were rated as comfortable for sitting or standing. These conditions were satisfactory for the intended use of the river front area.
- The wind conditions in the Reception Garden were typically rated year-round as suitable for sitting or standing. These conditions were appropriate for the planned use of the social garden space.
- Wind comfort (i.e., wind force) in all outdoor spaces were rated as sitting or standing in all seasons. These wind conditions meet the desired wind comfort levels for the planned outdoor amenity spaces.
- Thermal comfort of pedestrians has not been considered in this study, but as wind speeds are relatively low in the areas tested, the inclusion of shade through trees, trellis/canopies, arbors, etc. would be welcome on hot and sunny summer days.
- There are no recommendations or need for wind control measures in the design of the new laboratory building and overbuild of FDR Drive.

Should you have any questions or concerns, please do not hesitate to contact the undersigned.

Sincerely,
Novus Environmental Inc.

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Senior Specialist – Microclimate

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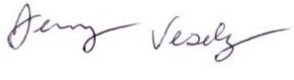
Principal, Specialist



Jenny Vesely, B.Eng., EIT
Scientist

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Appendix A

Pedestrian Wind Comfort and Wind Safety Analysis

Spring (April – June) and Autumn (October – December)

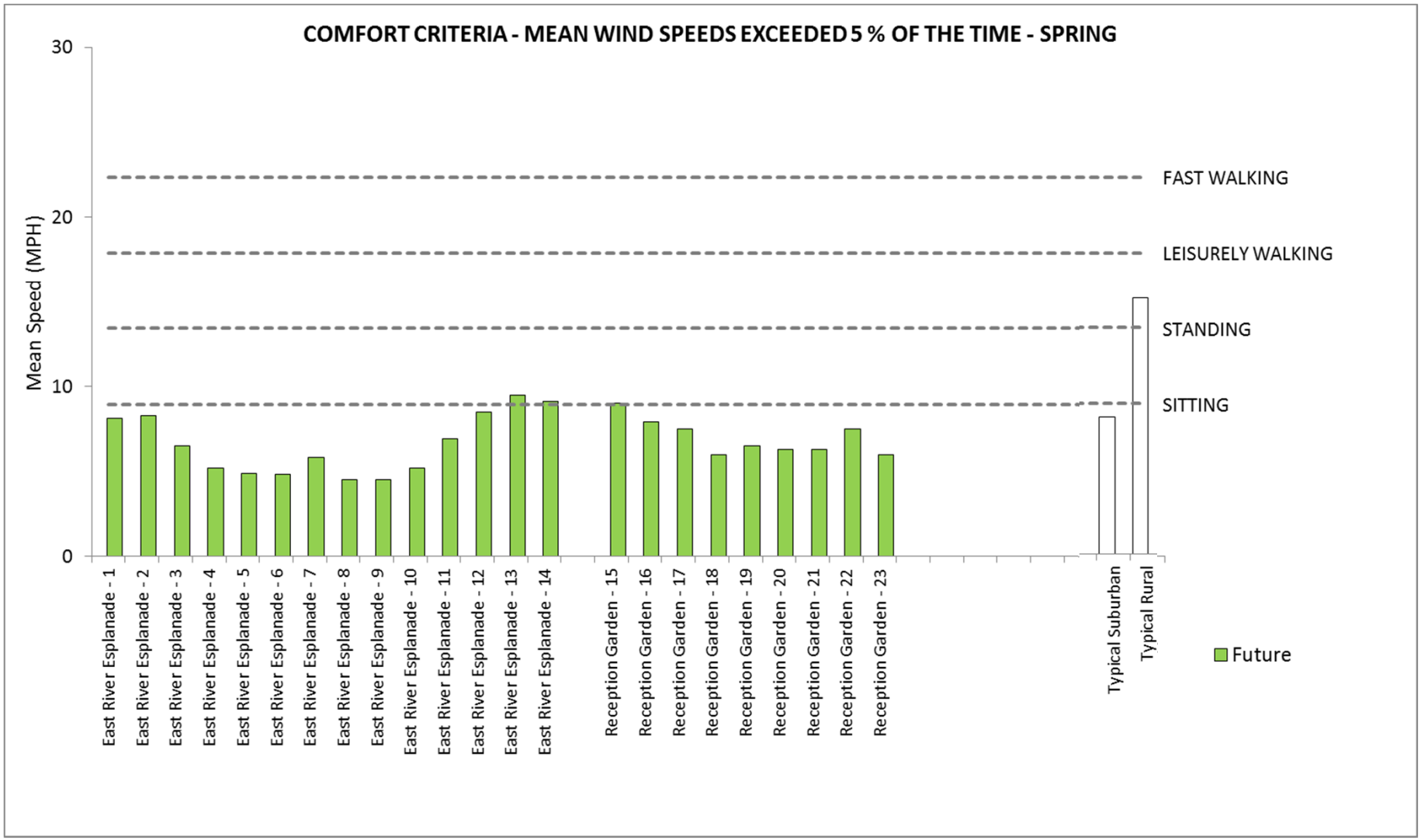

Figure A1: Wind Comfort Results for East River Esplanade and Reception Garden - Spring

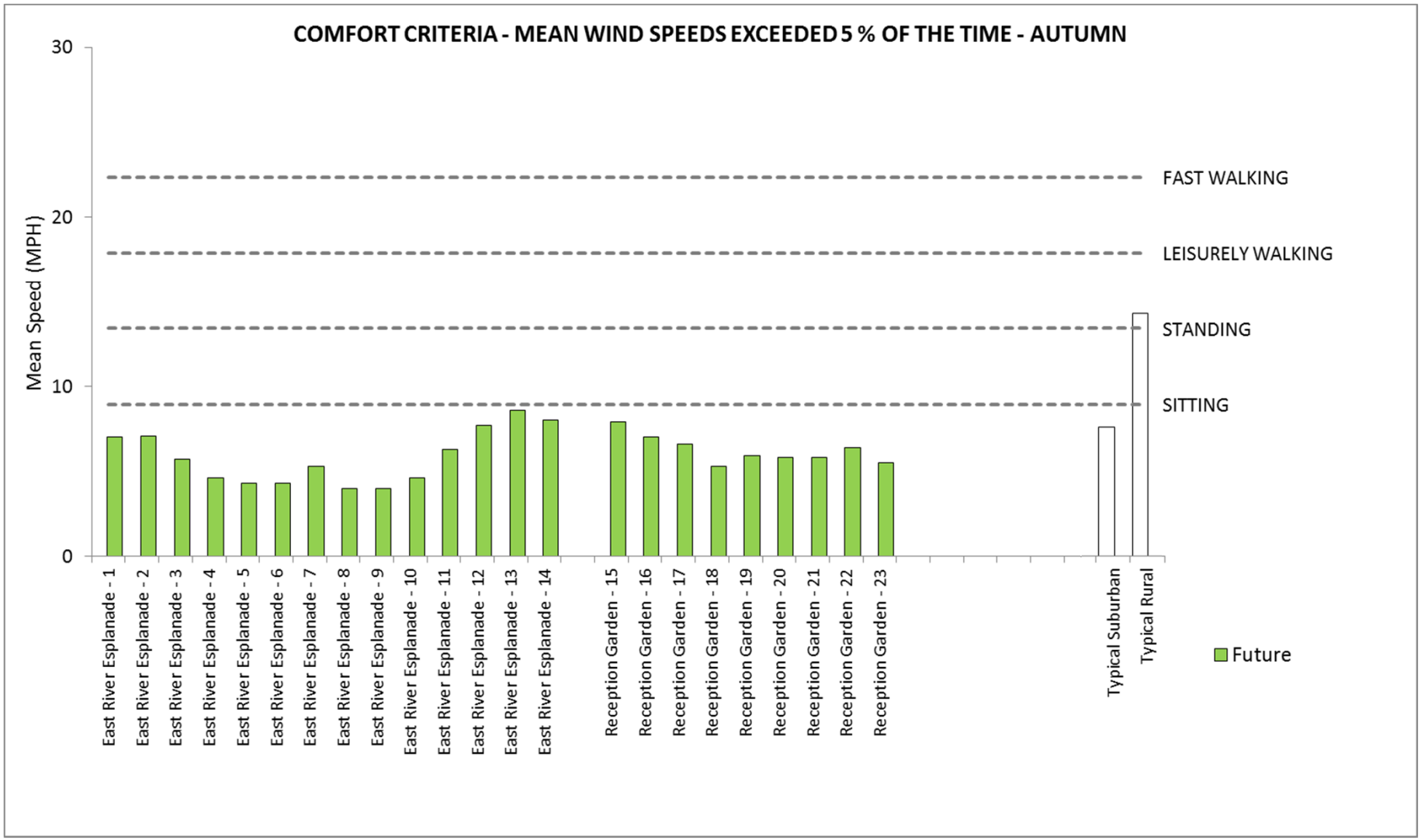

Figure A2: Wind Comfort Results for East River Esplanade and Reception Garden - Autumn

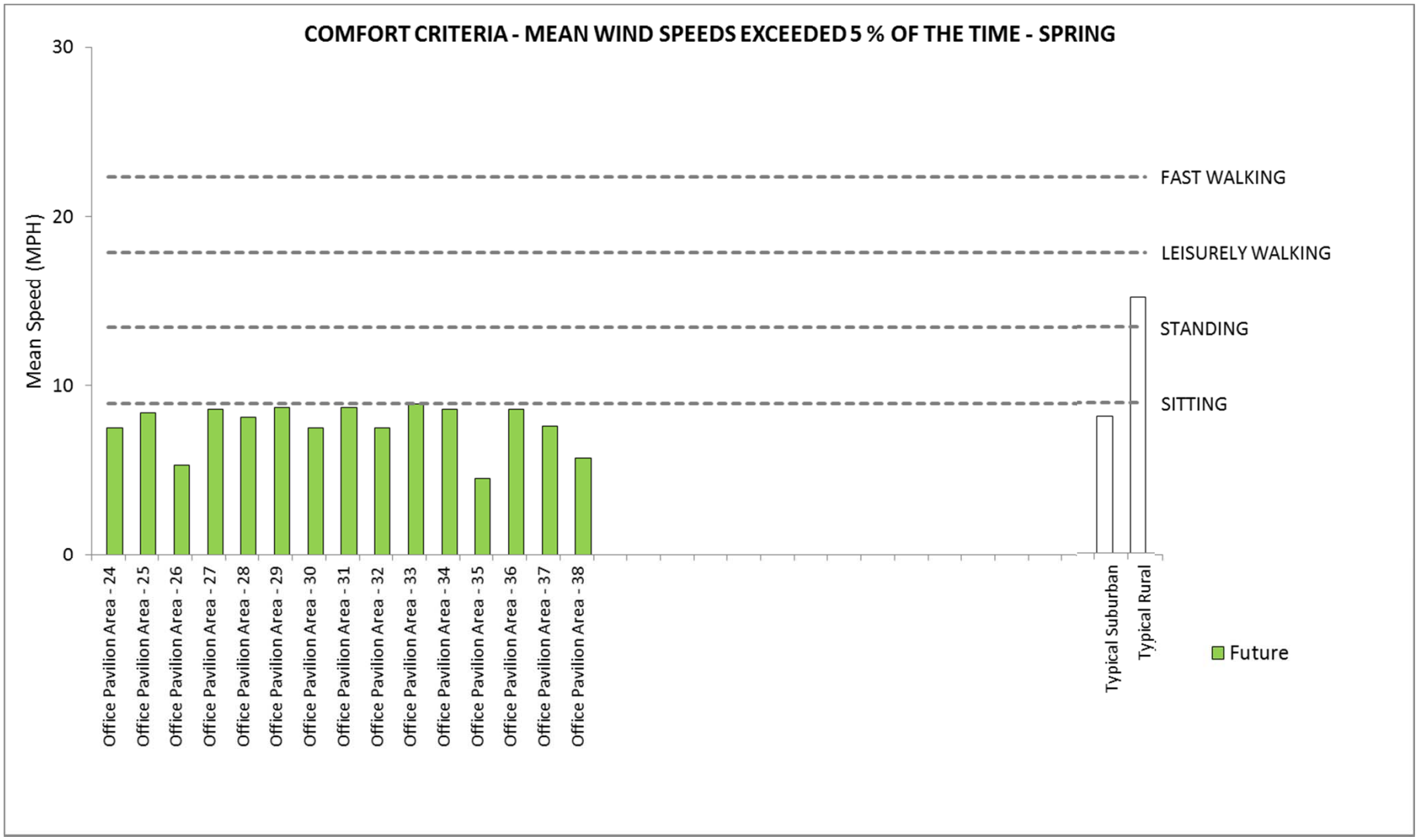

Figure A3: Wind Comfort Results for Office Pavilion Area - Spring

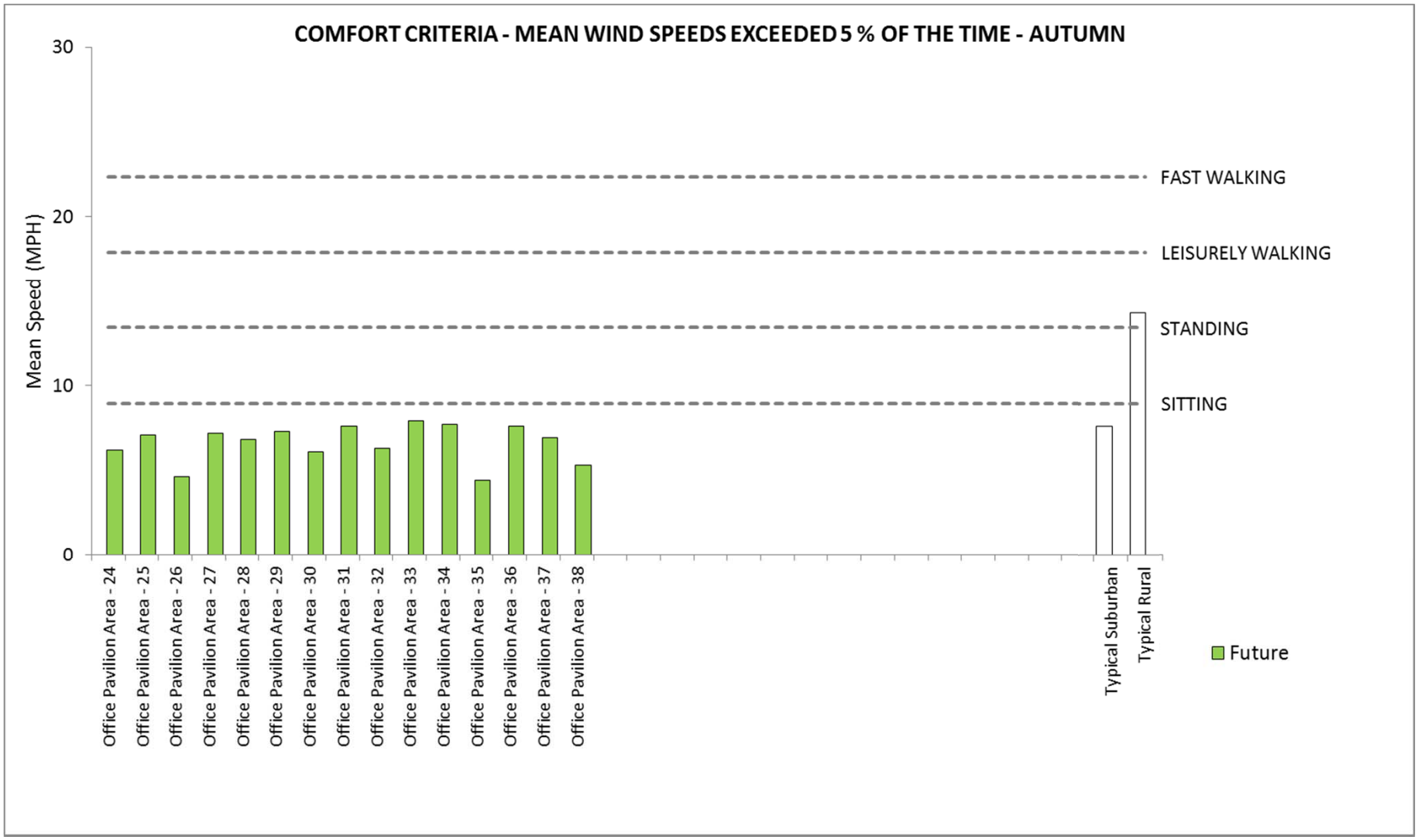

Figure A4: Wind Comfort Results for Office Pavilion Area - Autumn

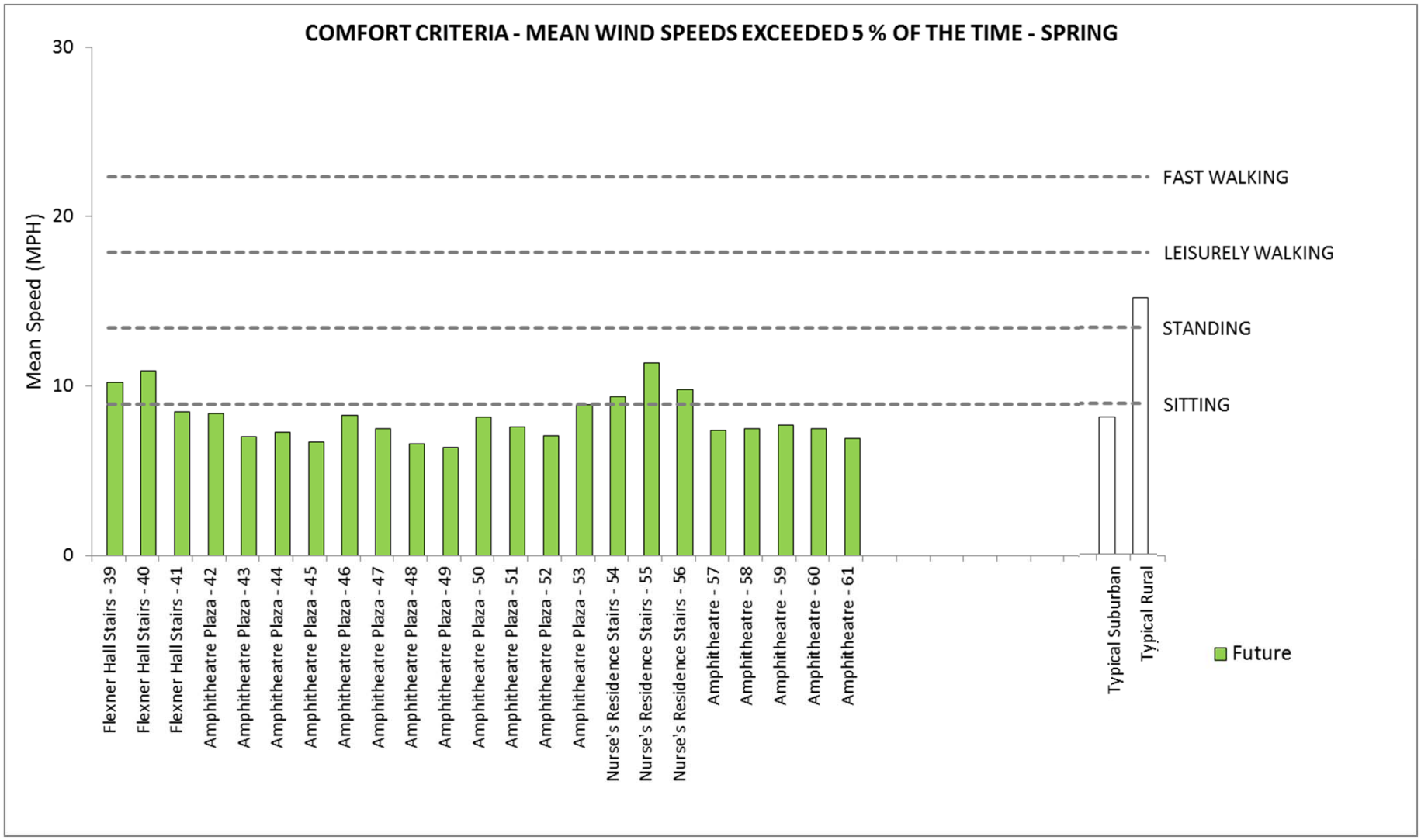

Figure A5: Wind Comfort Results for Stairs and Amphitheatre Plaza - Spring

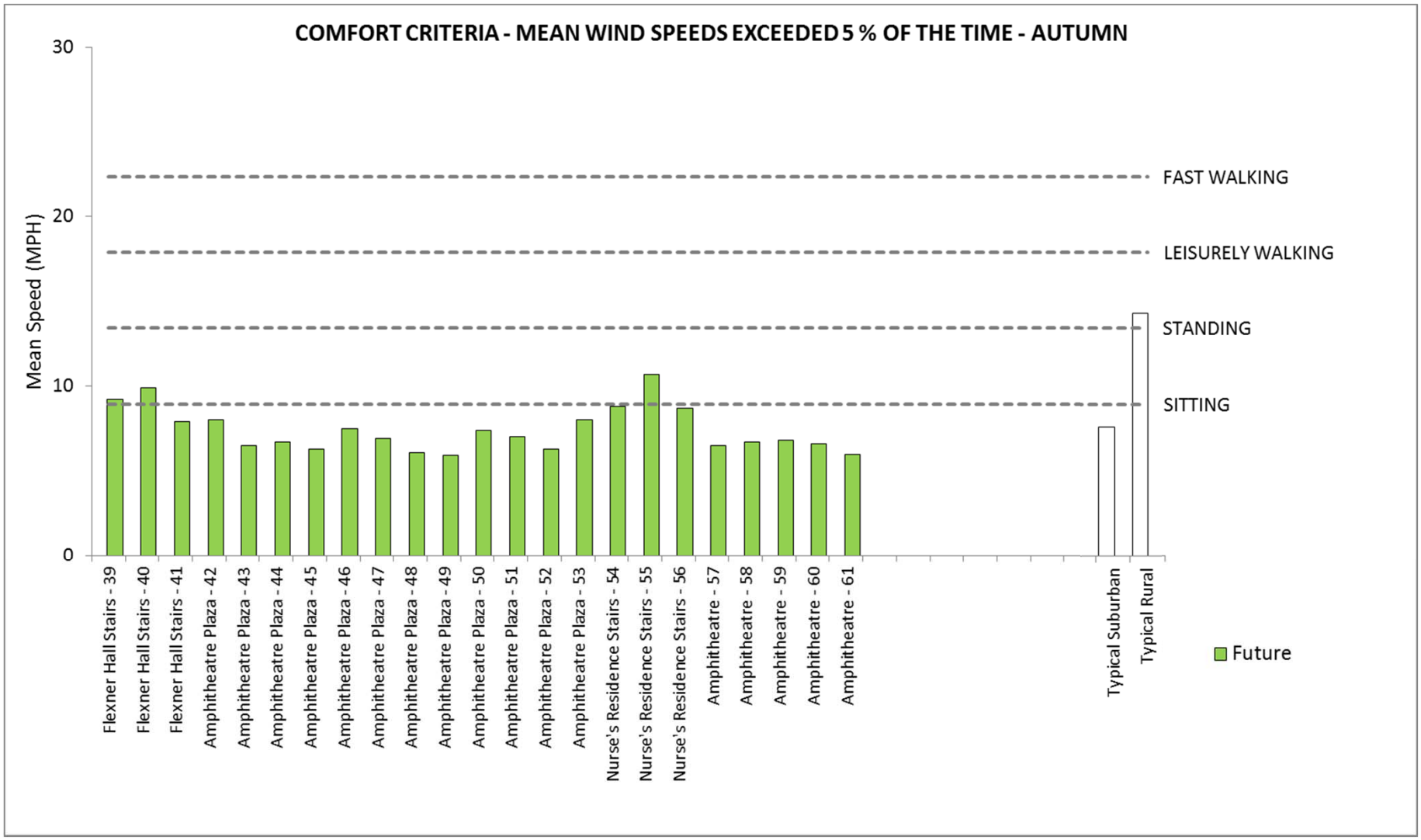

Figure A6: Wind Comfort Results for Stairs and Amphitheatre Plaza - Autumn

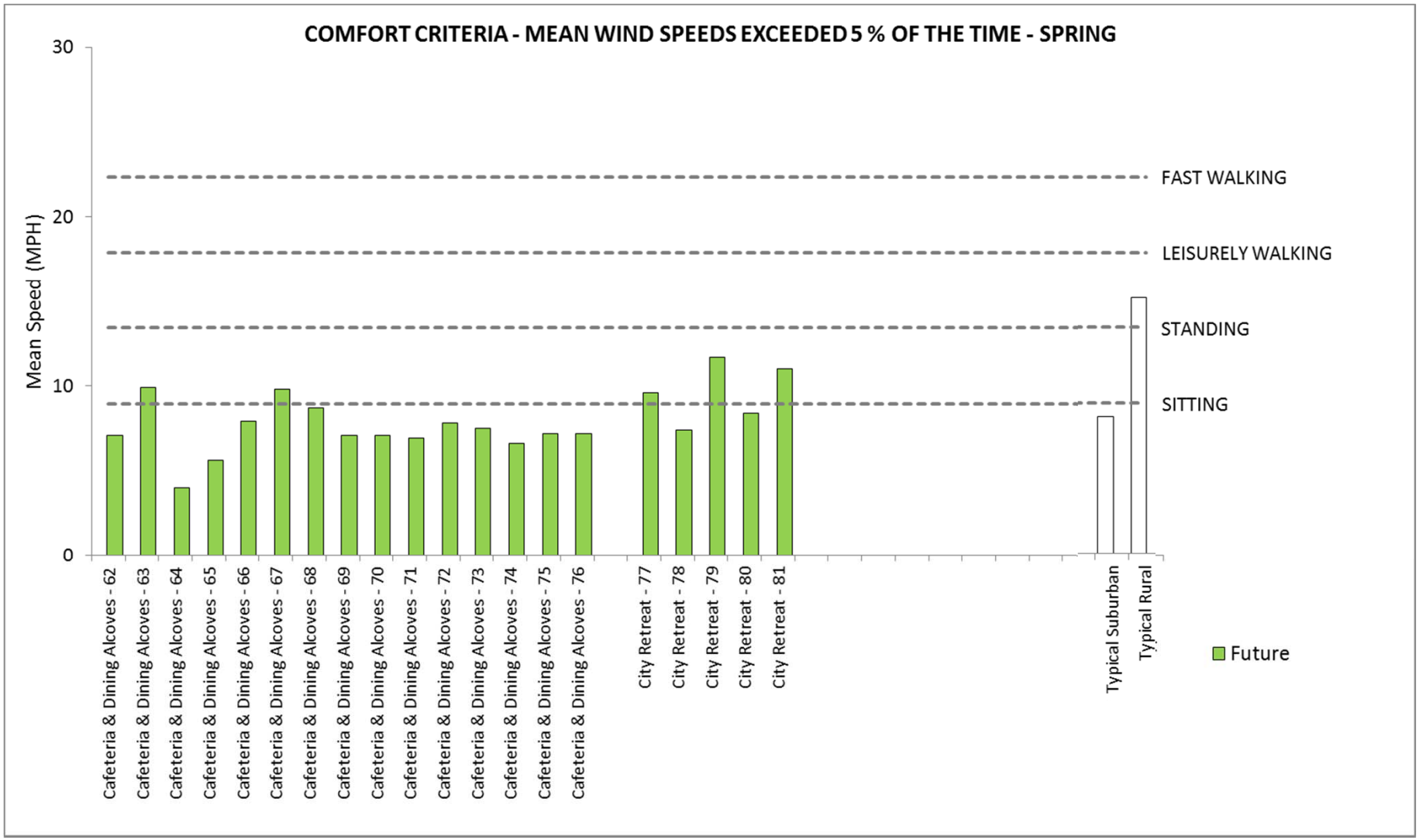

Figure A7: Wind Comfort Results for Cafeteria & Dining Alcoves and City Retreat - Spring

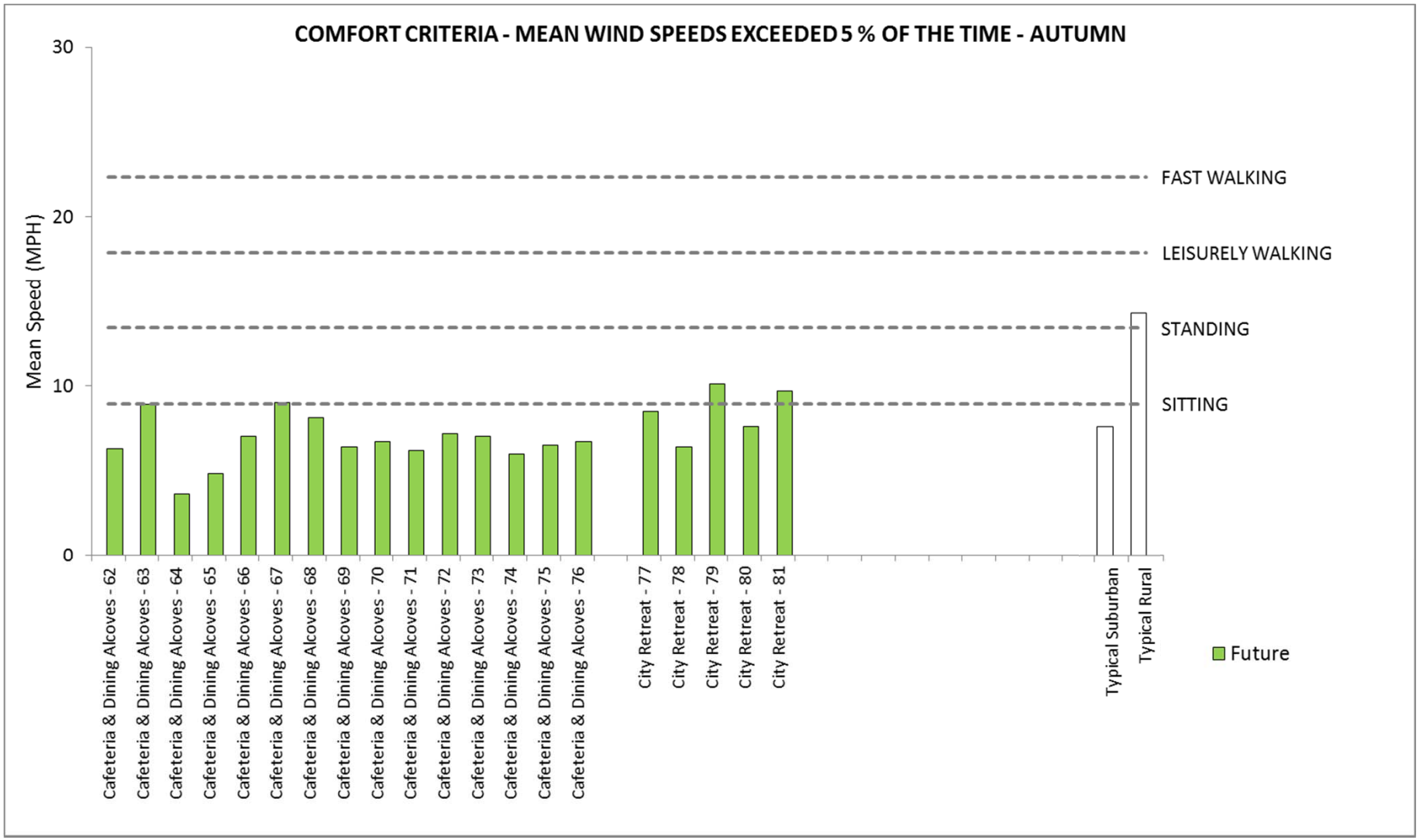

Figure A8: Wind Comfort Results for Cafeteria & Dining Alcoves and City Retreat - Autumn