THEAKSTON ENVIRONMENTAL

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REPORT

PRELIMINARY PEDESTRIAN LEVEL WIND STUDY

506-516 Church Street

Toronto, Ontario

Graywood CM Limited Partnership

REPORT NO. 20601wind **July 9, 2020**

An International Reputation for Excellence

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1. EXECUTIVE SUMMARY

The mixed-use Development proposed by Graywood CM Limited Partnership for 506-516 Church Street in the City of Toronto, has been assessed for environmental standards with regard to pedestrian level wind velocities relative to comfort and safety. The pedestrian level wind and gust velocities measured for the forty (40) locations tested were quantitatively assessed and determined well within safety criteria and most are within the comfort criteria described within.

The proposed new building at 506-516 Church Street, herein referred to as the proposed Development, involves a plan to develop a 15 storey building that steps back from Church Street and the existing 508-510 Church Street façade that will remain. Rooftop Outdoor Amenity Spaces are proposed within a central 2nd level courtyard and atop a 4th level step in the southeast façade. Based upon this analysis, wind conditions on and around the proposed Development are predicted to be suitable for the intended purposes, under normal to high ambient wind conditions.

The proposed Development is, for all intents and purposes, surrounded to prevailing windward directions by an urban mix of buildings supporting residential and commercial uses, with related open areas and mature vegetation that present a relatively coarse terrain to approaching winds, limiting the wind's opportunity to accelerate upon approach from most directions. Along with existing buildings in the surroundings, approved developments and buildings under construction were included on the site proximity model.

Urban developments provide surface roughness, which induces turbulence that can be wind friendly, while suburban settings similarly, though to a lesser extent, prevent wind from accelerating as the wind's boundary layer profile thins at the pedestrian level. Conversely, open settings afford wind the opportunity to accelerate. High-rise buildings typically exacerbate wind conditions within their immediate vicinity, to varying degrees, by redirecting wind currents to the ground level and along streets and open areas. Transition zones from open, and/or suburban, to urban settings often prove problematic, as winds exacerbated by relatively more open settings are redirected to flow over, around, down, and between buildings.

The proposed Development penetrates winds that formerly flowed over the site. The increased blockage relative to the existing setting causes wind to redirect to flow over the building, without consequence, and/or, depending upon the angle of incidence, around, or down the building towards the pedestrian level, as downwash. The Development features various stepped conditions that discourage downwash associated with prevailing winds, deflecting a portion of said flows around the building at elevations well above the pedestrian level. This mitigative design feature as well as other wind friendly design elements: irregular façades, balconies, canopies, overhangs and others, when considered in concert, further moderate wind.

Comfort conditions expected at the proposed Development site are in many cases similar to the existing setting, and considered acceptable to the urban context. Where mitigation was required, it was achieved through the incorporation of the following design features:

- parapet walls
- stepped façades
- overhangs
- canopies
- balconies
- landscaping

and others, that were included in the proposed Development's massing and landscape design. The mitigation features contribute to pedestrian comfort conditions that are suitable to the context. The proposed entrances and Outdoor Amenity Spaces of the proposed Development are expected to realise conditions suitable to the intended use and no further mitigation is required. The proposed Development will realize wind conditions acceptable to a typical urban context.

Respectfully submitted,

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2. INTRODUCTION

Graywood CM Limited Partnership retained Theakston Environmental to study the pedestrian level wind environment for the proposed Development located at 506-516 Church Street in the City of Toronto as shown on the aerial photo in Figure 2a. The proposed Development involves construction of a 15 storey mixed-use building, in a configuration as shown in Figure 2b, the Site Plan.

Quinlan Liang of Graywood Developments initiated the request and Diamond Schmitt Architects provided architectural drawings. The co-operation and interest of the Client and their sponsors in all aspects of this study is gratefully acknowledged.

The specific objective of the study is to determine areas of higher than normal wind velocities induced by the shape and orientation of the proposed building and surroundings. The wind velocities are rated in accordance with the safety and comfort of pedestrians, notably at entrances to the building, sidewalks, courtyards on the property, as well as other buildings in the immediate vicinity.

In order to obtain an objective analysis of the wind conditions for the property, the wind environment was tested in two configurations. The existing configuration included the low-rise commercial buildings currently on site as well as existing and approved buildings in the surrounding area. The proposed configuration replaced the existing buildings with the proposed Development. Mitigation procedures were assessed during these tests to determine their impact on the various wind conditions.

The laboratory techniques used in this study are established procedures that have been developed specifically for analyses of this kind. The methodology, summarized herein, describes criteria used in the determination of pedestrian level wind conditions. The facilities used by Theakston are ideal for observance of the Development at various stages of testing, and the development of wind mitigation measures, if necessary.

3. OBJECTIVES OF THE STUDY

1. To quantitatively assess, by model analyses, the pedestrian level wind environment under existing conditions and future conditions with the proposed Development.

2. To assess mitigative solutions.

3. To publish a Consultant's report documenting the findings and recommendations.

4. METHOD OF STUDY

4.1 General

The Theakston Environmental wind engineering facility was developed for the study of, among other sciences, the pedestrian level wind environment occurring around buildings, with focus on the safety and comfort of pedestrians. To this end, physical scale models of proposed Development sites, and immediate surroundings, are built, instrumented and tested at the facility with resulting wind speeds measured for different wind directions at various locations likely to be frequented by pedestrians. This quantitative analysis provides predictions of wind speeds for various probabilities of occurrence and for various percentages of time that are ultimately weighted relative to a historical range of wind conditions, and provided to the client

The techniques applied to wind and other studies carried out at the facility, utilise a boundary layer wind tunnel and/or water flume (Figure 1). The testing facility has been developed for these kinds of environmental studies, and has been adapted with equipment, testing procedures and protocols, in order to provide results comparable to full scale. The Boundary Layer Wind Tunnel lends itself well to the simultaneous acquisition of large data streams while the water flume is excellent for flow visualisation.

The purpose of this Pedestrian Level Wind Study is to evaluate the pedestrian level wind speeds for a full range of wind directions. To accomplish this, the wind's mean speed boundary layer profiles are simulated and applied to a site-specific model under test, instrumented with differential pressure probes at locations of interest. During testing, pressure readings are taken over a one-hour model scale period of time, at a full-scale height of approximately 1.8m and correlated to mean and gust wind speeds, expressed as ratios of the gradient wind speed.

The mean and gust wind speeds at the forty (40) points tested were subsequently combined with the design probability distribution of gradient wind speed and direction, (wind statistics) recorded at Airports in the vicinity, to provide predictions of the full-scale pedestrian level wind environment. Predictions of the full-scale pedestrian level wind environment are presented as the wind speed exceeded 5% of the time, based on annual, and wind for the seasons in Figures 6a – 6e. Criterion employed by Theakston Environmental was developed by others and us and published in the attached references. The methodology has been applied to over 800 projects on this continent and abroad.

4.2 Meteorological Data

The wind climate for Toronto that was used in the analysis was based on historical records of wind speed and direction measured at Pearson International Airport for the period between 1980 and 2017. The meteorological data includes hourly wind records and annual extremes. The analysis of the hourly wind records provides information to develop the statistical climate model of wind speed and direction. From this model, predicted wind speeds regardless of wind direction for various return periods can be derived. The record of annual extremes was also used to predict wind speeds at various return periods. Based on the analysis of the hourly records, the predicted hourly-mean wind speed at 10m, corrected for a standard open exposure definition, is 25 m/s for a return period of 50 years.

4.3 Statistical Wind Climate Model

For the analysis of the data, the wind climate model is converted to a reference height of 500m using a standard open exposure wind profile. The mean-hourly wind speed at a 500m reference height used for this study is 45.6m/s for a return period of 50 years. The corresponding 1-year return period wind speed at the 500m height is 36m/s.

The design probability distribution of mean-hourly wind speed and wind direction at reference height is shown for Pearson International Airport in Figure 5. Both annual and seasonal distributions are shown. From this it is apparent that winds can occur from any direction, however, historical data indicates the directional characteristics of strong winds are north through west to southwest and said winds are most likely to occur during the winter and spring seasons.

4.4 Wind Simulation

To simulate the correct macroclimate, the upstream flow passes over conditioning features placed upstream of the model, essentially strakes and an appropriately roughened surface, as required to simulate the full-scale mean speed boundary layer approach flow profiles occurring at the site.

4.5 Pedestrian Level Wind Velocity Study

A physical model of the proposed Development and pertinent surroundings, including existing buildings, roadways, pathways, terrain and other features, was constructed to a scale of 1:500. The model is based upon information gathered during a site visit to the proposed Development site, and surrounding area. Diamond Schmitt Architects provided architectural drawings. City of Toronto aerial photographs and site visit photographs were also used in development of the model to ensure the model reasonably represents conditions at the proposed Development. The model is constructed on a circular base so that, by rotation, any range of wind directions can be assessed. Structures and features that are deemed to have an impact on the wind flows are included upwind of the scale model.

In these studies, the effects of wind were analysed using omni-directional wind velocity probes that are placed on the model and located at the usual positions of pedestrian activity. The probes measure both mean and fluctuating wind speeds at a height of approximately 1.8m. During testing, the model sample period is selected to represent 1hr of sampling time at full scale. The velocities measured by the probes are recorded by a computerized data acquisition system and combined with historical meteorological data via a post-processing program.

4.6 Pedestrian Comfort Criteria

The assignment of pedestrian comfort takes into consideration pedestrian safety and comfort attributable to mean and gust wind speeds. Gusts have a significant bearing on safety, as they can affect a person's balance, while winds flowing at or near mean velocities have a greater influence upon comfort.

Figure 6 presents results for the mean wind speed that is exceeded 5% of the time. These speeds are directly related to the pedestrian comfort at a particular point. The overall comfort rating, for existing and proposed, are depicted in Figure 7. Table 1, below, summarizes the comfort criteria used in the presentation of the results depicted in Figures 6 and 7.

Table 1: Comfort Criteria

ACTIVITY	Mean Wind Speed Exceeded 5% of the Time		Description
COMFORT	***km/h***	***m/s*** (used in Fig. 6)	
Sitting	0-14	0-4	Tree leaves rustle, flags wave slightly. Recommended for outdoor space where people may sit for extended periods.
Standing	0-22	0-6	Small branches move, flags flap and ripple. Suitable for locations where people might sit for short periods or stand in relative comfort.
Leisurely Walking	0-29	0-8	Large branches sway, umbrellas used with difficulty, flags beat and pop. Suitable for activity areas.
Fast Walking	0-36	0-10	Whole trees sway, difficult to walk. This is considered the acceptable upper limit for comfort for the average population.
Uncomfortable	>36	>10	Winds exceed the "Fast Walking" category, can be tolerable for short duration, but will likely be an inconvenience to walking.

The activities are described as suitable for Sitting, Standing, Leisurely Walking or Fast Walking, depending on average wind speed exceeded 5% of the time. For a point to be rated as suitable for Sitting, for example, the wind conditions must not exceed 14*km/h* (4*m/s*), more than 5% of the time. Thus, in the plots (Figure 6), the upper limit of each bar ends within the range described by the comfort category. For sitting, the rating would include conditions ranging from calm up to wind speeds that would rustle tree leaves or wave flags slightly, as presented in the Beaufort Scale included in the Appendices and in Table 1 above. As the name infers, the category is recommended for outdoor space where people might sit for extended periods.

The Standing category is slightly more tolerant of wind, including wind speeds from calm up to 22*km/h* (6*m/s*). In this situation, the wind would rustle tree leaves and, on occasion, move smaller branches while flags flap and ripple. This category would be suitable for locations where people might sit for short periods or stand in relative comfort. The Leisurely Walking category includes wind speeds from calm up to 29*km/h* (8*m/s*). These winds would set tree limbs in motion, lift leaves, litter and dust, and the locations are suitable for activity areas. The Fast Walking category is much more tolerant of wind, including wind speeds up to 36*km/h* (10*m/s*). In this case, whole trees would sway and it would be difficult to walk. This is considered as the acceptable upper limit for comfort for the average population. The Uncomfortable category covers a broad range of wind conditions, including wind speeds above 36*km/h* (10*m/s*).

In Figure 6, the probe locations are listed along the bottom of the chart; beneath the graphical representation of the Mean Wind Speed exceeded 5% of the time. Along the right edge of the plot the comfort categories are shown. The background of the plot is lightly shaded in colours corresponding to the categories shown in Table 1. Each category represents a 2*m/s* (or more) interval. The location is rated as suitable for Sitting, Standing, Leisurely Walking or Fast Walking, if the bar extends into the corresponding interval.

The charts represent the average person's response to wind force annually and for four seasons. Effects such as wind chill and humidex (based on perception) are not considered. Also clothing is not considered, since clothing and perceived comfort varies greatly among the population. There are many variables that contribute to a person's perception of the wind environment beyond the seasonal variations presented. While people are generally more tolerant of wind during the summer months, than during the winter, due to the wind cooling effect, people become acclimatized to a particular wind environment. Persons dwelling near the shore of an ocean, large lake or open field are more tolerant of wind than someone residing in a sheltered wind environment.

4.7 Pedestrian Safety Criteria

Safety criteria are also included in the analysis to ensure that strong winds do not cause a loss of balance to individuals occupying the area. The safety criteria are based on wind speeds exceeded once per year as shown in Table 2.

Both the Comfort and Safety Criteria are based on those developed at the Allan G. Davenport Wind Engineering Group Boundary Layer Wind Tunnel Laboratory, located on the campus of The University of Western Ontario. These criteria were developed for pedestrian wind studies and are used in studies around the world.

Table 2: Safety Criteria

ACTIVITY	Mean Wind Speed Exceeded once per year		Description
SAFETY	***km/h***	***m/s*** (used in Fig. 8)	
All-Weather Areas	0 - 54	0 - 15	Areas that need to be used in all weather conditions, such as building entrances, sidewalks, etc.
Fair-Weather Areas	0 - 72	0 - 20	Areas that are not used or can be closed in severe weather, such as park benches, lookout points, etc.
Exceeding Fair Weather Areas	>72	>20	Areas that are considered to pose a serious hazard and are undesirable regardless of activity.

4.8 Pedestrian Comfort Criteria – Seasonal Variation

The level of comfort perceived by an individual is highly dependent on seasonal variations of climate. Perceived comfort is also specific to each individual, and depends on the clothing choices. The comfort criterion that is being used averages the results across the general population to remove effects of individuals and clothing choices, however, seasonal effects are important. For instance, a terrace or outdoor amenity space may have limited use during the winter season, but require acceptable comfort during the summer.

The comfort of a site is based on the “annual” results of the study, Figures 6a and 7a and 7b. In cases where seasonal comfort is important, results have been included for the seasons; winter, spring, summer, and fall (see Figures 6b to 6e and Figures 7c to 7j).

When compared to the annual average wind speed, winter winds are about 12.5% higher and summer winds are about 16% lower.

5. RESULTS

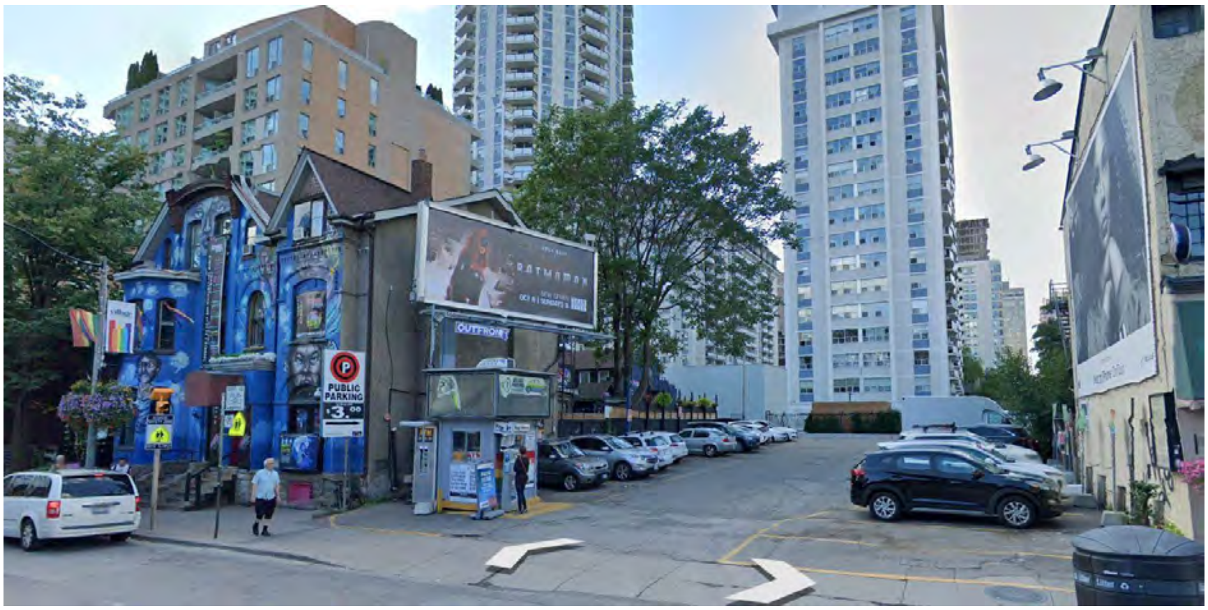
5.1 Study Site and Test Conditions

<u>Subject Site</u>

The proposed Development occupies a portion of the block of lands bound by Maitland Street to the north, Church Street to the east, Alexander Street to the south, and Donna Shaw Lane to the west. The subject parcel of land is currently occupied by 2 low-rise commercial buildings with the façade of 508-510 Church Street to remain. The Development site shares the block with additional low-rise buildings to the immediate north and south at 518 Church Street and

504 Church Street, as well as an 11 storey building at 70 Alexander Street. The site and its immediate surrounds are shown in Figure 2a.

The proposed Development is a 15 storey building that steps back from Church Street and the existing 508-510 Church Street façade that will remain. The main residential lobby entrance is accessed at the southeast corner of the building along Church Street, with commercial entrances also proposed along Church Street and Donna Shaw Lane. Vehicular access to the underground parking area is proposed via Donna Shaw Lane. Rooftop Outdoor Amenity Spaces are proposed within a central 2nd level courtyard and atop a 4th level step in the southeast façade. The site plan is presented in Figure 2b.



View of the existing conditions at 506-516 Church Street looking southwest (Google).

Surrounding Area

Urban lands supporting commercial and residential buildings bound the Property to all compass points.

The site shares its immediate surrounds with low rise commercial buildings abutting the site to the north and south at 518 Church Street and 504 Church Street, respectively, with an 11 storey building just beyond to the south at 70 Alexander Street. To the southwest, across Alexander Street, are the three 14 storey City Park Cooperative Apartment buildings at 484 Church Street and 51 and 31 Alexander Street. To the southeast is the low-rise Church Street Junior Public School and related open lands.

To the west of the Development site are the Village Green Apartments consisting of two 19 storey slab-style apartment buildings and a 28 storey cylindrical building with low to mid-rise buildings beyond. To the north of the site are mainly low-rise residential and commercial buildings fronting Maitland Street and beyond, with an 18 storey residential tower to the northeast at 100 Maitland Street. To the east of the Development site are further low-rise commercial and residential buildings fronting Church Street, Alexander Place, and Mutual Street, with a 10 storey residential building at 100 Alexander Street.

Lands in the surrounding area are slated for urban intensification and are in the various stages of approvals. To the west of the Development site, along Yonge Street, are 52 and 23 storey towers proposed for 501 Yonge Street, as well as 48 and 58 storey towers proposed for 475 Yonge Street. To the northwest of the Development site is a 45 storey tower proposed at 20-26 Maitland Street. Further to the north is a 37 storey tower proposed at 46 Wellesley Street East, as well as a 39 storey tower at 66 Wellesley Street East and a 12 storey building at 572 Church Street. To the northeast of the development site is a 29 storey tower proposed for 81 Wellesley Street East. To the south of the site are 28 and 9 storey buildings proposed at 411 Church Street and 70 Carlton Street, respectively.

In summary, various low to high-rise developments occupy the immediate surrounds, with lands subject to urban intensification slated for lands further removed from the site. Figures 2a and 2b depict the site and its immediate context. The site model, shown in Figure 3, is built to a scale of 1:500.

Macroclimate

For the proposed Development, the upstream wind flow during testing was conditioned to simulate an atmospheric boundary layer passing over urban terrain. The terrain within the site's immediate vicinity was incorporated into the proximity model. Historical meteorological data recorded from the Toronto Pearson International Airport was used in this analysis. The data is presented as annual as well as for the four seasons, winter, spring, summer, and fall; the resulting wind roses are presented as mean velocity and percent frequency in Figures 5a-e. Note: Weather data recorded at stations nearer the site were considered in the analysis, however, considering the fulsomeness of available data, proximity to water, and immediate surroundings, Pearson was deemed most appropriate for assessment purposes. The mean velocities presented in the wind roses are measured at an elevation of 10m. Thus, representative ground level velocities at a height of 2m, for an urban macroclimate, are 52% of the mean values indicated on the wind rose (for suburban and rural macroclimates the values are 63% and 78% respectively). The macroclimate for the proposed Development area varies, with the terrain types associated with wind direction, resulting in what are considered urban terrains. Urban terrain types dominate pertinent surroundings to most compass points, with suburban lands occupying immediate surrounds to the north and east of the site.

Winter (November 16 to March 31) has the highest mean velocities of the seasons with prevailing winds from the north and west, with significant components from north through west to southwest as indicated in Figure 5b. Spring (April 1 to June 15) has the second highest mean wind velocities and the prevailing winds tend to be from the North to West quadrant (Figure 5c). Summer (June 16 to September 15) has the lowest mean wind velocities of the seasons with prevailing winds from north through west to south as indicated in Figure 5d. During the fall, (September 16 to November 15) the possible directions for prevailing winds include the North to Southwest sector (Figure 5e). The magnitudes of the mean wind velocities are between spring and summer winds. Reported pedestrian comfort conditions pertain to annual, unless stated otherwise.

5.2 Pedestrian Level Wind Velocity Study

On the site model forty (40) wind velocity measurement probes were located on and around the proposed Development, other buildings and activity areas to determine conditions related to comfort and safety. Figure 4 depicts probe locations at which pedestrian level wind velocity measurements were taken in the existing and proposed scenarios. For the existing setting, the subject building was removed, and the site model was retested with the existing buildings.

Measurements of pedestrian level mean and gust wind speeds at the various locations shown were taken over a period of time equivalent to one hour of measurements at full-scale. The mean ground level wind velocity measured is presented as a ratio of gradient wind speed, in the plots of Figure B in the Appendix, for each point in the existing and proposed scenarios. These relative wind speeds are presented as polar plots in which the radial distance for a particular wind direction represents the wind speed at the location for that wind direction, expressed as a ratio of the corresponding wind speed at gradient height. They do not assist in assessing wind comfort conditions until the probability distribution gradient wind speed and direction is applied.

The design probability distribution gradient wind speed and direction, taken from historical meteorological data for the area (Figures 5a – 5e) was combined with pedestrian level mean and gust wind speeds measured at each point to provide predictions of the percentage of time a point will be comfortable for a given activity. These predictions of mean and maximum or "gust" wind speeds are provided on an annual and seasonal basis in Figures 6a - 6e.

The ratings for a given location are conservative by design; when the existing surroundings and proposed building's fine massing details and actual landscaping are taken into consideration, the results tend toward a more comfortable site than quantitative testing alone would indicate.

Venturi action, scour action, downwash and other factors, as discussed in the Appendix on wind flow phenomena, can be associated with large buildings, depending on their orientation and configuration. These serve to increase wind velocities. Open areas within a heavily developed area may also encounter high wind velocities. Consequently, wind force effects are common in heavily built-up areas. The Development site is surrounded by an urban setting to prevailing and remaining compass points with winds generally flowing over low-rise and high-rise residential, retail and industrial buildings. As such, the surroundings can be expected to influence wind at the site to varying degrees.

It should be noted that the probes are positioned at points typically subject to windy conditions in an urban environment in order to determine the worst-case scenario.

Review of Probe Results

The probe results, as follows, were clustered into groups comprised of Public Street Conditions, Neighbouring Site Conditions, Pedestrian Entrance Conditions, and Outdoor Amenity

Conditions. The measurement locations are depicted in Figure 4 and are listed in Figures 6a – 6e annually and for the seasons for the existing and proposed configurations. The results are also graphically depicted for the existing and proposed configurations annually, and for the seasons in Figures 7a – 7j. The following discusses anticipated wind conditions and suitability for the points' intended use.

5.2.1 Public Street Conditions

Church Street

Probes 1 through 15, and 35 and 36, were located along Church Street, within the zone of influence of the proposed Development. Their locations are depicted in Figure 4, their comfort ratings are listed annually and for each of the seasons in Figures 6a – 6e and depicted in Figures 7a through 7j. Probes situated on Church Street indicate wind conditions in the existing setting that are mainly suitable for sitting or standing on an annual basis, with the exception of probe 1 that is located at the intersection with Wellesley Street East, and rated suitable for leisurely walking. The comfortable conditions can be attributed to the mainly low-rise buildings flanking Church Street, with windier conditions realised proximate to high-rise developments that tend to deflect winds to flow down and around buildings and ultimately along portions of Church Street.

With inclusion of the proposed Development a general realignment of pedestrian wind conditions was noted along the street, the changes insufficient to change the predicted annual pedestrian comfort levels, with a few exceptions. Probe 4, situated at the corner of Church Street and Maitland Street, realised a sufficient increase in winds to change the annual rating from standing to leisurely walking and probe 12 similarly changed annual ratings from sitting to standing. Conversely, probes 6 and 14 realised an improvement in winds with inclusion of the proposed Development that changed the annual rating from standing to sitting.

The above noted can be attributed to the proposed Development causing a realignment of winds that reduces apparent wind effects at the pedestrian level for several points for several wind directions, but causes an increase in winds for others, as indicated in the Appendices Figure B, Ground Level Wind Velocity Plots presented as a ratio of gradient wind velocity. Increased winds are attributed to the proposed Development redirecting winds through downwash and other phenomena, to flow along portions of Church Street. For probes 4 and 12, dominant winds emanating from the west and flowing down Maitland Street, will come in contact with the proposed Development and flow down and along the façade and around the corner, resulting in elevated wind conditions. Conversely, the improvements noted at a few probes along Church Street to the southwest of the development site can be attributed to additional blockage to winds emanating from dominant northwesterly directions with incorporation of the proposed building.

The subtle changes to wind conditions realised along Church Street are a reasonable expectation understanding that the proposed Development, while involving a substantial change to the proposed Development site, is a relatively minor change to the streetscape, given the tower steps back significantly from the street. The proposed Development employs an overall wind mitigative design including a stepped massing that has irregular façades and is punctuated with balconies, discouraging downwash.

As such, all probe locations along Church Street, with the above noted exceptions, retained their original annual pedestrian comfort ratings. The street remains suitable for its intended purpose year-round and for activities requiring longer exposure times, mainly suitable for sitting, through the summer. Consideration of existing and proposed building elements that are too fine to incorporate into the model, and landscaping, will result in more comfortable conditions than those reported. Note: probes are typically situated in activity areas that are of interest and/or anticipated to realise windy conditions, providing a conservative result.

Church Street falls within the pedestrian level wind velocity safety criteria as an All-Weather Area, as described in Section 4.7 and depicted in Figure 9.

Wellesley Street East

Probe 16 was located on Wellesley Street East, situated to the northwest of the proposed Development site. The probe was situated proximate to high-rise developments at 46 and 66 Wellesley Street East and as such realises relatively windy conditions in the existing setting, suitable for standing in the summer and leisurely walking through the remainder of the year. With inclusion of the proposed Development, the probe realises very similar conditions, retaining the existing comfort conditions. The area will remain suitable for the intended use and falls within the safety criteria as an All-Weather Area.

Maitland Street

Probes 17, 18, and 21 through 27 were located along Maitland Street, within the zone of influence of the proposed Development. In the existing setting, the probes situated along Maitland Street are annually rated as suitable for standing, with the exception of probe 17 that is rated for leisurely walking. In the winter months, windier conditions are realised along the street with conditions suitable for leisurely walking realised at probes 18, 23, and 26, and conditions rated for fast walking at probe 17. The windier conditions were noted proximate to higher-rise buildings and related open areas along the street that allow the wind to flow down and around the façades and ultimately over portions of the street.

With inclusion of the proposed Development, very similar conditions were noted along the street; the subtle changes were insufficient to change the annual ratings for any of the points. Through the winter months, probe 21 realised a subtle increase in winds that was sufficient to change the comfort rating from standing to leisurely walking. Conversely, probe 23 realised subtle improvements that changed the winter rating from leisurely walking to standing. Probe 17 realised very little change in wind conditions and remained rated for fast walking in the winter months.

The similar conditions noted along Maitland Street can be attributed to the proposed Development being removed from the street and employing overall wind mitigative design features. Maitland Street will remain comfortable and appropriate to the intended purpose. Consideration of proposed building elements that are too fine to incorporate into the model, and landscaping, will result in more comfortable conditions than those reported. Maitland Street falls within the pedestrian level wind velocity safety criteria as an All-Weather Area, as described in Section 4.7 and depicted in Figure 9.

Alexander Street

Probes 29 through 33 were situated along the above-named street situated to the south of the proposed Development. Their predicted comfort ratings are depicted in Figures 7a through 7j. In the existing setting, the street is annually rated as suitable for standing at probes 29, 32, and 33, with windier conditions, rated for leisurely walking, proximate to the 28 storey cylindrical Village Green Apartment building, and calmer conditions rated for sitting at probe 31. With inclusion of the proposed Development, probes along the street realise increased blockage to winds from specific directions, and exacerbated winds from others, resulting in overall similar comfort conditions. Probe 30 realised improvements to winds emanating from the northeast and southwest, improving the annual rating from leisurely walking to standing, while probe 33 realised an increase to winds from the east and west flowing along Alexander Street, changing the annual rating from standing to leisurely walking.

Similar to Maitland Street, the subtle changes to winds along Alexander Street with inclusion of the proposed Development can be attributed to the proposed Development being removed from the street and having an overall wind mitigative design. Consideration of proposed building elements that are too fine to incorporate into the model, and landscaping, will result in more comfortable conditions than those reported. Alexander Street falls within the pedestrian level wind velocity safety criteria as an All-Weather Area.

Mutual Street

Probe 34 was situated on Mutual Street, proximate to a 10 storey building at 100 Alexander Street. In the existing setting, the point was rated as suitable for standing year-round and with inclusion of the proposed Development, the comfort ratings were unchanged. The area will remain comfortable and suitable for the intended use and within the safety criteria as an All-Weather Area.

Donna Shaw Lane

Probes 37 and 38 were situated on Donna Shaw Lane, to the immediate west of the proposed Development, and were rated as annually suitable for standing in the existing setting. With inclusion of the proposed Development, the probes realised a significant realignment of winds due to the proposed Development redirecting winds to flow down and around the façades of the building and along adjacent streets, however the changes in winds did not alter the comfort ratings. Donna Shaw Lane will remain comfortable and suitable for the intended use and within the safety criteria as an All-Weather Area.

5.2.2 Neighbouring Site Conditions

Probes 19 and 20 were respectively located at the north and south entrances to the neighbouring slab style apartment building at 55 Maitland Street. The points were rated as suitable for sitting in the summer and standing through the remainder of the year in the existing setting. In the proposed setting, the areas realised an increase in blockage to winds emanating from the easterly directions, however winds from these directions are uncommon as seen in the Figure 5 Wind Roses, and as such the comfort ratings were unchanged. The entrances to the neighbouring apartment building at 55 Maitland Street will remain comfortable and suitable to the intended use.

Probe 28 was located between neighbouring buildings at 40 and 50 Alexander Street. The area is relatively well sheltered from the majority of the wind climate and as such realises conditions suitable for standing year-round in both the existing and proposed settings. The area remains comfortable and suitable for the intended use with inclusion of the proposed Development.

The above-mentioned neighbouring properties fall within the pedestrian level safety criteria as All-Weather Areas.

5.2.3 Pedestrian Entrance Conditions

Probe 36 was situated adjacent to the Main Entrance to the Residential Lobby along the Church Street sidewalk. The area is well sheltered from dominant winds emanating from the west through northwesterly directions and as such realises comfortable conditions, suitable for sitting year-round. The entrance is recessed into the façade of the building and incorporates a vestibule and as such is expected to realise more comfortable conditions than those reported. The Main Residential Entrance will be comfortable and appropriate to the area’s intended purpose.

Probes 35 and 5 were also located along the Church Street sidewalk adjacent to commercial entrances to the proposed Development. The areas are similarly protected from large portions of the wind climate as such will experience conditions suitable for sitting year-round. Probe 37 was situated along Donna Shaw Lane proximate to another commercial entrance to the proposed Development. The entrance is also well protected, however it will be exposed to occasional winds emanating from northeasterly directions that flow around the corner of the Development and over the area. The entrance is rated for standing year-round and will be comfortable for the intended use.

Wind conditions comfortable for standing are preferable at building entrances, while conditions suitable for walking are suitable for walkways. Conditions at the entrances to the proposed Development are considered appropriate to the area’s intended purpose, and will realise more comfortable conditions with consideration of design and landscape elements that were too fine to include in the massing model. The entrances to the proposed Development fall within the safety criteria as All-Weather Areas.

5.2.4 Outdoor Amenity Conditions

Outdoor Amenity Spaces are proposed for the 2nd and 4th levels of the proposed Development, as represented by probes 39 and 40. The 2nd level amenity space is located within an internal courtyard and as such is protected from the majority of the wind climate. The 2nd level space is predicted to be suitable for sitting year-round and suitable for the intended use. The 4th level amenity space is located atop a step on the southeast façade of the building and as such is protected from dominant winds emanating from the westerly through northwesterly directions. The space will be susceptible to winds from the easterly through northeasterly directions, however winds from these directions are uncommon as seen in the Figure 5 Wind Roses, and as such the 4th level amenity space is predicted to realise conditions suitable for sitting year-round and will be suitable for the intended use. The proposed Outdoor Amenity Spaces do not require further mitigation, and consideration of design and landscape features that were too fine to include in the model will result in conditions more comfortable than those reported. The amenity spaces are predicted comfortable and suitable for the intended use, and fall within the pedestrian safety criteria as All-Weather Areas.

5.3 Summary

The observed wind velocity and flow patterns at the proposed Development are largely influenced by approach wind characteristics that are dictated by the urban surrounding areas to prevailing and less dominant wind directions. These surroundings moderate wind flow in streamlines near the pedestrian level, resulting in generally comfortable conditions with localised windy conditions proximate to the corners of large buildings that are exposed to winds, and open areas within gaps between significant buildings. Historical weather data recorded at Pearson International Airport indicates that strong winds of a mean wind speed greater than 30 km/h occur approximately 13 percent of the time during the winter months and 4 percent of the time during the summer.

Once the subject site is developed, ground level winds at many locations will improve, with occasional localized areas of higher pedestrian level winds, resulting in wind conditions that are predicted as windy at times, but remain comfortable and appropriate to the areas' intended purpose throughout the year. The relationship between surface roughness and wind is discussed in the Appendix and shown graphically in Figure A of the same section.

As such, the site is mainly predicted suitable for sitting or standing under normal wind conditions annually; however, under high ambient winter wind conditions with winds emanating from specific directions, a few probe locations along adjacent streets will experience windier conditions, but remain appropriate to the intended purpose. The consideration of proposed surface roughness, and future urbanization will result in conditions more comfortable than those reported herein.

The proposed Development will realize wind conditions acceptable to a typical urban context.

6. FIGURES:

Figure 1: Laboratory Testing Facility

Figure 2a: Site Aerial Photo

Figure 2b: Site Plan

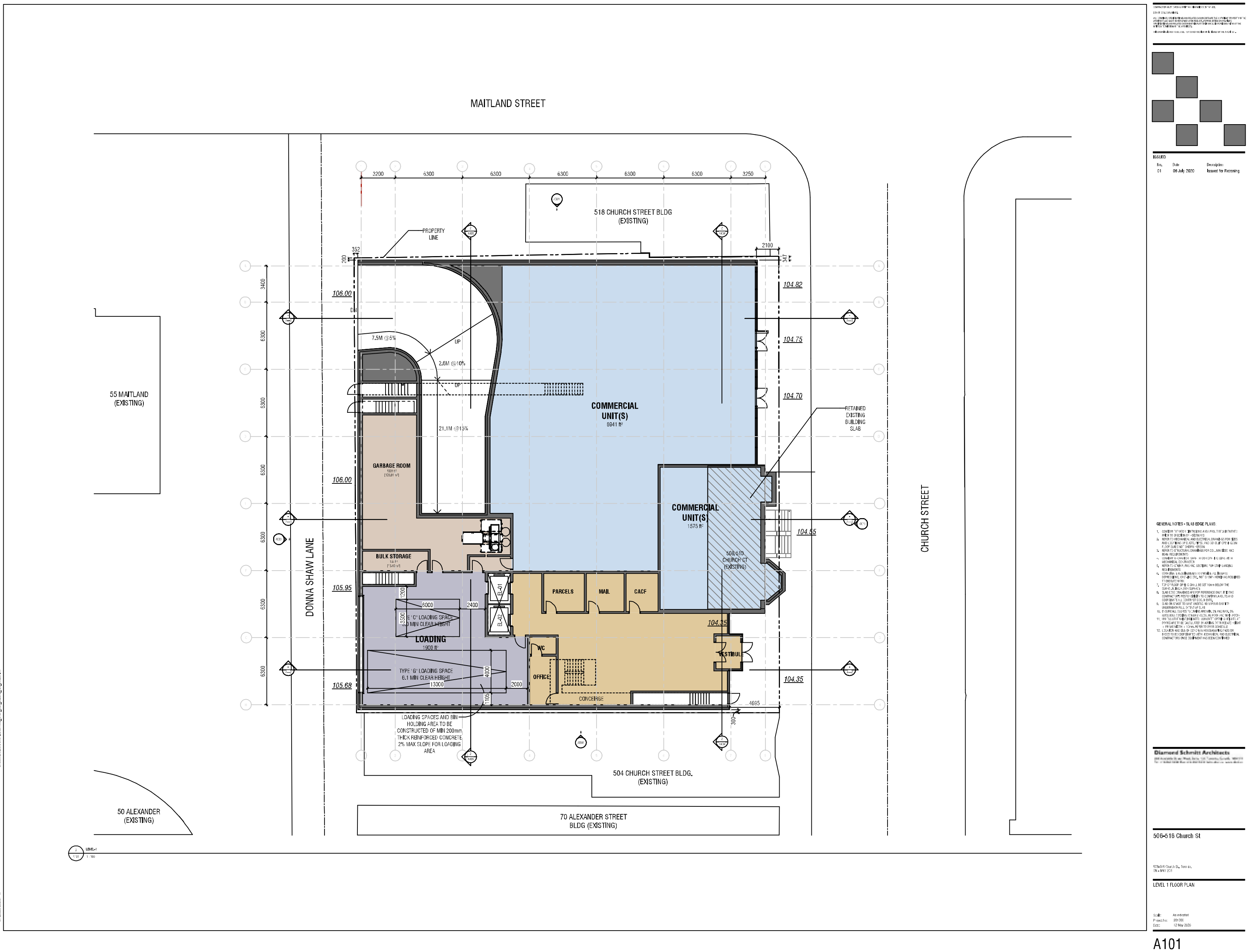
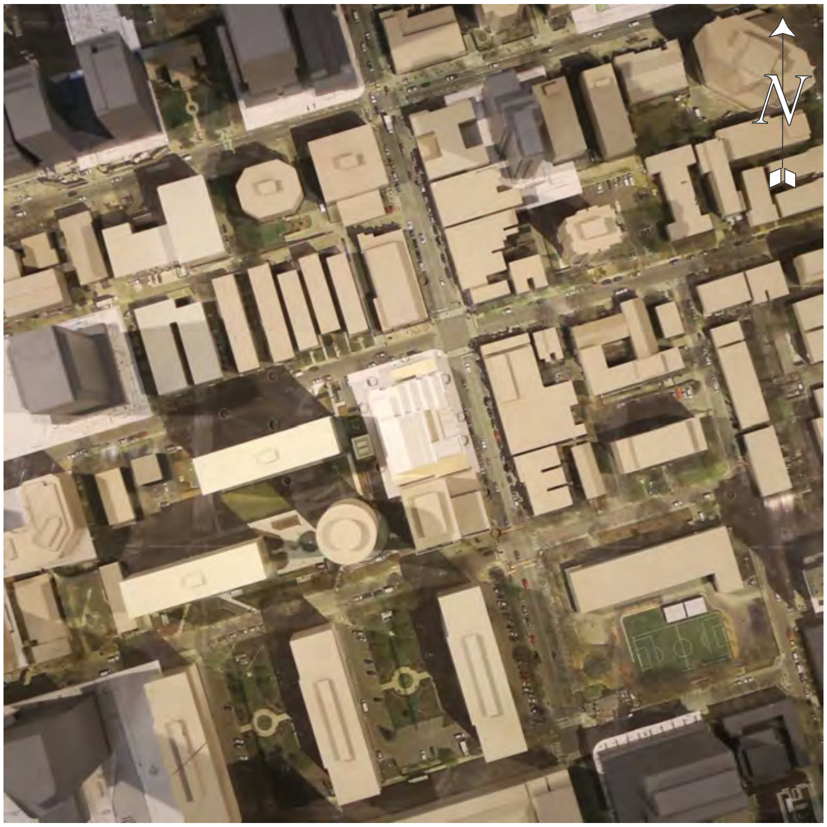
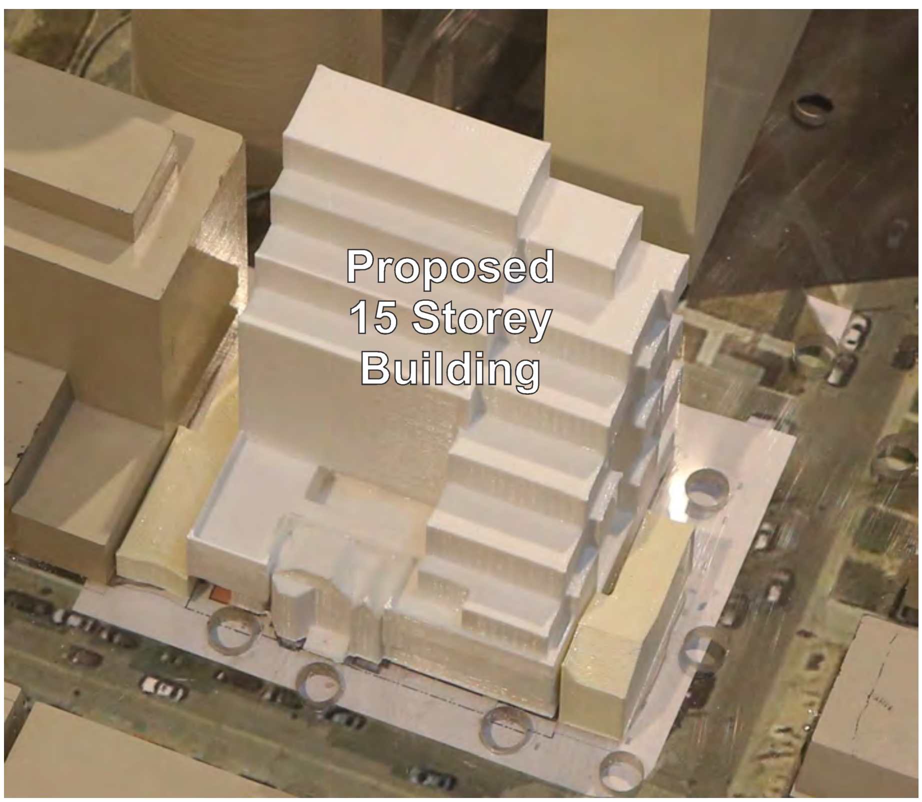


Figure 3: 1:500 Scale model of test site



a) Overall view of model - Proposed Site



b) Close-up view of model - Proposed Site

Figure 4: Location plan for pedestrian level wind velocity measurements.

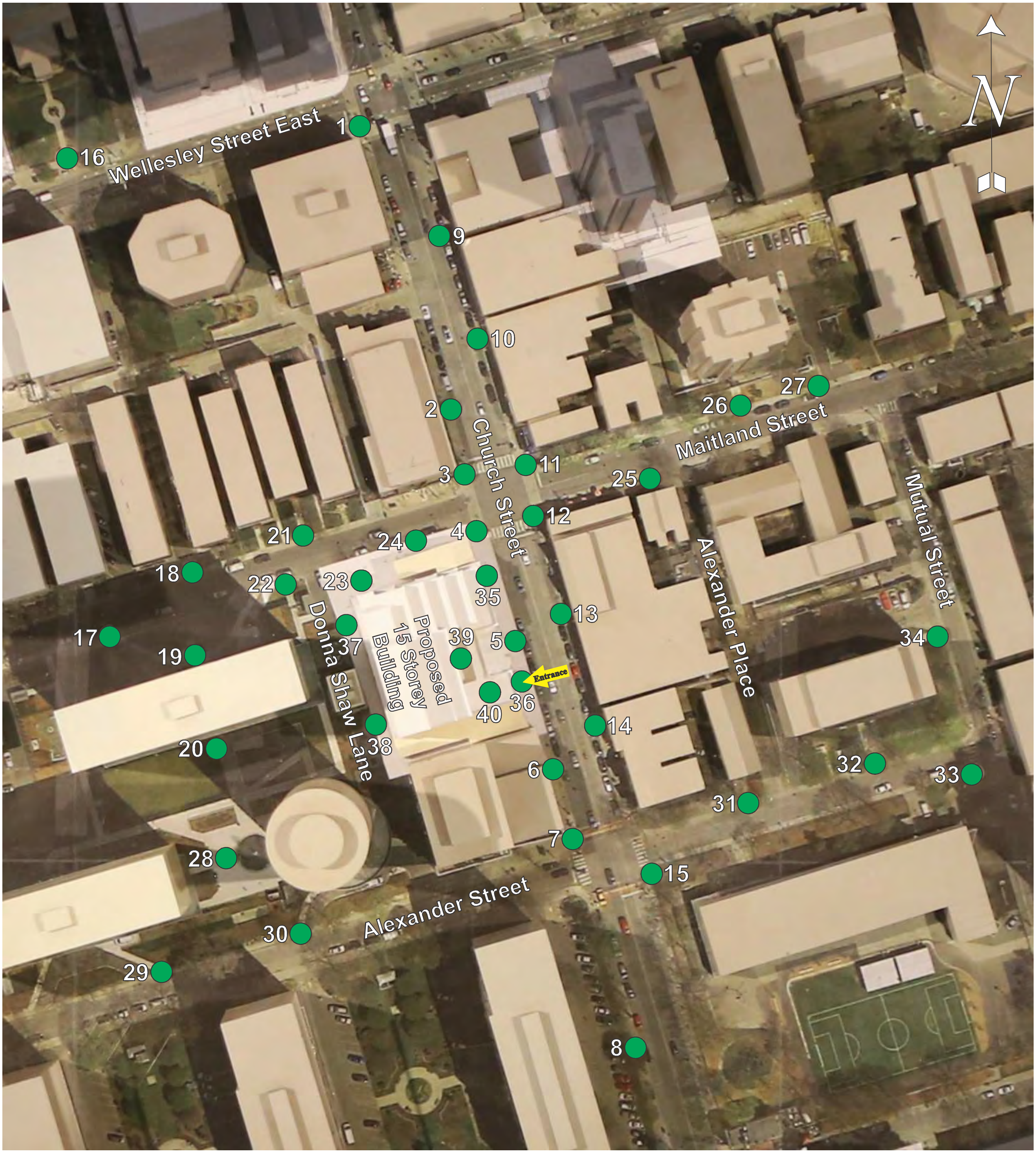


Figure 5a: Annual Wind Rose - Pearson International Airport.

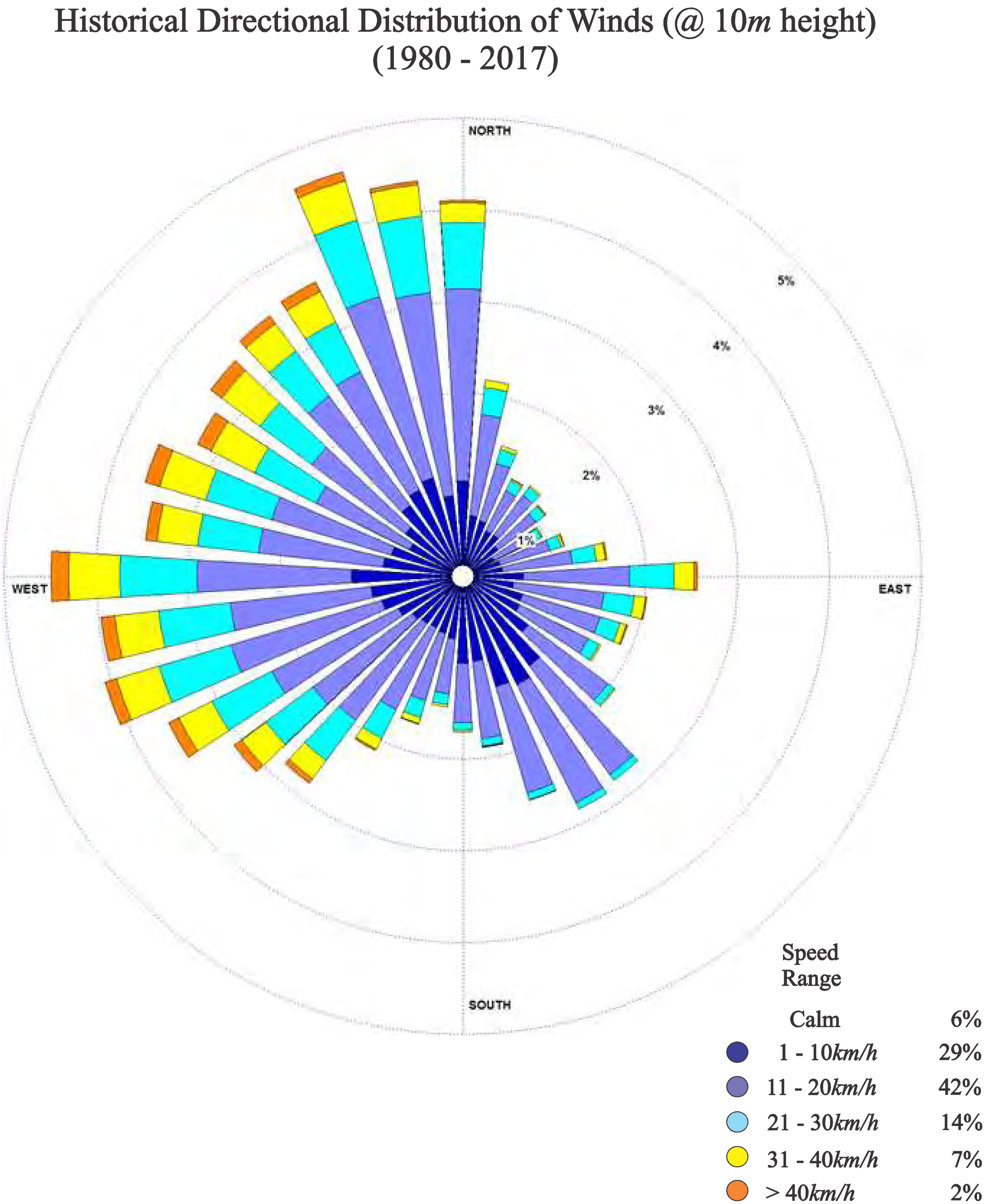
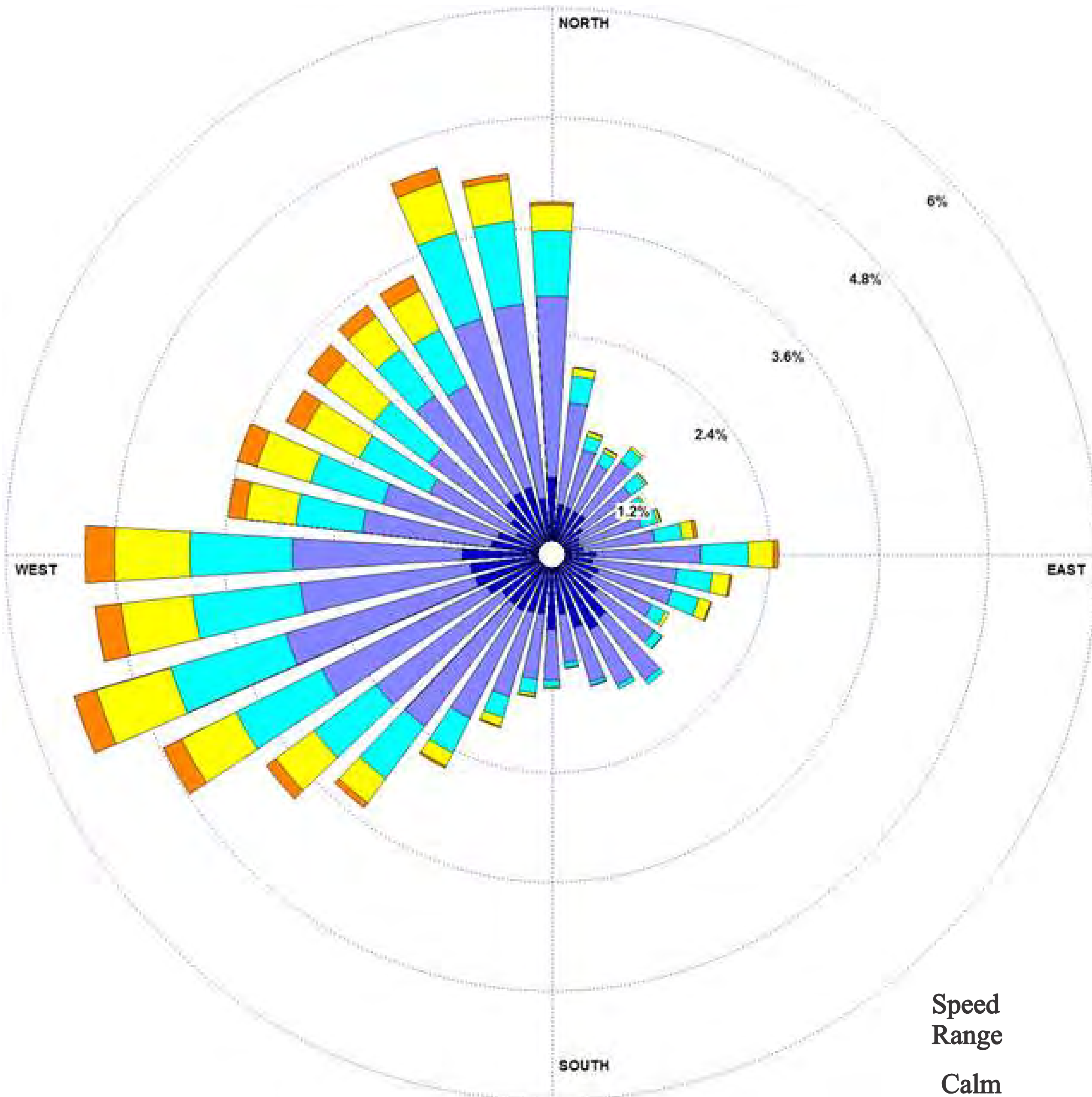


Figure 5b: Winter Wind Rose - Pearson International Airport.

Historical Directional Distribution of Winds (@ 10*m* height)
November 16 through March 31 (1980 - 2017)

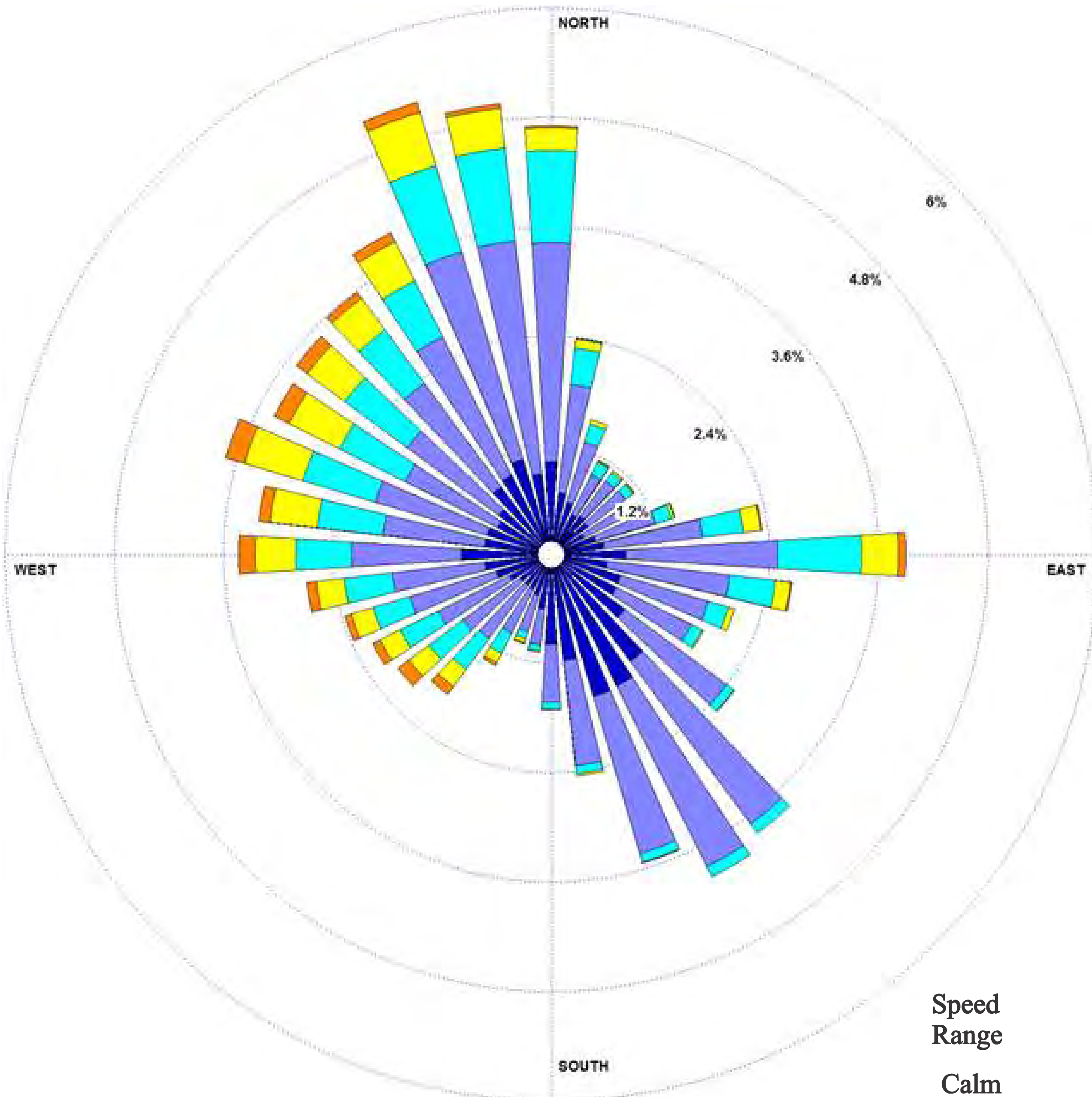


Speed Range

	Calm	5%
●	1 - 10*km/h*	23%
●	11 - 20*km/h*	41%
●	21 - 30*km/h*	18%
●	31 - 40*km/h*	10%
●	> 40*km/h*	3%

Figure 5c: Spring Wind Rose - Pearson International Airport.

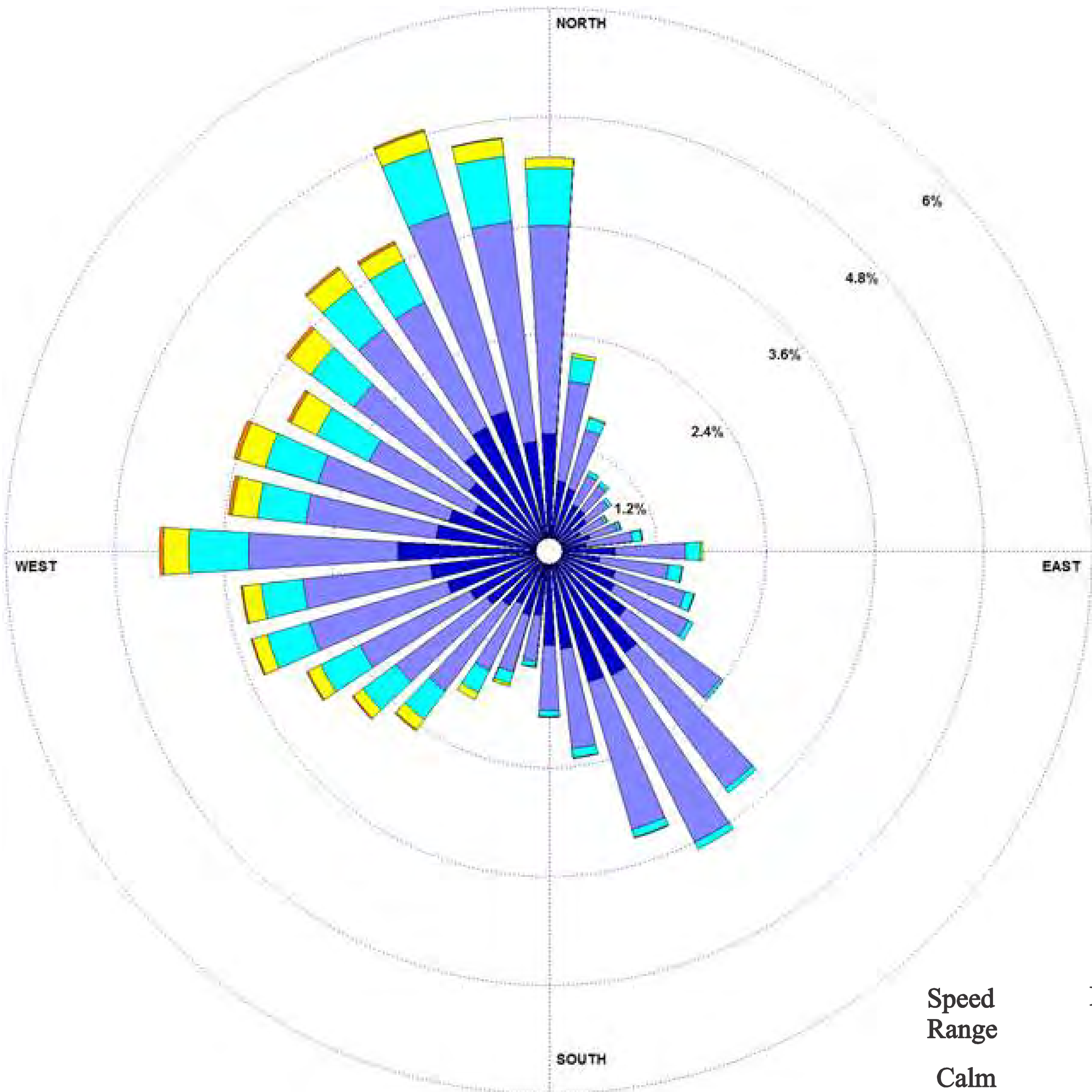
Historical Directional Distribution of Winds (@ 10*m* height)
April 1 through June 15 (1980 - 2017)



Speed Range	Probability (%)
Calm	5%
1 - 10*km/h*	28%
11 - 20*km/h*	42%
21 - 30*km/h*	15%
31 - 40*km/h*	8%
> 40*km/h*	2%

Figure 5d: Summer Wind Rose - Pearson International Airport.

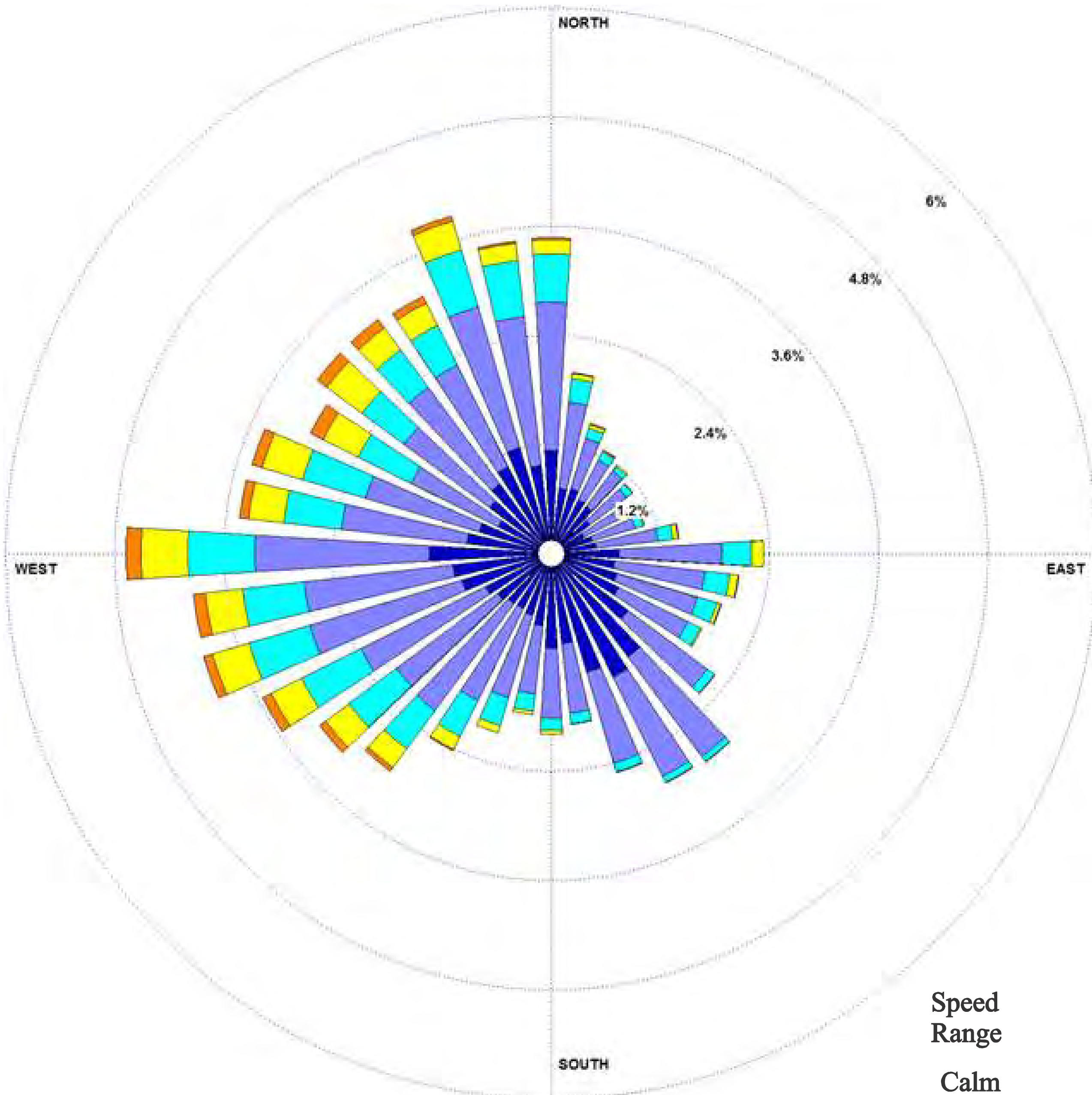
Historical Directional Distribution of Winds (@ 10*m* height)
June 16 through September 15 (1980 - 2017)



Speed Range	Probability (%)
Calm	8%
1 - 10*km/h*	35%
11 - 20*km/h*	42%
21 - 30*km/h*	11%
31 - 40*km/h*	4%
> 40*km/h*	<1%

Figure 5e: Fall Wind Rose - Pearson International Airport.

Historical Directional Distribution of Winds (@ 10*m* height)
September 16 through November 15 (1980 - 2017)



Speed Range	Probability (%)
Calm	8%
1 - 10*km/h*	31%
11 - 20*km/h*	40%
21 - 30*km/h*	13%
31 - 40*km/h*	6%
> 40*km/h*	2%

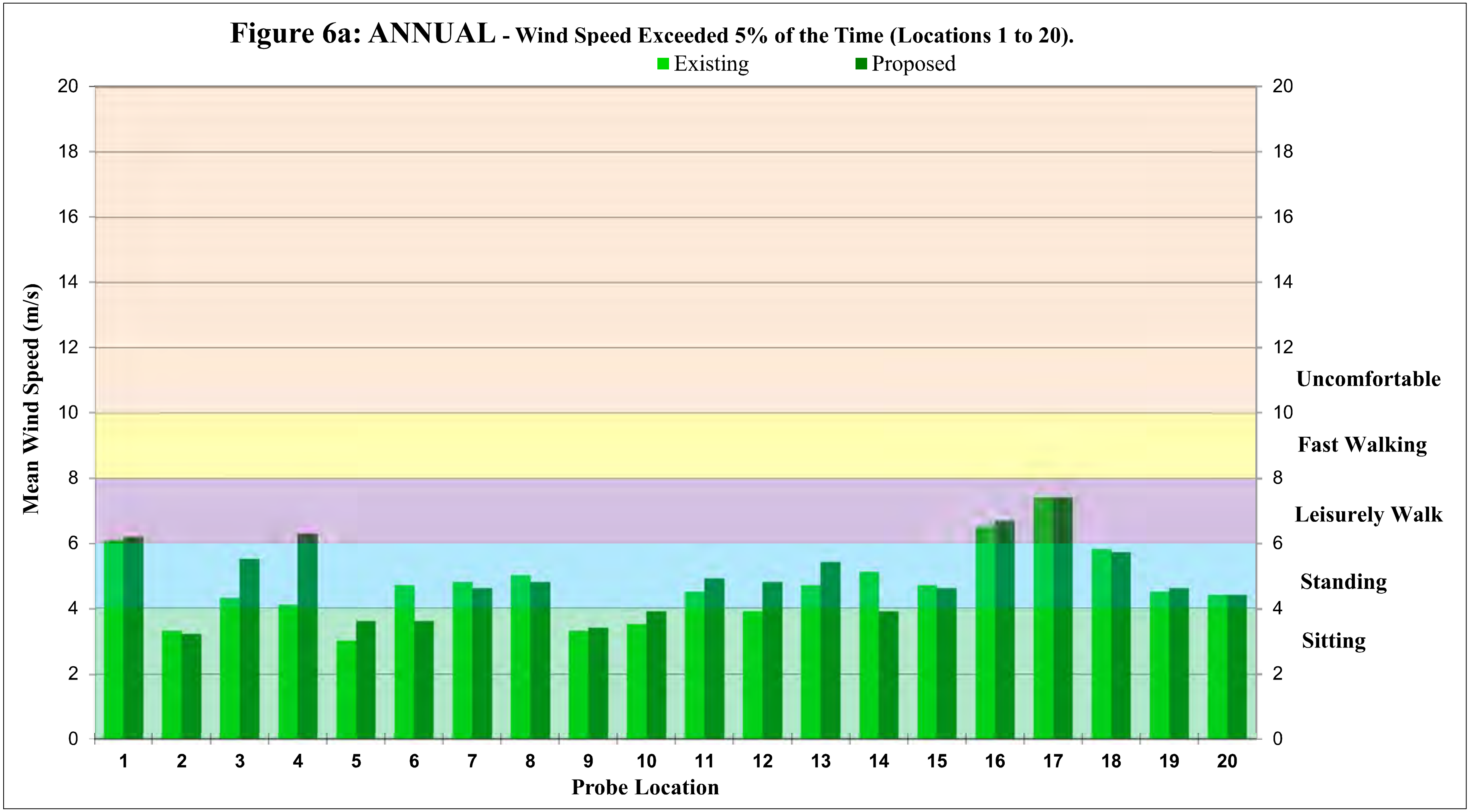


Figure 6a: ANNUAL - Wind Speed Exceeded 5% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Fast Walking
Leisurely Walk
Standing
Sitting
0
2
4
6
8
10
12
14
16
18
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

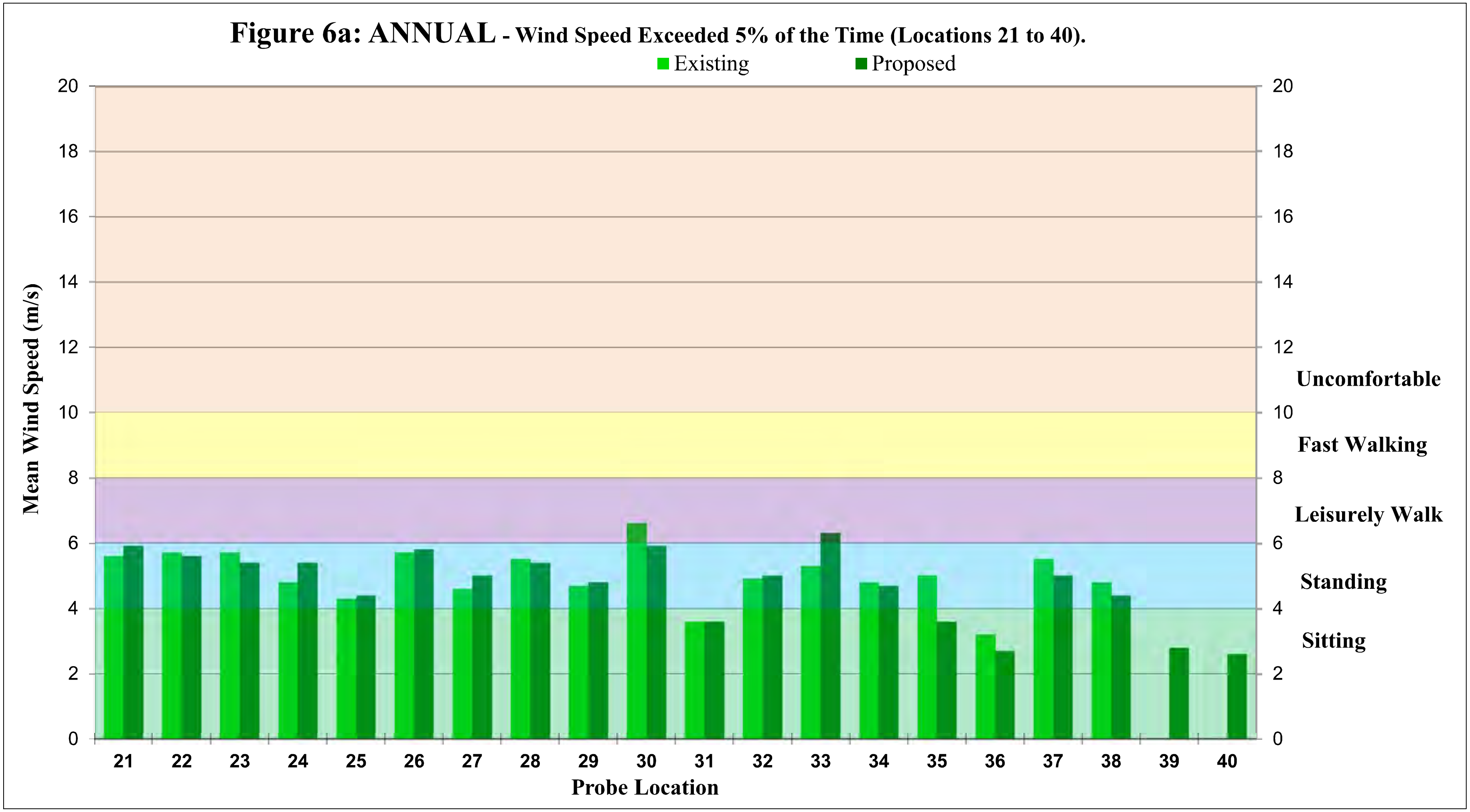


Figure 6a: ANNUAL - Wind Speed Exceeded 5% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Fast Walking
Leisurely Walk
Standing
Sitting
0
2
4
6
8
10
12
14
16
18
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

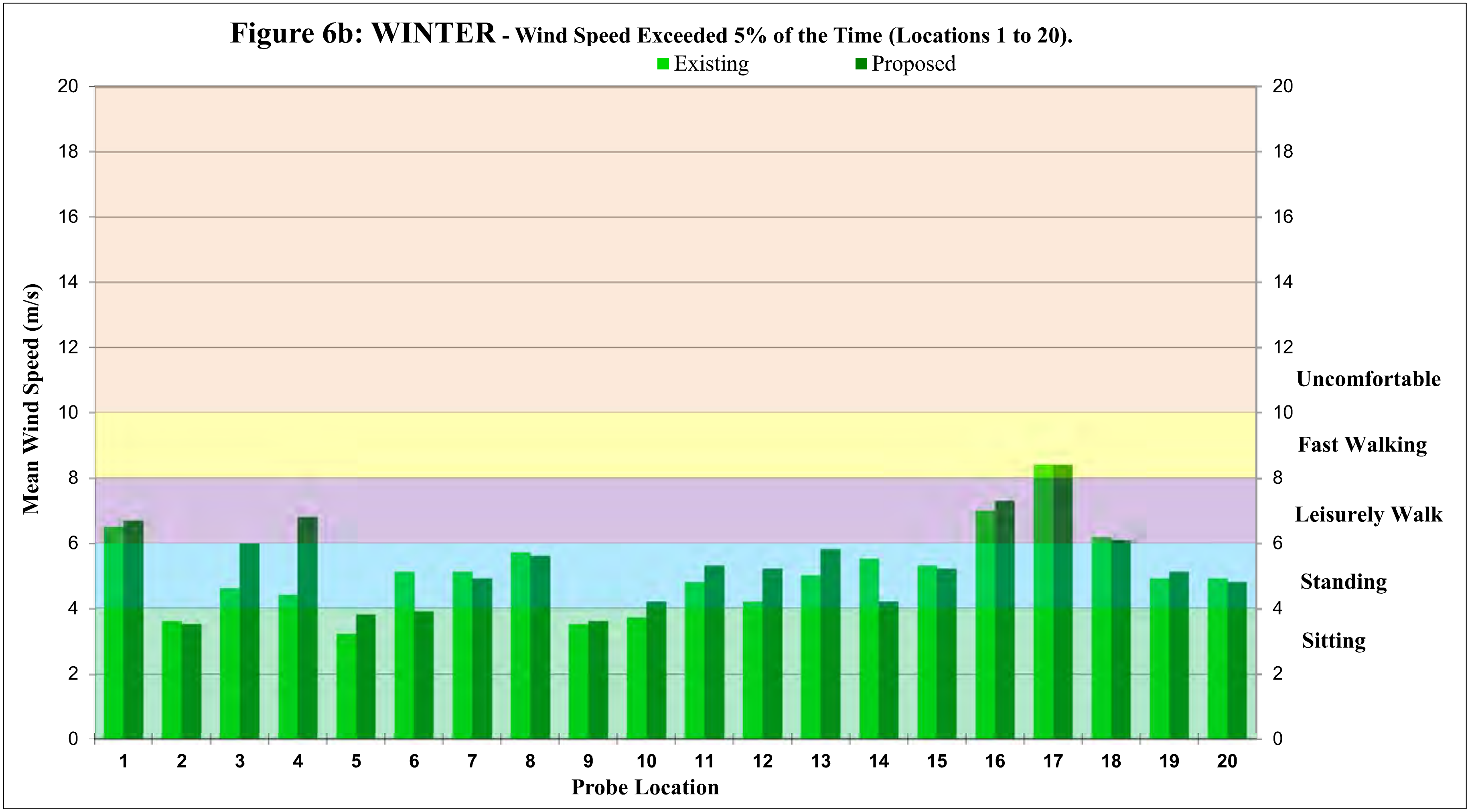


Figure 6b: WINTER - Wind Speed Exceeded 5% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
20
18
16
14
12
10
8
6
4
2
0
Uncomfortable
Fast Walking
Leisurely Walk
Standing
Sitting
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Probe Location

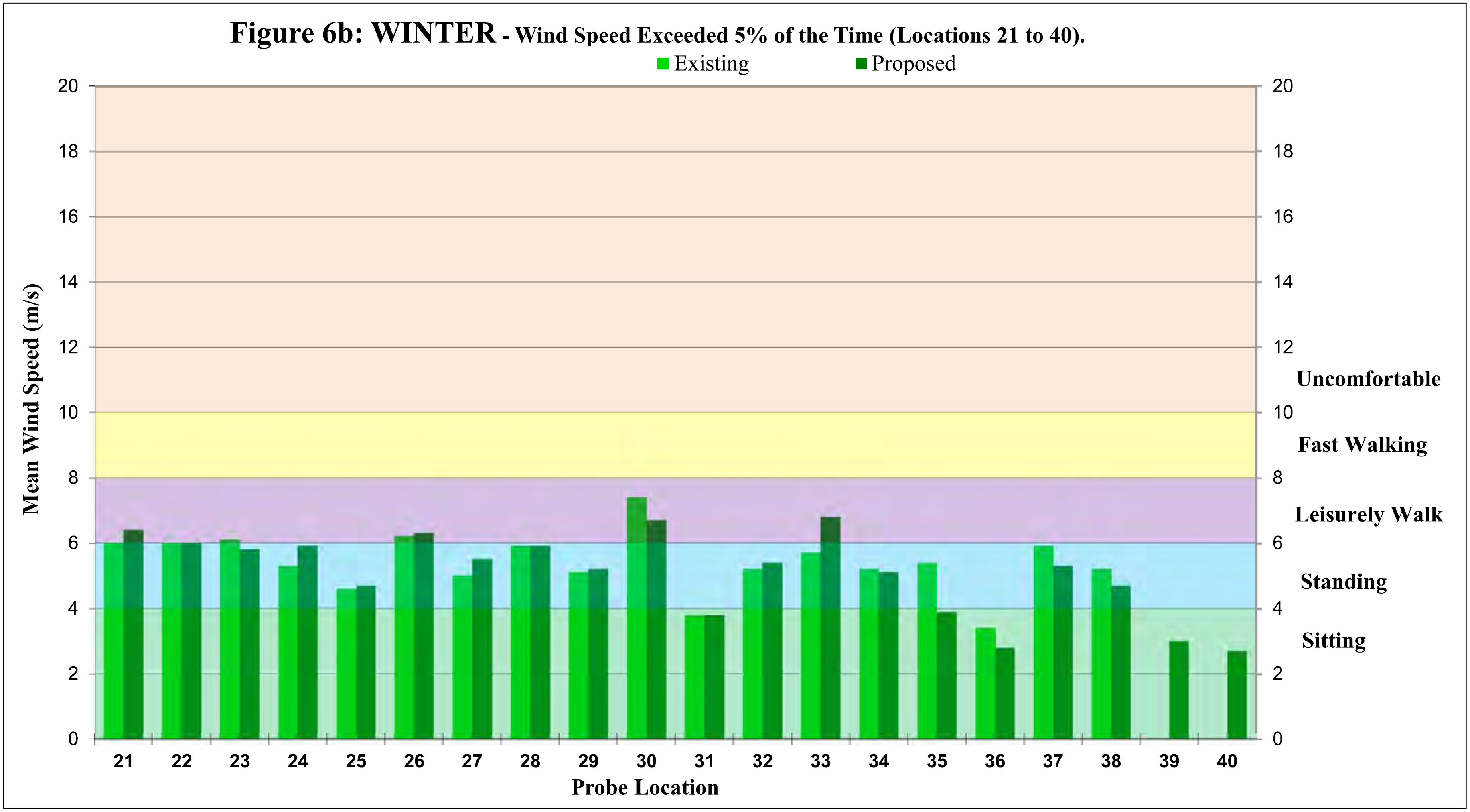


Figure 6b: WINTER - Wind Speed Exceeded 5% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
20
18
16
14
12
10
8
6
4
2
0
Uncomfortable
Fast Walking
Leisurely Walk
Standing
Sitting
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Probe Location

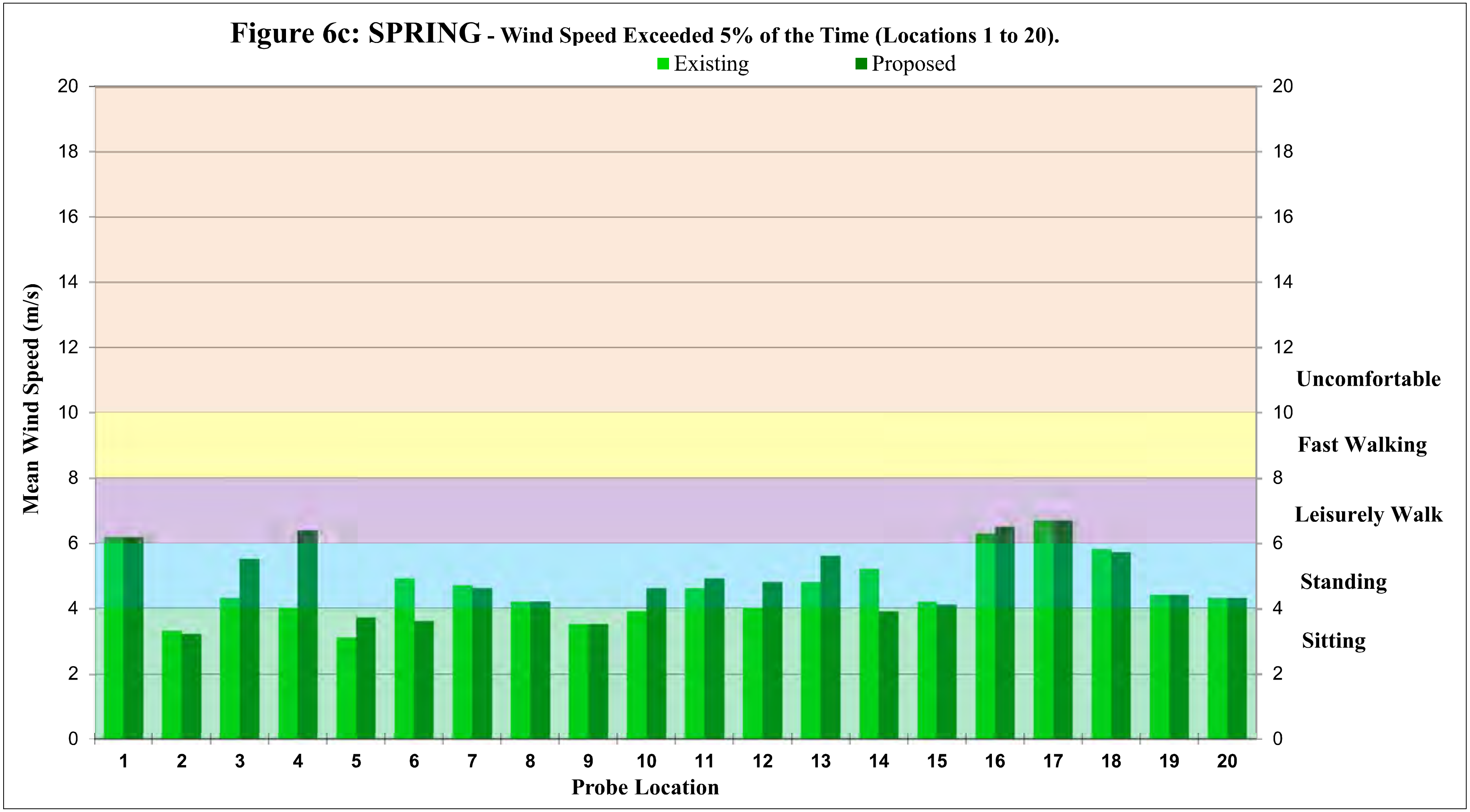


Figure 6c: SPRING - Wind Speed Exceeded 5% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Fast Walking
Leisurely Walk
Standing
Sitting
0
2
4
6
8
10
12
14
16
18
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

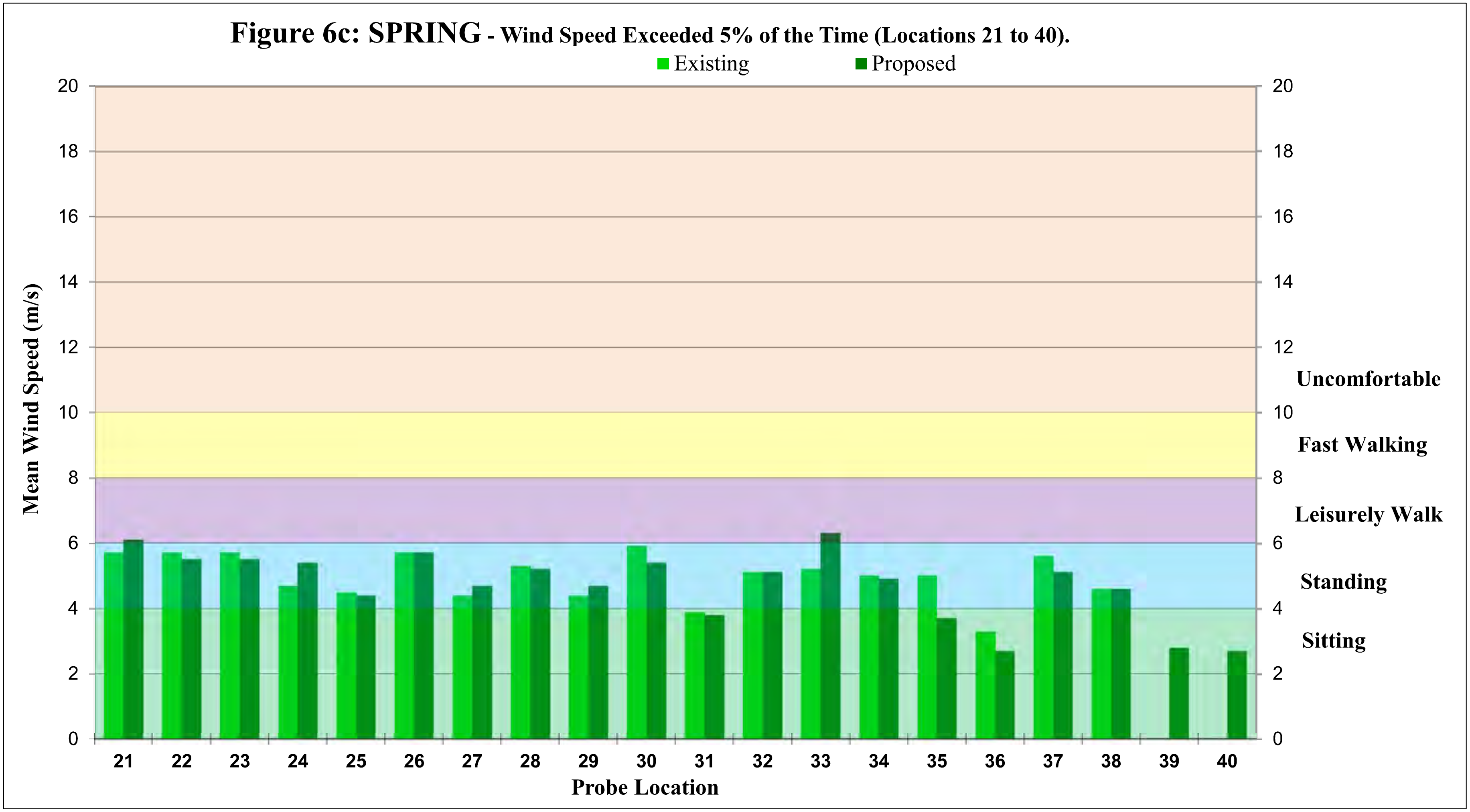


Figure 6c: SPRING - Wind Speed Exceeded 5% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Fast Walking
Leisurely Walk
Standing
Sitting
0
2
4
6
8
10
12
14
16
18
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

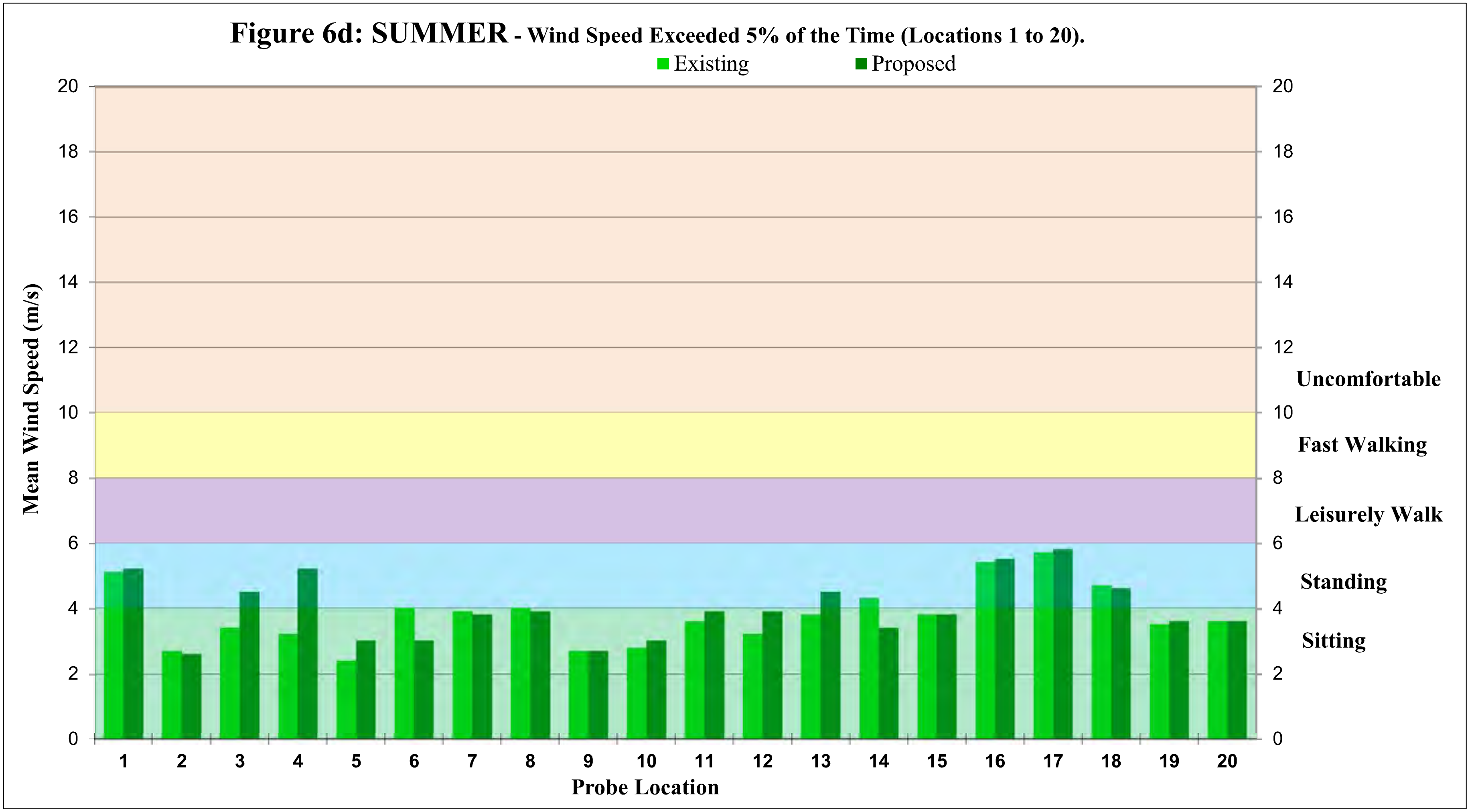


Figure 6d: SUMMER - Wind Speed Exceeded 5% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Fast Walking
Leisurely Walk
Standing
Sitting

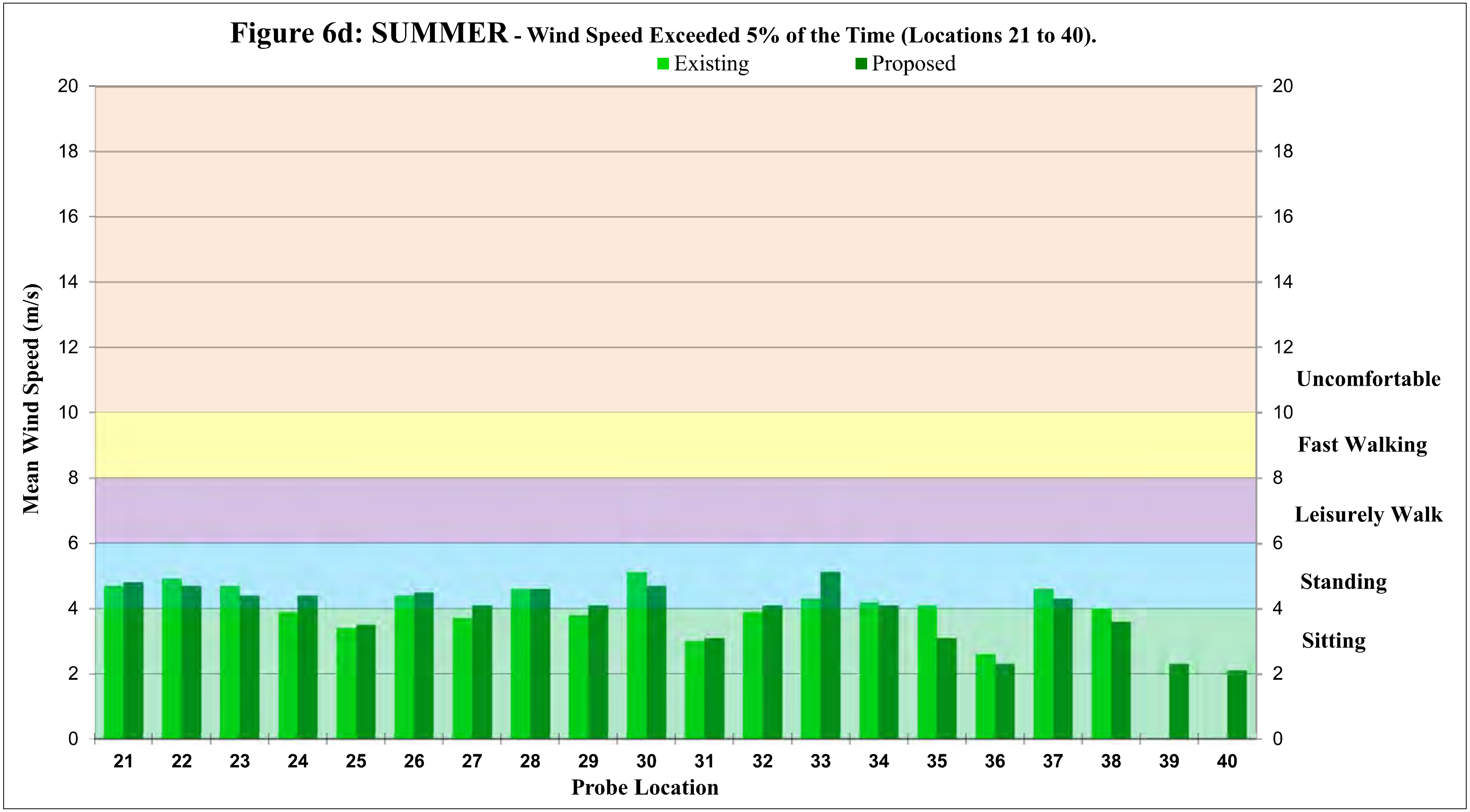
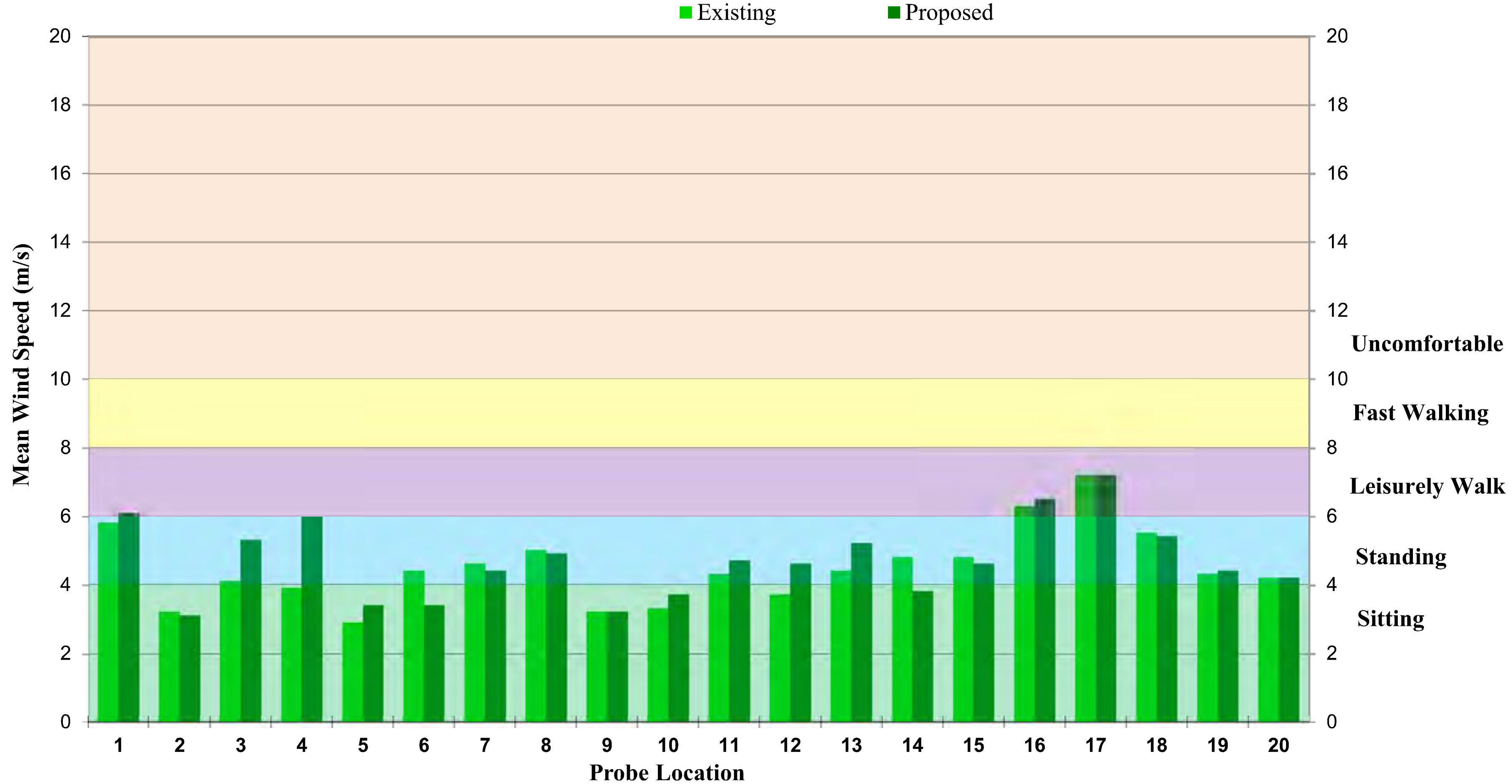


Figure 6d: SUMMER - Wind Speed Exceeded 5% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
0
2
4
6
8
10
12
14
16
18
20
Uncomfortable
Fast Walking
Leisurely Walk
Standing
Sitting
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location

Figure 6e: FALL - Wind Speed Exceeded 5% of the Time (Locations 1 to 20).



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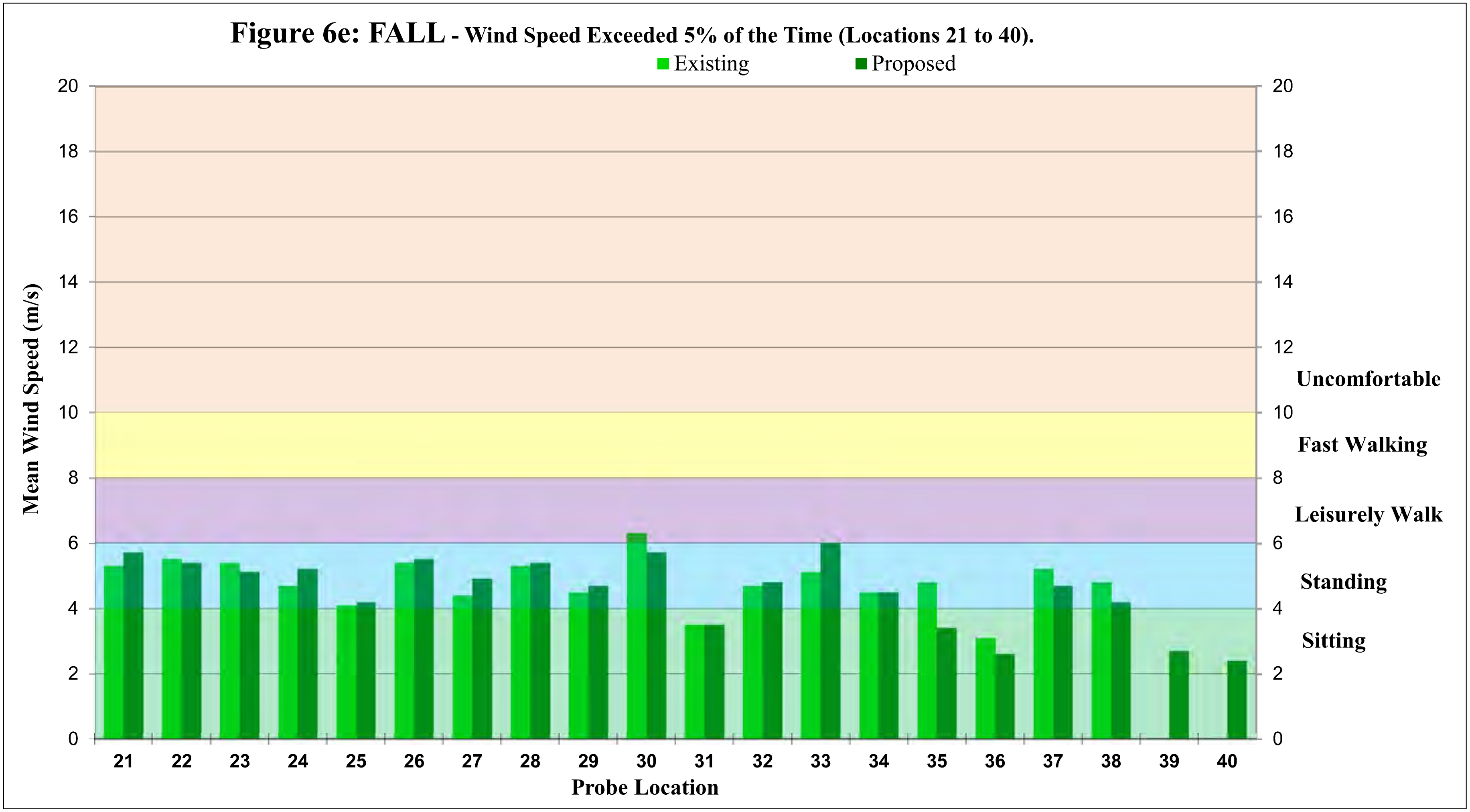
Figure 6e: FALL - Wind Speed Exceeded 5% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Fast Walking
Leisurely Walk
Standing
Sitting
0
2
4
6
8
10
12
14
16
18
20
21
22
23
24
25
26
27
28
29
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35
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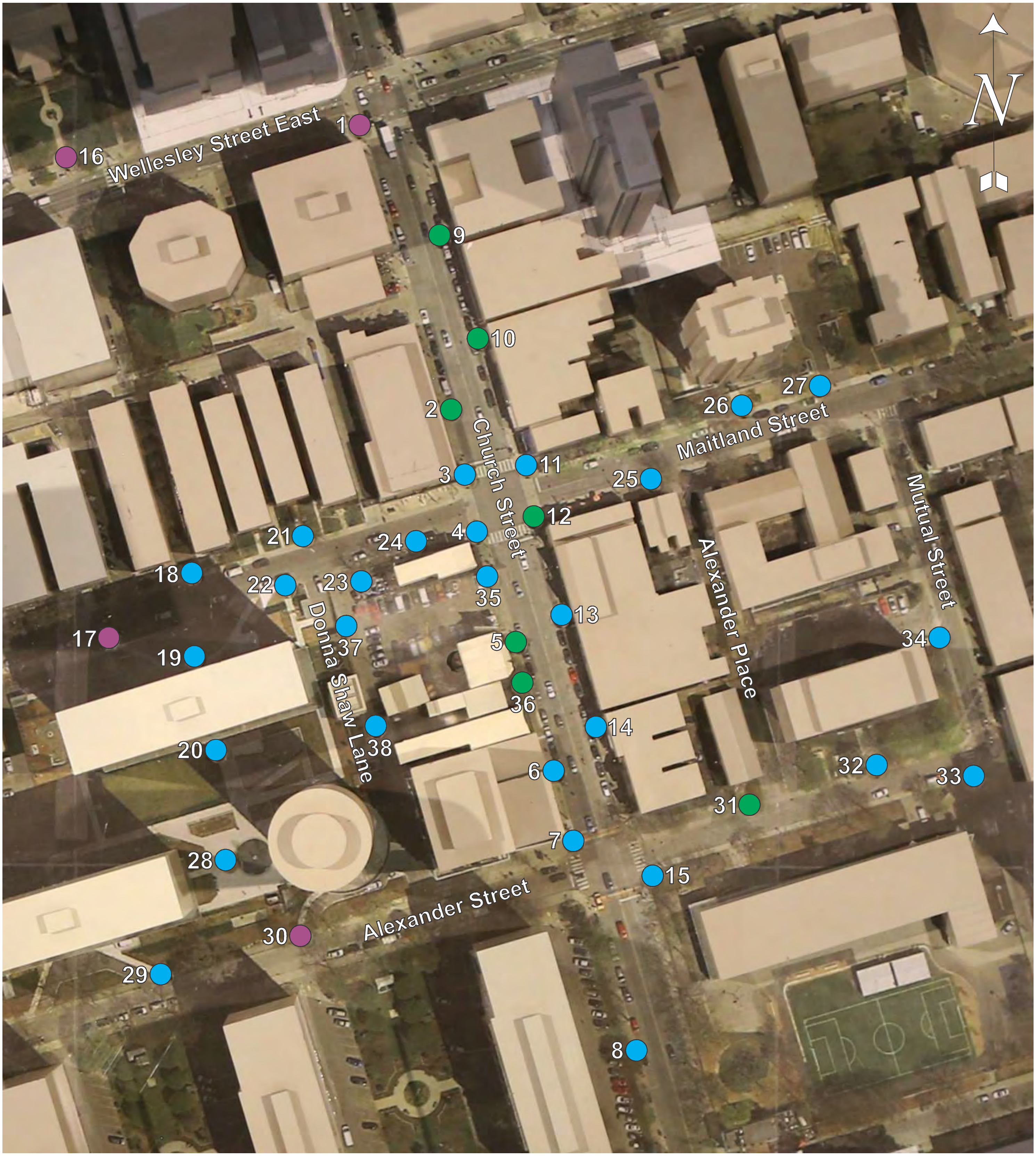
37
38
39
40

Figure 7a: Pedestrian level wind velocity comfort categories.



Comfort Categories - Annual - Existing

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

Figure 7b: Pedestrian level wind velocity comfort categories.

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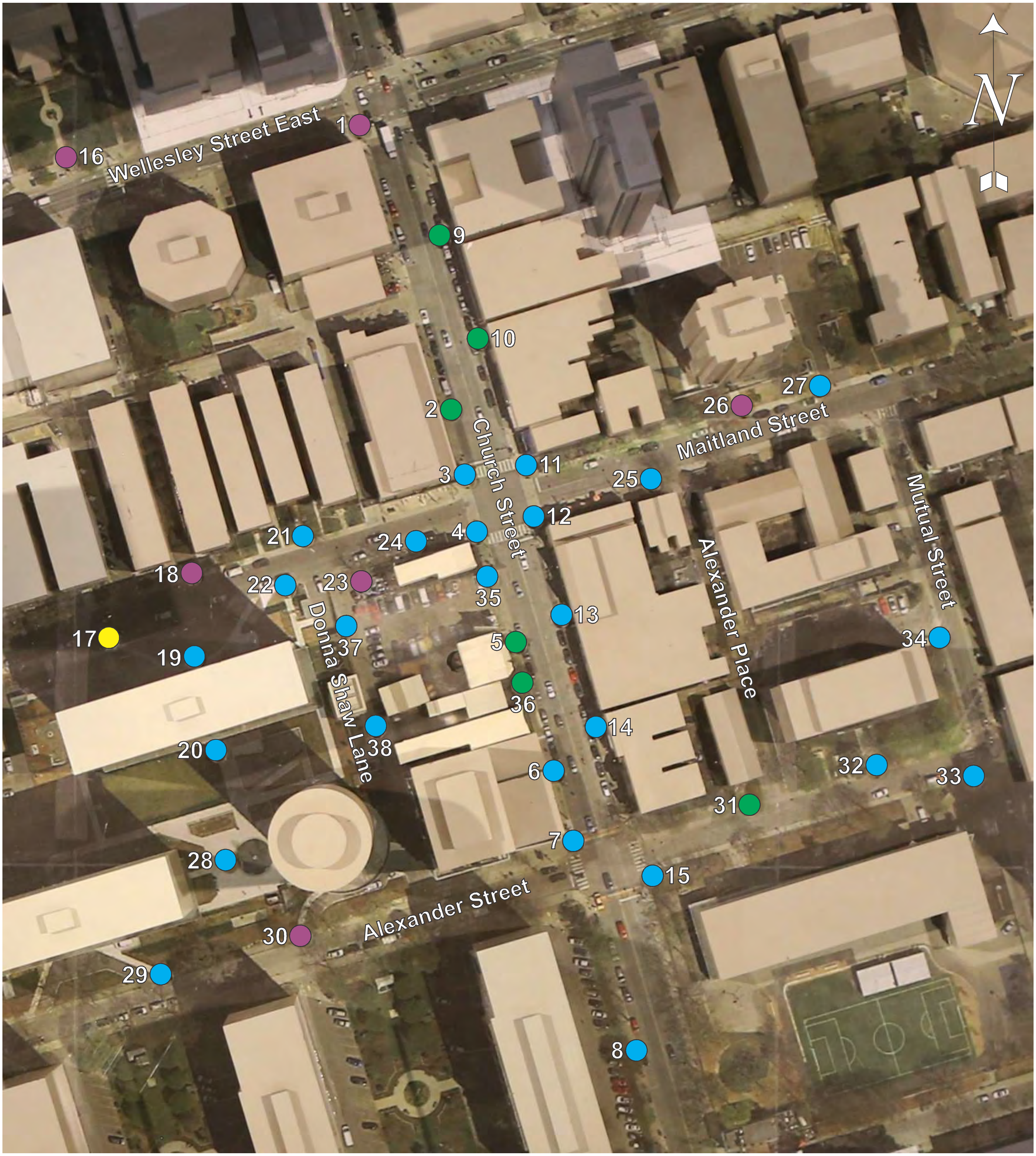
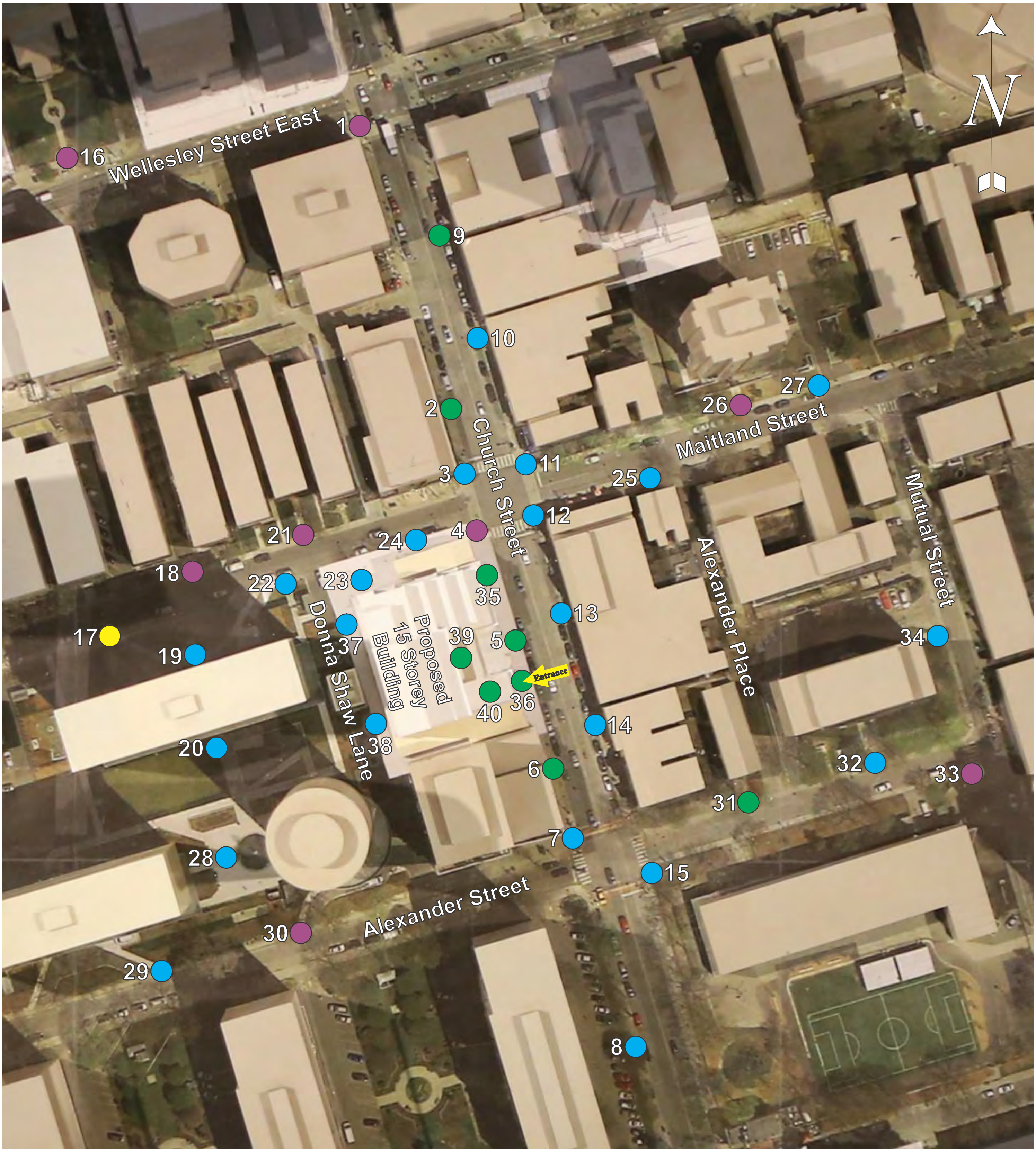
Figure 7c: Pedestrian level wind velocity comfort categories.



Comfort Categories - Winter - Existing

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

Figure 7d: Pedestrian level wind velocity comfort categories.



Comfort Categories - Winter - Proposed

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

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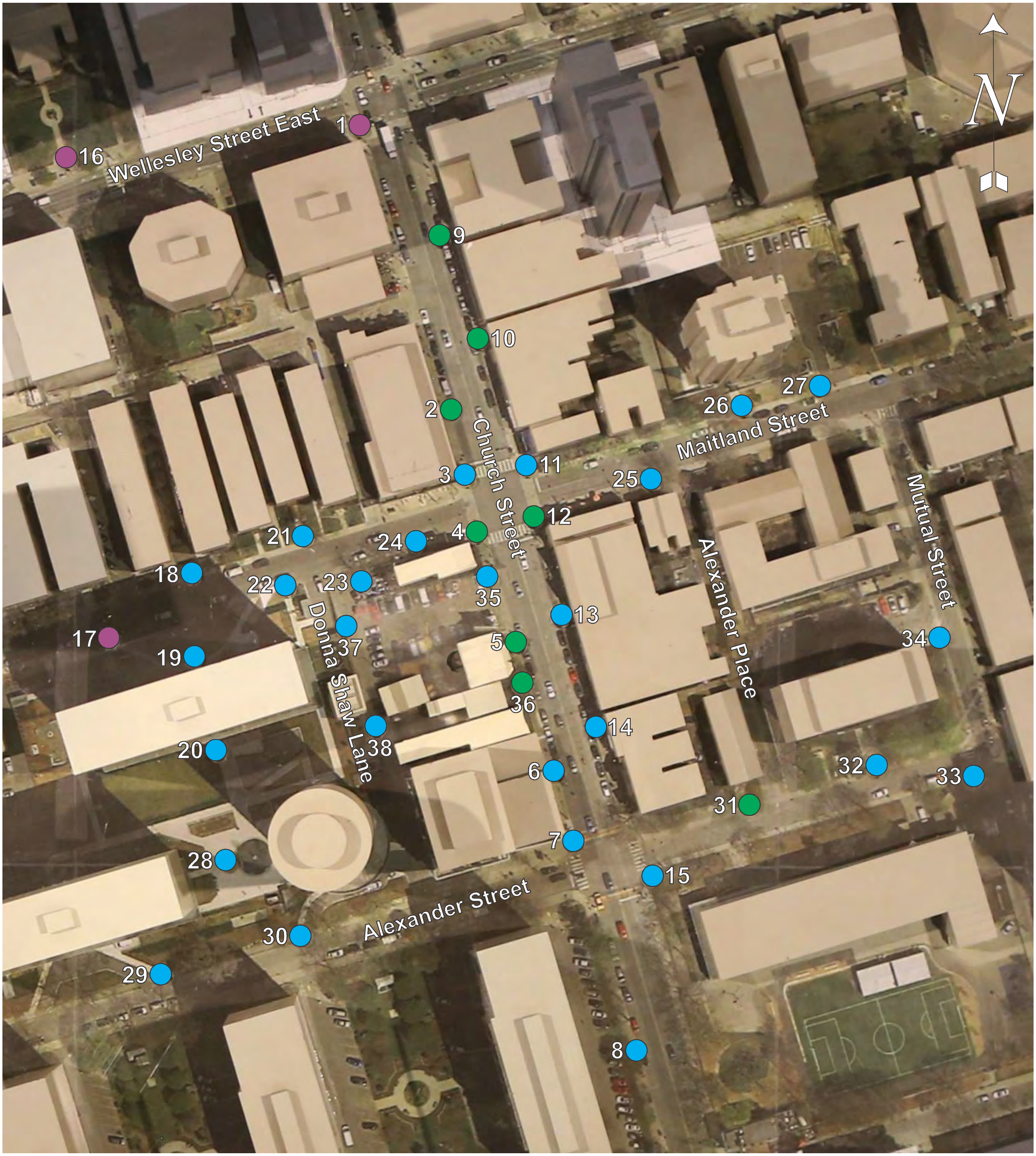
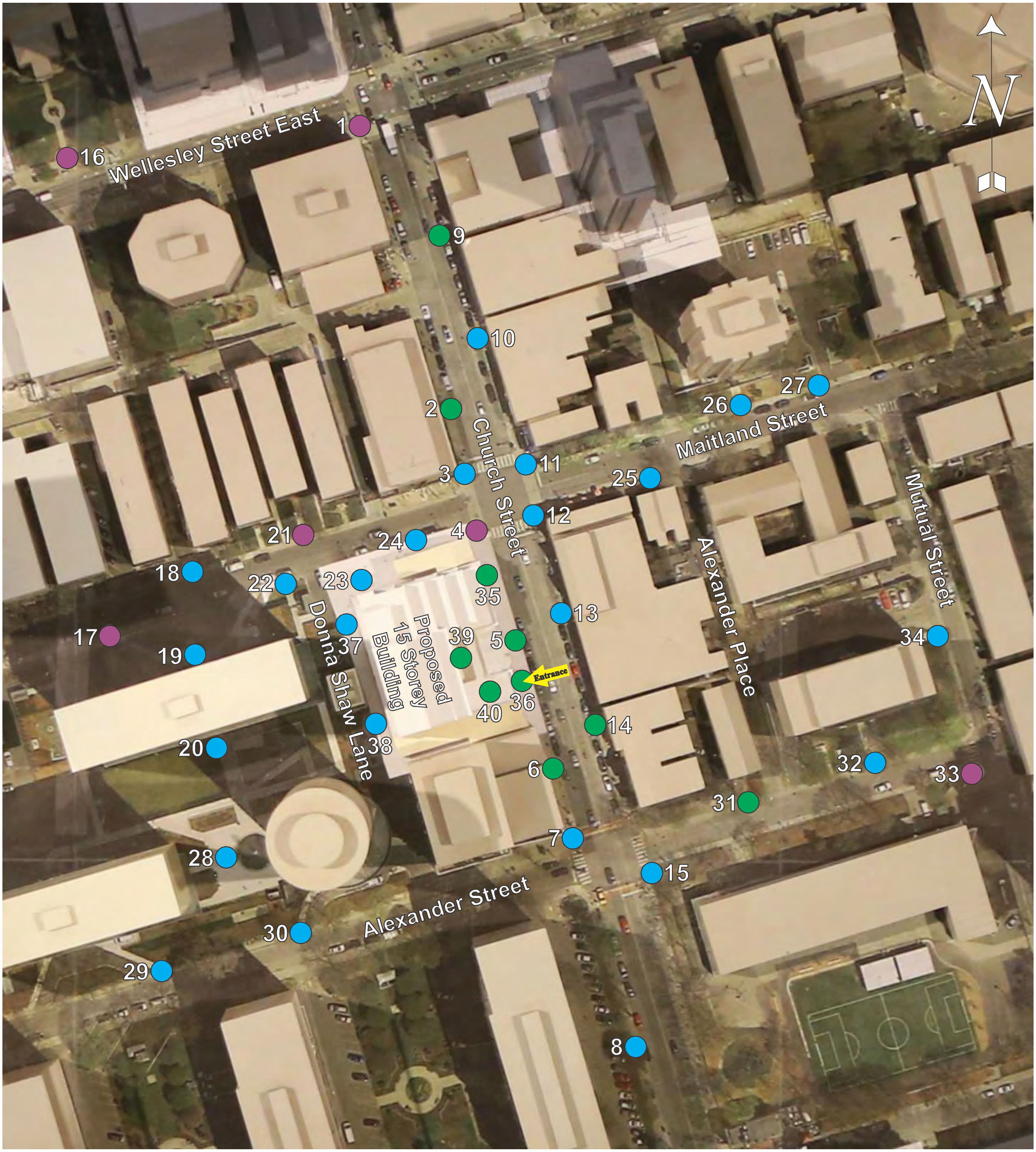
Figure 7e: Pedestrian level wind velocity comfort categories.



Comfort Categories - Spring - Existing

Sitting · Standing · Leisurely Walking · Fast Walking · Uncomfortable

Figure 7f: Pedestrian level wind velocity comfort categories.



Comfort Categories - Spring - Proposed

Sitting · Standing · Leisurely Walking · Fast Walking · Uncomfortable

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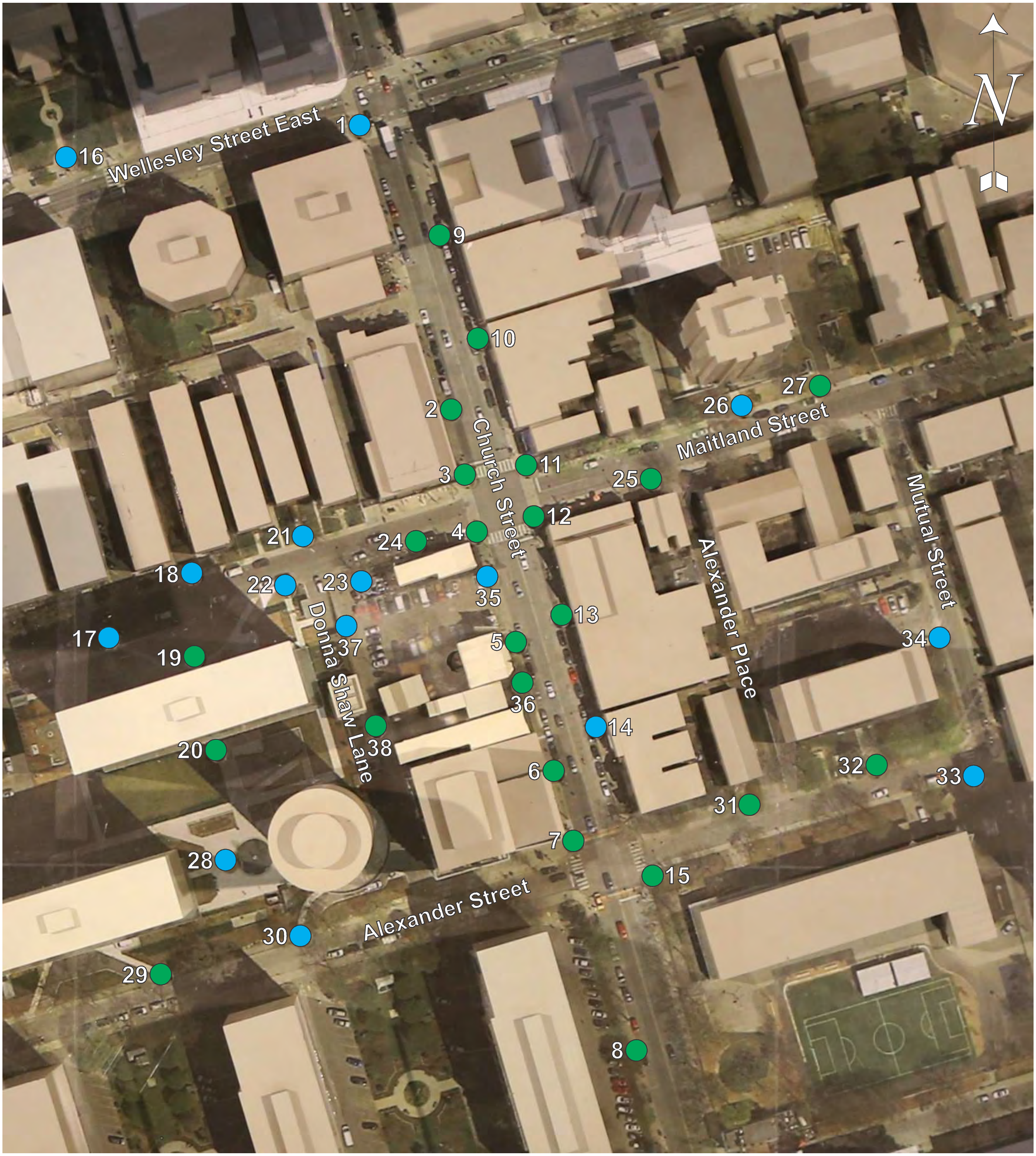
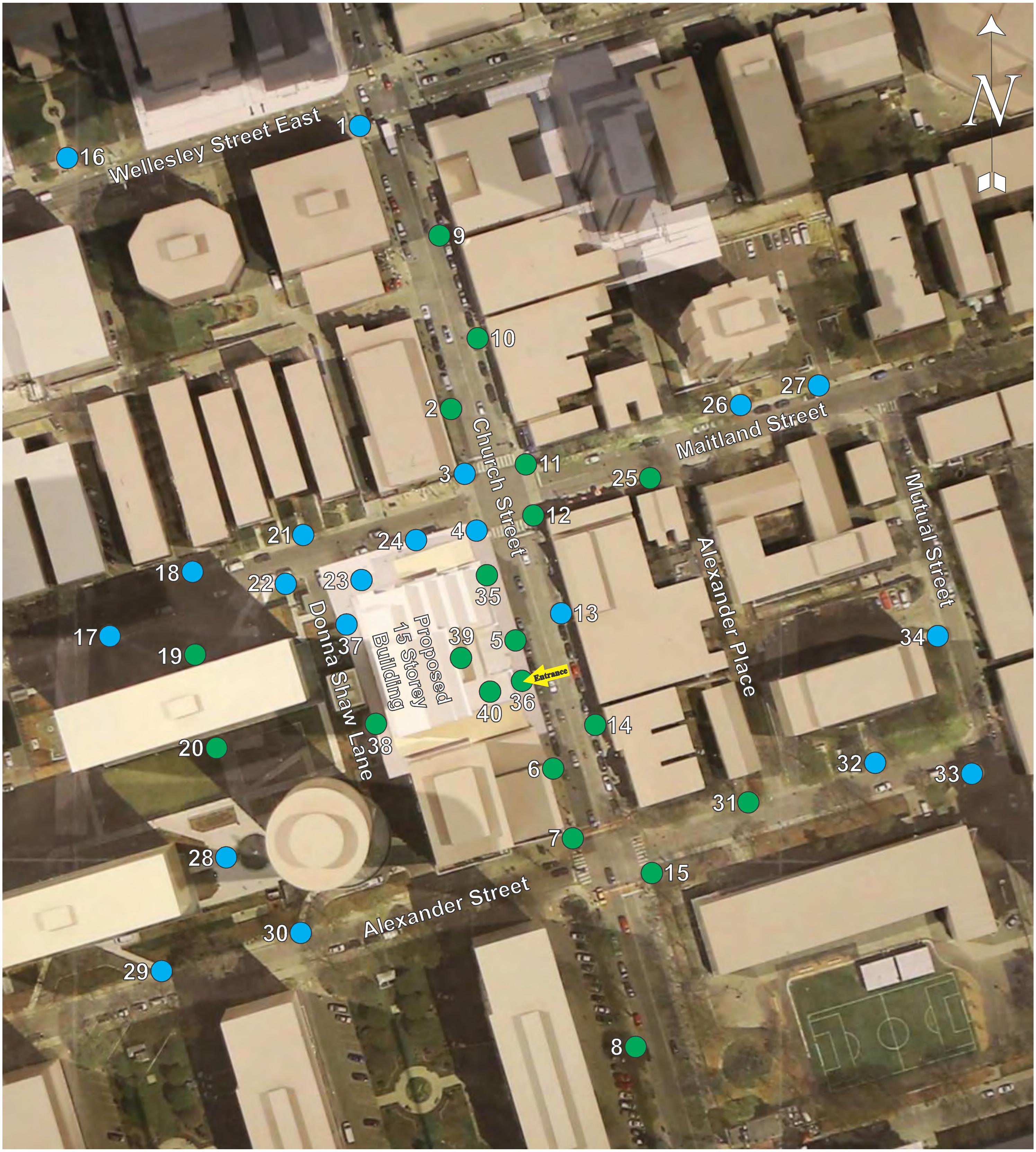
Figure 7g: Pedestrian level wind velocity comfort categories.



Comfort Categories - Summer - Existing

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

Figure 7h: Pedestrian level wind velocity comfort categories.



Comfort Categories - Summer - Proposed

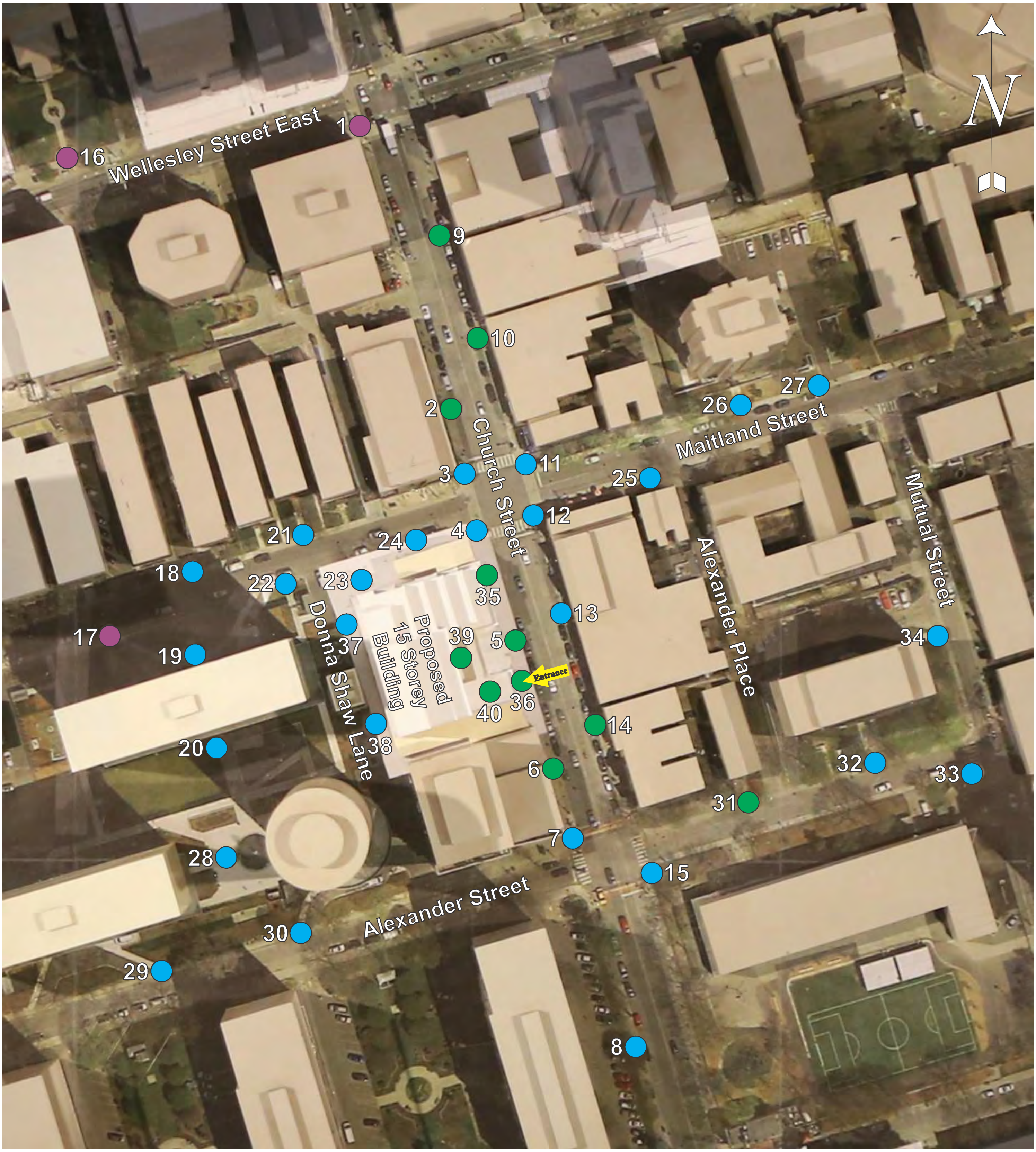
Sitting Standing Leisurely Walking Fast Walking Uncomfortable

Figure 7i: Pedestrian level wind velocity comfort categories.

Comfort Categories - Fall - Existing

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

Figure 7j: Pedestrian level wind velocity comfort categories.



Comfort Categories - Fall - Proposed

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

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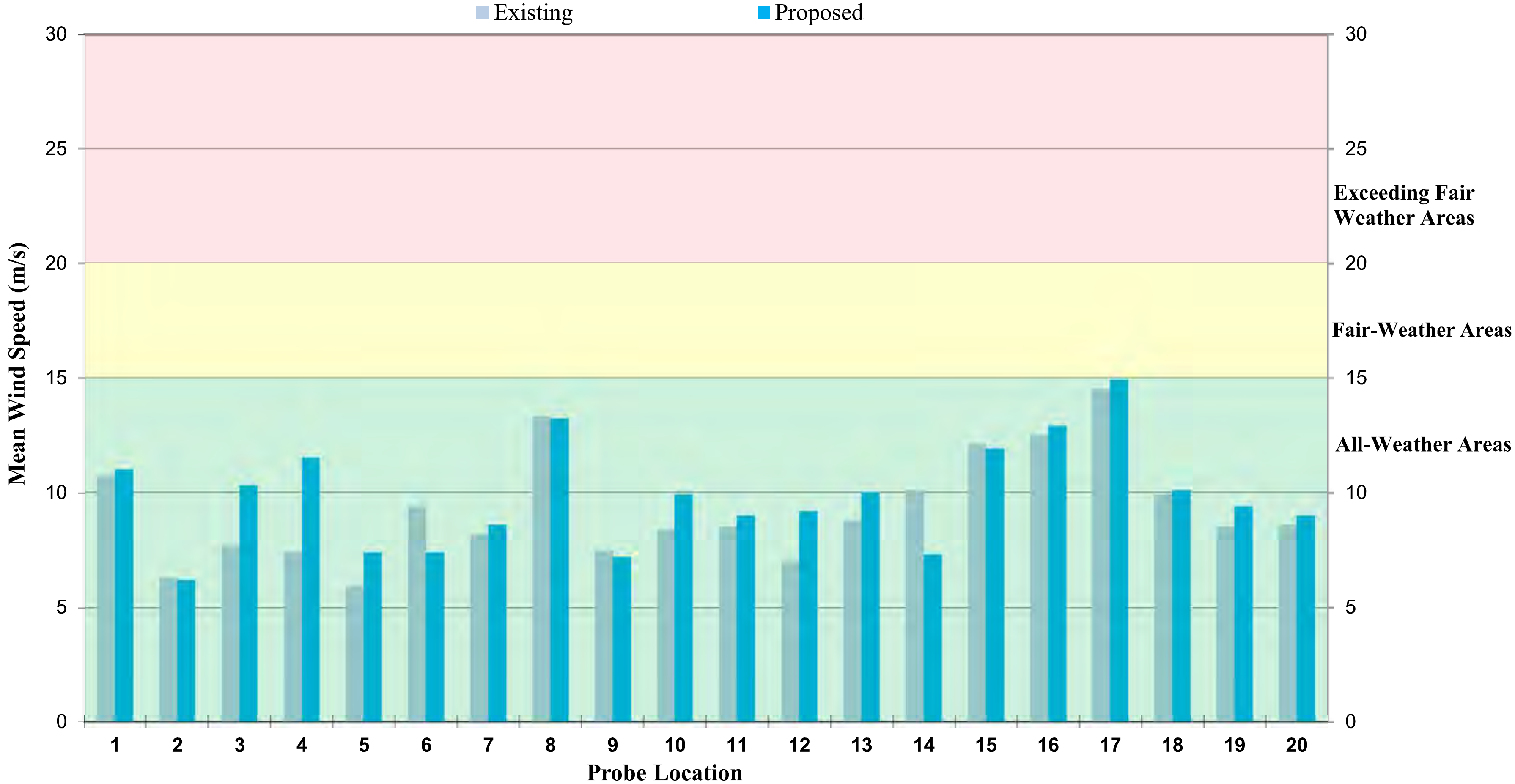
Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Once Per Year (Locations 1 to 20).



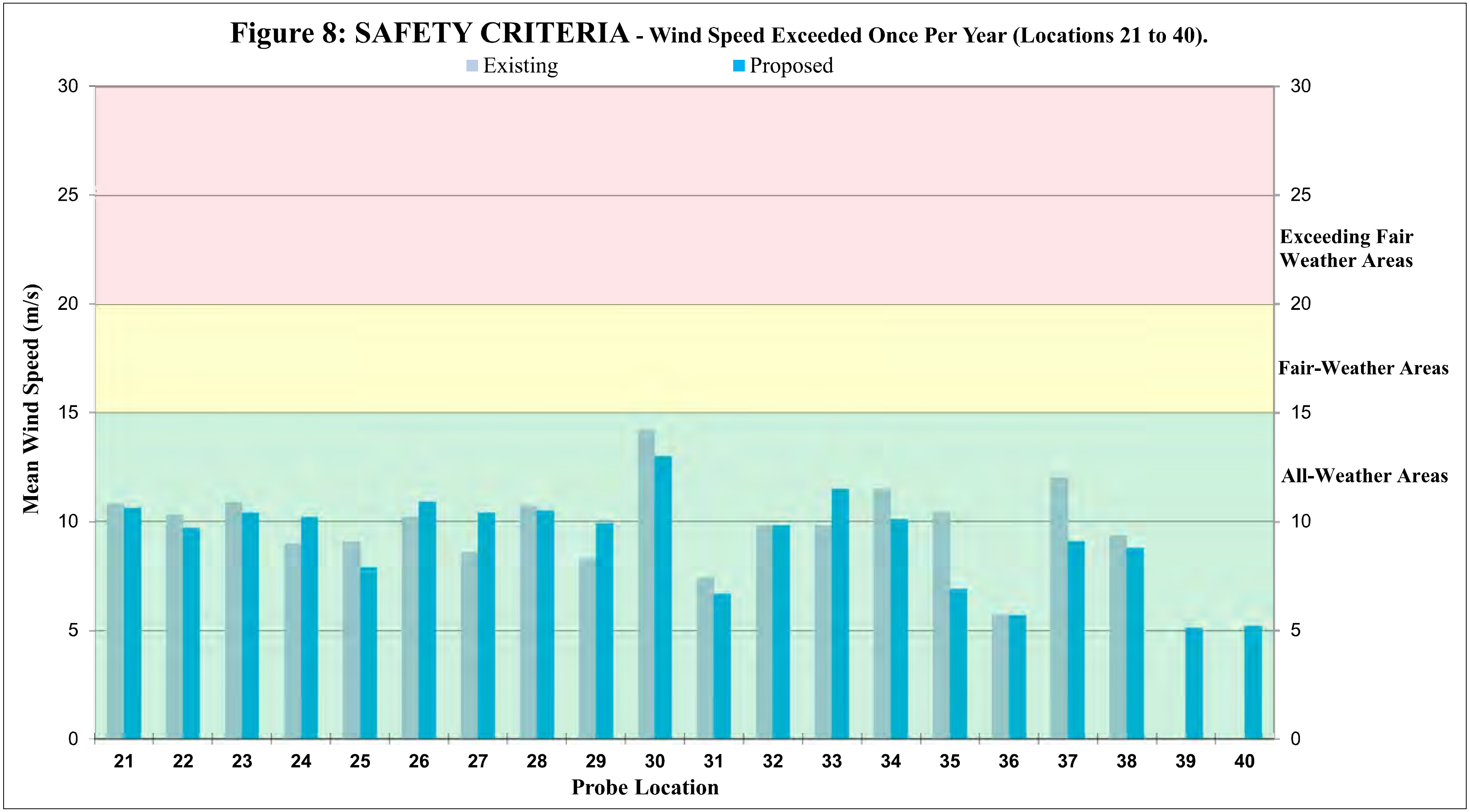


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Once Per Year (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (m/s)
Exceeding Fair Weather Areas
Fair-Weather Areas
All-Weather Areas
0
5
10
15
20
25
30
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Probe Location

Figure 9a: Pedestrian level wind velocity safety criteria.

Safety Criteria - Existing

All-Weather Areas Fair-Weather Areas Exceeding Fair-Weather Areas

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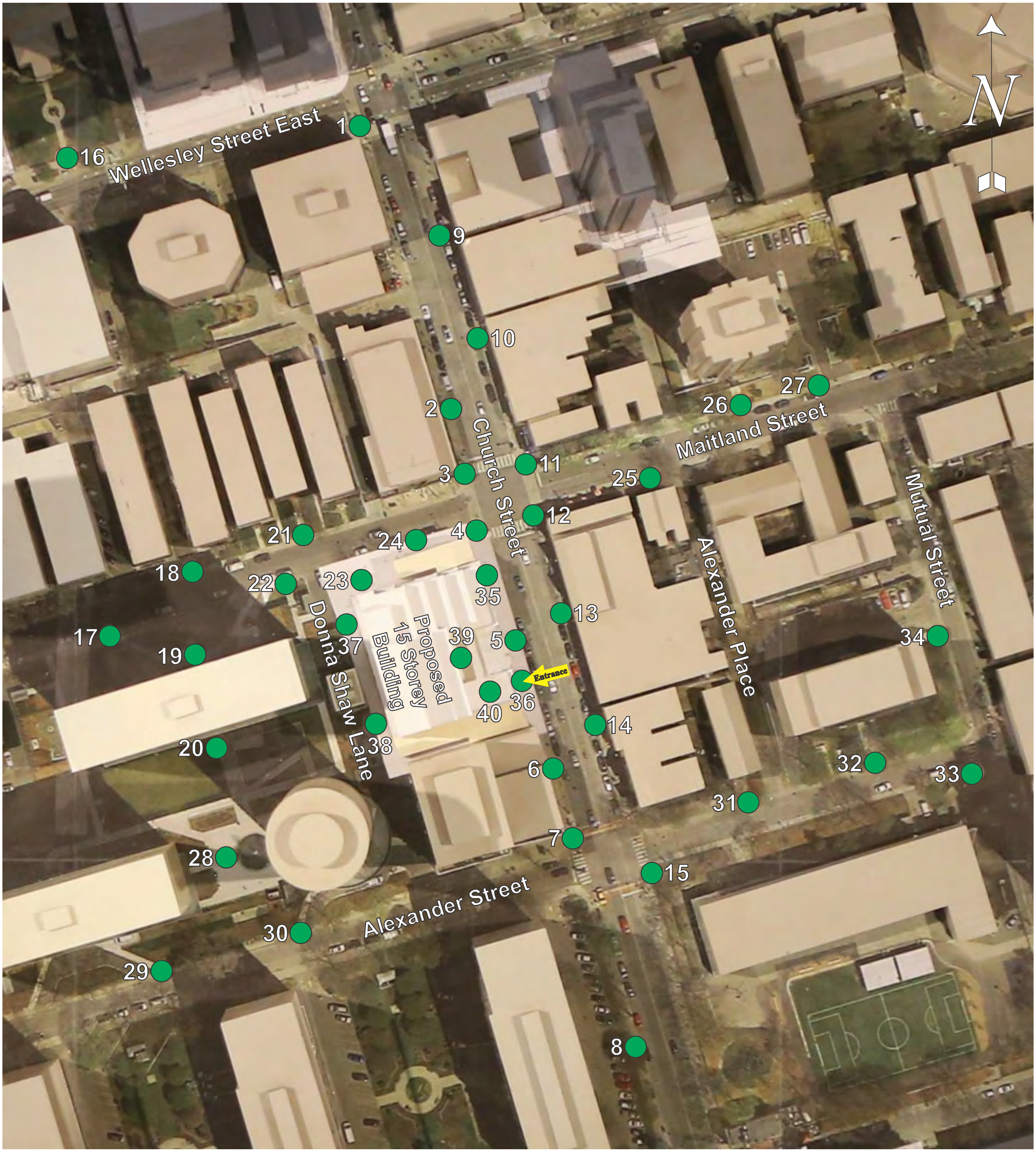
Figure 9b: Pedestrian level wind velocity safety criteria.



Safety Criteria - Proposed

All-Weather Areas · Fair-Weather Areas · Exceeding Fair-Weather Areas

7. APPENDIX

BACKGROUND AND THEORY OF WIND MOVEMENT

During the course of a modular analysis of an existing or proposed site, pertinent wind directions must be analysed with regard to the macroclimate and microclimate. In order for the results of the study to be valid, the effects of both climates must be modelled in test procedures.

Macroclimate

Wind velocity, frequency and directions are used in tests with models to establish part of the macroclimate. These variables are determined from meteorological data collected at the closest weather monitoring station. This information is used in the analysis of the site to establish upstream (approach) wind and weather conditions.

When evaluating approach wind velocities and characteristic profiles in the field it is necessary to evaluate certain boundary conditions. At the earth's surface, "no slip" conditions require the wind speed to be zero. At an altitude of approximately one kilometre above the earth's surface, the motion of the wind is governed by pressure distributions associated with large-scale weather systems. Consequently, these winds, known as "geostrophic" or "freestream" winds, are independent of the surface topography. In model simulation, as in the field, the area of concern is the boundary layer between the earth's surface and the geostrophic winds. The term boundary layer is used to describe the velocity profile of wind currents as they increase from zero to the geostrophic velocity.

The approach boundary layer profile is affected by specific surface topography upstream of the test site. Over relatively rough terrain (urban) the boundary layer is thicker and the wind speed increases rather slowly with height. The opposite is true over open terrain (rural). The following power law equation is used to represent the mean velocity profile for any given topographic condition:

$$\frac{U}{U_F} = \left(\frac{z}{z_F}\right)^a$$

where U = wind velocity (m/s) at height z (m)
a = power law exponent
and subscript $_F$ refers to freestream conditions

Typical values for a and z_F are summarized below:

Terrain	a	z_F (m)
Rural	0.14 - 0.17	260 - 300
Suburban	0.20 - 0.28	300 - 420
Urban	0.28 - 0.40	420 - 550

Wind data is recorded at meteorological stations at a height z_{ref} , usually equal to about 10m above grade. This historical mean wind velocity and frequency data is often presented in the form of a wind rose. The mean wind velocity at z_{ref} , along with the appropriate constants based on terrain type, are used to determine the value for U_F , completing the definition of the boundary layer profile specific to the site. The following Figure shows representations of the boundary layer profile for each of the above terrain conditions:

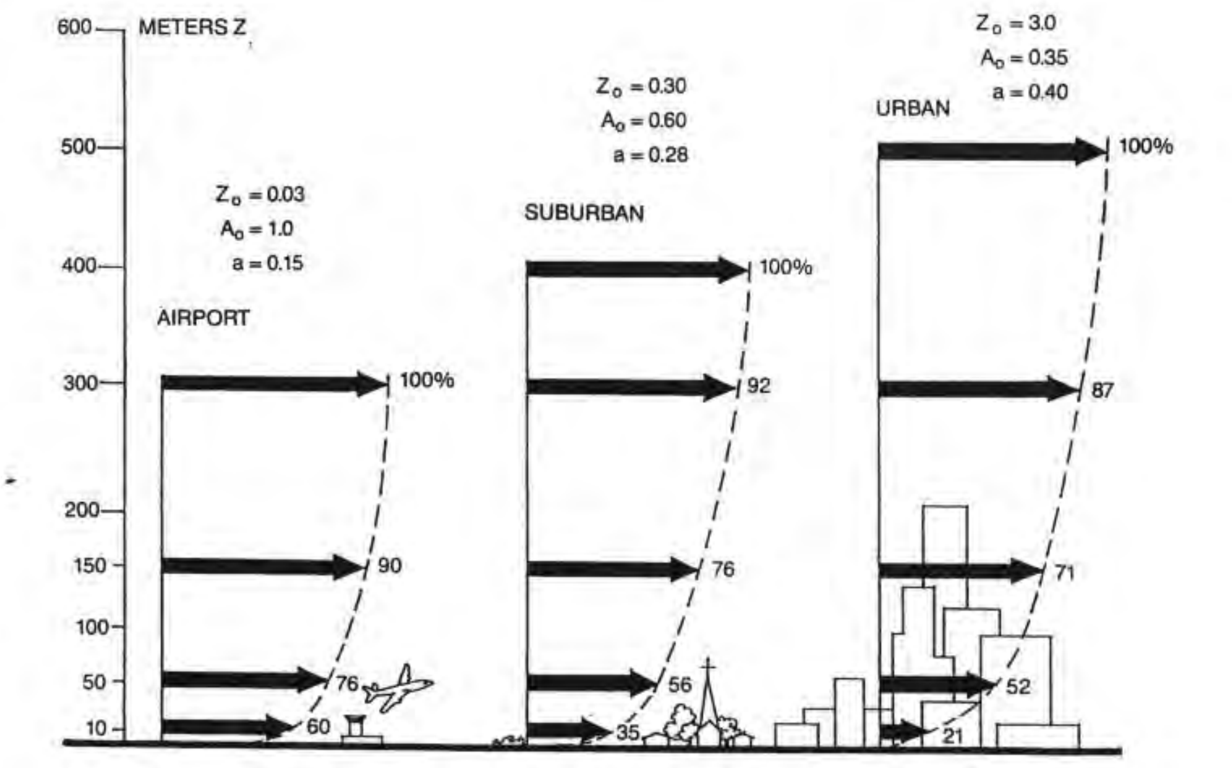


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

For the above velocity profiles, ground level velocities at a height of $z = 2m$, for an urban macroclimate are approximately 52% of the mean values recorded at the meteorological station at a height equal to $z_{ref} = 10m$. For suburban and rural conditions, the values are 63% and 78% respectively. Thus, for a given wind speed at z_{ref} open terrain or fields (rural) will experience significantly higher ground level wind velocities than suburban or urban areas.

When a boundary layer wind flows over one terrain onto another, the boundary layer profile shape rapidly changes to that dictated by the new terrain. If the preceding wind flow is over rough suburban terrain and an open area is encountered a rapid increase in ground level winds will be realized. A similar effect will occur when large low-density residential areas are demolished to accommodate high-rise developments. The transitional open area will experience significantly higher pedestrian level winds than the previous suburban setting. Once the high-rise development is established, ground level winds will moderate with localized areas of higher pedestrian level winds likely to occur. Pedestrian level wind velocities respond to orientation and shape of the development and if the site is not appropriately engineered or mitigated, pedestrian level wind may be problematic.

Microclimate

The specific wind conditions related to the study site are known as the microclimate, which are dictated mainly by the following factors:

- The orientation and conformation of buildings within the vicinity of the site.
- The surrounding contours and pertinent landscape features.

The microclimate establishes the effect that surrounding buildings or landscape features have on the subject building and the effect the subject building has on the surrounds. For the majority of urban test sites the proper microclimate can be established by modelling an area of 300*m* in radius around the subject building. If extremely tall buildings are present then the study area must be larger, and if the building elevations are on the order of a few floors, smaller areas will suffice to establish the required microclimate.

General Wind Flow Phenomena

Wind flow across undulating terrain contains parallel streamlines with the lowest streamline adjacent to the surface. These conditions continue until the streamlines approach vertical objects. When this occurs there is a general movement of the streamlines upward ("Wind Velocity Gradient") and as they reach the top of the objects turbulence is generated on the lee side. This is one of the reasons for unexpected high wind velocities as this turbulent action moves to the base of the objects on the lee side.

Other fluid action occurs through narrow gaps between buildings (Venturi Action) and at sharp edges of a building or other vertical objects (Scour Action). These conditions are predictable at selected locations but do not conform to a set direction of wind as described by a macroclimate condition. In fact, the orientation and conformation of buildings, streets and landscaping establish a microclimate.

Because of the "Wind Velocity Gradient" phenomena, there is a "downwash" of wind at the face of buildings and this effect is felt at the pedestrian level. It may be experienced as high gusty winds or drifting snow. These effects can be obviated by windbreak devices on the windward side or by canopies over windows and doors on the lee side of the building.

The intersection of two streets or pedestrian walkways have funnelling effects of wind currents from any one of the four directions and is particularly severe at corners if the buildings project to the street line or are close to walkways.

Some high-rise buildings have gust effects as the wind velocities are generated suddenly due to the orientation and conformation of the site. Since wind velocities are the result of energy induced wind currents the solution to most problems is to reduce the wind energy at selected locations by carefully designed windbreak devices, often landscaping, to blend with the surrounds.

The Beaufort Scale is often used as a numerical relationship to wind speed based upon an observation of the effects of wind. Rear-Admiral Sir Francis Beaufort, commander of the Royal Navy, developed the wind force scale in 1805, and by 1838 the Beaufort wind force scale was made mandatory for log entries in ships of the Royal Navy. The original scale was an association of integers from 0 to 12, with a description of the effect of wind on the behaviour of a full-rigged man-of-war. The lower Beaufort numbers described wind in terms of ship speed, mid-range numbers were related to her sail carrying ability and upper numbers were in terms of survival. The Beaufort Scale was adopted in 1874 by the International Meteorological Committee for international use in weather telegraphy and, with the advent of anemometers, the scale was eventually adopted for meteorological purposes. Eventually, a uniform set of equivalents that non-mariners could relate to was developed, and by 1955, wind velocities in knots had replaced Beaufort numbers on weather maps. While the Beaufort Scale lost ground to technology, there remains the need to relate wind speed to observable wind effects and the Beaufort Scale remains a useful tool.

Abbreviated Beaufort Scale

Beaufort Number	Description	Wind Speed			Observations
		km/h	*m/s*	h=2*m* for Urban *m/s*	
2	Slight Breeze	6-11	1.6-3.3	< ~2	Tree leaves rustle; flags wave slightly; vanes show wind direction; small wavelets or scale waves.
3	Gentle Breeze	12-19	3.4-5.4	< ~3	Leaves and twigs in constant motion; small flags extended; long unbreaking waves.
4	Moderate Breeze	20-28	5.5-7.9	< ~4	Small branches move; flags flap; waves with whitecaps.
5	Fresh Breeze	29-38	8.0-10.7	< ~6	Small trees sway; flags flap and ripple; moderate waves with many whitecaps.
6	Strong Breeze	39-49	10.8-13.8	< ~8	Large branches sway; umbrellas used with difficulty; flags beat and pop; larger waves with regular whitecaps.
7	Moderate Gale	50-61	13.9-17.1	< ~10	Sea heaps up, white foam streaks; whole trees sway; difficult to walk; large waves.
8	Fresh Gale	62-74	17.2-20.7	> ~10	Twigs break off trees; moderately high sea with blowing foam.
9	Strong Gale	75-88	20.8-24.4		Branches break off trees; tiles blown from roofs; high crested waves.

Wind speeds indicated above, in *km/h* and *m/s*, are at a reference height of 10 metres, as are the wind speeds indicated on the Figure 5 wind roses. The mean wind speeds at pedestrian level, for an urban climate, would be approximately 56% of these values. The 3rd column for wind speed is shown for reference, at a height of 2*m*, in an urban setting. The approximate Comfort Category Colours are shown above. The relationship between wind speed and height relative to terrain is discussed in the appendices.

Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

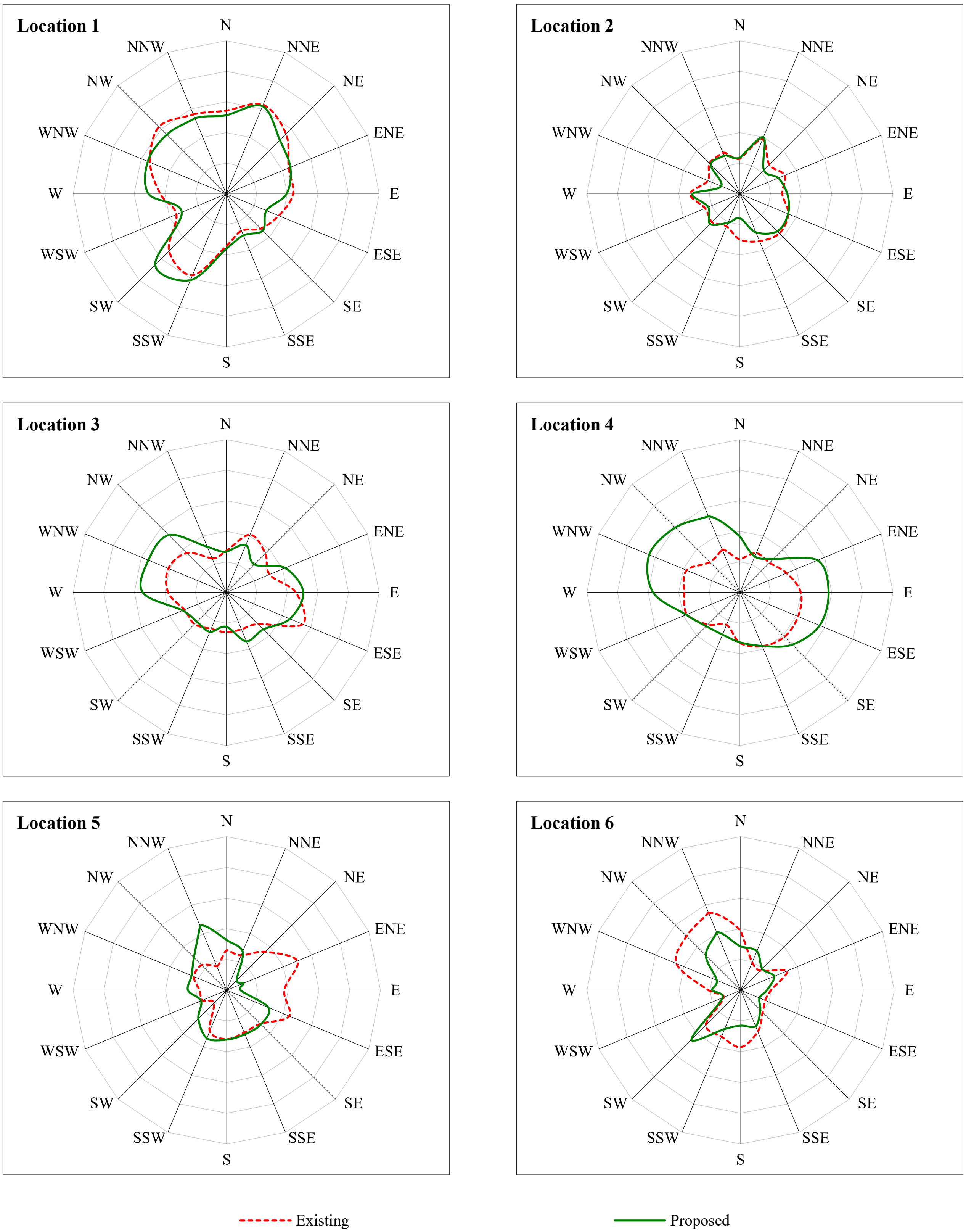


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

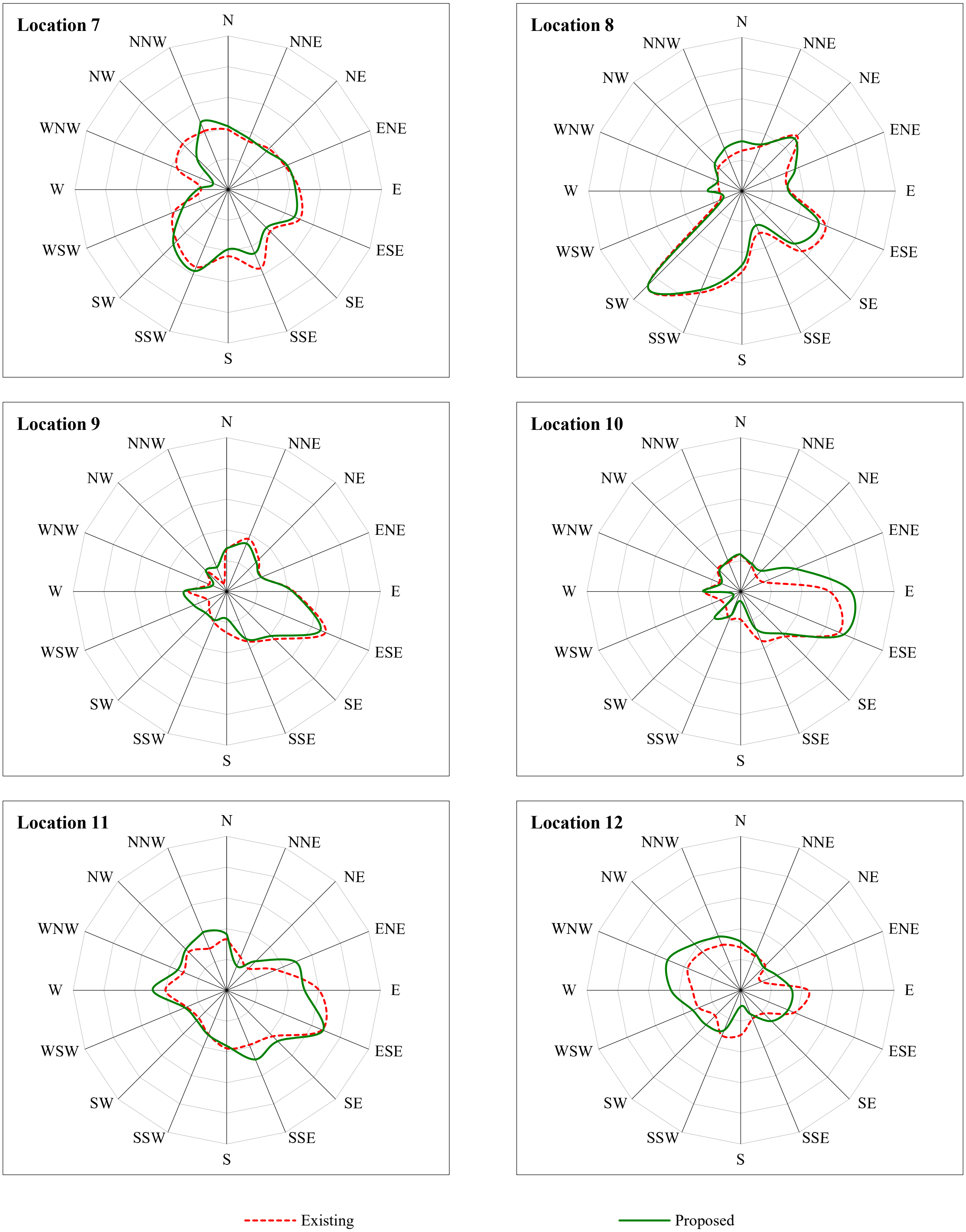


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

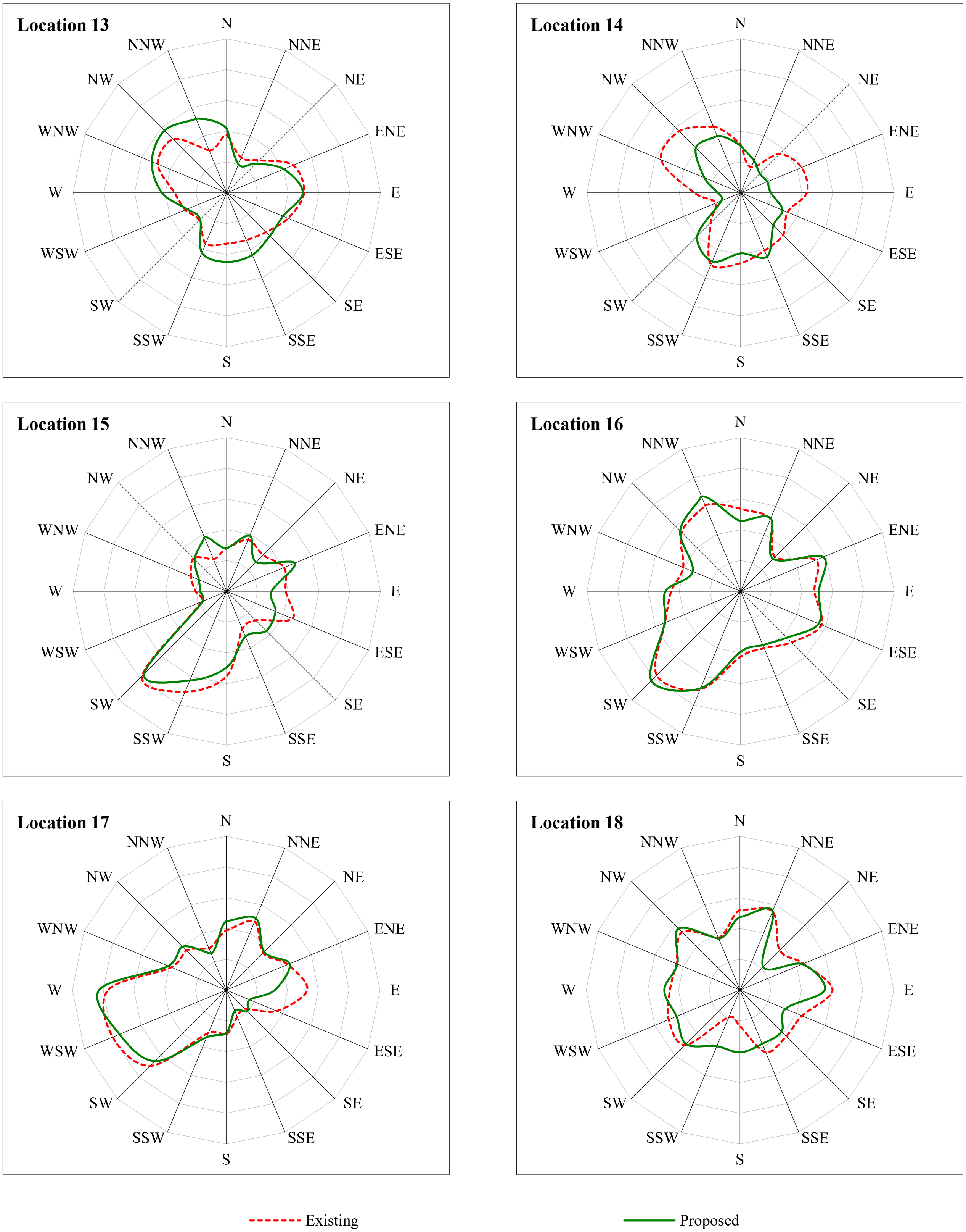


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

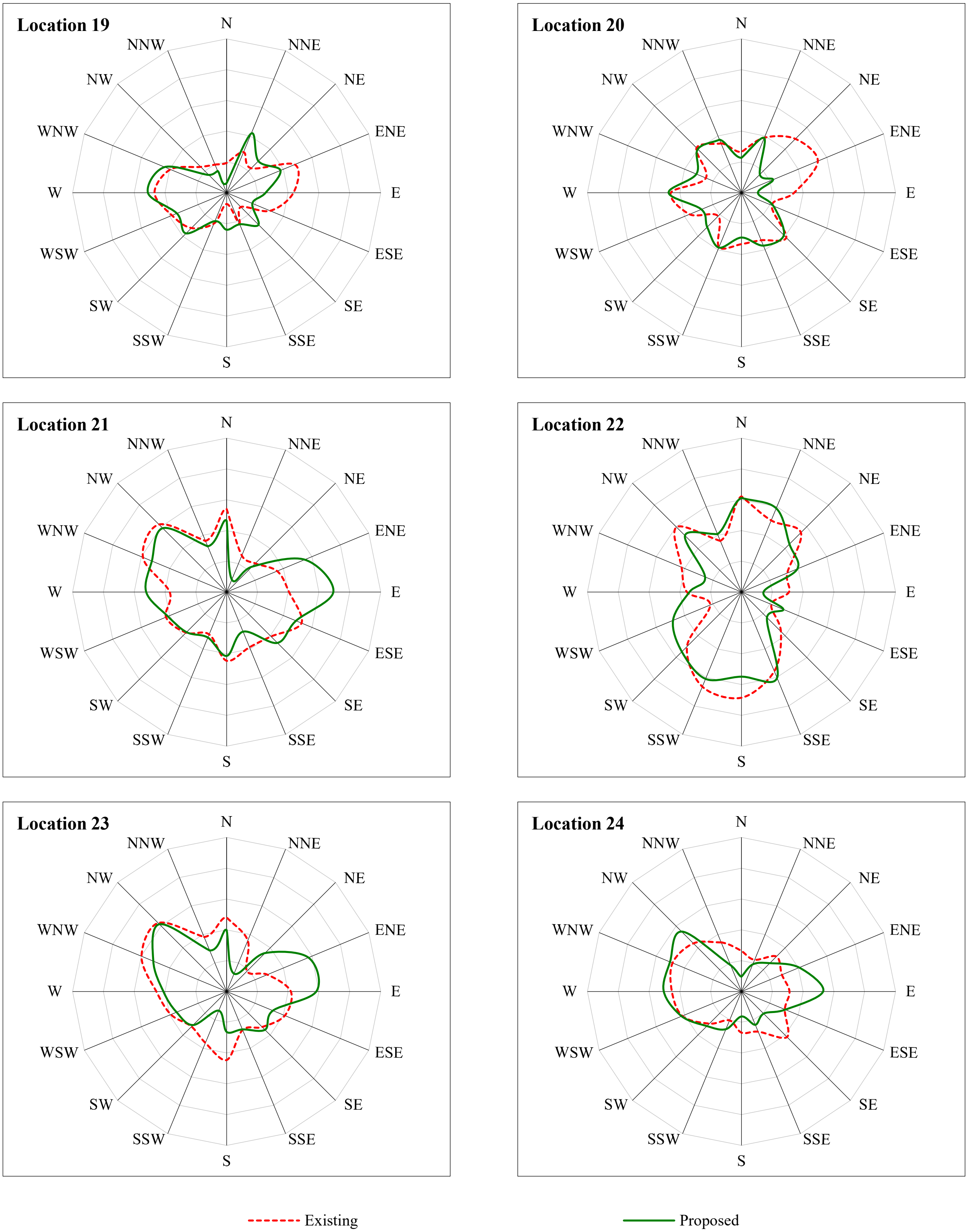
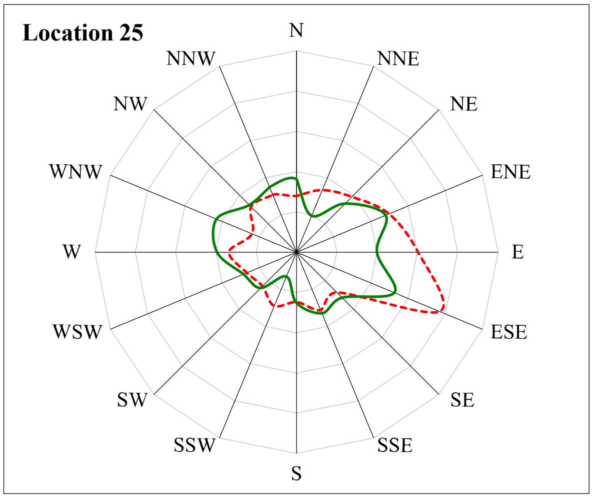
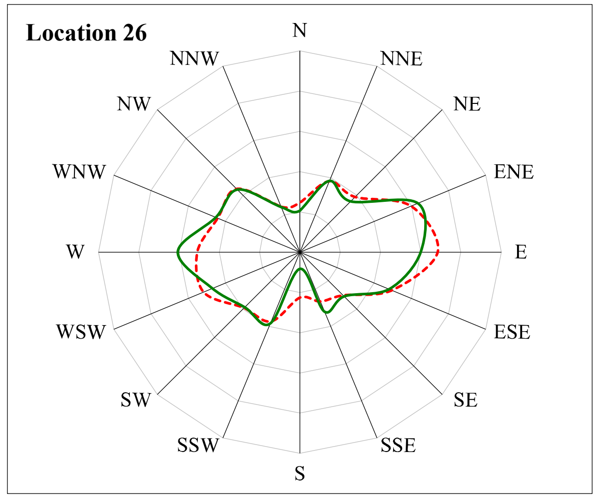
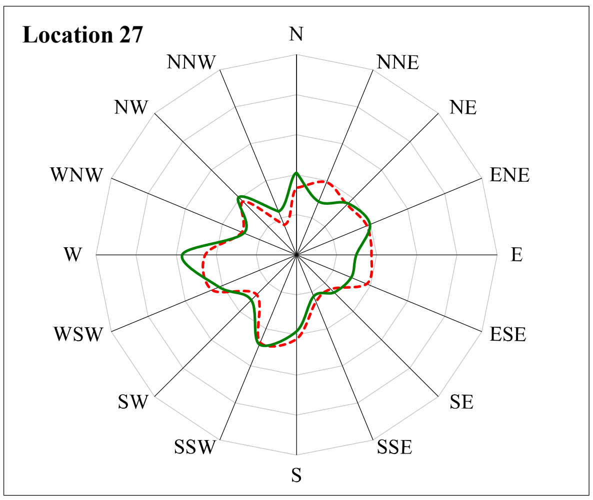
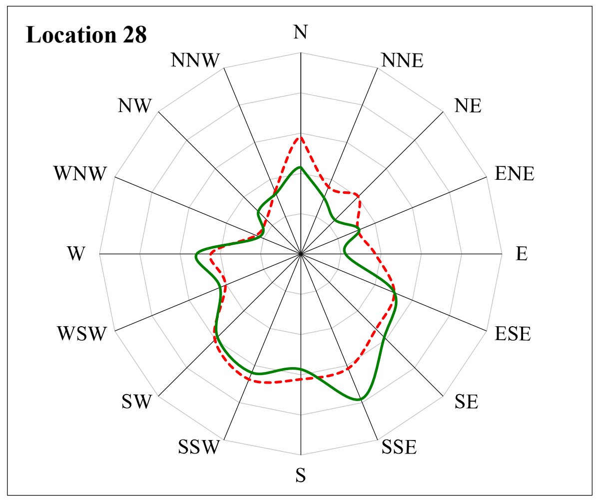


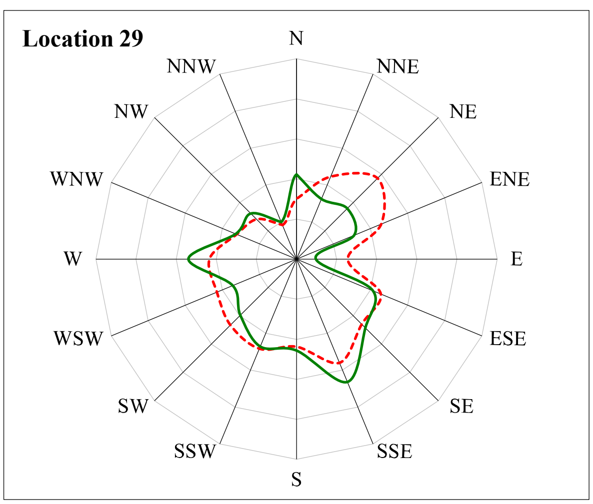
Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

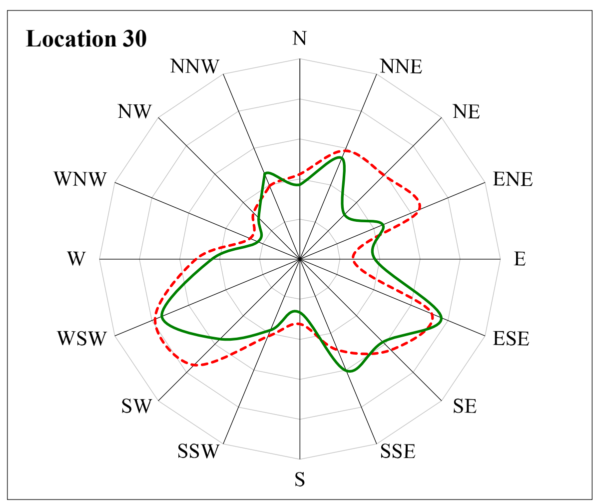












Existing

Proposed

Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

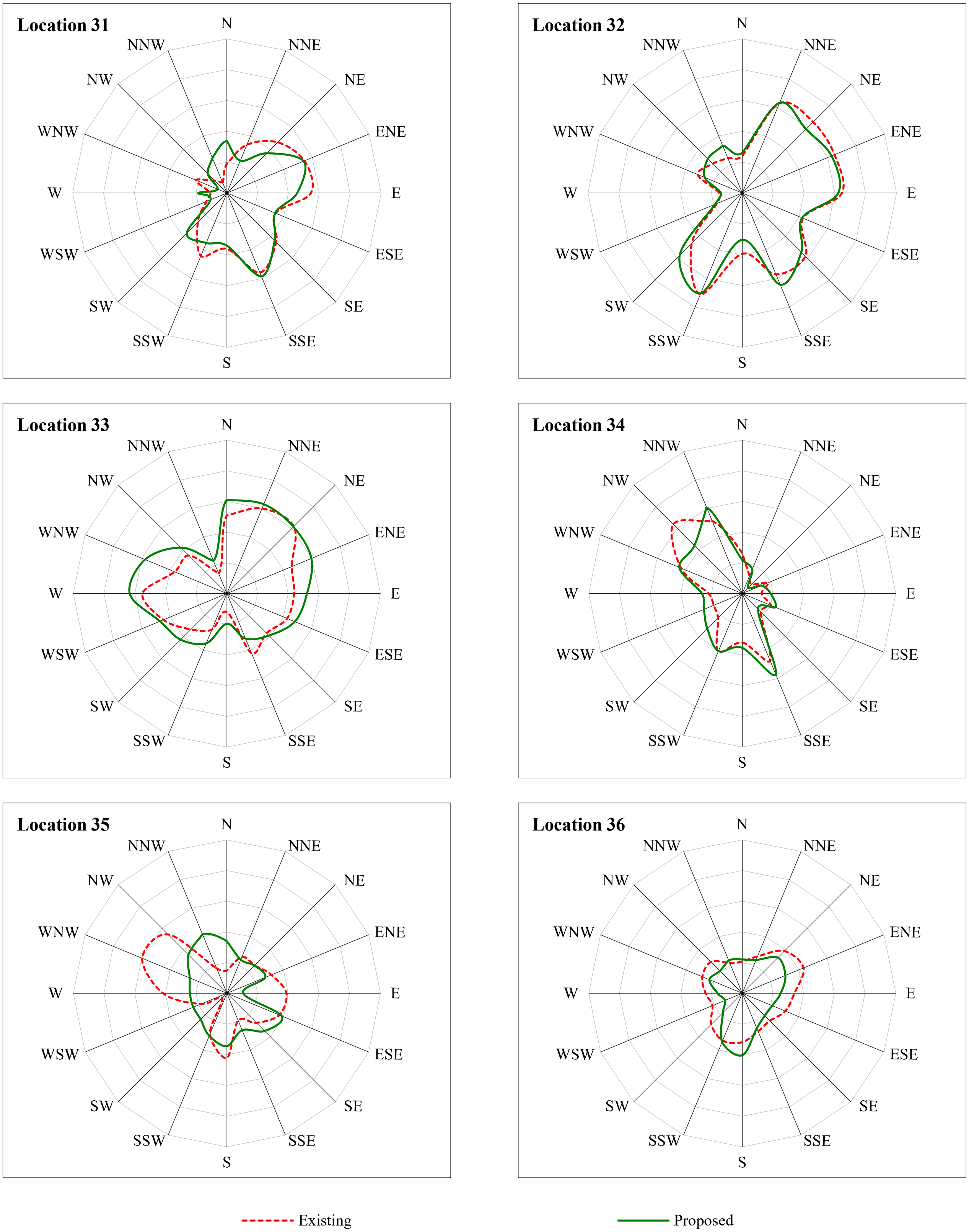
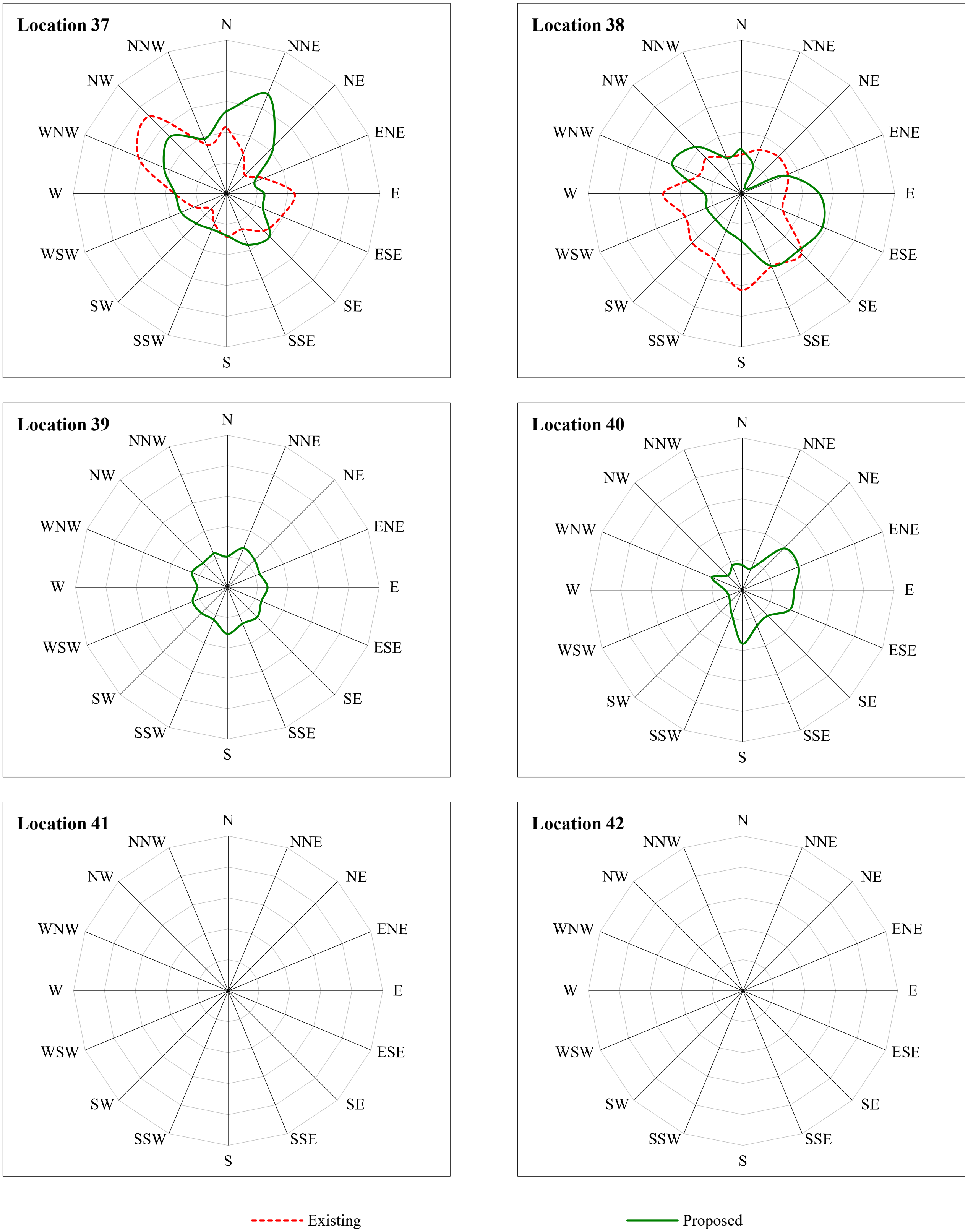


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



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