THEAKSTON ENVIRONMENTAL

Consulting Engineers • Environmental Control Specialists

REPORT

FINAL PEDESTRIAN LEVEL WIND STUDY

86 – 90 Dundas Street East

MISSISSAUGA, ONTARIO

Mississauga I GP INC.

REPORT NO. 19533wind **September 19, 2019**

An International Reputation for Excellence

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1. EXECUTIVE SUMMARY

The mixed-use Development proposed by Mississauga I GP INC., for the property municipally known as 86-90 Dundas Street East, occupying lands to the south of Dundas Street East and east of Hurontario Street, in the City of Mississauga, 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 thirty-eight (38) locations tested are within safety criteria and most are within the comfort criteria described within.

The Development involves a proposal to build a 16 storey mixed-use residential building with a 6 storey podium. Outdoor amenity spaces are proposed at the 7th level atop the podium along the southwest side of the building and at grade to the south and southeast of the building. The proposed Development's residential lobby is accessed via a driveway that runs along the northeast side of the building, set beneath the podium overhang. Access to the vehicular drop off driveway, underground parking, and services is provided off Dundas Street East, from the north boundary of the property.

The Development is, for all intents and purposes, surrounded to prevailing windward directions by a suburban mix of residential and commercial development, related open areas, and mature vegetation. These buildings and related open areas have a sympathetic relationship with the pending wind climate.

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.

These phenomena were observed at the site with prevailing southwesterly winds that have opportunity to accelerate over the relatively open lands of Dundas Street. The relatively open setting cumulatively accounts for the moderately windy conditions observed in the existing setting along Dundas Street East proximate to the Development site. With inclusion of the proposed Development, winds that formerly flowed over the existing lands are redirected, tending to split with portions flowing over, around and down the proposed building's façades. At the pedestrian level, the winds redirect to travel horizontally along the building, around the corners and beyond, creating minor windswept areas and, on occasion, windy conditions at or near the building's corners, and these conditions are primarily attributable to the setting.

Winds emanating from remaining compass points are more effectively mitigated, though to varying degrees, by the local surrounds, and as such, upon impact with the proposed, tend to split, flowing over, and to a lesser extent around and down the building's faces. At the podium levels, the winds redirect to travel horizontally along the roof of the podium, around the corners and beyond, with limited influence upon pedestrian comfort conditions.

These phenomena result in:

- wind conditions along **Dundas Street East** that are generally improved, predicted comfortable, suitable for sitting, standing or walking during the winter months, suitable for the intended purpose,
- an improvement in wind conditions along **Camilla Road** and essentially unchanged wind conditions along **Shepard Avenue** and **Jaguar Valley Drive**, which were predicted suitable for standing or better in the proposed setting,
- winter conditions along a portion of the **Laneway** to the northeast that are suitable for walking, but remain suitable for the intended purpose, and
- seasonally appropriate comfort conditions at the proposed **Amenity Spaces** upon consideration of massing and landscaping features that were too fine to incorporate into the model, along with recommended mitigation.

The proposed Development employs podiums, overhangs, stepped façades, landscaping, and other wind mitigative devices that will deflect or otherwise redirect downwash prior to its influencing the surroundings. These, in concert with surface features that are too fine to incorporate into the model, and future urban development, will improve predicted pedestrian comfort conditions. The proposed Development will realize wind conditions acceptable to a typical suburban context.

Subsequent to testing the model, the massing of the proposed Development was revised whereby the notable changes are as follows:

- the tower was increased from 15 to 16 storeys,
- the 6th level step in the podium along the southeast façade was removed, and
- the 6th level step in the podium along the southwest façade was brought down to the second level.

The massing revisions are considered minor and are not expected to have an appreciable impact on pedestrian level wind conditions. As such the conclusions and recommendations of this report remain valid.

Respectfully submitted,

Stephen Pollock, P. Eng. Paul Kankainen, M.A.Sc.

2. INTRODUCTION

Theakston Environmental Consulting Engineers, Fergus, Ontario, were retained by Mississauga I GP INC., to study the pedestrian level wind environment for their proposed mixed-use residential Development occupying lands to the south of Dundas Street East. The Development will be located in the City of Mississauga, with the site as depicted on the Aerial Photo in Figure 2a. The Development involves a proposal to construct a 16 storey mixed-use residential building with a 6 storey podium in the configuration shown in Figure 2b.

Jeff Murva with Emblem Developments initiated the request, and Studio JCI 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 buildings, sidewalks, courtyards on the property, as well as 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 existing and proposed buildings in the surrounding area. The proposed configuration included the Development's subject building.

The laboratory techniques used in this Pedestrian Level Wind 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 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 respects methodology described by Mississauga for the predictions of pedestrian comfort for various probabilities of occurrence and percentages of time that are weighted relative to the historical range of wind conditions.

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 visualisation of the complex wind flow patterns often realised in an urban environment.

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 thirty-eight (38) 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 20% 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 the Mississauga region 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 500*m* using a standard open exposure wind profile. The mean-hourly wind speed at a 500*m* reference height used for this study is 45.6*m/s* for a return period of 50 years. The corresponding 1-year return period wind speed at the 500*m* height is 36*m/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 fall 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. Studio JCI provided architectural drawings. City of Mississauga aerial 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 20% 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	**Gust Equivalent Mean Speed Exceeded 20% of the Time**		**Description**
COMFORT	***km/h***	***m/s*** (used in Fig. 6)	
Sitting	0-10	0-2.8	Calm or light breezes desired for outdoor restaurants and seating areas where one can read a paper without having it blown away.
Standing	0-15	0-4.2	Gentle breezes suitable for main building entrances and bus stops.
Walking	0-20	0-5.6	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering.
Uncomfortable	>20	>5.6	Strong winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended.

The activities are described as suitable for Sitting, Standing, Walking, or Uncomfortable, depending on average wind speed exceeded 20% of the time. For a point to be rated as suitable for Sitting, for example, the wind conditions must not exceed 10*km/h* (2.8*m/s*), more than 20% 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. 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 15*km/h* (4.2*m/s*). In this situation, the wind would rustle tree leaves and, on occasion, move smaller branches while flags flap. This category would be suitable for locations where people might sit for short periods or stand in relative comfort. The Walking category includes wind speeds from calm up to 20*km/h* (5.6*m/s*). These winds would set tree limbs in motion, lift leaves, litter and dust, and the locations are suitable for activity areas. The Uncomfortable category covers a broad range of wind conditions that are generally a nuisance for most activities, including wind speeds above 20*km/h* (15.6*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 20% 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 5*km/h* (or more) interval. The location is rated as suitable for Sitting, Standing, Walking, or Uncomfortable, 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 nine times 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. The comfort criteria were subsequently revised for the Mississauga Urban Design Terms of Reference for Wind Comfort and Safety Studies, in consultation with RWDI and more closely respects the Lawson criteria.

Table 2: Safety Criteria

ACTIVITY	Mean Wind Speed Exceeded 9 times per year		Description
SAFETY	***km/h***	***m/s*** (used in Fig. 8)	
All-Weather	0-90	0-25	Acceptable gust speeds that will not adversely affect a pedestrian's balance and footing.
Exceeding All-Weather	>90	>25	Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required.

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

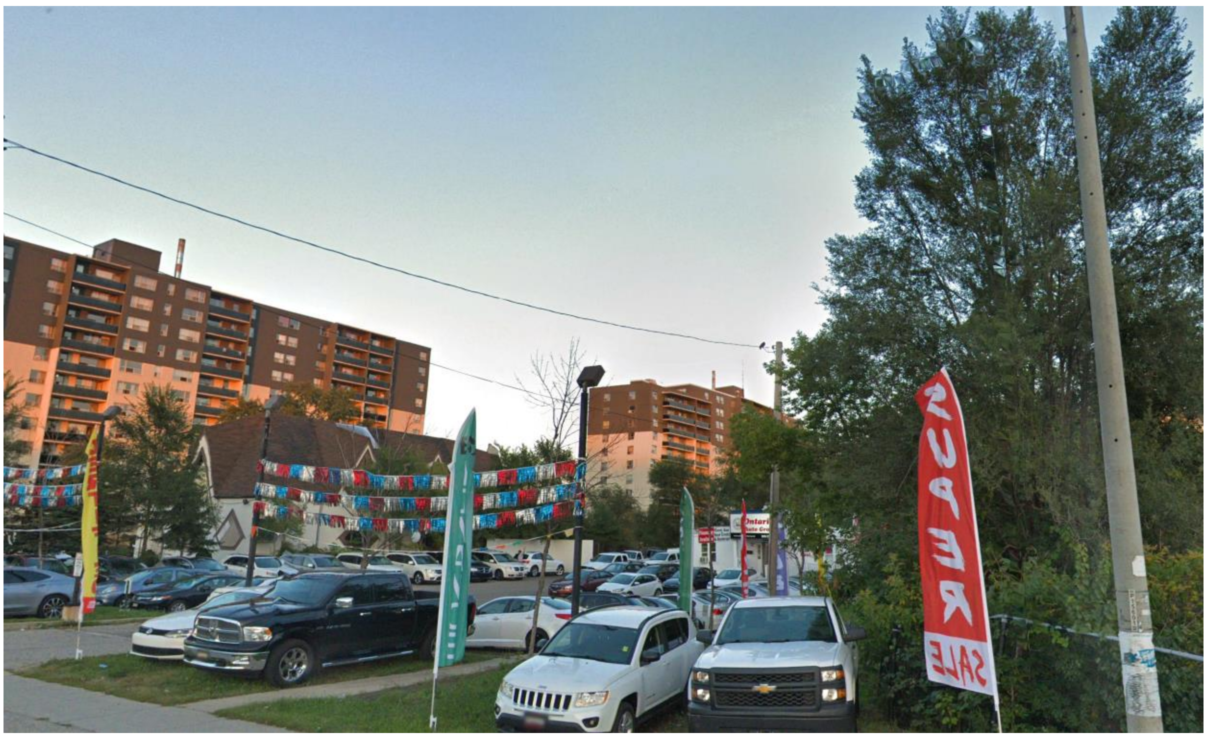
5.1 Study Site and Test Conditions

Proposed Development

The Proposed Development occupies a block of land bounded by King Street East to the southeast, Shepard Avenue to the southwest, Dundas Street East to the northwest, and Camilla Road to the northeast. Note: Mississauga's street orientation is relative to the Lake Ontario Shoreline resulting in east/west orientated streets in the subject area being offset by approximately 50 degrees north. The site consists of 5,411 square metres and is currently occupied by low-rise commercial (formerly a restaurant and auto sales) which shares the block with low through high-density residential buildings, street related office and commercial (along

Dundas Street East) and associated parking and green spaces. The block of lands is bisected by Cooksville Creek that flows along the southwest boundary of the Site, the verges of the creek populated with relatively mature vegetation (Figure 2a).

The Development involves a proposal to construct a 16 storey mixed-use residential building with a 6 storey podium. Outdoor amenity spaces are proposed at the 7th level atop the podium along the southwest side of the building and at grade to the south and southeast of the building. The proposed Development's residential lobby is accessed via a driveway that runs along the northeast side of the building, set beneath the podium overhang. Access to the vehicular drop off driveway, underground parking, and services is provided off Dundas Street East, from the north boundary of the property.



86-90 Dundas Street East Development Site Looking East (Google)

<u>Surrounding Area</u>

The most noteworthy buildings in the immediate surroundings, by proximity are two slab style 12 storey residential buildings situated to the immediate east of the Proposed (Tiffany and Skyline Apartments respectively at 100 and 120 Dundas Street East) with low to mid-rise office and residential buildings beyond. To the south beyond the forested area along Cooksville Creek is a strip mall (60 Dundas Street East), followed by the 10 and 18 storey King Gardens Place Retirement Residence at 85 and 75 King Street East with related parking and low-rise residential and a mature mix of deciduous and coniferous plantings beyond. To the immediate west of the Development site is primarily low-rise street related commercial development along Dundas Street East and Hurontario Street with related parking areas. Farther to the west there is a 6 storey mixed use building at 3025 Hurontario Street, approximately 250m away, and a 13 storey mixed-use building along Agnes Street, approximately 400m away. To the immediate north are 2 storey strip malls and associated parking areas with John C. Price Park and an Outdoor Rink beyond. These outdoor areas are adjacent to Cooksville Creek and are forested with a mix of deciduous and coniferous plantings. Farther to the north are three slab style residential buildings ranging in height from 12 to 29 storeys, accessed from Kirwin Avenue. These buildings are more than 250m removed from the Development 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 suburban 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. For studies in the City of Mississauga, the data is split up into four seasons, spring, summer, fall and winter, and the resulting wind roses are presented as mean velocity and percent frequency in Figures 5b-e. The mean velocities presented in the wind roses are measured at an elevation of 10*m*. Thus, representative ground level velocities at a height of 2*m*, 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 this area is predominantly suburban.

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 generally pertain to annual conditions unless stated otherwise.

5.2 Pedestrian Level Wind Velocity Study

On the site model, thirty-eight (38) wind velocity measurement probes were located around the Proposed Development and 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 "existing" site model retested with the current site.

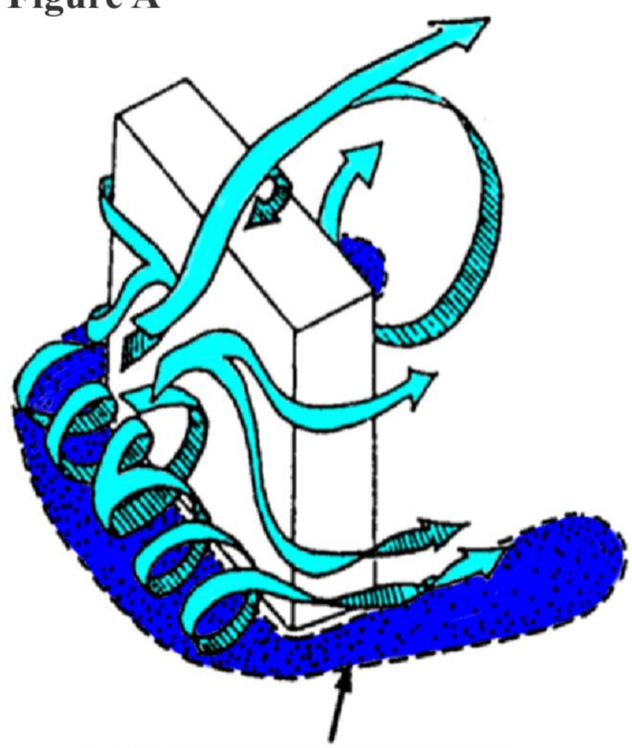
Measurements of pedestrian level mean and gust wind speeds at the various locations shown were taken over a period of time equivalent to one hour of measurements at full-scale. The mean ground level wind velocity measured is presented as a ratio of gradient wind speed, in the plots of Figure B in the 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 are applied.

The design probability distribution gradient wind speed and direction, taken from historical meteorological data for the area (see 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 a 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 open to a predominantly suburban setting to prevailing and remaining compass points with winds flowing over and between mature vegetation, low-rise, mid-rise, and high-rise buildings and open spaces. As such, the surroundings can be expected to influence wind at the site to varying degrees. Note: Probes are positioned at points typically subject to windy conditions in a suburban environment in order to determine the worst-case scenario.

Figure A



High-rise buildings may exacerbate wind conditions within their immediate vicinity, to varying degrees, by redirecting wind currents to the ground level and along streets and open areas. In general, wind will split upon impact with a high-rise building, with portions flowing down the face of the building to the pedestrian level as downwash, where it is deflected, or otherwise redirected to flow along the building and around its corners, creating localized zones of increased pedestrian level wind (Figure A). Conversely, points situated to the leeside, or in the wake of buildings will often enjoy an improvement in pedestrian comfort. As such, it is reasonable to expect inclusion of the proposed development will alter wind conditions under specific wind directions and velocities from those of the existing site condition, resulting in an improvement over the existing conditions at some points, with more windy conditions at others.

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

5.3 Review of Probe Results

The probe results, as follows, were clustered into groups comprised of Public Street Conditions, Neighbouring Properties, Amenity Space, and Pedestrian Entrance Conditions. The measurement locations are depicted in Figure 4 and the resulting pedestrian comfort conditions are listed in Figures 6a – 6e annually and for the seasons for the existing and proposed configurations. The results are also graphically depicted annually, and for the seasons in Figures 7a – 7j. The following discusses anticipated wind conditions and suitability for the points' intended use.

Public Street Conditions

Dundas Street East
Dundas Street East is orientated in a near northeast – southwest direction and is approximately perpendicular to Hurontario Street. Probes 1 through 15 were located along Dundas Street East, within the zone of influence of the proposed Development, as indicated 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 along Dundas Street East indicate annual wind conditions that are mainly suitable for standing in the existing setting. Slightly windier conditions, suitable for walking, are predicted at probe location 13, to the northeast of the site; conversely, Locations 1 and 4 are relatively more sheltered and rated as suitable for sitting.

For locations along Dundas Street East that were observed as windier in the existing setting, the rating can be partially attributed to northeasterly through easterly and westerly winds being deflected on approach by the 12 storey slab style apartment building at 120 Dundas Street East to flow along Dundas Street East, accounting for windy, though not uncomfortable winter wind conditions in the existing setting.

Inclusion of the proposed 16 storey building had only a minor impact on the winds realized along Dundas Street East. Many of the points realized slight improvement to wind, insufficient to change comfort ratings, with the exception of the above-mentioned Probe 13, that improved from walking to standing annually. Conversely a few points along the street realised a slight increase in wind, only sufficient to change point 4, across the road from the proposed Development, from sitting to standing annually. The similar conditions along Dundas Street East can be attributed to the proposed building's podium and setback from the street, reducing the impact of downwash from the building. Mitigation of downwash conditions is well understood and was further applied through design whereby canopies, balconies, overhangs, as well as other design features, were employed. These, considered in concert with massing features that were too fine to be incorporated into the surroundings, will further improve the wind conditions realized along the street.

Dundas Street East will remain comfortable and suitable for its intended purpose and within the pedestrian level wind velocity safety criteria as an All-Weather Area, as described in Section 4.7 and depicted in Figure 9.

Jaguar Valley Drive, Shepard Avenue and Camilla Road

Probes 16 through 20 were located along the above-named streets within the zone of influence of the proposed Development. These test locations also indicate a comfortable setting in the existing configuration, with the probe locations predicted as suitable for standing annually, and suitable to the respective areas' intended purposes.

The additional wind blockage created by the proposed 86-90 Dundas Street East Development to winds that traditionally flowed over the area, induces a slight improvement in wind conditions realised along the adjacent streets. The impact is insufficient to change comfort ratings from suitable for standing annually, with the exception of probe location 20 on Camilla Road that improved to sitting. The streets are predicted comfortable for the intended use and within the pedestrian level wind velocity safety criteria as All-Weather Areas.

Neighbouring Properties

Probes 21 through 26 were placed on or about neighbouring properties in the immediate surrounds that might be affected with inclusion of the proposed 86-90 Dundas Street East Development. Of these probes 21 through 24 were located along the driveway or proximate to the entrances serving the 12 storey Tiffany and Skyline Apartments, respectively at 100 and 120 Dundas Street East. The analysis indicates existing conditions that are suitable for standing annually at the instrumented entrances and along the driveway.

With inclusion of the proposed Development points 22 to 24 realised annual conditions similar to the existing setting, however, point 21 realised an increase to winds in the area that resulted in a shift in categories to walking at the north end of the driveway to the Tiffany Apartment building. In the winter months, the area is predicted to be windier, with conditions suitable for walking predicted at points 21 to 23. These changes can be attributed to winds, that formerly flowed over the relatively more open subject property, being deflected to flow around the proposed development and through the gap created between the buildings. The neighbouring

Tiffany Apartment driveway and Skyline Apartment property are flanked with mature deciduous and coniferous trees and fencing that will present a significant restriction to winds flowing through the area. This, considered in concert with the subject and neighbouring buildings' landscape and design features that were too fine to incorporate into the model, will result in pedestrian comfort conditions more comfortable than those reported, suitable for the intended use throughout the winter months.

The 60 Dundas strip mall realises an improvement to winds, sufficient to change the annual comfort category to sitting for probes 25 and 26. As such, each of the above-mentioned points remain appropriate to the respective area's intended purpose with inclusion of the proposed Development and are within the pedestrian level wind velocity safety criteria as All-Weather Areas, as described in Section 4.7 and depicted in Figure 9.

Amenity Space

Outdoor amenity space is proposed for the 7th level along the southwest side of the proposed Development's podium, as depicted in Figure 2b. The amenity space as proposed is in the wake of the tower and the neighbouring buildings with winds from specific directions, however, as indicated by the appendices Figure B for probe 38, the area is susceptible to northwesterly through southwesterly winds flowing over portions of the roof, resulting in localised windy conditions, on the occasion of high ambient winds from said directions. The area is predicted suitable for standing in the summer and fall and walking in the spring months, however, given the area is at the transition to standing in the spring, it will likely realise conditions suitable for standing seasonally. Consideration of the building's design details that were too fine to incorporate into the model will further improve the predicted comfort conditions.

The amenity space is predicted to be suitable for standing much of the time, and as such is expected to be marginally suitable for the intended purpose. In order to achieve longer exposures required to accommodate the desired activities, a mitigation plan is recommended, as discussed below. We expect the space will be subject to seasonal use and will, with mitigation in place, reflect a reasonable balance between pedestrian comfort and functionality, and will be suitable for its intended purpose.

The grounds situated to the south and southeast of the proposed Development adjacent to Cooksville Creek, as represented by probes 33 to 37, are predicted as annually suitable for standing along the edges of the property and sitting within closer proximity to the building. The area to the south of the building is in the aerodynamic shade region of the proposed Development to much of the northern wind climate and as such realises slightly more comfortable conditions, suitable for sitting in the summer. Portions of this area more proximate to building corners, as represented by probes 35 and 37 will be susceptible to northwesterly and southeasterly winds flowing around the corners and over the space, resulting in conditions suitable for standing in the spring and fall for location 35 and standing in the spring for location 37. The area would benefit from additional mitigation, as discussed below, to allow for longer exposure times further into the shoulder seasons.

The area to the southeast of the proposed Development is relatively more open and exposed to winds emanating from the northeast and southwest that are directed to flow through gaps between the neighbouring and proposed buildings and over the area. The area will experience comfort conditions suitable for standing seasonally and as such will require appropriate mitigation to improve conditions to be suitable to the areas' intended purpose. The analysis was conducted without the subject and neighbouring buildings' fine design features or existing and proposed hard and soft landscape features in place. As such, we reasonably expect prevailing pedestrian comfort conditions will be better than those predicted.

A mitigation plan is recommended for the Amenity Areas, if activities requiring longer exposure times are desired. This might be accomplished with a landscaping plan for the Rooftop Amenity Space that includes appropriately engineered windscreens, railings, trellises, coarse vegetation, and others, which considered cumulatively, will further improve wind conditions in the residential amenity area, making it more suitable to the intended purpose. Similar concepts applied to the at-grade Amenity Areas will improve pedestrian comfort conditions to within acceptable guidelines there as well. Consideration of existing and proposed surface roughness features too fine to incorporate into the massing model will result in comfort ratings better than those predicted.

Pedestrian Entrance Conditions

Probes 27 through 30 were placed along the sidewalk at or near the Dundas Street East Retail Entrances and probes 31 and 32 near the Main Residential Lobby Entrance adjacent to the driveway, as depicted in Figure 4. The locations exhibit moderately windy conditions in the existing setting, suitable for standing annually. These existing conditions are attributable to what is considered a relatively open setting; the low-rise commercial buildings and related parking areas situated to much of the prevailing wind climate will afford wind opportunity to accelerate on approach.

With the inclusion of the proposed Development, the wind is deflected over, and/or around and down the building towards the pedestrian level, the ultimate as downwash. Of the portion of the wind that does downwash to the pedestrian level, the majority is intercepted by balconies, stepped conditions, and overhangs at the podium, where it is deflected to flow around the building above the pedestrian level. This mechanism is observed in the results from locations 27 through 30, where comfort conditions improved significantly with the inclusion of the proposed Development, however, the annual improvement was only sufficient to change the comfort ratings to sitting at locations 28 and 29. The retail entrances along Dundas Street East are predicted comfortable and suitable for the intended purpose throughout the seasons.

Locations 31 and 32, situated proximate to the main entrance accessed from the vehicular drop-off are set beneath an overhang and protected from significant portions of the dominant wind climate, and as such are predicted comfortable and suitable for sitting year-round. Note: The locations were displaced by the existing building and as such were not tested in the existing setting.

Wind conditions comfortable for standing are preferable at building entrances, while conditions suitable for walking are suitable for sidewalks. Conditions at the proposed main residential entrance and related walkways are considered comfortable, and suitable to the intended purpose. Consideration of existing and proposed surface roughness features too fine to incorporate into the massing model will improve the comfort ratings.

5.4 Summary

The observed wind velocity and flow patterns at the Development are largely influenced by approach wind characteristics that are dictated by the suburban mix of residential and commercial development, related open areas, and mature vegetation mitigating the wind, to different degrees, on approach. Historical weather data 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 5 percent of the time during the summer. Once the subject site is developed, ground level winds at several locations will improve, with occasional localized areas of higher pedestrian level winds. The relationship between surface roughness and wind is discussed in the Appendix and shown graphically in Figure A of the same section.

Consideration of existing and proposed building features too fine to incorporate into the massing model, along with recommended mitigation through the implementation of the landscape plan, will improve the predicted comfort ratings beyond those reported herein, resulting in conditions suitable for the intended use.

6. FIGURES

Figure 1: Laboratory Testing Facility

Figure 2a: Site Aerial Photo

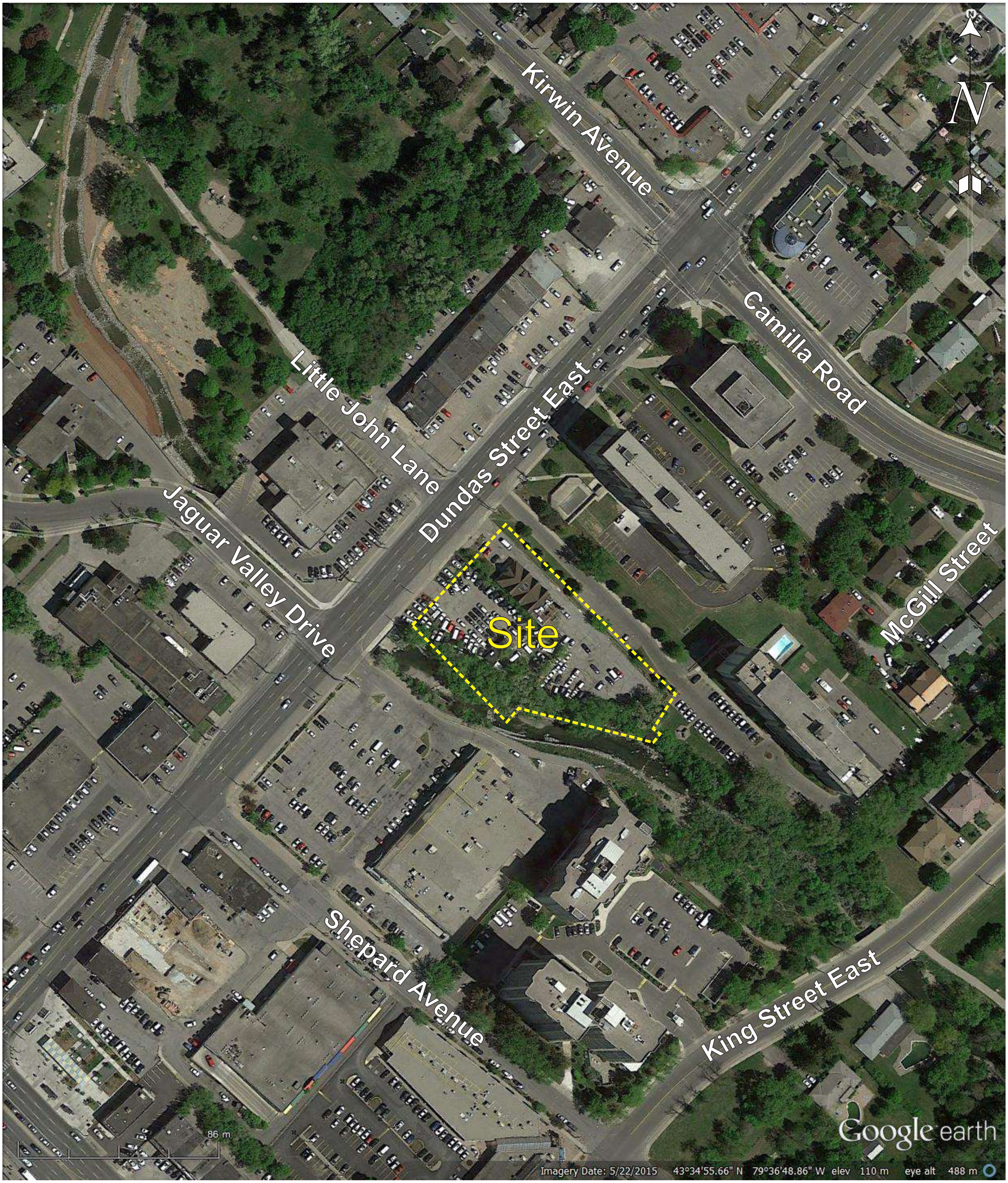


Figure 2b: Site Plan

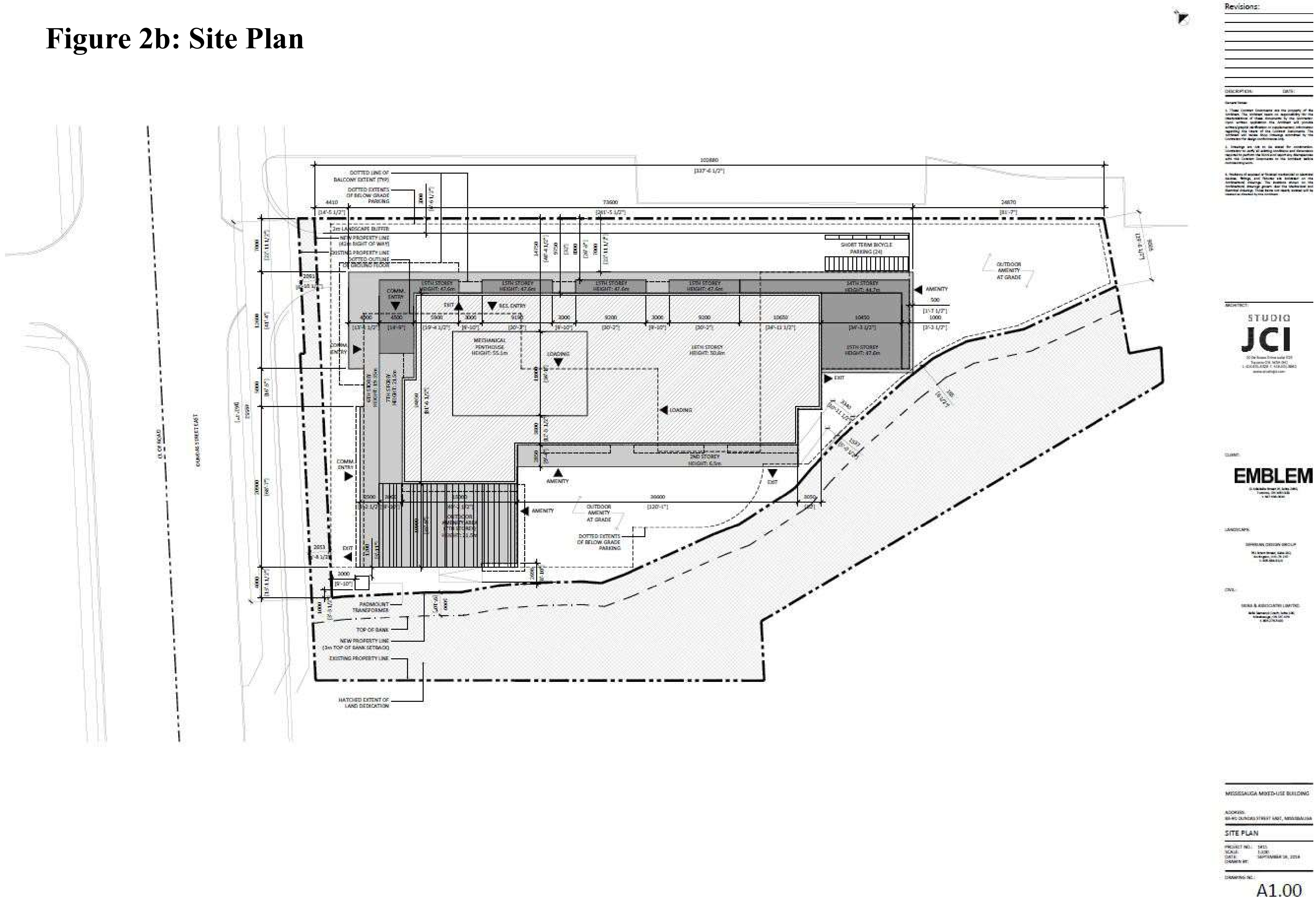
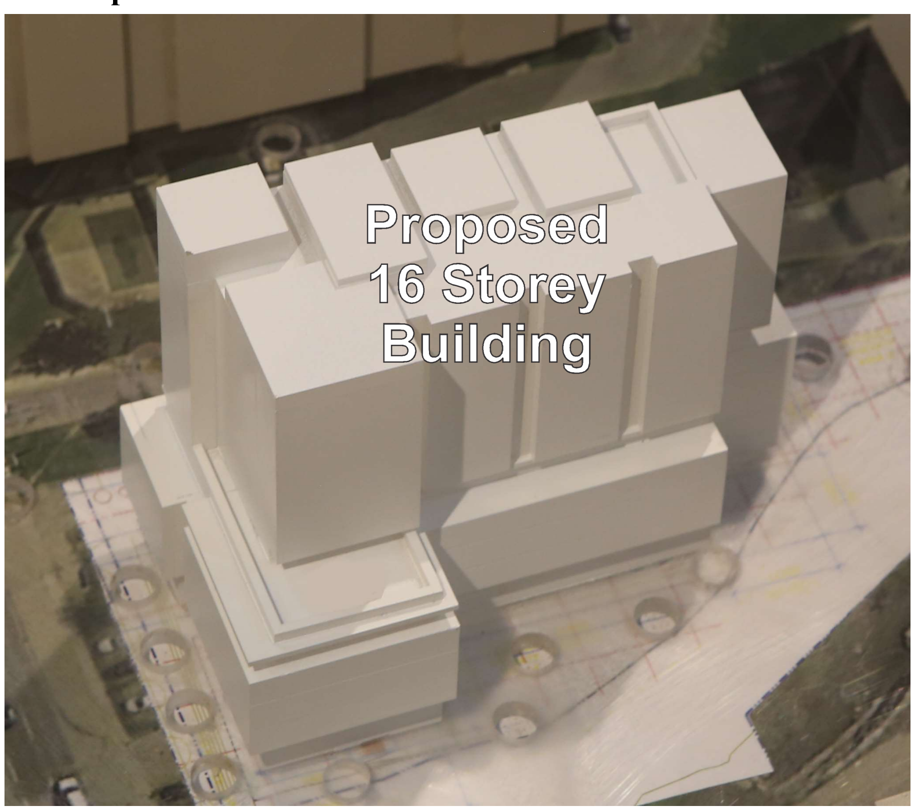


Figure 3: 1:500 Scale model of test site

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.

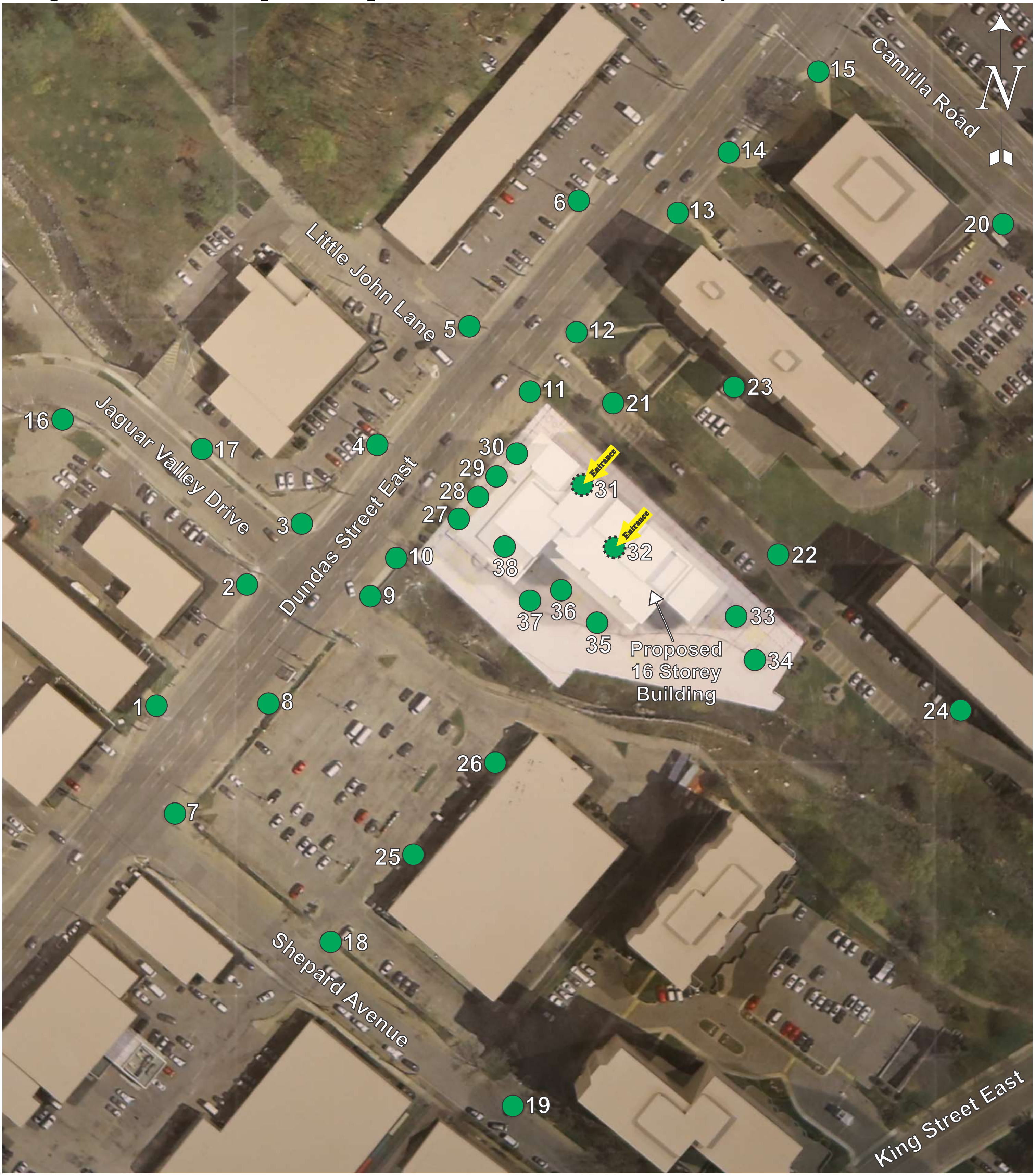


Figure 5a: Annual Wind Rose - Pearson International Airport.

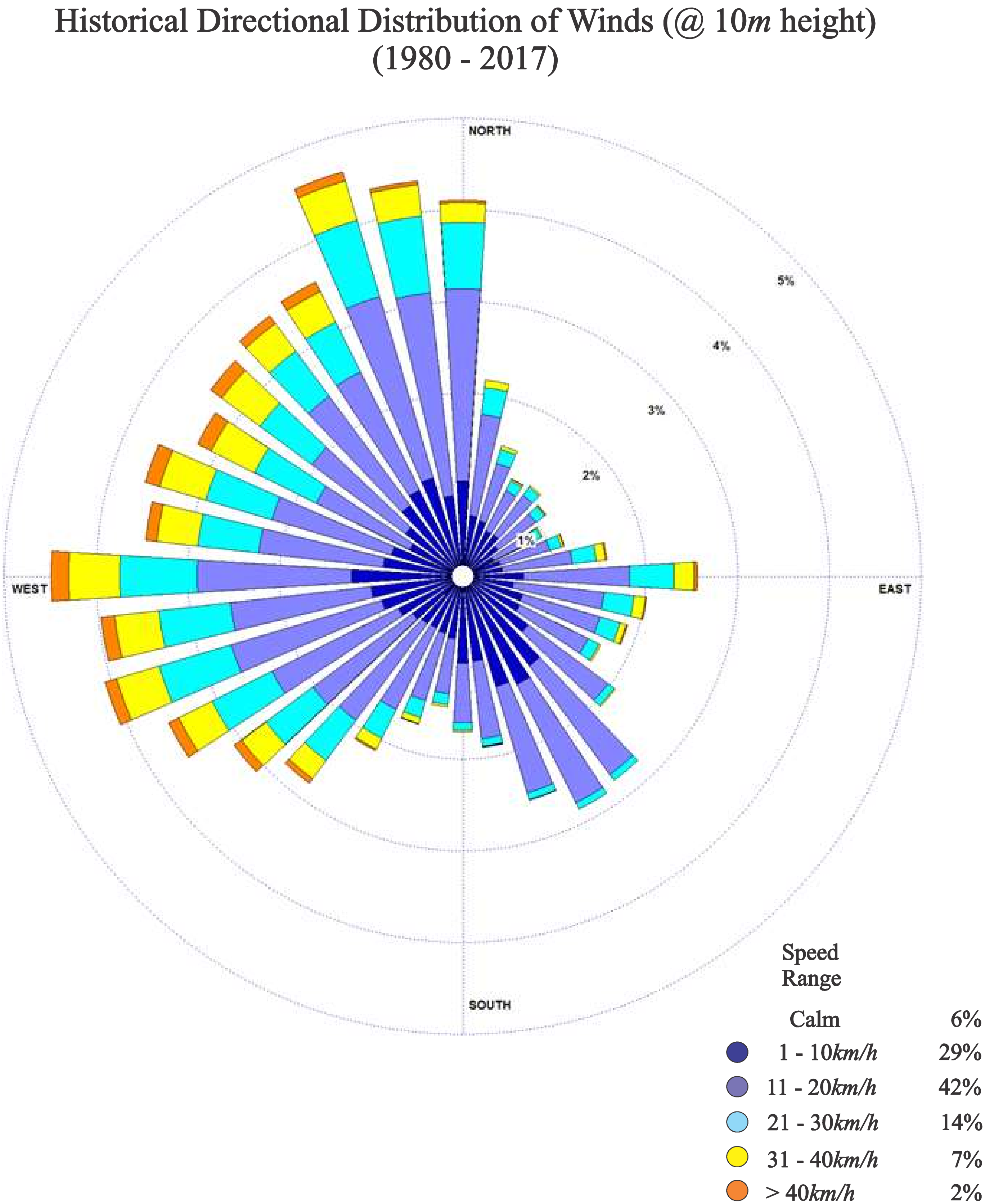
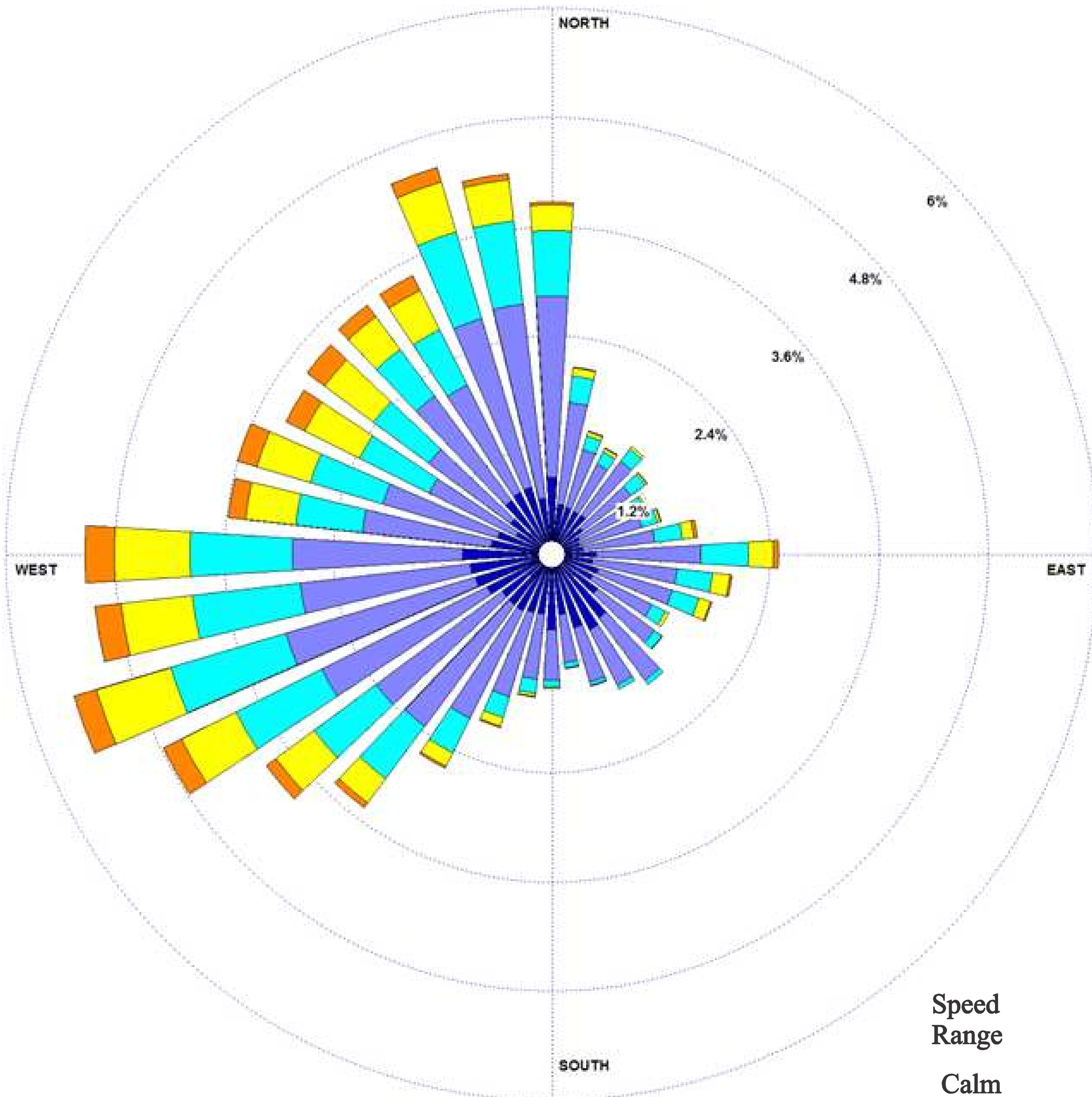


Figure 5b: Winter Wind Rose - Pearson International Airport.

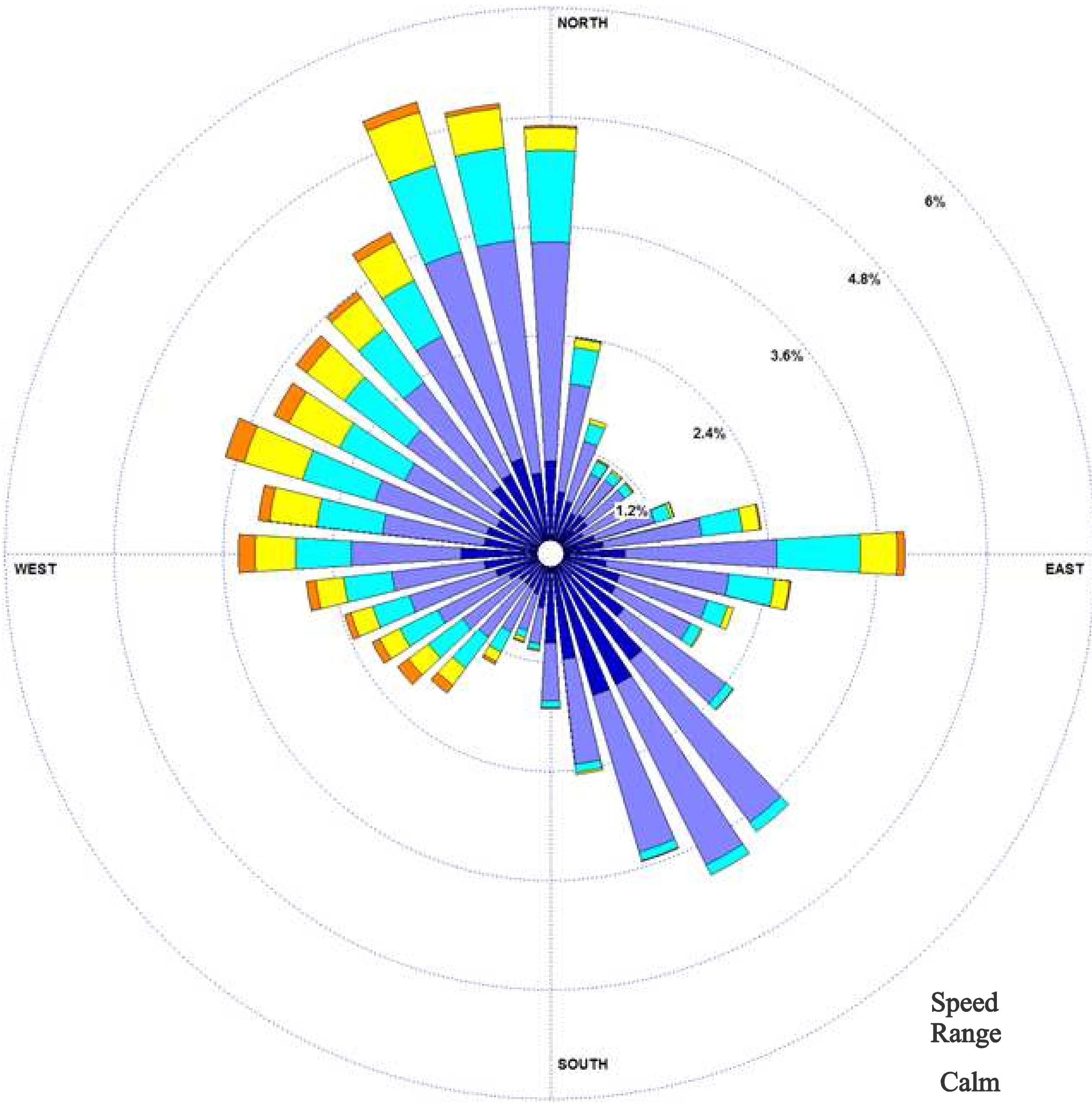
Historical Directional Distribution of Winds (@ 10*m* height)
November 16 through March 31 (1980 - 2017)



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%

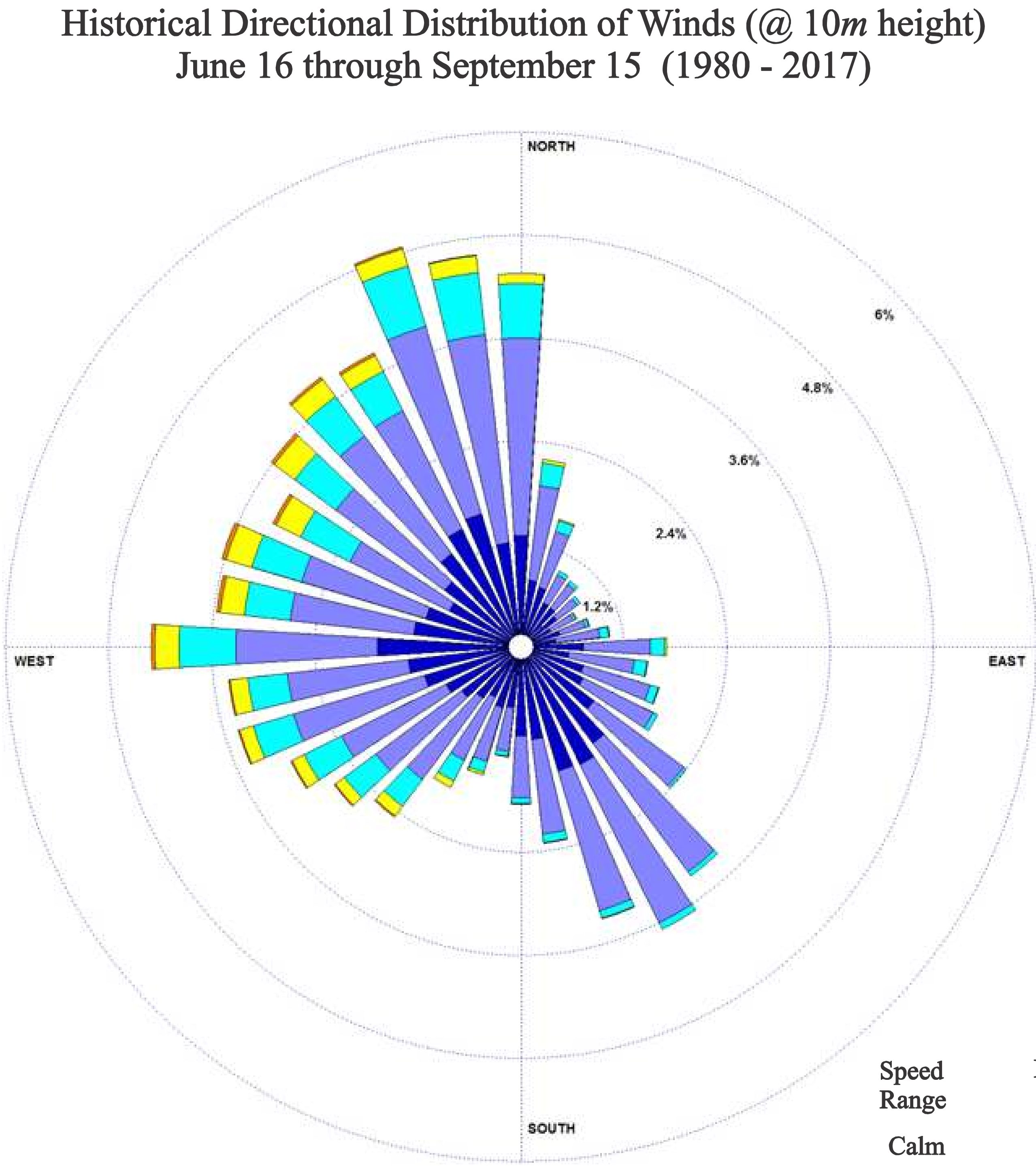
Figure 5c: Spring Wind Rose - Pearson International Airport.

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.



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.

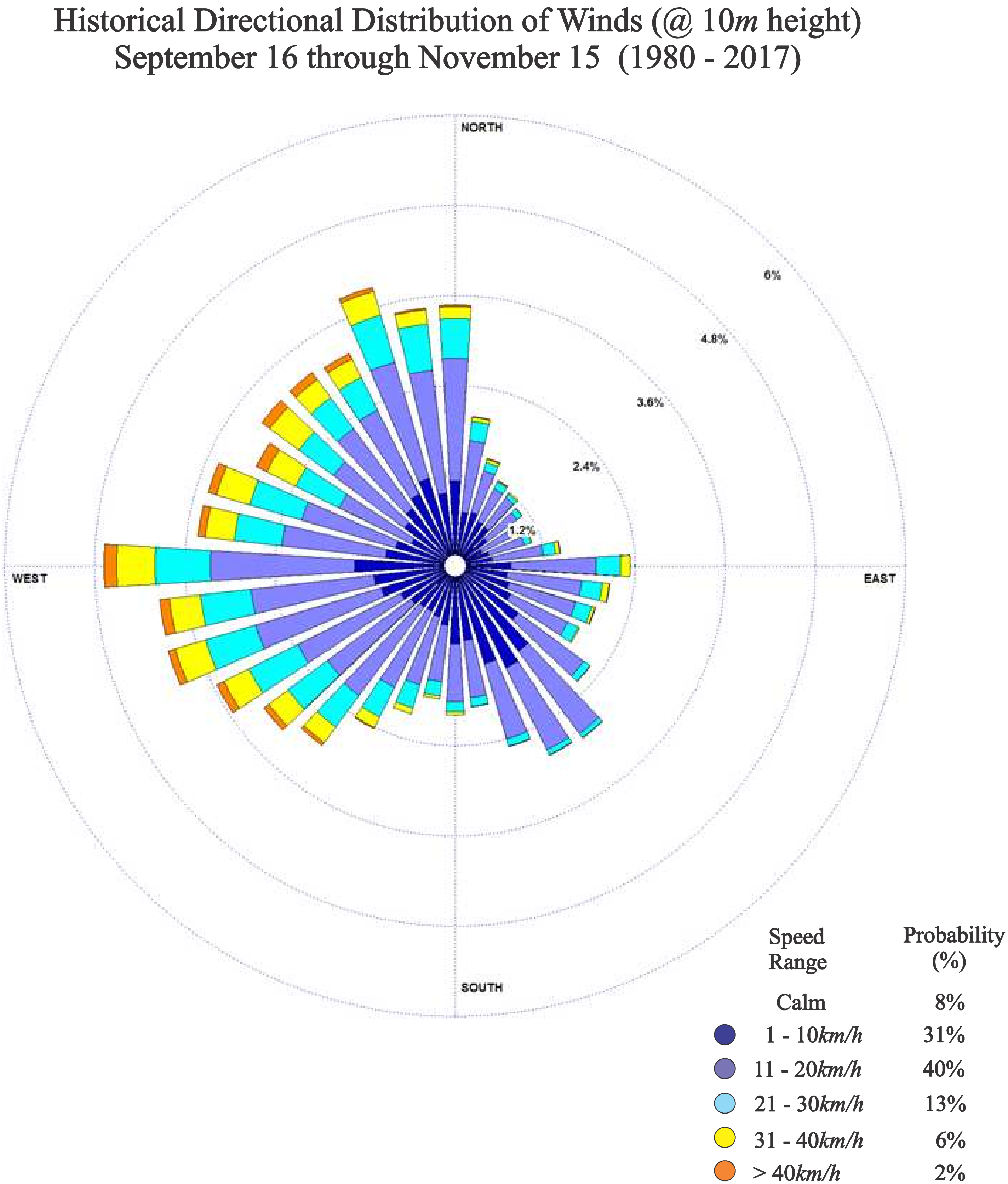
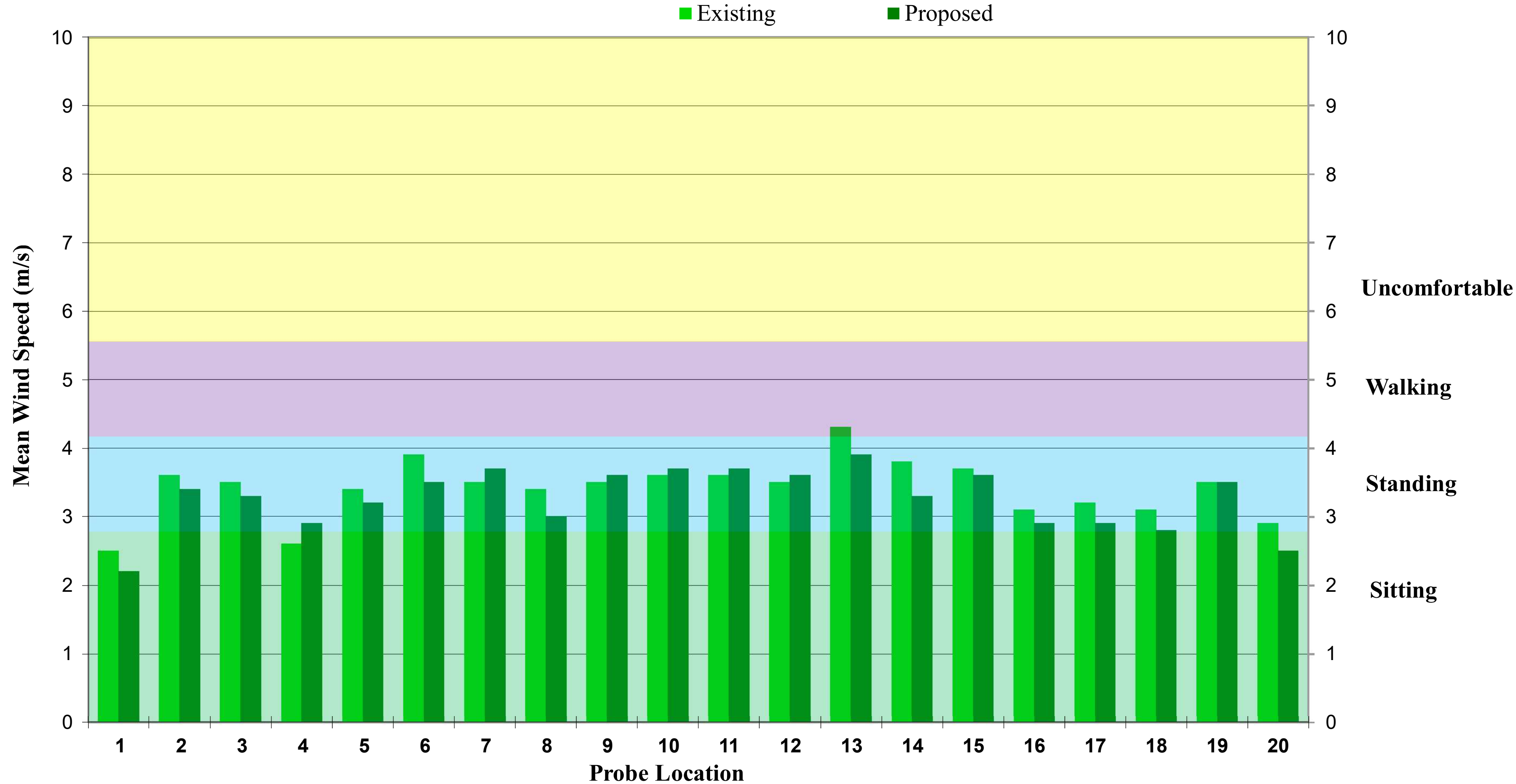


Figure 6a: ANNUAL - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).



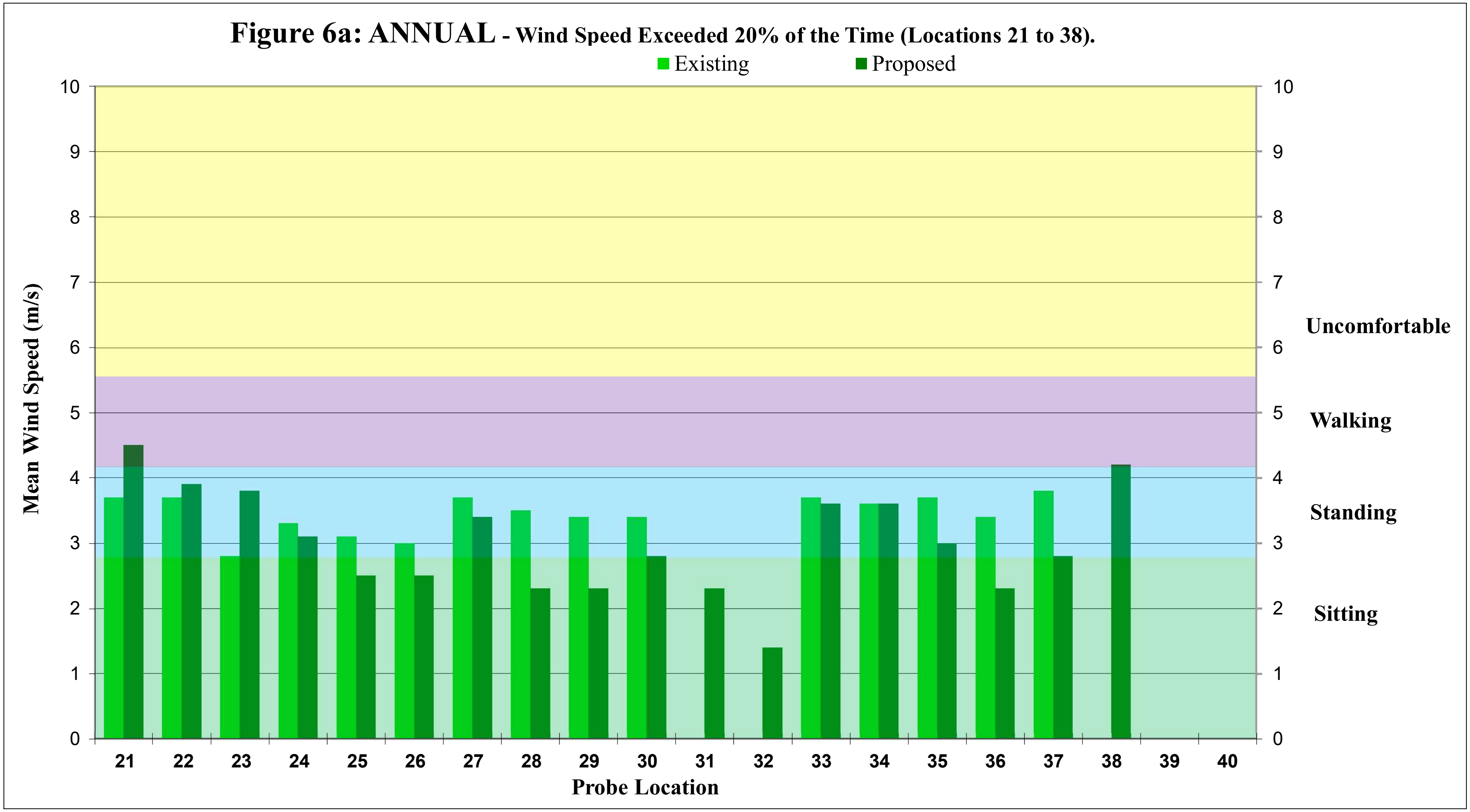


Figure 6a: ANNUAL - Wind Speed Exceeded 20% of the Time (Locations 21 to 38).
Existing
Proposed
Mean Wind Speed (m/s)
Uncomfortable
Walking
Standing
Sitting
Probe Location
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
0 1 2 3 4 5 6 7 8 9 10

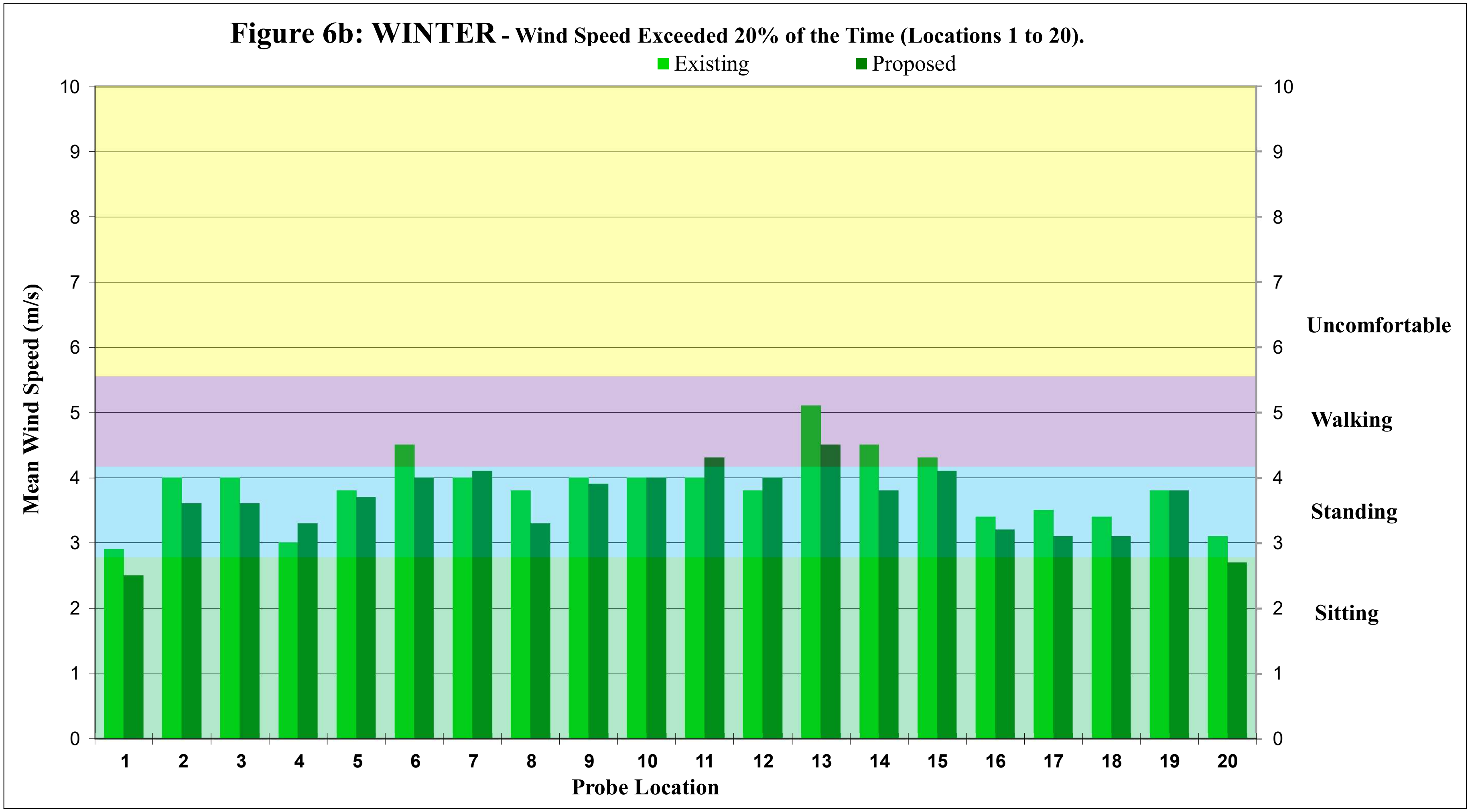


Figure 6b: WINTER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
2
3
4
5
6
7
8
9
10
1
2
3
4
5
6
7
8
9
10
11
12
13
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16
17
18
19
20

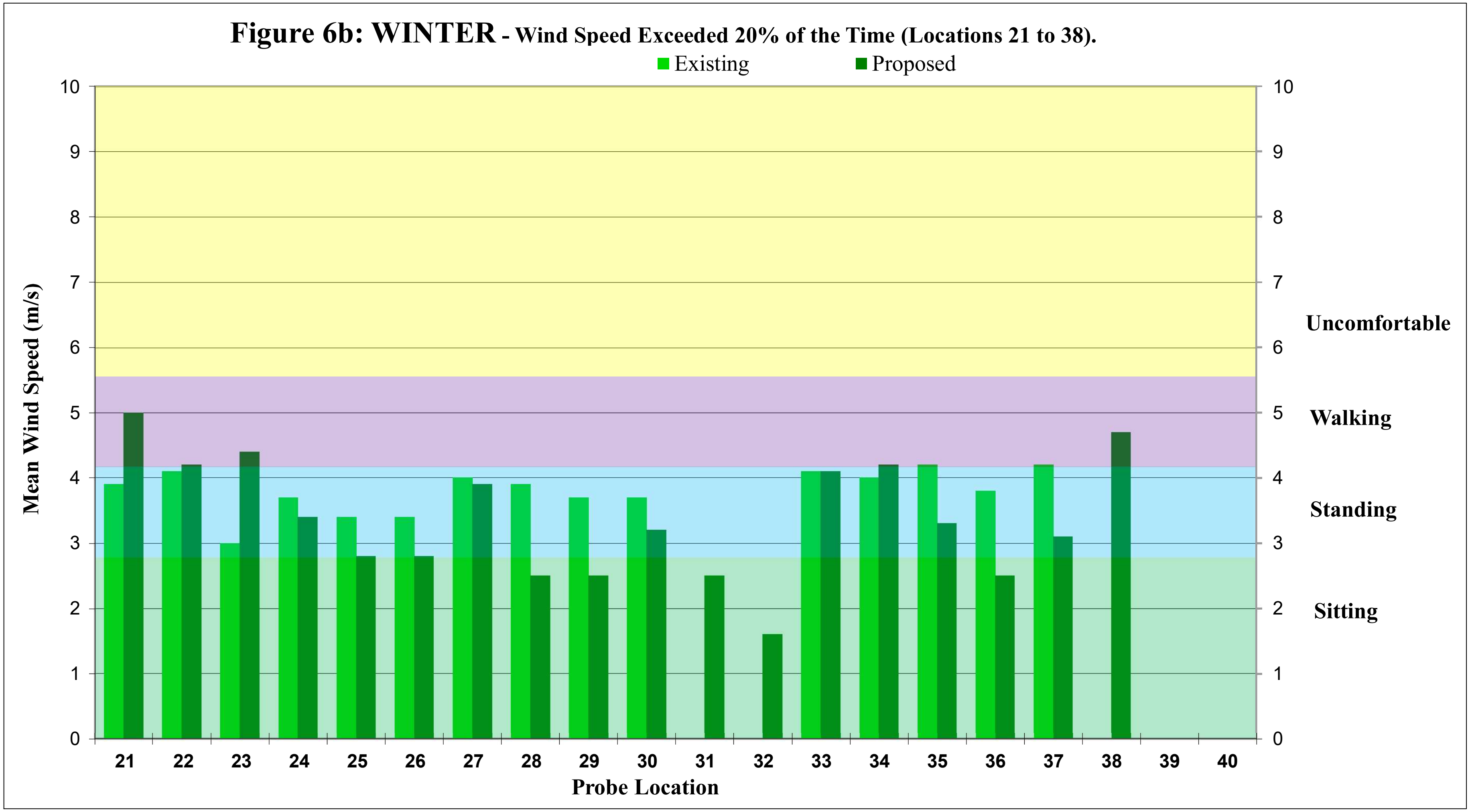
Figure 6b: WINTER - Wind Speed Exceeded 20% of the Time (Locations 21 to 38).
Existing
Proposed
Mean Wind Speed (m/s)
Uncomfortable
Walking
Standing
Sitting
Probe Location
0
1
2
3
4
5
6
7
8
9
10
21
22
23
24
25
26
27
28
29
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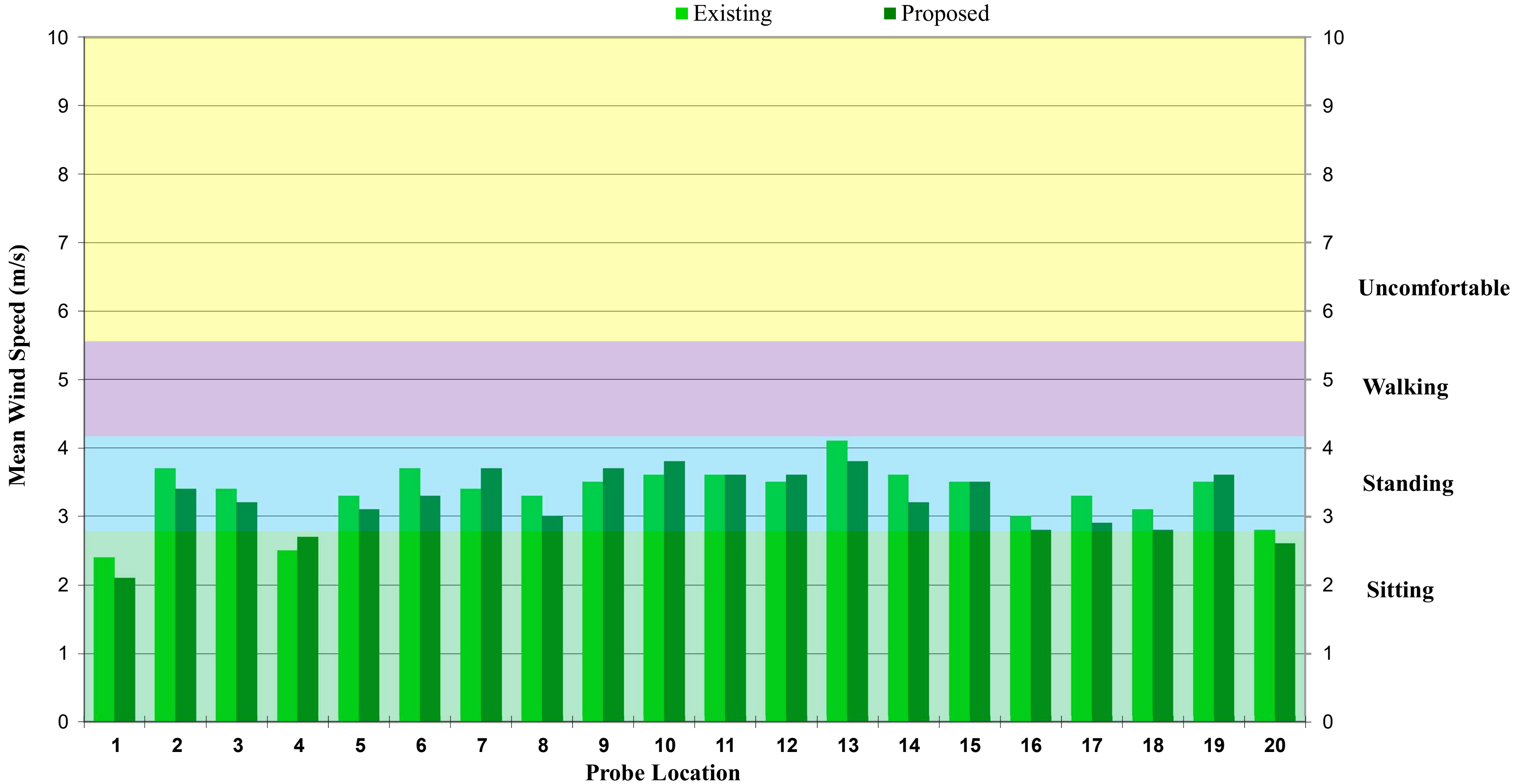
35
36
37
38
39
40

Figure 6c: SPRING - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).



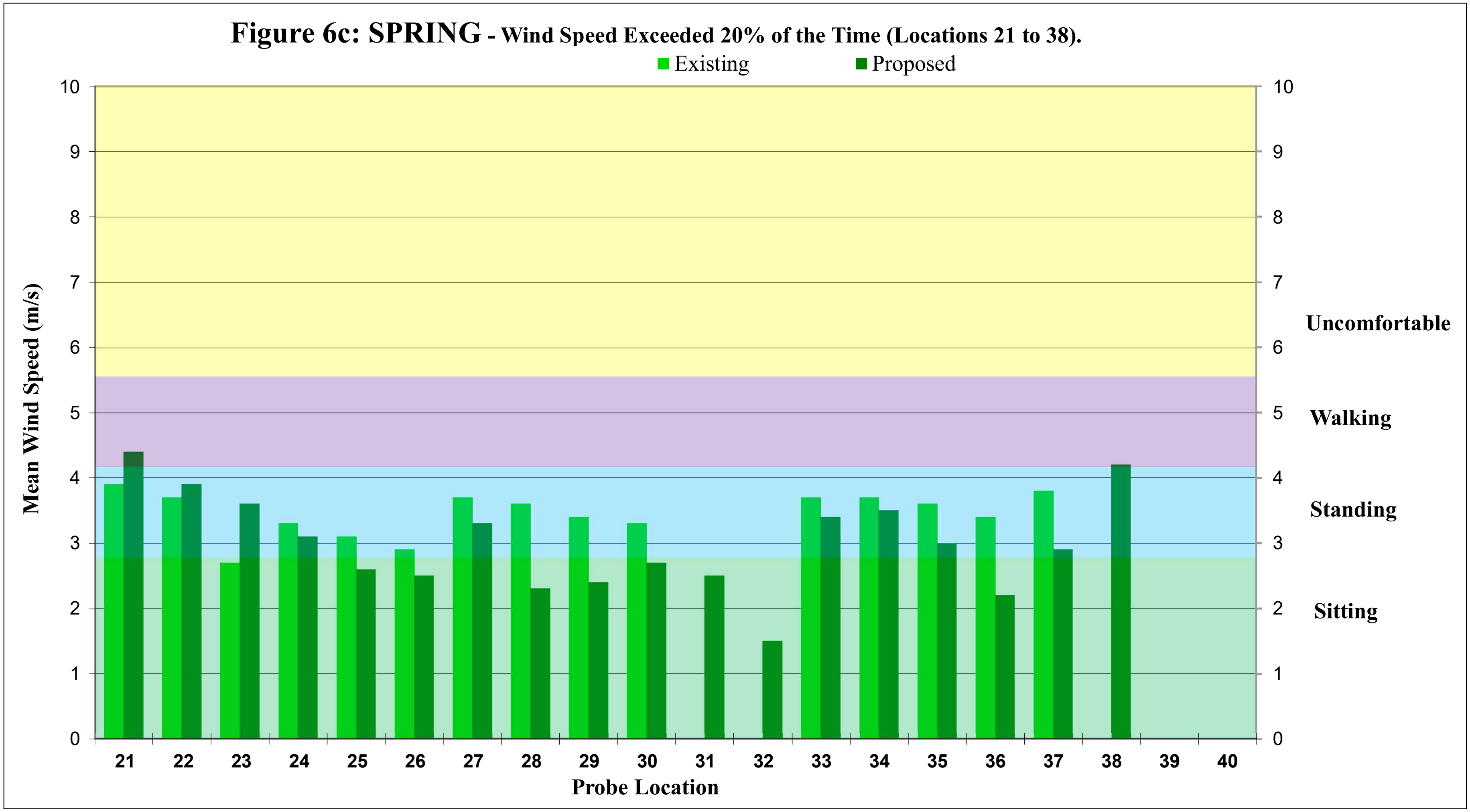


Figure 6c: SPRING - Wind Speed Exceeded 20% of the Time (Locations 21 to 38).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
2
3
4
5
6
7
8
9
10
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

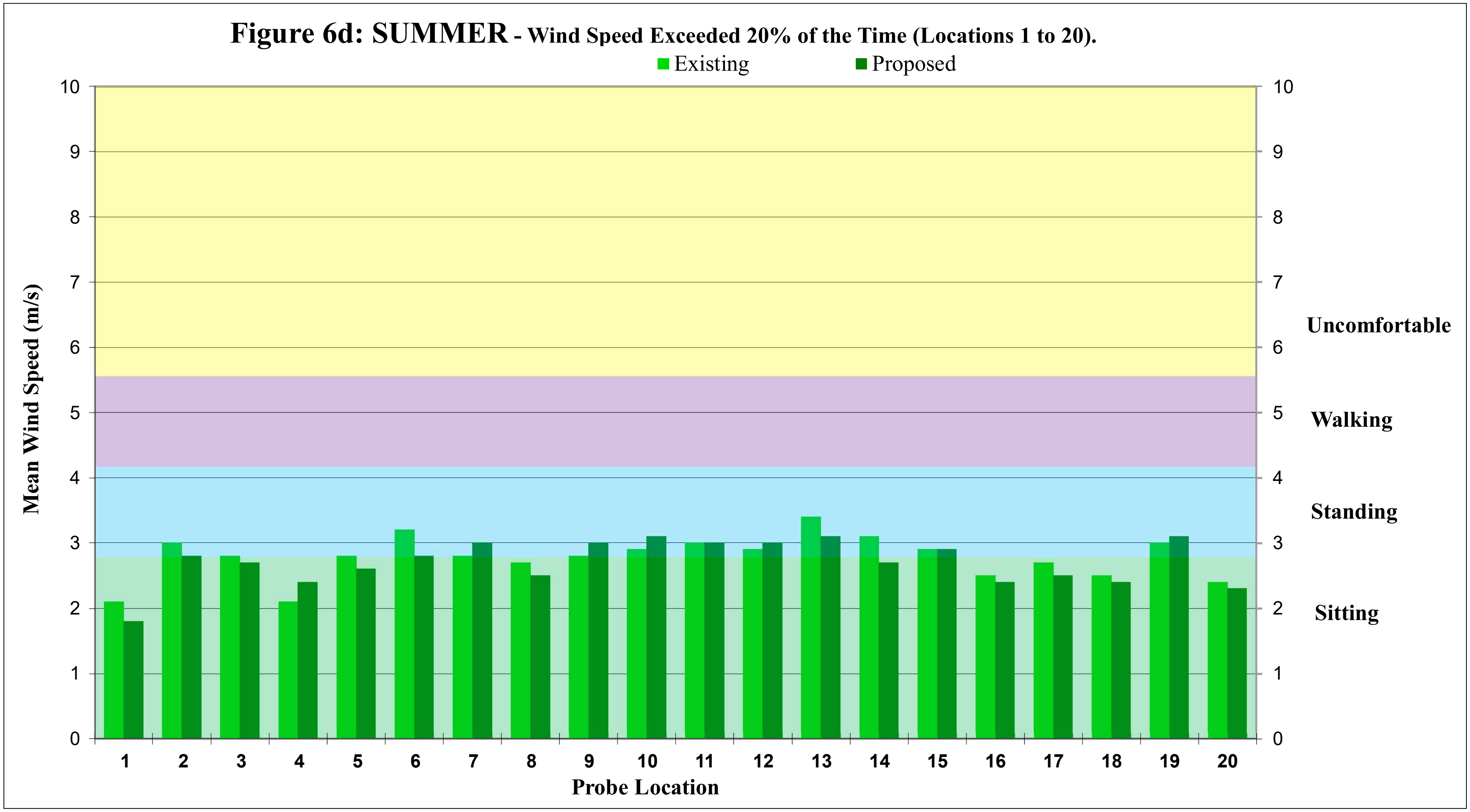


Figure 6d: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting

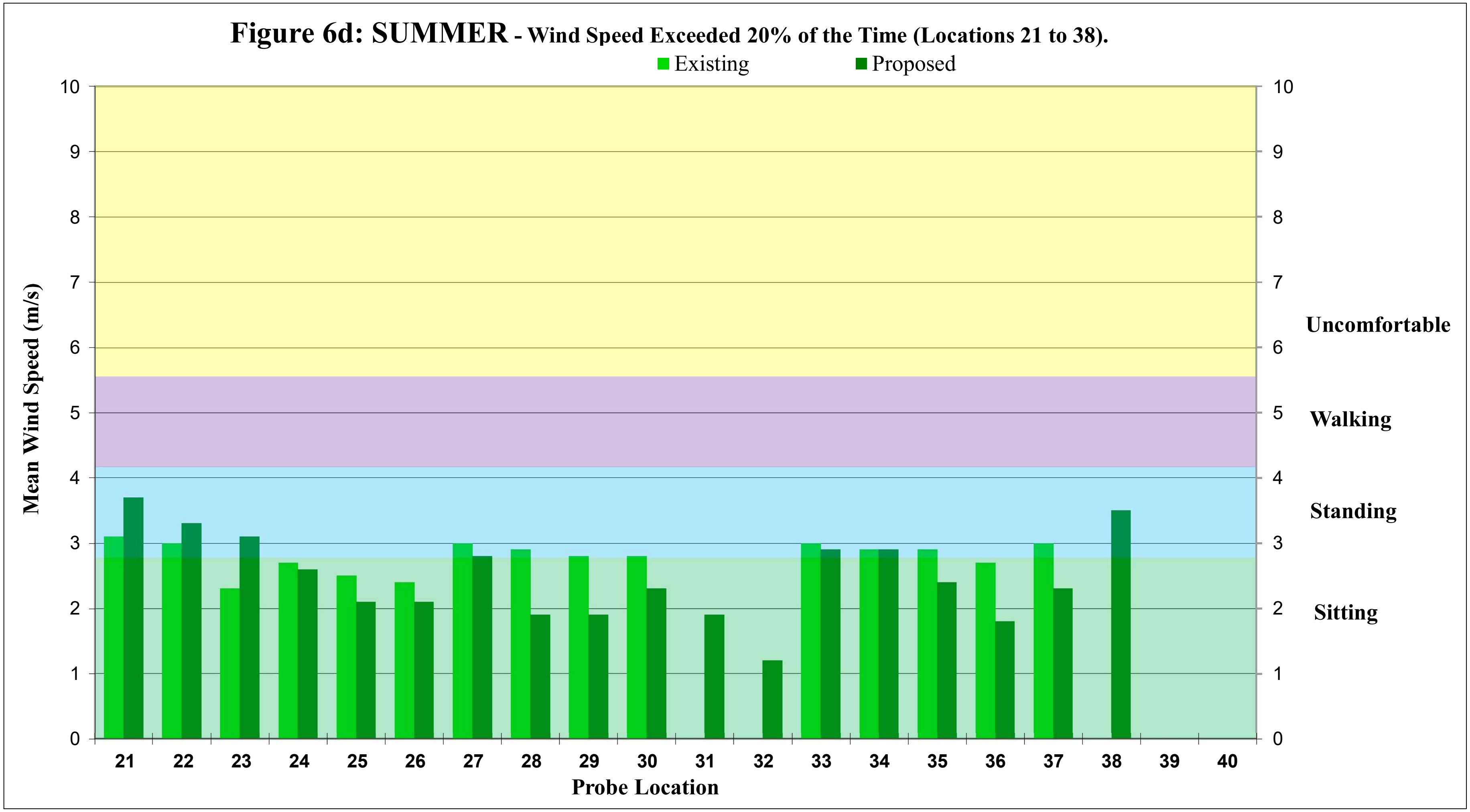
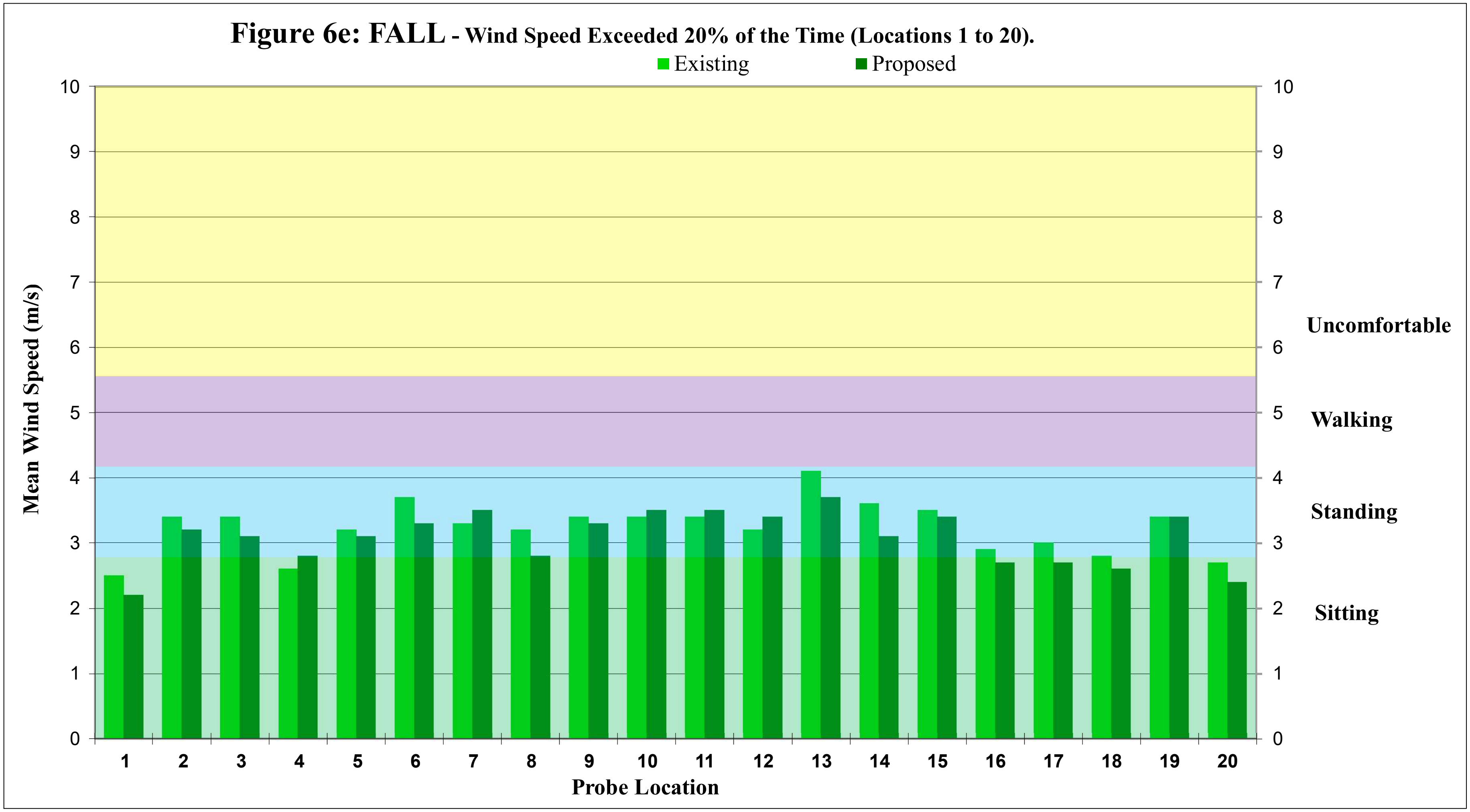


Figure 6d: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 21 to 38).
Existing
Proposed
Mean Wind Speed (m/s)
0
1
2
3
4
5
6
7
8
9
10
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location
Uncomfortable
Walking
Standing
Sitting



Theakston Environmental

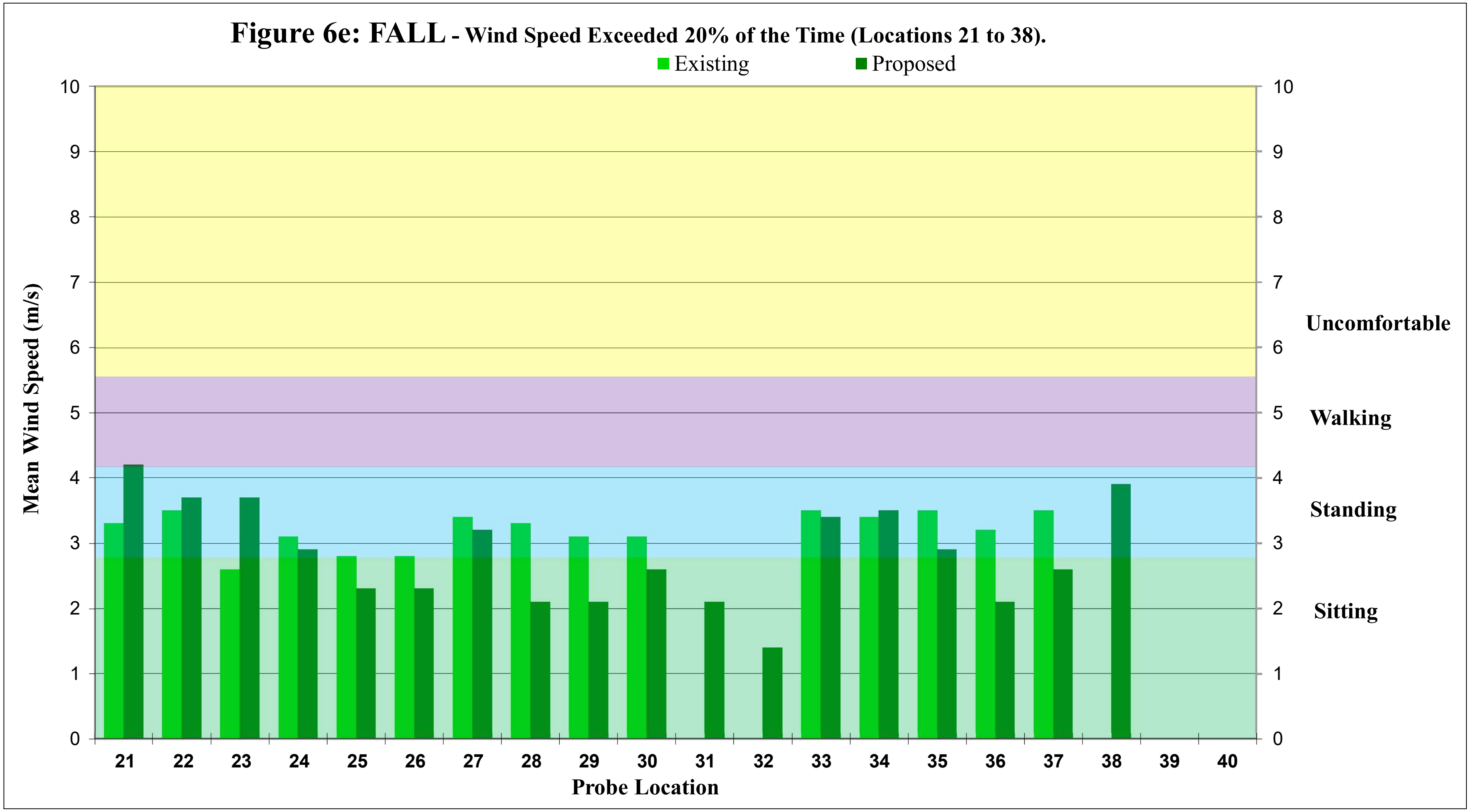


Figure 6e: FALL - Wind Speed Exceeded 20% of the Time (Locations 21 to 38).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
2
3
4
5
6
7
8
9
10
21
22
23
24
25
26
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29
30
31
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37
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40

Figure 7a: Pedestrian level wind velocity comfort categories.

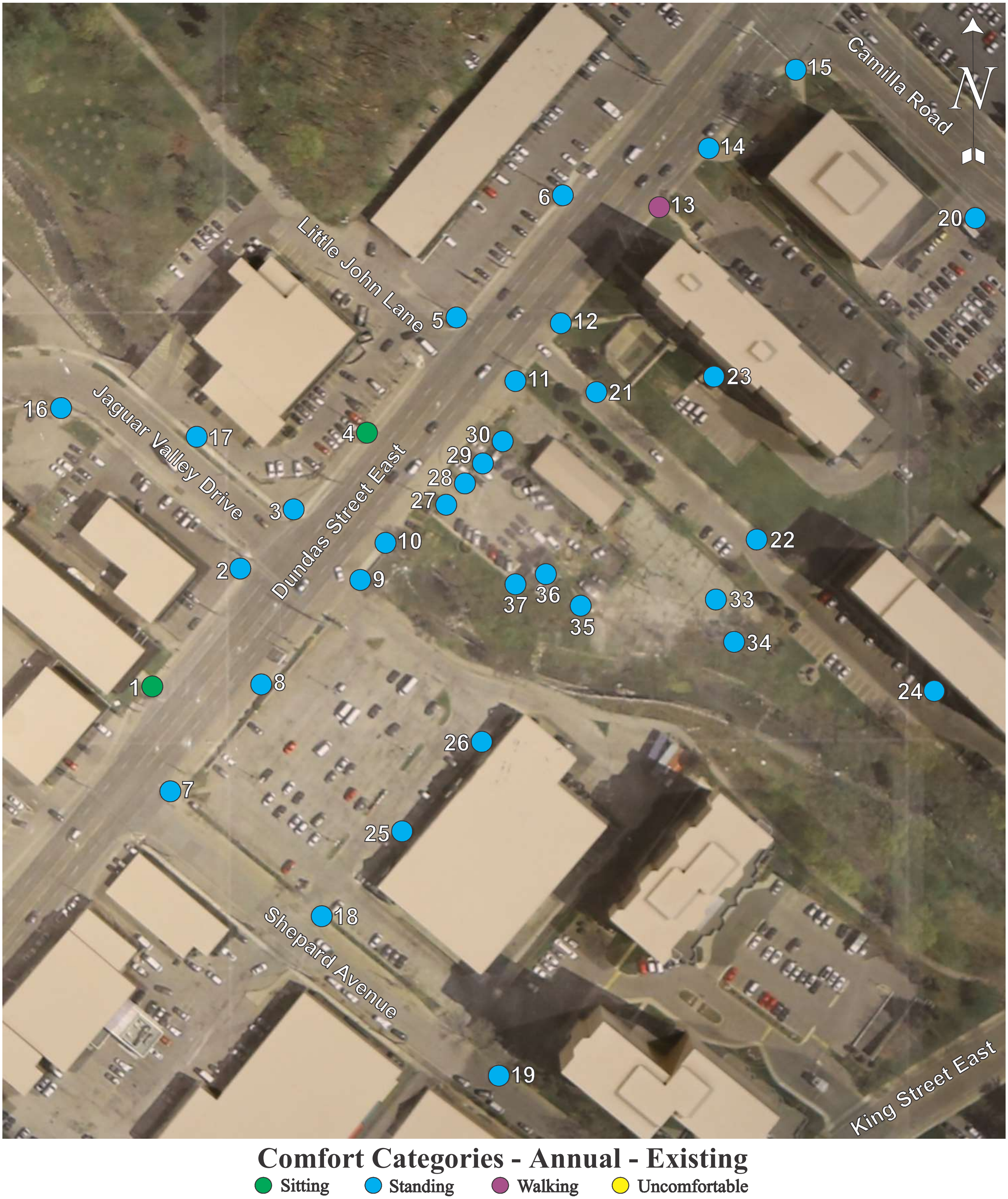
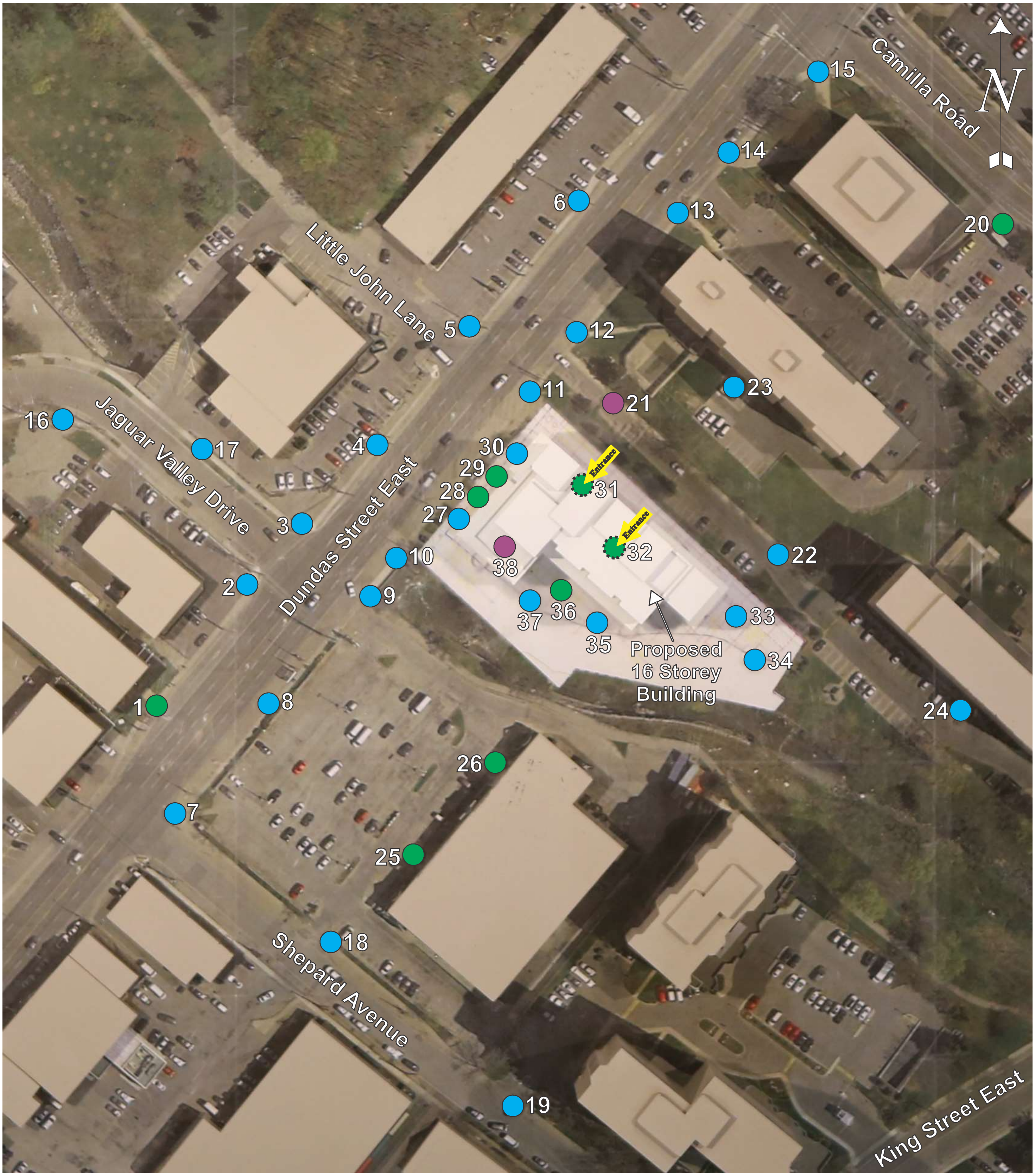


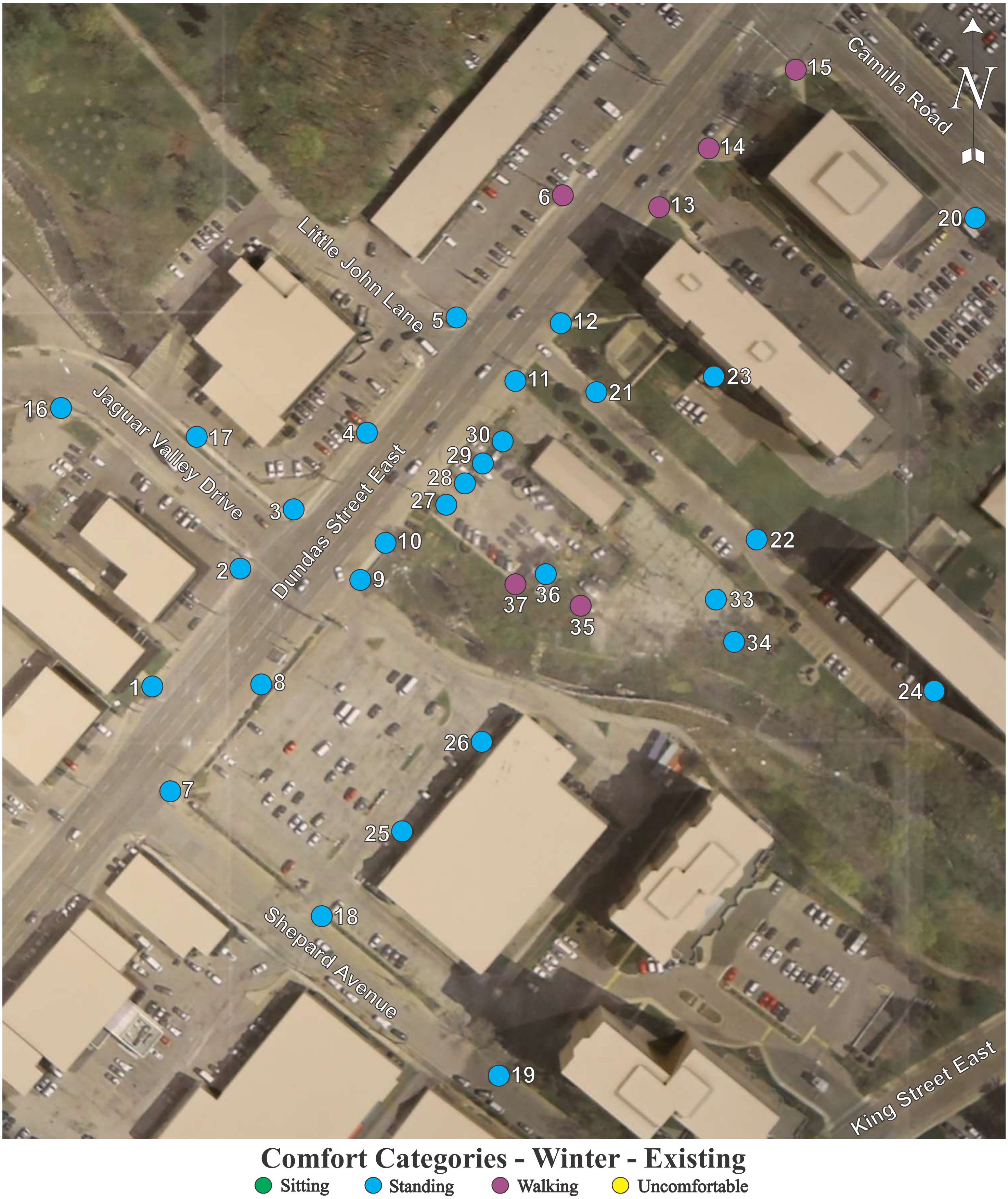
Figure 7b: Pedestrian level wind velocity comfort categories.



Comfort Categories - Annual - Proposed

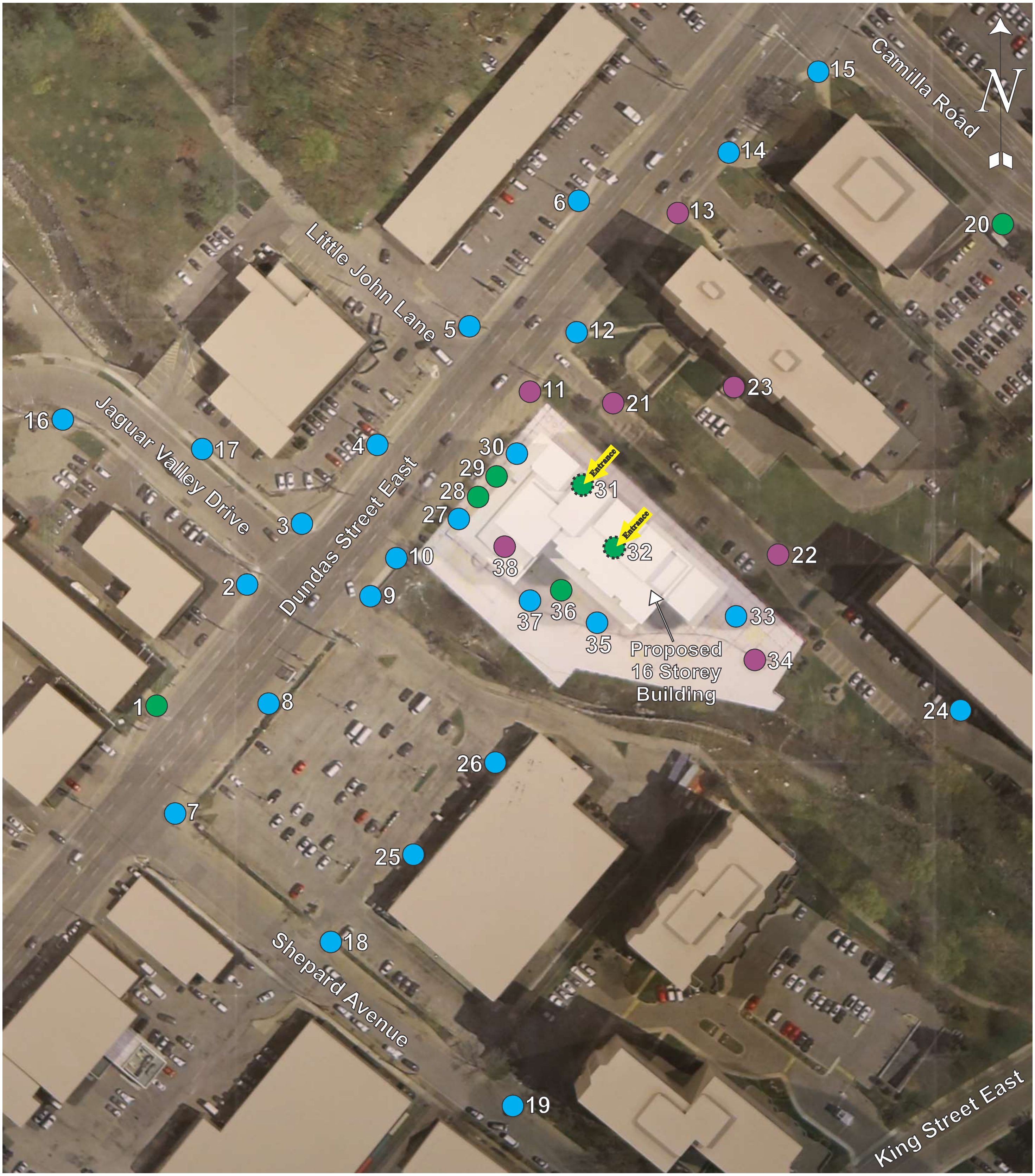
Sitting Standing Walking Uncomfortable

Figure 7c: Pedestrian level wind velocity comfort categories.



Theakston
Environmental

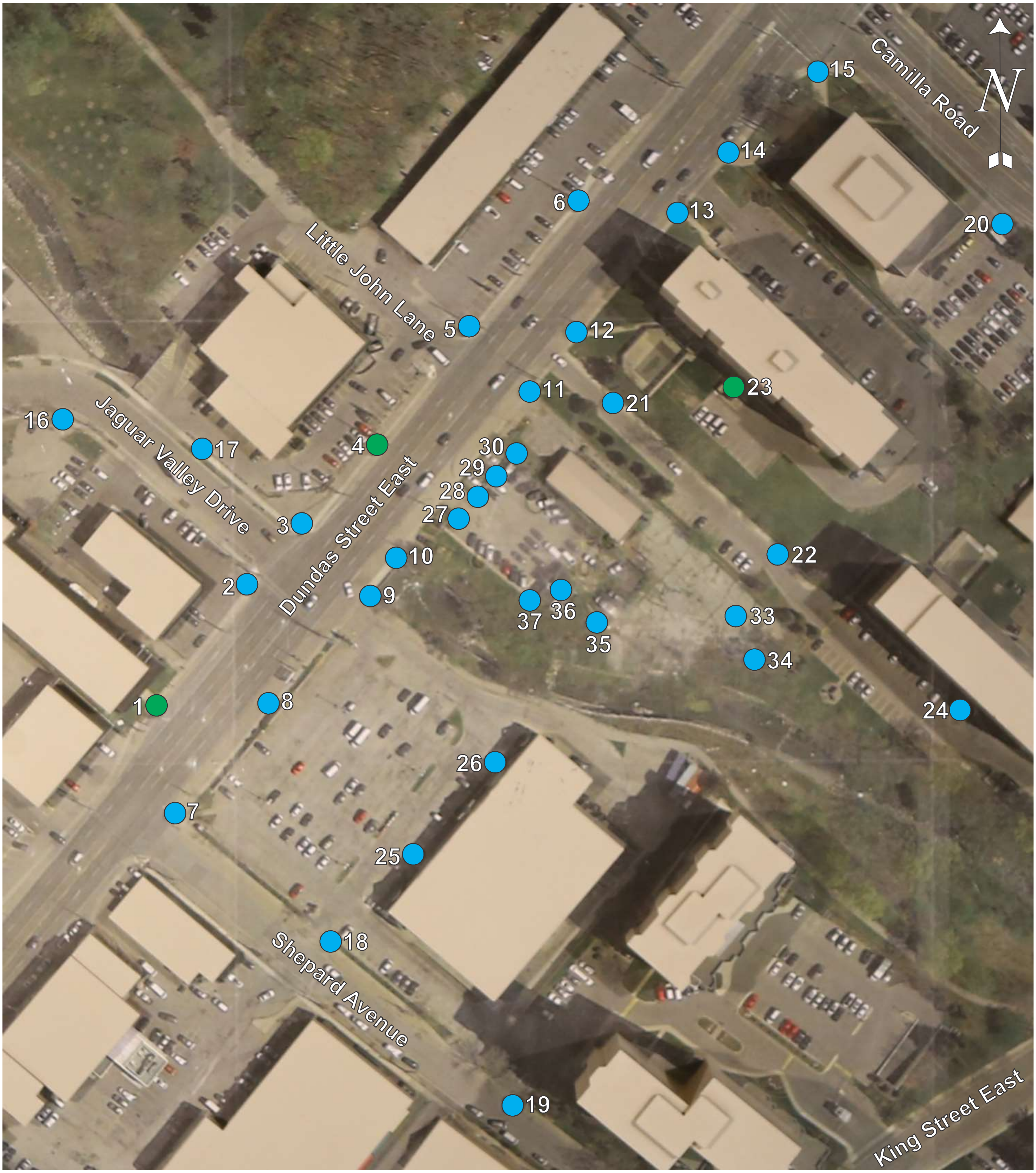
Figure 7d: Pedestrian level wind velocity comfort categories.



Comfort Categories - Winter - Proposed

Sitting Standing Walking Uncomfortable

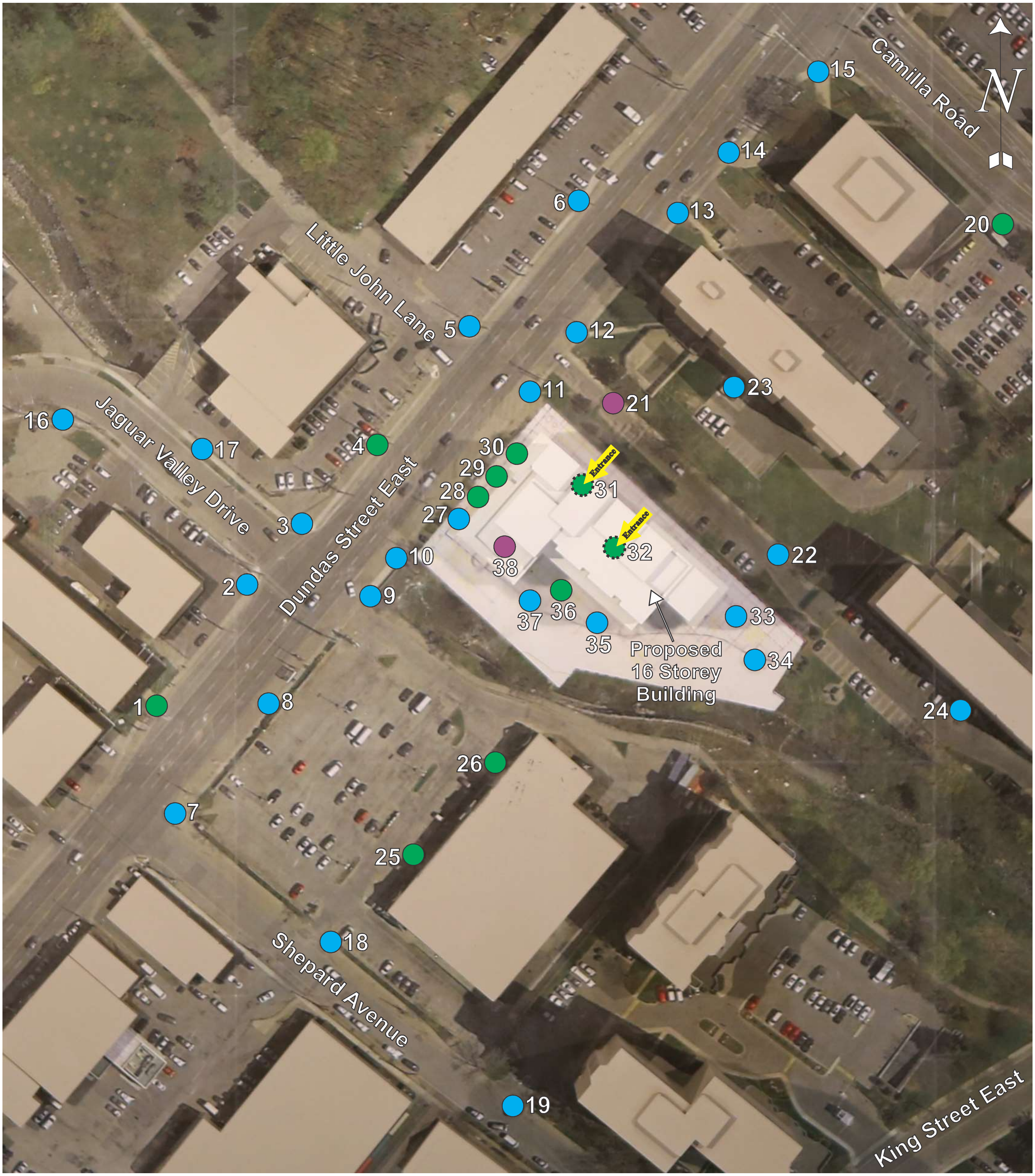
Figure 7e: Pedestrian level wind velocity comfort categories.



Comfort Categories - Spring - Existing

Sitting Standing Walking Uncomfortable

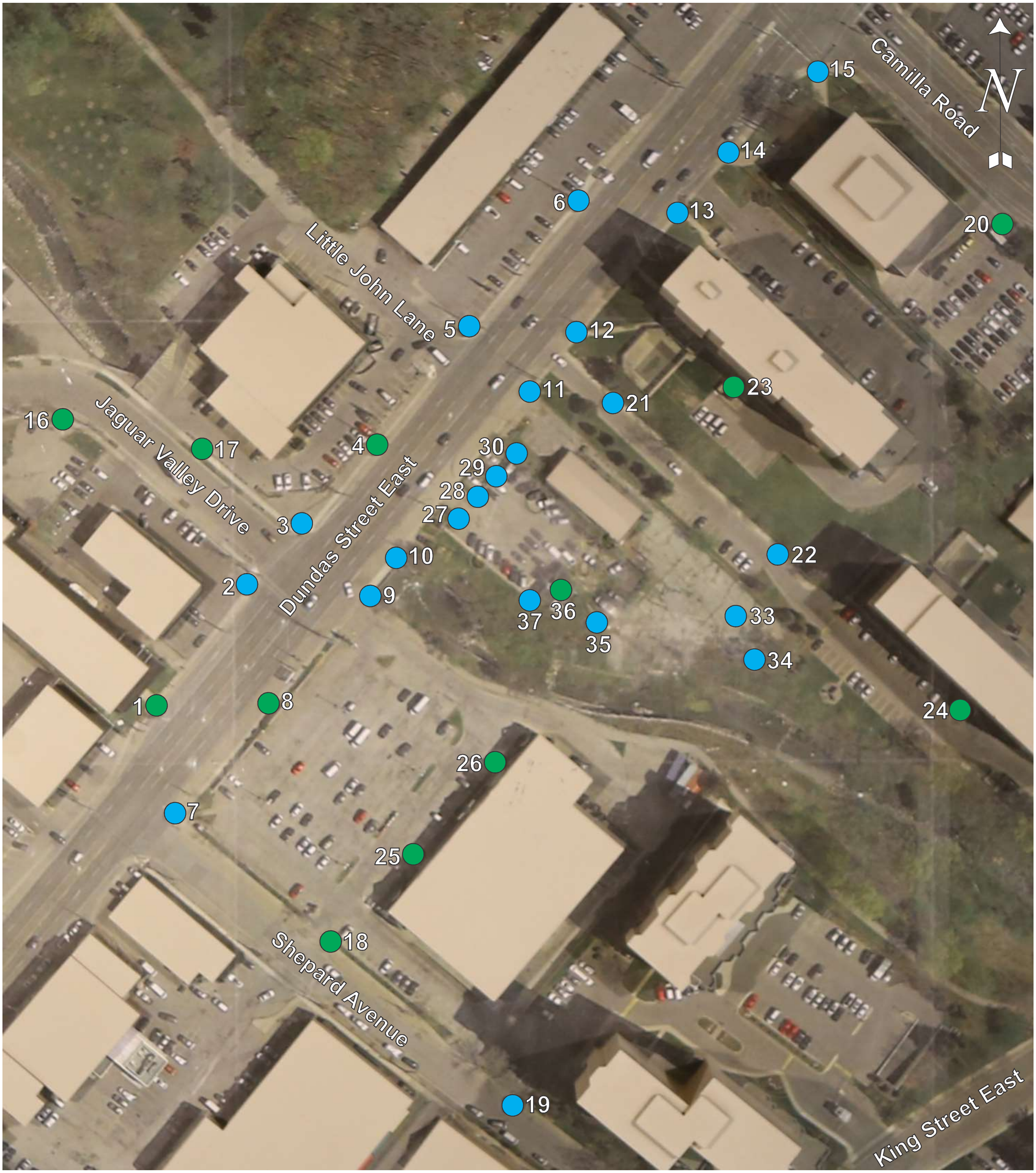
Figure 7f: Pedestrian level wind velocity comfort categories.



Comfort Categories - Spring - Proposed

Sitting | Standing | Walking | Uncomfortable

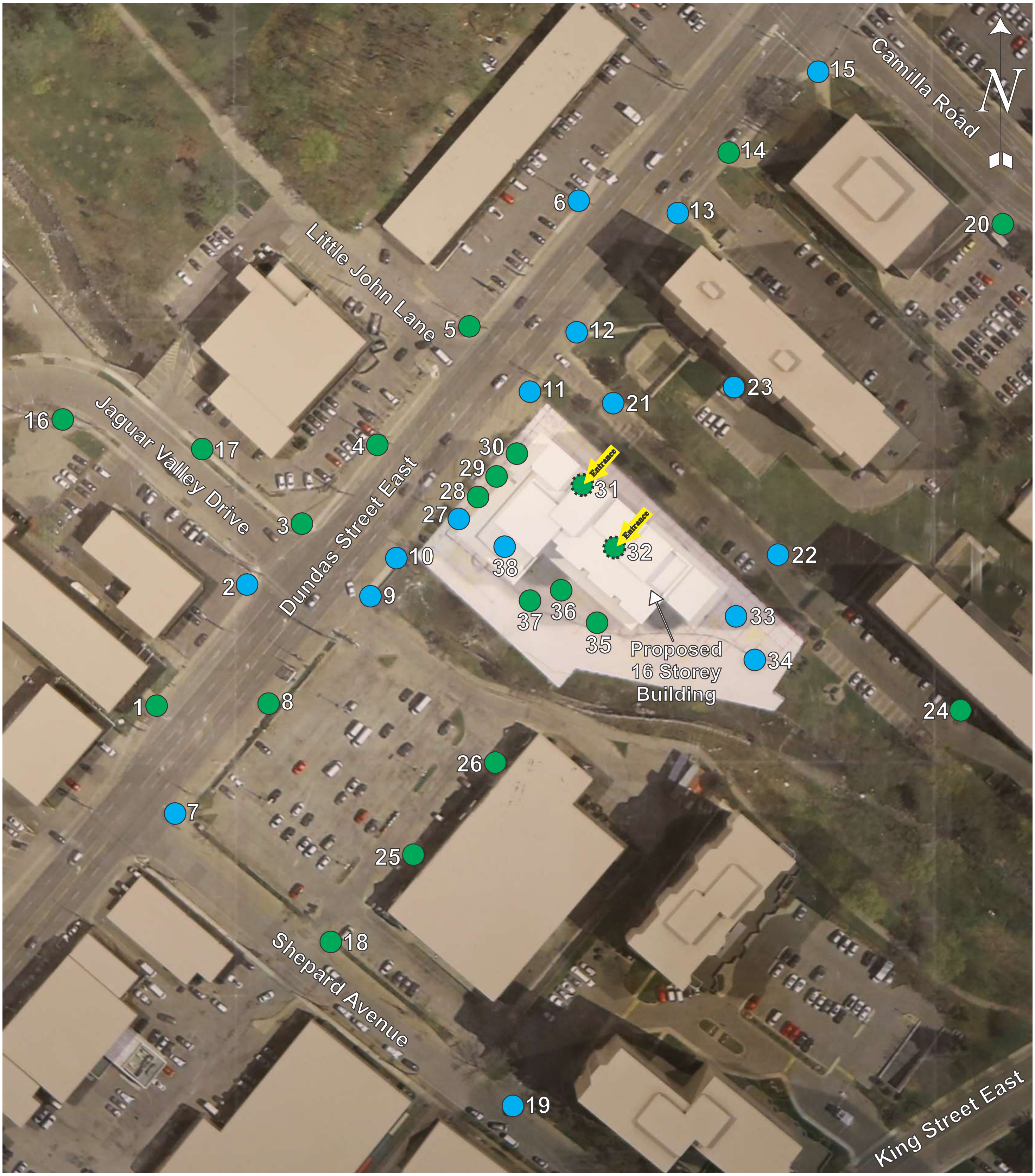
Figure 7g: Pedestrian level wind velocity comfort categories.



Comfort Categories - Summer - Existing

Sitting · Standing · Walking · Uncomfortable

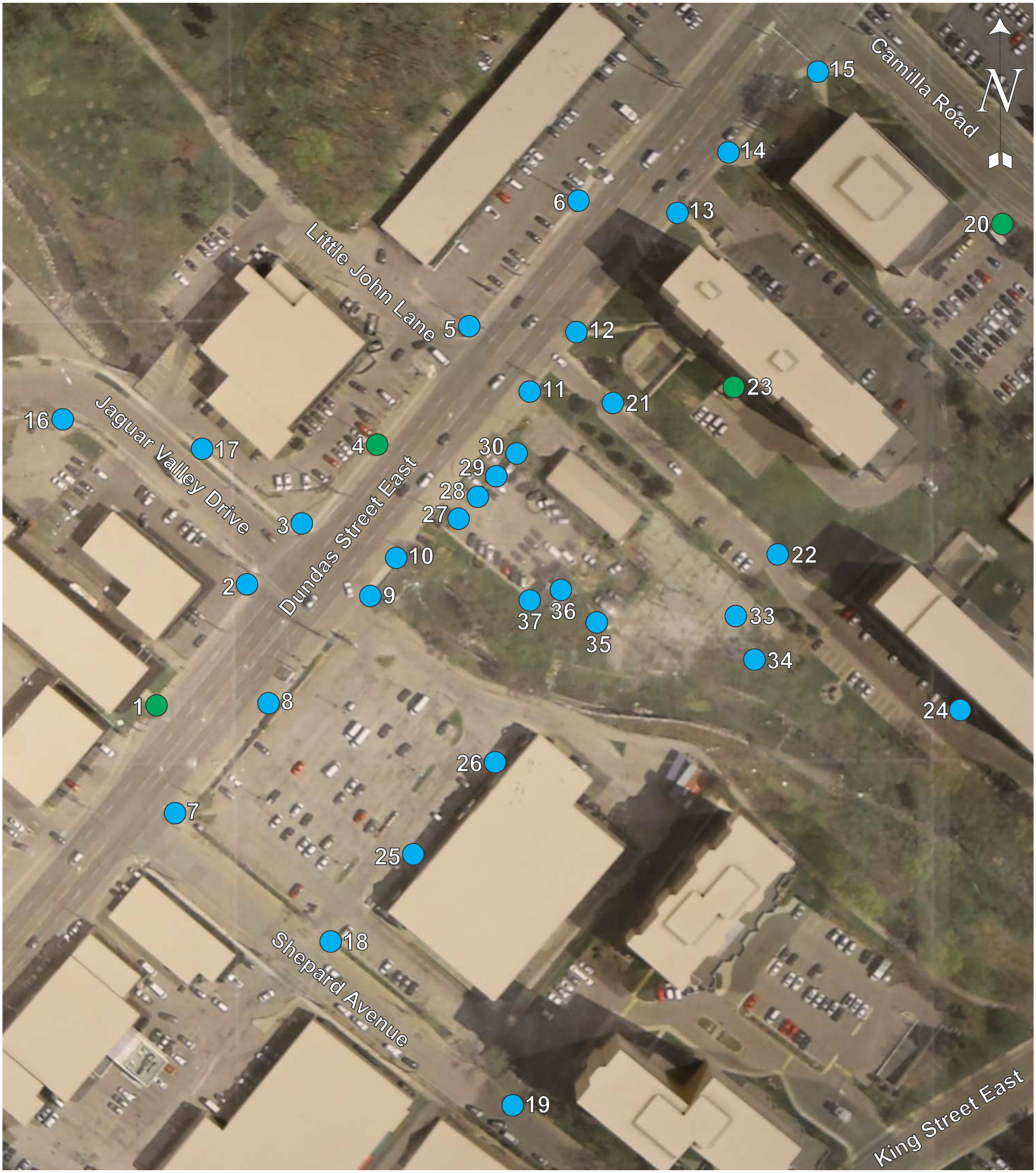
Figure 7h: Pedestrian level wind velocity comfort categories.



Comfort Categories - Summer - Proposed

Sitting · Standing · Walking · Uncomfortable

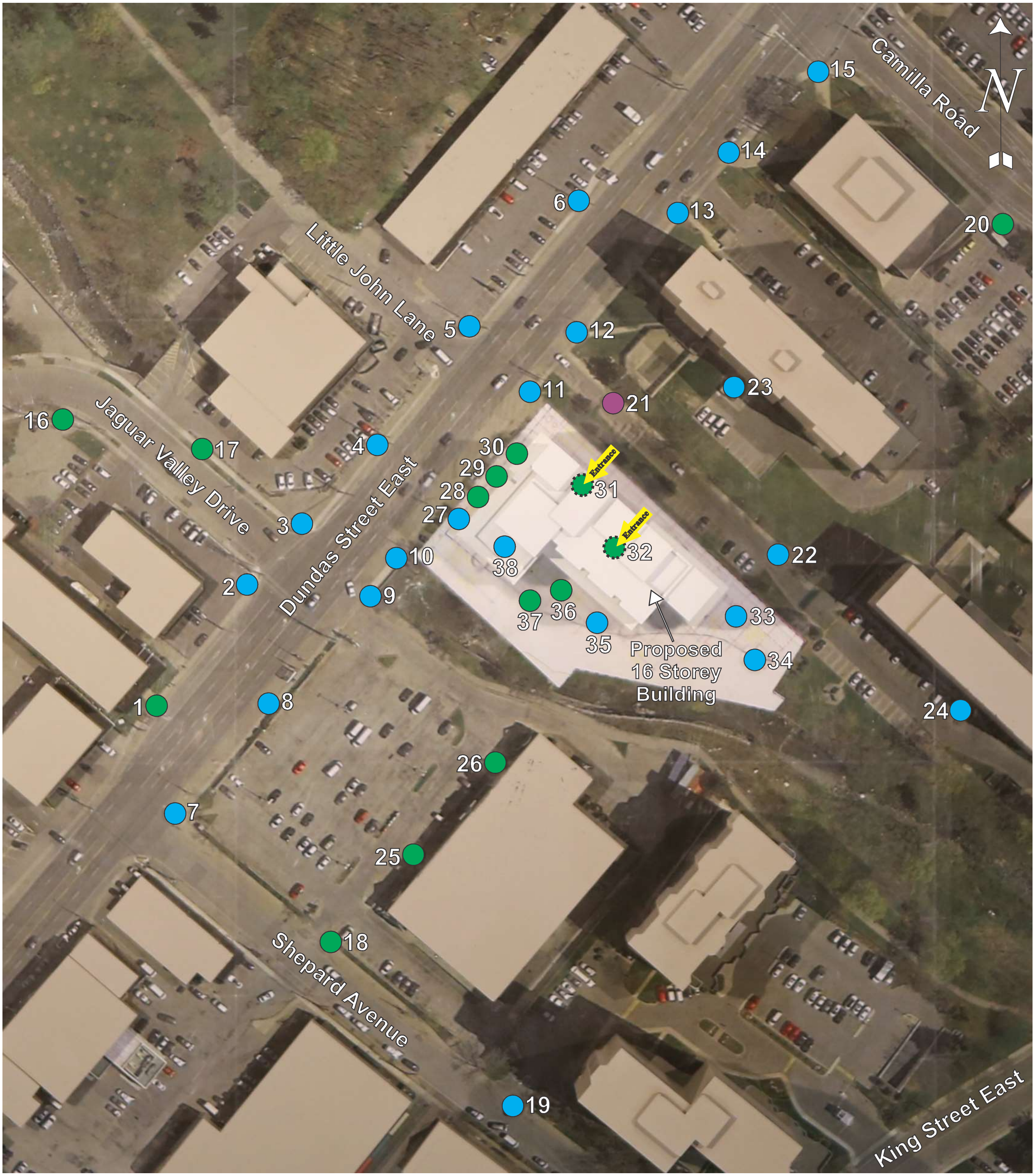
Figure 7i: Pedestrian level wind velocity comfort categories.



Comfort Categories - Fall - Existing

Sitting Standing Walking Uncomfortable

Figure 7j: Pedestrian level wind velocity comfort categories.



Comfort Categories - Fall - Proposed

Sitting · Standing · Walking · Uncomfortable

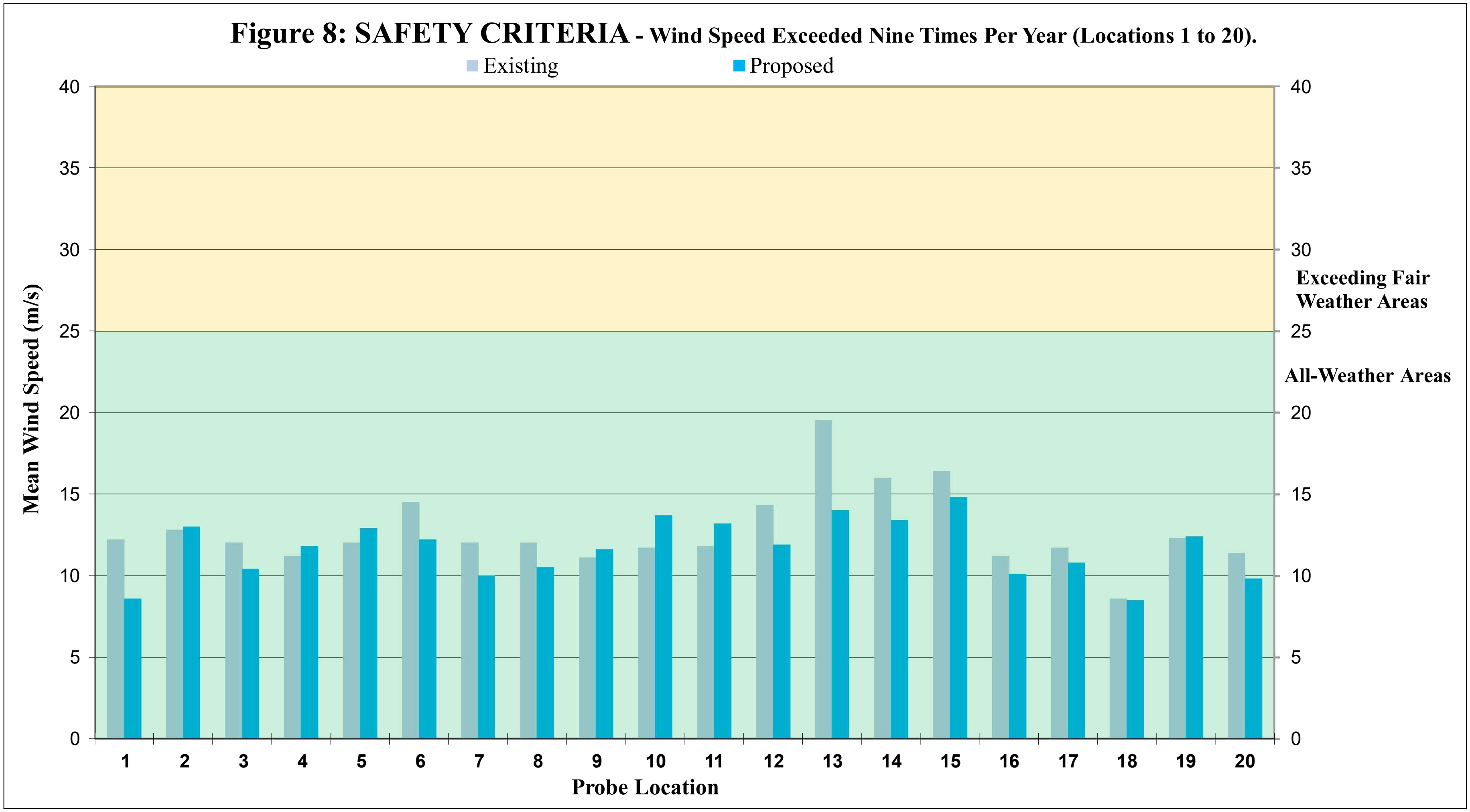


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Exceeding Fair Weather Areas
All-Weather Areas

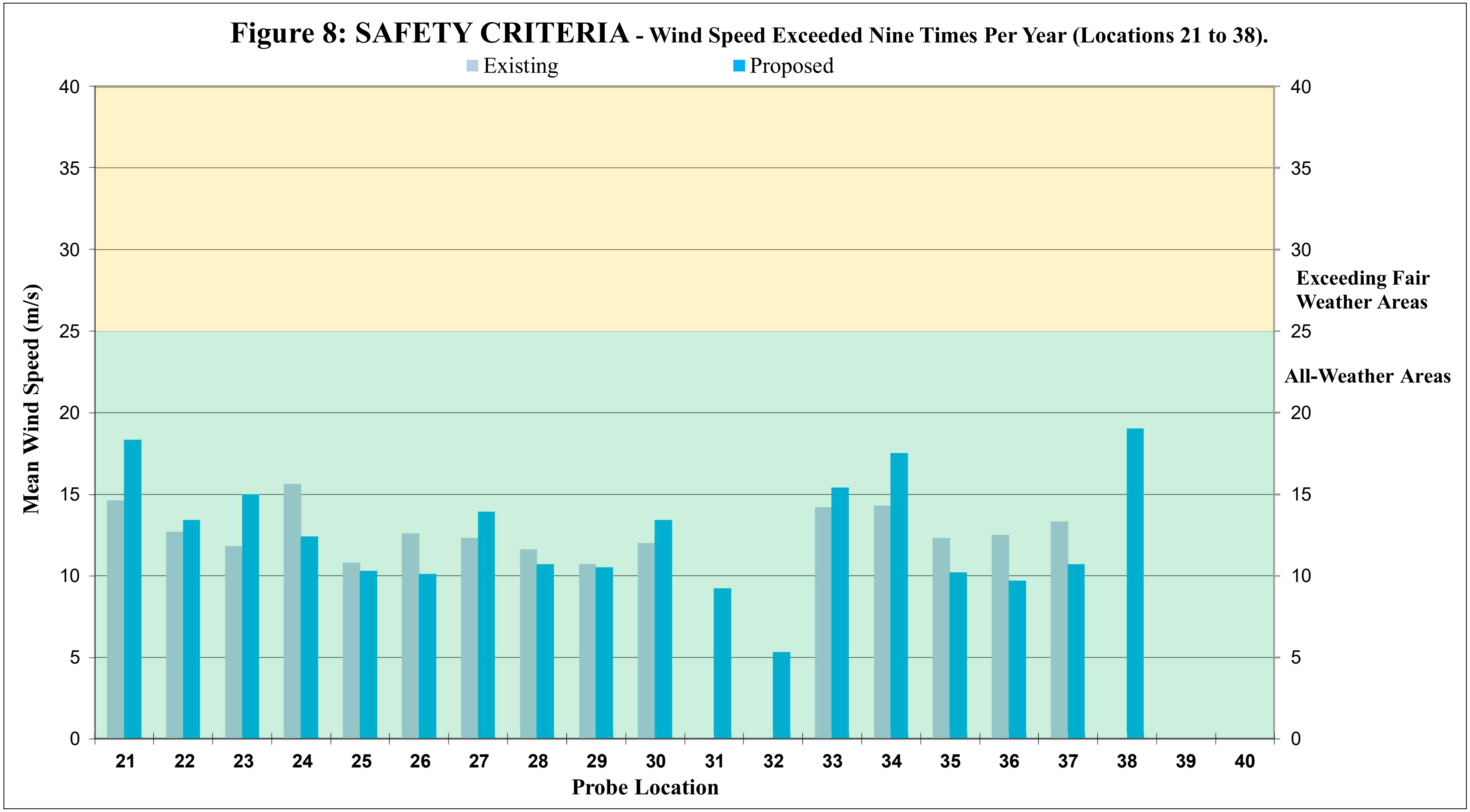
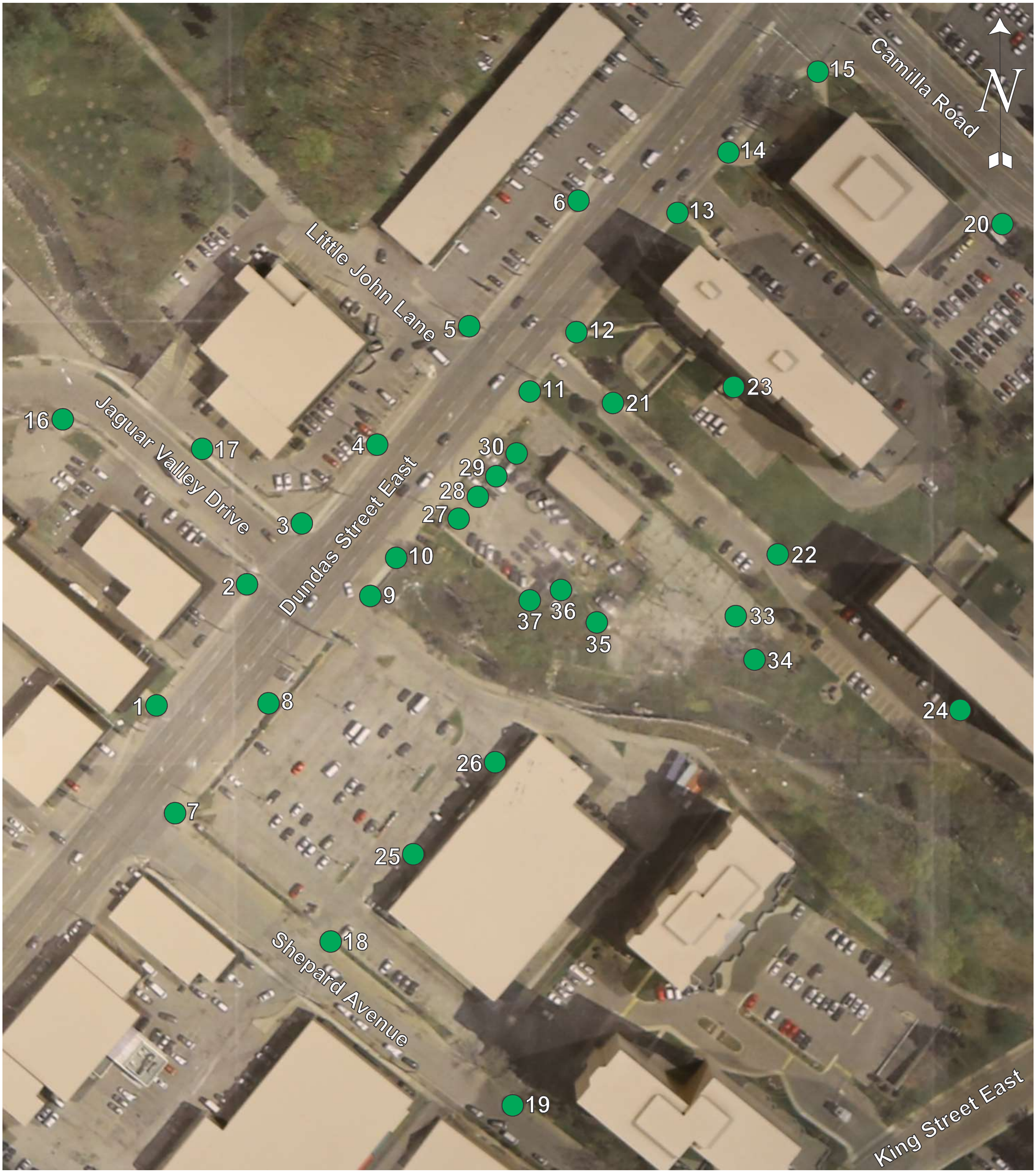


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 21 to 38).
Existing
Proposed
Mean Wind Speed (m/s)
0
5
10
15
20
25
30
35
40
Exceeding Fair Weather Areas
All-Weather Areas
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location

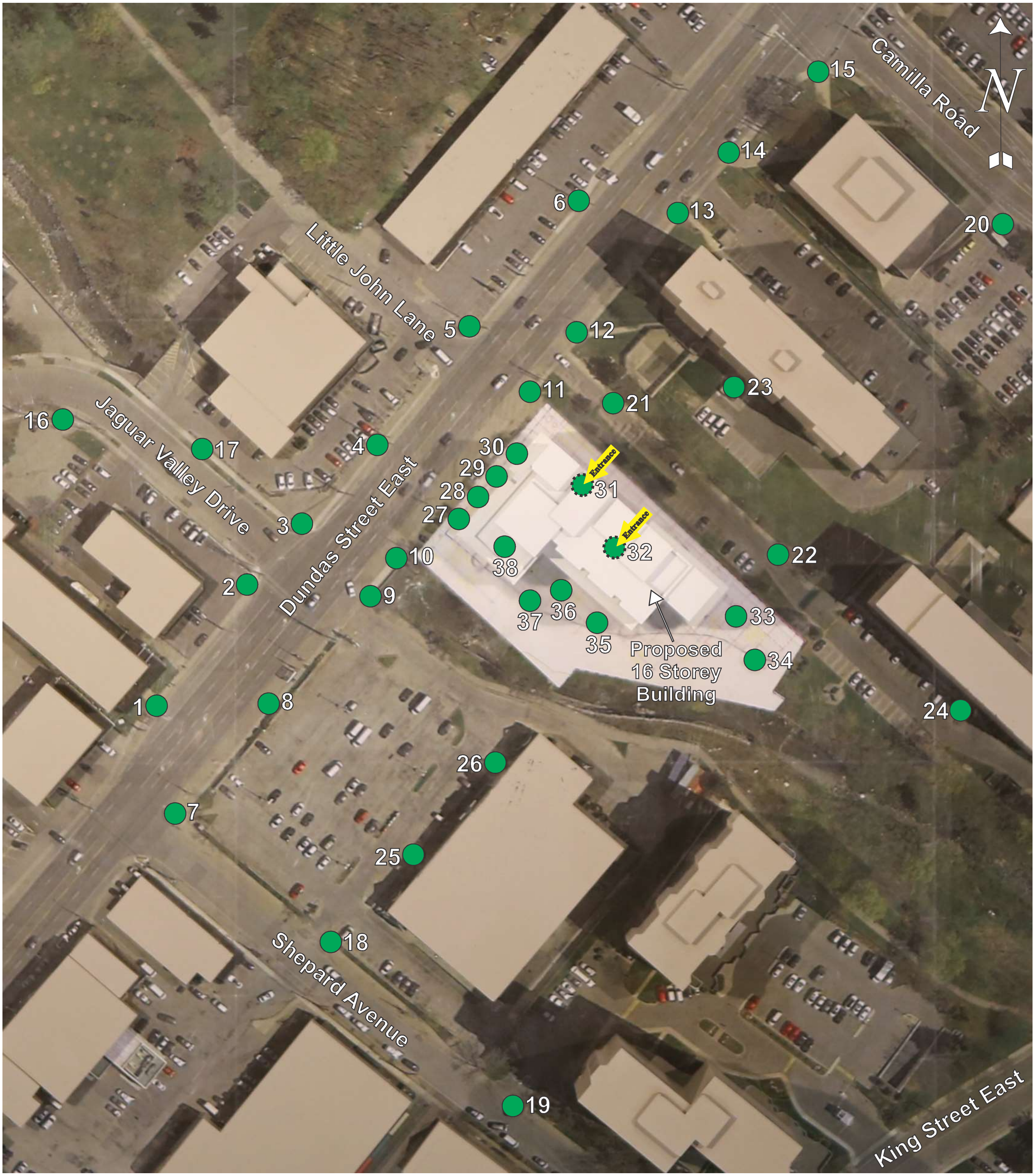
Figure 9a: Pedestrian level wind velocity safety criteria.



Safety Criteria - Existing

All-Weather Areas Exceeding Fair-Weather Areas

Figure 9b: Pedestrian level wind velocity safety criteria.



Safety Criteria - Proposed

● All-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:

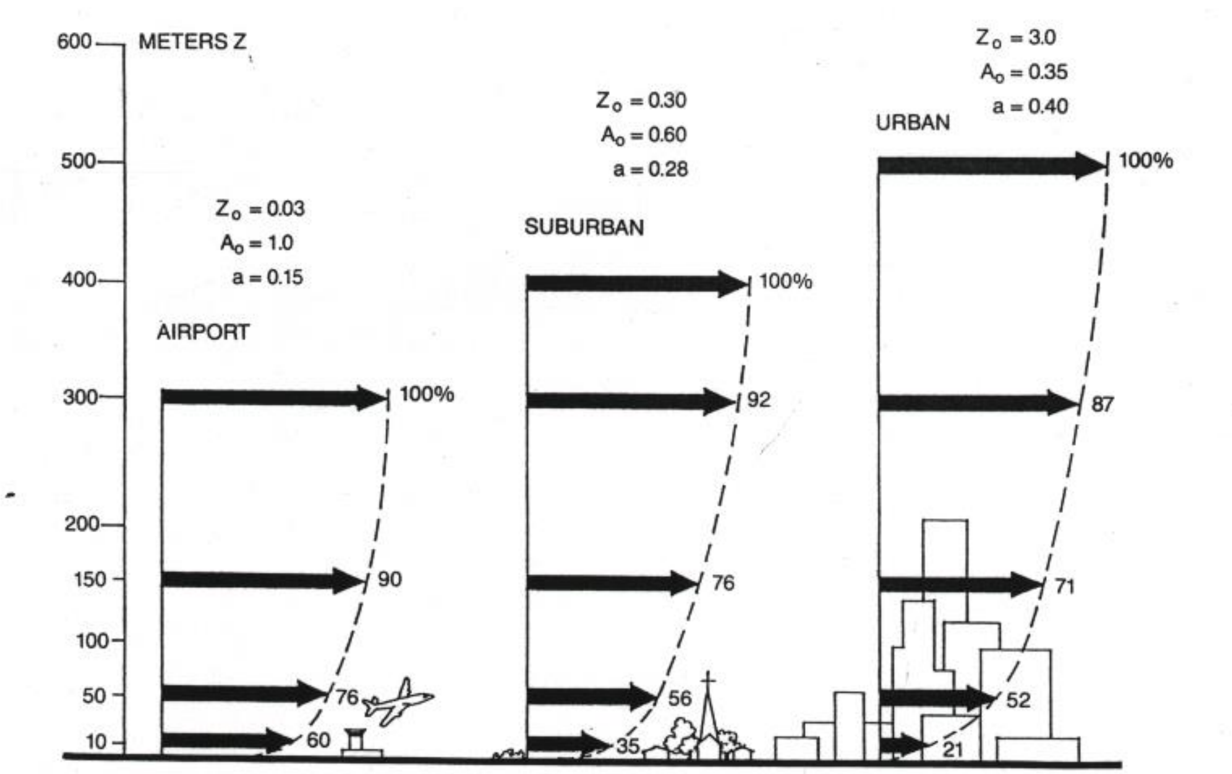


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

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 300m 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.

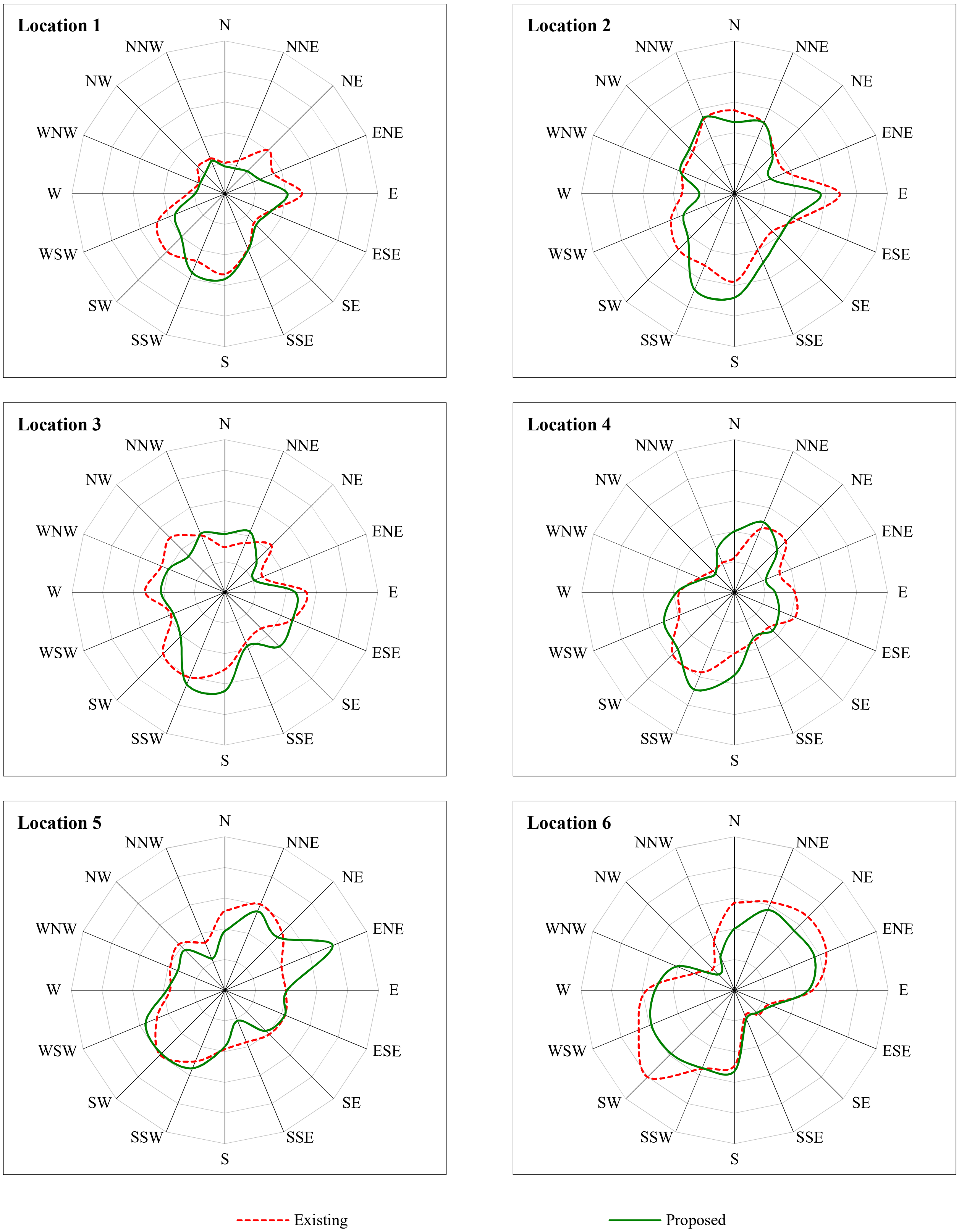
The Beaufort Scale is often used as a numerical relationship to wind speed based upon an observation of the effects of wind. Rear-Admiral Sir Francis Beaufort, commander of the Royal Navy, developed the wind force scale in 1805, and by 1838 the Beaufort wind force scale was made mandatory for log entries 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.



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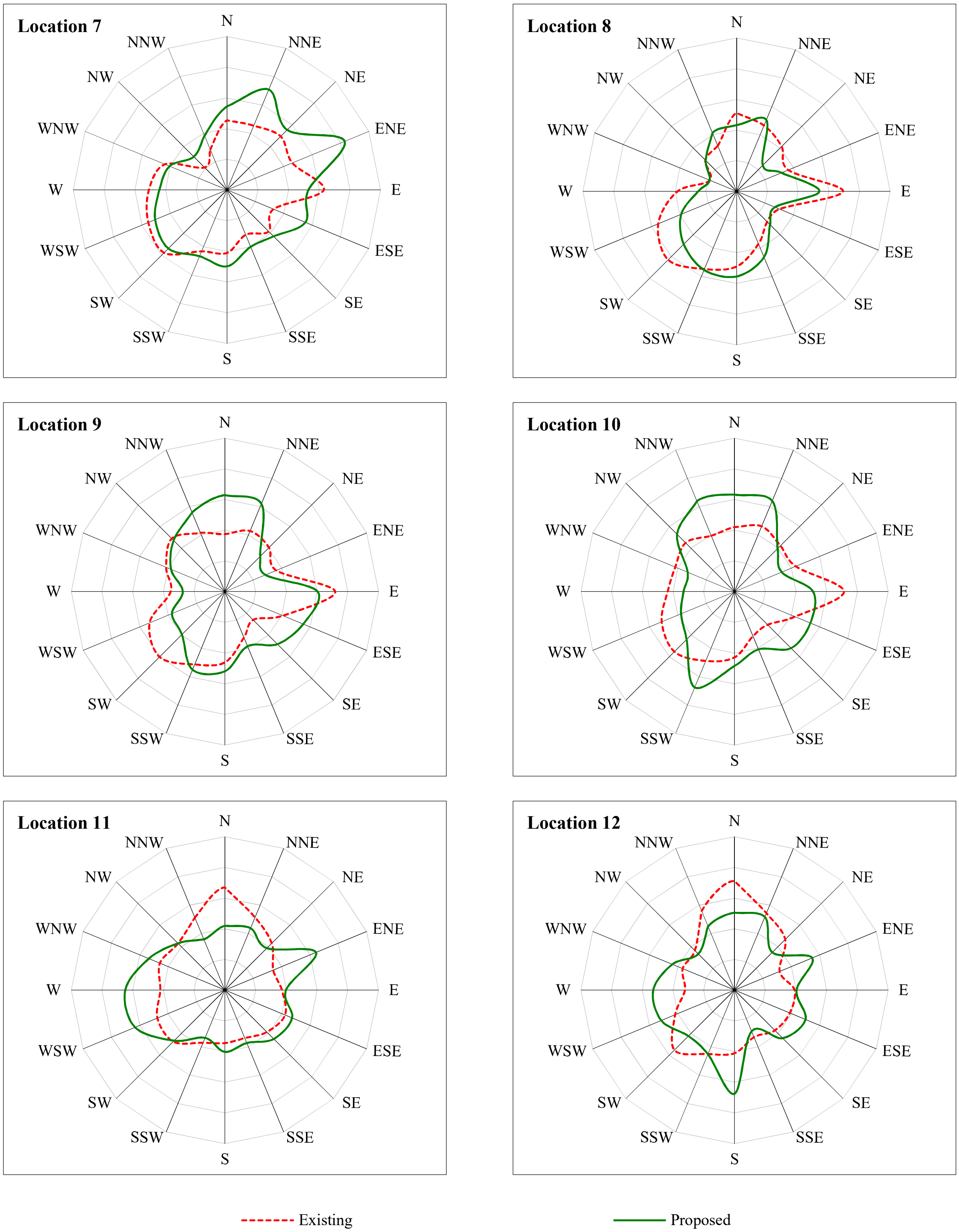

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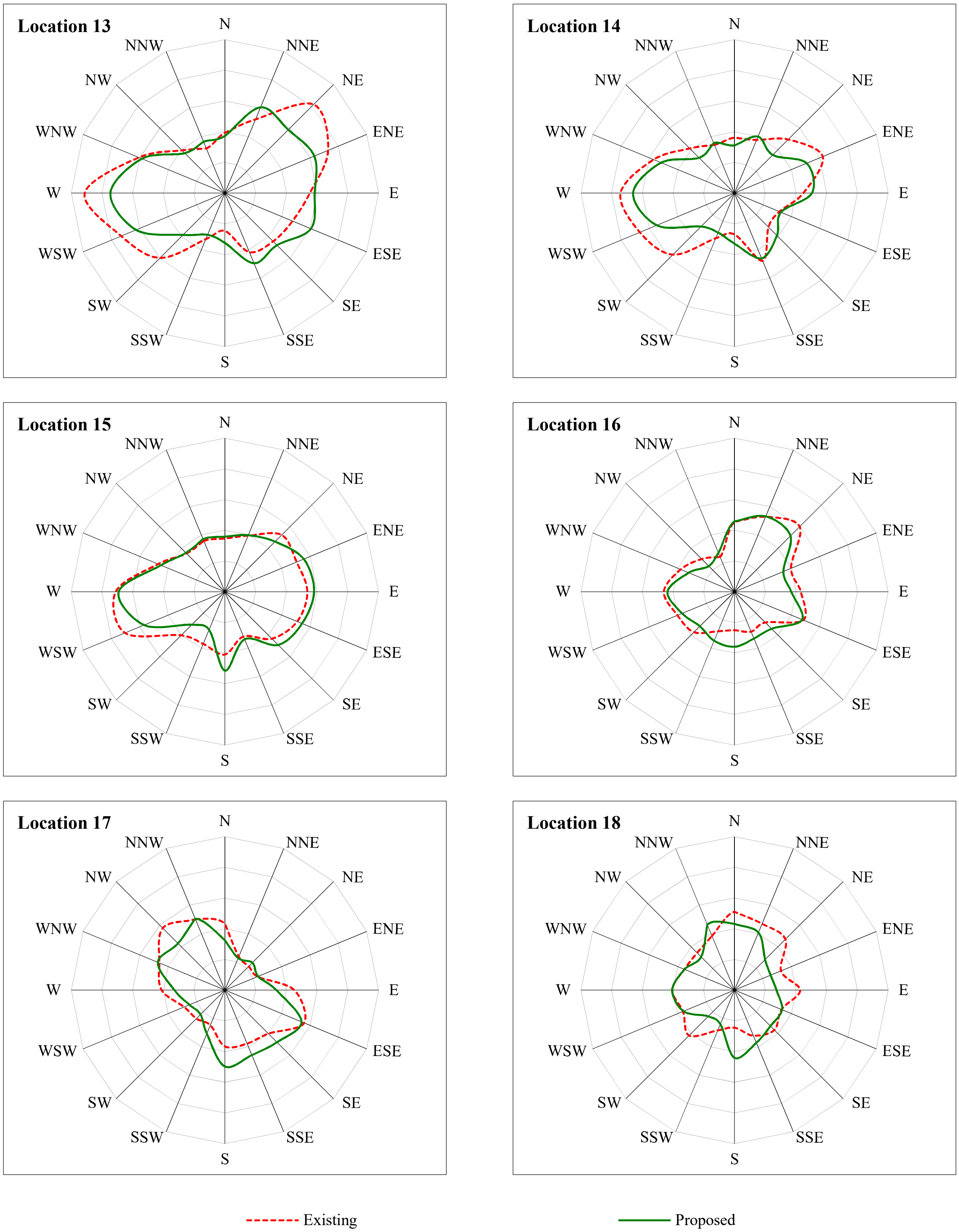

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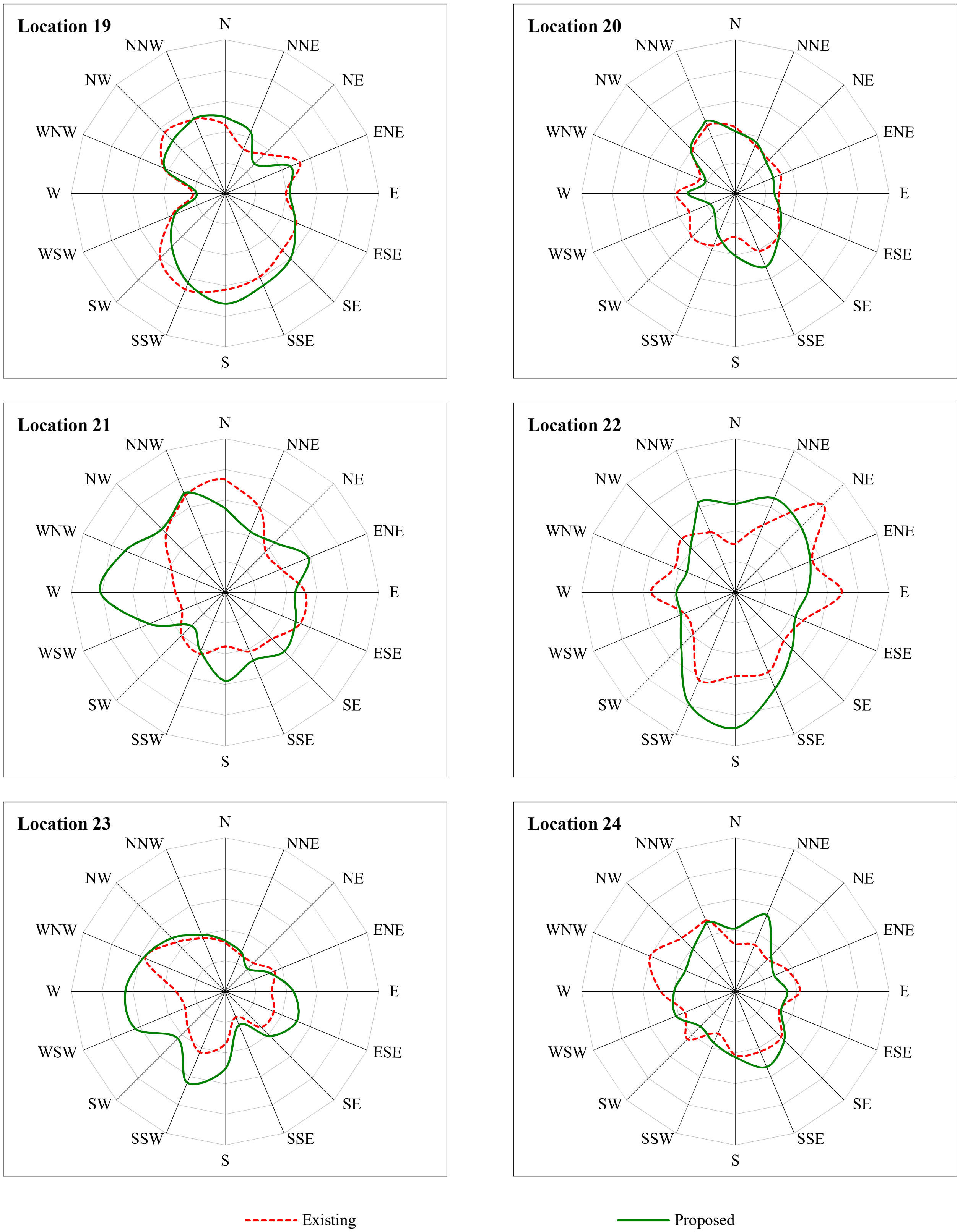

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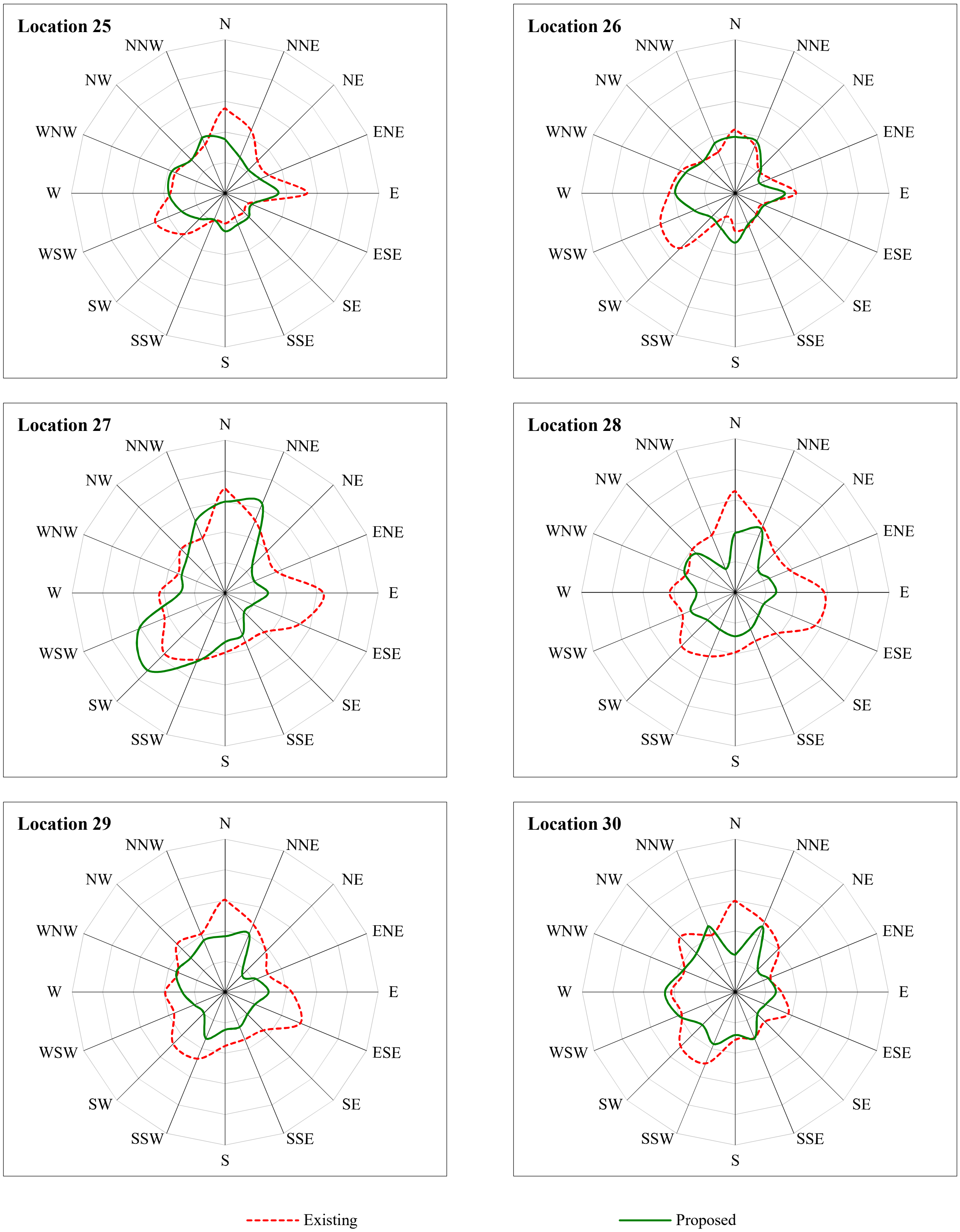

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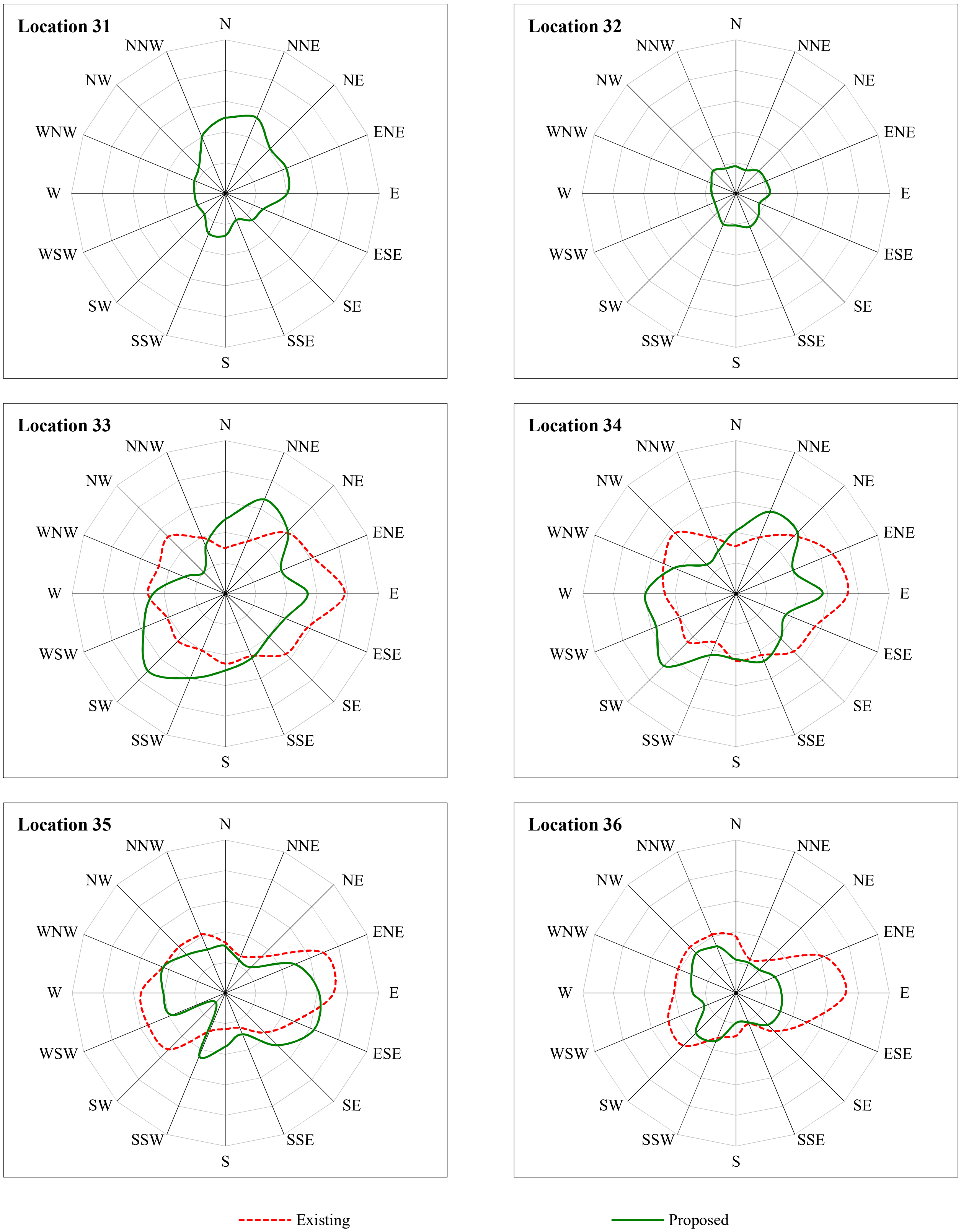

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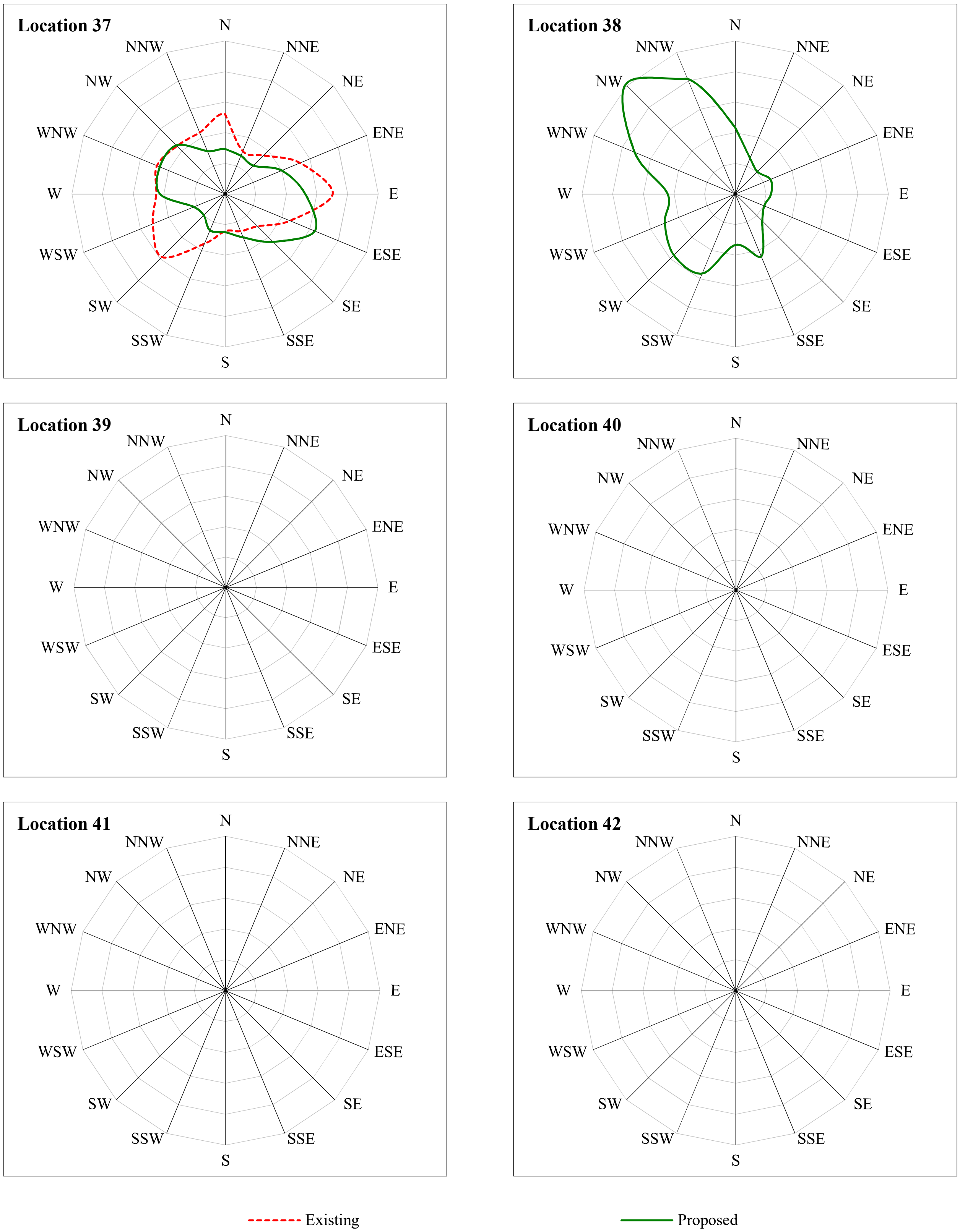

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