REPORT

PEDESTRIAN LEVEL WIND STUDY

126 – 140 Bradford Street

BARRIE, ONTARIO

Crown (Bradford) Developments Inc.

REPORT NO. 23034wind **November 3, 2023**

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1. EXECUTIVE SUMMARY

The mixed-use Development proposed by Crown (Bradford) Developments Inc. for the property municipally known as 126-140 Bradford Street, in the City of Barrie, 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 sixty-eight (68) locations tested are within safety criteria and most are within the comfort criteria described within.

The proposed Development involves construction of two 45 storey towers, denoted Tower A and Tower B, connected by a 6 storey podium. The Development is, for all intents and purposes, surrounded to prevailing windward directions by a suburban mix of low through mid-rise commercial and residential buildings, as well as associated surface parking and open spaces. 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.

The proposed Development redirects winds that formerly flowed over the low-rise site. The increased blockage relative to the existing setting causes wind to redirect to flow over the proposed buildings, without consequence, and/or, depending upon the angle of incidence, around, or down the buildings toward the pedestrian level, as downwash. The Development features a podium that intercepts downwash associated with prevailing winds, deflecting a portion of said flows around the building at elevations above the pedestrian level. This mitigative design feature as well as other wind friendly design elements including overhangs, balconies, and others, when considered in concert, further moderate wind. This results in moderate changes to the impending wind climate realised at the site and in the surrounds with inclusion of the proposed Development, relative to the existing setting.

Winds are mitigated to varying degrees by the existing and proposed surrounds, and upon impact with the proposed Development, tend to split, flowing over, and/or around and down the buildings' façades. At the pedestrian level, the winds redirect to travel horizontally along the buildings, around the corners and beyond, resulting in localised windswept areas near the buildings' corners and in gaps between buildings. As a result, ground level winds at many locations remain similar to the existing setting, with localised areas of higher pedestrian level winds noted proximate to the proposed Development. The site and surrounds are predicted

mainly suitable for sitting or standing throughout the year in the proposed setting, with localised walking conditions noted during the spring proximate to the northeast corner of the proposed Development along Bradford Street. The proposed Development incorporates wind mitigative design features that include:

- podium
- balconies
- building overhangs
- recessed entrances

and others that contribute to pedestrian comfort conditions that are generally suitable to the context. A mitigation plan is recommended for the 7th level Outdoor Amenity Space in order to achieve more comfortable conditions than reported that are appropriate for the areas' intended use.

The proposed Development is predicted to realise conditions suitable to a typical suburban context.

Respectfully submitted,

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2. INTRODUCTION

Crown (Bradford) Developments Inc. retained Theakston Environmental Consulting Engineers to study the pedestrian level wind environment for their proposed mixed-use Development occupying a portion of a block of land bound by Victoria Street to the north, Bradford Street to the east, John Street to the south, and Sanford Street to the west, within the City of Barrie, as seen on the Aerial Photo in Figure 2a. Kirkor Architects and Planners 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 Development 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.

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 current low-rise buildings on site, as well as existing and proposed buildings in the surrounding area. The proposed configuration included the subject Development. Mitigation procedures were assessed during these tests to determine their impact on the various wind conditions.

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 in accordance with the City of Barrie's Terms of Reference.

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. Theakston's Boundary Layer Wind Tunnel, which lends itself well to the simultaneous acquisition of large data streams, was used to measure the wind environment at the site while the water flume is excellent for flow visualisation and can be used to help understand problematic wind flow conditions.

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 sixty-eight (68) points tested were subsequently combined with the design probability distribution of gradient wind speed and direction (wind statistics) recorded at Lake Simcoe Regional Airport 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 the seasons in Figures 6a – 6d. 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 Barrie region that was used in the analysis was based on historical records of wind speed and direction measured at Lake Simcoe Regional Airport for the period between 2005 and 2022. 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 Lake Simcoe Regional Airport in Figure 5. From this it is apparent that winds can occur from any direction, however, historical data indicates the directional characteristics of strong winds are from mainly the northwest and said winds are most likely to occur during the spring.

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 virtual site visit to the proposed Development site, and surrounding area. Kirkor Architects and Planners provided architectural drawings. City of Barrie 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 Gust Equivalent Mean (GEM) 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. A comparison of pedestrian level comfort conditions for each probe is shown in a table in Figure 10. 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***	
Sitting	0-10	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	Gentle breezes suitable for main building entrances and bus stops.
Walking	0-20	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering.
Uncomfortable	>20	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* (5.6*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 for the 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.

Table 2: Safety Criteria

ACTIVITY	**Mean Wind Speed Exceeded 9 Times per year**	**Description**
SAFETY	***km/h***	
Pass	0 - 90	Acceptable gust speeds that will not adversely affect a pedestrian's balance and footing.
Exceeding	>90	Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required.

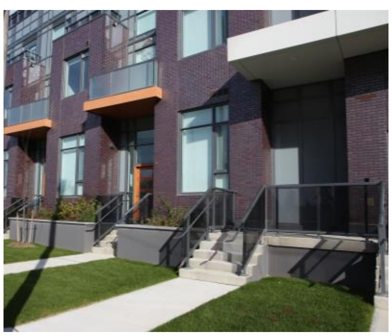
4.8 Pedestrian Comfort Criteria – Seasonal Variation

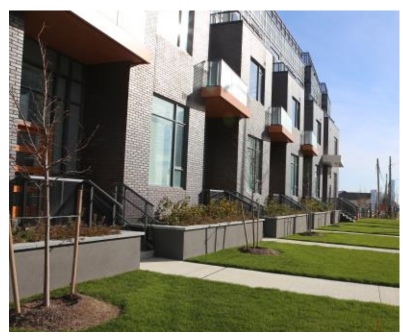
The level of comfort perceived by an individual is highly dependent on seasonal variations of climate. Perceived comfort is also specific to each individual and depends on the clothing choices. The comfort criterion that is being used averages the results across the general population to remove effects 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. When compared to the annual average wind speed, winter winds are about 1% higher and summer winds are about 9% lower.

4.9 Wind Mitigation Strategies

Wind mitigative features such as podiums, setbacks, stepped façades, balconies, notches, overhangs, canopies, and others, assist in discouraging downwash associated with prevailing winds. These features deflect portions of said winds around buildings at elevations well above the pedestrian level, and moderate upsets to wind conditions with inclusion of new developments. Additional mitigative features may also be applied for localised areas that experience conditions that are inappropriate for the intended use. These features, discussed below, add roughness into wind streamlines and protect exposed areas from high pedestrian level winds.

Entrances to buildings may be mitigated by locating them away from building corners and through recessing the entrances into the façades of the building. Additional mitigative features such as railings, canopies, coarse plantings, porous wind screens, and others, would further assist in mitigating said areas. Examples of these wind mitigation measures are shown below.





Examples of Wind Mitigative Measures at Entrances (recessed entrances, railings, canopies, raised planters, coniferous trees).

Activity areas such as Outdoor Amenity Spaces may similarly be mitigated through implementation of 1.8m – 2.4m high or higher perimeter wind screens, trellises, raised planters, coarse plantings, and others, situated about the spaces as practical. Examples of these wind mitigative measures are shown below.

Examples of Wind Mitigative Measures at Activity Spaces (wind screens, raised planters, trellises)

The model was assessed with selected mitigation strategies during these tests to determine their impact on the various wind conditions. Further testing may be required in order to determine the effectiveness of any additionally proposed wind mitigative features, if desired.

5. RESULTS

5.1 Study Site and Test Conditions

<u>Proposed Development</u>

The Development involves a proposal to construct two 45 storey towers, denoted Tower A and Tower B, and located at the north and south ends of the site, respectively. The towers are connected by a 6 storey podium which accommodates Outdoor Amenity Space at the 7^{th} level. The Main Residential Entrances to the towers are located at the northeast and southeast corners of the proposed Development, accessed via Bradford Street. Retail Entrances are also proposed along the eastern façade of the building and accessed via Bradford Street.

The development site is in a configuration as shown in Figure 2b.

View of the Development site looking northwest from Bradford Street

Surrounding Area

The proposed Development site is located on a portion of land bound by Victoria Street to the north, Bradford Street to the east, John Street to the south, and Sanford Street to the west, within the City of Barrie. The property is, for all intents and purposes, surrounded by a suburban mix of low through mid-rise residential and commercial buildings and associated surface parking and open spaces. Lake Simcoe is located approximately 375m to the east of the Development site, as indicated in Figure 2a.

The Development site shares the block with low-rise commercial buildings to the north and south and low-rise residential houses along the west. Lands to the immediate east of the Development site, across Bradford Street, are unoccupied. More removed, low-rise commercial buildings and associated open spaces primarily front Bradford Street. Low-rise residential neighbourhoods and mature vegetation occupy the lands to the northwest through west to south of the Development site. Surface parking and unoccupied land are located to the northwest, proximate to the intersection of Vespra Street and Sanford Street. Mid-rise residential buildings and low-rise commercial buildings front Lakeshore Drive with open parkland and low-rise commercial buildings associated with the Lake Simcoe waterfront beyond.

Figures 2a and 2b depict the site and its immediate context and 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 Lake Simcoe Regional Airport was used in this analysis. The data was divided into four seasons, winter, spring, summer, and fall, and the resulting wind roses are presented as mean velocity and percent frequency in Figures 5a-d. 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).

Winter (December through February) has the second highest mean velocities of the seasons with prevailing winds from the north through west to southwest, as indicated in Figure 5a. Spring (March through May) has the highest mean wind velocities and the prevailing winds are predominantly from the northwest through west directions with additional components from the southeast quadrant (Figure 5b). Summer (June through August) has the lowest mean wind velocities of the seasons with prevailing winds similarly from the northwest through west, as indicated in Figure 5c. During the fall, (September through November) the main directions for prevailing winds include the northwest through west to southwest sector (Figure 5d). Reported pedestrian comfort conditions generally pertain to winter conditions unless stated otherwise.

5.2 Pedestrian Level Wind Velocity Study

On the site model, sixty-eight (68) wind velocity measurement probes were located around the proposed Development and other 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 buildings were 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 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 – 5d) 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 – 6d.

The ratings for a given location are conservative by design; when the existing surroundings and proposed buildings' 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 compass points with winds flowing over and between mature vegetation, low through mid-rise buildings and open spaces. Lake Simcoe is located approximately 375m to the east of the Development site, providing an open approach to winds, affording opportunity to accelerate. 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.

5.3 Review of Probe Results

The probe results, as follows, were clustered into groups comprised of Public Street Conditions, Neighbouring Site Conditions, Internal Site Conditions, Pedestrian Entrance Conditions and Outdoor Amenity Space Conditions. The measurement locations are depicted in Figure 4 and the resulting pedestrian comfort conditions are listed in Figures 6a – 6d for the seasons for the existing and proposed configurations. The results are also graphically depicted for the seasons in Figures 7a – 7h, and compared in a table in Figure 10. The following discusses anticipated wind conditions and suitability for the points' intended use.

Public Street Conditions

Sanford Street
Probes 1 through 16 were located along Sanford Street within the zone of influence of the proposed Development site. Their locations are depicted in Figure 4, their comfort ratings are listed for the seasons in Figures 6a – 6d and depicted in Figures 7a through 7h. In the existing setting, the probes situated along Sanford Street indicate wind conditions that are suitable for sitting throughout the year. The comfortable existing conditions can be attributed to the flanking low-rise buildings which direct winds to flow up and over the street, above the pedestrian level.

With inclusion of the proposed Development, areas of Sanford Street realised increases in winds from specific directions, however the changes were insufficient to change the seasonal comfort ratings, with exception. Probe 14 realised increases in northwesterly through northeasterly winds that were sufficient to change the spring rating from sitting to standing.

Overall, the changes to wind conditions along Sanford Street are expected to be minimal in the proposed setting and the street will remain comfortable and appropriate for its intended use throughout the year. Sanford Street also passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Bradford Street
Probes 17 through 40 were located along Bradford Street within the zone of influence of the proposed Development site. In the existing setting, Bradford Street realises conditions rated for sitting throughout the year, with the exception of standing conditions at probes 28 and 30 in the spring season. The comfortable conditions can again be attributed to the low-rise surroundings deflecting wind to flow up and over the street.

With inclusion of the proposed Development, a realignment of winds was noted along Bradford Street. The changes can be attributed to the proposed Development reducing apparent wind effects at the pedestrian level for several wind directions, but causing an increase to 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 down and around the buildings and along portions of Bradford Street. Conversely, improvements in wind conditions can be attributed to the proposed Development providing blockage to winds from specific directions and effectively reducing the propensity for winds being deflected to flow along the street.

The changes were sufficient to change comfort categories at various probes along Bradford Street from sitting to standing throughout the year. Probes 23, 25, and 26 realised sufficient increases in winds to change the spring ratings from sitting to walking, and probe 28 similarly changed from standing to walking in the spring.

Overall, Bradford Street remains comfortable and appropriate for its intended use throughout the year with inclusion of the proposed Development and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Ellen Street

Probes 41, 42, and 43 were located along Ellen Street, situated to the east of the proposed Development site. Ellen Street was rated suitable for sitting throughout the year in the existing setting. With inclusion of the proposed Development, the area realises increases in winds emanating from the northwest and southwest that were sufficient to change the seasonal ratings from sitting to standing at probes 42 and 43 in the winter and spring, and probe 43 in the fall as well. Ellen Street remains comfortable and appropriate for its intended use throughout the year with inclusion of the proposed Development and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Victoria Street

In addition to the probes situated at the intersections with Sanford Street and Bradford Street, discussed above, probes 44 through 49 were located along Victoria Street within the zone of influence of the proposed Development site. In the existing setting, the street was rated suitable for sitting throughout the year. With inclusion of the proposed Development, areas of Victoria Street realised increases in winds from westerly and easterly through southeasterly directions. The increases were sufficient to change the ratings from sitting to standing at probe 45 in the spring and probe 46 in the winter, spring, and fall. Victoria Street will remain comfortable and appropriate for its intended use throughout the year and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

John Street

In addition to the probes situated at the intersections with Sanford Street and Bradford Street, discussed above, probes 50 through 53 were located along John Street within the zone of influence of the proposed Development site. The street was rated suitable for sitting throughout the year in the existing setting, with the exception of standing conditions which remain at probe 53 in the spring season. In the proposed setting, probes 51 and 52 realised increases in northwesterly through northeasterly winds that change the winter and spring ratings from sitting to standing. John Street will remain comfortable and appropriate for its intended use throughout the year and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Neighbouring Site Conditions

Probe 54 was located within the patio at the neighbouring 118 Bradford Street building, situated to the north of the proposed Development. The area was rated suitable for sitting throughout the year in the existing setting and remains as such with inclusion of the proposed Development. The neighbouring patio remains suitable for its intended purpose throughout the year.

Probe 55 was located proximate to the entrance to the neighbouring 111 Bradford Street building, situated to the northeast of the Development site. The area was rated suitable for sitting throughout the year in the existing setting. A relatively subtle increase in southeasterly winds was sufficient to change the spring rating from sitting to standing in the proposed setting, however the remainder of the seasons retained their original comfort rating of sitting. The neighbouring entrance will remain comfortable and appropriate for its intended use throughout the year in the proposed setting.

Probe 56 was situated proximate to the entrance to the neighbouring 144 Bradford Street building, located to the immediate south of the Development site. The Entrance was rated suitable for sitting year-round in the existing setting. In the proposed setting, an increase in northeasterly and southwesterly winds was sufficient to change the winter and spring ratings from sitting to standing. The neighbouring entrance will remain comfortable for its intended use year-round with inclusion of the proposed Development.

The above-mentioned neighbouring site conditions pass the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Internal Site Conditions

Probes 57 through 59 were located within a landscape buffer along the western property line of the site. The area is exposed to northerly and southerly winds that are deflected by the proposed Development to flow down and along the western façade, however it is protected from much of the easterly and westerly wind climate by the proposed buildings and surrounds. As a result, the area is rated suitable for sitting throughout much of the year, with the exception of standing conditions at probe 59 in the winter and probes 58 and 59 in the spring. The area will be comfortable and appropriate for its intended use throughout the year and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Pedestrian Entrance Conditions

Probe 60 was positioned proximate to the Main Residential Entrance to Tower A, accessed via Bradford Street. The Entrance is exposed to dominant winds emanating from the northwest and east through southeast that are directed to flow down the towers and around the northeast corner of the Development. As such, the entrance is rated suitable for walking in the spring and standing throughout the remainder of the year. The entrance is recessed into the façade and located beneath an overhang of the building above and therefore is expected to realise more comfortable conditions than the probe beyond. The spring rating of walking is near the transition to standing conditions, and with consideration of these proposed mitigative features, is expected to be suitable for standing, or better, throughout the year. As such, the Main Residential Entrance to Tower A will be comfortable and suitable for the intended use, year-round.

Probe 63 was positioned proximate to the Main Residential Entrance to Tower B, accessed via Bradford Street. The Entrance is exposed to winds emanating from the east through northeast and southwest that are directed to flow down the towers and around the southeast corner of the Development. As such, the entrance is rated suitable for sitting in the summer and standing throughout the remainder of the year. The entrance is recessed into the façade and located beneath an overhang of the building above and therefore is expected to realise more comfortable conditions than the probe beyond. The Main Residential Entrance to Tower B will be comfortable and suitable for the intended use, year-round.

Probes 61 and 62 were located adjacent to Retail Entrances to the proposed Development, accessed via Bradford Street. The area is protected from much of the wind climate by the proposed buildings and as such realises comfortable conditions, suitable for sitting year-round. The Retail Entrances to the proposed Development will be comfortable and suitable for the intended uses throughout the year.

Conditions suitable for standing or better are preferred at Entrances, while conditions suitable for walking are appropriate for sidewalks. As a result, the Residential and Retail Entrances are expected to be comfortable and suitable for the intended uses year-round. Consideration of design and landscape features that were too fine to include in the massing model will result in more comfortable conditions than reported.

The above-mentioned Residential and Retail Entrances to the proposed Development pass the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Outdoor Amenity Space Conditions

Probes 64 through 68 were located within the 7th level Outdoor Amenity Space, atop the podium connecting Tower A and Tower B. The area will be exposed to large portions of the wind climate, mainly emanating from the east and west, that are directed to flow down and around the towers and through the gap between, resulting in conditions suitable for standing throughout the summer and fall, and mainly walking in the spring, with the exception of spring standing conditions at probe 67. The space was tested with 2.0*m* high screen walls along the eastern and western edges of the space, however additional mitigation is recommended in order to achieve conditions appropriate for the area's intended use. The mitigation plan may include higher perimeter screen walls, porous wind screens, coniferous vegetation, raised planter beds populated with coarse plantings, trellises, canopies, and others situated throughout the space as practical. With consideration of an appropriate mitigation plan for the area, the 7th level Outdoor Amenity Space is expected to realise comfortable conditions that are seasonally suitable for the intended use.

The above-mentioned Outdoor Amenity Space passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

5.4 Summary

The observed wind velocity and flow patterns at the proposed Development are largely influenced by approach wind characteristics that are dictated by the surrounding areas to prevailing and less dominant wind directions. These surroundings moderate wind flow in streamlines near the pedestrian level from most directions, resulting in comfortable conditions at the existing site and in the surrounds, suitable for sitting through the majority of the year. Historical weather data recorded at Lake Simcoe Regional Airport indicates that strong winds of a mean wind speed greater than 30km/h occur approximately 3% of the time during the winter months and 2% of the time during the summer.

Once the subject site is developed, ground level winds at many locations will be similar to the existing setting, with localised areas of higher pedestrian level winds noted proximate to the proposed Development, however the areas will remain suitable for the intended uses. The site and surrounds are predicted mainly suitable for sitting or standing throughout the year in the proposed setting, with localised walking conditions noted during the spring proximate to the northeast corner of the proposed Development along Bradford Street. The consideration of proposed surface roughness features such as fine design and landscape elements will result in conditions more comfortable than those reported herein. The relationship between surface roughness and wind is discussed in the Appendix and shown graphically in Figure A of the same section.

A mitigation plan is recommended for the 7th level Outdoor Amenity Space in order to achieve more comfortable conditions than reported that are appropriate for the areas' intended use.

The proposed Development is predicted to realise conditions suitable to a typical suburban context.

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Appendix: Background and Theory of Wind Movement 58

Figure 1: Laboratory Testing Facility

Figure 2a: Site Aerial Photo

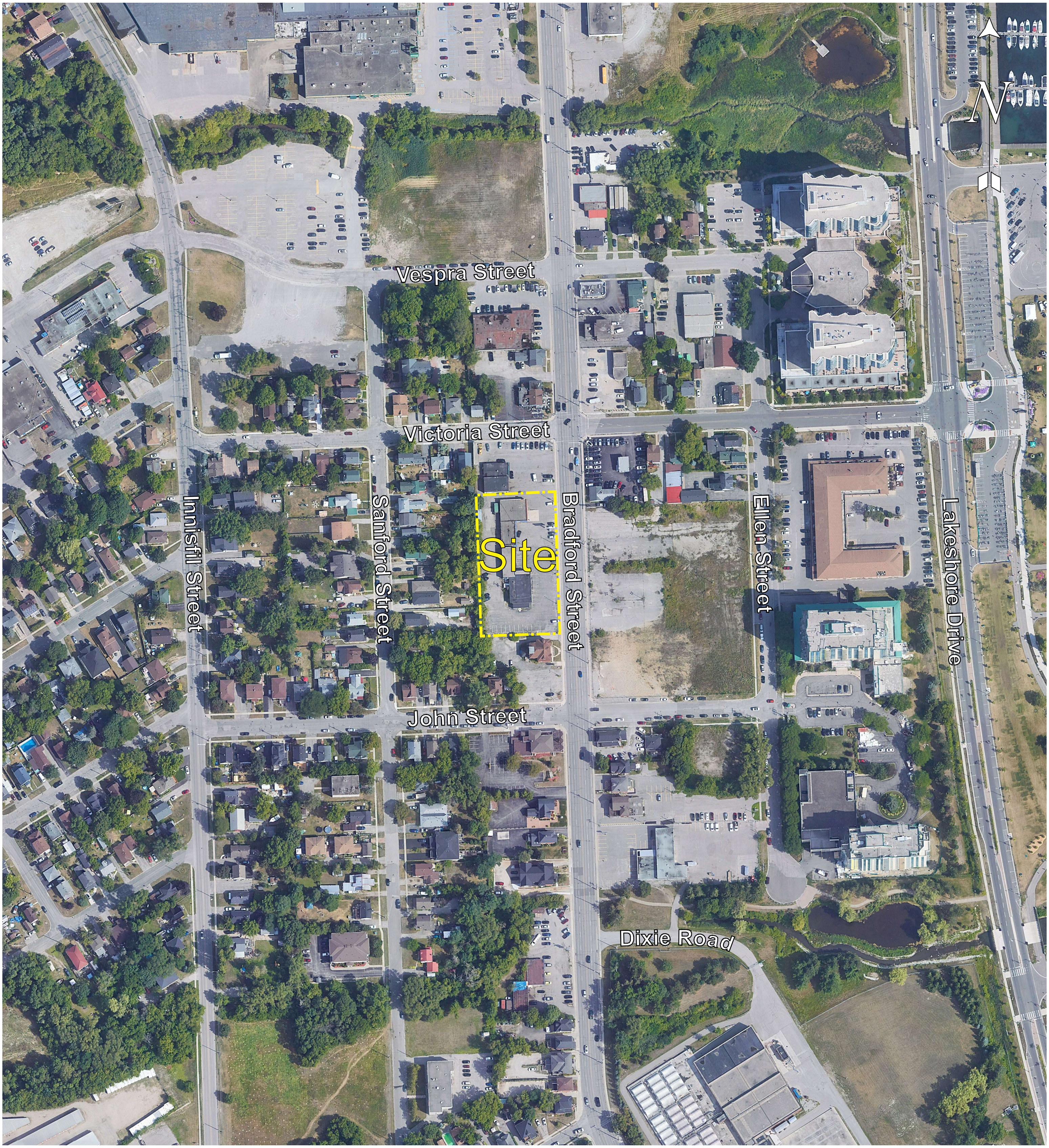

Figure 2b: Site Plan

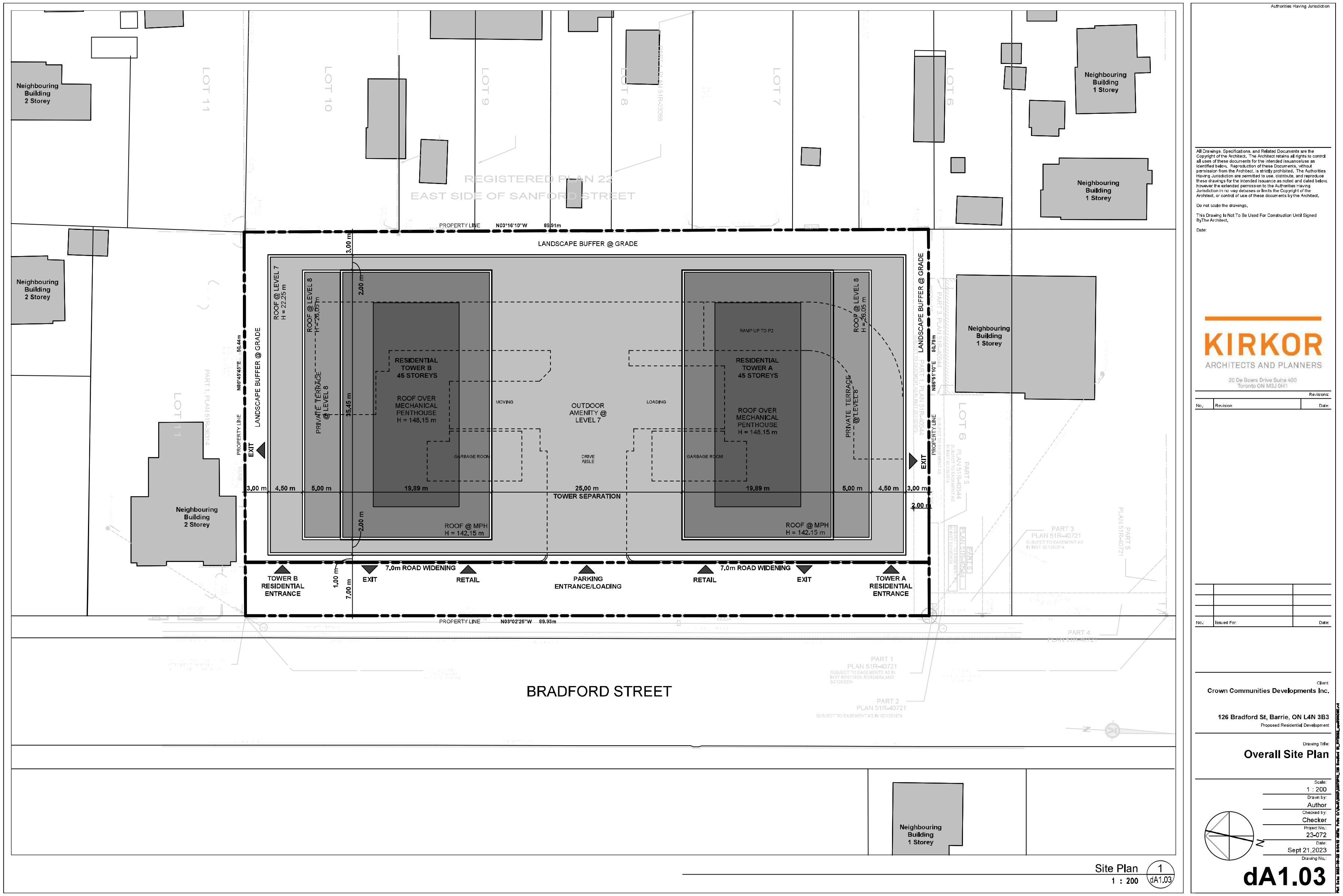

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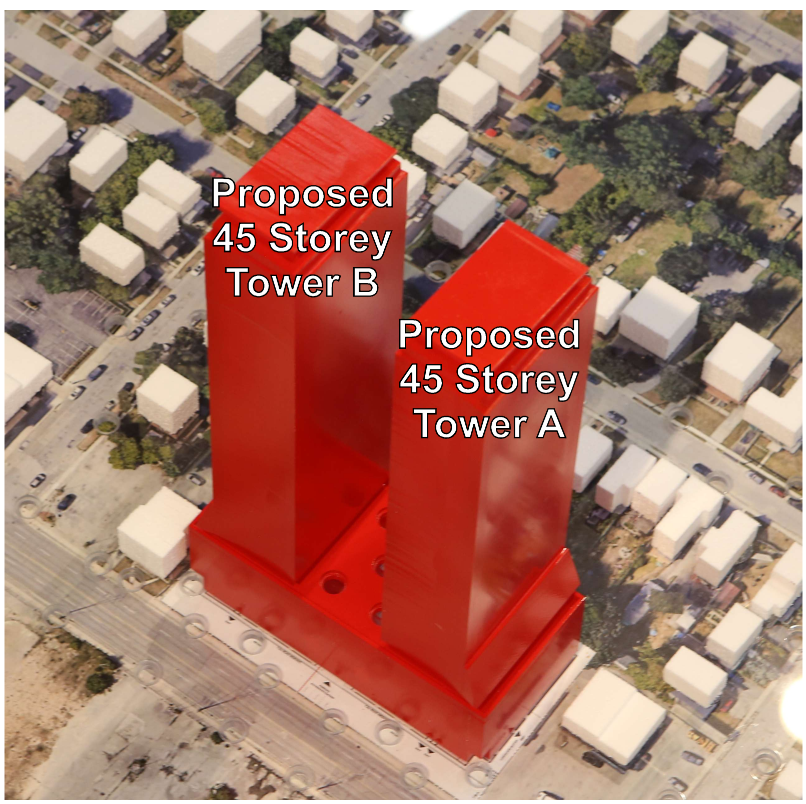
Figure 3: 1:500 Scale Model of Test Site

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: Winter Wind Rose - Lake Simcoe Regional Airport

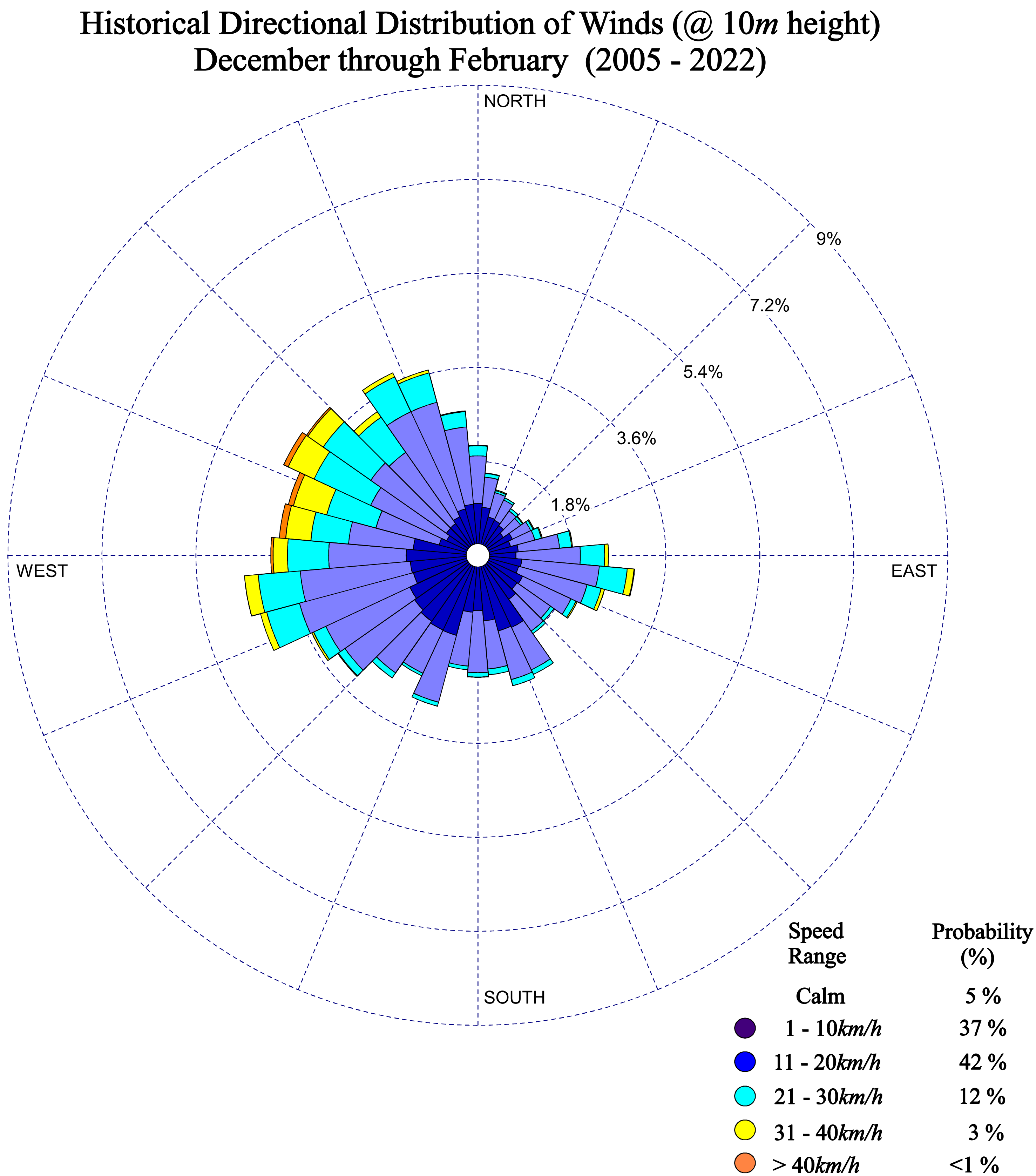


Figure 5b: Spring Wind Rose - Lake Simcoe Regional Airport

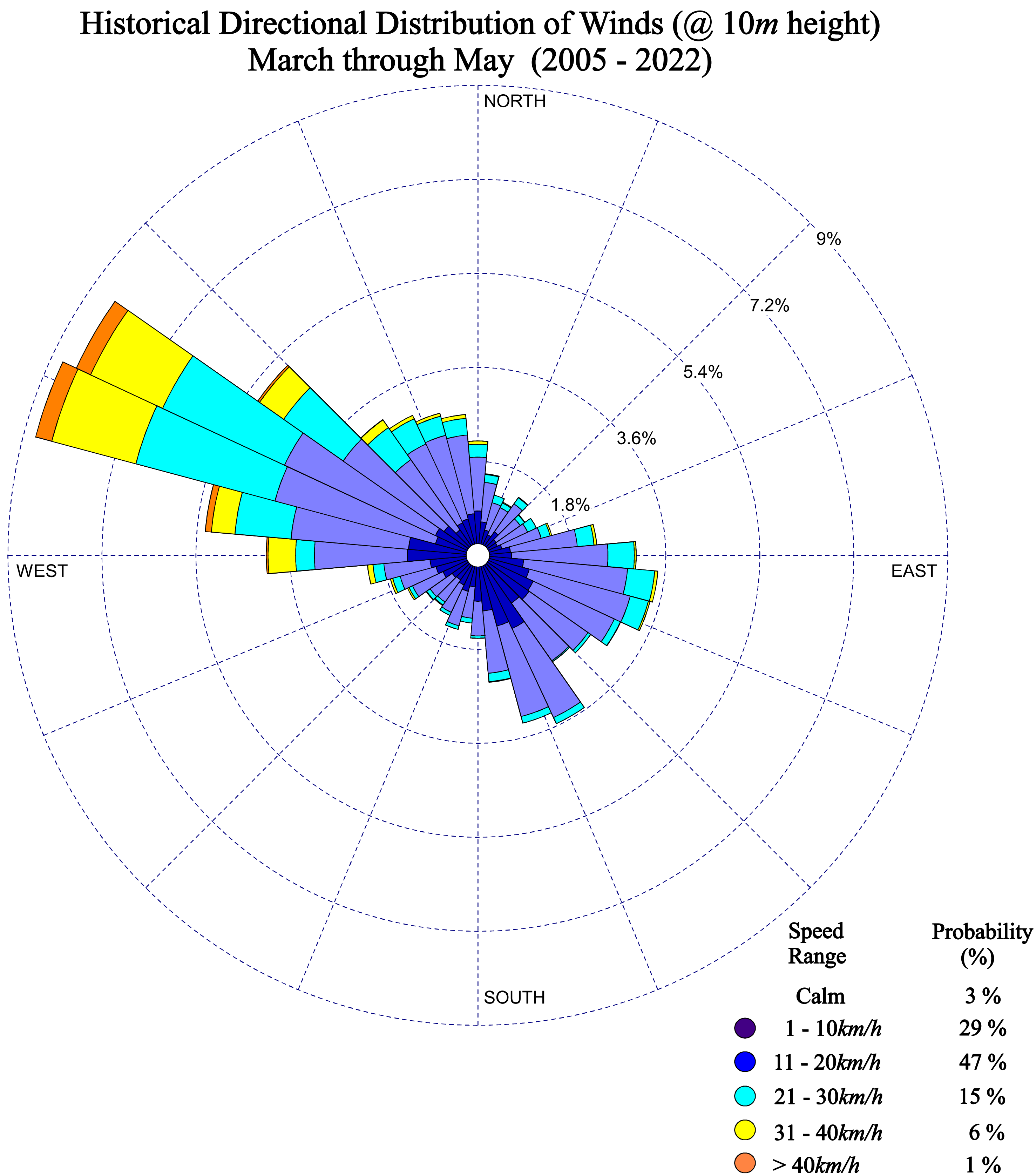
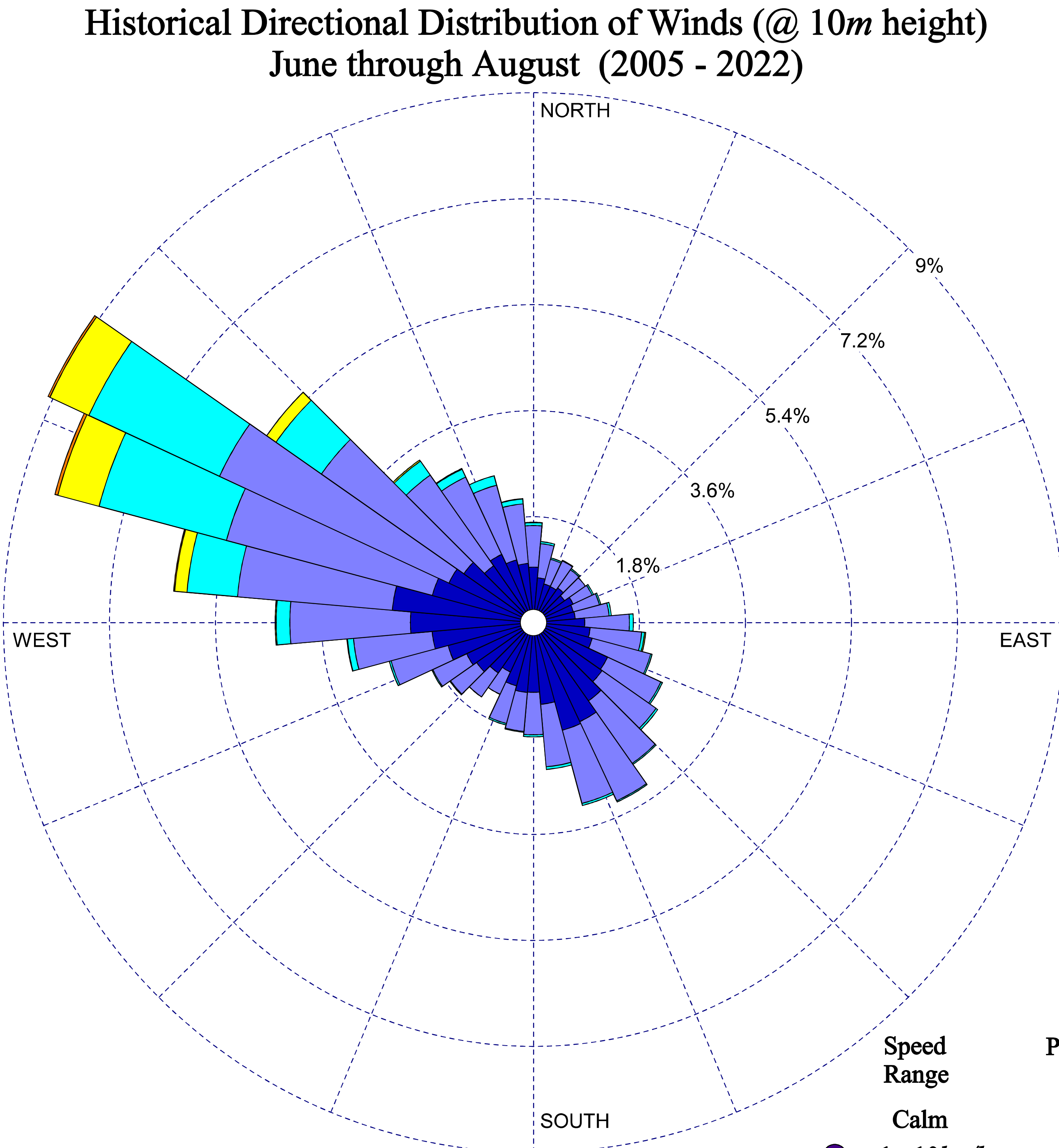


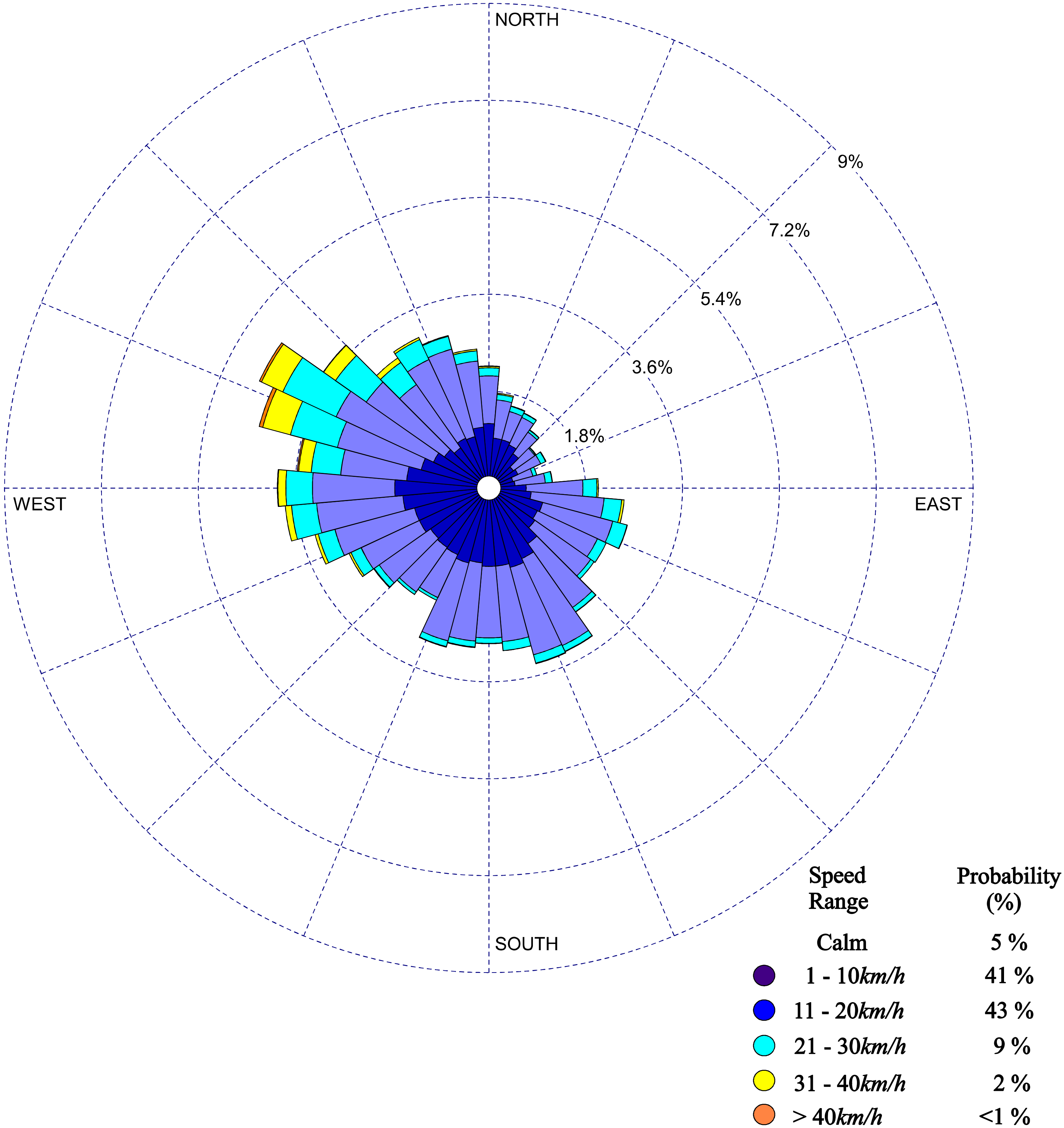
Figure 5c: Summer Wind Rose - Lake Simcoe Regional Airport



Speed Range	Probability (%)
Calm	4 %
1 - 10*km/h*	44 %
11 - 20*km/h*	42 %
21 - 30*km/h*	8 %
31 - 40*km/h*	2 %
> 40*km/h*	<1 %

Figure 5d: Fall Wind Rose - Lake Simcoe Regional Airport

Historical Directional Distribution of Winds (@ 10*m* height)
September through November (2005 - 2022)



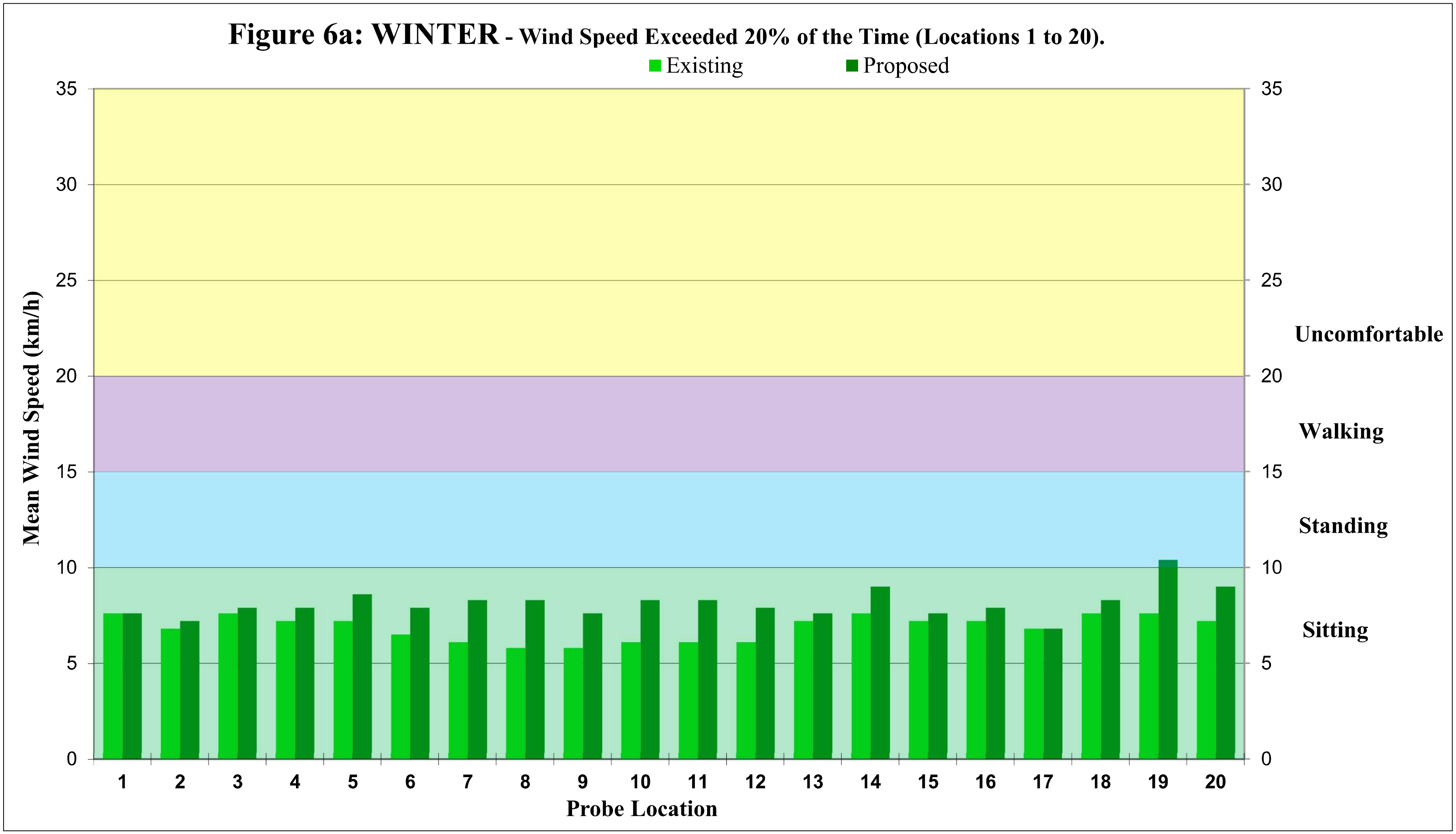


Figure 6a: WINTER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (km/h)
Probe Location
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Uncomfortable
Walking
Standing
Sitting

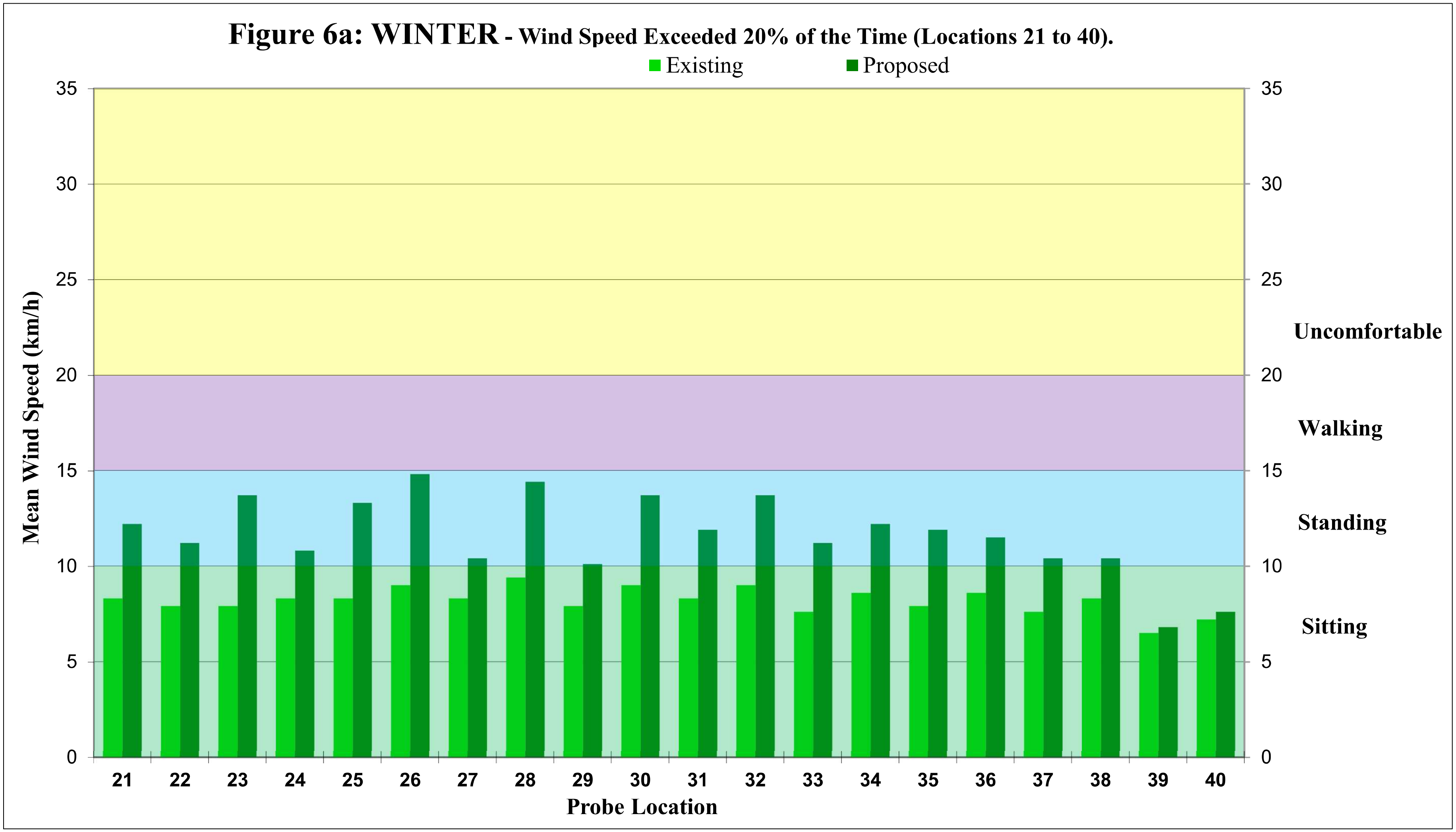


Figure 6a: WINTER - Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (km/h)
0
5
10
15
20
25
30
35
Uncomfortable
Walking
Standing
Sitting
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location

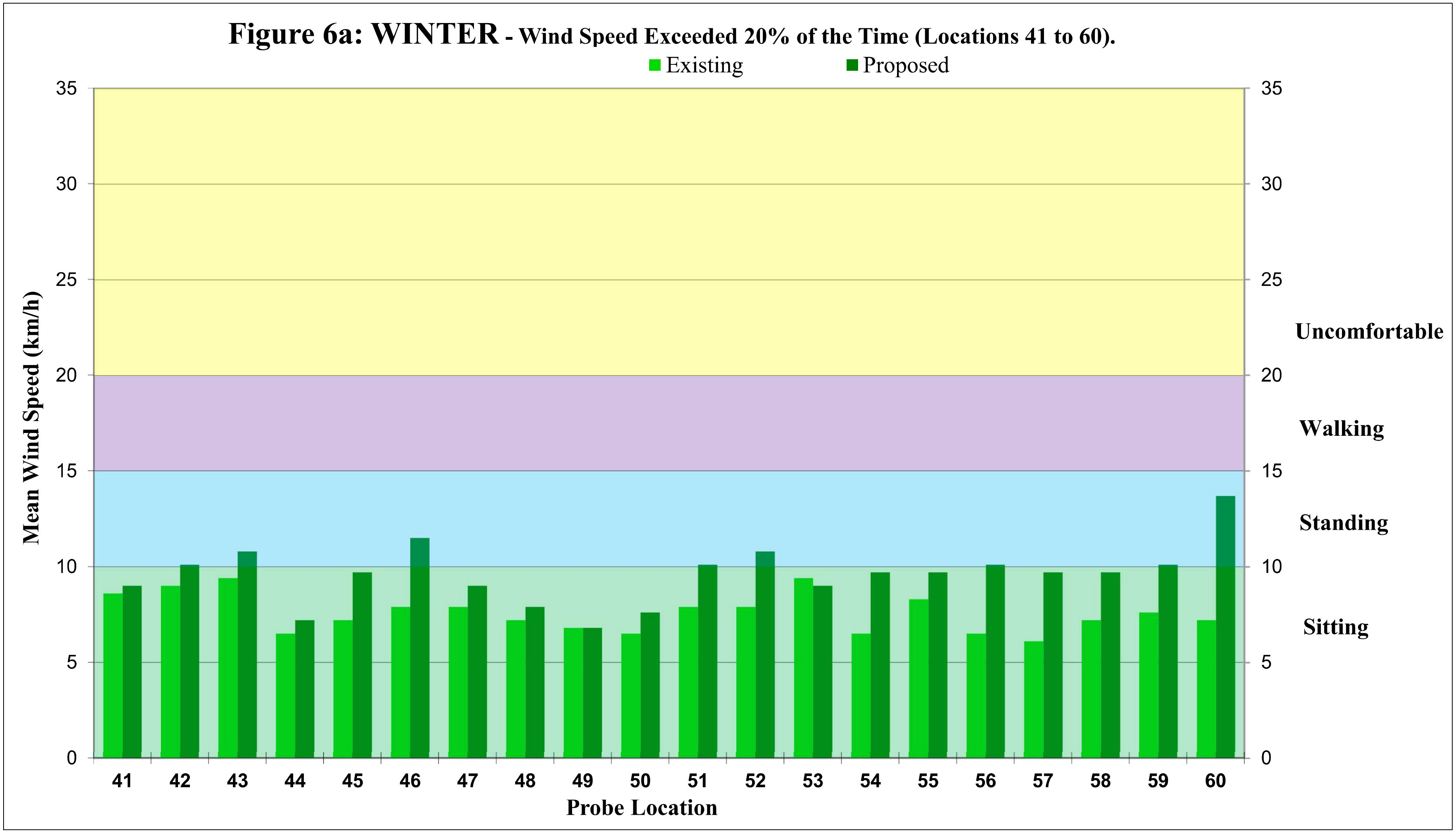


Figure 6a: WINTER - Wind Speed Exceeded 20% of the Time (Locations 41 to 60).
Existing
Proposed
Mean Wind Speed (km/h)
0
5
10
15
20
25
30
35
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Probe Location
Uncomfortable
Walking
Standing
Sitting

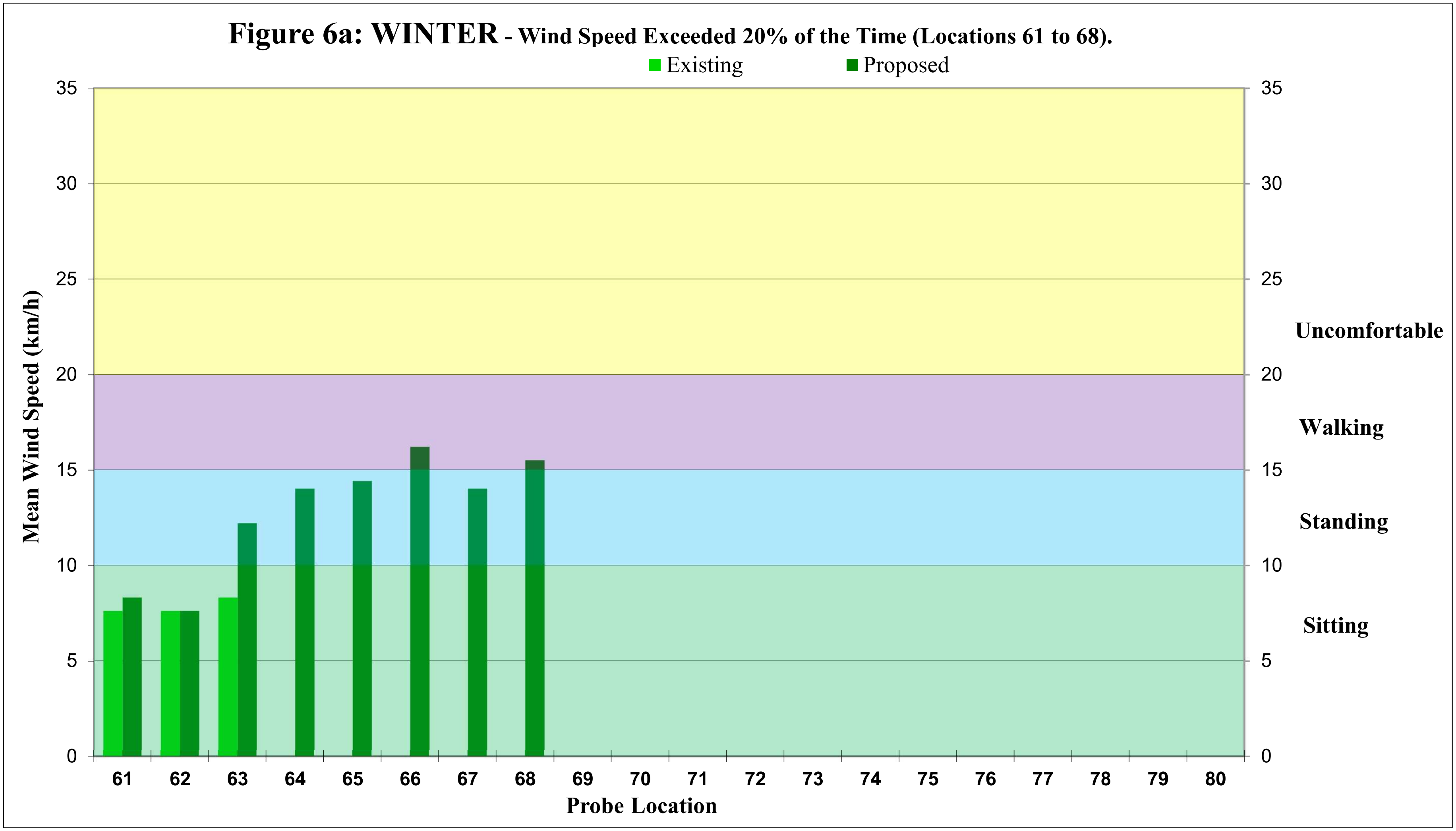


Figure 6a: WINTER - Wind Speed Exceeded 20% of the Time (Locations 61 to 68).
Existing
Proposed
Mean Wind Speed (km/h)
0
5
10
15
20
25
30
35
Uncomfortable
Walking
Standing
Sitting
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
Probe Location

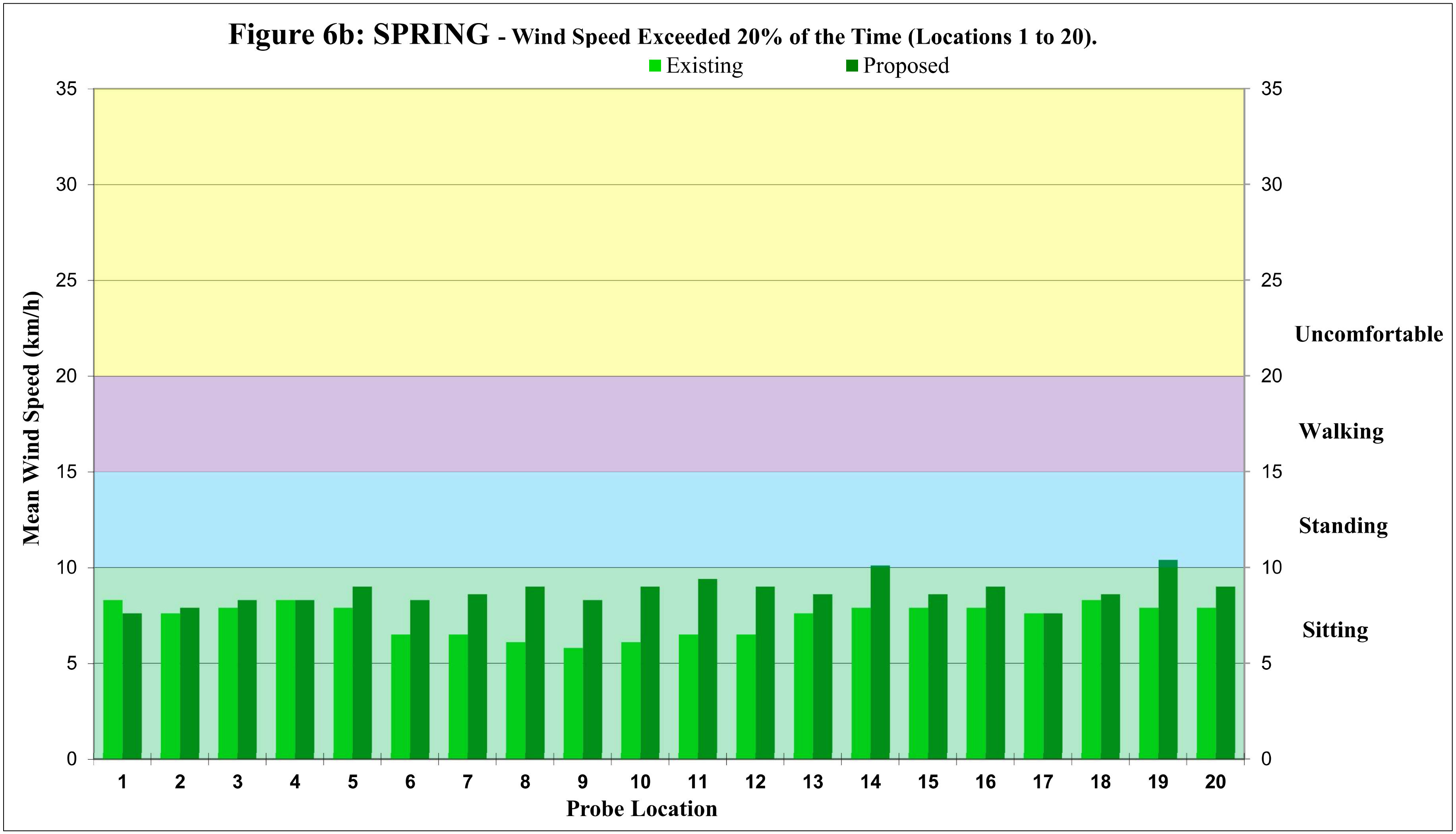


Figure 6b: SPRING - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

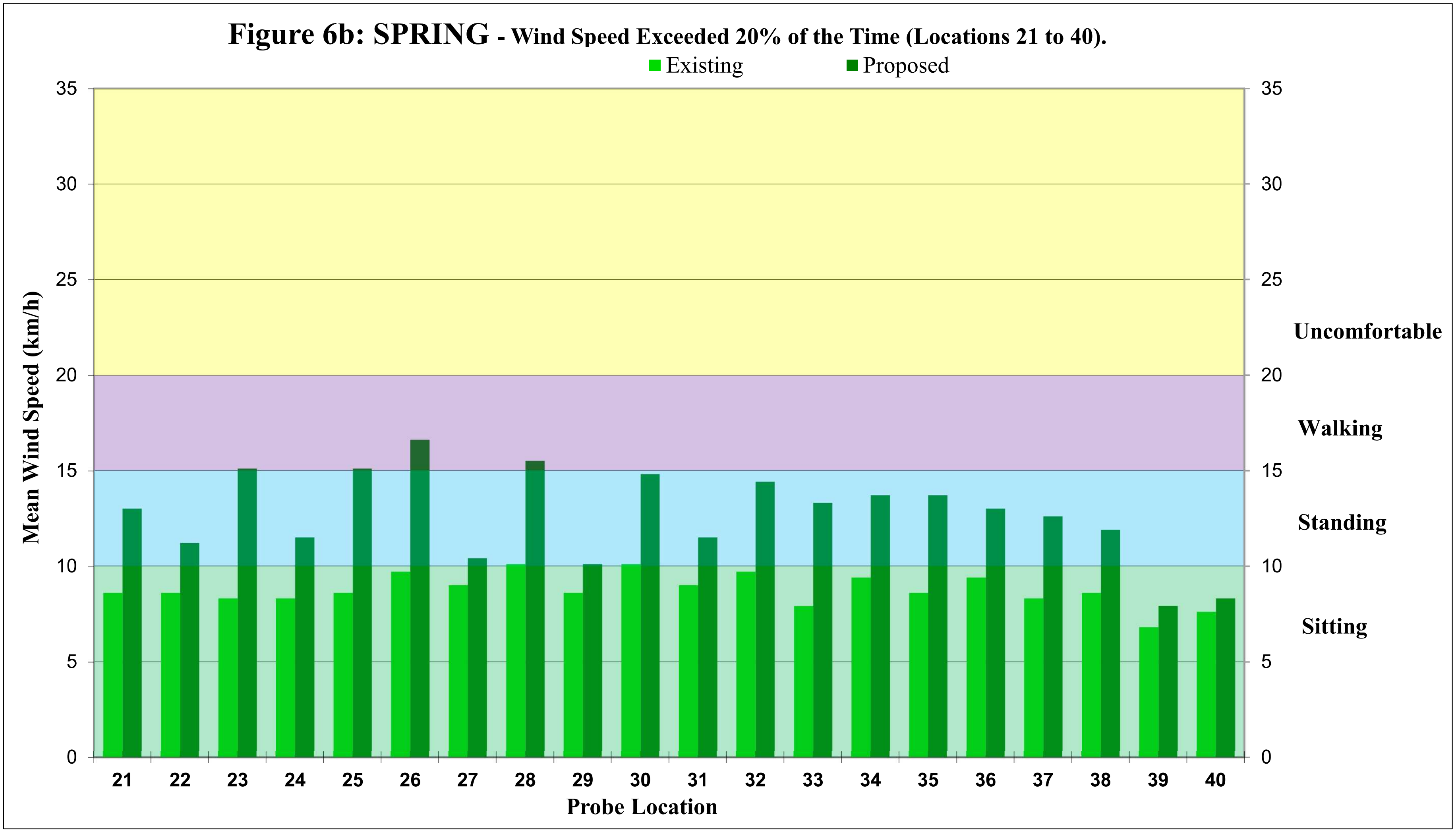


Figure 6b: SPRING - Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (km/h)
35
30
25
20
15
10
5
0
Uncomfortable
Walking
Standing
Sitting
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location

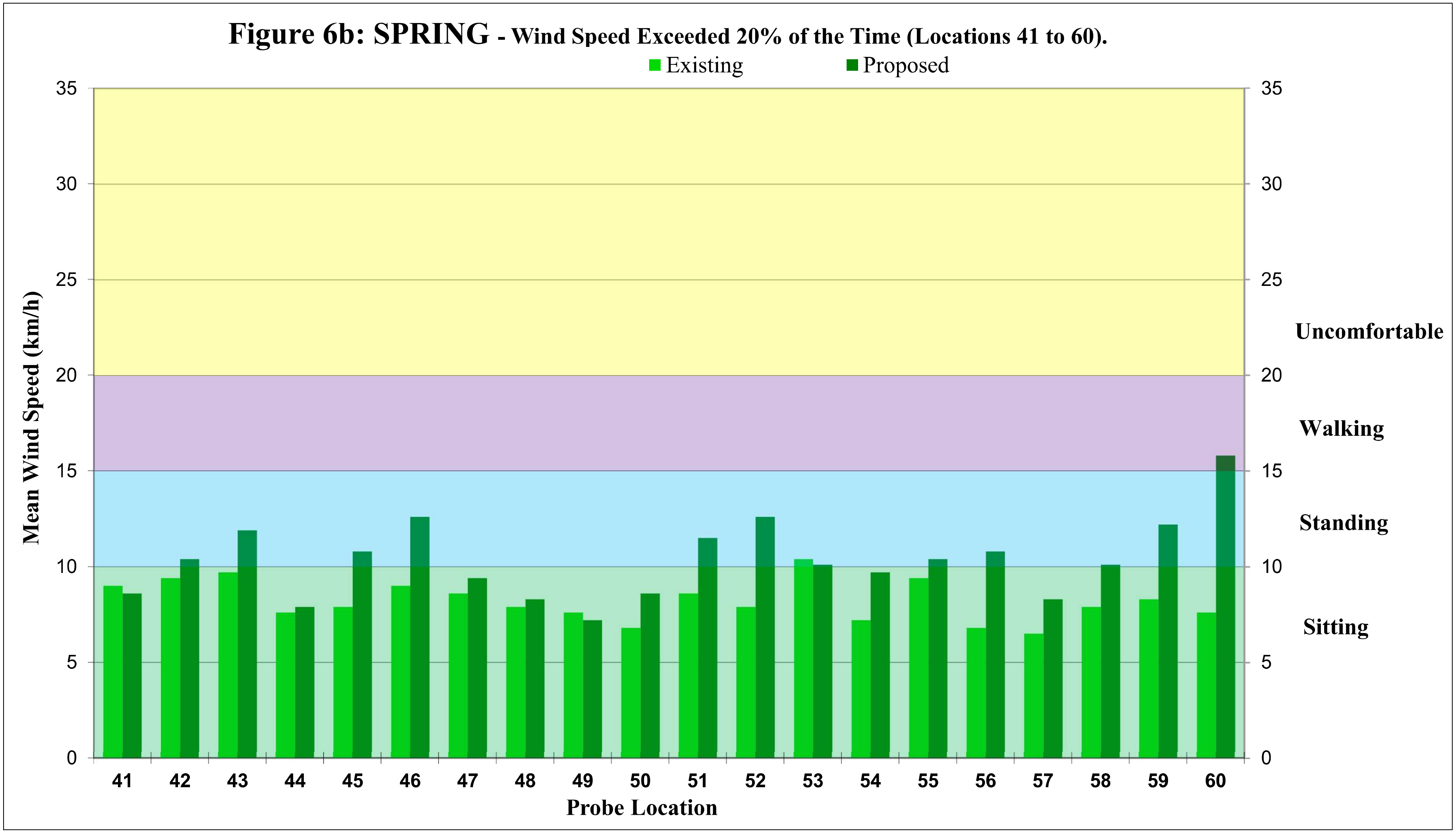


Figure 6b: SPRING - Wind Speed Exceeded 20% of the Time (Locations 41 to 60).
Existing
Proposed
Mean Wind Speed (km/h)
35
30
25
20
15
10
5
0
Uncomfortable
Walking
Standing
Sitting
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Probe Location

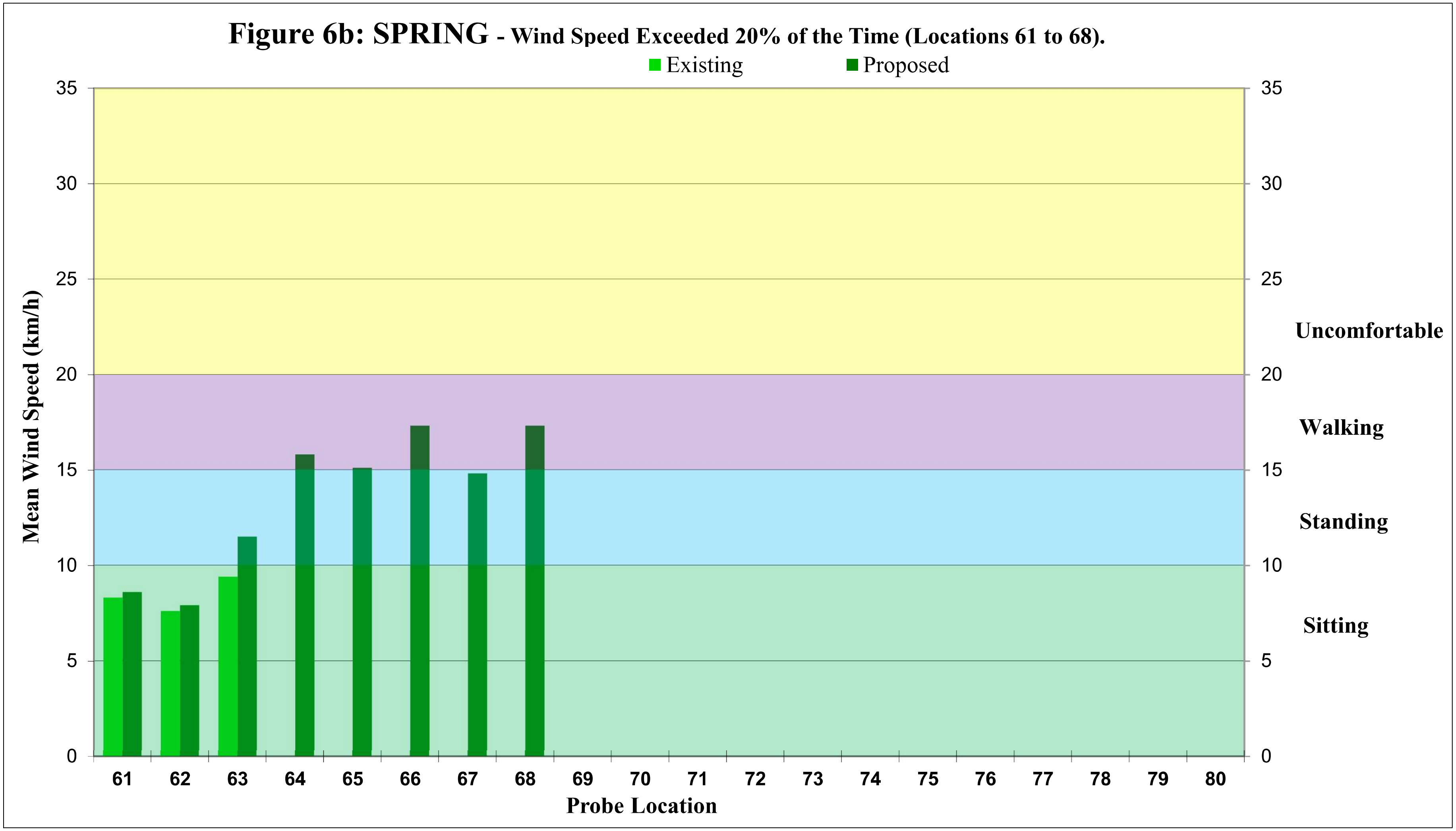


Figure 6b: SPRING - Wind Speed Exceeded 20% of the Time (Locations 61 to 68).
Existing
Proposed
Mean Wind Speed (km/h)
35
30
25
20
15
10
5
0
Uncomfortable
Walking
Standing
Sitting
61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
Probe Location

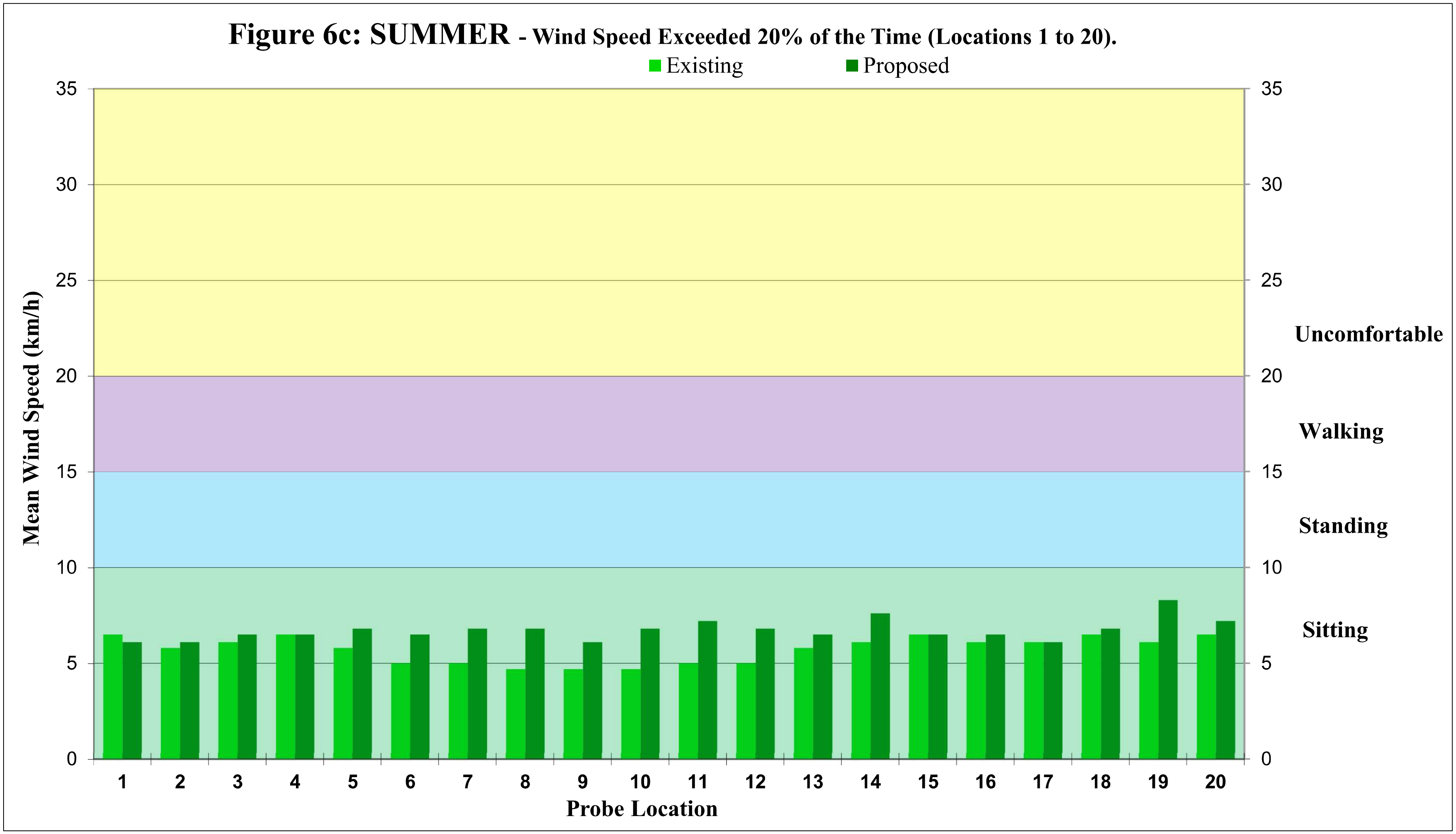


Figure 6c: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

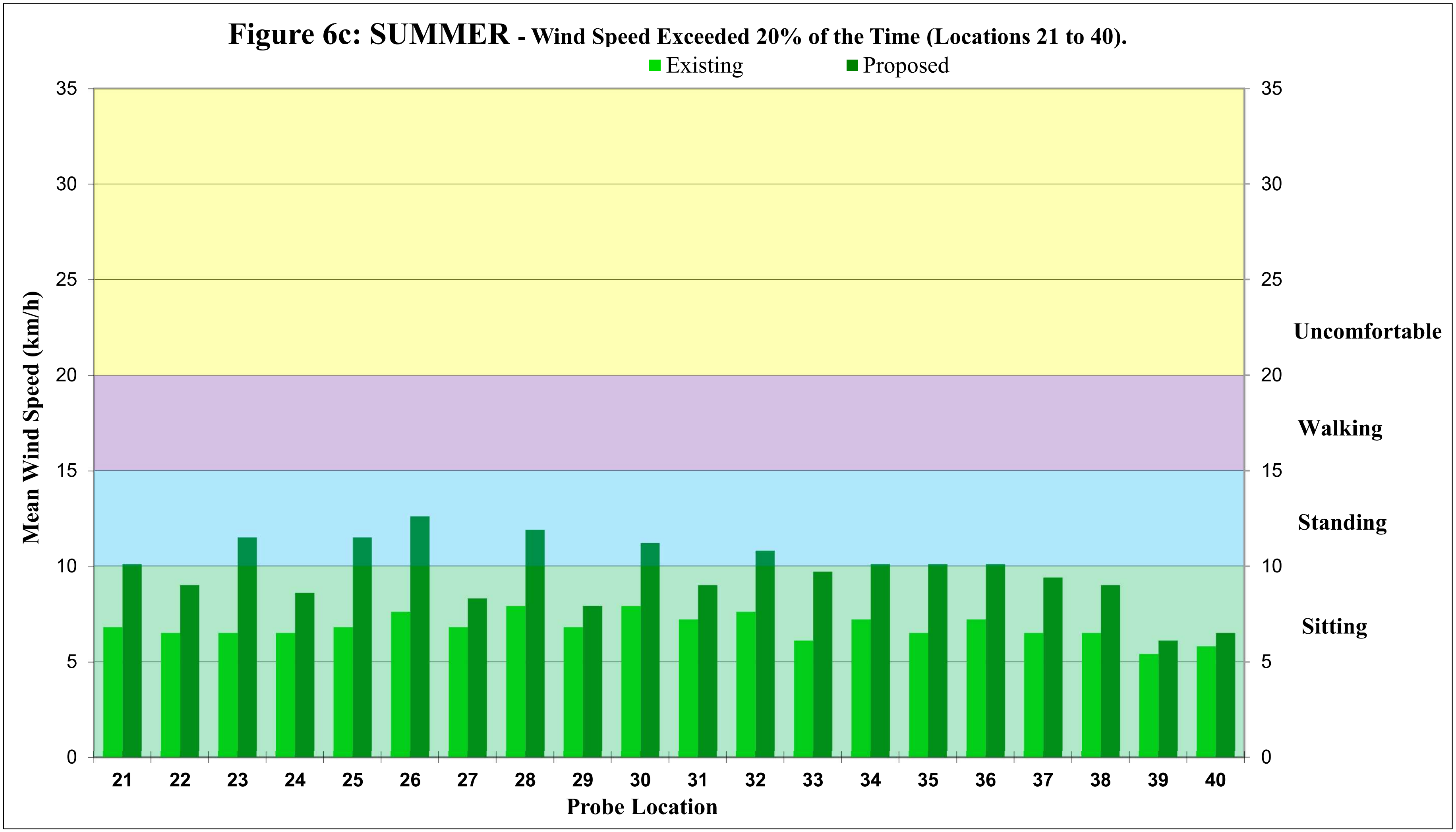
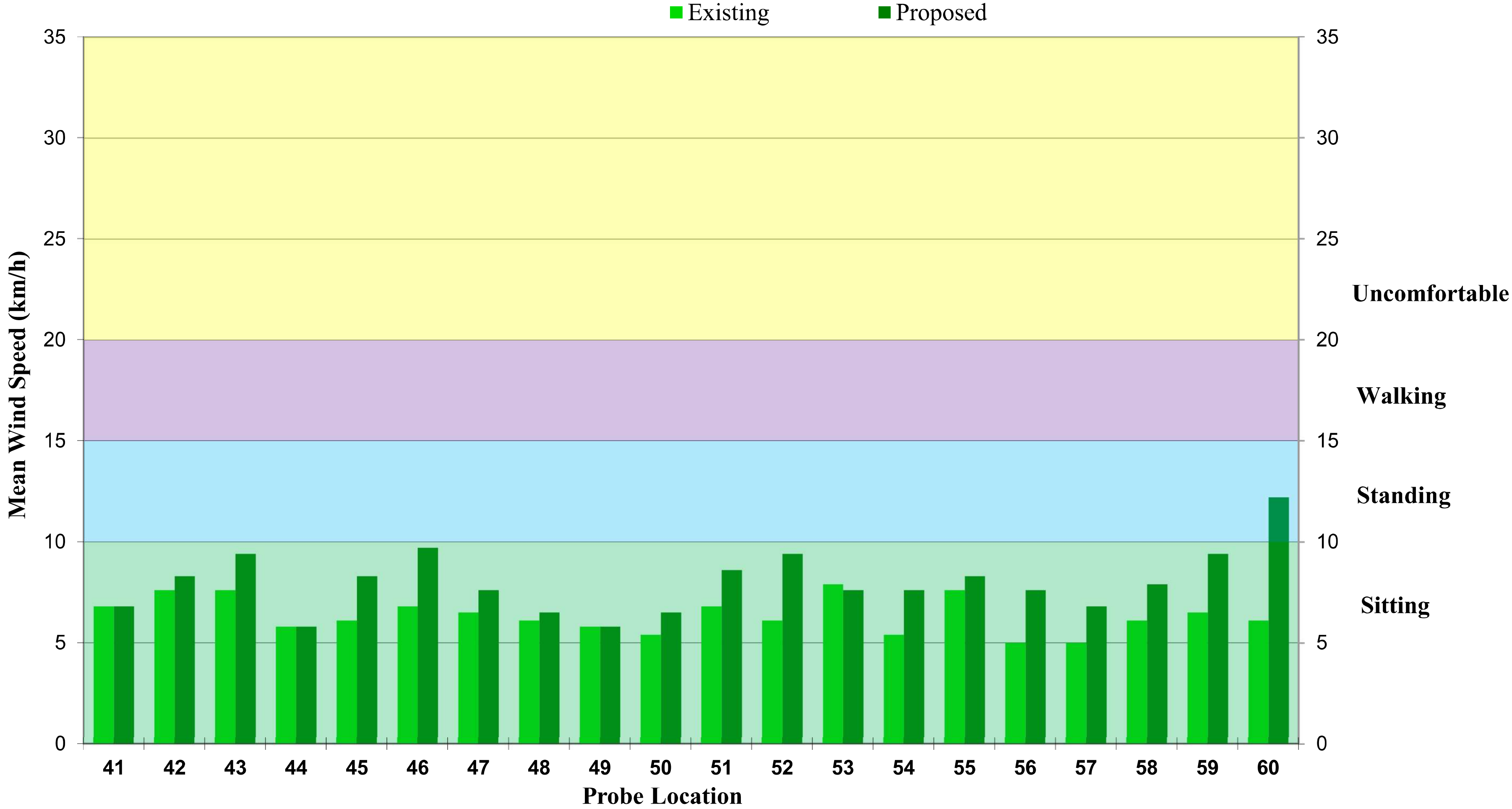


Figure 6c: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (km/h)
0
5
10
15
20
25
30
35
Uncomfortable
Walking
Standing
Sitting
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location

Figure 6c: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 41 to 60).



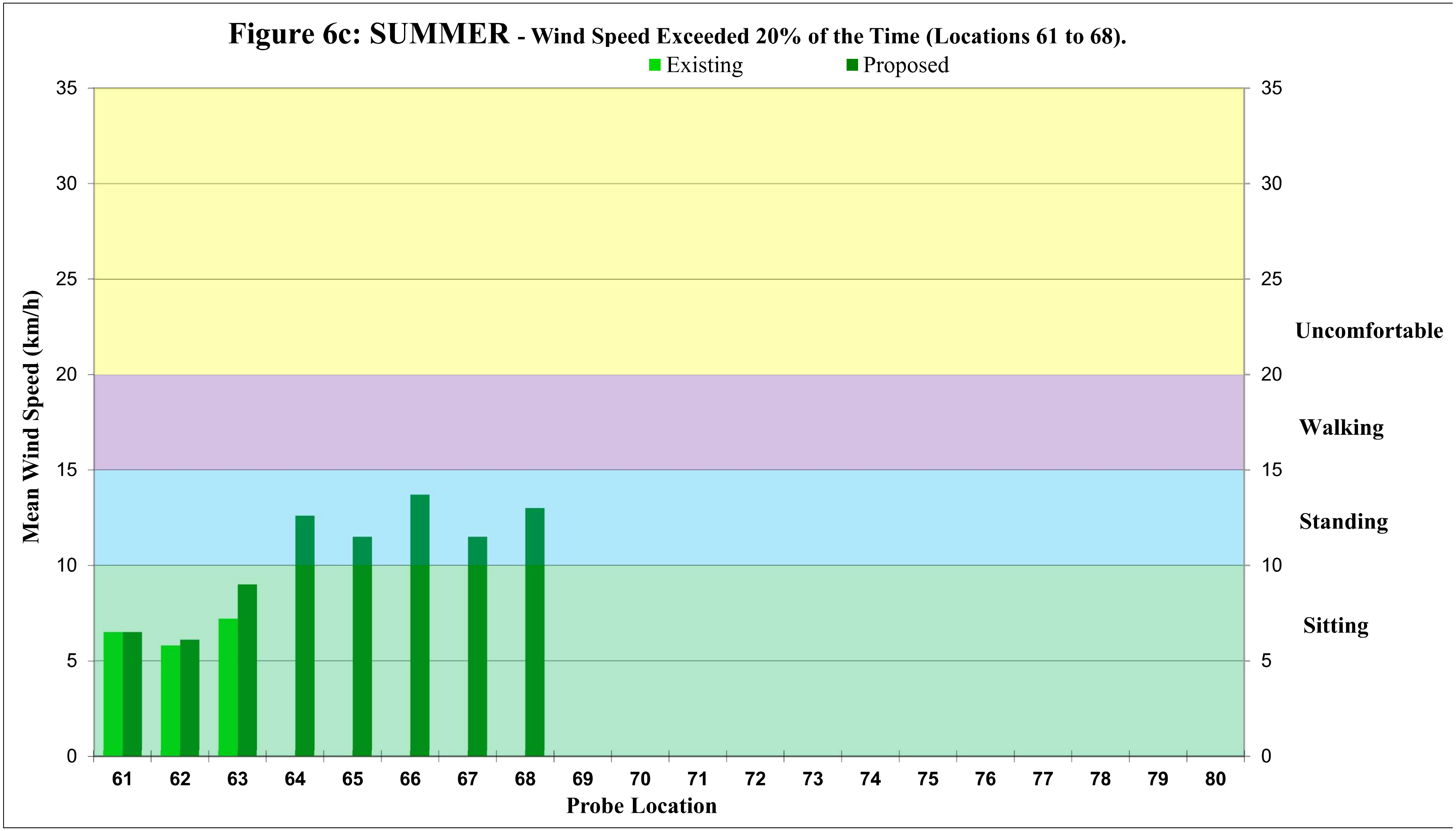


Figure 6c: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 61 to 68).
Existing
Proposed
Mean Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80

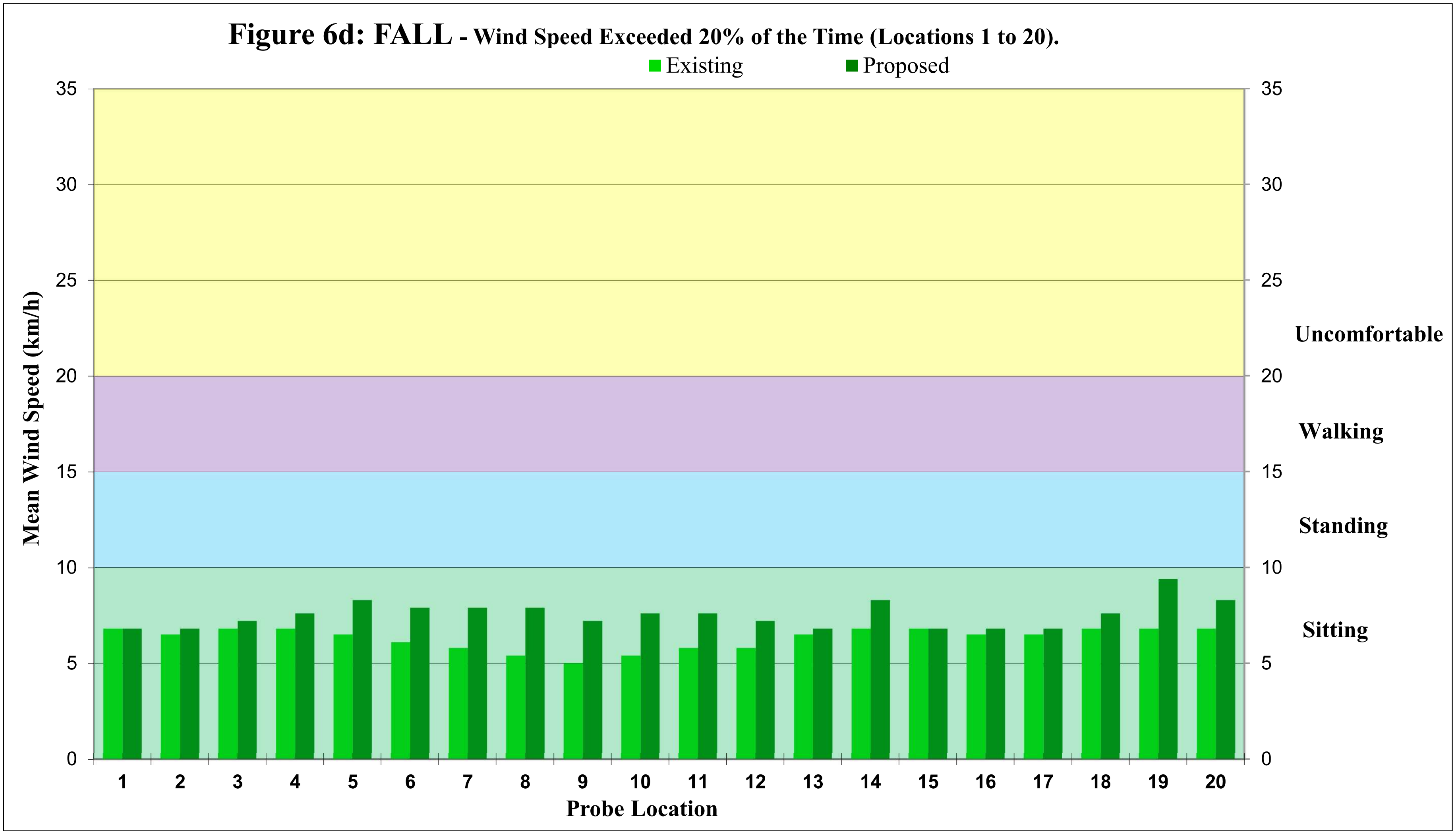


Figure 6d: FALL - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

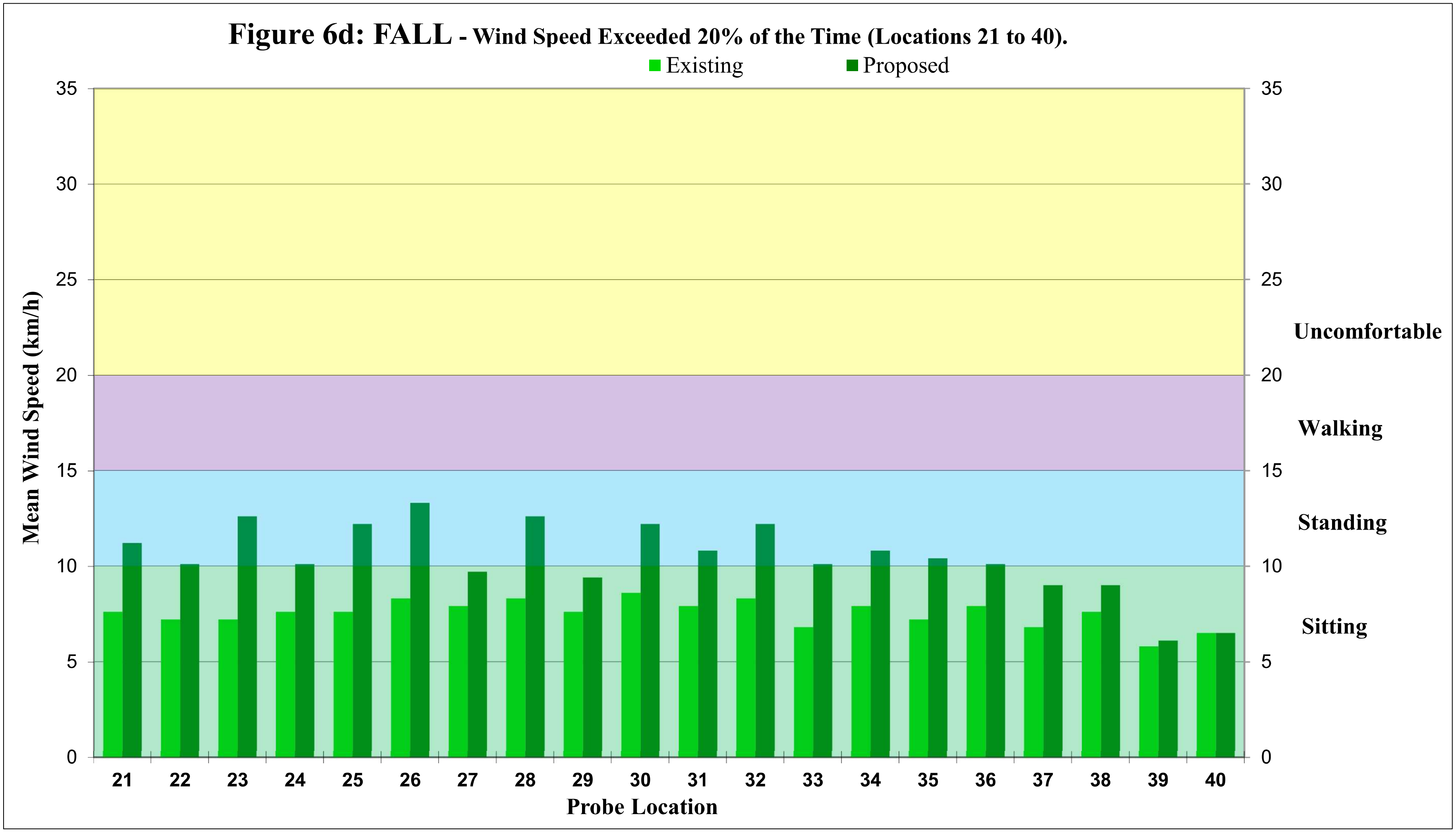


Figure 6d: FALL - Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (km/h)
Uncomfortable
Walking
Standing
Sitting
Probe Location
0
5
10
15
20
25
30
35
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

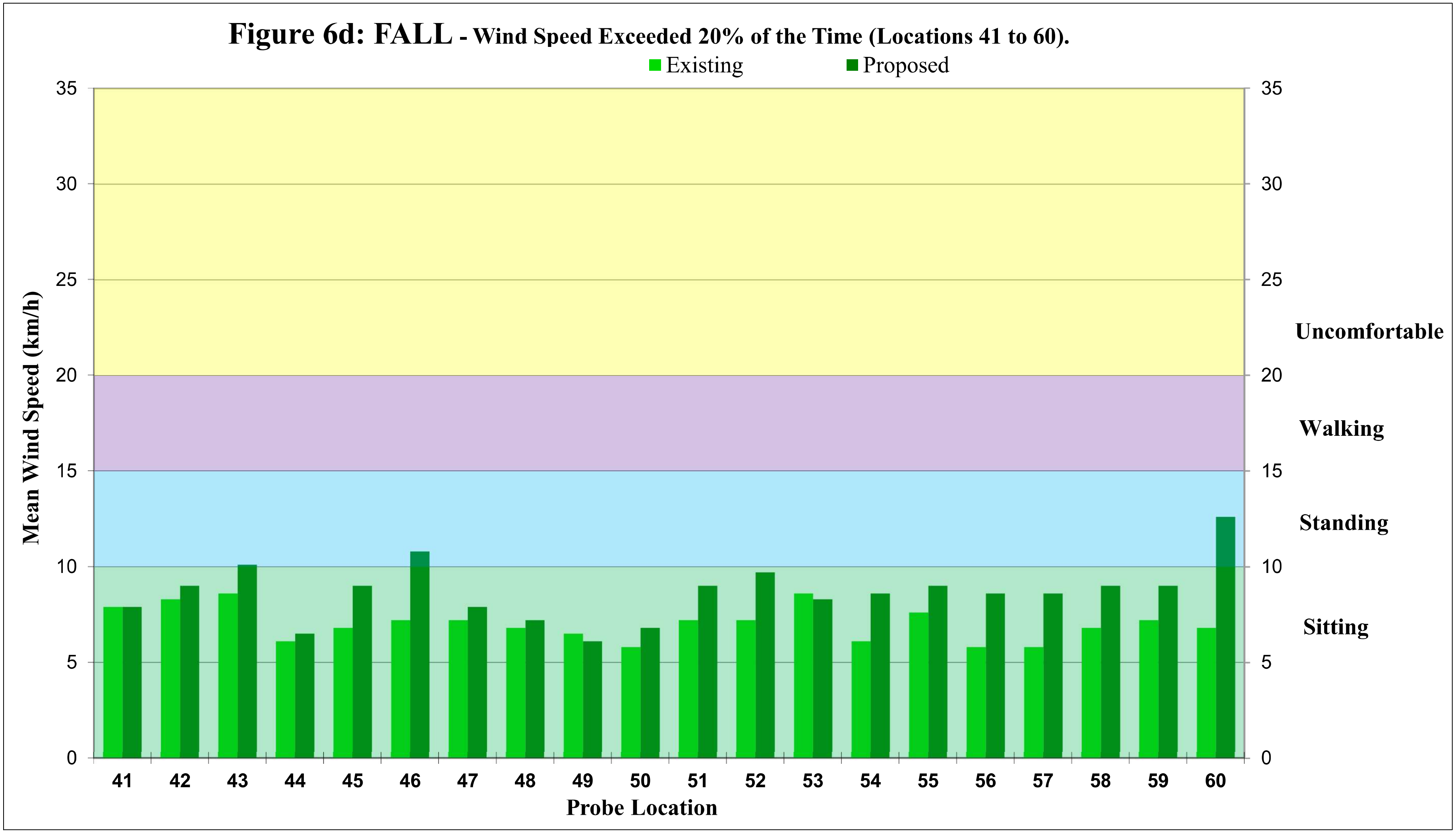


Figure 6d: FALL - Wind Speed Exceeded 20% of the Time (Locations 41 to 60).
Existing
Proposed
Mean Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

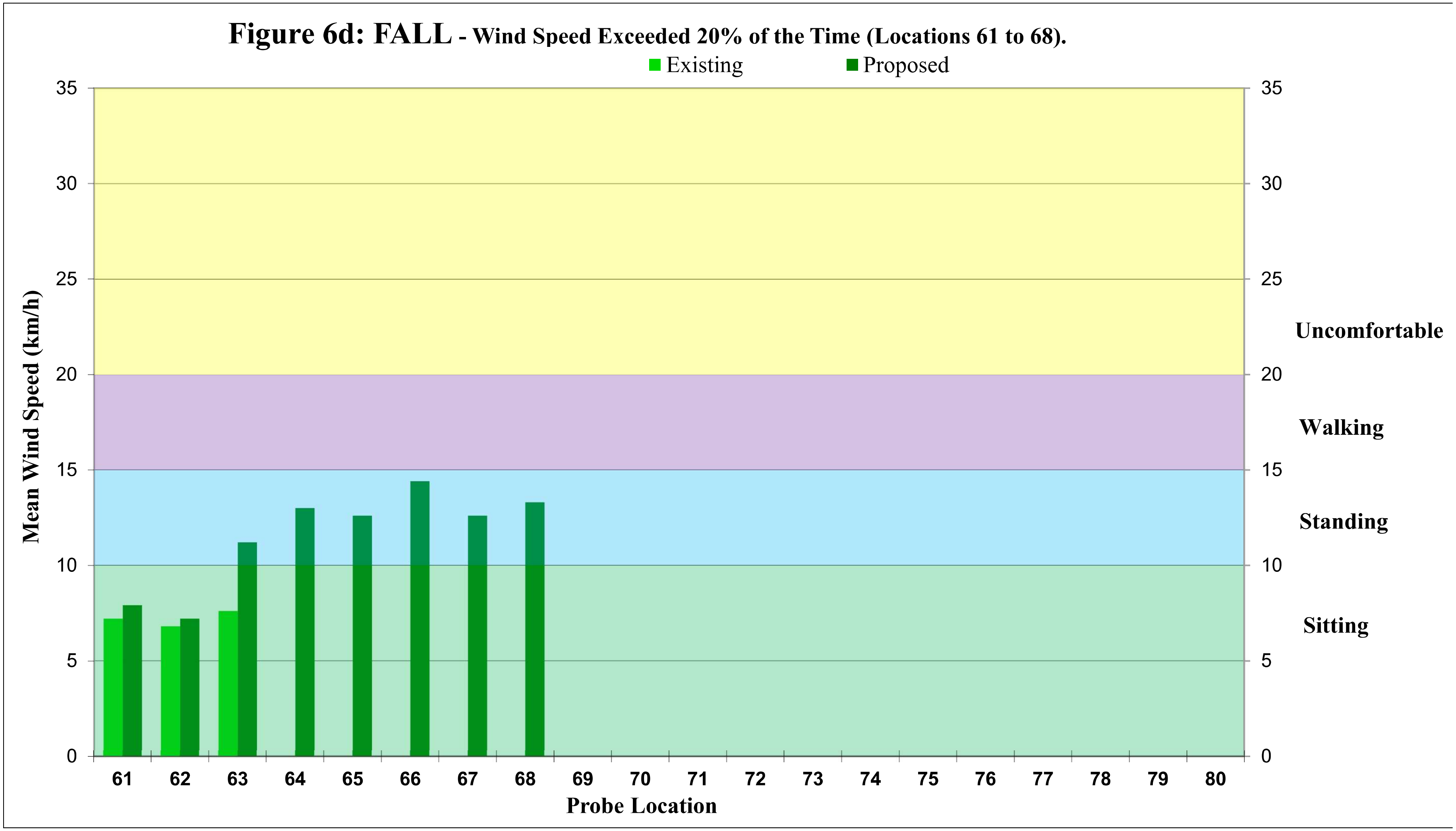
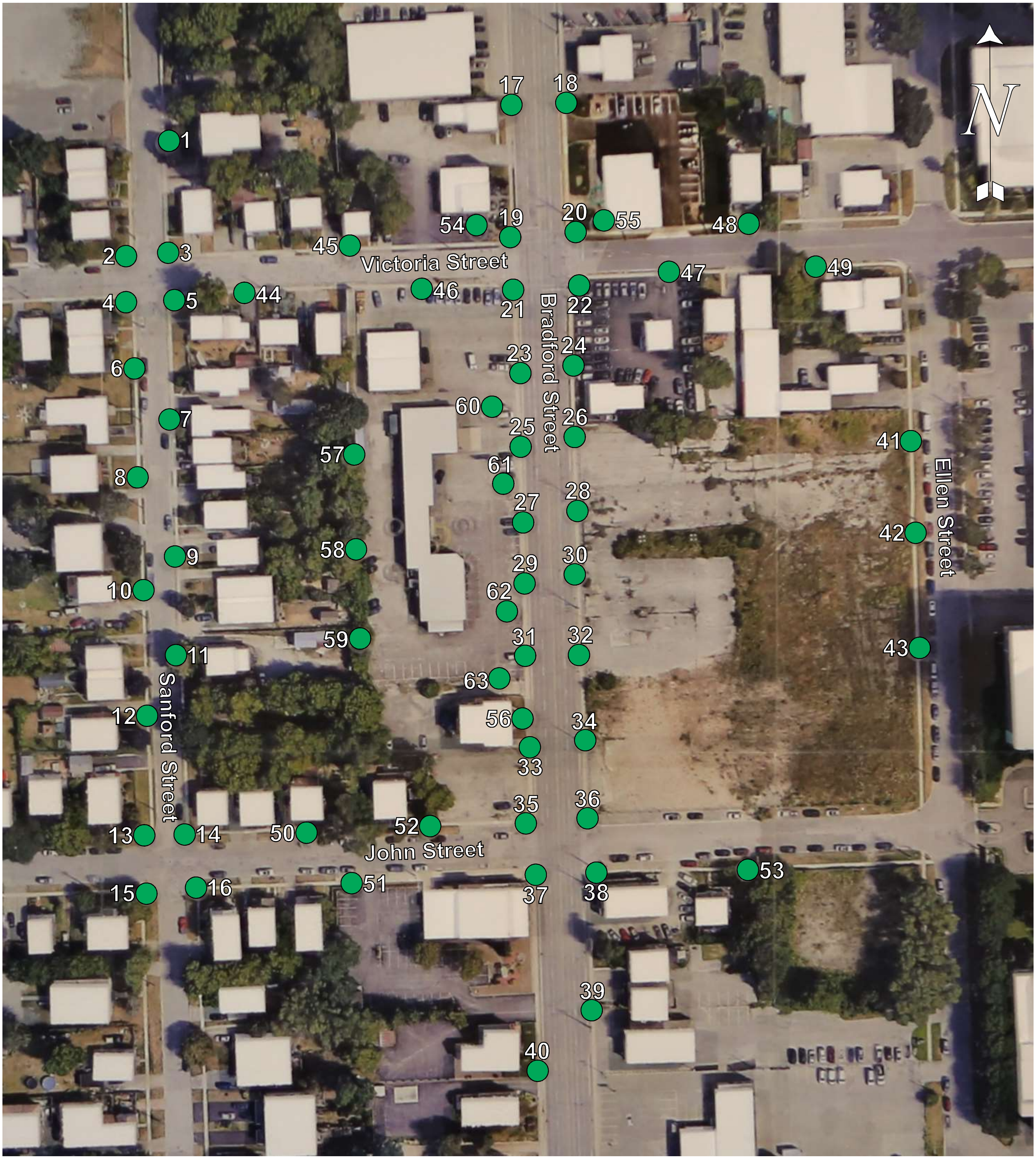


Figure 6d: FALL - Wind Speed Exceeded 20% of the Time (Locations 61 to 68).
Existing
Proposed
Mean Wind Speed (km/h)
35
30
25
20
15
10
5
0
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
Probe Location
Uncomfortable
Walking
Standing
Sitting

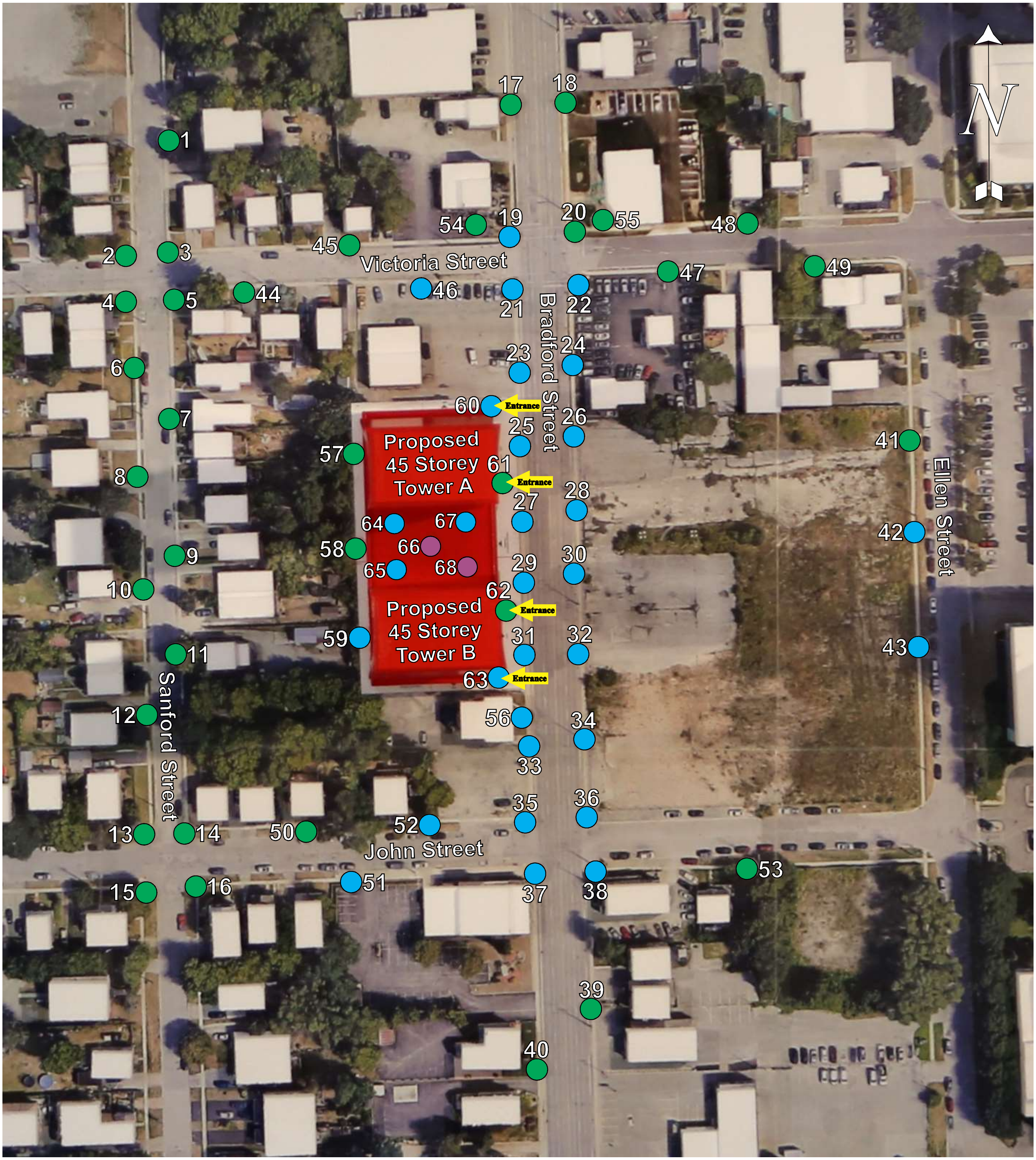
Figure 7a: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Winter - Existing

Sitting Standing Walking Uncomfortable

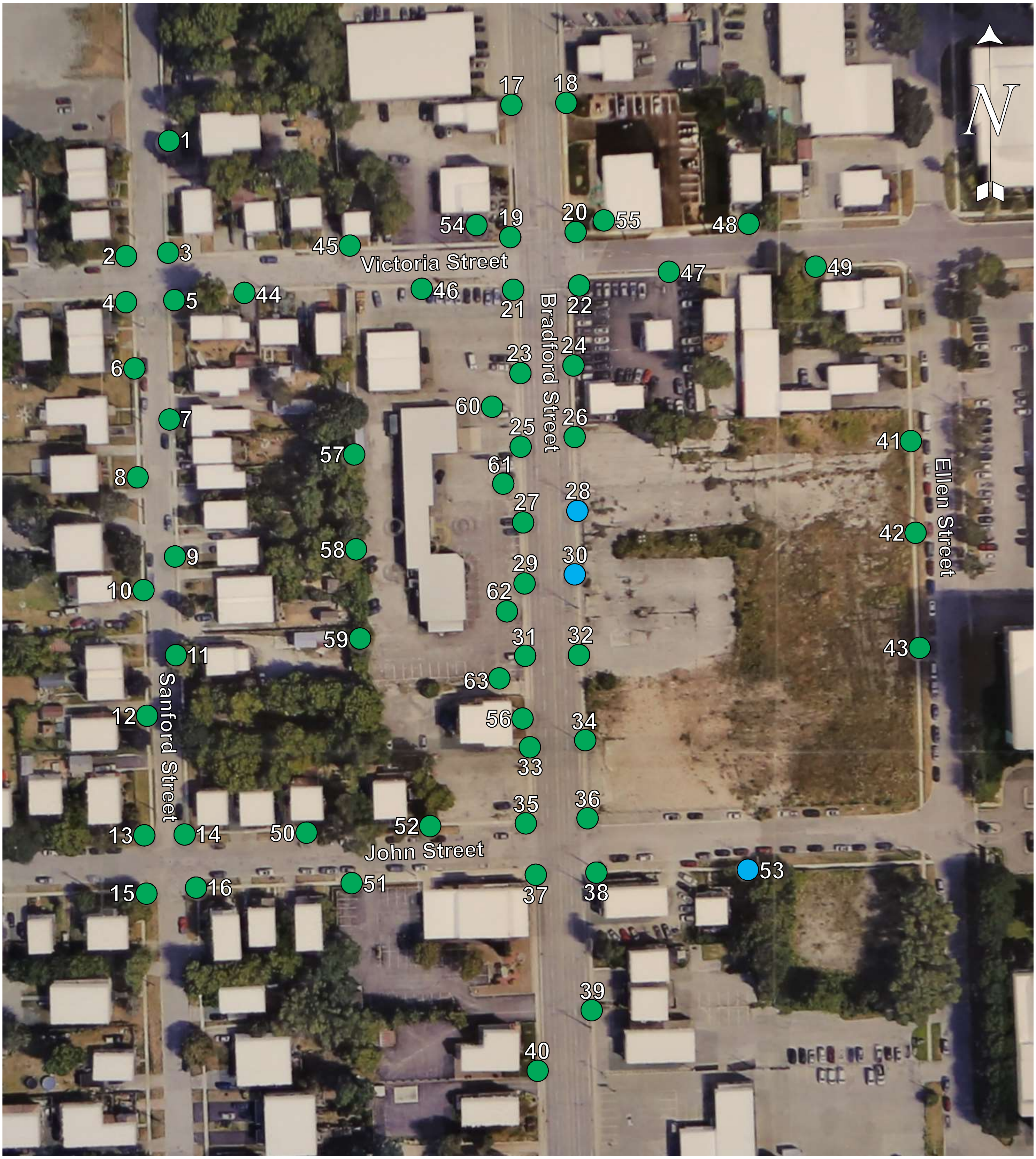
Figure 7b: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Winter - Proposed

Sitting · Standing · Walking · Uncomfortable

Figure 7c: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Spring - Existing

Sitting · Standing · Walking · Uncomfortable

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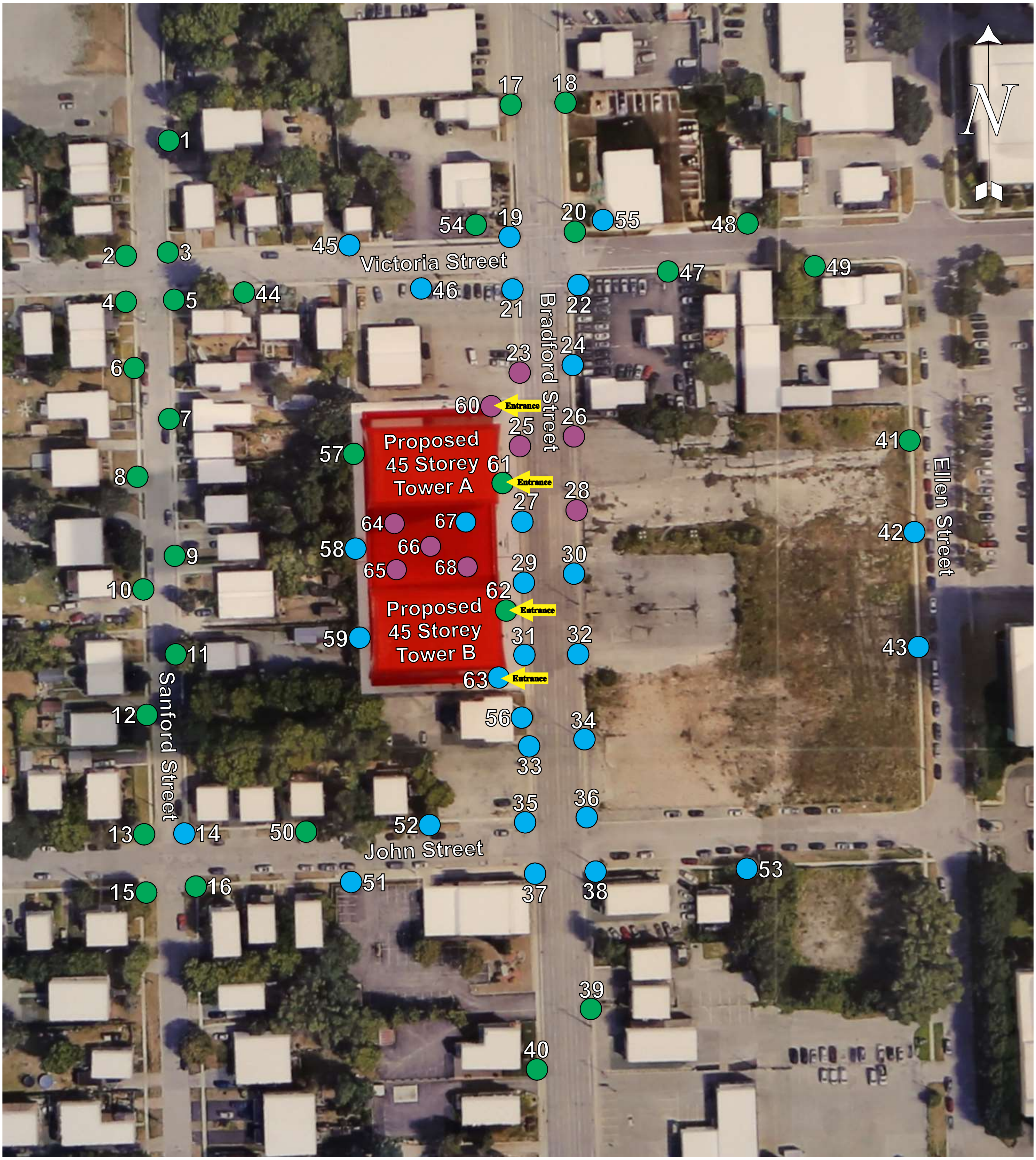
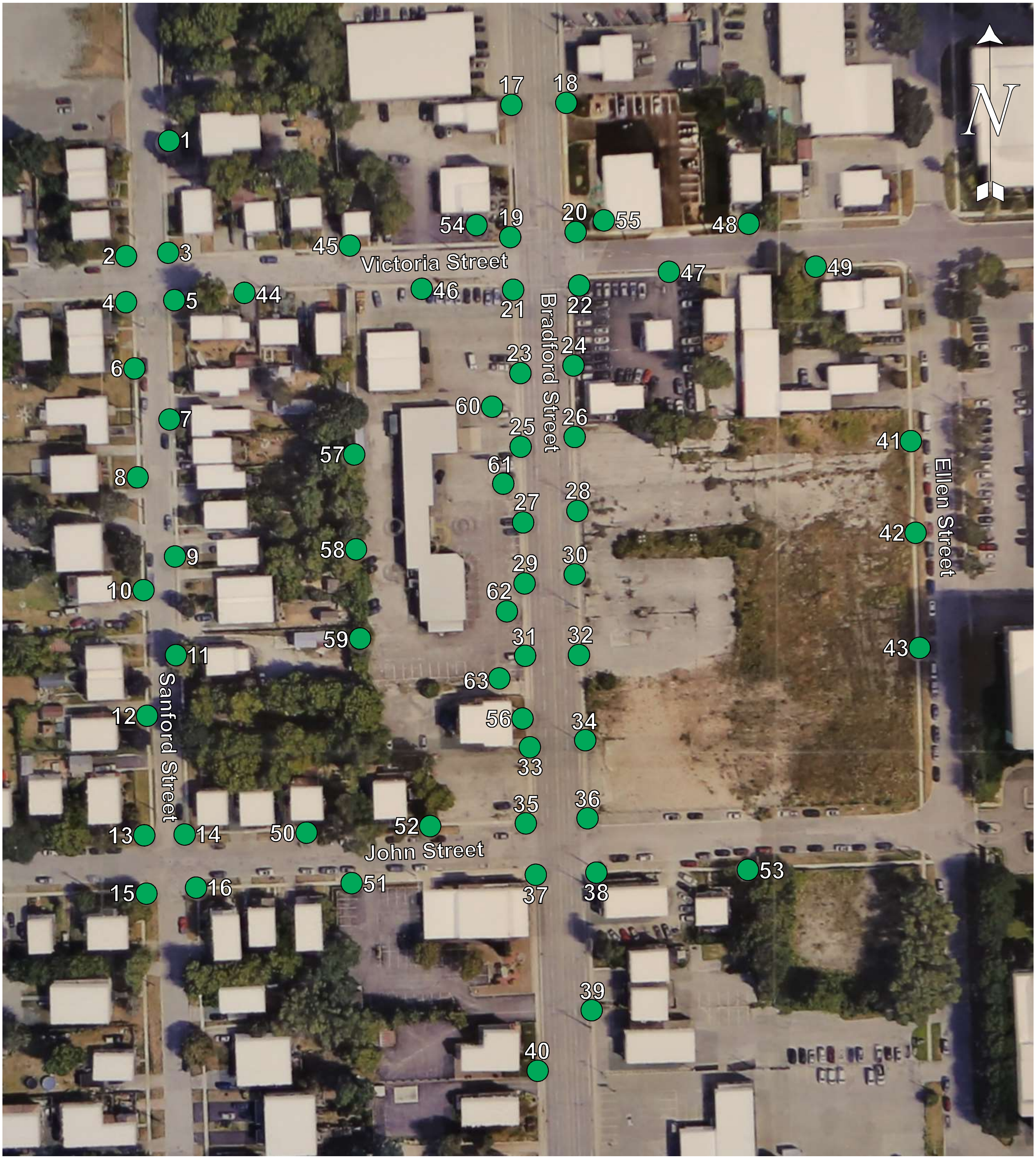
Figure 7d: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Spring - Proposed

Sitting Standing Walking Uncomfortable

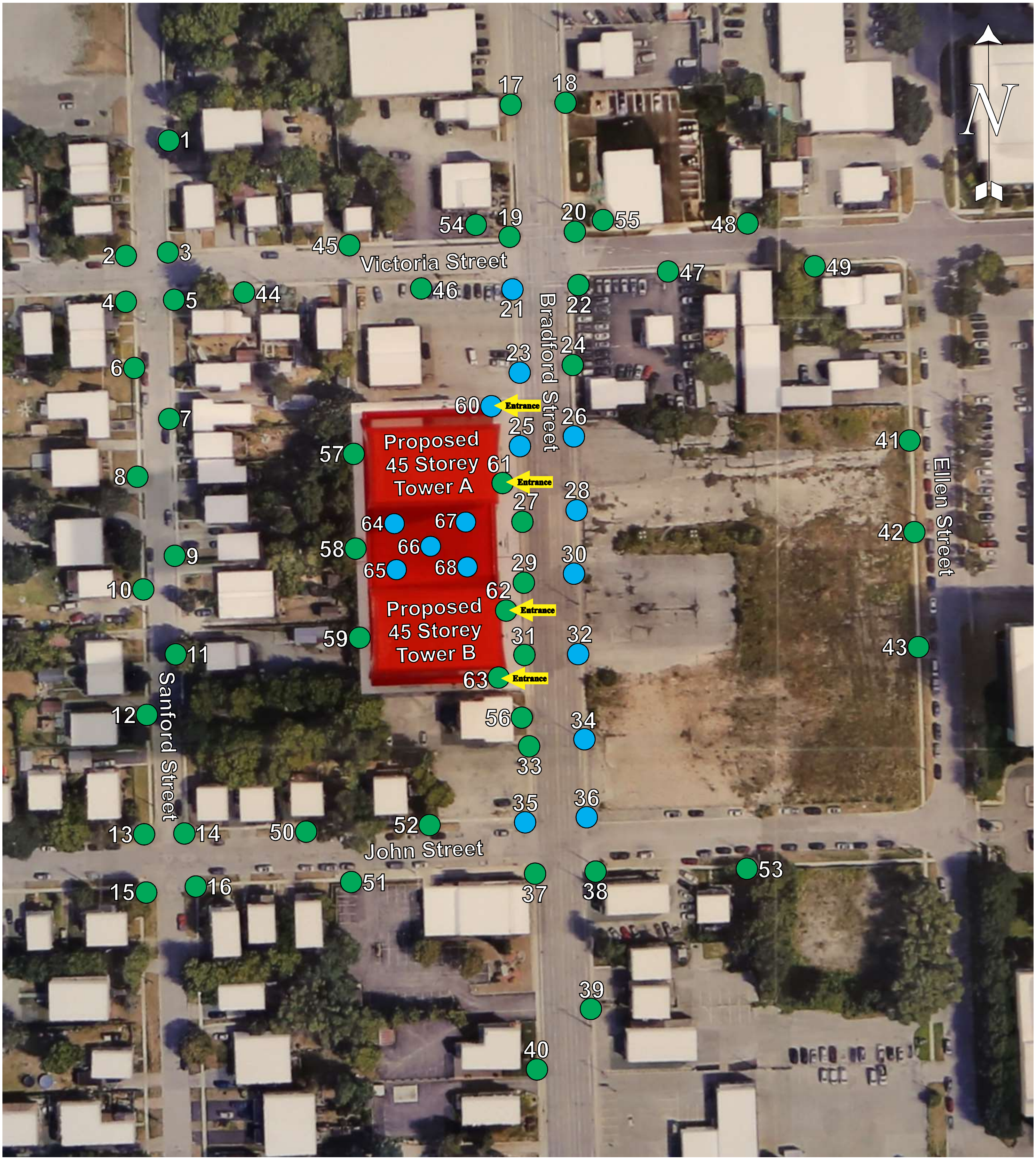
Figure 7e: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Summer - Existing

Sitting   Standing   Walking   Uncomfortable

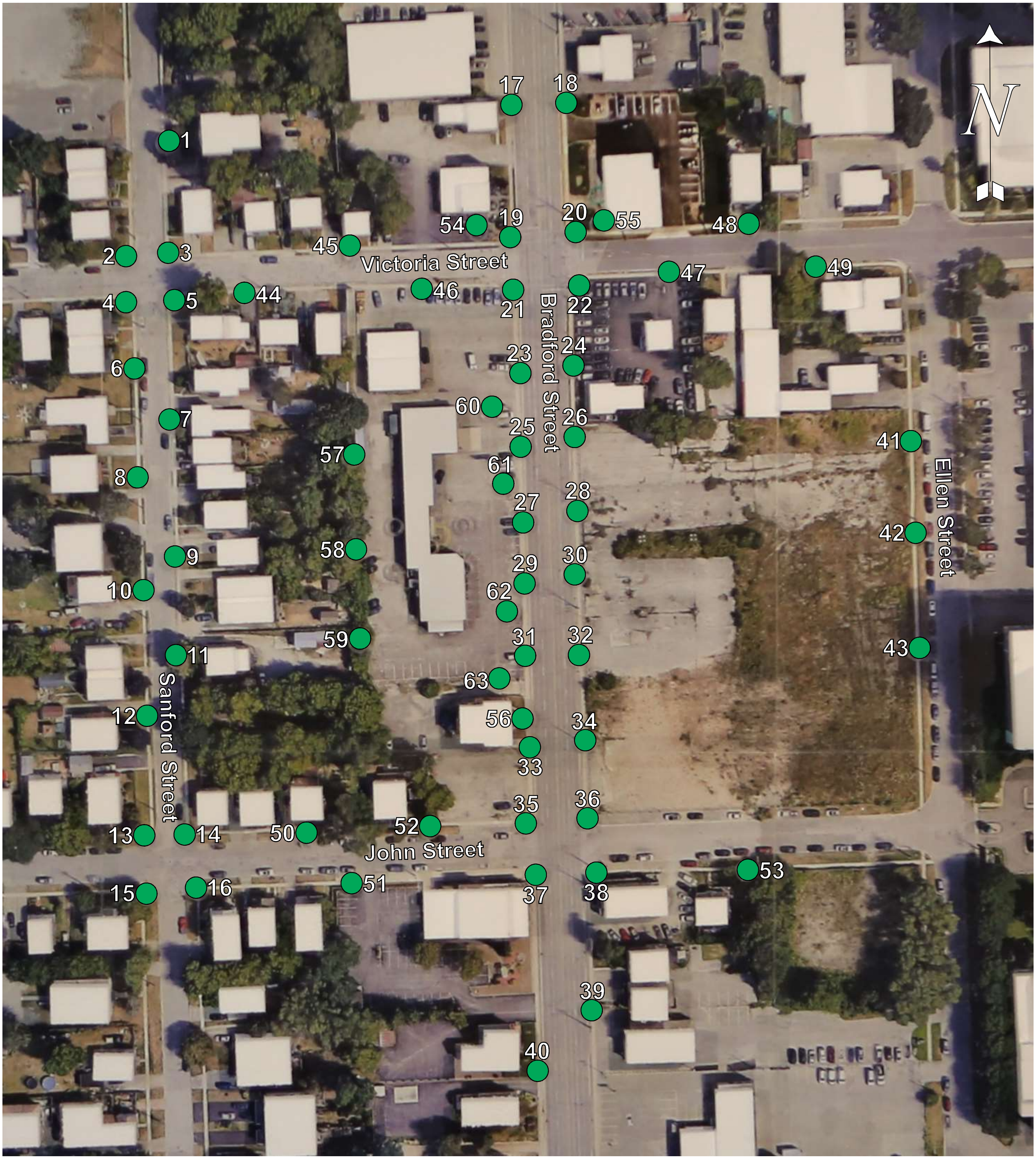
Figure 7f: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Summer - Proposed

Sitting   Standing   Walking   Uncomfortable

Figure 7g: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Fall - Existing

Sitting Standing Walking Uncomfortable

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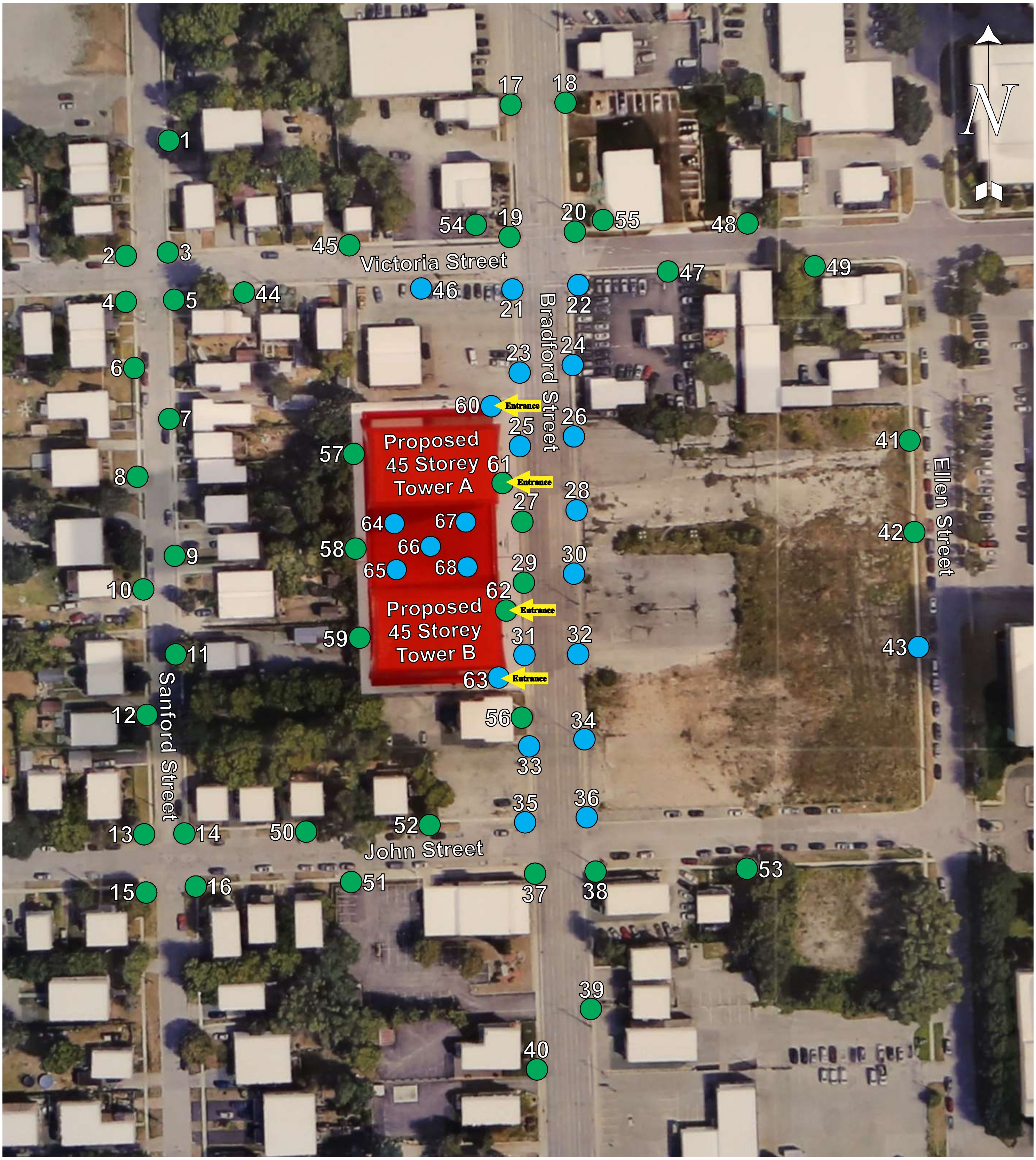
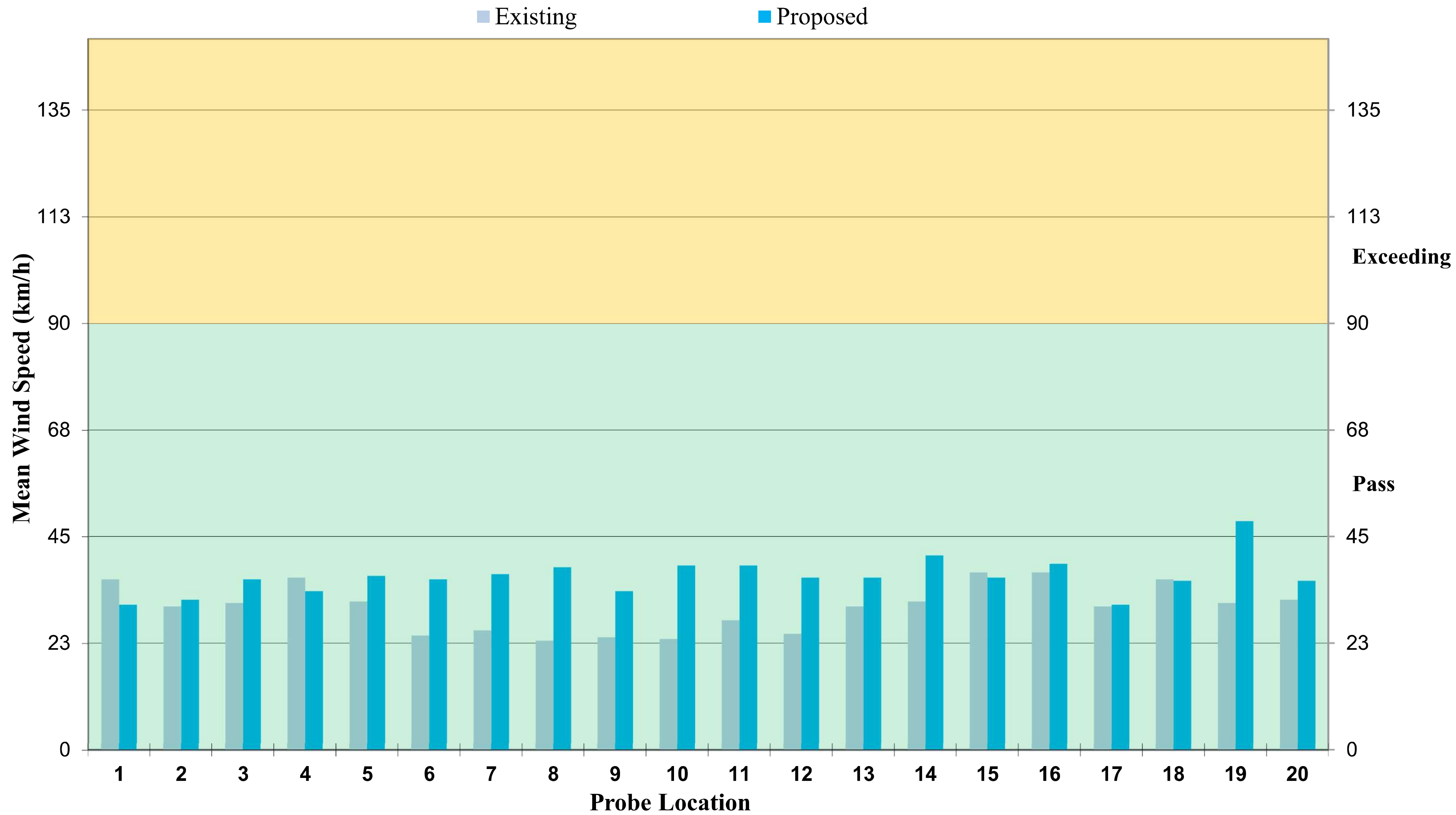
Figure 7h: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Fall - Proposed

Sitting Standing Walking Uncomfortable

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



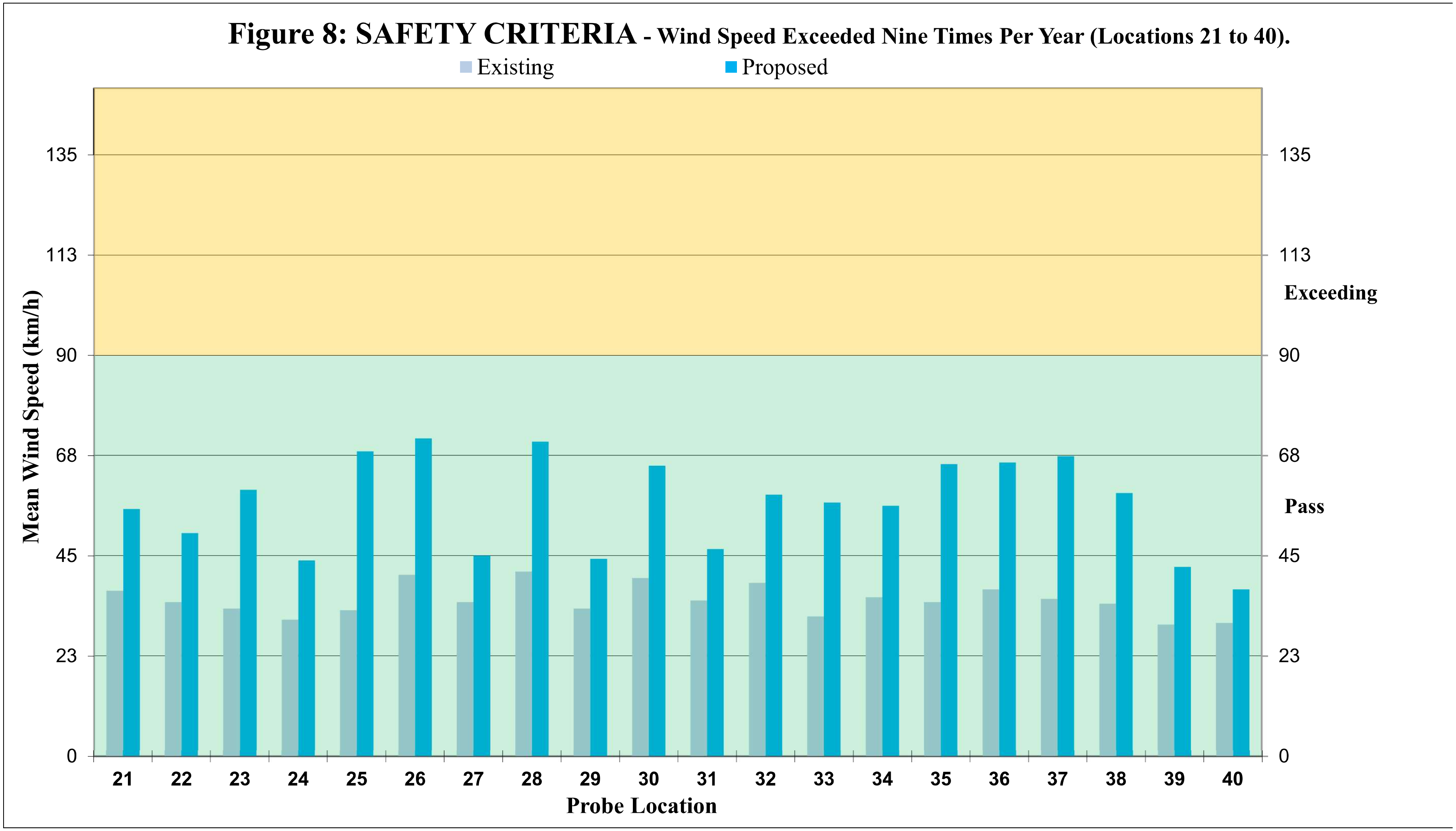
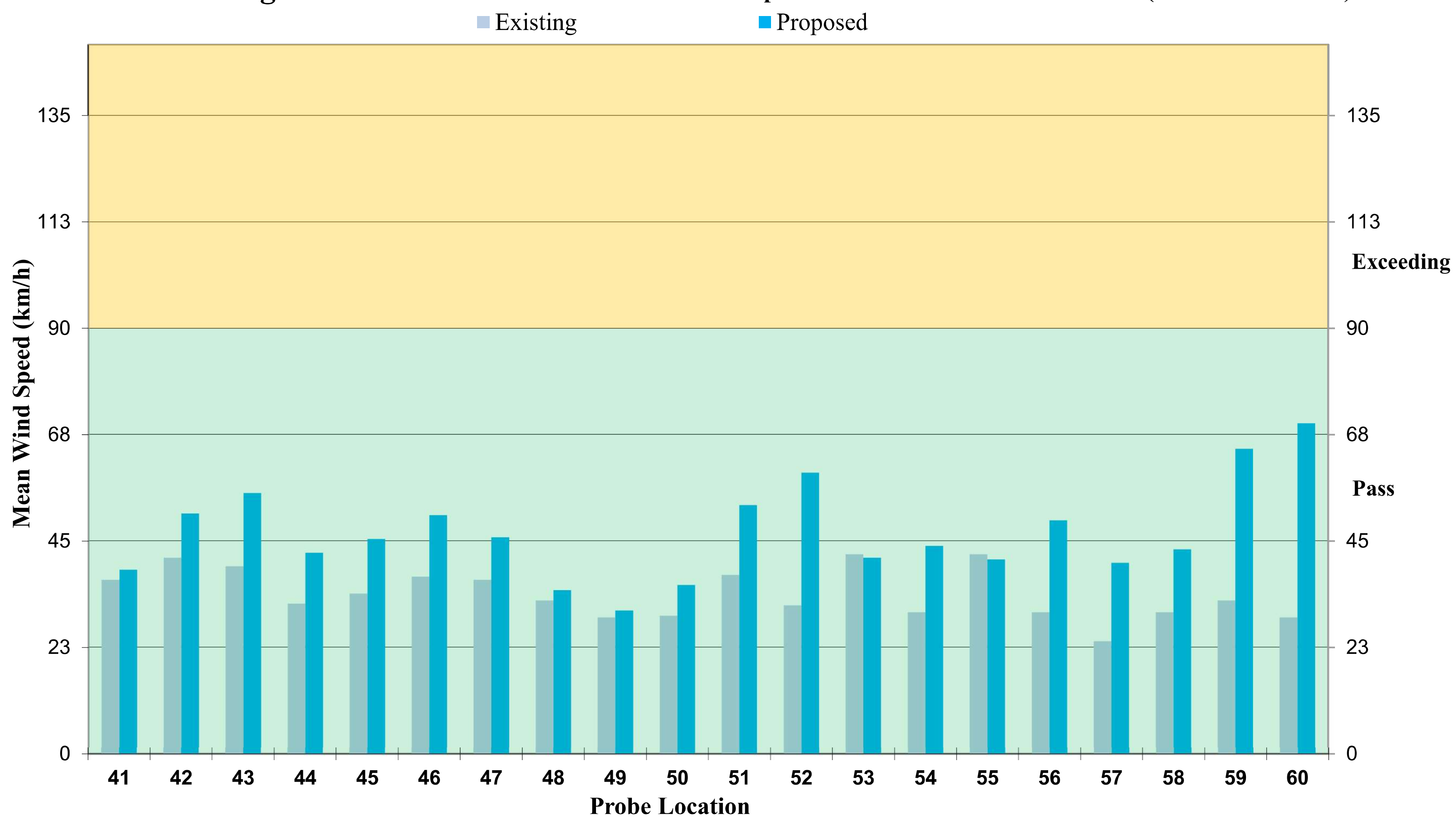


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 21 to 40).
Existing
Proposed
Mean Wind Speed (km/h)
0
23
45
68
90
113
135
Exceeding
Pass
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location

Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 41 to 60).



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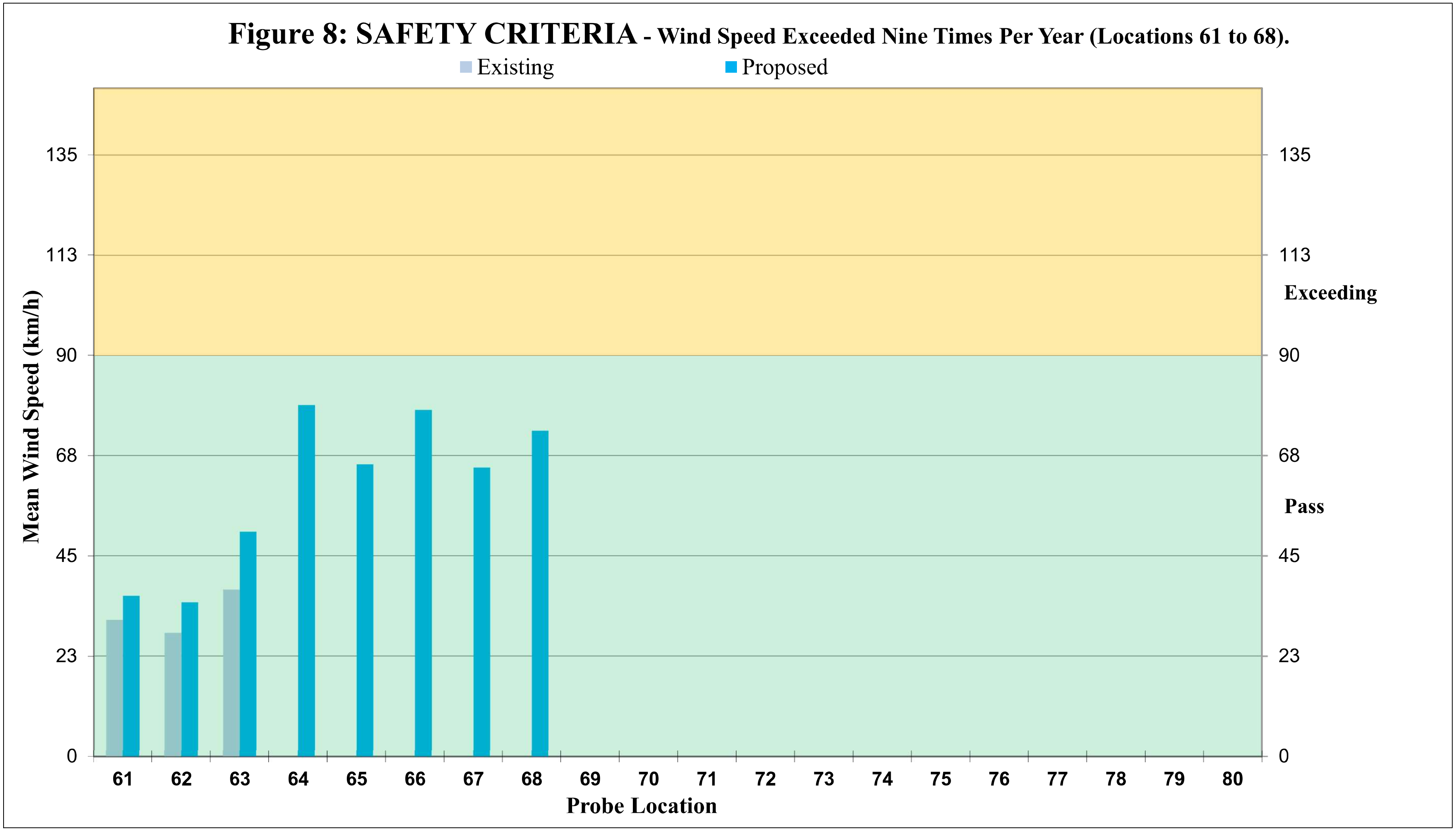
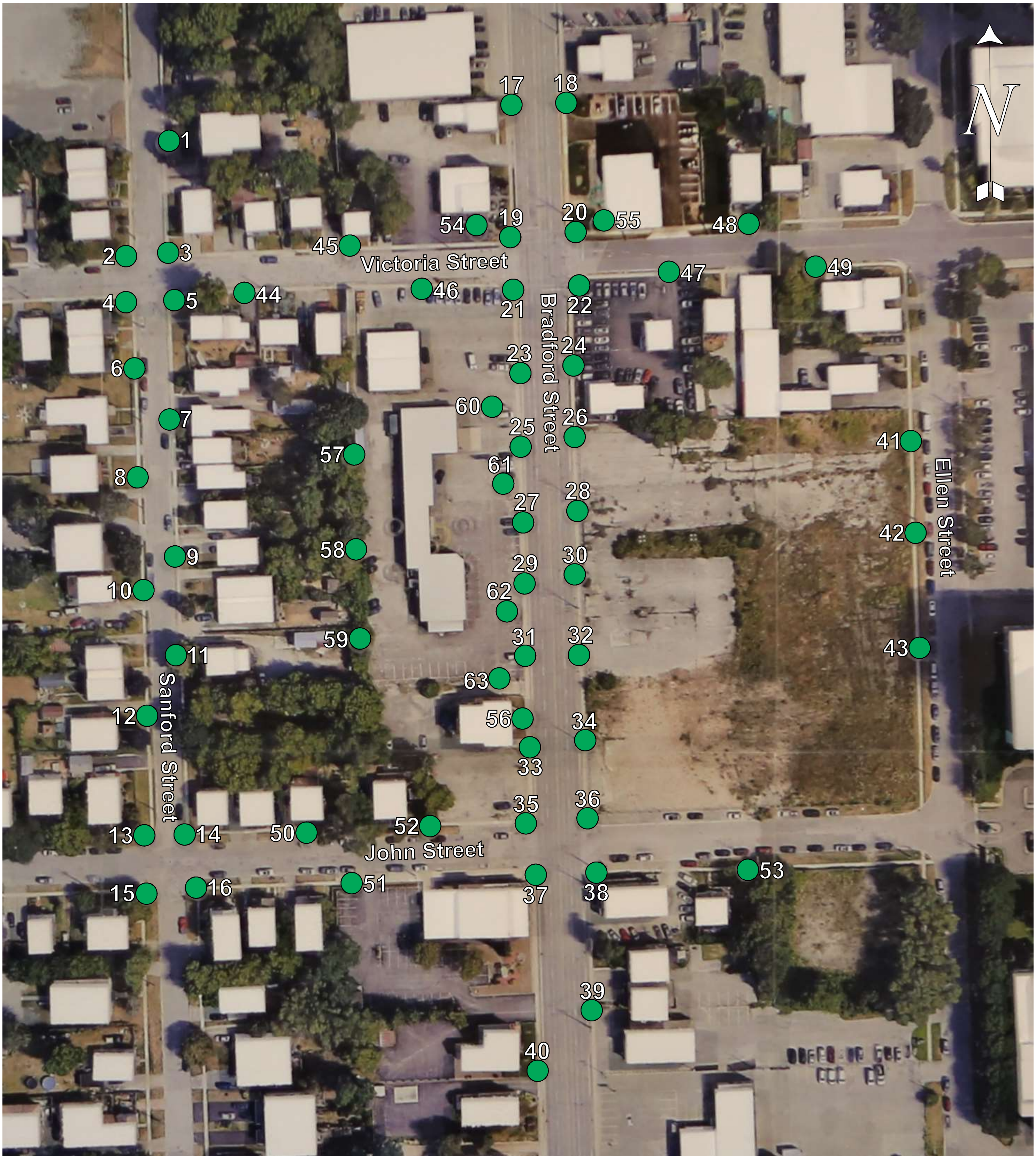


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 61 to 68).
Existing
Proposed
Mean Wind Speed (km/h)
135
113
90
68
45
23
0
Exceeding
Pass
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
Probe Location

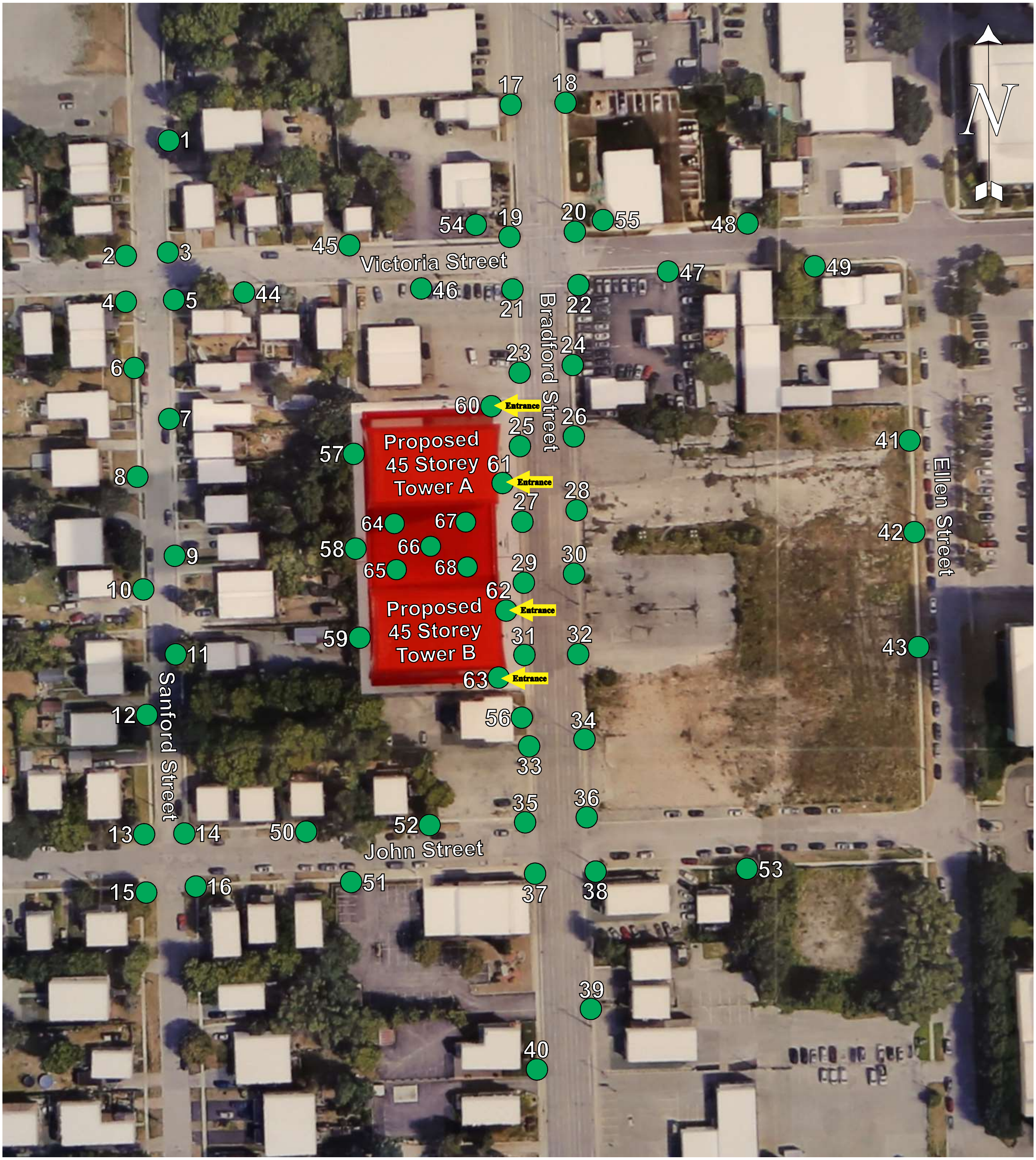
Figure 9a: Pedestrian Level Wind Velocity Safety Criteria



Safety Criteria - Existing

Pass Exceeding

Figure 9b: Pedestrian Level Wind Velocity Safety Criteria



Safety Criteria - Proposed

Pass Exceeding

Figure 10: Pedestrian Level Wind Comfort and Safety Comparison Table

	Mean Wind Speed (km/h)									
	Winter		Spring		Summer		Fall		Safety	
Probe	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
1	7.6	7.6	8.3	7.6	6.5	6.1	6.8	6.8	36.0	30.6
2	6.8	7.2	7.6	7.9	5.8	6.1	6.5	6.8	30.2	31.7
3	7.6	7.9	7.9	8.3	6.1	6.5	6.8	7.2	31.0	36.0
4	7.2	7.9	8.3	8.3	6.5	6.5	6.8	7.6	36.4	33.5
5	7.2	8.6	7.9	9.0	5.8	6.8	6.5	8.3	31.3	36.7
6	6.5	7.9	6.5	8.3	5.0	6.5	6.1	7.9	24.1	36.0
7	6.1	8.3	6.5	8.6	5.0	6.8	5.8	7.9	25.2	37.1
8	5.8	8.3	6.1	9.0	4.7	6.8	5.4	7.9	23.0	38.5
9	5.8	7.6	5.8	8.3	4.7	6.1	5.0	7.2	23.8	33.5
10	6.1	8.3	6.1	9.0	4.7	6.8	5.4	7.6	23.4	38.9
11	6.1	8.3	6.5	9.4	5.0	7.2	5.8	7.6	27.4	38.9
12	6.1	7.9	6.5	9.0	5.0	6.8	5.8	7.2	24.5	36.4
13	7.2	7.6	7.6	8.6	5.8	6.5	6.5	6.8	30.2	36.4
14	7.6	9.0	7.9	10.1	6.1	7.6	6.8	8.3	31.3	41.0
15	7.2	7.6	7.9	8.6	6.5	6.5	6.8	6.8	37.4	36.4
16	7.2	7.9	7.9	9.0	6.1	6.5	6.5	6.8	37.4	39.2
17	6.8	6.8	7.6	7.6	6.1	6.1	6.5	6.8	30.2	30.6
18	7.6	8.3	8.3	8.6	6.5	6.8	6.8	7.6	36.0	35.6
19	7.6	10.4	7.9	10.4	6.1	8.3	6.8	9.4	31.0	48.2
20	7.2	9.0	7.9	9.0	6.5	7.2	6.8	8.3	31.7	35.6
21	8.3	12.2	8.6	13.0	6.8	10.1	7.6	11.2	37.1	55.4
22	7.9	11.2	8.6	11.2	6.5	9.0	7.2	10.1	34.6	50.0
23	7.9	13.7	8.3	15.1	6.5	11.5	7.2	12.6	33.1	59.8
24	8.3	10.8	8.3	11.5	6.5	8.6	7.6	10.1	30.6	43.9
25	8.3	13.3	8.6	15.1	6.8	11.5	7.6	12.2	32.8	68.4
26	9.0	14.8	9.7	16.6	7.6	12.6	8.3	13.3	40.7	71.3
27	8.3	10.4	9.0	10.4	6.8	8.3	7.9	9.7	34.6	45.0
28	9.4	14.4	10.1	15.5	7.9	11.9	8.3	12.6	41.4	70.6
29	7.9	10.1	8.6	10.1	6.8	7.9	7.6	9.4	33.1	44.3
30	9.0	13.7	10.1	14.8	7.9	11.2	8.6	12.2	40.0	65.2
31	8.3	11.9	9.0	11.5	7.2	9.0	7.9	10.8	34.9	46.4
32	9.0	13.7	9.7	14.4	7.6	10.8	8.3	12.2	38.9	58.7
33	7.6	11.2	7.9	13.3	6.1	9.7	6.8	10.1	31.3	56.9
34	8.6	12.2	9.4	13.7	7.2	10.1	7.9	10.8	35.6	56.2
35	7.9	11.9	8.6	13.7	6.5	10.1	7.2	10.4	34.6	65.5
36	8.6	11.5	9.4	13.0	7.2	10.1	7.9	10.1	37.4	65.9
37	7.6	10.4	8.3	12.6	6.5	9.4	6.8	9.0	35.3	67.3
38	8.3	10.4	8.6	11.9	6.5	9.0	7.6	9.0	34.2	59.0
39	6.5	6.8	6.8	7.9	5.4	6.1	5.8	6.1	29.5	42.5
40	7.2	7.6	7.6	8.3	5.8	6.5	6.5	6.5	29.9	37.4

	Mean Wind Speed (km/h)									
	Winter		Spring		Summer		Fall		Safety	
Probe	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
41	8.6	9.0	9.0	8.6	6.8	6.8	7.9	7.9	36.7	38.9
42	9.0	10.1	9.4	10.4	7.6	8.3	8.3	9.0	41.4	50.8
43	9.4	10.8	9.7	11.9	7.6	9.4	8.6	10.1	39.6	55.1
44	6.5	7.2	7.6	7.9	5.8	5.8	6.1	6.5	31.7	42.5
45	7.2	9.7	7.9	10.8	6.1	8.3	6.8	9.0	33.8	45.4
46	7.9	11.5	9.0	12.6	6.8	9.7	7.2	10.8	37.4	50.4
47	7.9	9.0	8.6	9.4	6.5	7.6	7.2	7.9	36.7	45.7
48	7.2	7.9	7.9	8.3	6.1	6.5	6.8	7.2	32.4	34.6
49	6.8	6.8	7.6	7.2	5.8	5.8	6.5	6.1	28.8	30.2
50	6.5	7.6	6.8	8.6	5.4	6.5	5.8	6.8	29.2	35.6
51	7.9	10.1	8.6	11.5	6.8	8.6	7.2	9.0	37.8	52.6
52	7.9	10.8	7.9	12.6	6.1	9.4	7.2	9.7	31.3	59.4
53	9.4	9.0	10.4	10.1	7.9	7.6	8.6	8.3	42.1	41.4
54	6.5	9.7	7.2	9.7	5.4	7.6	6.1	8.6	29.9	43.9
55	8.3	9.7	9.4	10.4	7.6	8.3	7.6	9.0	42.1	41.0
56	6.5	10.1	6.8	10.8	5.0	7.6	5.8	8.6	29.9	49.3
57	6.1	9.7	6.5	8.3	5.0	6.8	5.8	8.6	23.8	40.3
58	7.2	9.7	7.9	10.1	6.1	7.9	6.8	9.0	29.9	43.2
59	7.6	10.1	8.3	12.2	6.5	9.4	7.2	9.0	32.4	64.4
60	7.2	13.7	7.6	15.8	6.1	12.2	6.8	12.6	28.8	69.8
61	7.6	8.3	8.3	8.6	6.5	6.5	7.2	7.9	30.6	36.0
62	7.6	7.6	7.6	7.9	5.8	6.1	6.8	7.2	27.7	34.6
63	8.3	12.2	9.4	11.5	7.2	9.0	7.6	11.2	37.4	50.4
64	0.0	14.0	0.0	15.8	0.0	12.6	0.0	13.0	0.0	78.8
65	0.0	14.4	0.0	15.1	0.0	11.5	0.0	12.6	0.0	65.5
66	0.0	16.2	0.0	17.3	0.0	13.7	0.0	14.4	0.0	77.8
67	0.0	14.0	0.0	14.8	0.0	11.5	0.0	12.6	0.0	64.8
68	0.0	15.5	0.0	17.3	0.0	13.0	0.0	13.3	0.0	73.1
69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
77	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
78	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Comfort (km/h)				Safety (km/h)	
0 - 10	Sitting	15 - 20	Walking	0 - 90	Pass
10 - 15	Standing	20 +	Uncomf	90 +	Exceed

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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:

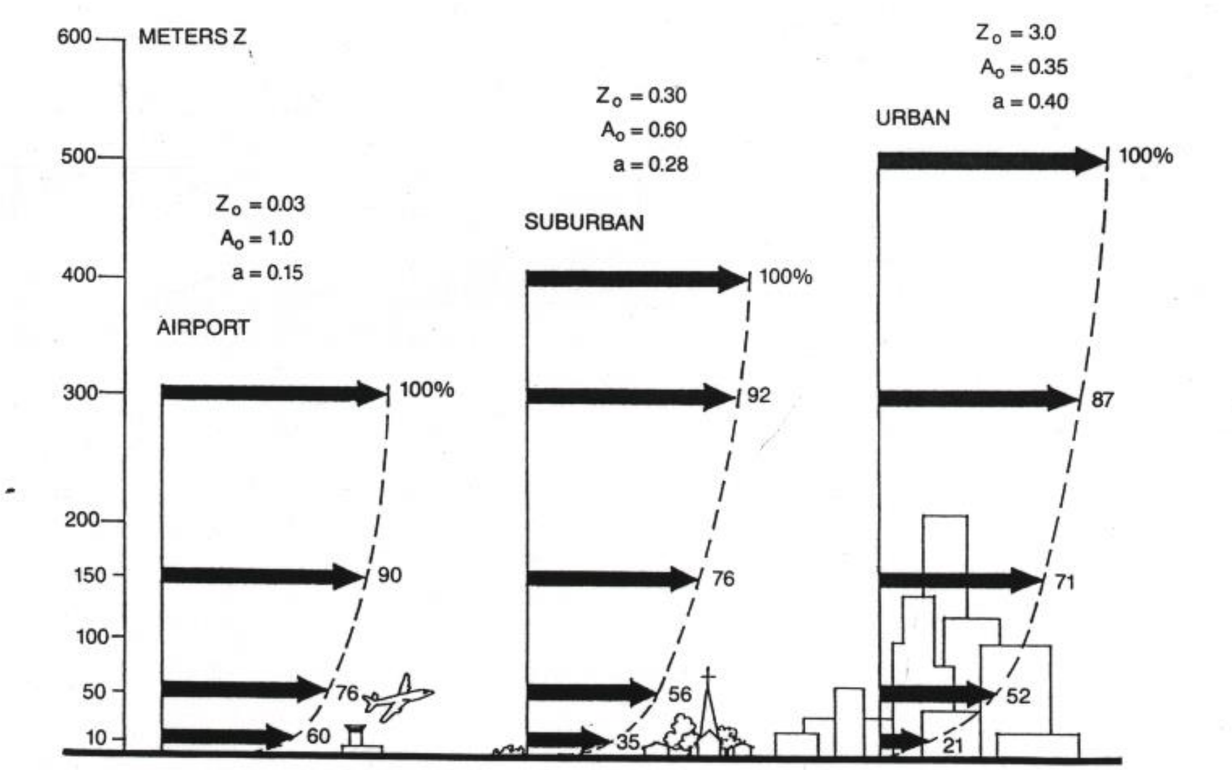


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

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.

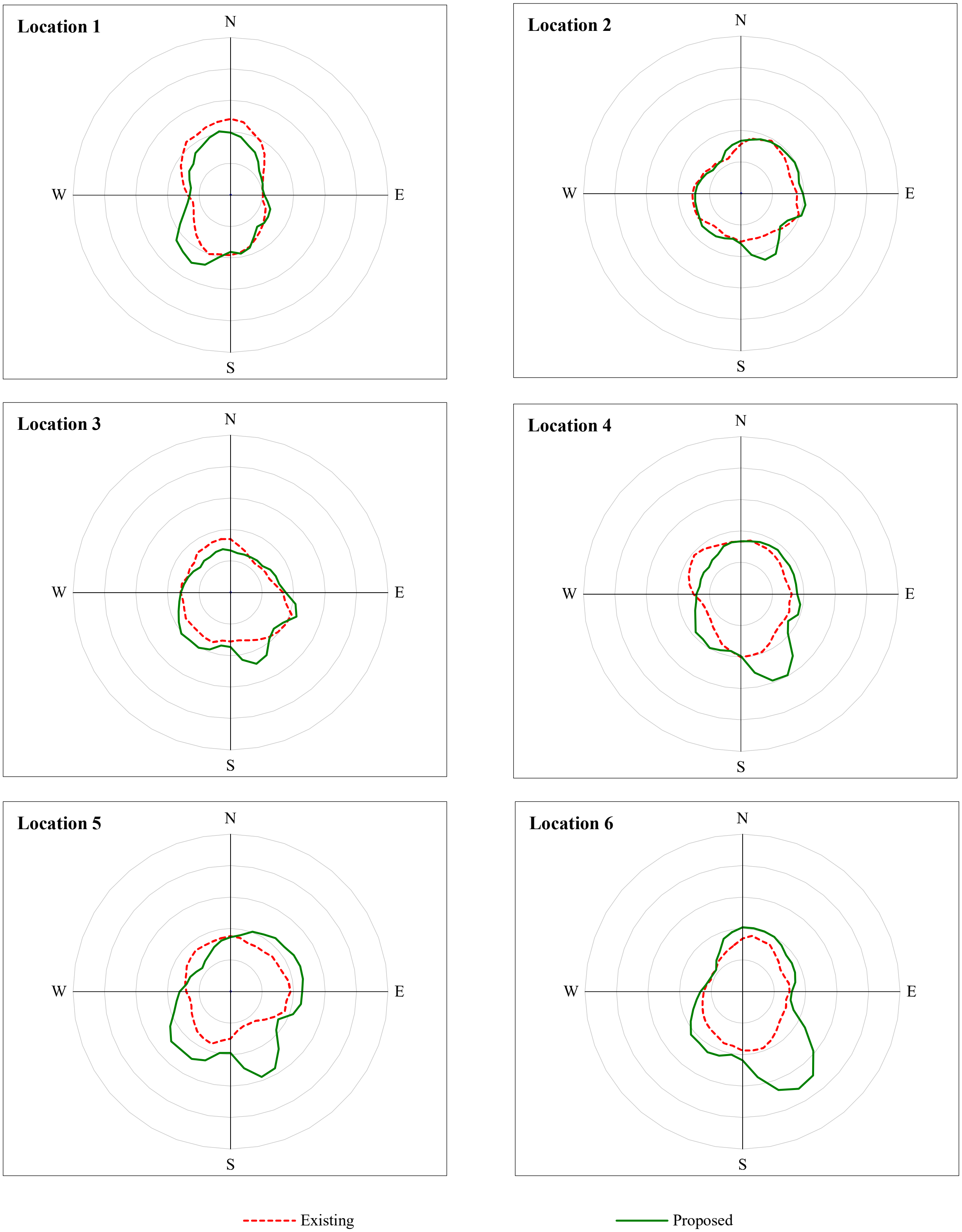


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

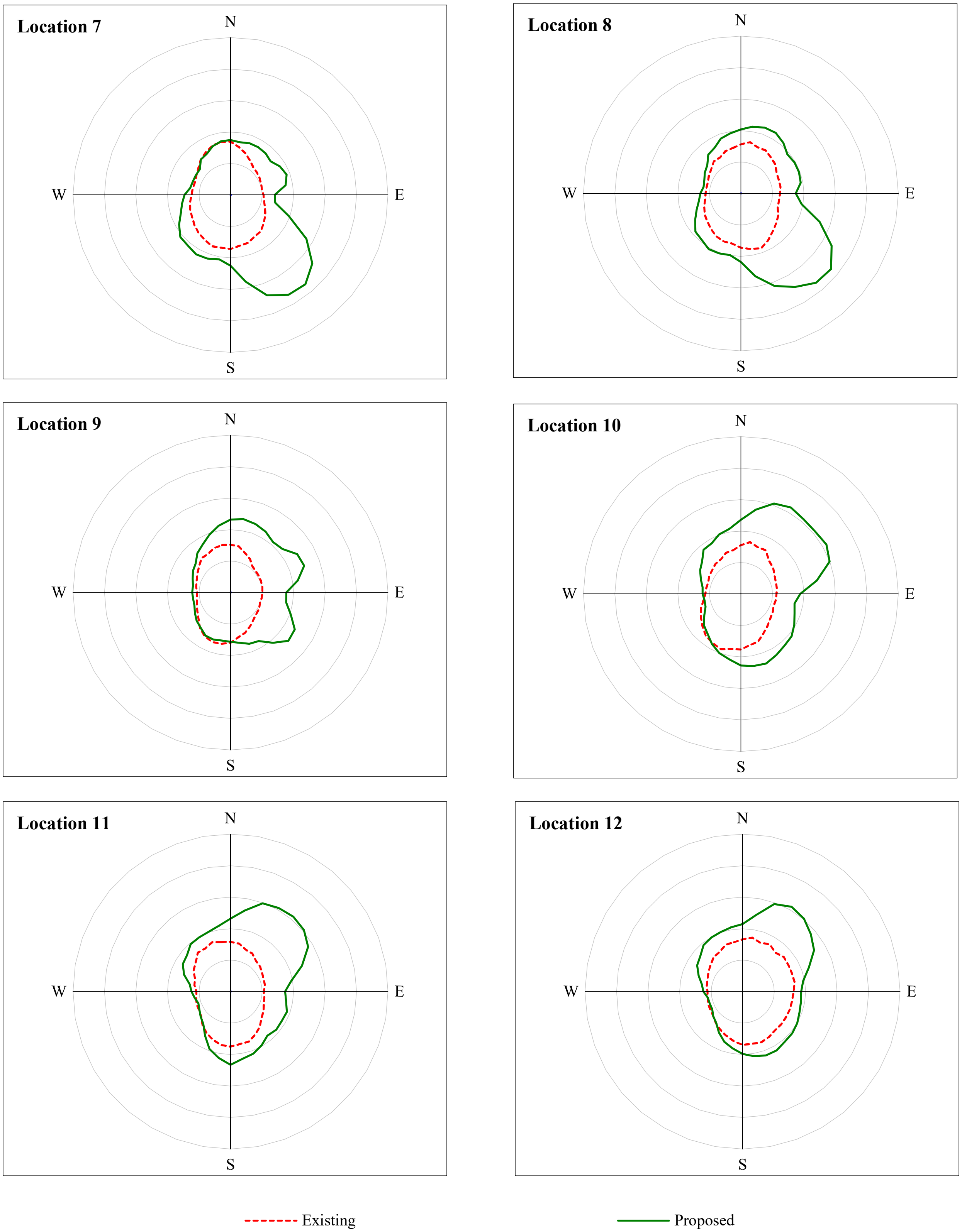


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

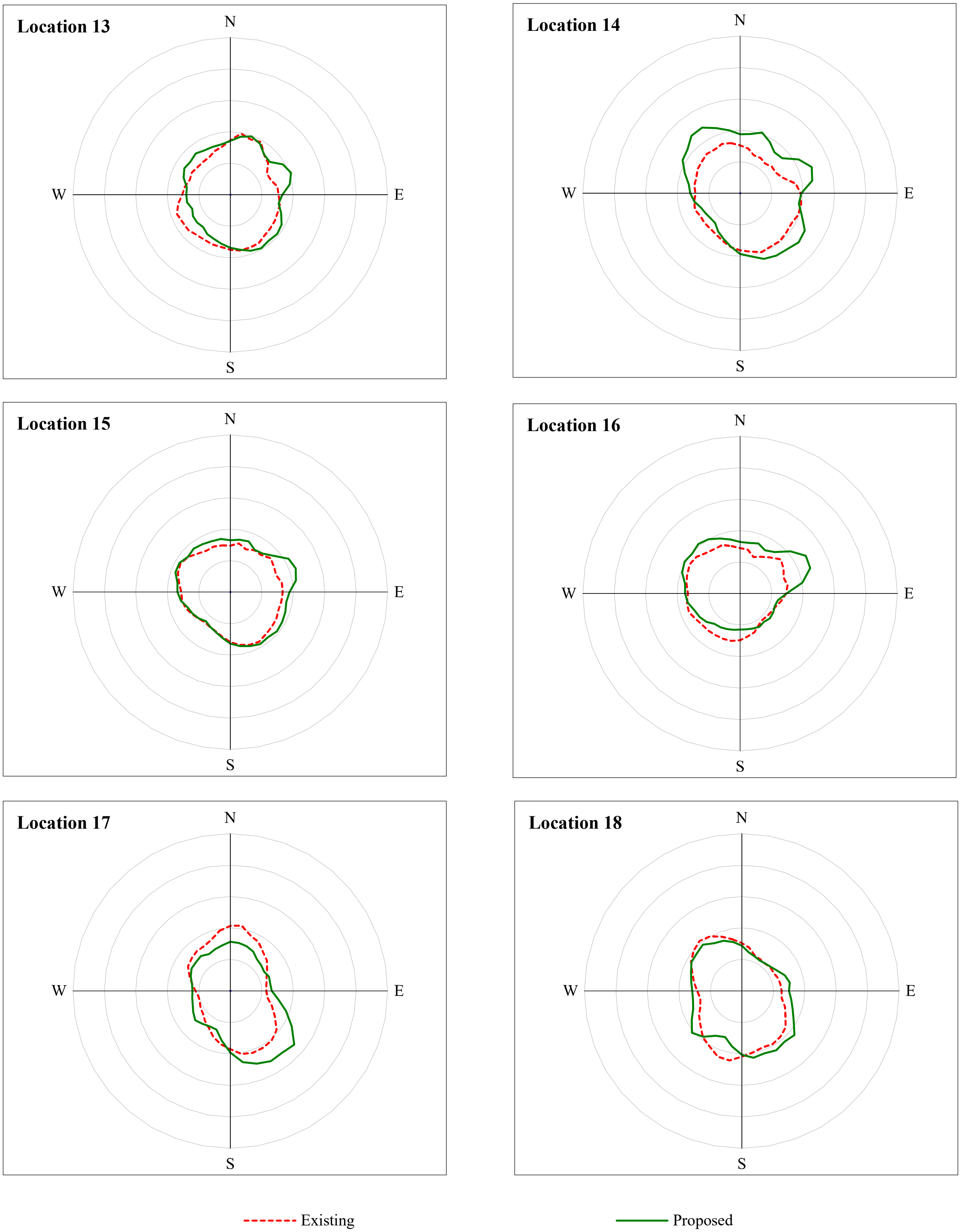
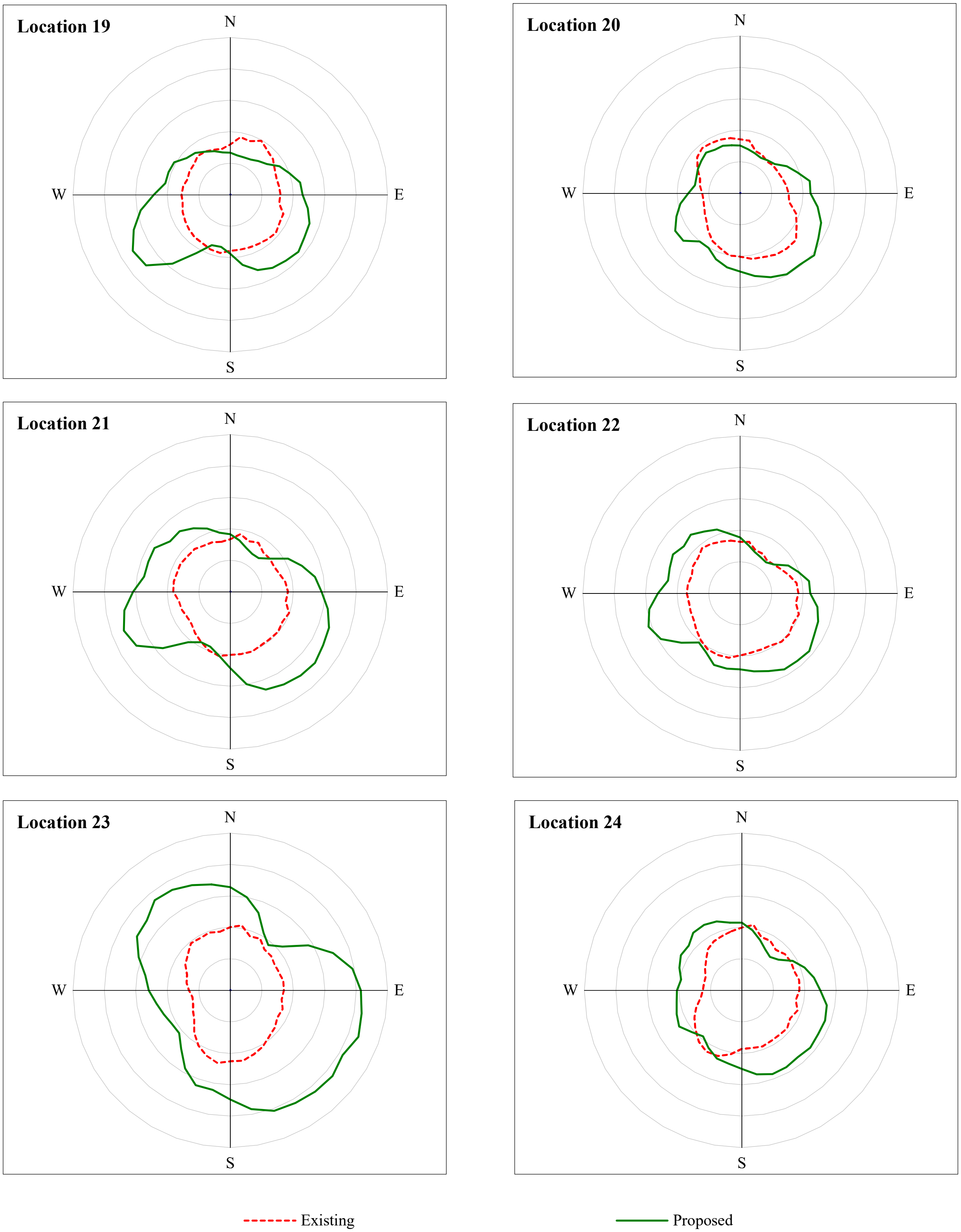


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



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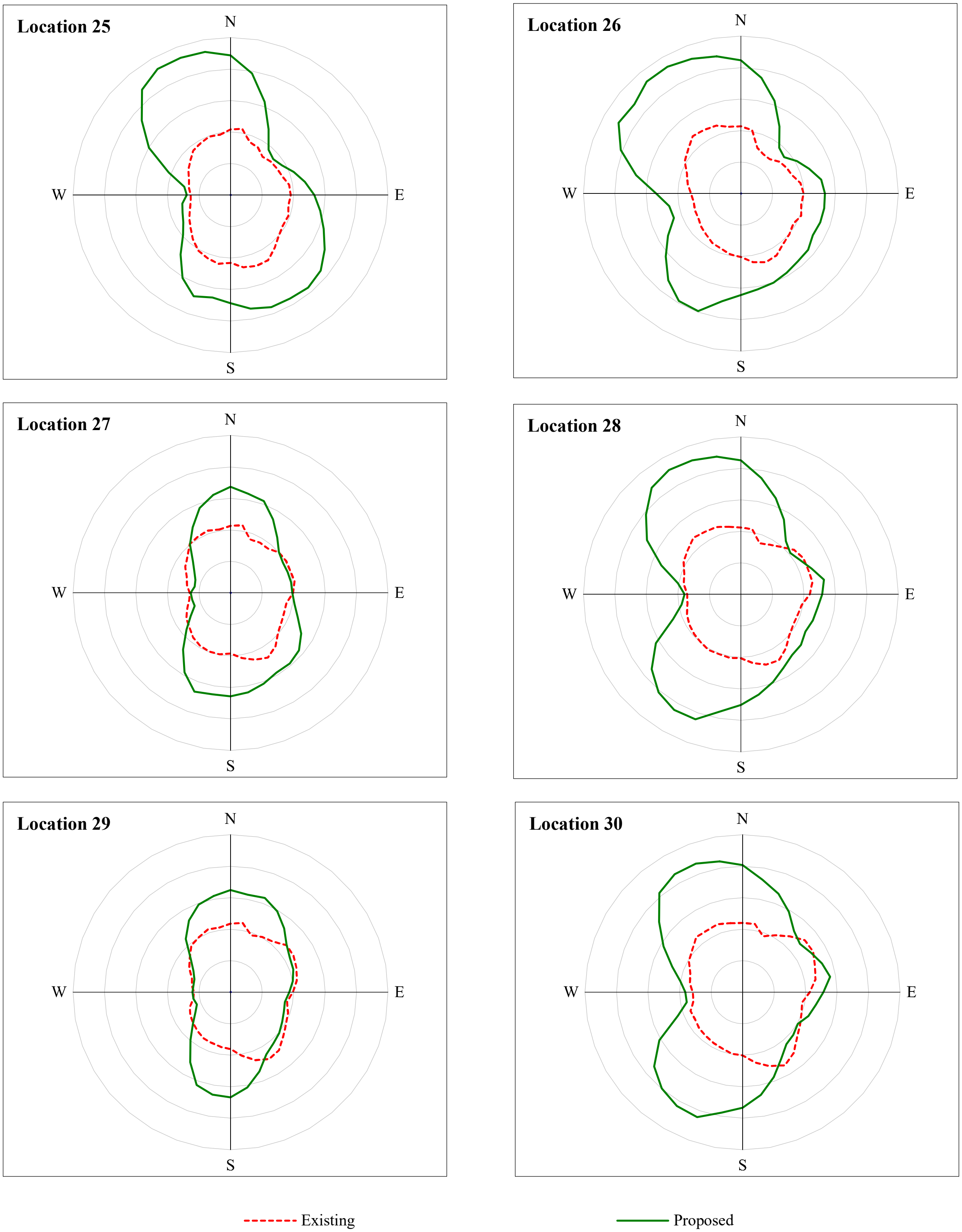

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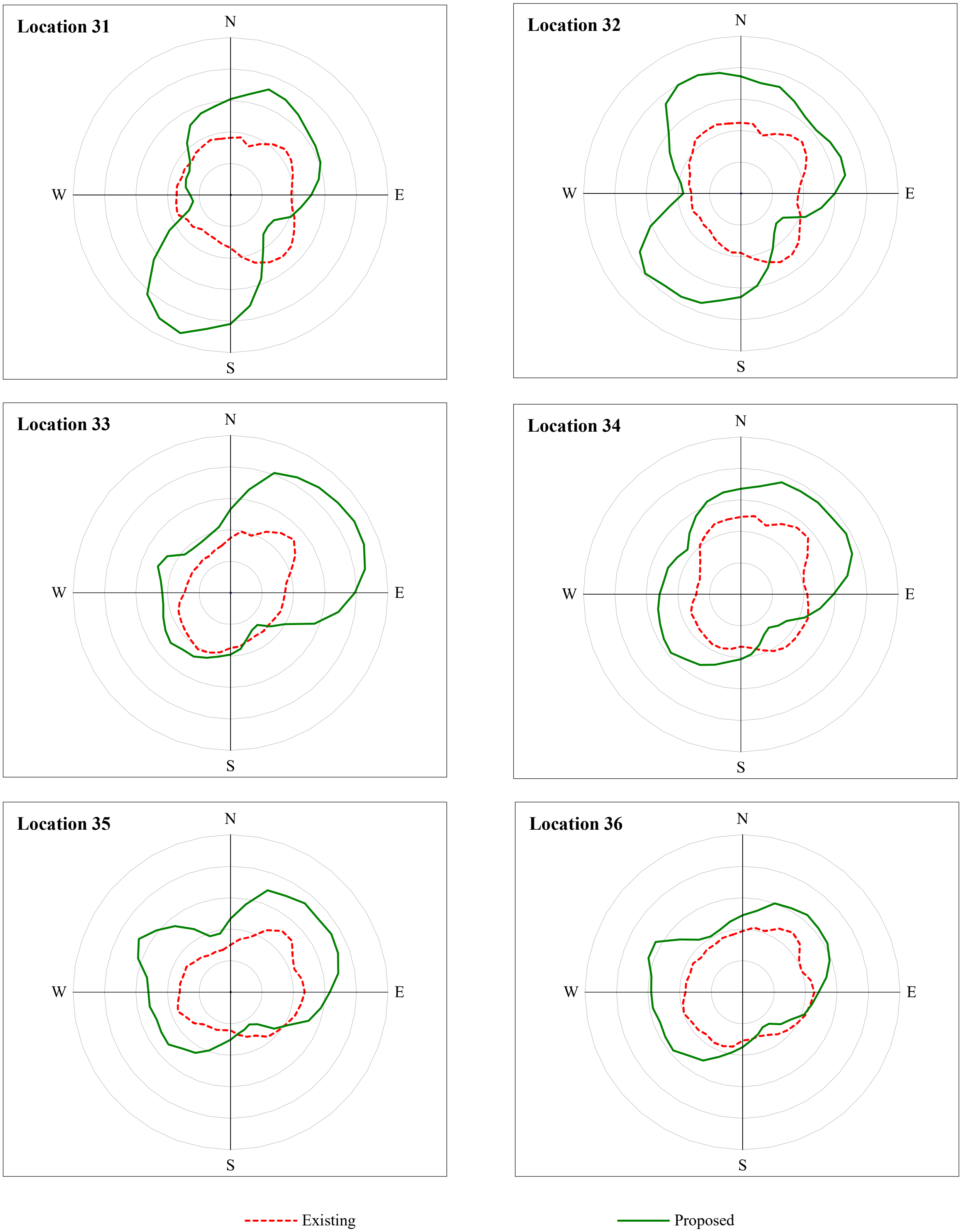
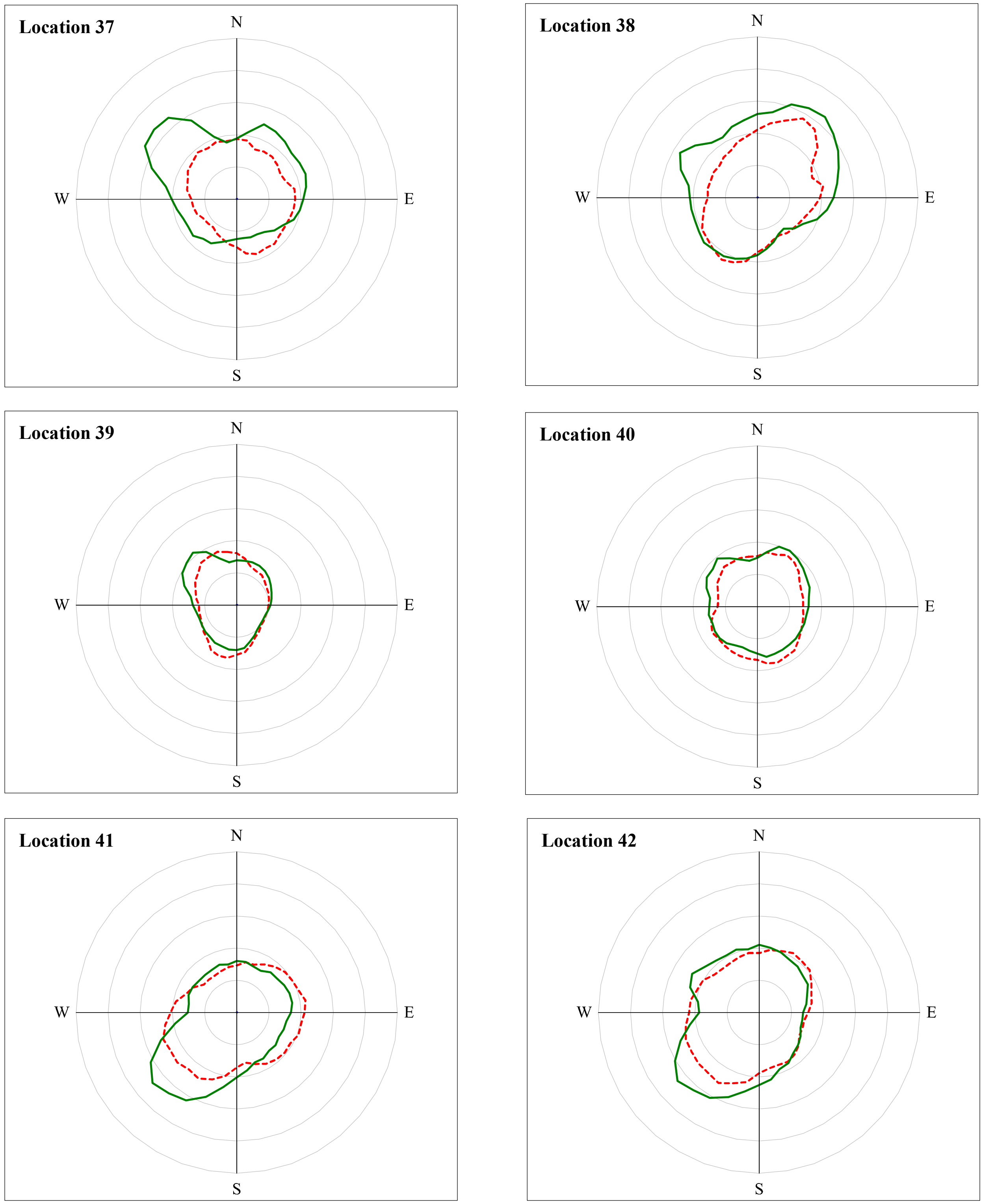


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



Existing   Proposed

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

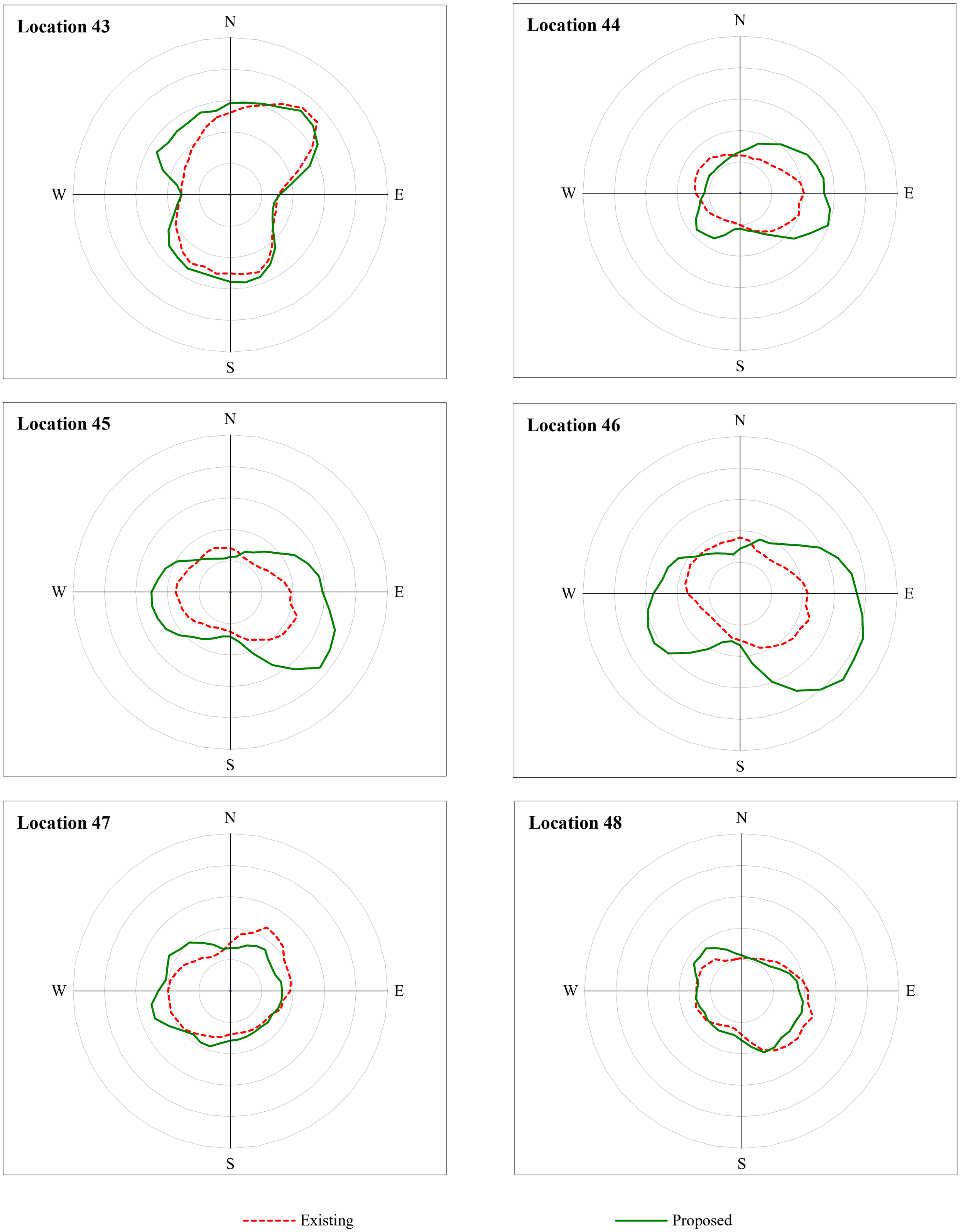


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

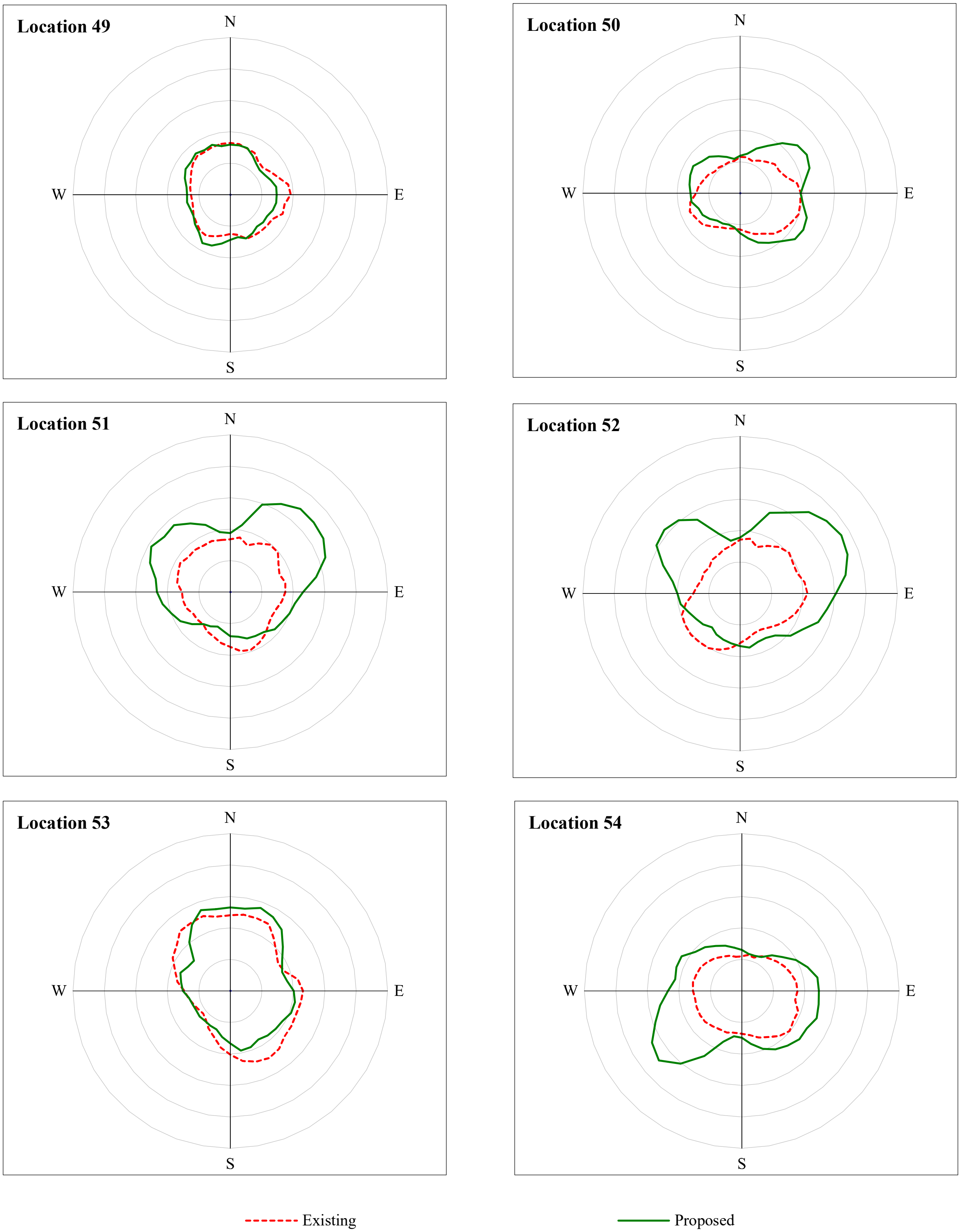
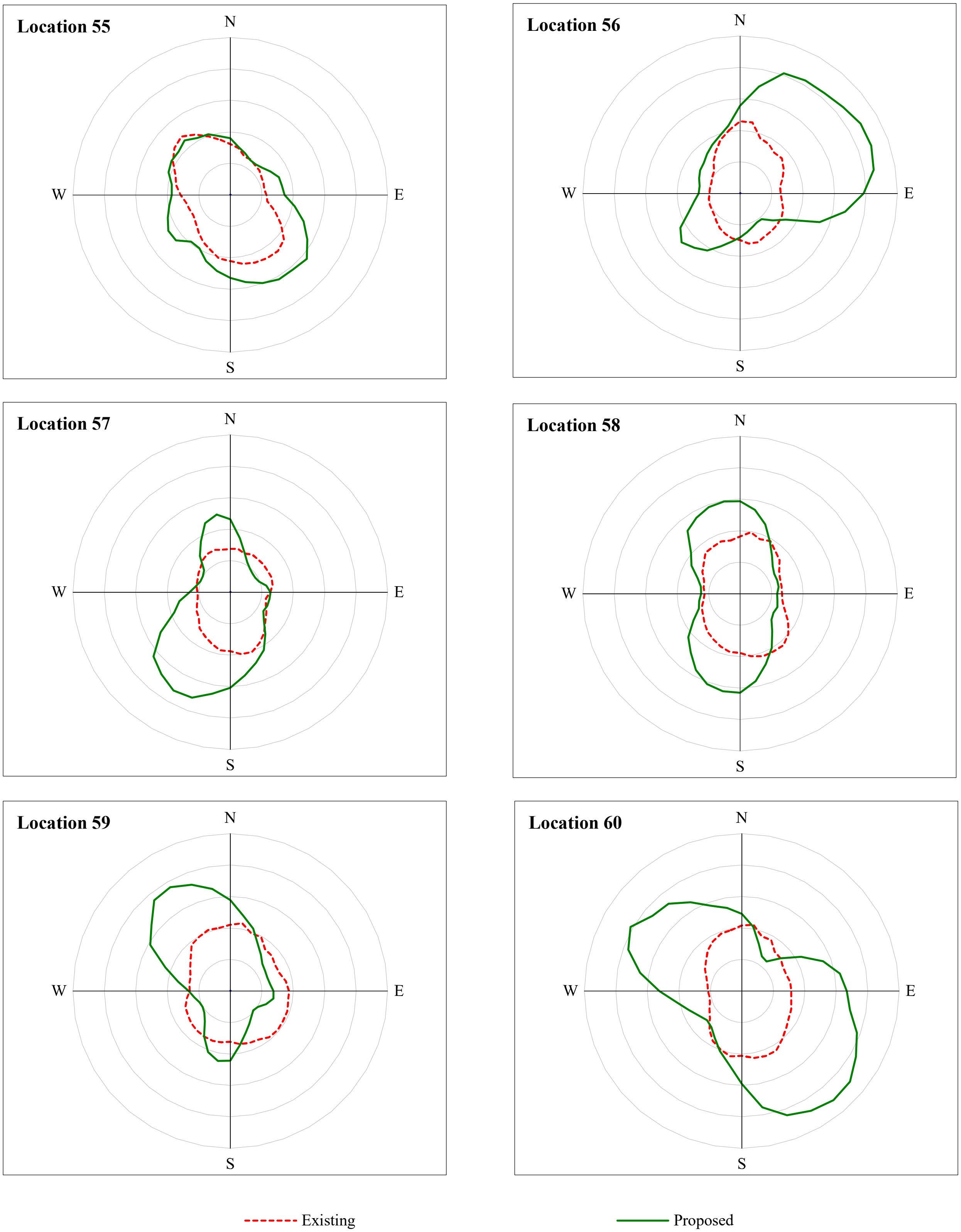


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



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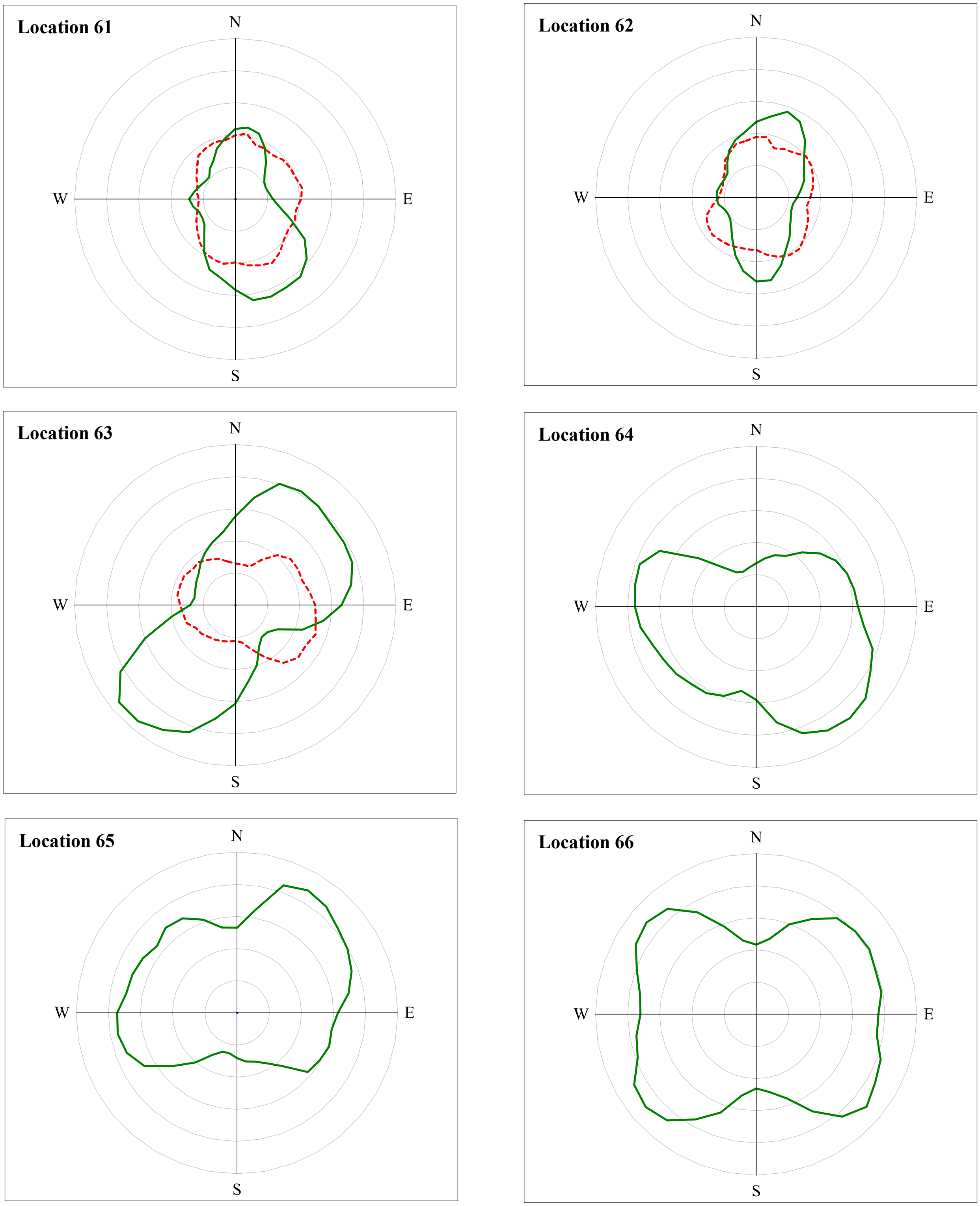
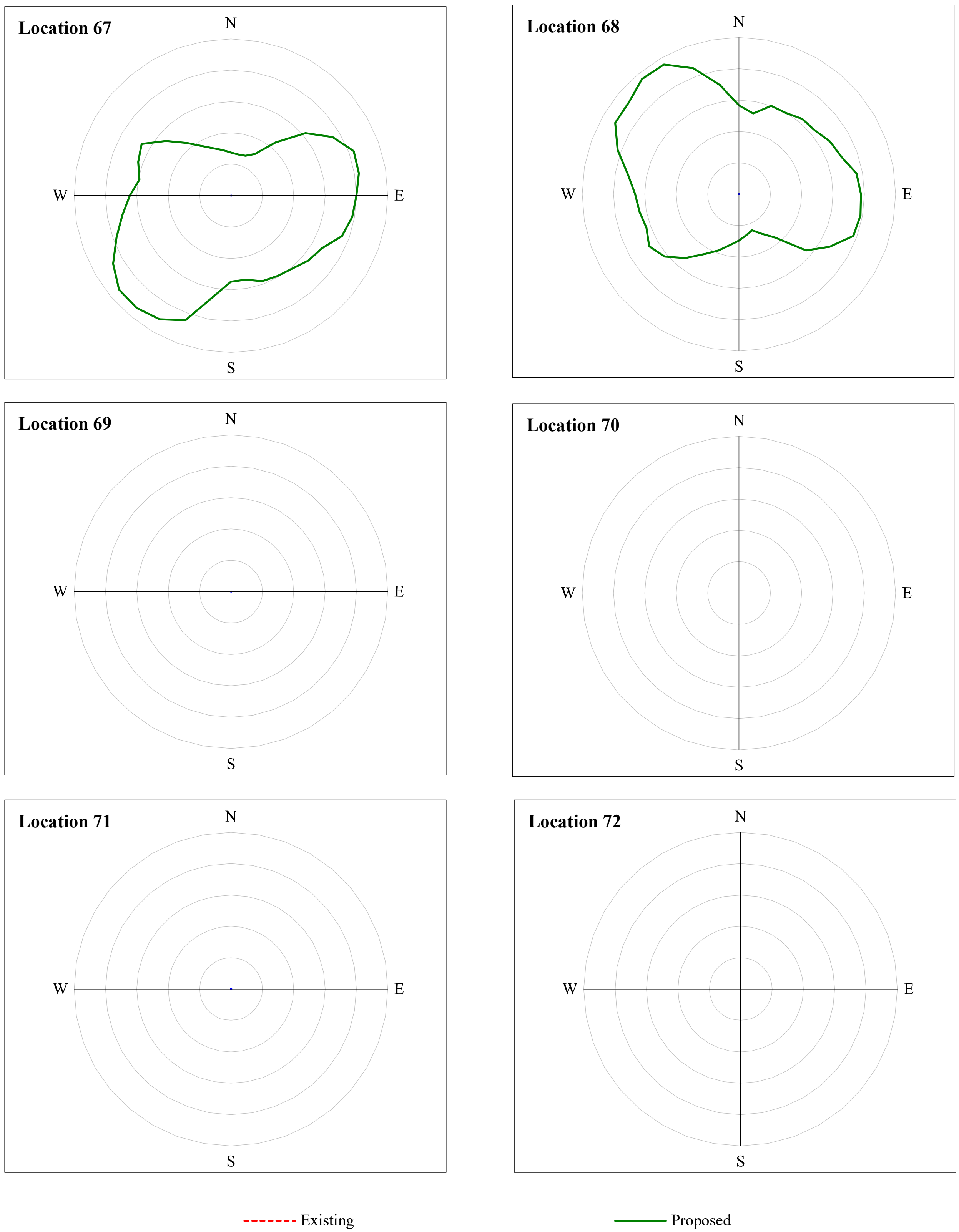


------ Existing   —— Proposed

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



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