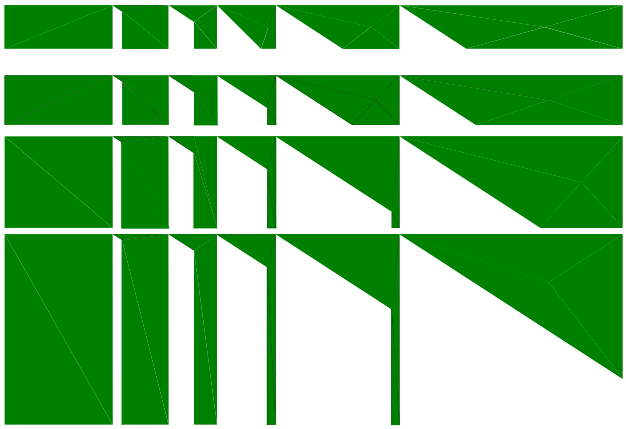
THEAKSTON ENVIRONMENTAL
Consulting Engineers • Environmental Control Specialists

REPORT

PEDESTRIAN LEVEL WIND STUDY

38-50 Park Road

Toronto, Ontario



Helberg Properties Limited

REPORT NO. 25210wind **July 9, 2025**

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1. EXECUTIVE SUMMARY

The mixed-use Development proposed by Helberg Properties Limited for their property municipally known as 38-50 Park Road, located to the north of the intersection of Collier Street and Park Road, in the City of Toronto, has been assessed for environmental standards with regard to pedestrian level wind velocities relative to comfort and safety. The pedestrian level wind and gust velocities measured for the seventy-eight (78) locations tested are within safety criteria and most are within the comfort criteria described within.

The Development involves a proposal to remove the existing buildings at 38 and 40 Park Road, and construct a 31 storey building connecting to the southwest of the existing 2 storey heritage building that will remain at 50 Park Road. The proposed Development is, for all intents and purposes, surrounded to prevailing windward directions by an urban mix of low to high-rise residential, commercial, and institutional buildings, as well as surrounding open lands and mature vegetation. These surrounds present a coarse terrain to approaching winds, limiting the wind's opportunity to accelerate on approach from several directions.

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

The proposed Development penetrates winds that formerly flowed over the site, the increased blockage relative to the existing setting causing wind to redirect to flow over the building, without consequence, and/or, depending upon the angle of incidence, around, or down the tower towards the pedestrian level, as downwash. The Development features wind friendly design elements such as stepped façades, balconies, landscaping, and others, which when considered in concert, moderate wind at the pedestrian level. This results in generally subtle changes to the impending wind climate realised at the site with inclusion of the proposed Development, relative to the existing setting.

Based upon this analysis ground level winds at some locations will improve, relative to the existing setting, with localized areas of higher pedestrian level winds. As such, the site and surrounds are predicted to be suitable for standing or sitting throughout the year, with localised spring walking conditions in the proposed breezeway. The proposed Development and surrounds are predicted to be suitable for the intended uses, and consideration of proposed surface roughness, such as fine design and landscape features that were too fine to include in the massing model, including the existing dense surrounding vegetation, are expected to result in more comfortable conditions than reported.

Where mitigation was necessary, it was achieved through the incorporation of the following design features:

- irregular/notched façades
- stepped façades
- balconies
- wind screens
- hard and soft landscaping

and others, that were included in the proposed Development's massing and landscape design. A mitigation plan is recommended for the MPH level Outdoor Amenity Space in order to achieve conditions that are appropriate for the intended use throughout the year. The proposed Development will realize wind conditions acceptable to a typical urban context.

Respectfully submitted,



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2. INTRODUCTION

Theakston Environmental Consulting Engineers, Fergus, Ontario, were retained by Helberg Properties Limited, to study the pedestrian level wind environment for their proposed Development located at 38-50 Park Road, in the City of Toronto, as shown on the Aerial Photo in Figure 2a. The Development involves a proposal to remove the existing buildings at 38 and 40 Park Road, and construct a 31 storey building connecting to the existing 2 storey heritage building that will remain at 50 Park Road, in the configuration shown in Figure 2b. BDP Quadrangle provided architectural drawings for the proposed Development. The co-operation and interest of the Client and their sponsors in all aspects of this study is gratefully acknowledged.

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

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

The laboratory techniques used in this 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 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, which is excellent for flow visualisation, 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, 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 seventy-eight (78) 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 Gust Equivalent Mean (GEM) wind speed exceeded 20% of the time, based on the seasons in Figures 6a through 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 Toronto 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 1993 and 2023. 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. 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 from the north through west to southwest and said winds are most likely to occur during the winter and spring seasons.

4.4 Wind Simulation

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

4.5 Pedestrian Level Wind Velocity Study

A physical model of the proposed Development and pertinent surroundings, including existing buildings, roadways, pathways, terrain, and other features, was constructed to a scale of 1:400. The model is based upon information gathered during a virtual site visit to the proposed Development site, and surrounding area. BDP Quadrangle provided architectural drawings. City of Toronto 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 1.5m. 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 Comfort Categories, which are based upon the four seasons and calculated as the Gust Equivalent Mean (GEM) wind speed exceeded 20% of the time, based on wind events occurring between 6:00 and 23:00. Gust Equivalent Mean (GEM) wind speed is the maximum of either mean wind speed or gust wind speed divided by 1.85. 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 Wind 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 effects of mean and gust wind conditions are described as suitable for Sitting, Standing, or Walking when said categories are realised 80% of the time, or greater. The Uncomfortable category encompasses wind conditions that exceed Walking criteria. For a point to be rated as suitable for Sitting, for example, the GEM wind conditions must not exceed 10*km/h*, 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 GEM wind speeds from calm up to 15*km/h,* occurring at least 80% of the time. 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,* occurring more than 80% of the time. 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* occurring more than 20% of the time.

In Figure 6, the probe locations are listed along the bottom of the chart; beneath the graphical representation of the GEM 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. 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 upon gust wind speeds exceeded nine times per year, using annual wind data recorded 24 hours daily, as shown in Table 2. Both the Comfort and Safety Criteria are based on those described in the City's Terms of Reference for Wind.

Table 2: Safety Criteria

ACTIVITY	Gust 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

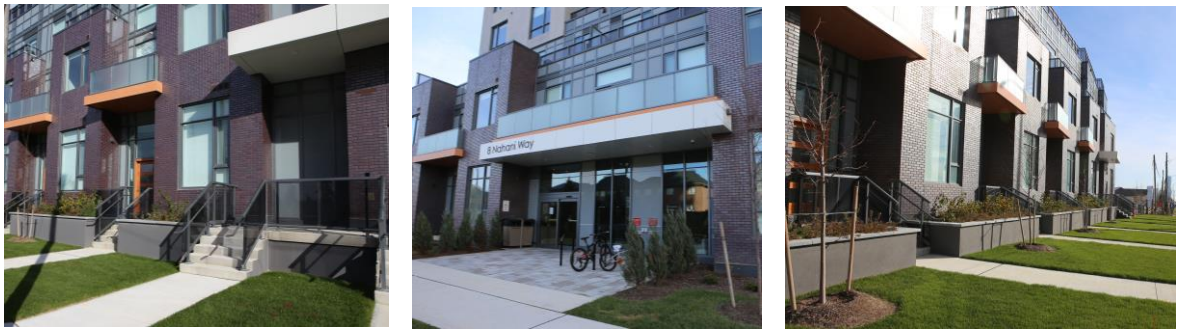
The level of comfort perceived by an individual is highly dependent on seasonal variations of climate. Perceived comfort is also specific to each individual and depends on the clothing choices. The comfort criterion that is being used averages the results across the general population to remove effects 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 9% higher and summer winds are about 11% 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 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

Proposed Development

The proposed Development occupies the block of lands bound by Collier Street and Church Street to the south, Yonge Street to the west, Aylmer Avenue to the north, and Park Road to the east, in the City of Toronto. The site is currently occupied by low and mid-rise buildings at 38 and 40 Park Road that will be removed, as well as a 2 storey heritage building at 50 Park Road that will remain. The site and its immediate surrounds are shown in Figure 2a.

The proposed Development involves construction of a 31 storey building abutting the 2 storey heritage building situated to the northeast. The Main Residential Entrance to the proposed Development is accessed along the southeastern façade via Park Road. A Staff Terrace is proposed along the northwestern façade of the building at-grade, and Outdoor Amenity Spaces are proposed atop a step in the building on the 2nd level, as well as at the MPH level. A breezeway bisects the building, accommodating access to the underground parking and loading from Park Road. The analysis is based upon project plans prepared by BDP Quadrangle and the site plan is presented in Figure 2b.



Existing conditions at the proposed Development site looking west from Park Road (Google).

Surrounding Area

The proposed Development site, for all intents and purposes, is surrounded to prevailing windward directions by an urban mix of low through high-rise residential, commercial, and institutional buildings, open lands, and related mature vegetation, as indicated in Figure 2a.

Lands to the immediate northwest through west of the site are occupied by open parkland populated with mature vegetation, with lands beyond dominated by mainly low-rise residential neighbourhoods and institutional buildings, with a few mid-rise buildings located to the northwest of the site. Lands to the northwest through west to southeast of the site transition quickly to densely populated low through high-rise urban buildings. Sites in the surrounds that are under construction or that have gained approvals were included in the model of the surrounds.

In summary, urban development mainly comprised of low through high-rise residential, commercial, and institutional buildings, as well as open lands and mature vegetation, occupy lands to all compass points relative to the subject site. The urban landscape has mitigative effects upon the wind climate to varying degrees, providing surface roughness that generally reduces the wind's energy at the pedestrian level. Figures 2a and 2b depict the site and its immediate context. The site model, shown in Figure 3, is built to a scale of 1:400.

Macroclimate

For the proposed Development, the upstream wind flow during testing was conditioned to simulate an atmospheric boundary layer passing over urban terrain. The terrain within the site's immediate vicinity was incorporated into the proximity model. Historical

meteorological data recorded from Toronto Pearson International Airport was used in this analysis. For studies in the City of Toronto, the data is presented for the four seasons, winter, spring, summer, and fall; 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 10m. Thus, representative ground level velocities at a height of 2m, for an urban macroclimate, are 52% of the mean values indicated on the wind rose (for suburban and rural macroclimates the values are 63% and 78% respectively). The macroclimate for the area varies, with the terrain types associated with wind direction, resulting in what is generally considered urban terrain.

Winter (December through February) 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 5a. Spring (March through May) has the second highest mean wind velocities and the prevailing winds tend to be from the North to West quadrant (Figure 5b). Summer (June through August) has the lowest mean wind velocities of the seasons with prevailing winds from north through west to south as indicated in Figure 5c. During the fall, (September through November) the possible directions for prevailing winds include the North to Southwest sector (Figure 5d). The magnitudes of the mean wind velocities are between spring and summer winds. Reported pedestrian comfort conditions pertain to the winter season, unless stated otherwise.

5.2 Pedestrian Level Wind Velocity Study

On the site model, seventy-eight (78) 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.

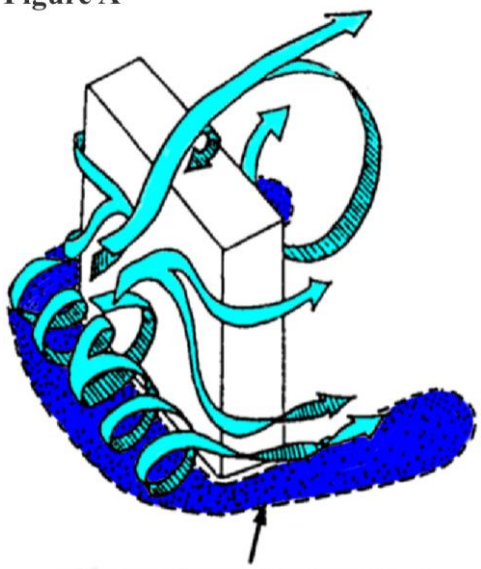
Measurements of pedestrian level mean and gust wind speeds at the various locations shown were taken over a period equivalent to one hour of measurements at full-scale. The mean ground level wind velocity measured is presented as a ratio of gradient wind speed, in the plots of Figure B in the Appendix, 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 for the seasons in Figures 6a – 6d. A table comparing comfort and safety ratings for each probe is provided in Figure 10.

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 urban setting to prevailing and remaining compass points with winds flowing over and between mature vegetation, low to 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 an urban environment to determine the worst-case scenario.

Figure A



Area of Strong Surface Wind

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.

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 through 6d for the four seasons for the existing and proposed configurations. The results are also graphically depicted in Figures 7a – 7h. The following discusses anticipated wind conditions and suitability for the points' intended use.

Public Street Conditions

Church Street

Probes 1 through 17 were located along Church Street, within the zone of influence of the proposed Development site. Their locations are depicted in Figure 4, the comfort ratings are listed for the seasons in Figures 6a through 6d and depicted in Figures 7a through 7h. The existing comfort conditions along Church Street are rated as suitable for sitting throughout the majority of the year, with localised standing conditions proximate to the intersections with Collier Street and Park Road. The windier conditions can be attributed to high-rise buildings flanking portions of the street which exacerbate winds in their vicinity as well as increased exposure realized at the intersections.

With inclusion of the proposed Development a realignment of winds was noted along Church Street. This can be attributed to the proposed Development causing a realignment of winds that reduces apparent wind effects at the pedestrian level for several wind directions, but causes 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 along portions of Church Street. Conversely, improvements in wind conditions can be attributed to the proposed Development effectively reducing the propensity for specific winds being deflected to flow along the street and over the areas.

The overall changes to comfort conditions along Church Street are fairly minor, with probes 3 and 12 realising sufficient blockage from northerly through northeasterly winds to improve the winter ratings from standing to sitting. Conversely, probe 7 realised an increase in northwesterly and northeasterly winds sufficient to change the summer and fall ratings from sitting to standing. The remaining probes along Church Street retained their original comfort ratings throughout the year. The subtle changes in wind conditions can mainly be attributed to the proposed Development being set away from Church Street and employing an overall mitigative design.

With inclusion of the proposed Development, Church Street remains comfortable and suitable for the intended use throughout the year. Consideration of design and landscape elements that were too fine to include in the massing model will result in more comfortable conditions than reported.

With inclusion of the proposed Development, Church Street passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Collier Street

Probes 18 through 29 were located along Collier Street within the zone of influence of the proposed Development. In the existing setting, the street realises conditions mainly suitable for sitting throughout the year, with localised standing conditions proximate to the intersections with Church Street and Park Road.

With inclusion of the proposed Development increases in northwesterly through northerly to easterly winds are realised along localised areas of Collier Street. This can be attributed to winds being deflected to flow down and around the tower and along areas of the street. The increase in winds was sufficient to change the seasonal ratings from sitting to standing at probe 20 in the winter, probes 20 through 22 in the spring, and probe 23 in the summer and fall. Conversely, probe 19 realises improvements in northerly winds, sufficient to improve the spring rating from standing to sitting.

Collier Street remains suitable for the intended use throughout the year with inclusion of the proposed Development. Consideration of design and landscape elements that were too fine to include in the massing model will result in more comfortable conditions than reported.

With inclusion of the proposed Development, Collier Street passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Park Road

In addition to the probes situated at the intersections with Church Street and Collier Street, and discussed above, probes 30 through 42 were located along Park Road, situated within the zone of influence of the proposed Development site. The street is rated suitable for sitting throughout the majority of the year, with localised standing conditions in the winter and spring seasons, particularly proximate to intersections with Collier Street and Rosedale Valley Road.

In the proposed setting, Park Road realises an increase in mainly northwesterly through northeasterly and southeasterly winds that are directed to flow down and around the proposed building and along the street. The increase in winds is sufficient to change the seasonal ratings from sitting to standing at probes 30, 31, 32, 34, and 35 in the winter, probes 31 through 34 in the spring, and probe 32 in the summer and fall. Conversely, subtle realignments in winds were sufficient to change the winter ratings from standing to sitting at probes 37 and 41.

Park Road remains comfortable and suitable for the intended use throughout the year in the proposed setting, and will realise more comfortable conditions with consideration of fine design and landscape elements. Park Road passes the pedestrian level wind velocity safety criteria.

Rosedale Valley Road

In addition to the probes situated at the intersection with Park Road, and discussed above, probes 43 through 45 were located along Rosedale Valley Road situated to the north of the proposed Development. In the existing setting the street realises conditions suitable for sitting throughout the majority of the year, with standing conditions at probe 43 in the winter and spring, and probe 45 in just the spring.

In the proposed setting, the conditions along Rosedale Valley Road remain similar, with the exception of probe 44 realising subtle increases in winds, sufficient to change the spring rating from sitting to standing. Rosedale Valley Road remains comfortable and suitable for the intended use throughout the year, and will realise more comfortable conditions with

consideration of fine design and landscape elements. Rosedale Valley Road also passes the pedestrian level wind velocity safety criteria.

Neighbouring Site Conditions

Neighbouring Buildings

Probe 46 was located at the main entrance to the neighbouring Fontainebleu Apartment, situated to the northwest of the proposed Development site. The area is rated for sitting year-round in both the existing and proposed settings and will be comfortable for the intended use.

Probes 66 and 67 were respectively located adjacent to the main entrance and a walkway for the neighbouring 66 Collier Street building to the southwest of the proposed Development site. In the existing setting, the entrance is rated for sitting in the fall and standing through the remainder of the year, and the walkway is rated for standing in the spring and sitting through the remainder of the year. In the proposed setting, the entrance realises subtle improvements in winds sufficient to change the summer rating from standing to sitting, and the walkway conversely changes from sitting to standing in the winter. The neighbouring 66 Collier Street entrance and walkway will remain comfortable and suitable for the intended uses throughout the year.

Neighbouring Parks

Probes 47 and 48 were located in the sports field to the north of Rosedale Valley Road. The field is rated suitable for standing through the majority of the year, with sitting conditions at probe 47 through the summer and fall. The conditions are unchanged with inclusion of the proposed Development, and as such the field remains suitable for the intended use.

Probes 49 through 57 were located within Lawren Harris Park, situated to the immediate north through northwest of the site. In the existing setting, the area is rated suitable for sitting throughout the majority of the year, with standing conditions at probe 49 in the winter, and probes 49, 50, 52, 54, 56, and 57 in the spring. In the proposed setting, the park realises increases in winds that are directed to flow down and around the building and over the area, resulting in conditions changing from sitting to standing at probes 50, 51, 53, 54, 56, and 57 in the winter, probes 51, 53, and 55 in the spring, probes 50 and 51 in the summer and fall, and probe 49 in the fall. The overall changes in winds are relatively minor, as noted in the figure 6a – 6d bar charts, and these areas will experience more comfortable conditions than reported with consideration of the existing dense vegetation throughout the park and surrounding area. As such, Lawren Harris Park is expected to be suitable for the intended use throughout the year.

Probes 58 through 61 were located within Hazeldean Park to the northeast of the proposed Development site. The park is rated for sitting in the summer and fall and standing in the winter and spring in the existing setting, with the exception of winter sitting conditions at probe 58. Hazeldean Park realises similar conditions in the proposed setting, with the exception of probe 61 improving from standing to sitting in the winter. Hazeldean Park is expected to be suitable for the intended use throughout the year, and will realise more comfortable conditions than reported with consideration of the existing dense vegetation throughout the park and surrounding area.

Probes 62 and 63 were situated in Harold Town Park, located to the southwest of the proposed Development site. In the existing setting, the park is rated for sitting in the summer and standing through the remainder of the year, with the exception of fall sitting conditions at probe 63. In the proposed setting, Harold Town Park realises subtle increases in winds, sufficient to change the ratings to standing year-round. The overall changes in winds are fairly minor, as noted in the figure 6a – 6d bar charts, and the park will experience more comfortable conditions than reported with consideration of the existing dense vegetation throughout the park and surrounding area. As such, Harold Town Park is expected to be suitable for the intended use throughout the year.

Probes 64 and 65 were respectively located within Asquith Green Park and Milner Parkette, situated to the southeast of the proposed Development site. Both parks are rated suitable for sitting throughout the year in the existing and proposed settings and as such will be comfortable for the intended uses.

The above-noted neighbouring buildings and parks pass the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Internal Site Conditions

Probe 68 was located within a Staff Terrace along the northwestern façade of the proposed building. The area is rated suitable for standing in the spring and sitting through the remainder of the year. The spring standing rating is near the transition to sitting, and with consideration of fine design and landscape elements, such as the dense surrounding vegetation, the area is expected to be suitable for the intended use throughout the year.

Probes 69 and 70 were located along the walkway adjacent to the northeastern façade of the existing heritage building. The area is well protected from the majority of the wind climate and as such experiences conditions suitable for sitting throughout the year, with the exception of spring standing conditions at probe 69. The standing rating is near the transition to sitting conditions, and with consideration of fine design and landscape elements such as the surrounding dense vegetation, the walkway is expected to be suitable for sitting year-round.

Probes 72 and 73 were located within the breezeway and rated suitable for walking in the spring and standing through the remainder of the year. The area may realise windy conditions on occasion of strong northwesterly or easterly through northeasterly winds, however the space will be generally suitable for the intended use as a walkway. Consideration of fine design and landscape elements are expected to result in more comfortable conditions than reported through the breezeway.

The above-noted internal site areas pass the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Pedestrian Entrance Conditions

Probe 71 was situated adjacent to the Main Residential Entrance to the proposed Development, accessed along Park Road. The entrance is set back into a notch in the façade of the building, and as such is protected from the majority of the wind climate, resulting in conditions suitable for sitting year-round. As such, the Main Residential Entrance will be comfortable and suitable for the intended use throughout the year.

Probe 33 was situated adjacent to the Main Entrance to the existing heritage building, accessed along Park Road. The entrance is rated suitable for sitting throughout the year in the existing setting. In the proposed setting, the entrance remains protected from the majority of the wind climate, however it becomes more exposed to northerly and southeasterly winds, sufficient to change the spring rating to standing. The existing building entrance remains comfortable and suitable for the intended use throughout the year.

Wind conditions comfortable for standing are preferable at building entrances, while conditions suitable for walking are suitable for walkways. The Entrances to the proposed and existing buildings will be comfortable and suitable for the intended uses throughout the year and pass the pedestrian level wind velocity safety criteria.

Outdoor Amenity Space Conditions

Outdoor Amenity Spaces are proposed atop steps in the northeastern and southwestern façades at the 2nd level of the building. The southwestern step is represented by probes 74 and 75, however the northeastern step was too small to accommodate conventional probes. The model was tested with 1.1m high perimeter wind screens around the areas. The southwestern step is well protected from large portions of the wind climate by the proposed building and surrounds, resulting in conditions suitable for standing in the spring and sitting throughout the remainder of the year. The spring standing conditions are near the transition to sitting, and with consideration of fine design and landscape features, such as trellises and plantings, the area is expected to be suitable for the intended use throughout the year. The northeastern step is expected to realise similar conditions to the southwestern portion of the space.

An Outdoor Amenity Space is also proposed on the MPH level, as represented by probes 76 through 78. The model was tested with 1.8m high perimeter wind screens around the area. The area is rated suitable for standing in the spring and sitting throughout the remainder of the year, with the exception of winter standing conditions at probe 77. The standing conditions are near the transition to sitting, however additional mitigation is recommended for the space, which may include raising the perimeter wind screens, porous wind screens, raised planters populated with coarse plantings, and/or others situated within the space. Consideration of an appropriate mitigation plan for the area will result in conditions that are suitable for the intended use throughout the year.

The 2nd and MPH level Outdoor Amenity Spaces pass 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, resulting in generally comfortable conditions in the existing setting. Historical weather data recorded at Toronto Pearson International Airport indicates that strong winds of a mean wind speed greater than 30 km/h occur approximately 14 percent of the time during the winter months and 6 percent of the time during the summer.

Once the subject site is developed, ground level winds at some locations will improve, with localized areas of higher pedestrian level winds, resulting in wind conditions that generally remain comfortable and appropriate to the areas' intended purposes throughout the year. As such, the site and surrounds are predicted to be suitable for standing or sitting throughout the year, with localised walking conditions in the spring within the proposed breezeway. Consideration of proposed surface roughness, such as fine design and landscape features that were too fine to include in the massing model, including the existing dense surrounding vegetation, are expected to result in more comfortable conditions than reported throughout the site and surrounds. 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 MPH level Outdoor Amenity Space in order to achieve conditions that are appropriate for the intended use throughout the year.

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

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Appendix: Background and Theory of Wind Movement 60

Figure 1: Laboratory Testing Facility





Figure 2a: Site Aerial Photo

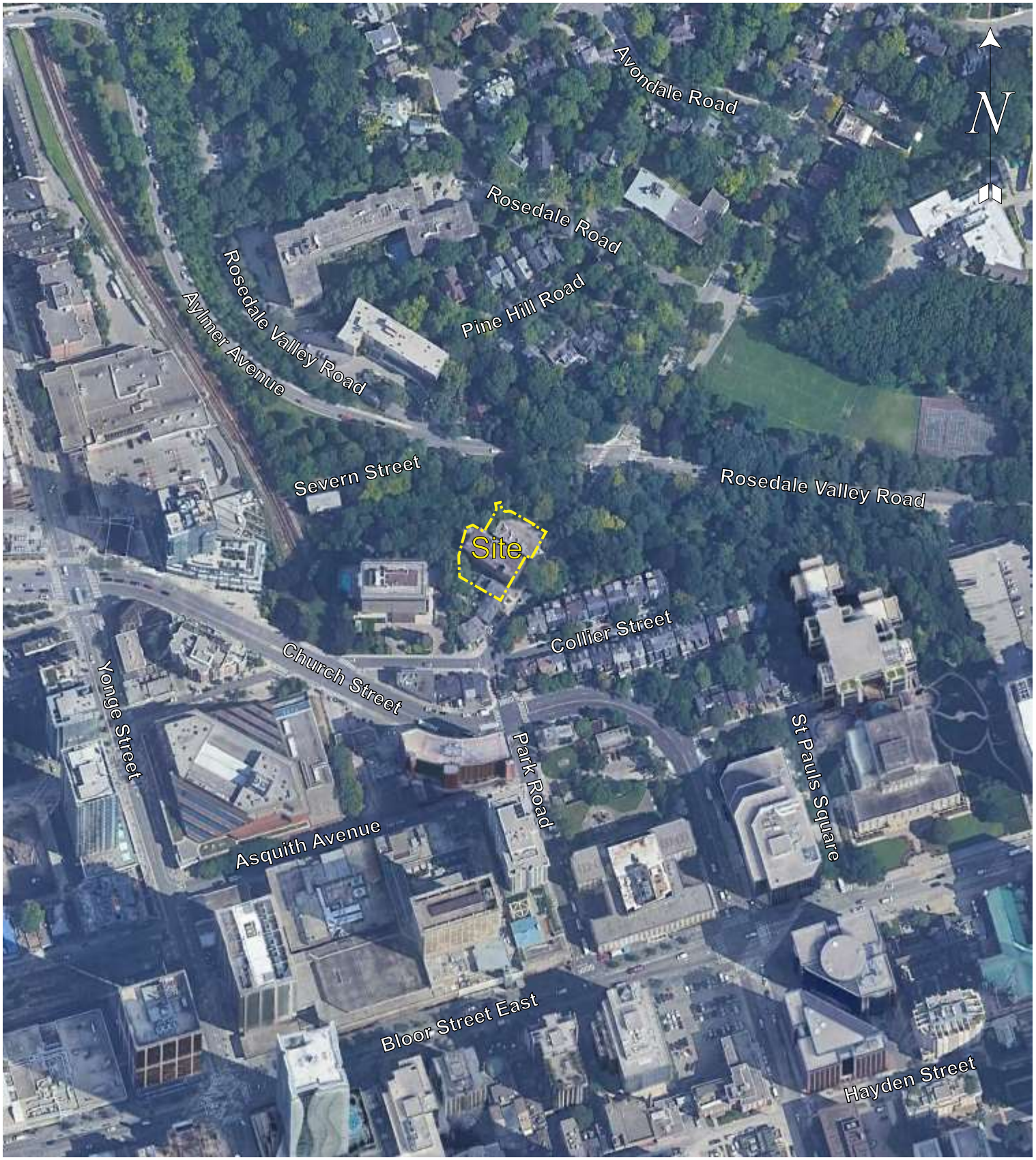


Figure 2b: Site Plan

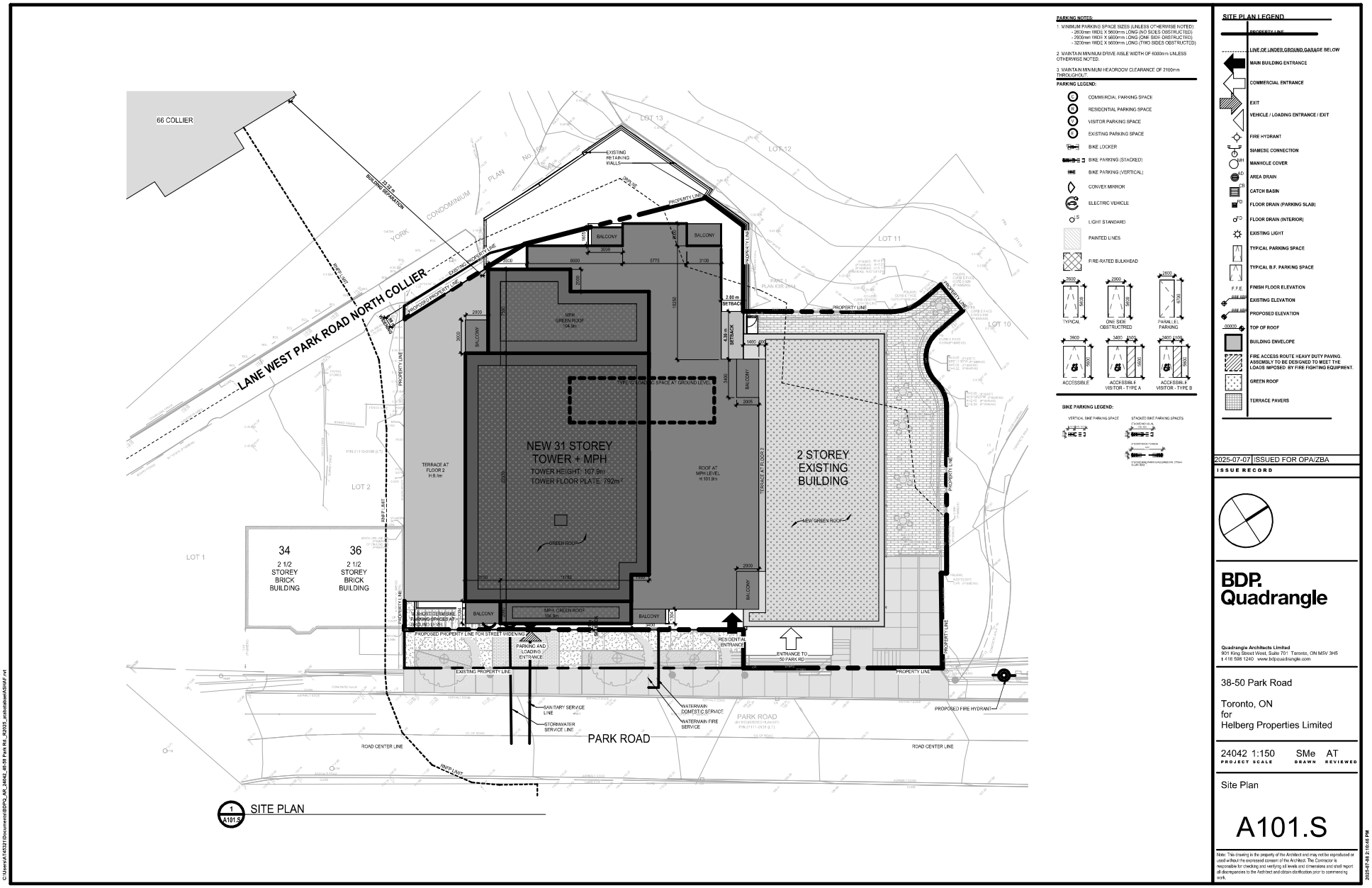
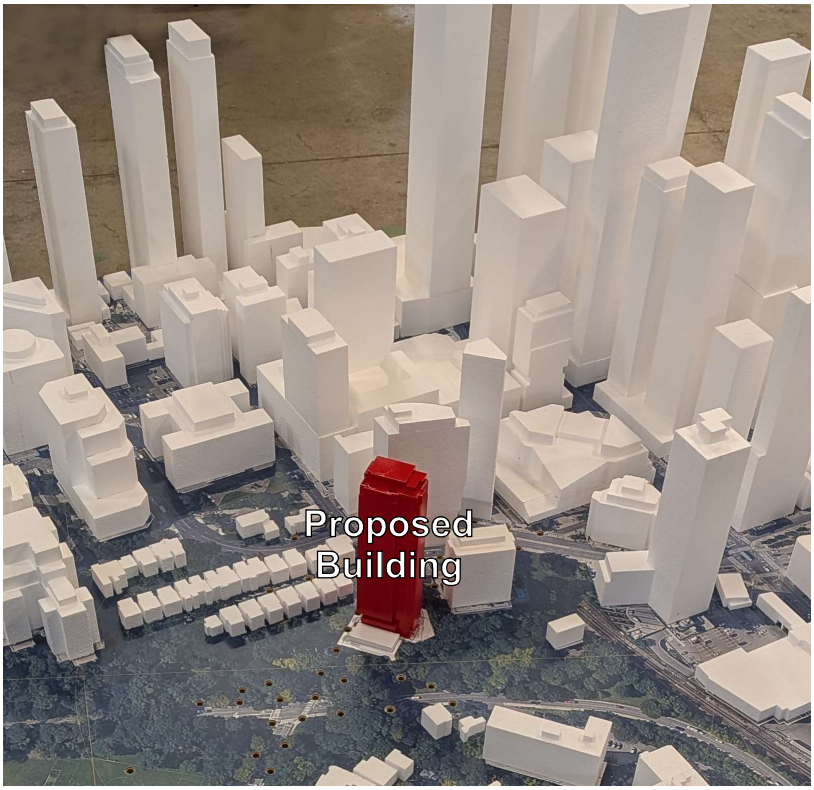


Figure 3: 1:400 Scale Model of Test Site



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 24

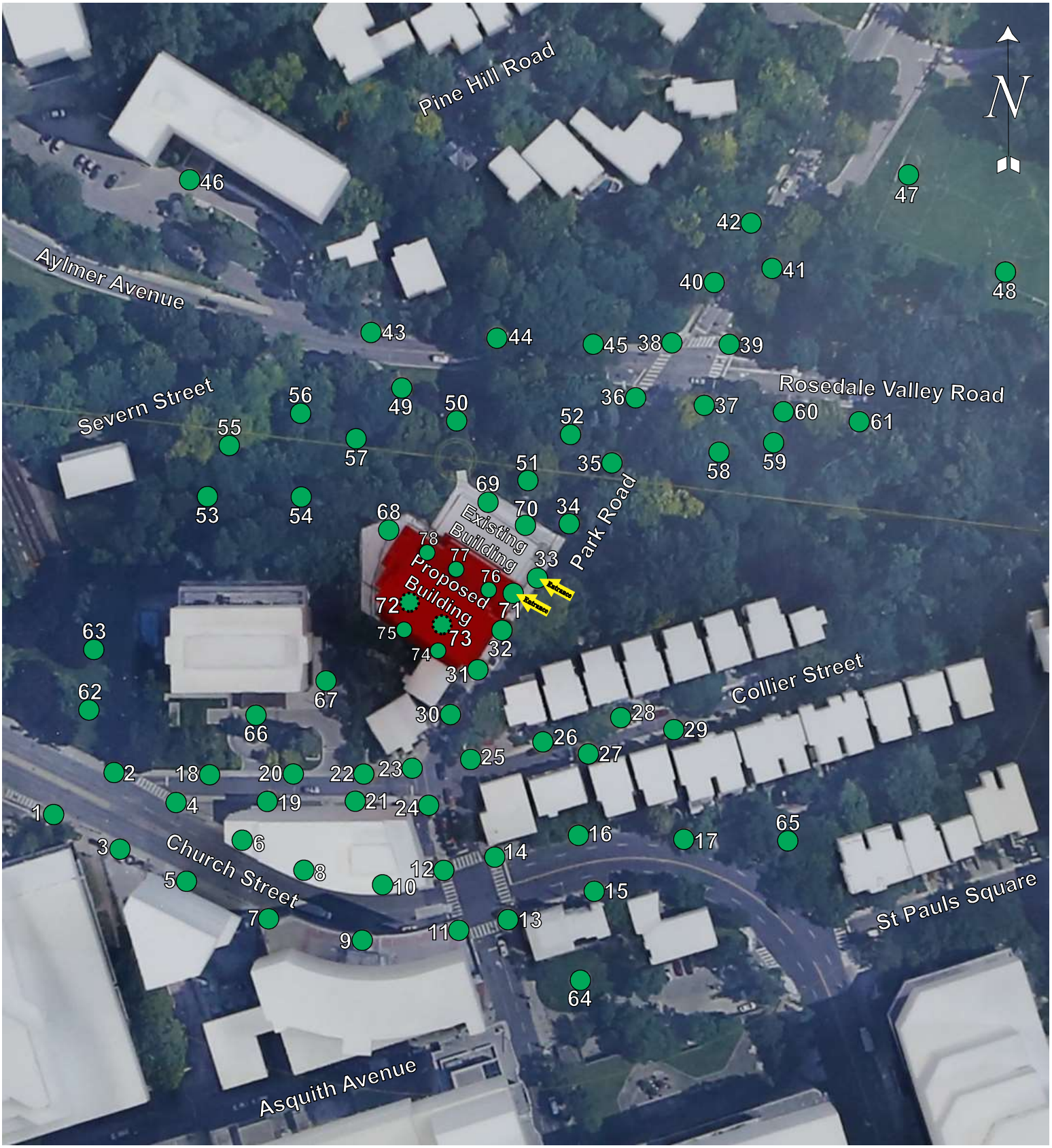


Figure 5a: Winter Wind Rose - Pearson International Airport

Historical Directional Distribution of Winds (@ 10*m* height)
December through February (1993 - 2023)

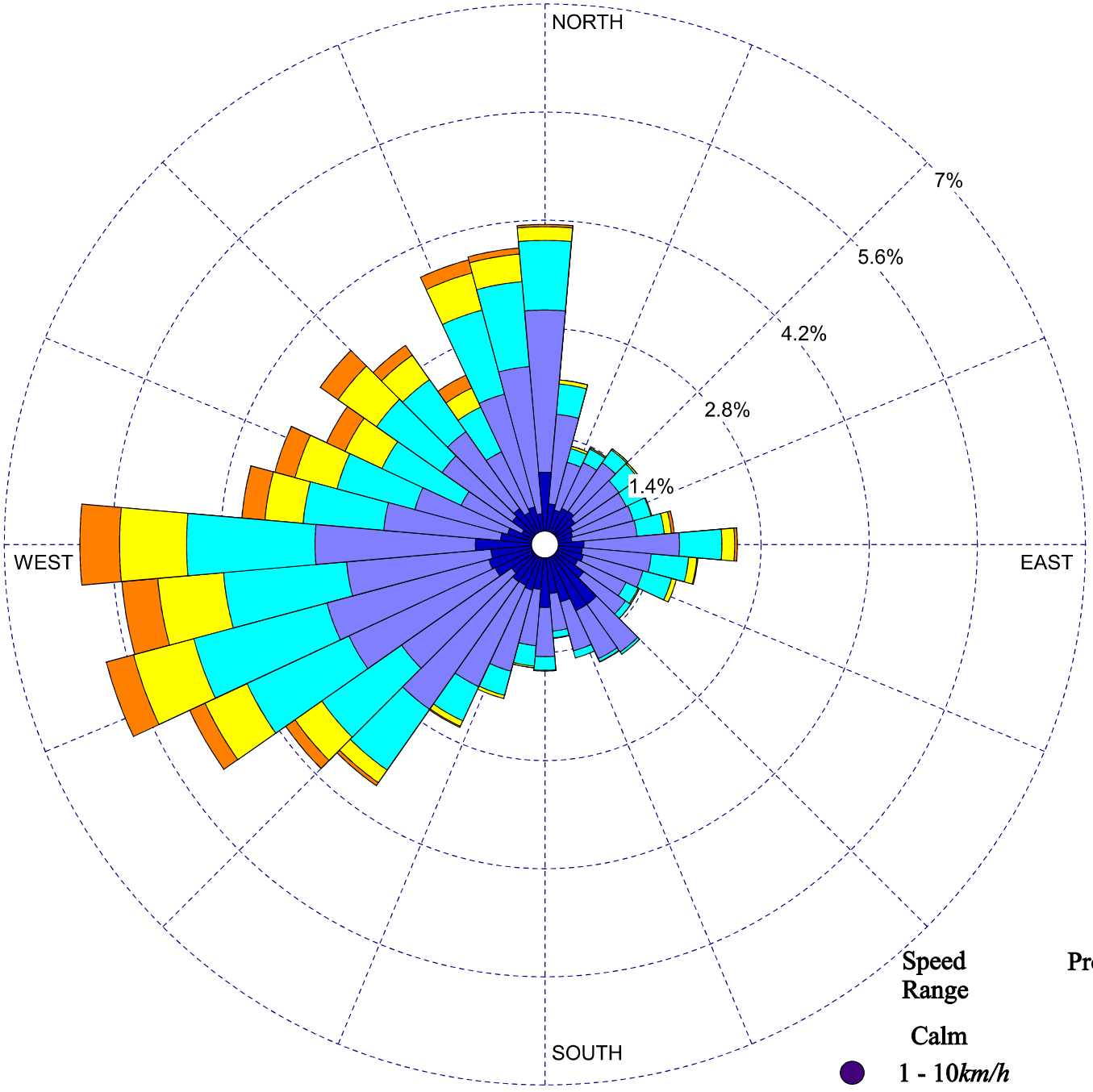
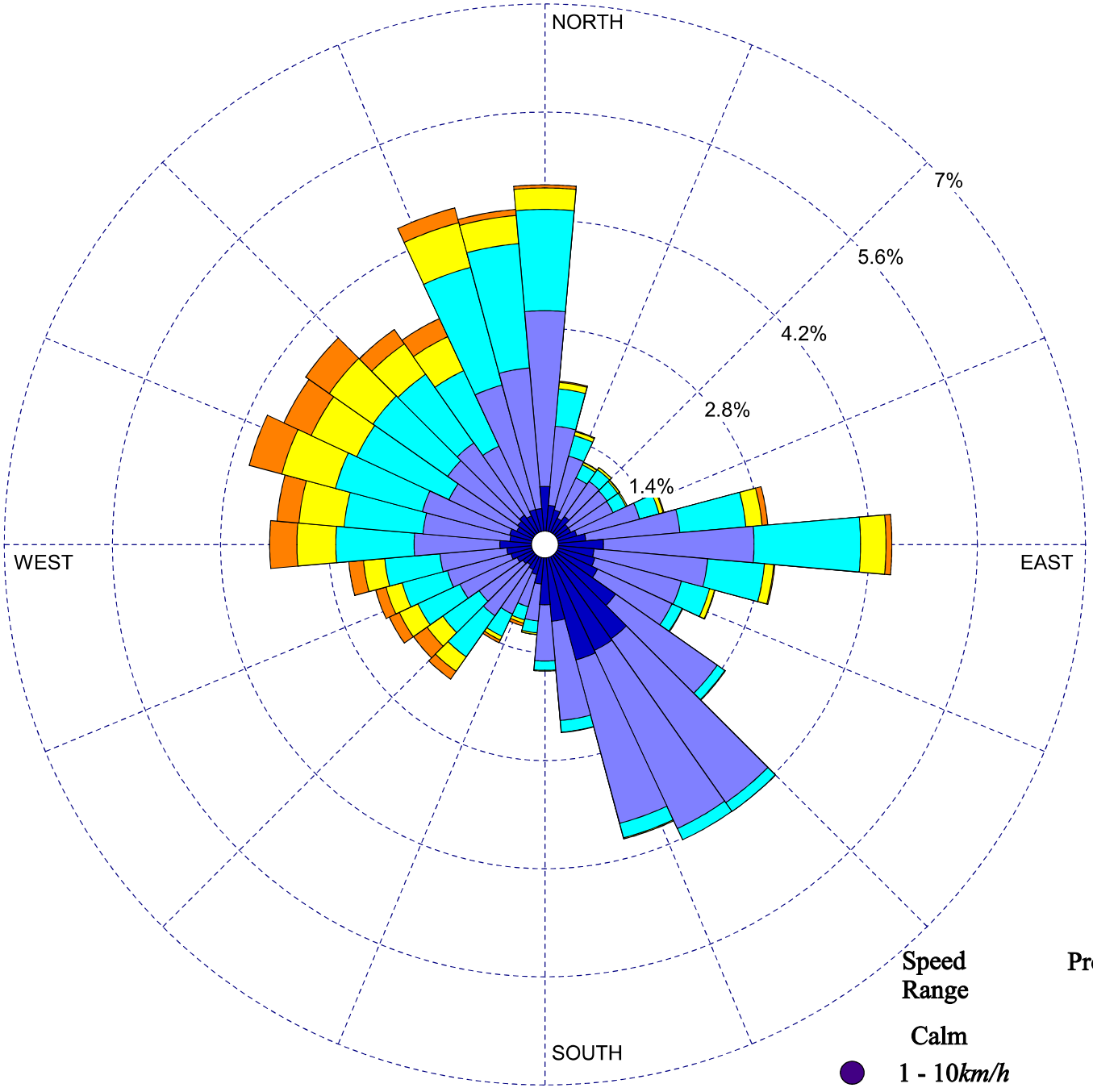


Figure 5b: Spring Wind Rose - Pearson International Airport

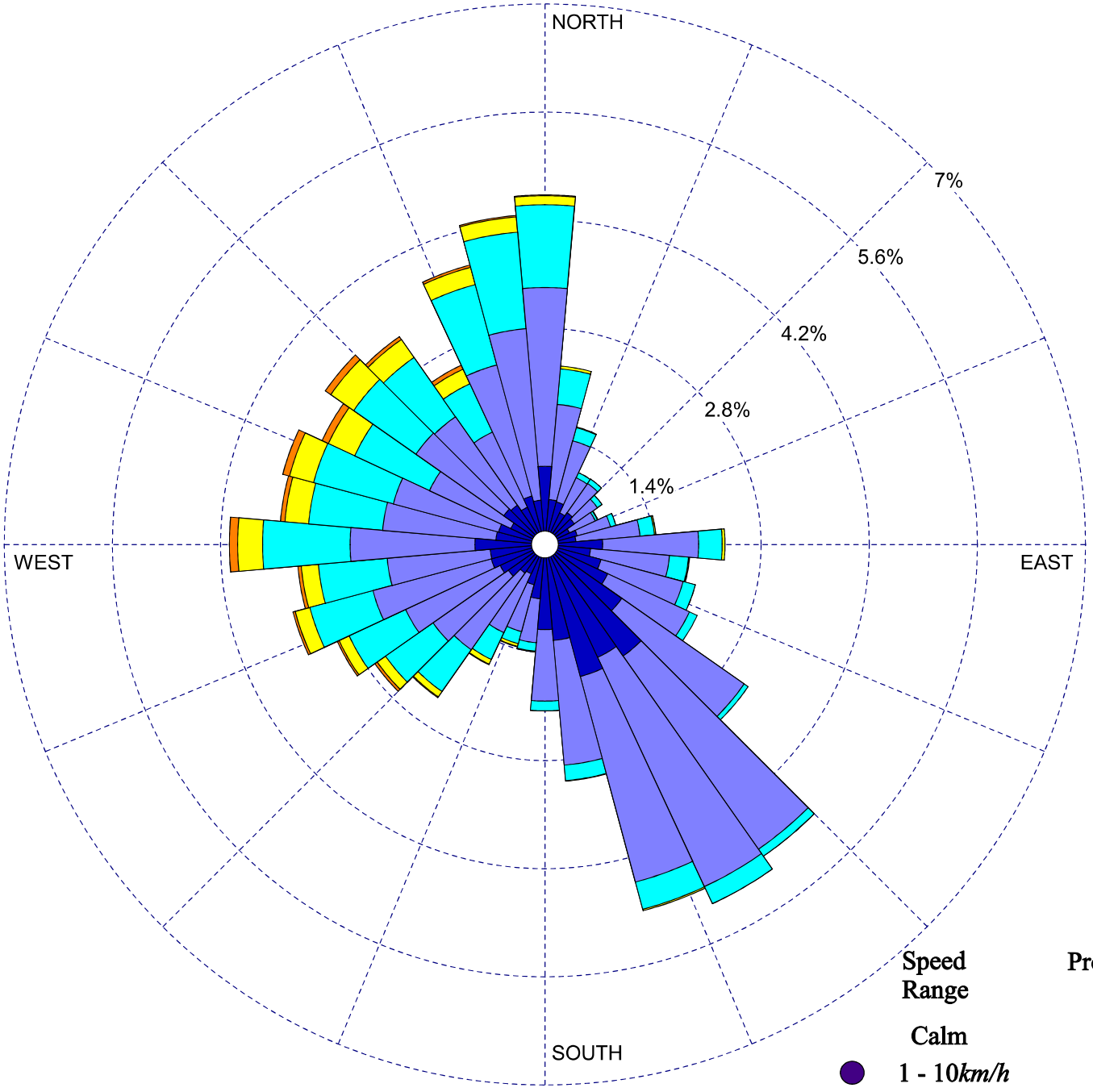
Historical Directional Distribution of Winds (@ 10*m* height)
March through May (1993 - 2023)



Speed Range	Probability (%)
Calm	3 %
1 - 10*km/h*	22 %
11 - 20*km/h*	41 %
21 - 30*km/h*	22 %
31 - 40*km/h*	8 %
> 40*km/h*	4 %

Figure 5c: Summer Wind Rose - Pearson International Airport

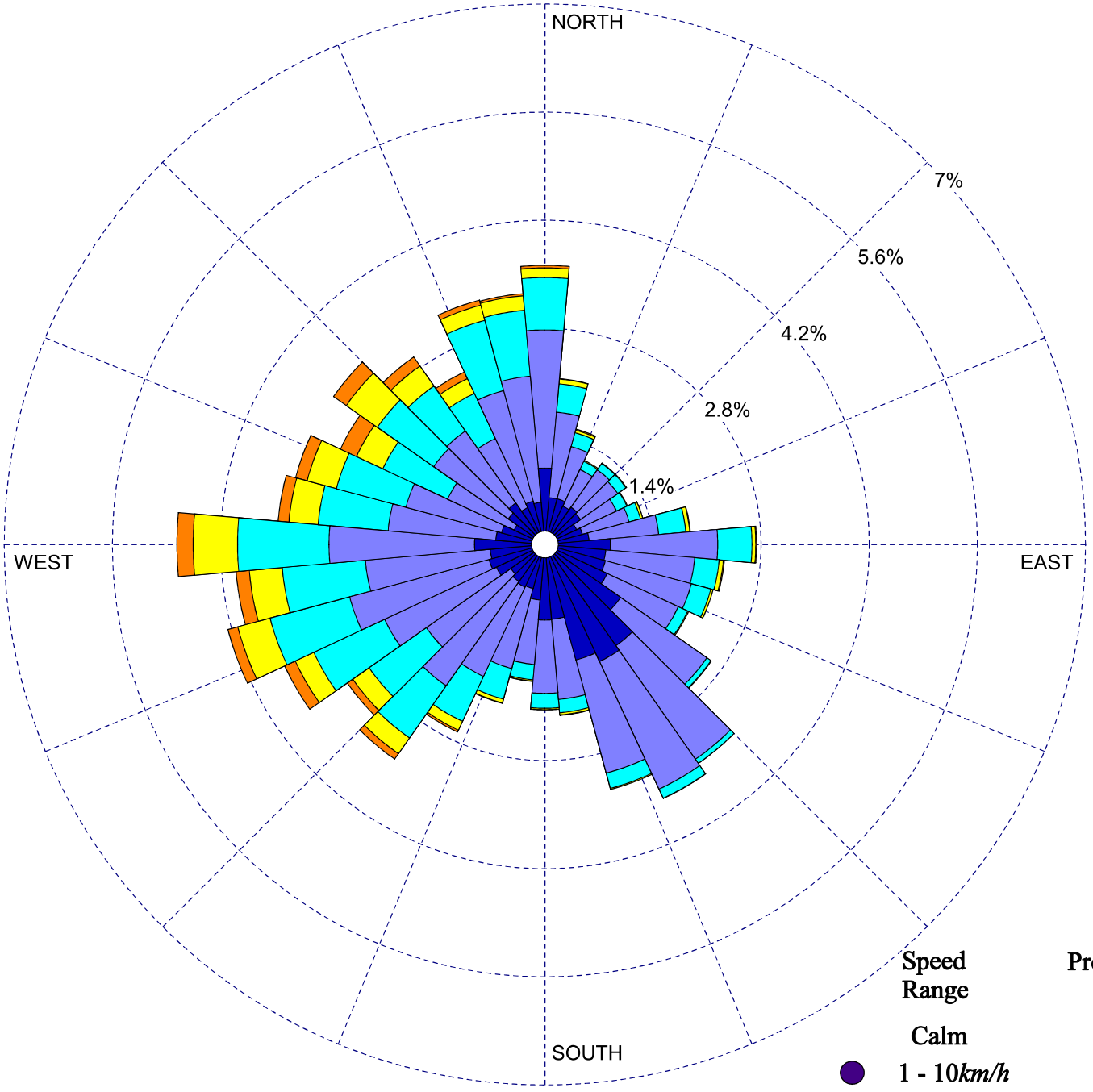
Historical Directional Distribution of Winds (@ 10*m* height)
June through August (1993 - 2023)



Speed Range	Probability (%)
Calm	3 %
1 - 10*km/h*	27 %
11 - 20*km/h*	48 %
21 - 30*km/h*	18 %
31 - 40*km/h*	4 %
> 40*km/h*	< 1%

Figure 5d: Fall Wind Rose - Pearson International Airport

Historical Directional Distribution of Winds (@ 10*m* height)
September through November (1993 - 2023)



Speed Range	Probability (%)
Calm	3 %
1 - 10*km/h*	27 %
11 - 20*km/h*	44 %
21 - 30*km/h*	18 %
31 - 40*km/h*	6 %
> 40*km/h*	2 %

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

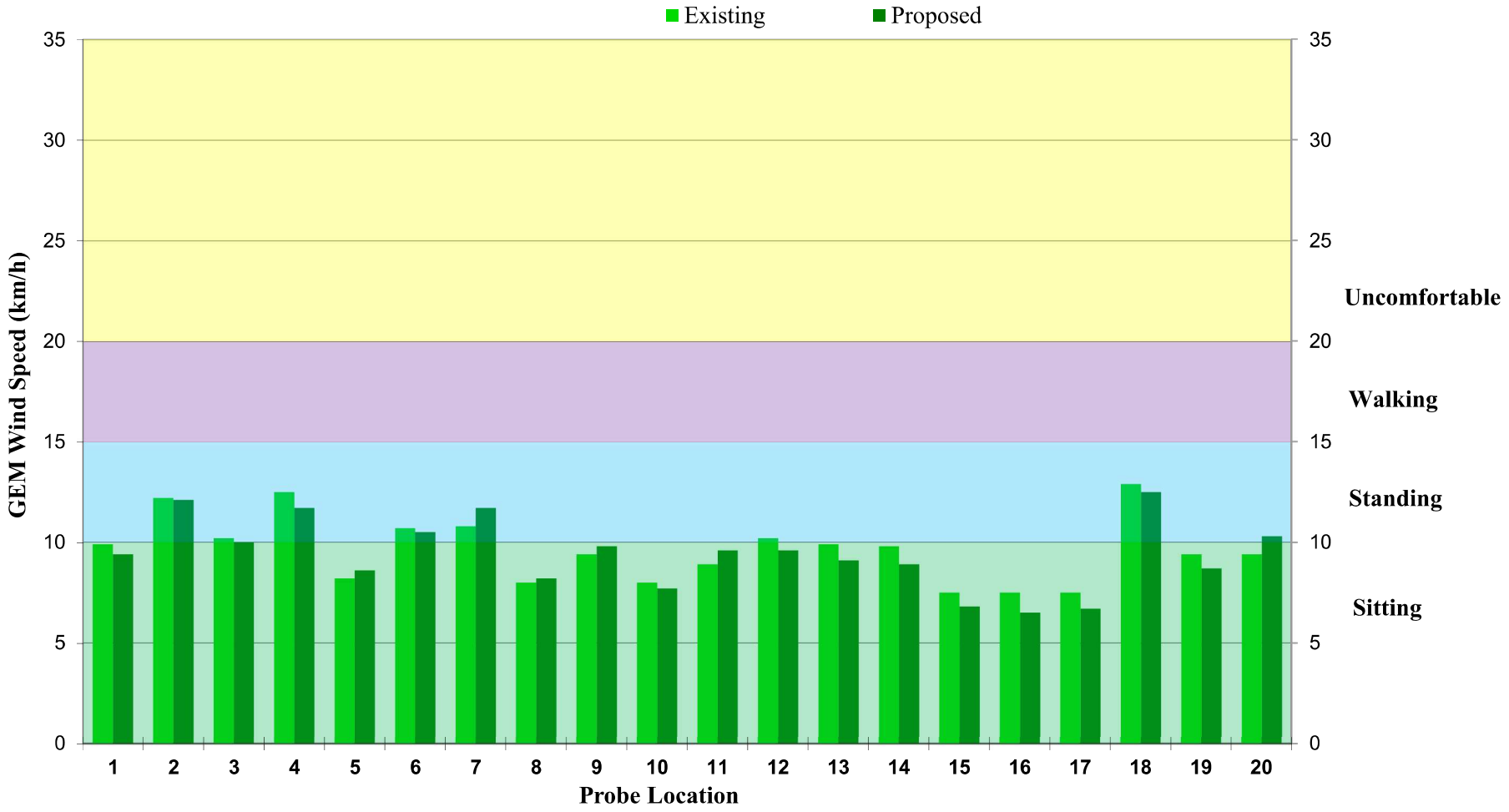


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 21 to 40).

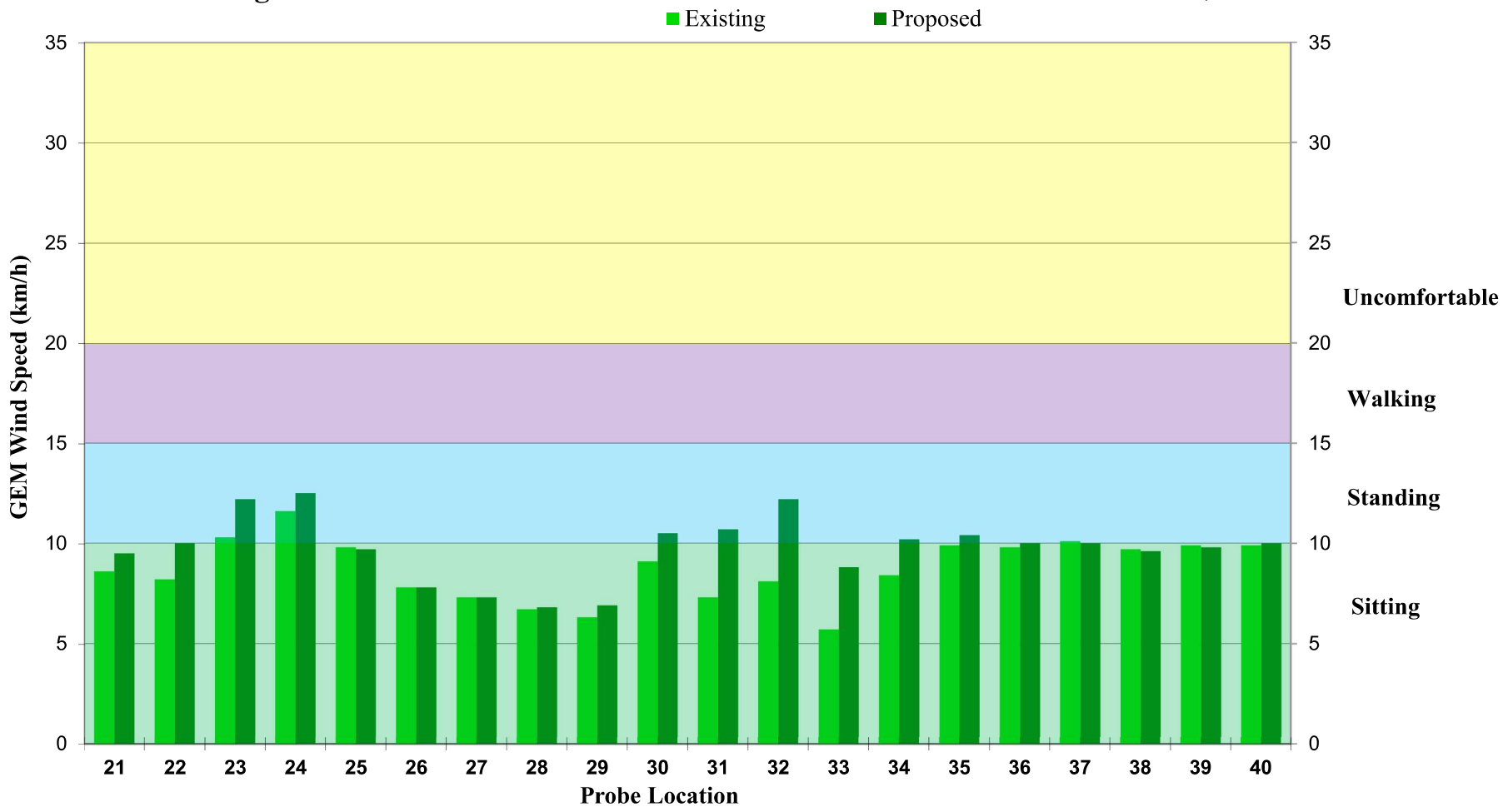


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 41 to 60).

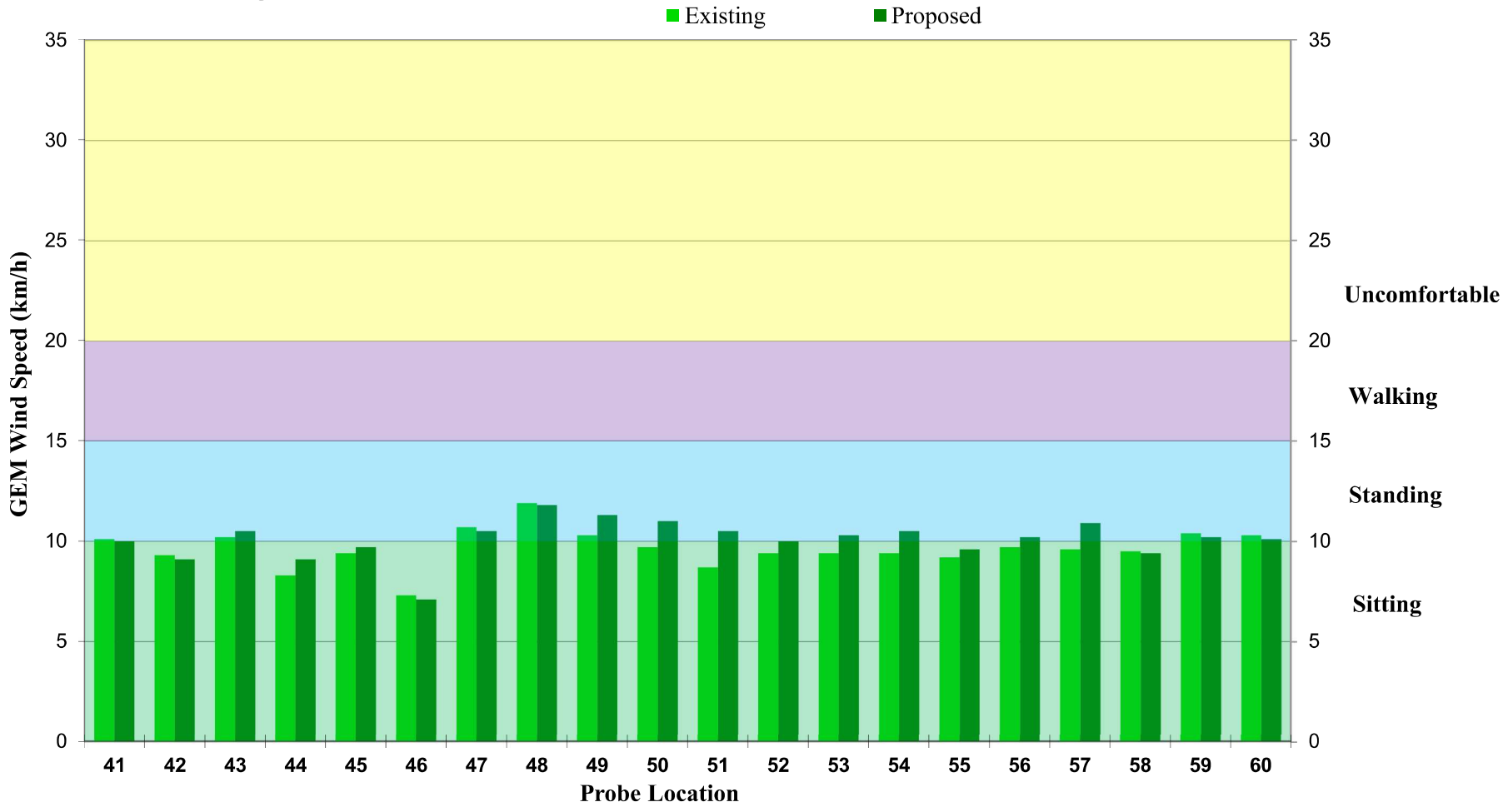


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 61 to 78).

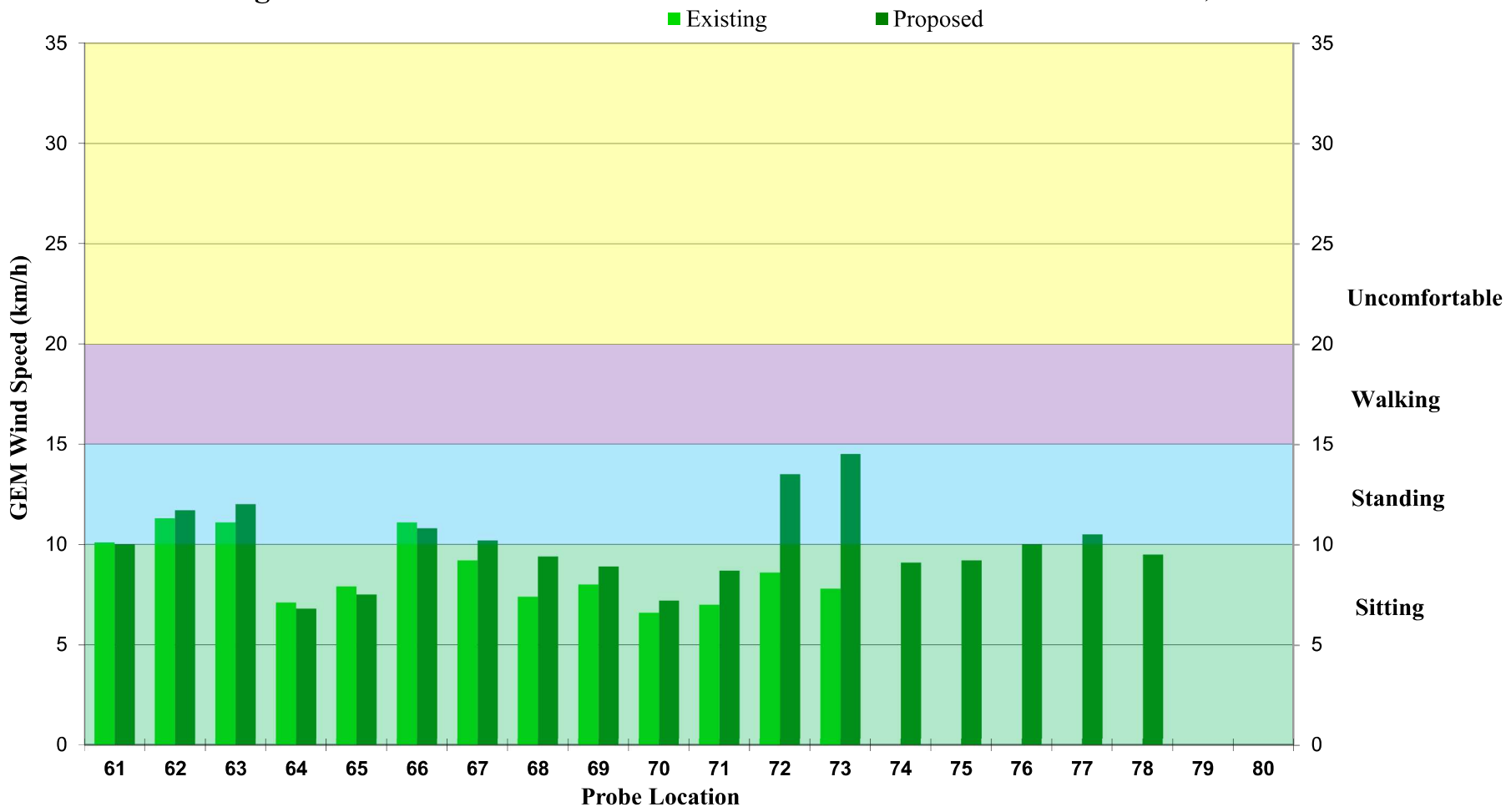


Figure 6b: SPRING - GEM Wind Speed Exceeded 20% of the Time (Locations 1 to 20).

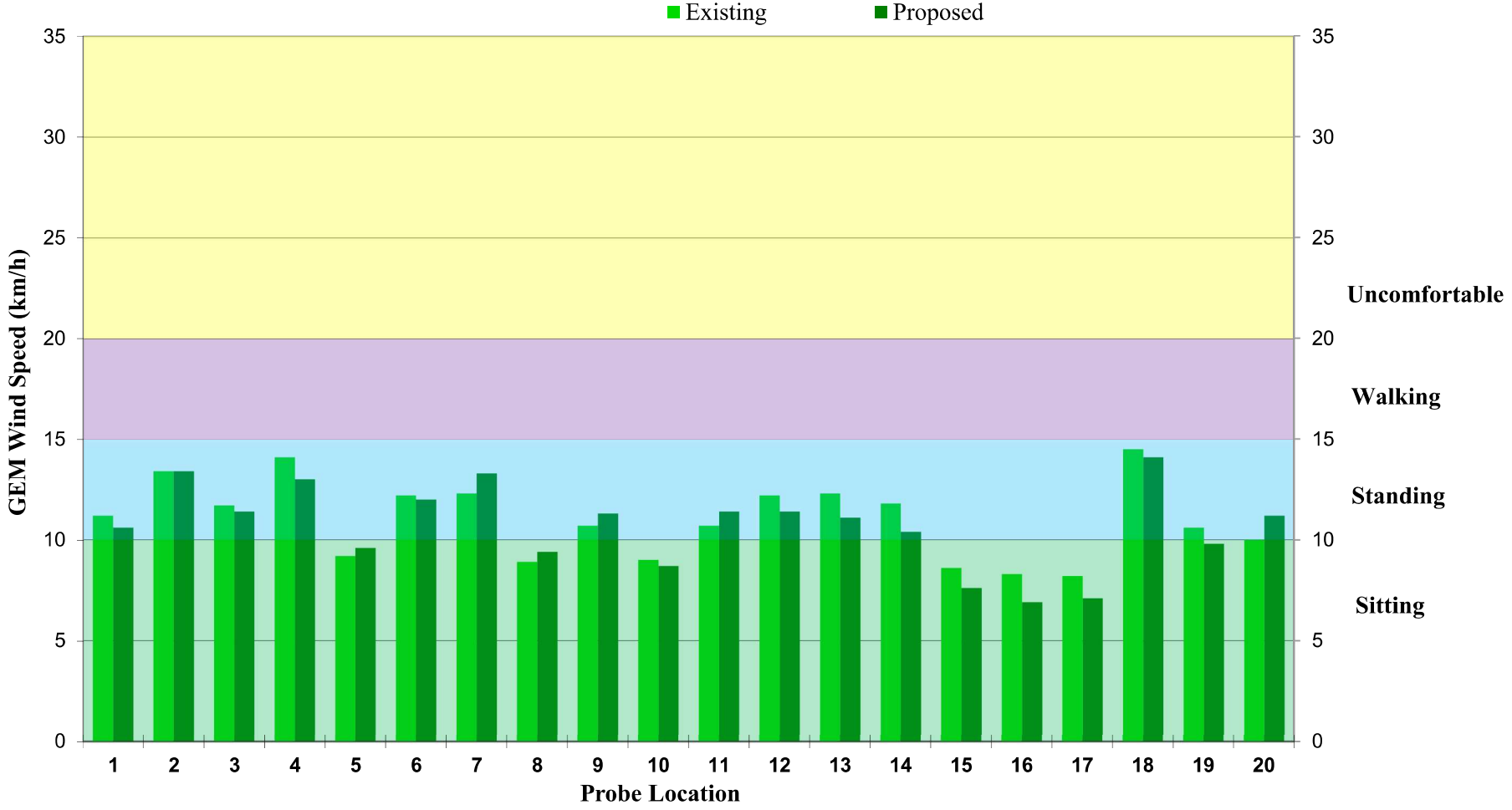


Figure 6b: SPRING - GEM Wind Speed Exceeded 20% of the Time (Locations 21 to 40).

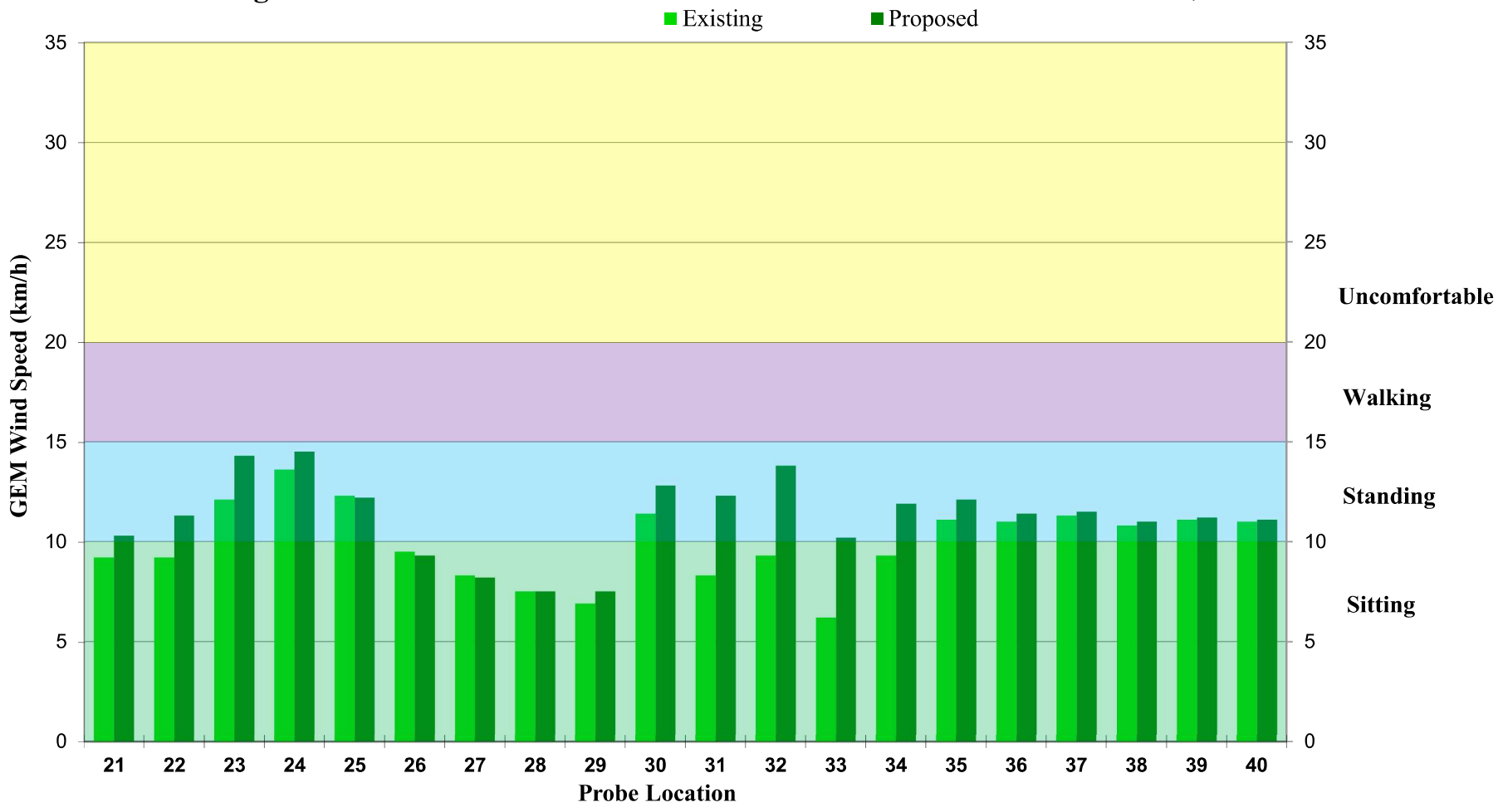


Figure 6b: SPRING - GEM Wind Speed Exceeded 20% of the Time (Locations 41 to 60).

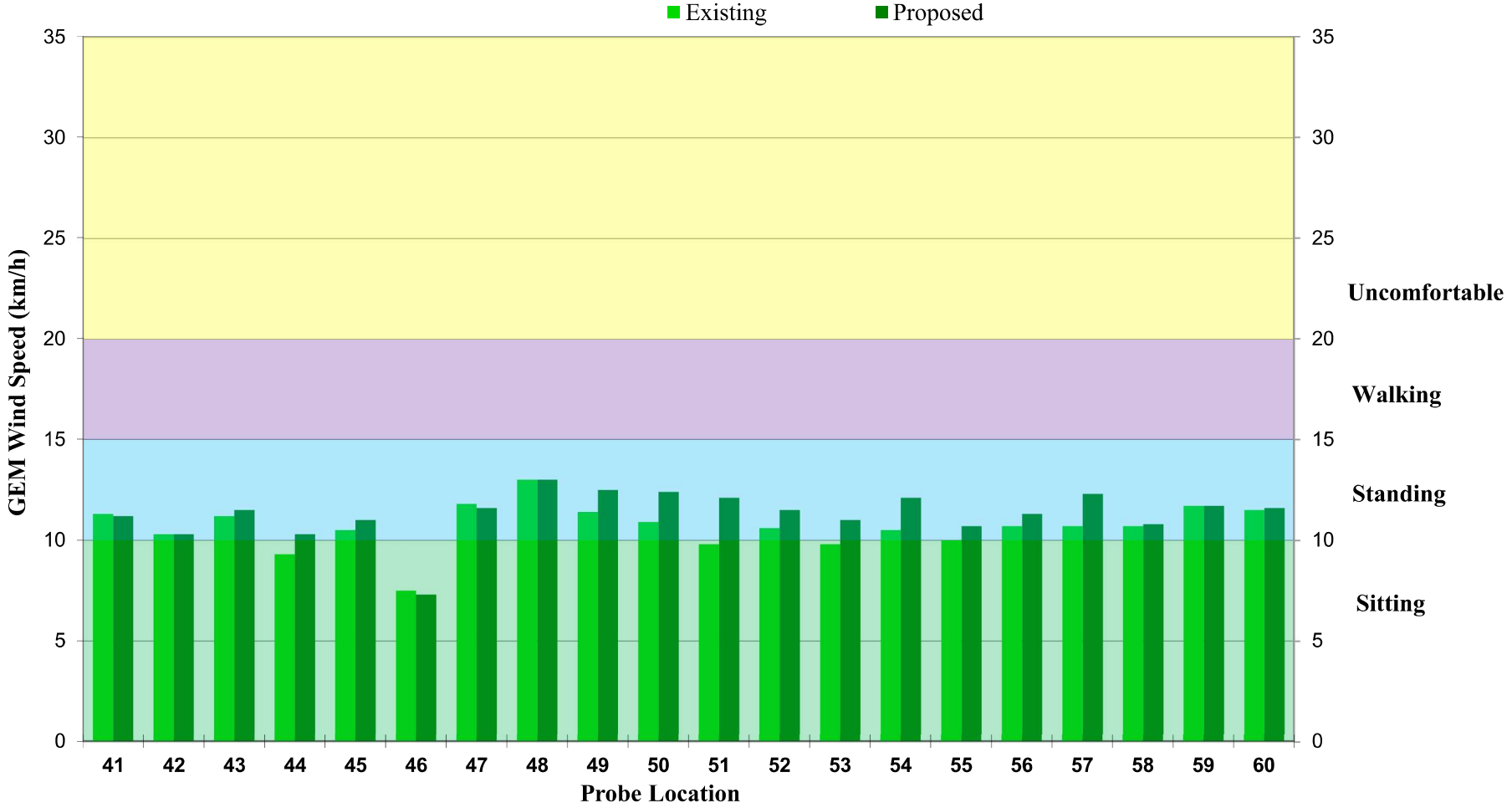
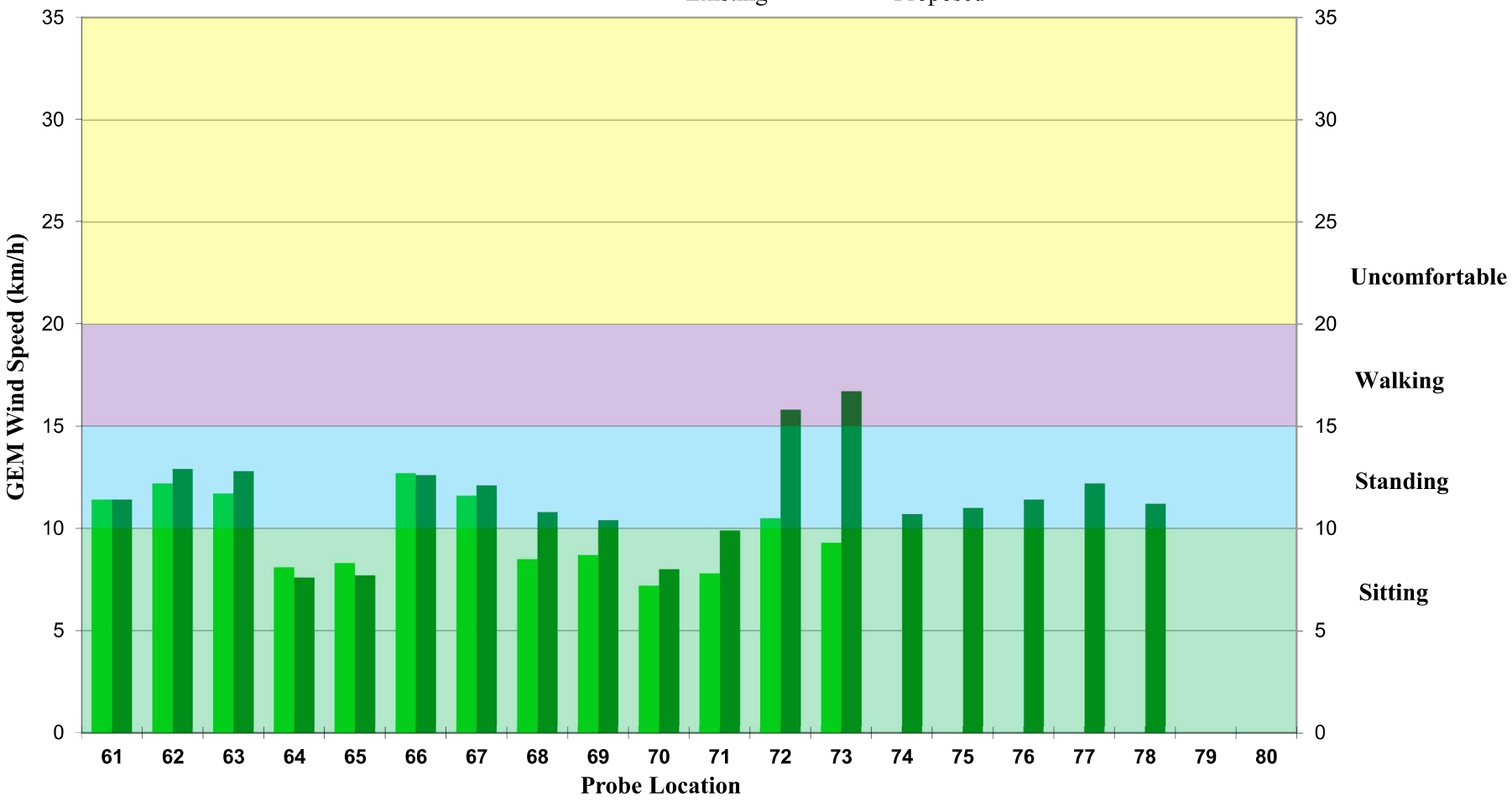


Figure 6b: SPRING - GEM Wind Speed Exceeded 20% of the Time (Locations 61 to 78).



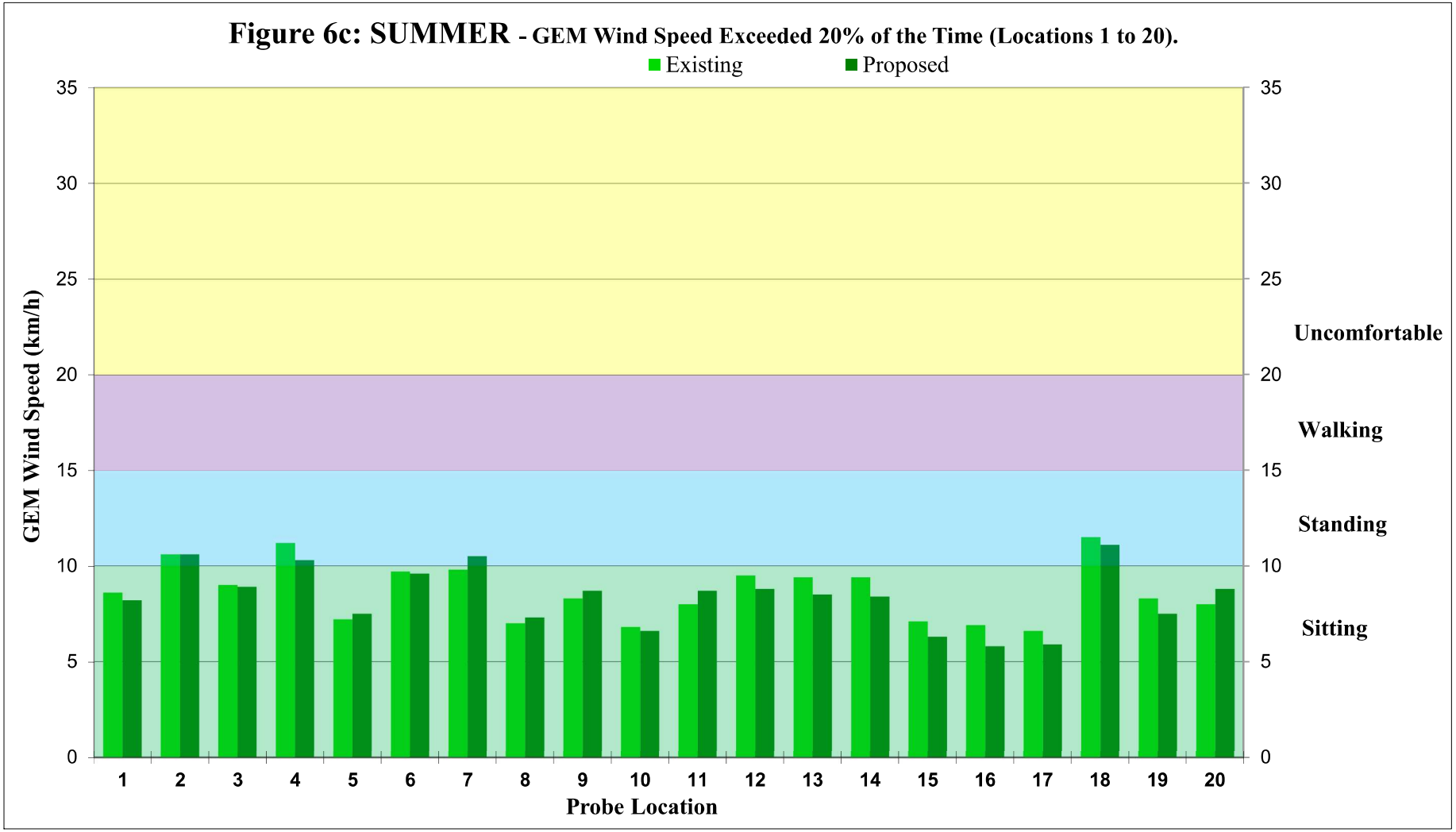
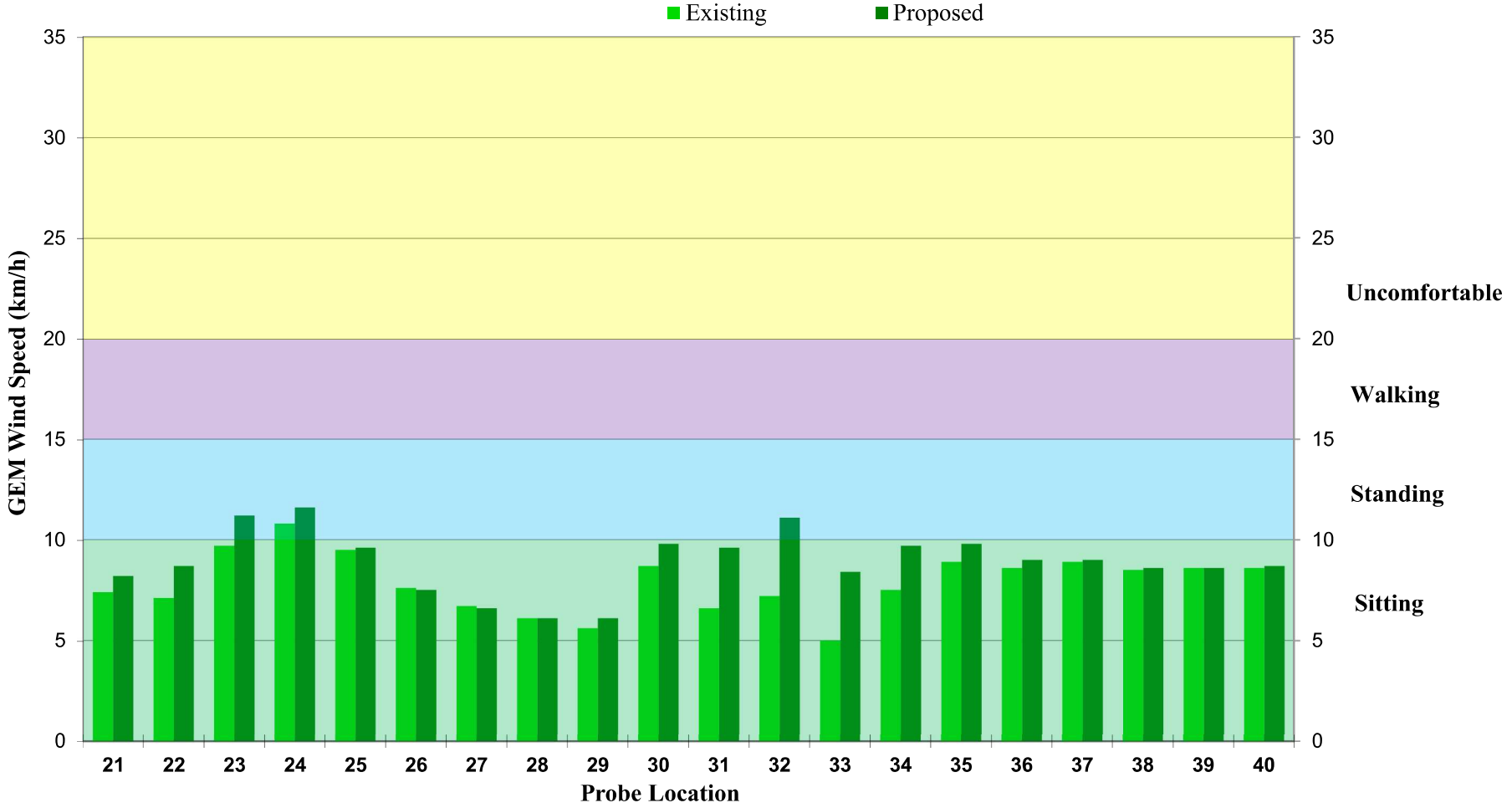


Figure 6c: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
GEM Wind Speed (km/h)
35
30
25
20
15
10
5
0
Uncomfortable
Walking
Standing
Sitting
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Probe Location

Figure 6c: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 21 to 40).



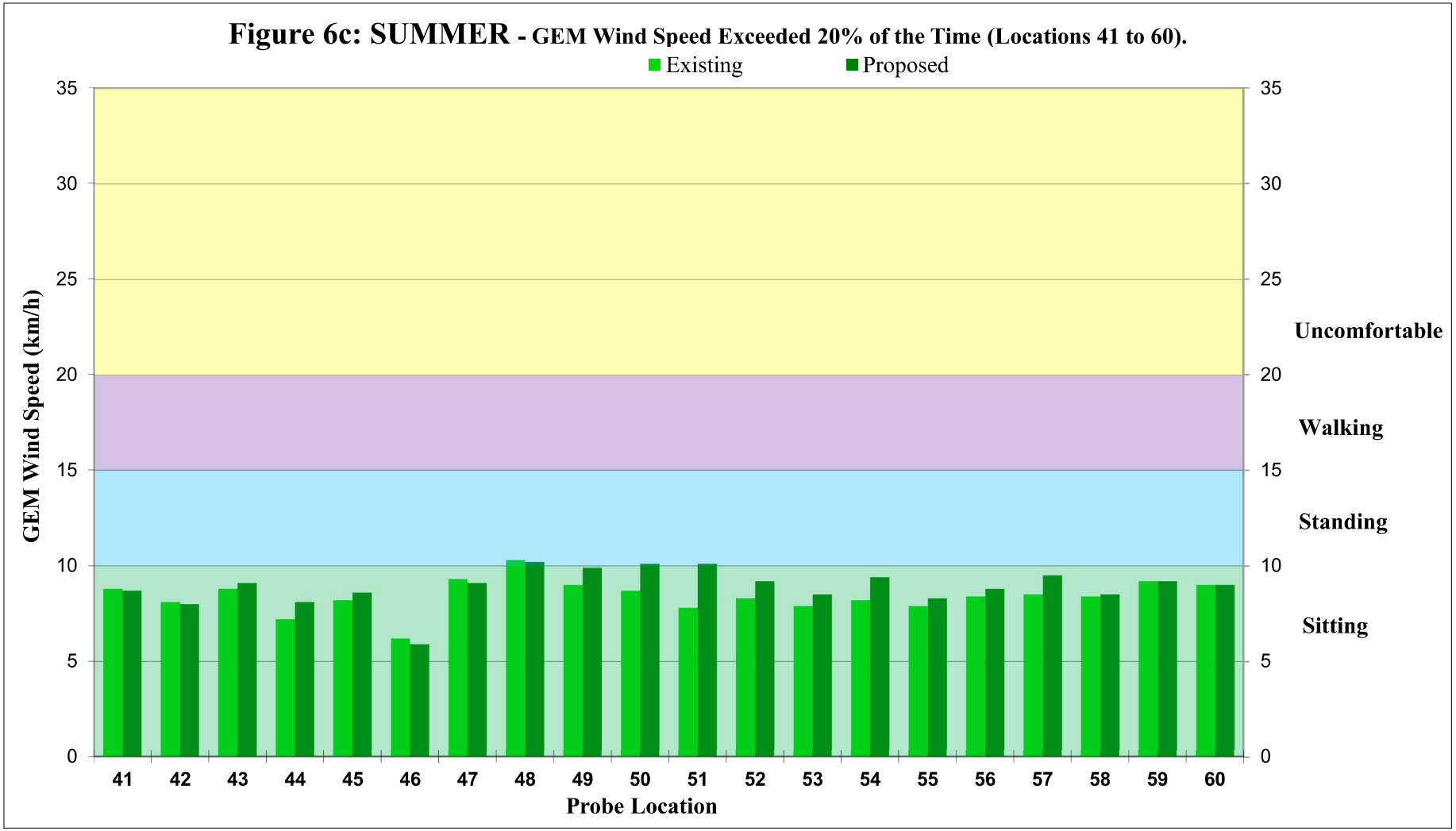


Figure 6c: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 41 to 60).
Existing
Proposed
GEM Wind Speed (km/h)
35
30
25
20
15
10
5
0
Uncomfortable
Walking
Standing
Sitting
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Probe Location

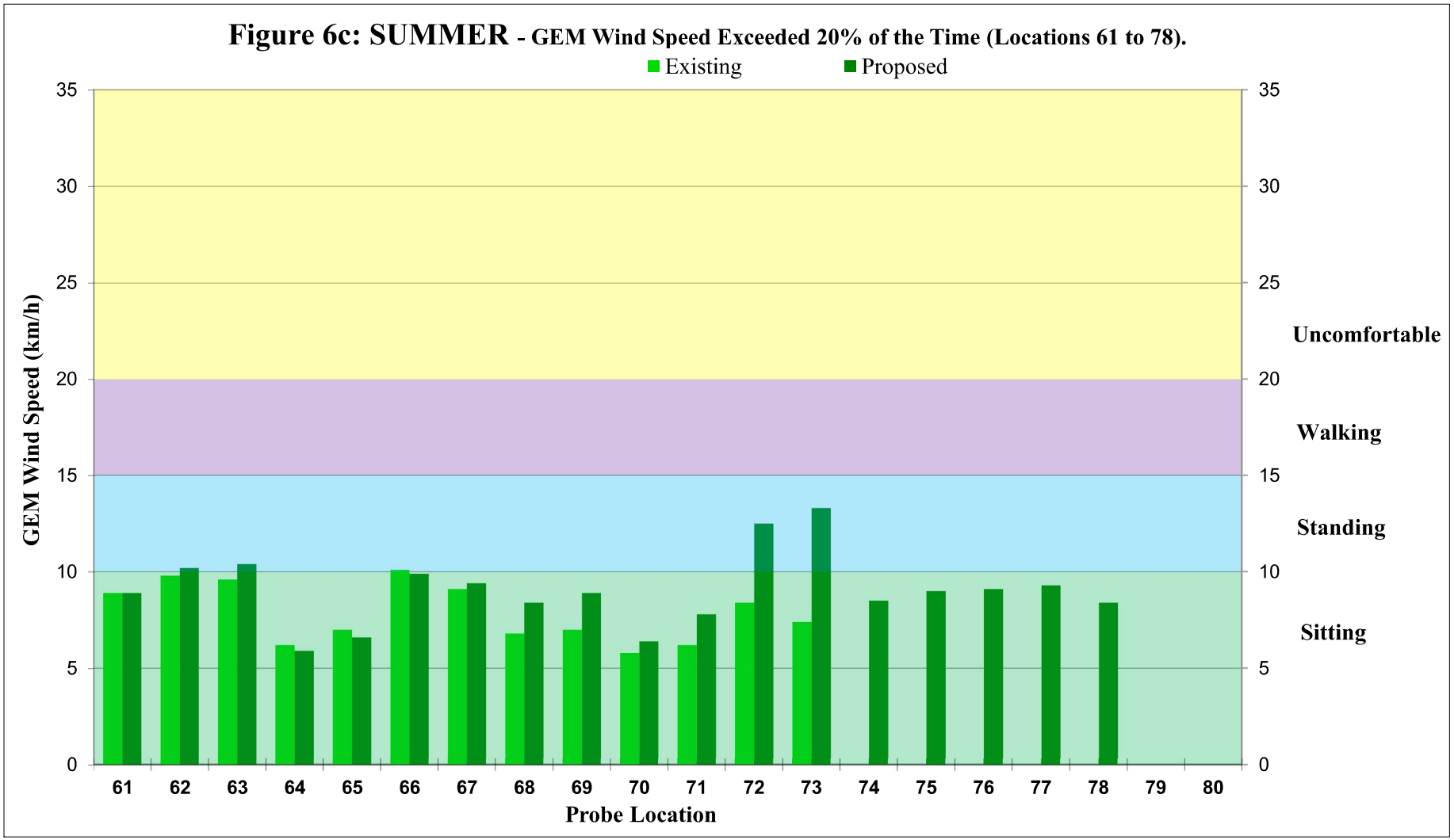


Figure 6c: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 61 to 78).
Existing
Proposed
GEM Wind Speed (km/h)
35
30
25
20
15
10
5
0
Uncomfortable
Walking
Standing
Sitting
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
Probe Location

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

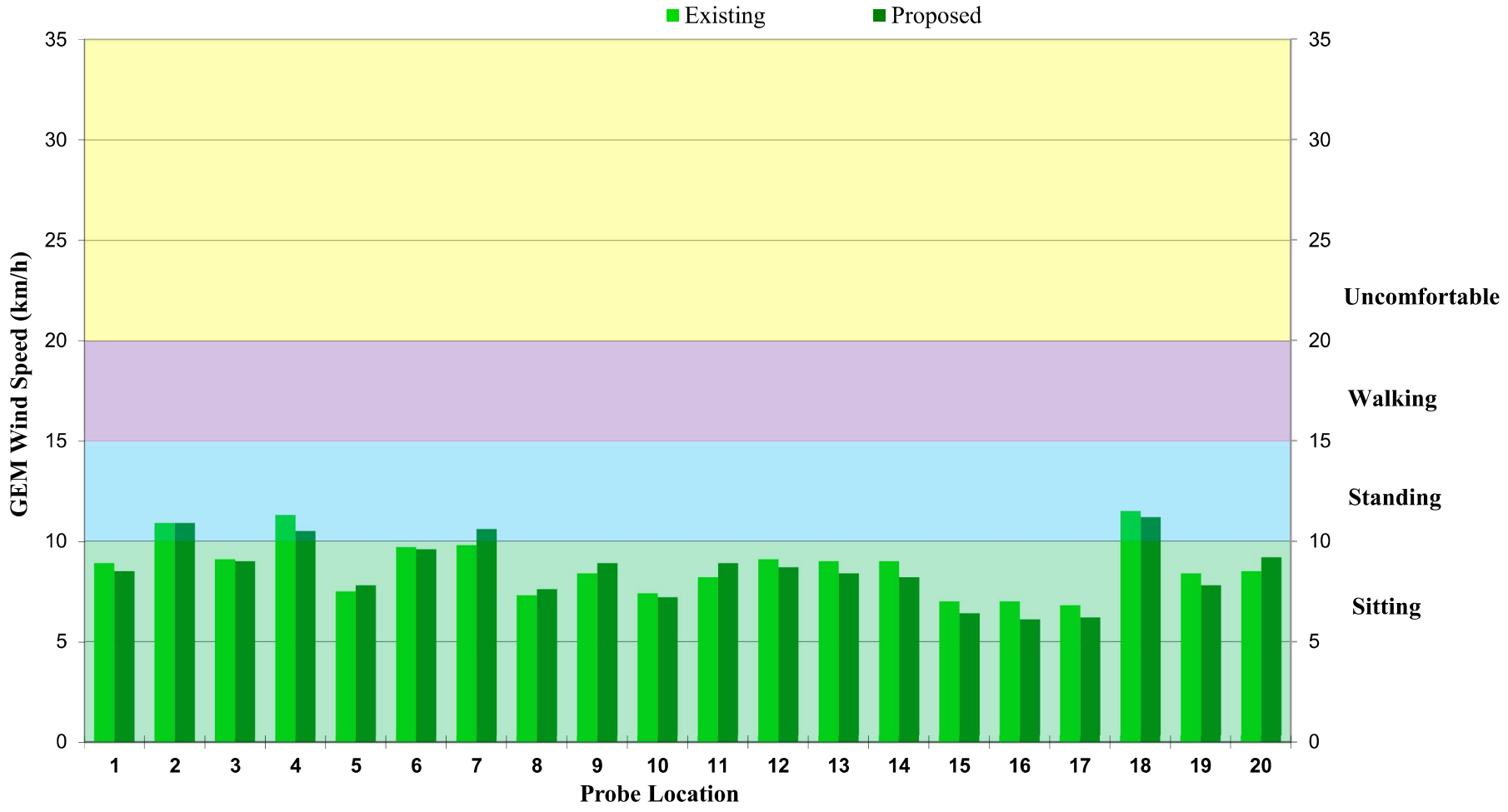


Figure 6d: FALL - GEM Wind Speed Exceeded 20% of the Time (Locations 21 to 40).

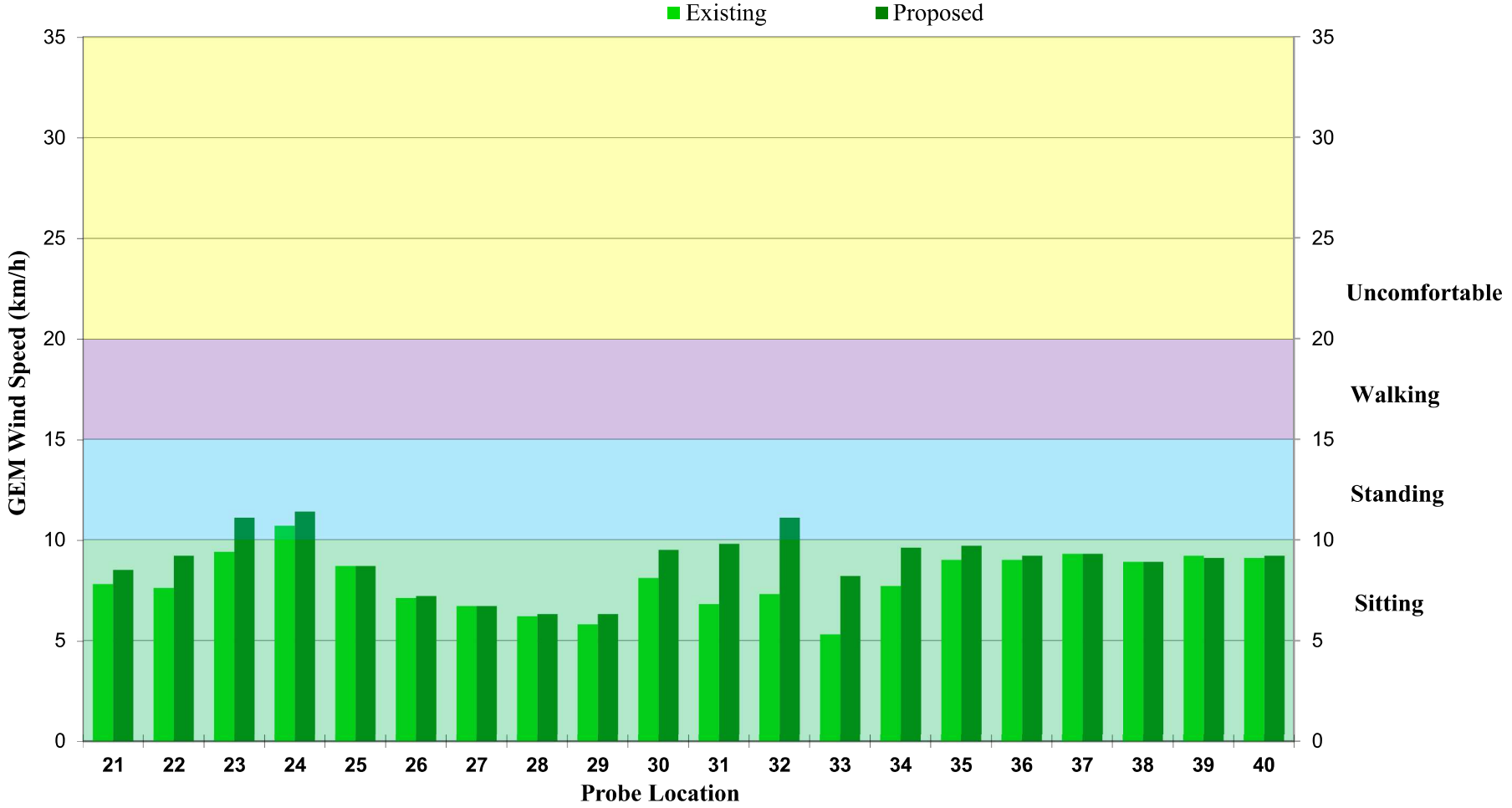


Figure 6d: FALL - GEM Wind Speed Exceeded 20% of the Time (Locations 41 to 60).

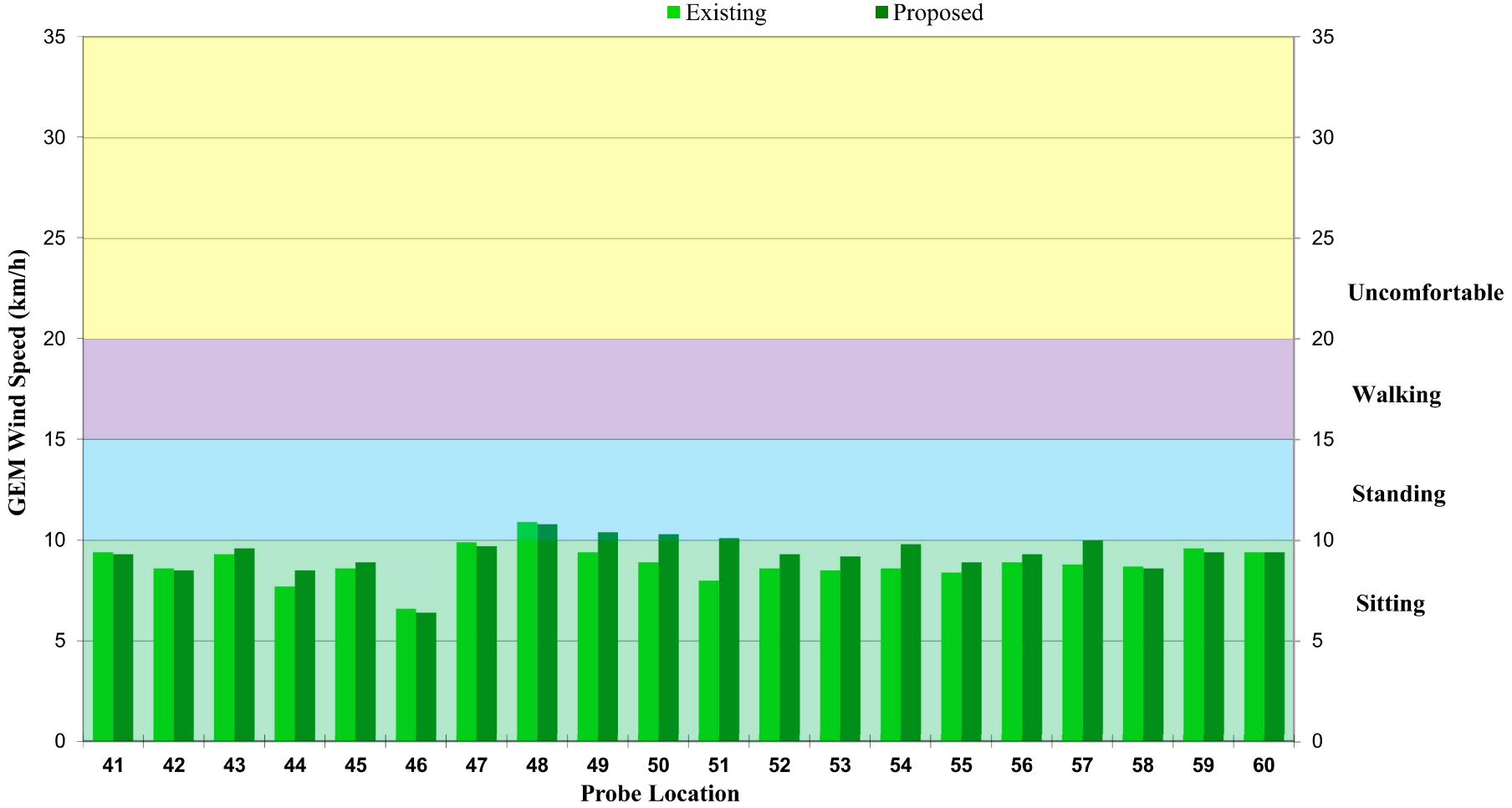


Figure 6d: FALL - GEM Wind Speed Exceeded 20% of the Time (Locations 61 to 78).

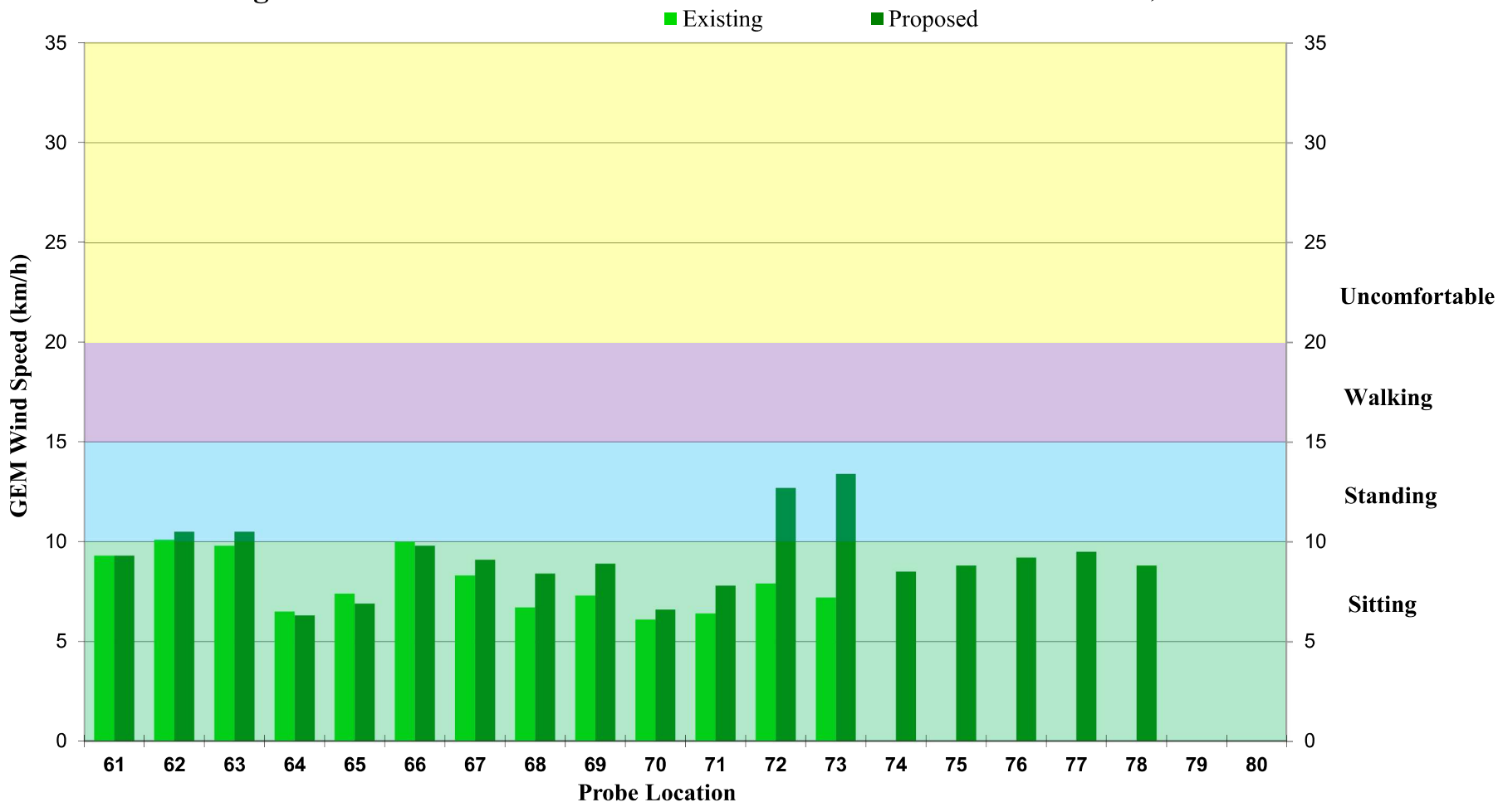


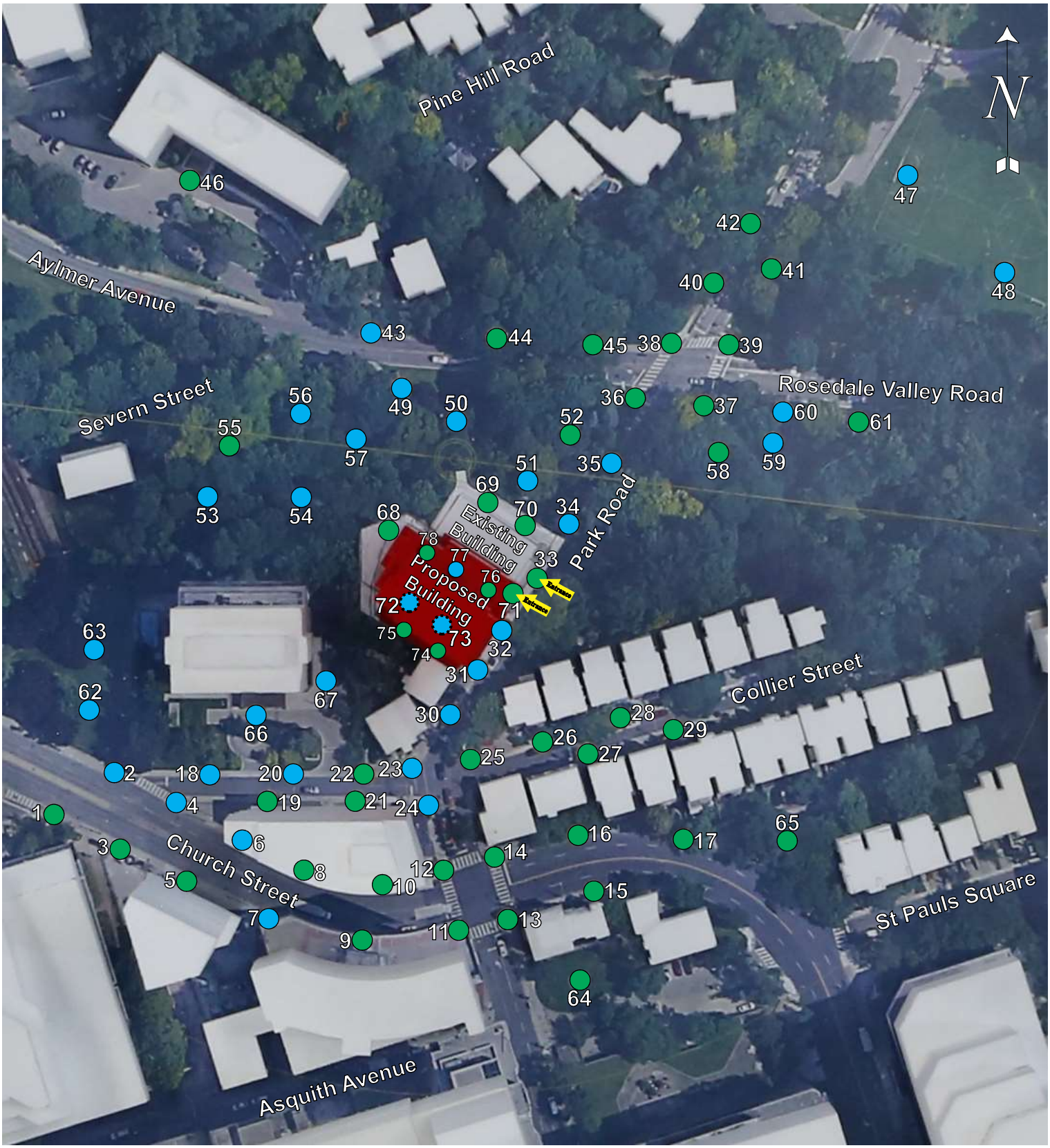
Figure 7a: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Winter - Existing

Sitting Standing Walking Uncomfortable

Figure 7b: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Winter - Proposed

Sitting Standing Walking Uncomfortable

Theakston Environmental

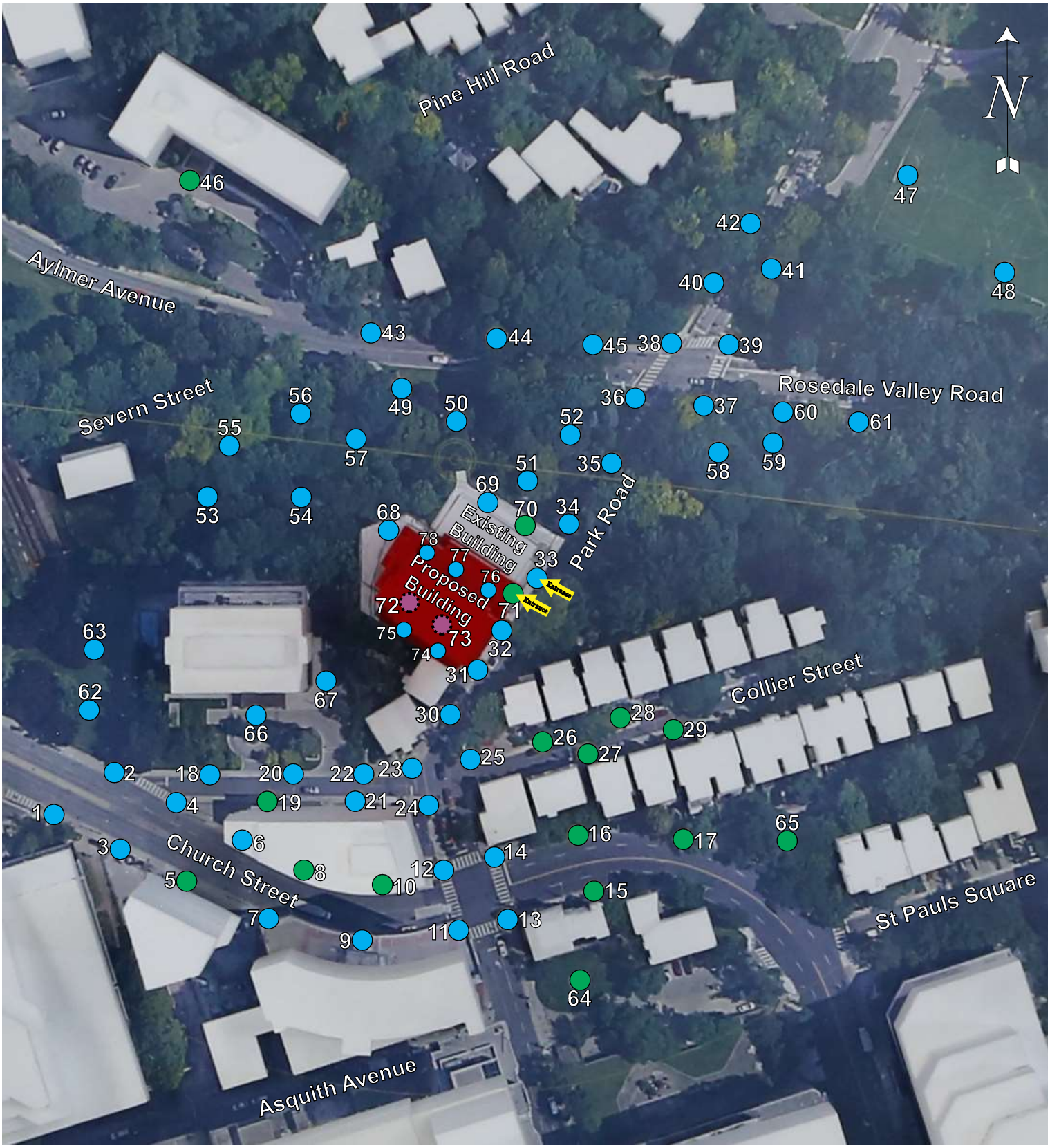
Figure 7c: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Spring - Existing

Sitting Standing Walking Uncomfortable

Figure 7d: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Spring - Proposed

Sitting Standing Walking Uncomfortable

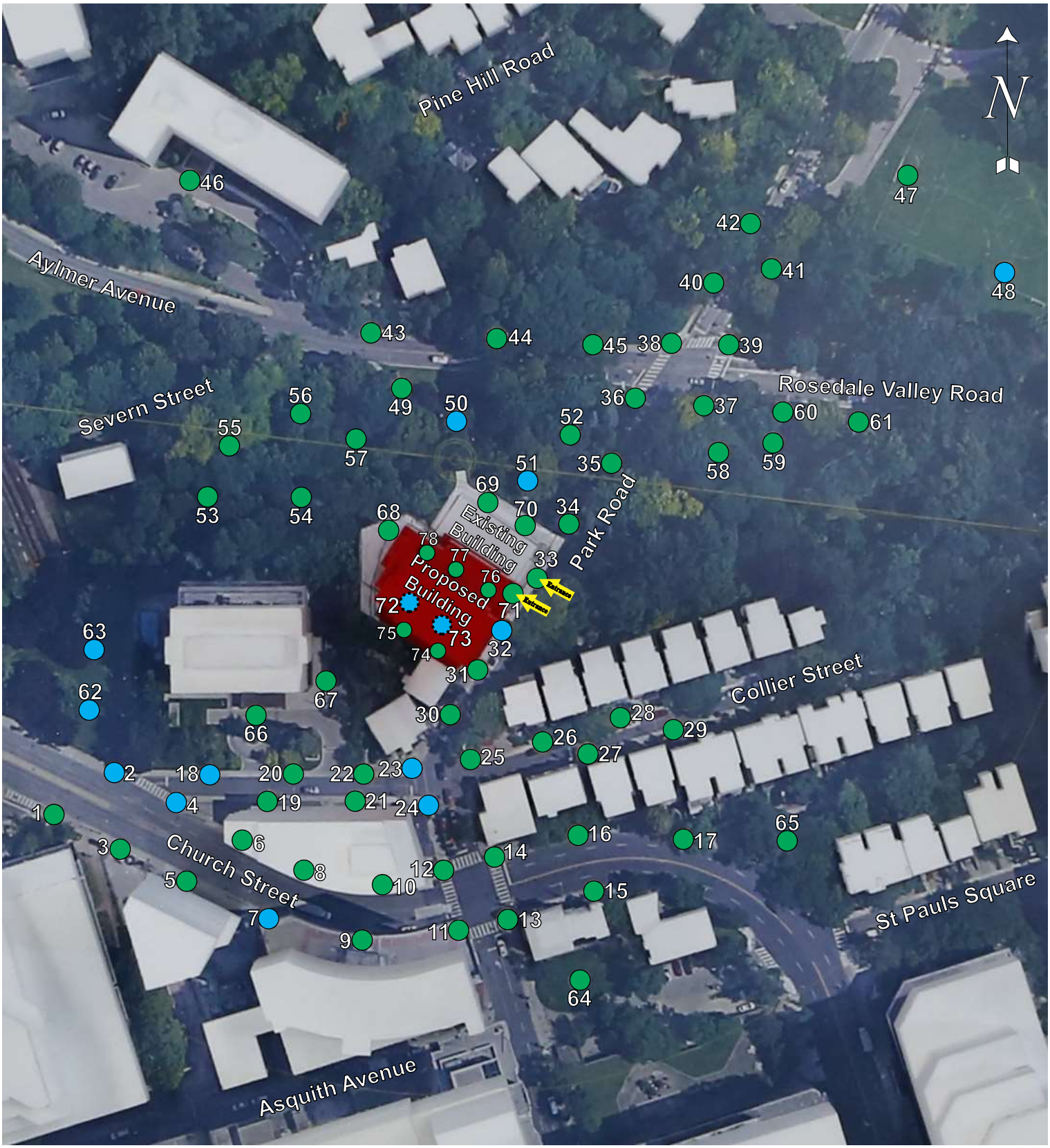
Figure 7e: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Summer - Existing

Sitting Standing Walking Uncomfortable

Figure 7f: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Summer - Proposed

Sitting Standing Walking Uncomfortable

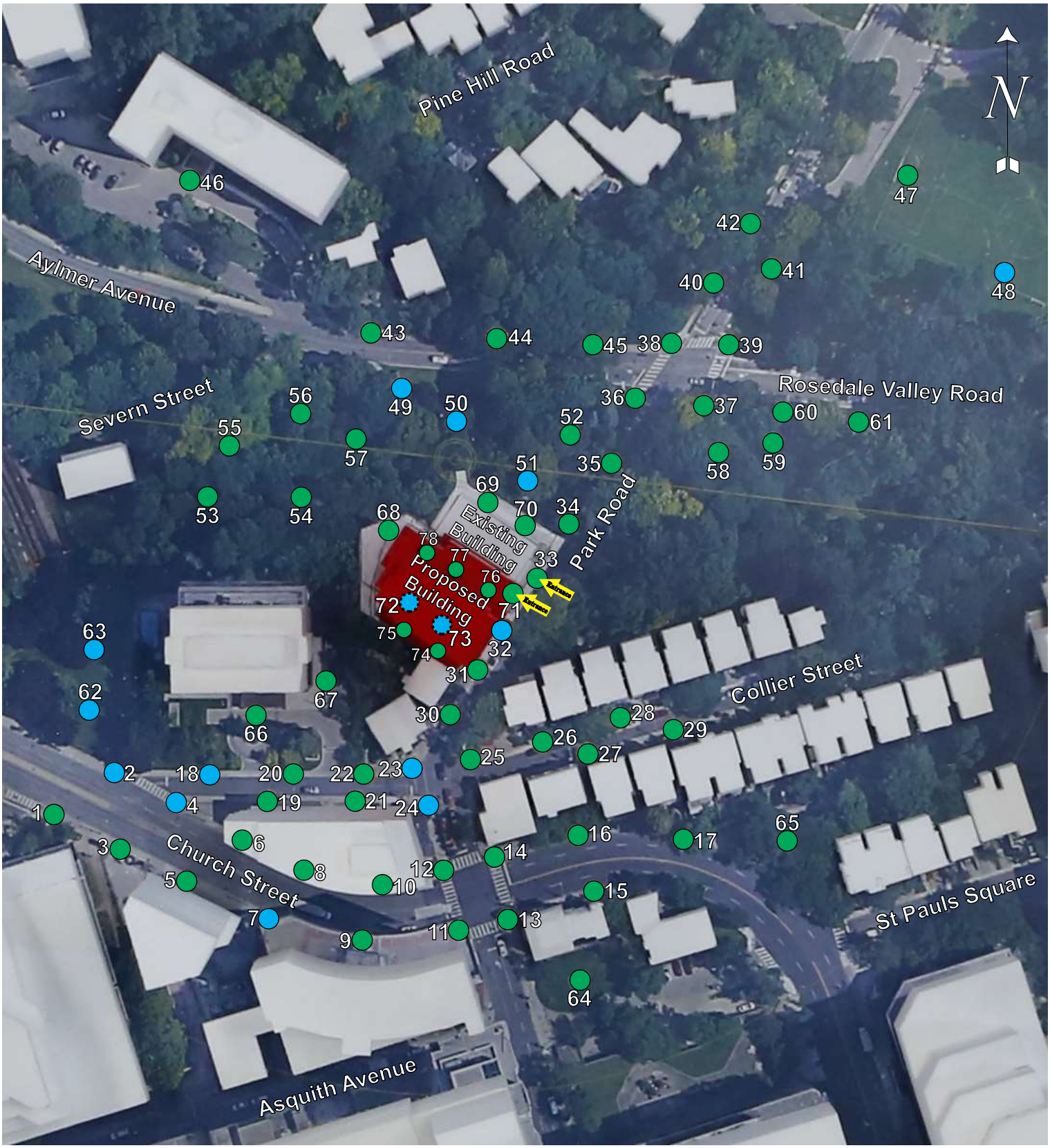
Figure 7g: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Fall - Existing

Sitting Standing Walking Uncomfortable

Figure 7h: Pedestrian Level Wind Velocity Comfort Categories



Comfort Categories - Fall - Proposed

Sitting Standing Walking Uncomfortable

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

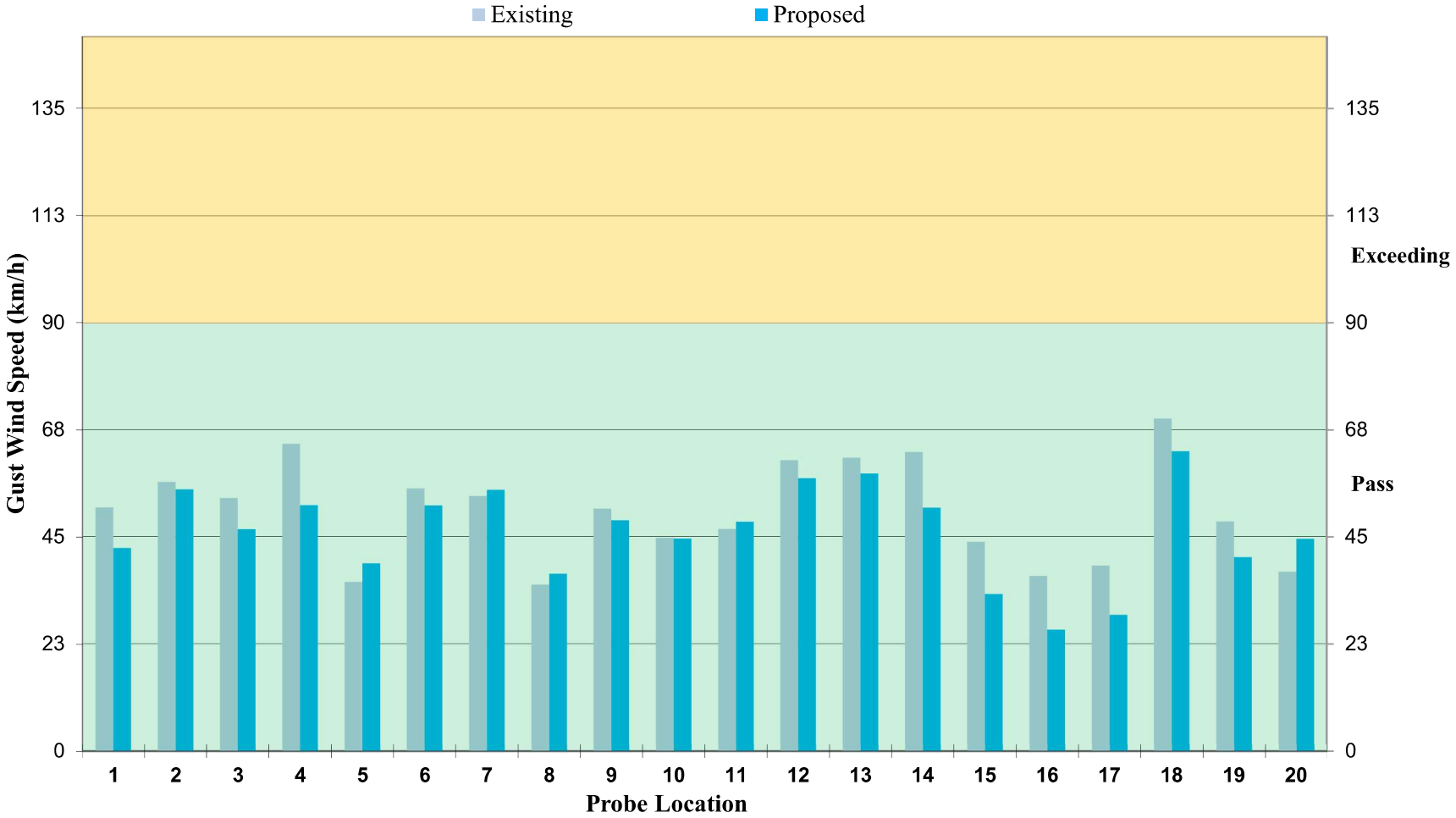


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 21 to 40).

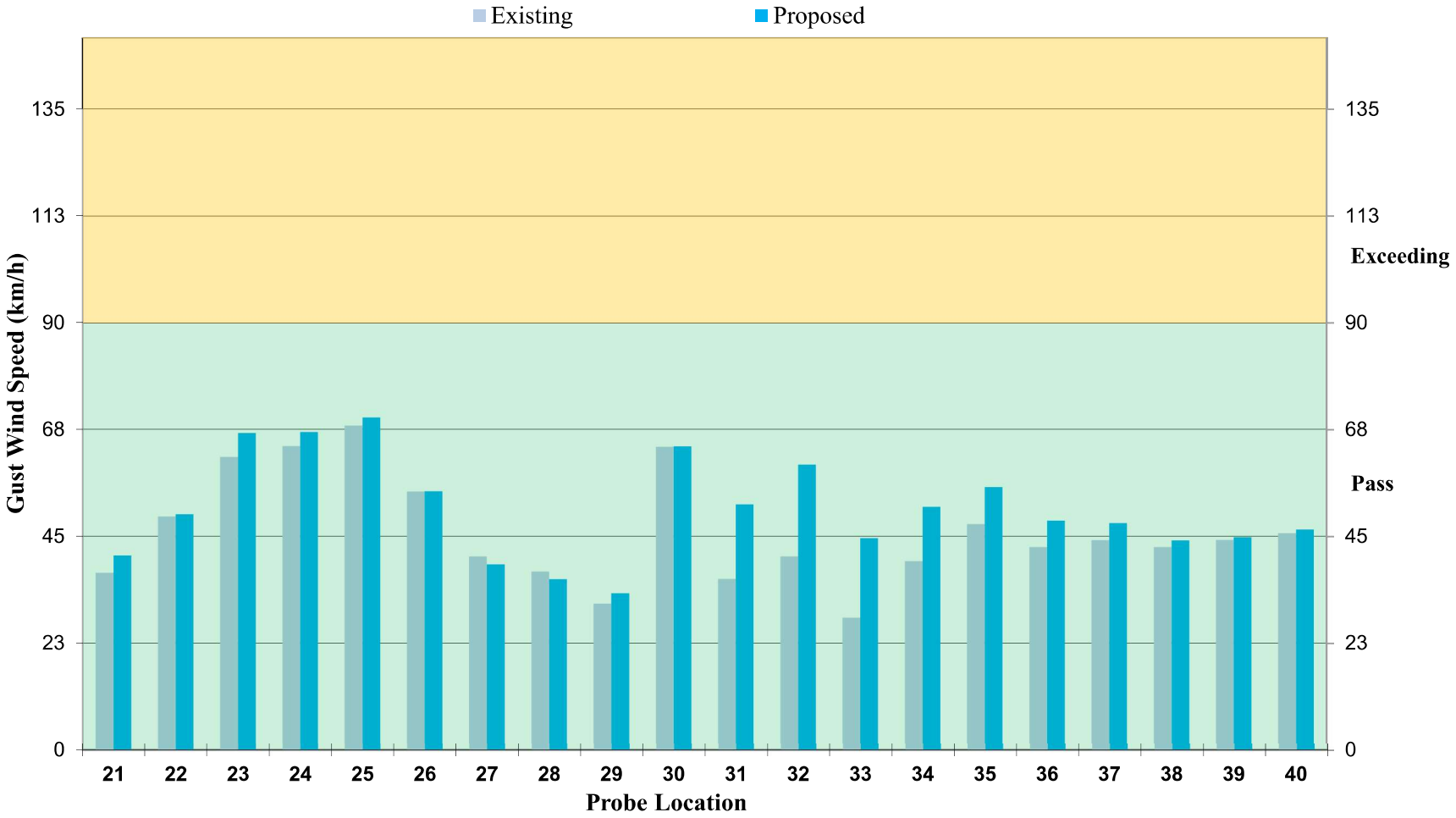


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 41 to 60).

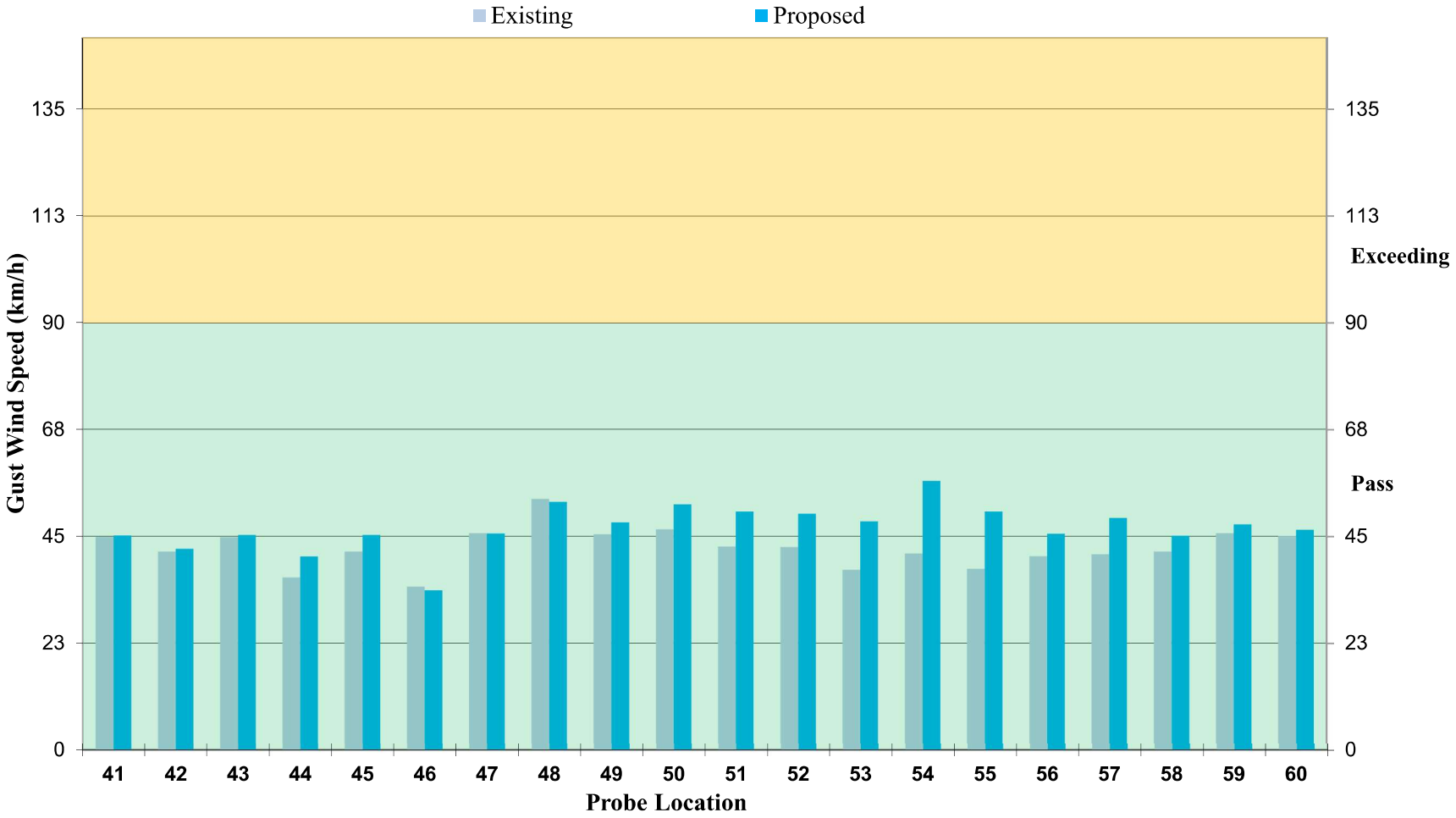


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 61 to 78).

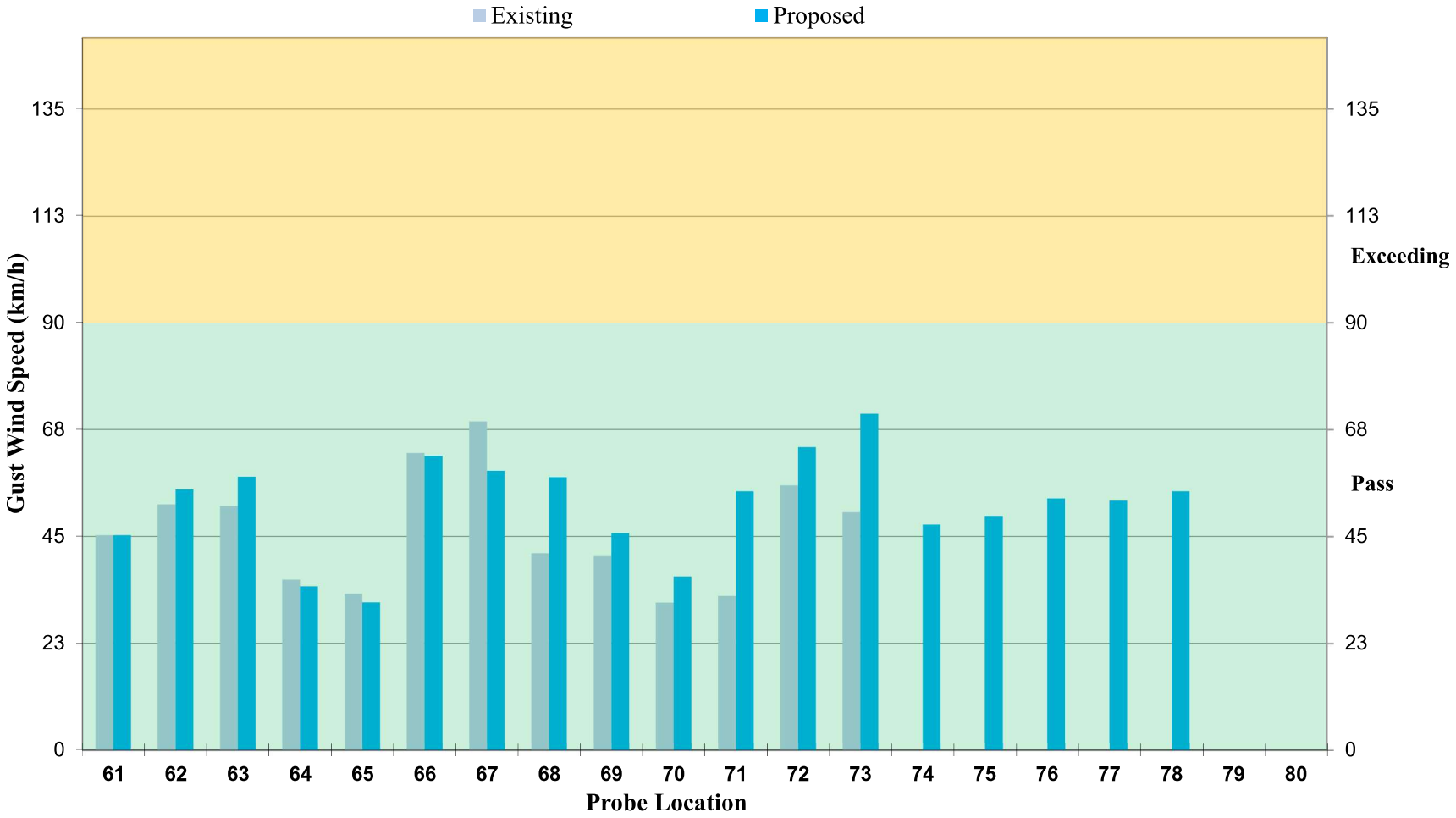


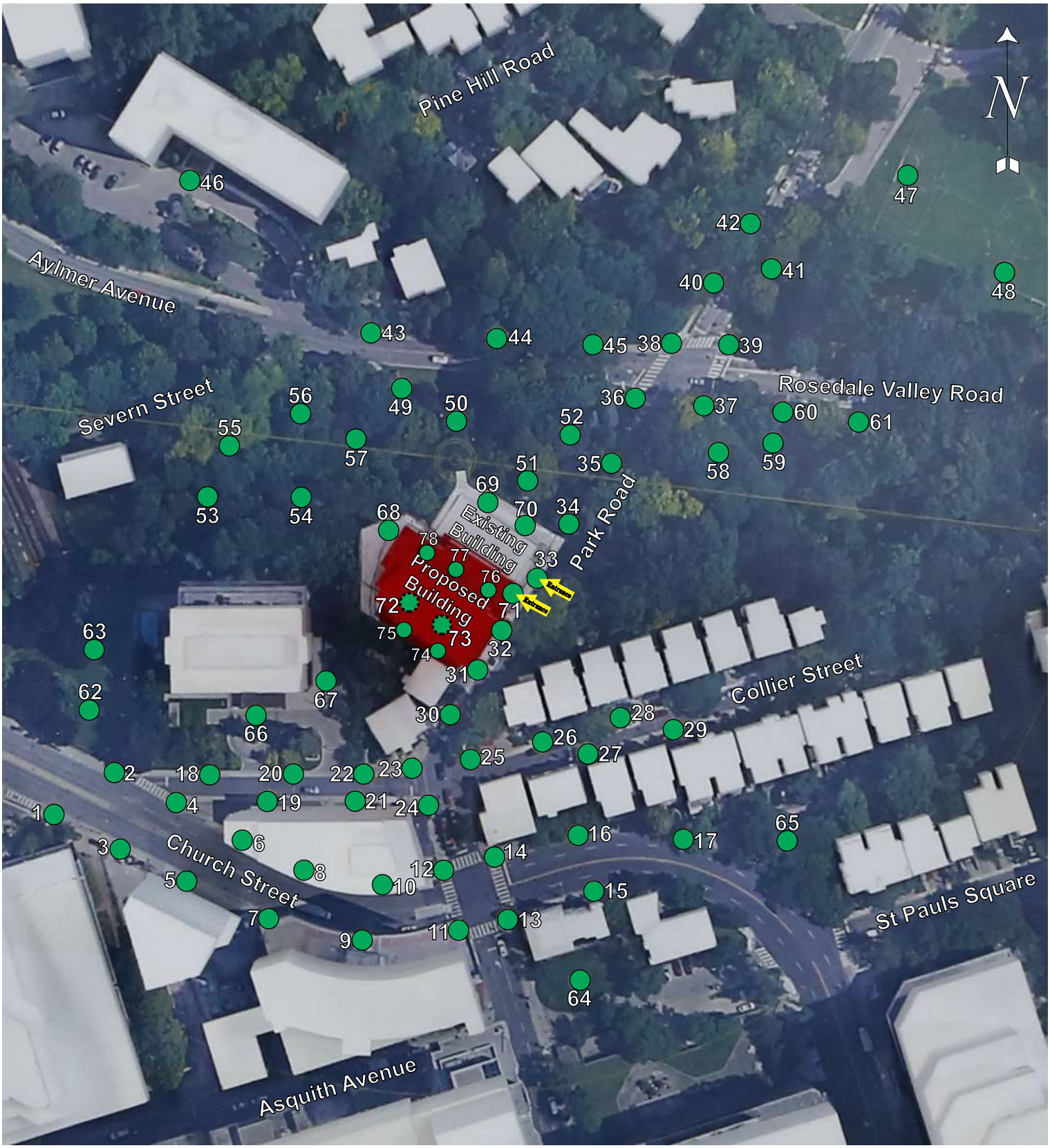
Figure 9a: Pedestrian Level Wind Velocity Safety Criteria



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

	GEM Speed (km/h)								Gust Speed (km/h)	
	Winter		Spring		Summer		Fall		Safety	
Probe	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
1	9.9	9.4	11.2	10.6	8.6	8.2	8.9	8.5	51.2	42.6
2	12.2	12.1	13.4	13.4	10.6	10.6	10.9	10.9	56.5	55.0
3	10.2	10.0	11.7	11.4	9.0	8.9	9.1	9.0	53.1	46.6
4	12.5	11.7	14.1	13.0	11.2	10.3	11.3	10.5	64.5	51.6
5	8.2	8.6	9.2	9.6	7.2	7.5	7.5	7.8	35.5	39.4
6	10.7	10.5	12.2	12.0	9.7	9.6	9.7	9.6	55.2	51.6
7	10.8	11.7	12.3	13.3	9.8	10.5	9.8	10.6	53.6	54.8
8	8.0	8.2	8.9	9.4	7.0	7.3	7.3	7.6	34.9	37.2
9	9.4	9.8	10.7	11.3	8.3	8.7	8.4	8.9	50.9	48.5
10	8.0	7.7	9.0	8.7	6.8	6.6	7.4	7.2	44.7	44.6
11	8.9	9.6	10.7	11.4	8.0	8.7	8.2	8.9	46.6	48.1
12	10.2	9.6	12.2	11.4	9.5	8.8	9.1	8.7	61.1	57.3
13	9.9	9.1	12.3	11.1	9.4	8.5	9.0	8.4	61.6	58.3
14	9.8	8.9	11.8	10.4	9.4	8.4	9.0	8.2	62.8	51.1
15	7.5	6.8	8.6	7.6	7.1	6.3	7.0	6.4	43.9	32.9
16	7.5	6.5	8.3	6.9	6.9	5.8	7.0	6.1	36.8	25.5
17	7.5	6.7	8.2	7.1	6.6	5.9	6.8	6.2	39.0	28.6
18	12.9	12.5	14.5	14.1	11.5	11.1	11.5	11.2	69.8	63.0
19	9.4	8.7	10.6	9.8	8.3	7.5	8.4	7.8	48.2	40.7
20	9.4	10.3	10.0	11.2	8.0	8.8	8.5	9.2	37.6	44.5
21	8.6	9.5	9.2	10.3	7.4	8.2	7.8	8.5	37.3	40.9
22	8.2	10.0	9.2	11.3	7.1	8.7	7.6	9.2	49.2	49.6
23	10.3	12.2	12.1	14.3	9.7	11.2	9.4	11.1	61.7	66.7
24	11.6	12.5	13.6	14.5	10.8	11.6	10.7	11.4	64.0	66.9
25	9.8	9.7	12.3	12.2	9.5	9.6	8.7	8.7	68.3	70.0
26	7.8	7.8	9.5	9.3	7.6	7.5	7.1	7.2	54.4	54.5
27	7.3	7.3	8.3	8.2	6.7	6.6	6.7	6.7	40.7	39.1
28	6.7	6.8	7.5	7.5	6.1	6.1	6.2	6.3	37.5	36.0
29	6.3	6.9	6.9	7.5	5.6	6.1	5.8	6.3	30.8	33.0
30	9.1	10.5	11.4	12.8	8.7	9.8	8.1	9.5	63.8	63.9
31	7.3	10.7	8.3	12.3	6.6	9.6	6.8	9.8	36.0	51.7
32	8.1	12.2	9.3	13.8	7.2	11.1	7.3	11.1	40.7	60.1
33	5.7	8.8	6.2	10.2	5.0	8.4	5.3	8.2	27.8	44.6
34	8.4	10.2	9.3	11.9	7.5	9.7	7.7	9.6	39.7	51.2
35	9.9	10.4	11.1	12.1	8.9	9.8	9.0	9.7	47.6	55.4
36	9.8	10.0	11.0	11.4	8.6	9.0	9.0	9.2	42.7	48.3
37	10.1	10.0	11.3	11.5	8.9	9.0	9.3	9.3	44.2	47.7
38	9.7	9.6	10.8	11.0	8.5	8.6	8.9	8.9	42.7	44.1
39	9.9	9.8	11.1	11.2	8.6	8.6	9.2	9.1	44.2	44.8
40	9.9	10.0	11.0	11.1	8.6	8.7	9.1	9.2	45.6	46.4

	GEM Speed (km/h)								Gust Speed (km/h)	
	Winter		Spring		Summer		Fall		Safety	
Probe	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
41	10.1	10.0	11.3	11.2	8.8	8.7	9.4	9.3	44.9	45.1
42	9.3	9.1	10.3	10.3	8.1	8.0	8.6	8.5	41.8	42.4
43	10.2	10.5	11.2	11.5	8.8	9.1	9.3	9.6	44.8	45.3
44	8.3	9.1	9.3	10.3	7.2	8.1	7.7	8.5	36.3	40.7
45	9.4	9.7	10.5	11.0	8.2	8.6	8.6	8.9	41.8	45.3
46	7.3	7.1	7.5	7.3	6.2	5.9	6.6	6.4	34.4	33.6
47	10.7	10.5	11.8	11.6	9.3	9.1	9.9	9.7	45.6	45.6
48	11.9	11.8	13.0	13.0	10.3	10.2	10.9	10.8	52.8	52.2
49	10.3	11.3	11.4	12.5	9.0	9.9	9.4	10.4	45.4	47.9
50	9.7	11.0	10.9	12.4	8.7	10.1	8.9	10.3	46.4	51.7
51	8.7	10.5	9.8	12.1	7.8	10.1	8.0	10.1	42.8	50.2
52	9.4	10.0	10.6	11.5	8.3	9.2	8.6	9.3	42.7	49.7
53	9.4	10.3	9.8	11.0	7.9	8.5	8.5	9.2	37.9	48.1
54	9.4	10.5	10.5	12.1	8.2	9.4	8.6	9.8	41.4	56.6
55	9.2	9.6	10.0	10.7	7.9	8.3	8.4	8.9	38.2	50.2
56	9.7	10.2	10.7	11.3	8.4	8.8	8.9	9.3	40.8	45.5
57	9.6	10.9	10.7	12.3	8.5	9.5	8.8	10.0	41.2	48.9
58	9.5	9.4	10.7	10.8	8.4	8.5	8.7	8.6	41.8	45.1
59	10.4	10.2	11.7	11.7	9.2	9.2	9.6	9.4	45.6	47.5
60	10.3	10.1	11.5	11.6	9.0	9.0	9.4	9.4	45.0	46.3
61	10.1	10.0	11.4	11.4	8.9	8.9	9.3	9.3	45.3	45.3
62	11.3	11.7	12.2	12.9	9.8	10.2	10.1	10.5	51.8	54.9
63	11.1	12.0	11.7	12.8	9.6	10.4	9.8	10.5	51.4	57.6
64	7.1	6.8	8.1	7.6	6.2	5.9	6.5	6.3	35.9	34.5
65	7.9	7.5	8.3	7.7	7.0	6.6	7.4	6.9	32.9	31.1
66	11.1	10.8	12.7	12.6	10.1	9.9	10.0	9.8	62.6	62.0
67	9.2	10.2	11.6	12.1	9.1	9.4	8.3	9.1	69.2	58.8
68	7.4	9.4	8.5	10.8	6.8	8.4	6.7	8.4	41.5	57.5
69	8.0	8.9	8.7	10.4	7.0	8.9	7.3	8.9	40.8	45.7
70	6.6	7.2	7.2	8.0	5.8	6.4	6.1	6.6	31.1	36.6
71	7.0	8.7	7.8	9.9	6.2	7.8	6.4	7.8	32.5	54.5
72	8.6	13.5	10.5	15.8	8.4	12.5	7.9	12.7	55.8	63.8
73	7.8	14.5	9.3	16.7	7.4	13.3	7.2	13.4	50.1	70.8
74	0.0	9.1	0.0	10.7	0.0	8.5	0.0	8.5	0.0	47.5
75	0.0	9.2	0.0	11.0	0.0	9.0	0.0	8.8	0.0	49.3
76	0.0	10.0	0.0	11.4	0.0	9.1	0.0	9.2	0.0	53.0
77	0.0	10.5	0.0	12.2	0.0	9.3	0.0	9.5	0.0	52.5
78	0.0	9.5	0.0	11.2	0.0	8.4	0.0	8.8	0.0	54.5
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

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:

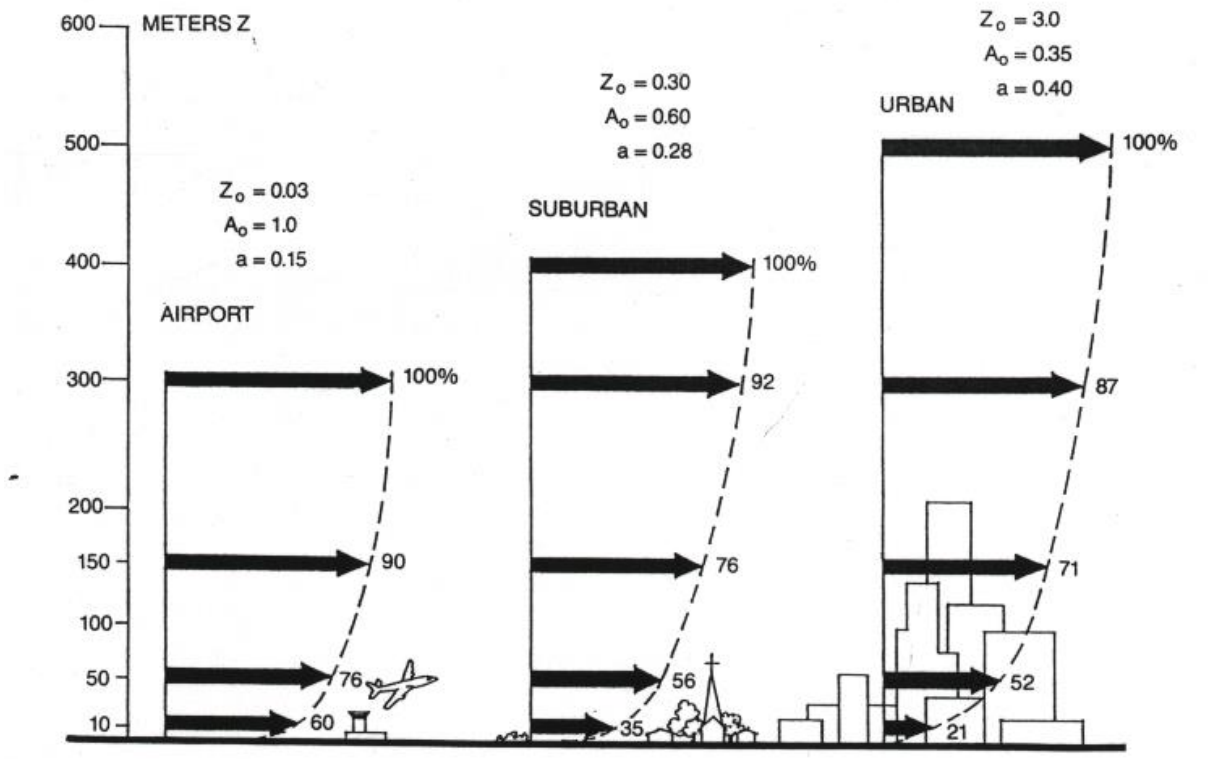


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

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.

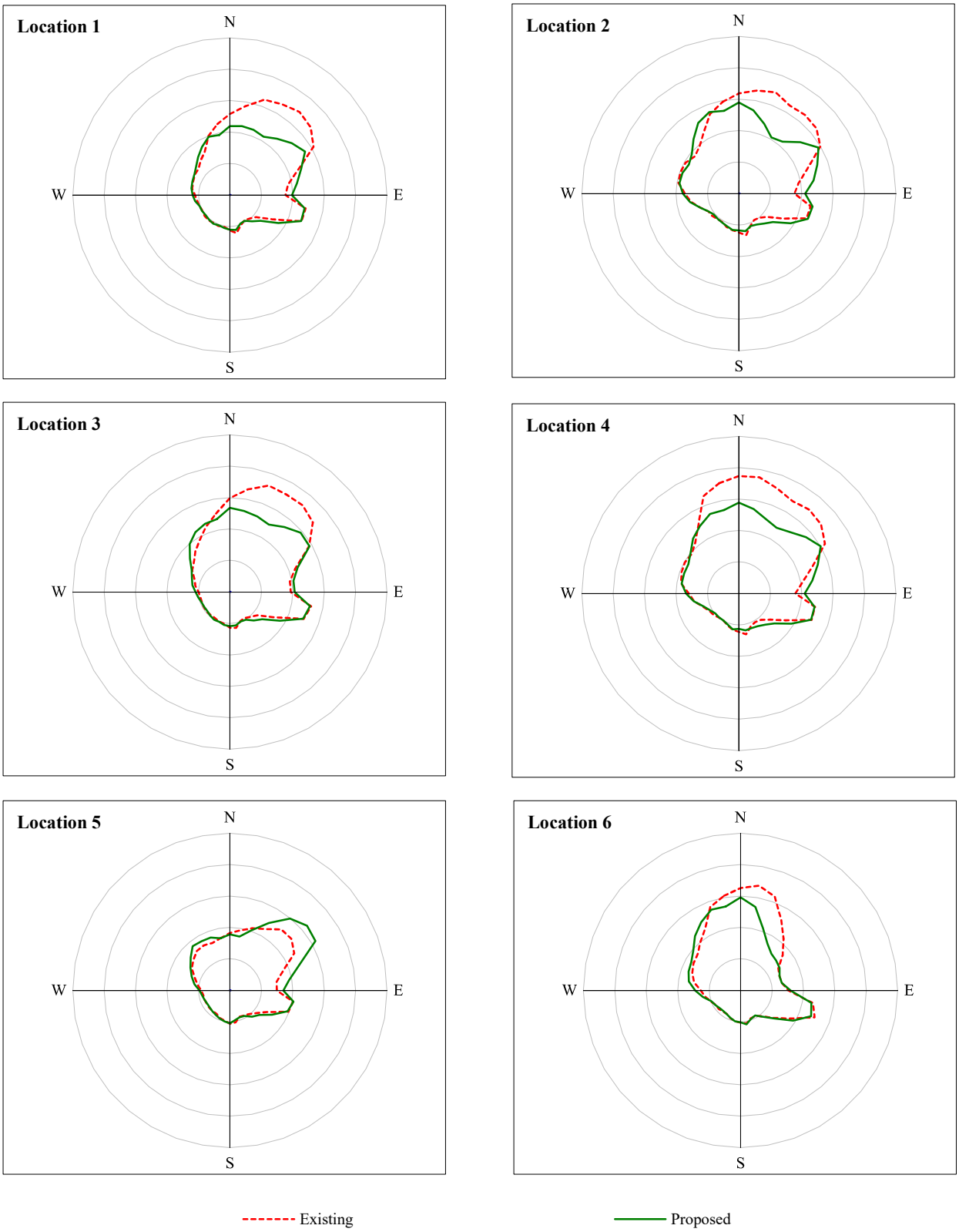
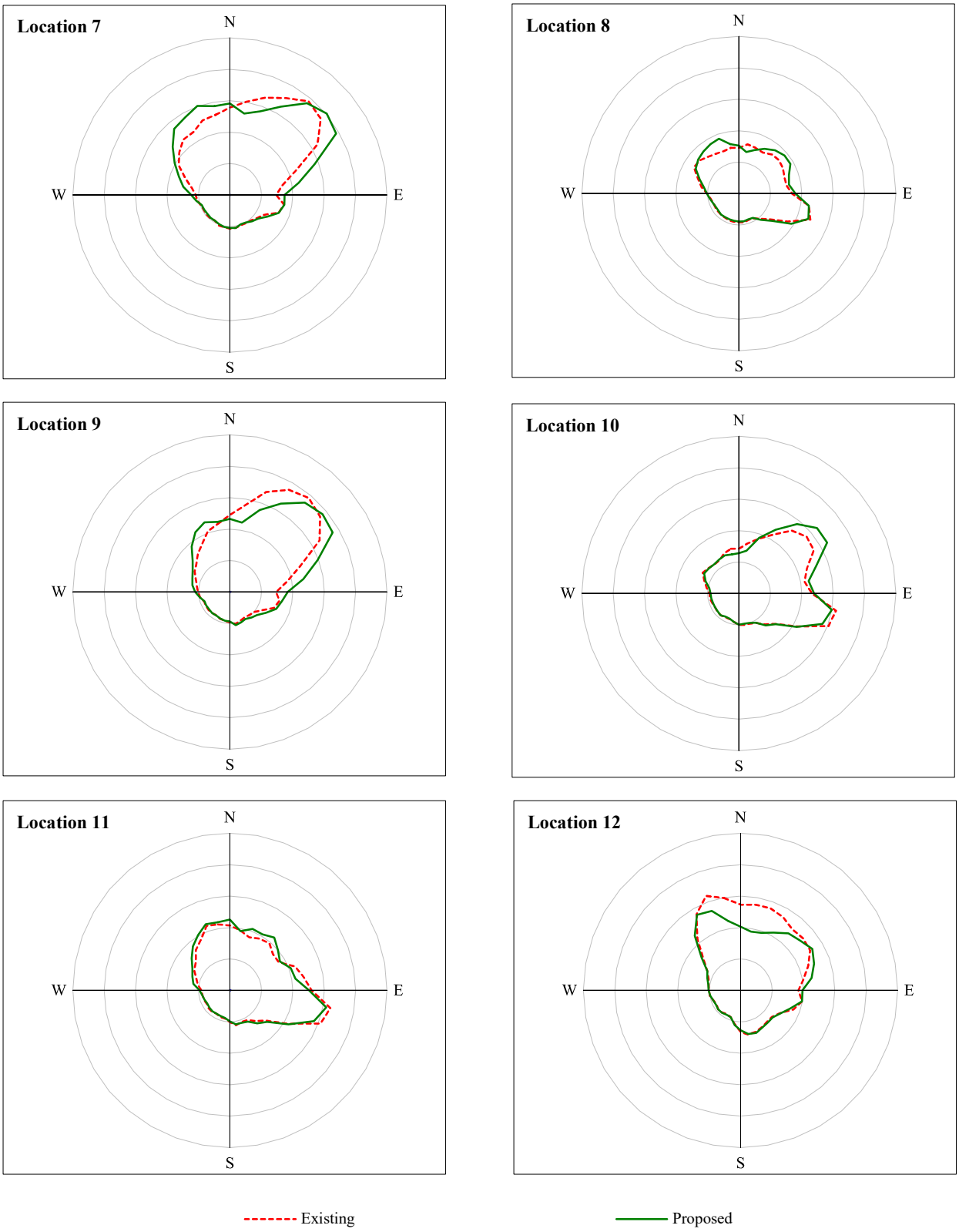


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



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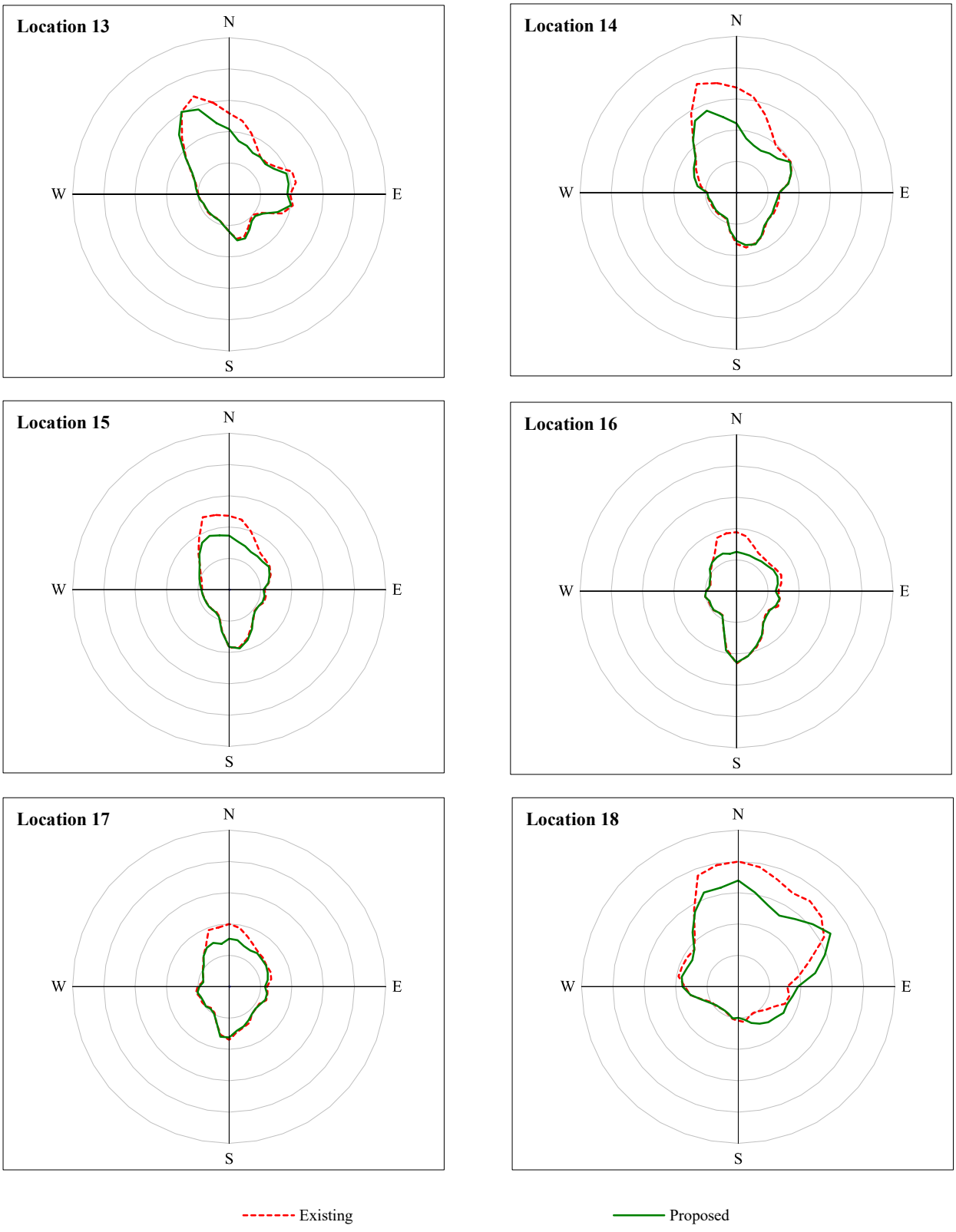

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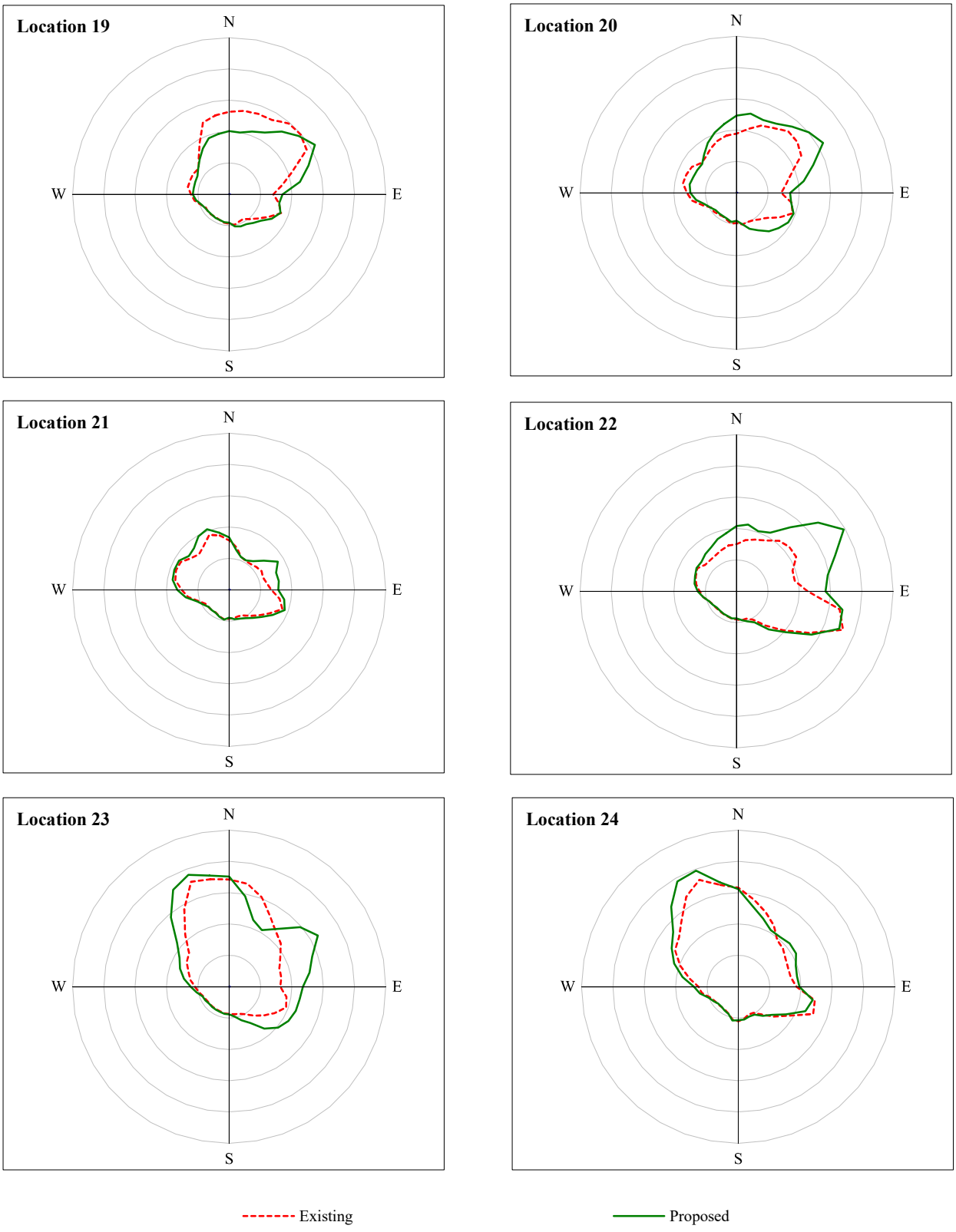

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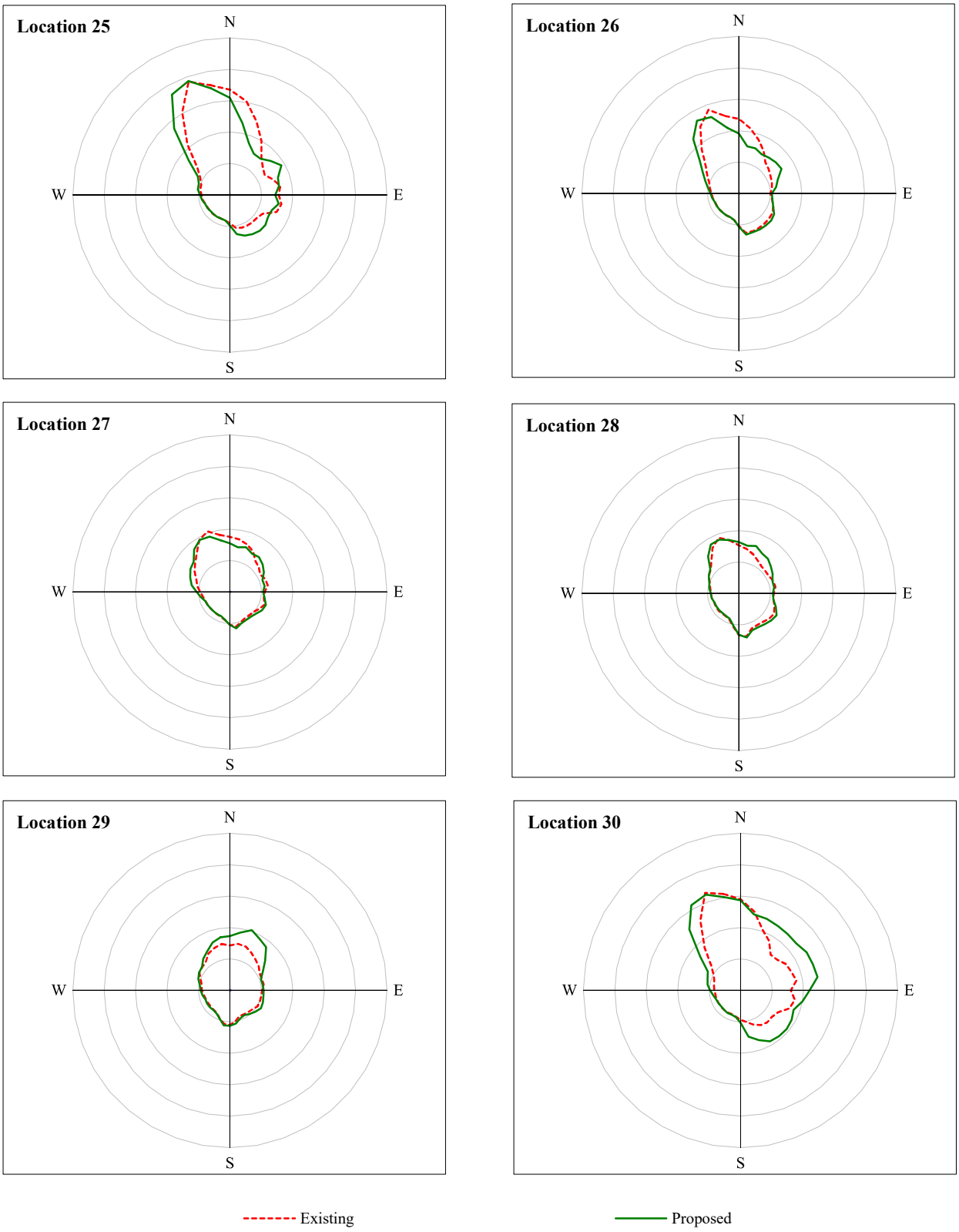

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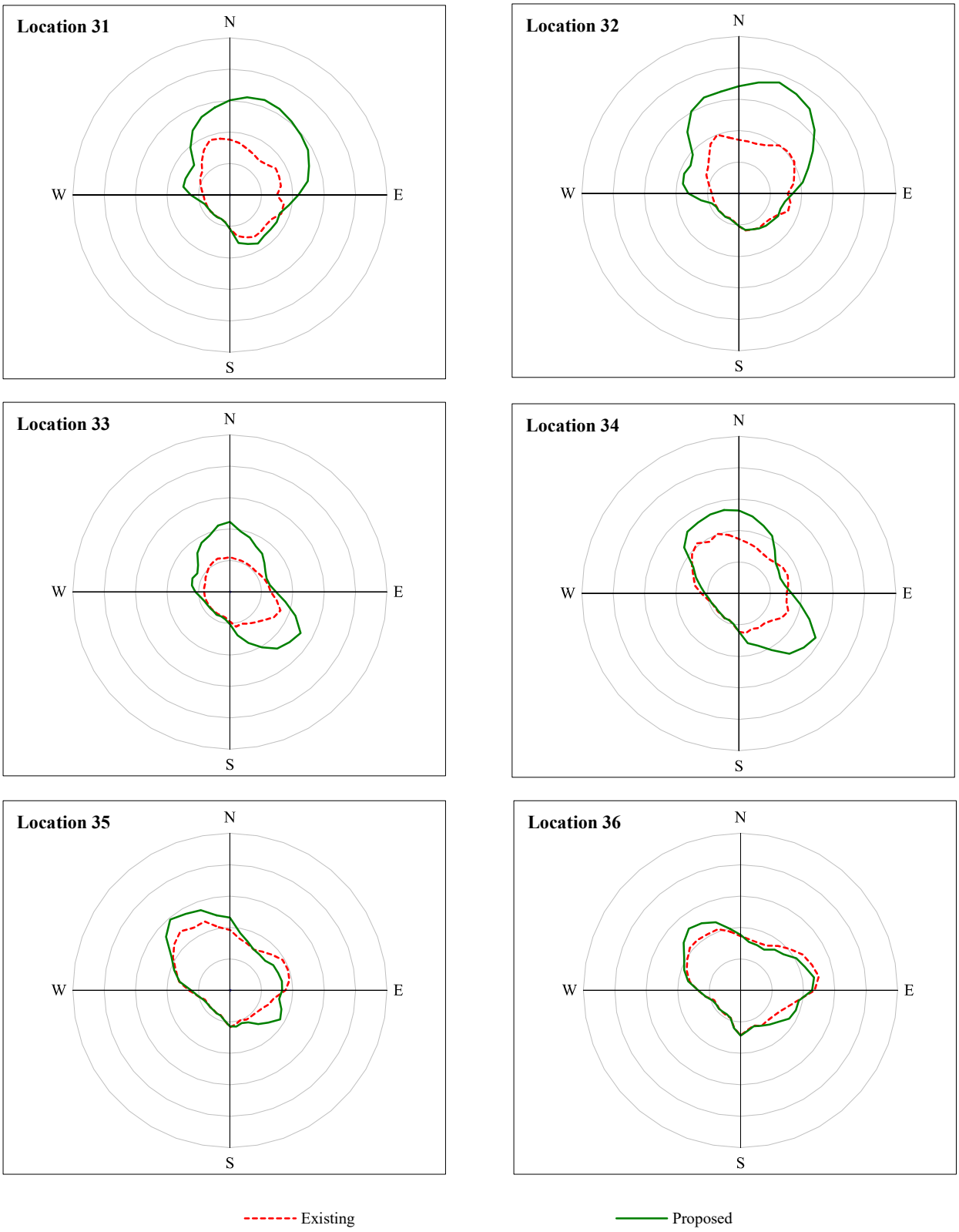

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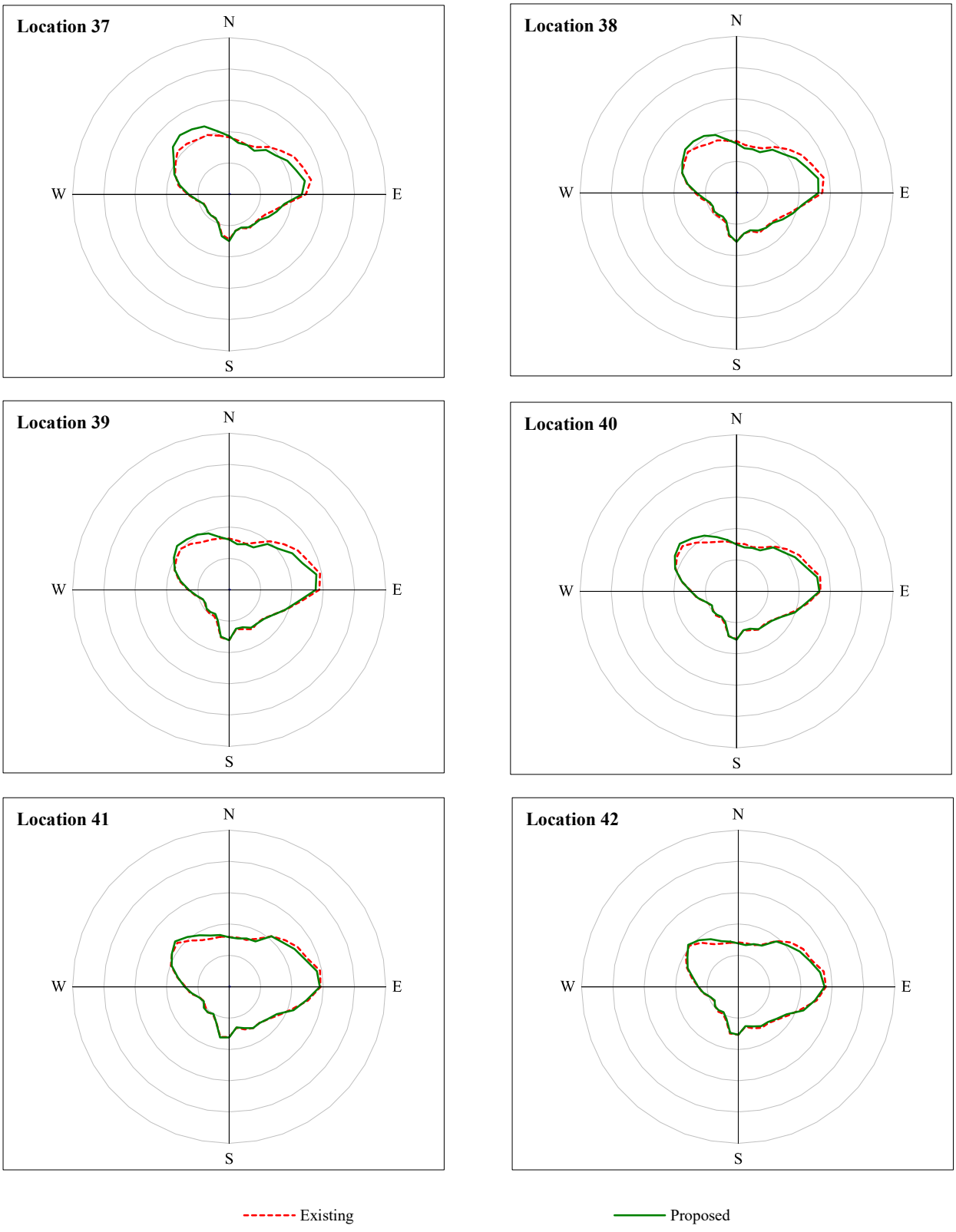

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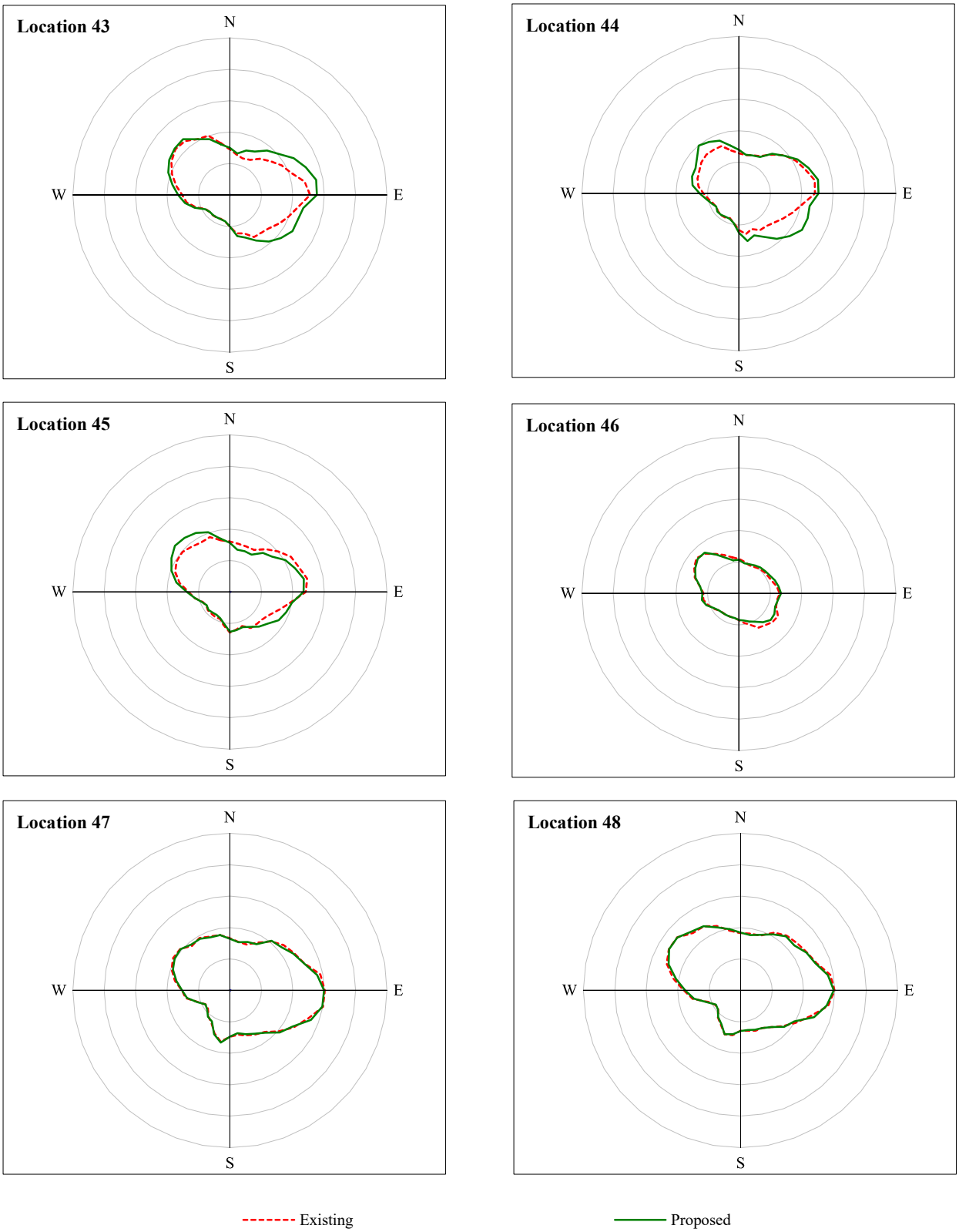

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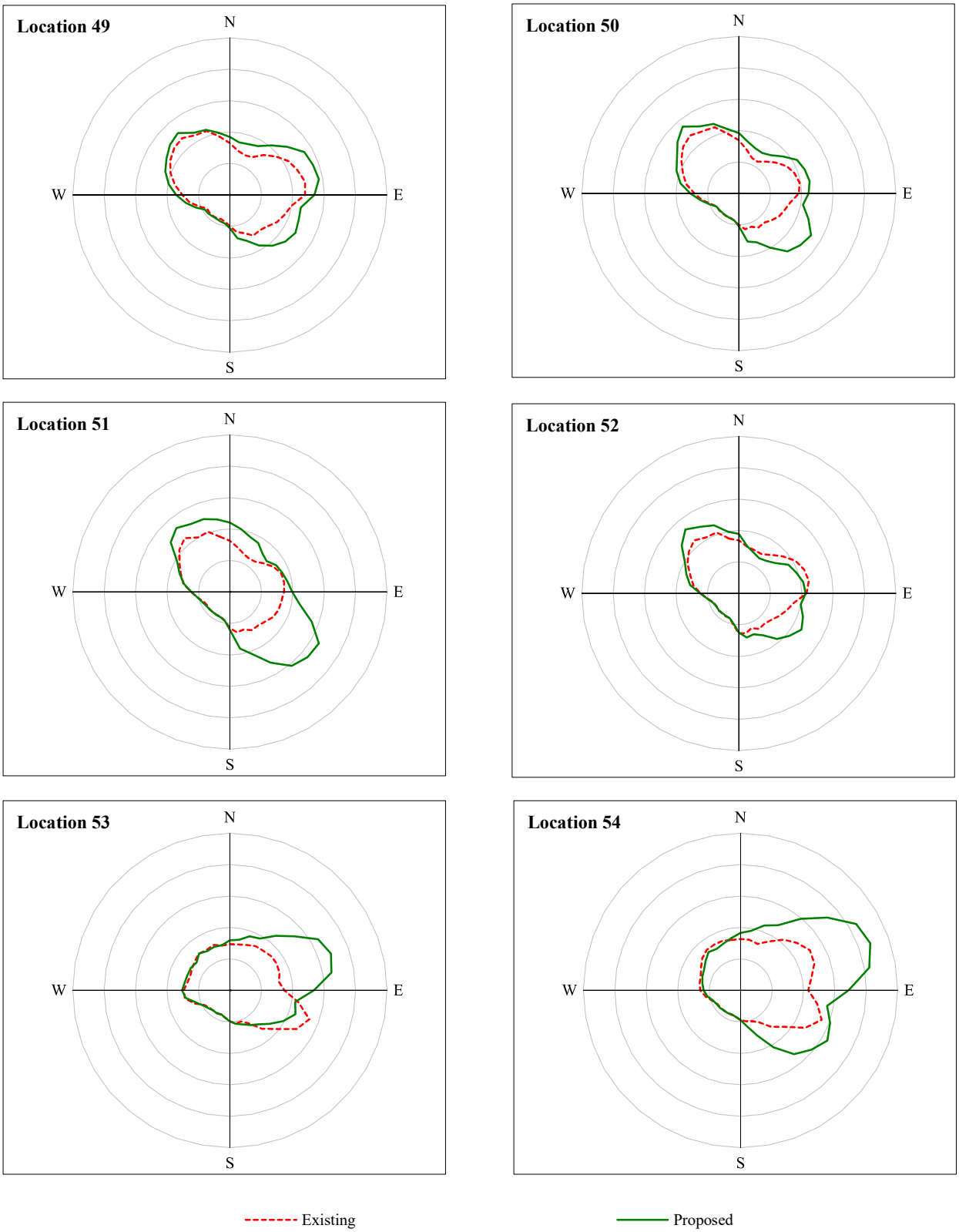

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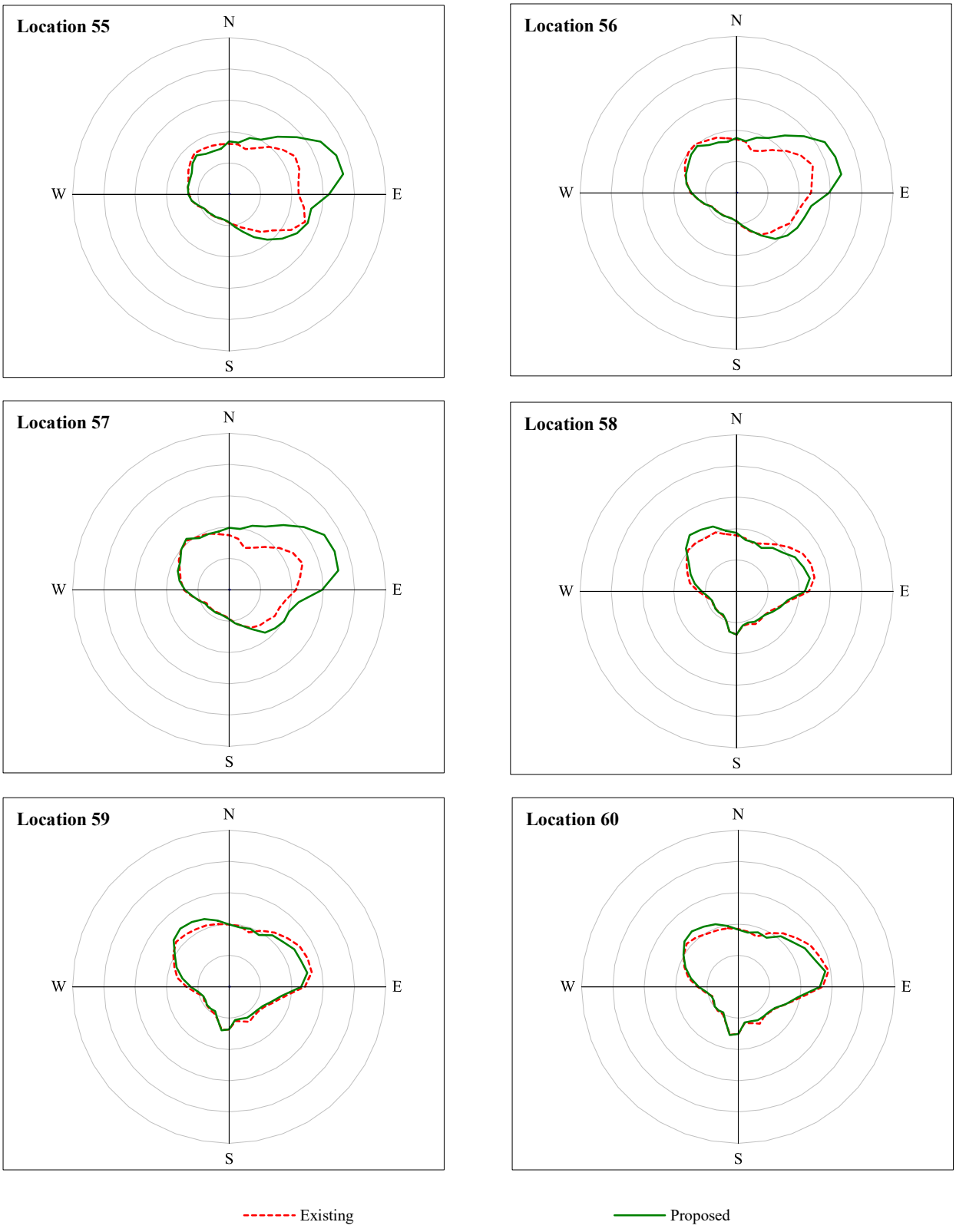


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

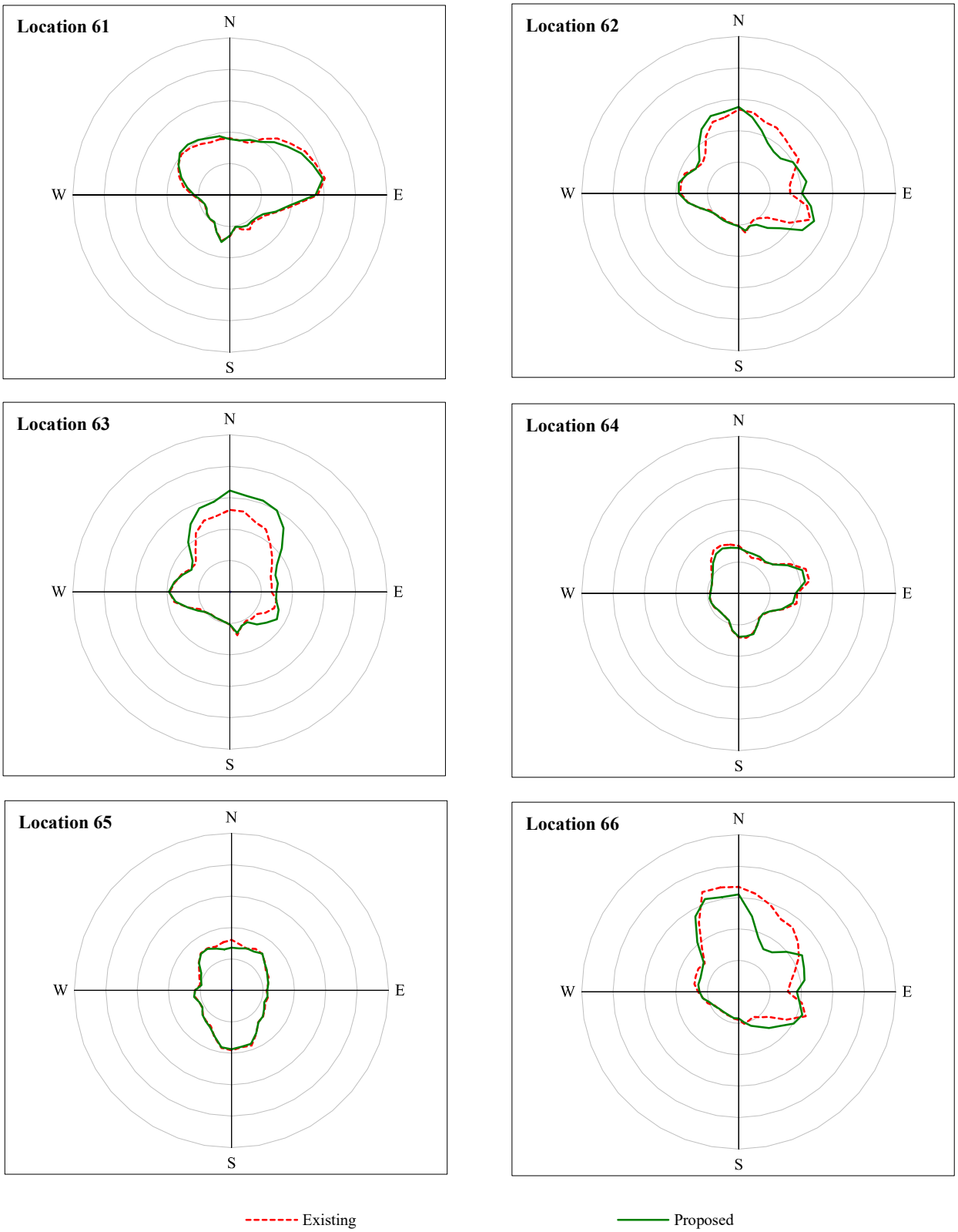


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.

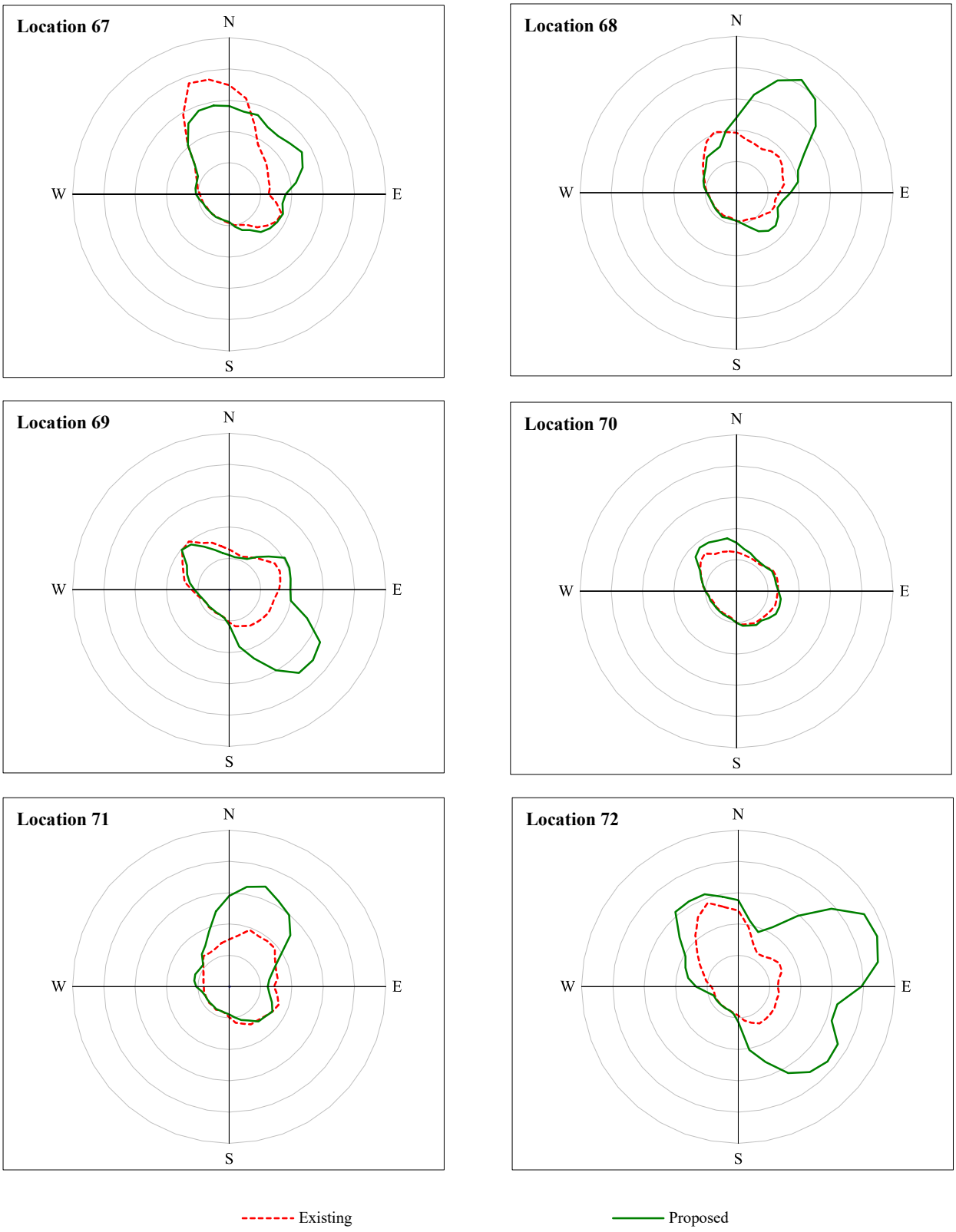
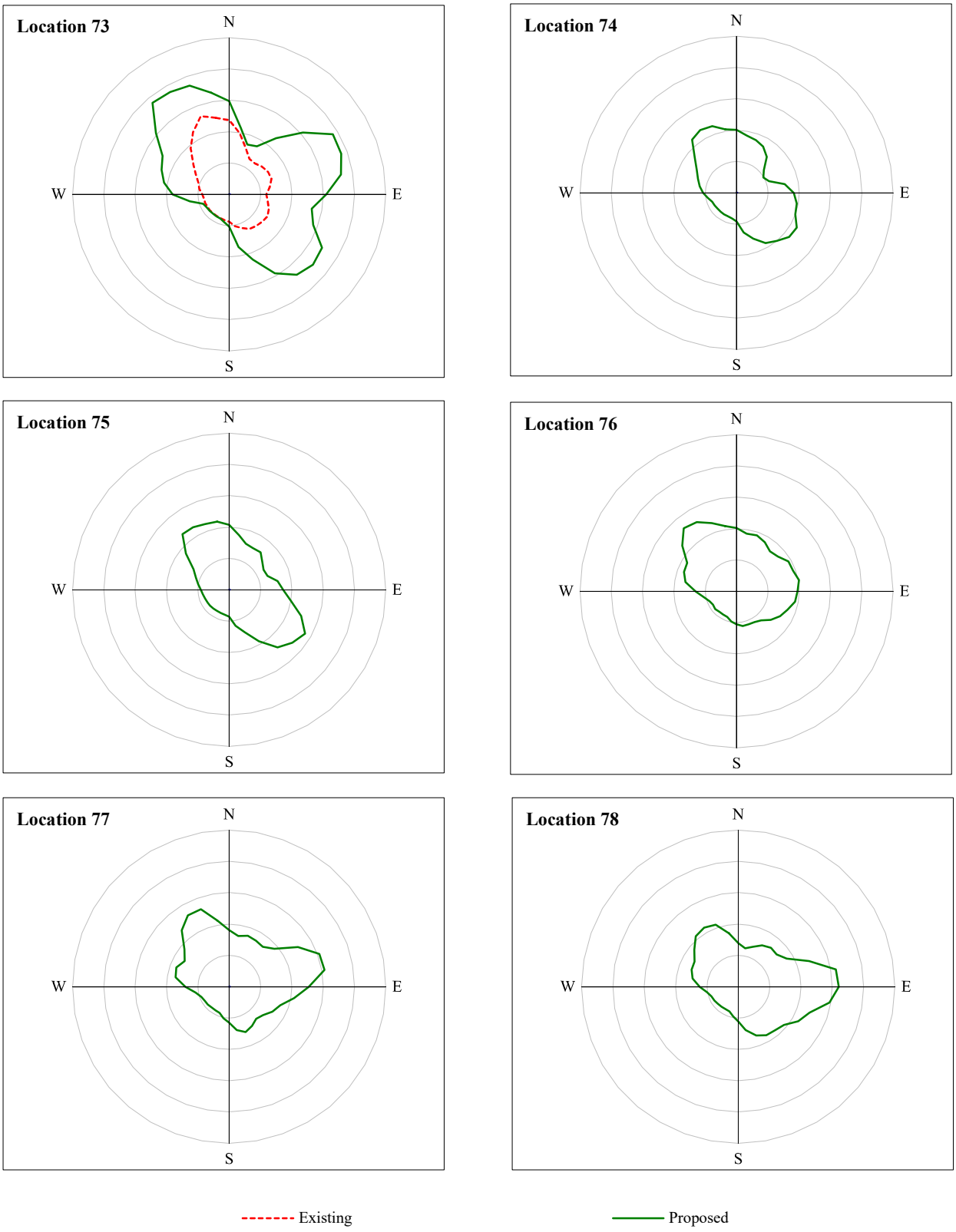


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



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