THEAKSTON ENVIRONMENTAL

Consulting Engineers • Environmental Control Specialists

REPORT

PEDESTRIAN LEVEL WIND STUDY

2555 Erin Centre Boulevard

Mississauga, Ontario

Starmont Estates Inc.

REPORT NO. 24110wind **September 26, 2024**

An International Reputation for Excellence

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1. EXECUTIVE SUMMARY

The mixed-use Development proposed by Starmont Estates Inc. for their property municipally known as 2555 Erin Centre Boulevard, located to the north of the intersection of Erin Mills Parkway with Erin Centre Boulevard, in the City of Mississauga, has been assessed for environmental standards with regard to pedestrian level wind velocities relative to comfort and safety. The pedestrian level wind and gust velocities measured for the seventy-one (71) locations tested are within safety criteria and most are within the comfort criteria described within.

The Development involves a proposal to remove the low-rise commercial building currently on site, and construct three residential towers, denoted Towers 1, 2, and 3, that are respectively 34, 31, and 28 storeys in height. Towers 1 and 2 are connected with a 4 storey podium that increases to 7 storeys along the southeast facade; the combined massing is referred to as Block A. Tower 3 has a 7 storey podium and the combined massing is referred to as Block B. The proposed Development is, for all intents and purposes, surrounded to prevailing windward directions by a mix of low through high-rise residential, commercial, and institutional buildings, mature vegetation and open spaces. The surrounding lands present a mix of surface textures that will introduce turbulence into the wind's streamlines on approach from some directions, thereby reducing the wind's energy and moderating pedestrian comfort levels. Conversely, the more open lands surrounding the site will allow winds opportunity to accelerate on approach.

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 site, the increased blockage relative to the existing setting causing wind to redirect to flow over the buildings, without consequence, and/or, depending upon the angle of incidence, around, or down the towers towards the pedestrian level, as downwash. The Development features wind friendly design elements such as podiums, stepped conditions, landscaping, and others, which, when considered in concert, moderate wind at the pedestrian level. This results in moderate changes to the impending wind climate realised at the site with inclusion of the proposed Development, relative to the existing setting.

Once the subject site is developed, ground level winds at several locations improve, while the majority of the site and surrounds realise windier conditions, however the areas generally remain comfortable and appropriate for their intended purposes throughout the year. The site and surrounds are predicted to be suitable for walking, standing, or sitting throughout the year, with localised uncomfortable conditions in the winter noted proximate to Block A's westmost and southmost corners and within the gap between Blocks A & B. Consideration of proposed surface roughness, such as design and landscape features that were too fine to include in the massing model, are expected to result in more comfortable conditions than those reported within. The relationship between surface roughness and wind is discussed in the Appendix and shown graphically in Figure A of the same section.

Mitigation plans are recommended to alleviate the uncomfortable conditions noted above, as well as for the Main Residential Entrance to Tower 1, the Retail Entrance fronting Erin Mills Parkway, the southmost Retail Entrance fronting Erin Centre Boulevard, the at-grade Outdoor Amenity Space along the northeast façade of Block B, the 5th level Outdoor Amenity Space atop the podium between Towers 1 & 2, and the 5th level Outdoor Amenity Space along the southwest façade of Tower 1. Portions of the 8th level Outdoor Amenity Spaces atop Blocks A & B fronting Erin Centre Boulevard realise seasonally appropriate conditions, however mitigation plans will be required in order to achieve sitting conditions throughout the Spaces.

The proposed Development will realize wind conditions acceptable to a typical transition zone between an urban and suburban/open setting.

Respectfully submitted,

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2. INTRODUCTION

Theakston Environmental Consulting Engineers, Fergus, Ontario, were retained by Starmont Estates Inc., to study the pedestrian level wind environment for their proposed Development located at 2555 Erin Centre Boulevard, in the City of Mississauga, as shown on the Aerial Photo in Figure 2a. The Development involves a proposal to remove the low-rise commercial building currently on site, and construct three residential towers, denoted Towers 1, 2, and 3, that are respectively 34, 31, and 28 storeys in height. Towers 1 and 2 are connected with a 7 storey podium, stepping down at the 4th level between the towers and along the Erin Mills Parkway and Erin Centre Boulevard façades. The combined massing is referred to as Block A. Tower 3 also has a 7 storey podium, stepping down at the 4th level along the Erin Centre Boulevard façade and the combined massing is referred to as Block B. The proposed Development is in a configuration as shown in Figure 2b. Arcadis 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 buildings 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 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 building currently on site as well as existing and approved buildings in the surrounding area. The proposed configuration replaced the existing building 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 in accordance with the City of Mississauga's Terms of Reference for Pedestrian Level Wind Studies.
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 1.5m 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-one (71) 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 and 6b. Criterion employed by Theakston Environmental was developed by others and us and published in the attached references. The methodology has been applied to over 800 projects on this continent and abroad.

4.2 Meteorological Data

The wind climate for the Mississauga region that was used in the analysis was based on historical records of wind speed and direction measured at Pearson International Airport for the period between 1980 and 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.

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. Arcadis provided architectural drawings. City of Mississauga aerial photographs were also used in development of the model to ensure the model reasonably represents conditions at the proposed Development. The model is constructed on a circular base so that, by rotation, any range of wind directions can be assessed. Structures and features that are deemed to have an impact on the wind flows are included upwind of the scale model.

In these studies, the effects of wind were analysed using omni-directional wind velocity probes that are placed on the model and located at the usual positions of pedestrian activity. The probes measure both mean and fluctuating wind speeds at a height of approximately 1.5m. 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 two 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 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 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 a portion of the block of lands bound by Erin Mills Parkway to the southwest, McFarren Boulevard to the northwest, Forest Hill Drive to the northeast, and Erin Centre Boulevard to the southeast, in the City of Mississauga. The site is currently occupied by a low-rise commercial building and surface parking that will be removed to accommodate the proposed Development. The site and its immediate surrounds are shown in Figure 2a.

The proposed Development involves construction of three residential towers, denoted Towers 1, 2, and 3, which are respectively 34, 31 and 28 storeys in height. Tower 1 is located in the southmost portion of the site and is connected to Tower 2 with a 7 storey podium that steps down at the 4th level between the towers and along the southwest and southeast façades; the combined massing is denoted Block A. The ground floor of Block A accommodates retail space. Block B is located within the northmost portion of the site and consists of Tower 3, which has a 7 storey podium, stepping down at the 4th level along the southeast façade. The Main Residential Entrance to Tower 1 is located proximate to the westmost corner of the building, fronting Erin Mills Parkway and the Main Residential Entrance to Tower 2 is located proximate to the eastmost corner of the building, fronting Erin Centre Boulevard. Retail Entrances are located along the southwest and southeast façades. The Main Residential Entrance to Tower 3 is located proximate to the southmost corner, fronting Erin Centre Boulevard. Vehicular access to the site is provided via a private driveway between Block A and Block B. Outdoor Amenity Spaces are proposed at grade along the northeast façade of Block B, at the 5th level atop the podium between Towers 1 & 2 and along the southwest façade of Tower 1, at the 8th level atop the Block A podium fronting Erin Centre Boulevard, and at the 8th level atop the podium of Block B.

The analysis is based upon project plans prepared by Arcadis and the site plan is presented in Figure 2b.

View of the existing conditions at the proposed Development site looking north from Erin Centre Boulevard (Google).

Surrounding Area

The proposed Development site, for all intents and purposes, is surrounded to prevailing windward directions by a predominantly suburban/open mix of low-rise residential and commercial buildings, mature vegetation, and open spaces. The area is undergoing urban intensification and there are several high-rise residential buildings in various stages of design through construction, as indicated in Figure 2a.

Lands to the north of the proposed Development are primarily occupied by mature vegetation and low-rise residential neighbourhoods are located beyond. Lands to the east of the Development site are similarly occupied by low-rise residential neighbourhoods. A stormwater management pond is located to the southeast of the proposed Development and the Development currently under construction at 2475 Eglinton Avenue West was included in the model of the surrounds, (Figure 1).

Lands south of the intersection of Erin Mills Parkway and Erin Centre Boulevard are occupied by the low-rise Erin Mills Town Centre and surface parking surrounding the building.

Lands to the west of the intersection of Erin Mills Parkway and Erin Centre Boulevard are occupied by 3 high-rise residential buildings, mature vegetation, open areas associated with playgrounds, sports fields, splashpads, Quenippenon Meadows Leash Free Park, and a low-rise Regional Facilities building located at 5220 Erin Mills Parkway.

In summary, a mix of low through high-rise residential and commercial buildings, mature vegetation, and open spaces occupy lands to all compass points relative to the subject site. The 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 to many compass points, and open spaces that afford wind the opportunity to accelerate upon approach from others.

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 suburban / open 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 Mississauga, the data is presented for two seasons, winter and summer; the resulting wind roses are presented as mean velocity and percent frequency in Figure 5. 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 suburban / open terrain.

Winter (November through April) has the higher mean velocities with prevailing winds from the north through west to southwest, as indicated in Figure 5a. Summer (May through October) has lower mean wind velocities with similar prevailing winds from the north through west, with a southeasterly component, as indicated in Figure 5b. Reported pedestrian comfort ratings generally pertain to winter conditions, unless stated otherwise.

5.2 Pedestrian Level Wind Velocity Study

On the site model, seventy-one (71) 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 buildings were removed, and the "existing" site model retested with the current site.

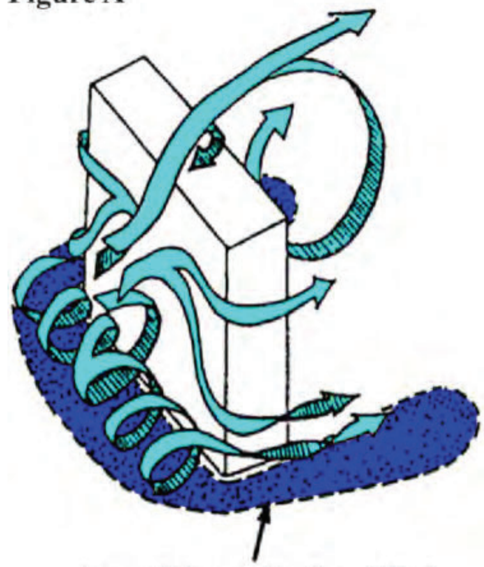
Measurements of pedestrian level mean and gust wind speeds at the various locations shown were taken over a period equivalent to one hour of measurements at full-scale. The mean ground level wind velocity measured is presented as a ratio of gradient wind speed, in the plots of Figure B in the Appendix, 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 Figure 5) 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 winter and summer in Figures 6a and 6b, respectively. 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 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/open setting, interspersed with high-rise buildings, to prevailing and remaining compass points with winds flowing over and between mature vegetation, predominantly low-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



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, 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 and 6b in winter and summer and for the existing and proposed configurations. The results are also graphically depicted for the existing and proposed configurations in Figures 7a – 7d, and compared in a table in Figure 10. The following discusses anticipated wind conditions and suitability for the points' intended use.

Public Street Conditions

Erin Centre Boulevard

Probes 1 through 22 were located along Erin Centre Boulevard, within the zone of influence of the proposed Development. Their locations are depicted in Figure 4, the comfort ratings are listed for the seasons in Figures 6a and 6b and depicted in Figures 7a through 7d. In the existing setting, the probes along Erin Centre Boulevard indicate conditions primarily suitable for standing throughout the year, apart from probe 1 in the winter and summer, and probes 13 – 15 in the winter, which were rated appropriate for walking, and probe 8 in the summer, which rated suitable for sitting. The conditions are a reasonable expectation given that the site is exposed to predominantly suburban/open surrounds to prevailing wind directions, affording wind the opportunity to accelerate upon approach.

With inclusion of the proposed Development, a realignment of winds was noted along Erin Centre Boulevard. This 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 along portions of Erin Centre Boulevard. 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 improvements in wind conditions were subtle and insufficient to change the comfort ratings. Conversely, the increase in winds observed along Erin Centre Boulevard was sufficient to change the comfort rating from standing to walking at probes 2, 4 – 8, 10 – 11, and 16 – 20 in the winter, as well as probes 2 – 4, 7 and 19 in the summer. Probe 3 realised an increase in winds flowing around the southmost corner of Block A that was sufficient to change the winter rating from standing to uncomfortable. Probe 8, located proximate to the southmost corner of Block B, realised an increase in winds flowing through the gap between Blocks A and B, as well as along the southeast façades of the buildings that was sufficient to change the rating from sitting to walking in the summer. Consideration of design and landscape elements that were too fine to include in the massing model will result in more comfortable conditions than those reported.

Overall, Erin Centre Boulevard remains comfortable and appropriate for its intended use, with exception of the above-noted uncomfortable condition, and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Erin Mills Parkway

Probes 23 through 34 were located along Erin Mills Parkway, within the zone of influence of the proposed Development. In the existing setting, Erin Mills Parkway is predicted mainly suitable for standing throughout the year, with the exception of probes 26, 33, and 34 in the winter, which were rated appropriate for walking.

With inclusion of the proposed Development, a realignment of winds was noted along Erin Mills Parkway, sufficient to change the winter ratings at probes 24, 25, 29, 31, and 32 from standing to walking, as well as probes 25 and 30 – 32 in the summer. Probe 30, located proximate to the westmost corner of Block A, realised an increase in winds from the northwest through north to northeast, and southwest through south to southeast, flowing along the northwest and southwest façades of the buildings that was sufficient to change the winter rating from standing to uncomfortable. Conversely, several of the probes realised improvements in winds from specific directions with inclusion of the proposed Development, however the improvements were insufficient to change the comfort categories.

Overall, Erin Mills Parkway remains comfortable and appropriate for its intended use, with exception of the above-noted uncomfortable condition, and passes the pedestrian level wind velocity safety criteria, as described in Section 4.7 and depicted in Figure 9.

Internal Site Conditions

Probes 41 through 46 were located alongside the Drop-Off Area between Blocks A & B. The area is exposed to large portions of the prevailing wind climate being redirected by the flanking buildings to flow down the façades and accelerate through the gap between the Towers. Consequently, the area was rated suitable for walking in the summer and predominantly uncomfortable in the winter, with exception of probes 41 and 46, which were rated suitable for walking. Mitigation is recommended in order to improve comfort conditions within the gap between the buildings.

Probes 52 through 57 were located along the northwest property boundary. The area is predominantly exposed to northerly winds being redirected to flow along the northwest façade of the buildings, except for probe 54, which was located within the gap between buildings and had strong northwesterly, easterly, and southerly components. The area was predominantly rated suitable for standing throughout the year, with exception of probe 52, which was rated suitable for walking in both the winter and summer, and probe 54, which was rated uncomfortable in the winter and suitable for walking in the summer. Consideration of the dense mature vegetation to the north of the site will improve conditions over those reported, however mitigation is recommended in order to improve the uncomfortable condition.

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

Pedestrian Entrance Conditions

The Main Residential Entrance to Tower 1, as represented by probe 35, is located proximate to the westmost corner of the building, fronting Erin Mills Parkway. The area is exposed to winds from the southwest through south to southeast, as shown in the Appendices Figure B: Ground level wind velocity as a ratio of gradient wind velocity and was, as a result, rated suitable for walking in the winter and standing in the summer. Wind conditions comfortable for standing, or better, are preferrable at building entrances, while walking conditions are acceptable for their adjacent sidewalks. Mitigation will therefore be required in order to achieve conditions appropriate for its intended use and can include relocating the entrance away from the corner, recessing the entrance into the façade such that wind cannot act upon the door leaves, incorporating a canopy and wind screens on both sides of the entrance, utilizing sliding doors, and/or incorporating landscaping along the sidewalks.

The Main Residential Entrance to Tower 2 is located proximate to the eastmost corner of the building, fronting Erin Centre Boulevard, and was represented by probe 40. The Entrance is fairly well protected from the dominant north through west to southwesterly winds and remains mainly exposed to winds from the southwest through south to southeast, flowing along the southeast façade of the Development. The resulting conditions were predicted suitable for standing throughout the year and are therefore considered comfortable and appropriate for the intended use.

Probe 47 was positioned proximate to the Main Residential Entrance to Tower 3, located along the Erin Centre Boulevard façade of the building near the southmost corner. The Entrance is predominantly exposed to winds from the northeast and southeast and was rated suitable for standing throughout the year. The Entrance is therefore considered comfortable and appropriate for its intended use.

Retail Entrances are located along the Erin Mills Parkway and Erin Centre Boulevard façades of Block A, and were represented by probes 36 through 39. Probe 36, positioned proximate to the Retail Entrance fronting Erin Mills Parkway, is predominantly exposed to winds from the southeast quadrant, as well as the northwest through west to southwest that are redirected by the proposed Development to flow down and around the building and along the façades, resulting in wind conditions suitable for walking throughout the year. Mitigation is therefore required in order to achieve conditions more appropriate for its intended use and can include recessing the entrance into the façade, incorporating a canopy above and wind screens on both sides of the entrance, utilizing sliding doors, and/or incorporating landscaping along the sidewalks. Probe 37 was located proximate to the southmost Retail Entrance along the Erin Centre Boulevard façade. The Entrance is exposed to winds from the southwest and near-east directions flowing along the façades. As a result, the Entrance was rated suitable for walking in the winter and standing in the summer and mitigation will be required, as described above, in order to achieve more comfortable conditions that are considered appropriate for its intended use. The remaining Retail Entrances fronting Erin Centre Boulevard, represented by probes 38 and 39, were rated suitable for standing throughout the year and are considered comfortable and appropriate for their intended use.

The above-mentioned 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

Outdoor Amenity Spaces are proposed at grade along the northeast façade of Block B, at the 5th level atop the podium between Towers 1 & 2, at the 5th level along the southwest façade of Tower 1, at the 8th level atop the Block A podium fronting Erin Centre Boulevard, and at the 8th level atop the podium of Block B.

Probes 48 through 51 were positioned within the Outdoor Amenity Space located at-grade along the northeast façade of Block B. The area is largely exposed to winds from near northerly and southeasterly directions, with the southmost area also being exposed to southerly winds. Upon contact with the building, the winds are redirected to flow down and along the northeast façade, resulting in wind conditions predicted appropriate for walking at probe 48 in the winter and summer and standing conditions throughout the year at probes 49 - 51. Generally, sitting conditions are desired within Outdoor Amenity Spaces in the summer. A mitigation plan will therefore be required in order to achieve sitting conditions and can include porous fencing, wind screens, canopies, landscaping, and/or others.

Probes 58 through 62 were positioned within the Outdoor Amenity Space at the 5th level atop the podium between Towers 1 & 2. The area was tested with a 1.9m high screen wall along the southwest boundary. The area was rated predominantly suitable for standing in the summer, with the exception of probe 60, which was rated appropriate for walking. In the winter, probes 58 through 60 were rated appropriate for walking and probes 61 and 62 were rated appropriate for standing. A mitigation plan including higher screen walls, wind screens, raised planter beds populated with coniferous vegetation, canopies, and/or others is recommended in order to achieve conditions more appropriate for its intended use.

Probes 63 through 68 were positioned within the 8th level Outdoor Amenity Space atop the Block A podium fronting Erin Centre Boulevard. The area was tested with a 1.9m high screen wall along the boundaries. Probes 63 and 68 were located to the southeast of Towers 1 & 2, respectively, and realise protection from said Towers, resulting in sitting conditions in the summer and standing conditions in the winter. The remaining probes are more exposed to winds flowing between the Towers, resulting in wind conditions suitable for standing in the summer and walking in the winter, with exception of probe 67 in the winter, which was appropriate for standing. Portions of the Amenity Space are therefore considered seasonally appropriate for its intended use. To achieve sitting conditions throughout the space, a mitigation plan will be required and can include higher screen walls, wind screens, canopies, trellises, raised planter beds populated with coniferous plantings, and/or others.

Probes 69 through 71 were located within the Outdoor Amenity Space at the 8th level atop the podium of Block B, fronting Erin Centre Boulevard. The area was tested with a 1.9m high screen wall along the boundaries. The portion of the Amenity Space in closer proximity to the tower realises wind conditions suitable for sitting in the summer. Probe 69 was also rated suitable for sitting in the winter and probe 70 was rated suitable for standing. Probe 71 was rated suitable for standing throughout the year. Portions of the Amenity Space are therefore considered seasonally appropriate for their intended use. Similar to above, to achieve sitting conditions throughout the Space, mitigation including higher screen walls, wind screens, trellises, canopies, raised planter beds populated with coniferous plantings, and/or others will be required.

The above-mentioned Outdoor Amenity Spaces pass the pedestrian level wind velocity safety criteria.

The Outdoor Amenity Space located at the 5th level along the southwest façade of Tower 1 was too narrow to instrument with conventional probes and an alternate means of assessing the space was employed. The Amenity Space is located within the aerodynamic shade region of Tower 1 for winds emanating from the north through northeast, however it remains exposed to much of the prevailing wind climate unmitigated upon approach from over predominantly lower surrounds. As a result, mitigation is recommended in order to achieve sitting conditions in the summer and can include canopies, wind screens, screen walls, landscaping, and/or others.

The 5th level Outdoor Amenity Space along the southwest façade of Tower 1 is predicted to pass the pedestrian level wind velocity safety criteria.

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. The surrounding lands present a mix of surface textures that will introduce turbulence into the wind's streamlines on approach from some directions, thereby reducing the wind's energy and moderating pedestrian comfort levels. Conversely, the more open lands surrounding the site will allow winds opportunity to accelerate on approach. This results in wind conditions appropriate predominantly for standing throughout the year in the existing setting. Historical weather data recorded at Toronto Pearson International Airport indicates that winds of a mean wind speed greater than 30 km/h occur approximately 15 percent of the time during the winter months and 7 percent of the time during the summer.

Once the subject site is developed, ground level winds at several locations improve, while the majority of the site and surrounds realise windier conditions, however the areas generally remain comfortable and appropriate for the areas' intended purposes throughout the year. The site and surrounds are predicted to be suitable for walking, standing, or sitting throughout the year, with localised uncomfortable conditions in the winter noted proximate to Block A's westmost and southmost corners and within the gap between Blocks A & B. Consideration of proposed surface roughness, such as design and landscape features that were too fine to include in the massing model, are expected to result in more comfortable conditions than those reported within. The relationship between surface roughness and wind is discussed in the Appendix and shown graphically in Figure A of the same section.

Mitigation plans are recommended to alleviate the uncomfortable conditions noted above, as well as for the Main Residential Entrance to Tower 1, the Retail Entrance fronting Erin Mills Parkway, the southmost Retail Entrance fronting Erin Centre Boulevard, the at-grade Outdoor Amenity Space along the northeast façade of Block B, the 5th level Outdoor Amenity Space atop the podium between Towers 1 & 2, and the 5th level Outdoor Amenity Space along the southwest façade of Tower 1. Portions of the 8th level Outdoor Amenity Spaces atop Blocks A & B fronting Erin Centre Boulevard realise seasonally appropriate conditions, however mitigation plans will be required in order to achieve sitting conditions throughout the Spaces.

The proposed Development will realize wind conditions acceptable to a typical transition zone between an urban and suburban/open setting.

6. FIGURES

Figure 1: Laboratory Testing Facility

Figure 2a: Site Aerial Photo

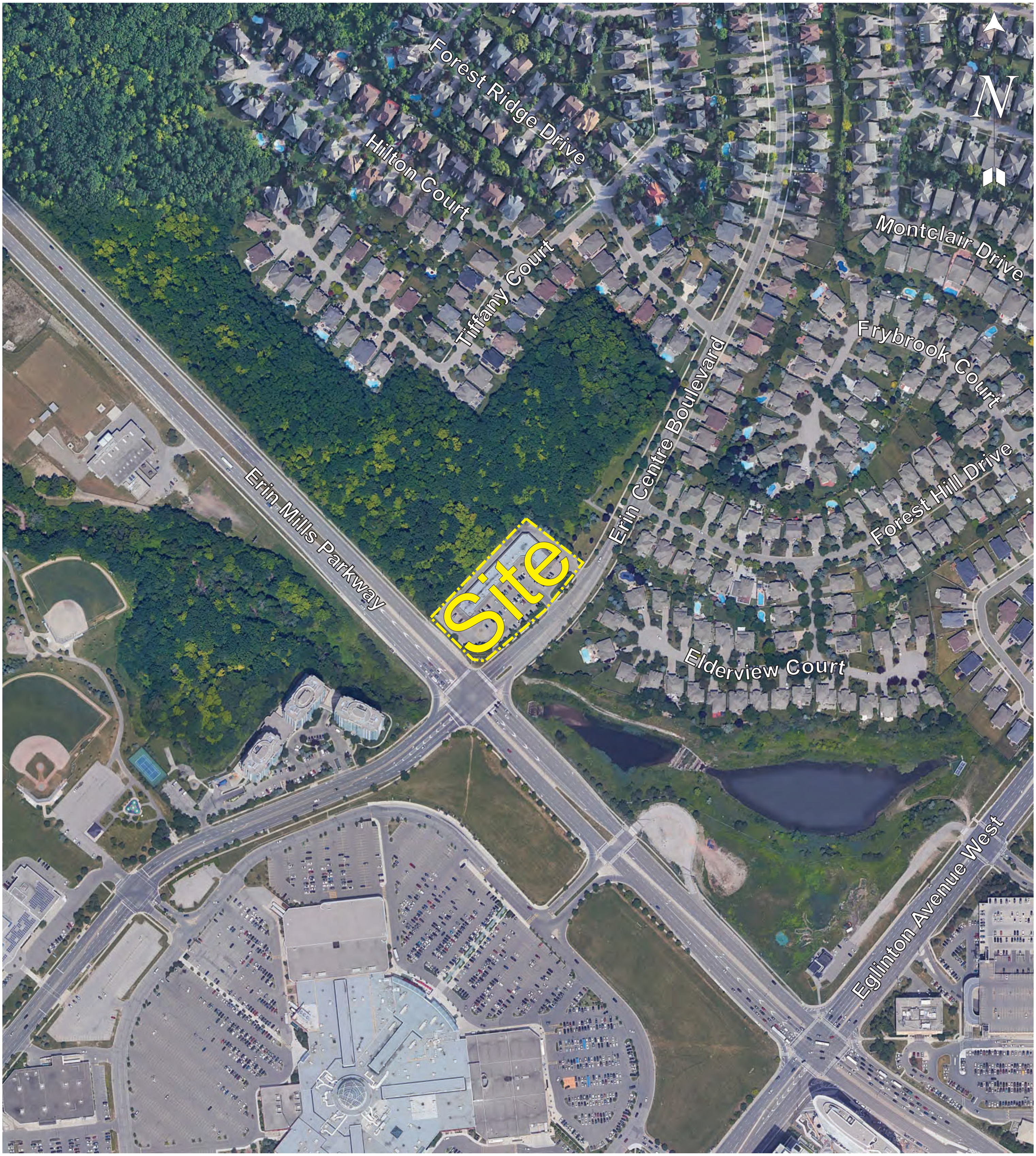
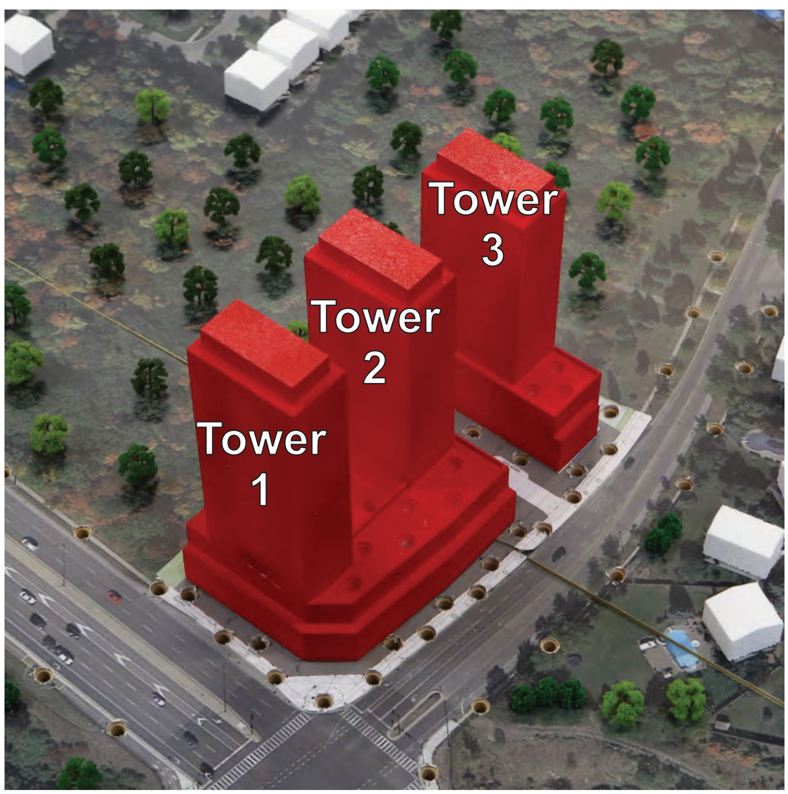


Figure 2b: Site Plan

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.

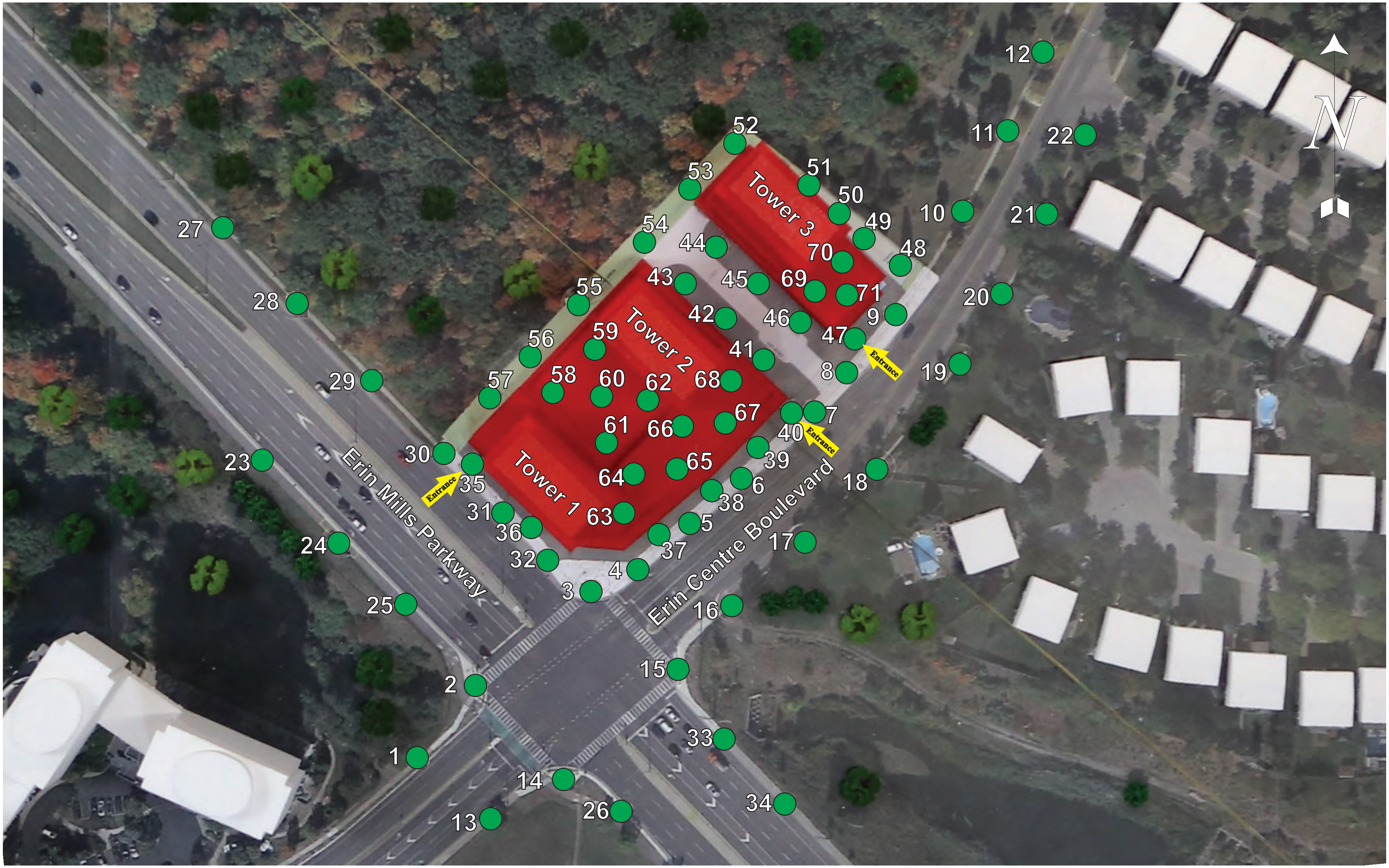


Figure 5a: Winter Wind Rose - Pearson International Airport

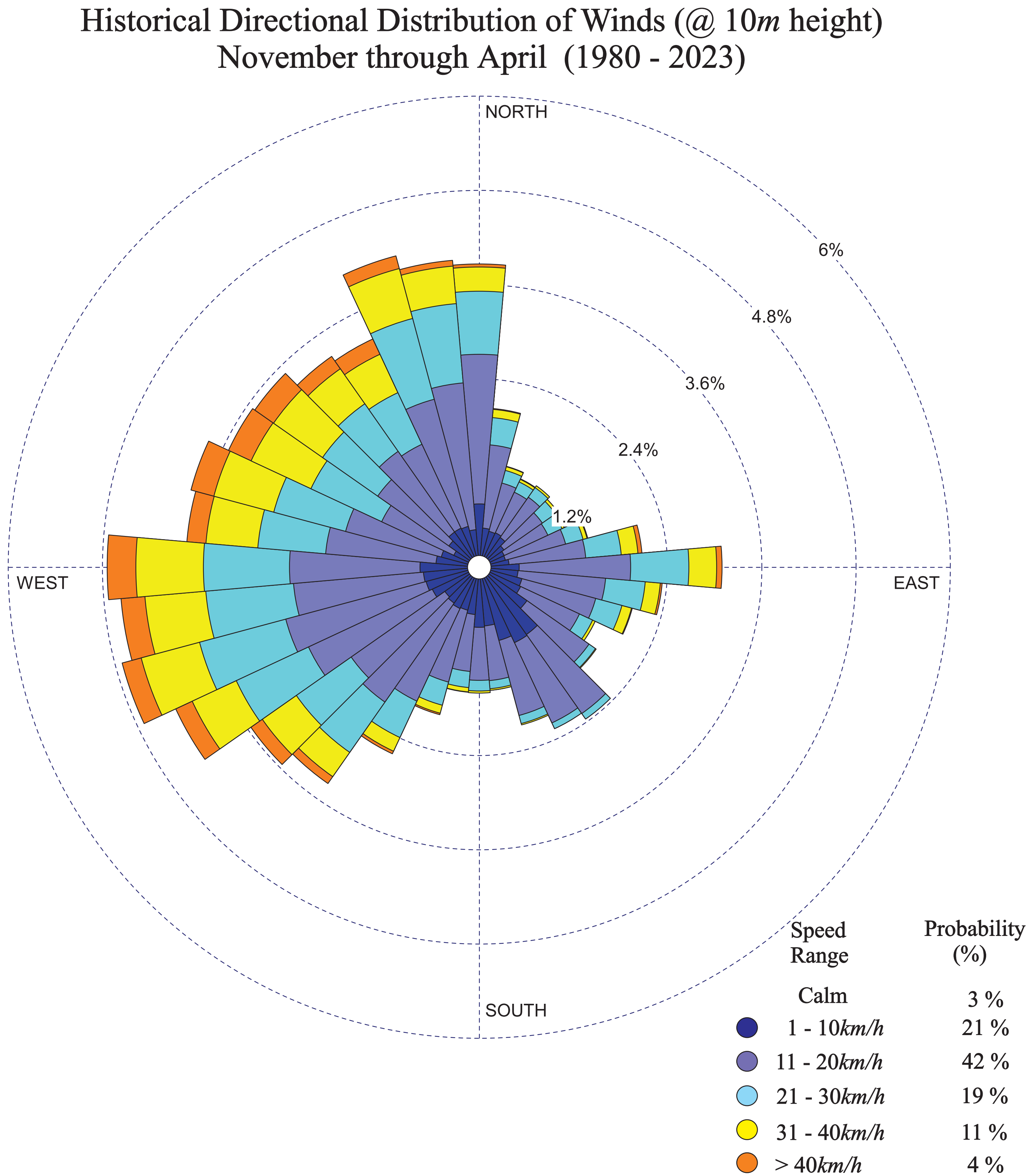


Figure 5b: Summer Wind Rose - Pearson International Airport

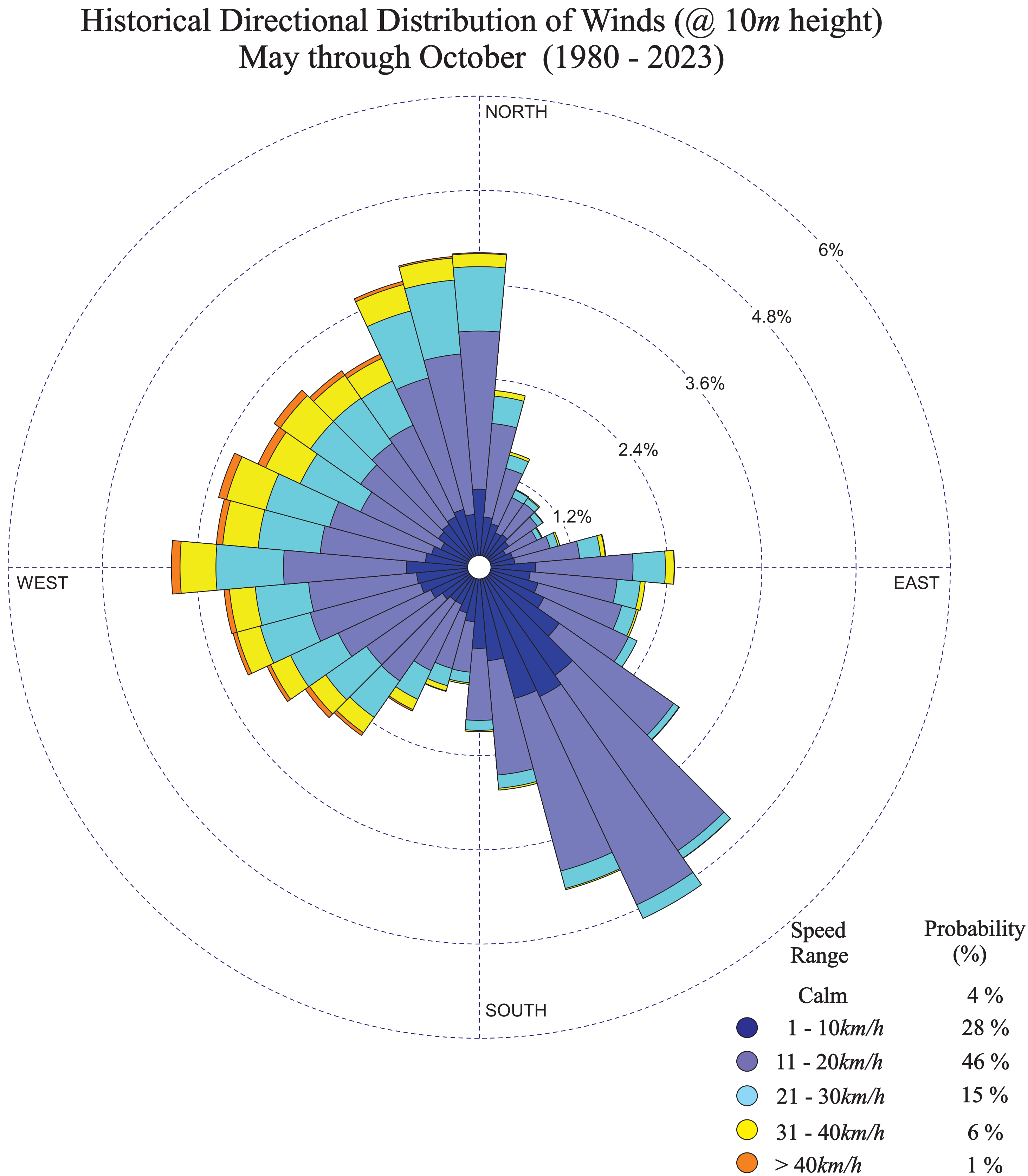
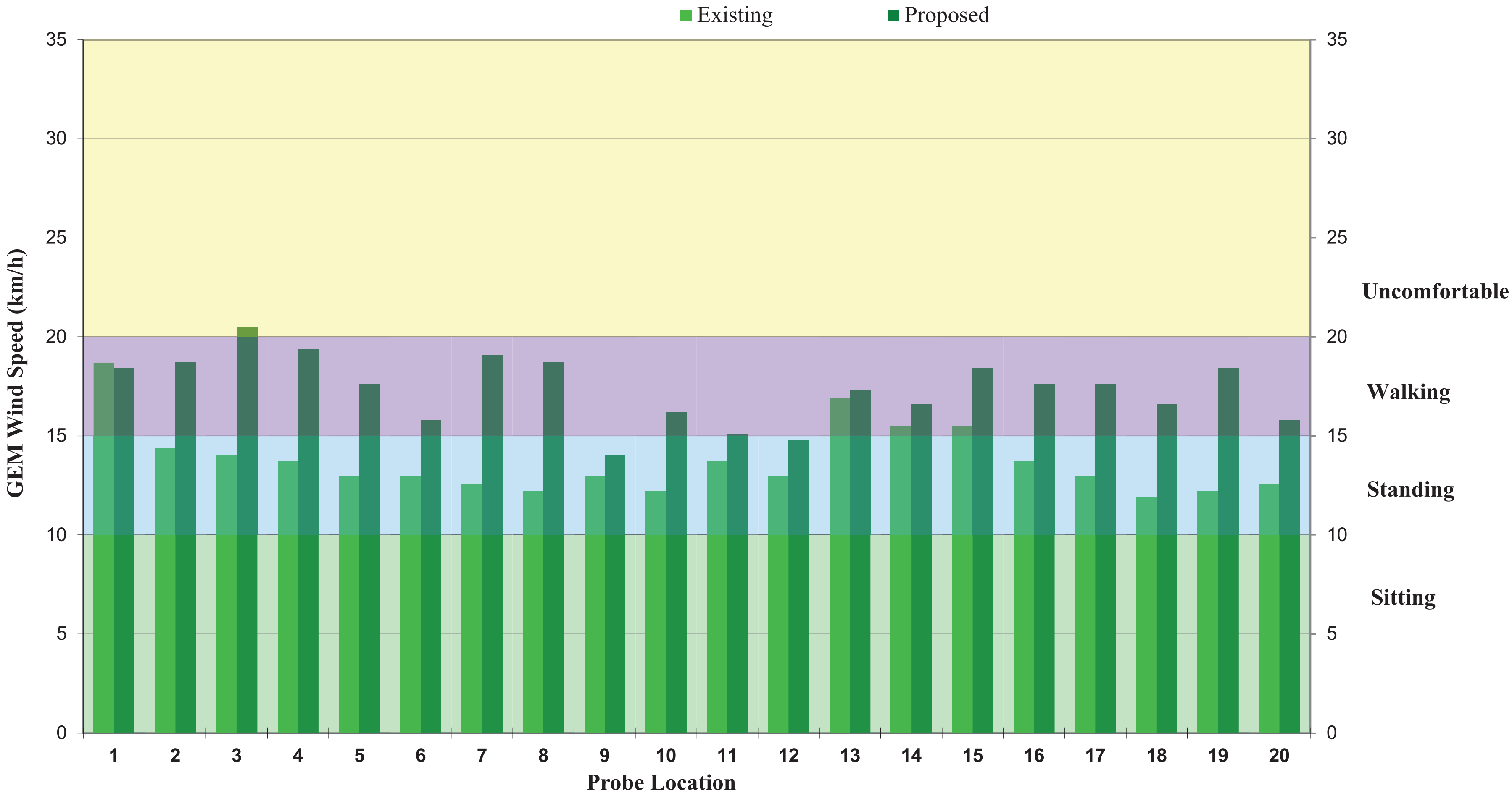


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 1 to 20).



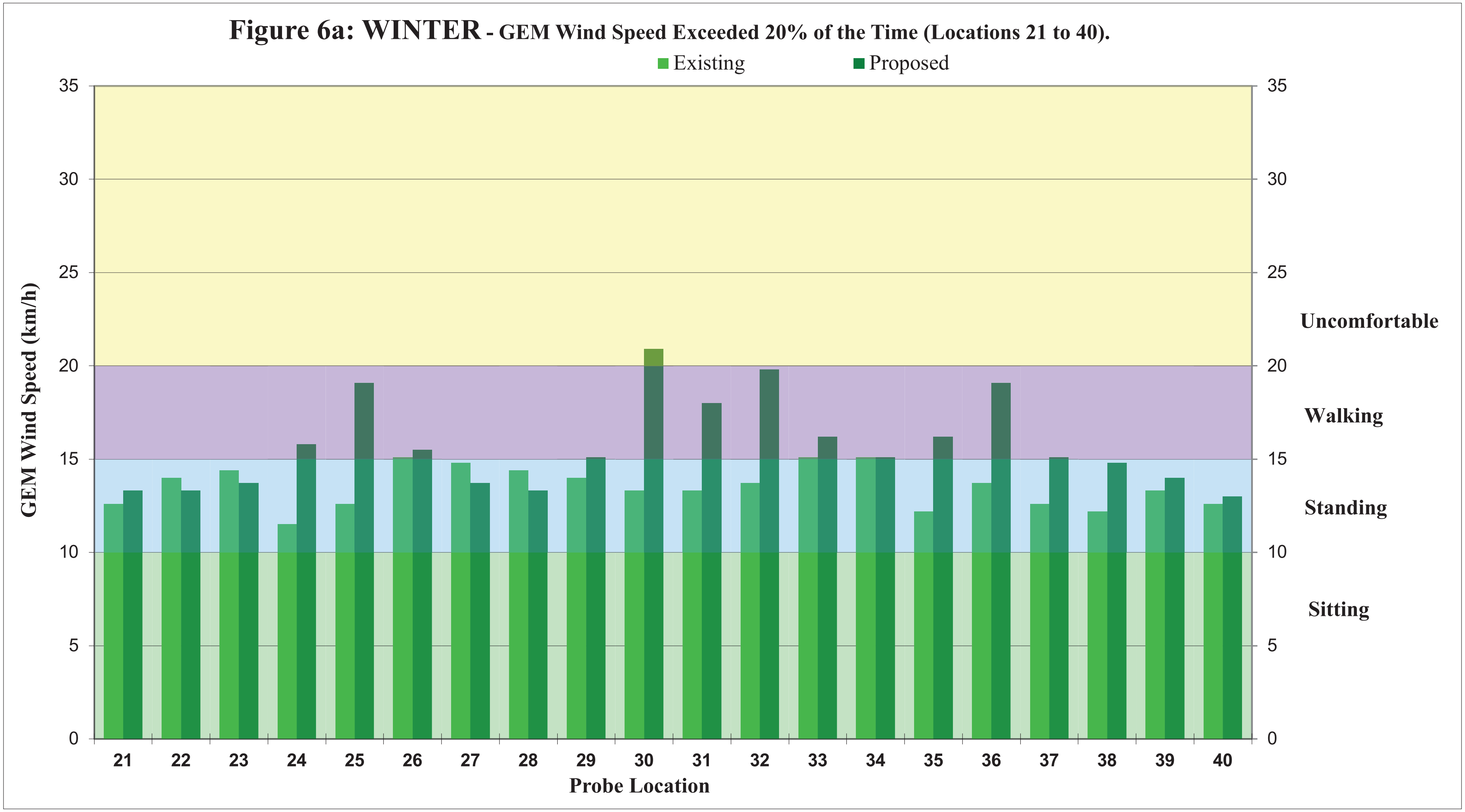
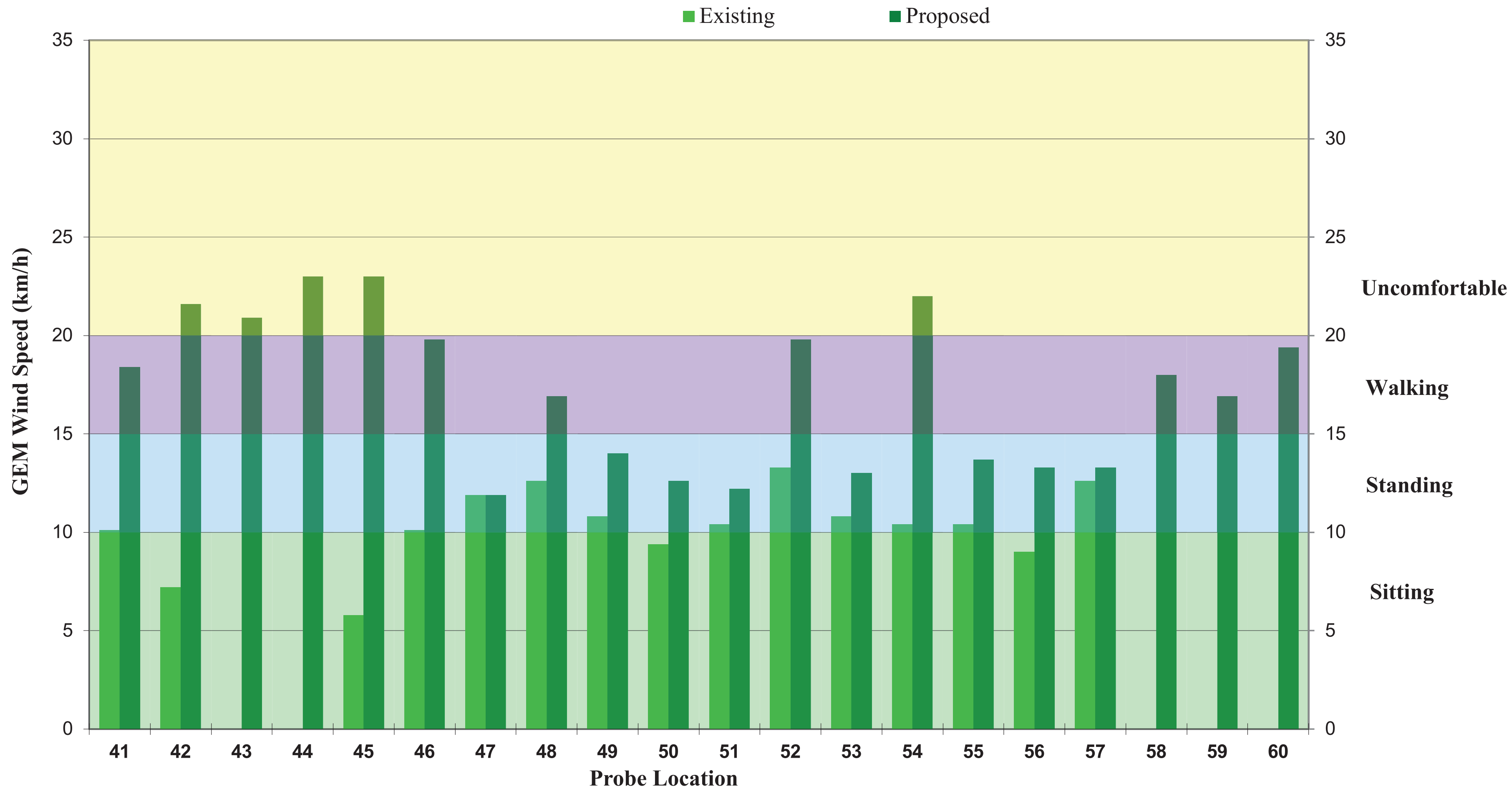


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
GEM Wind Speed (km/h)
0
5
10
15
20
25
30
35
Uncomfortable
Walking
Standing
Sitting
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location

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



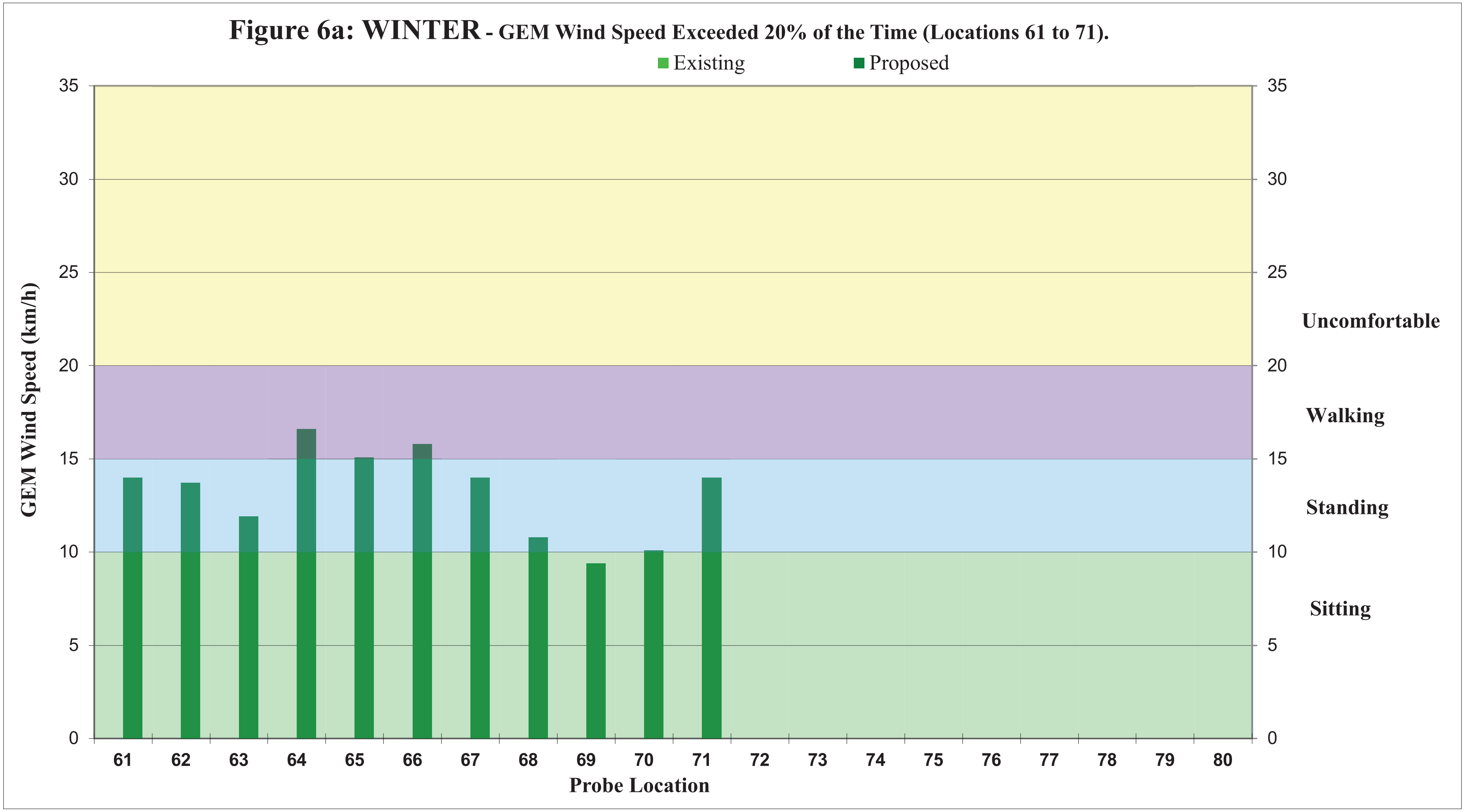
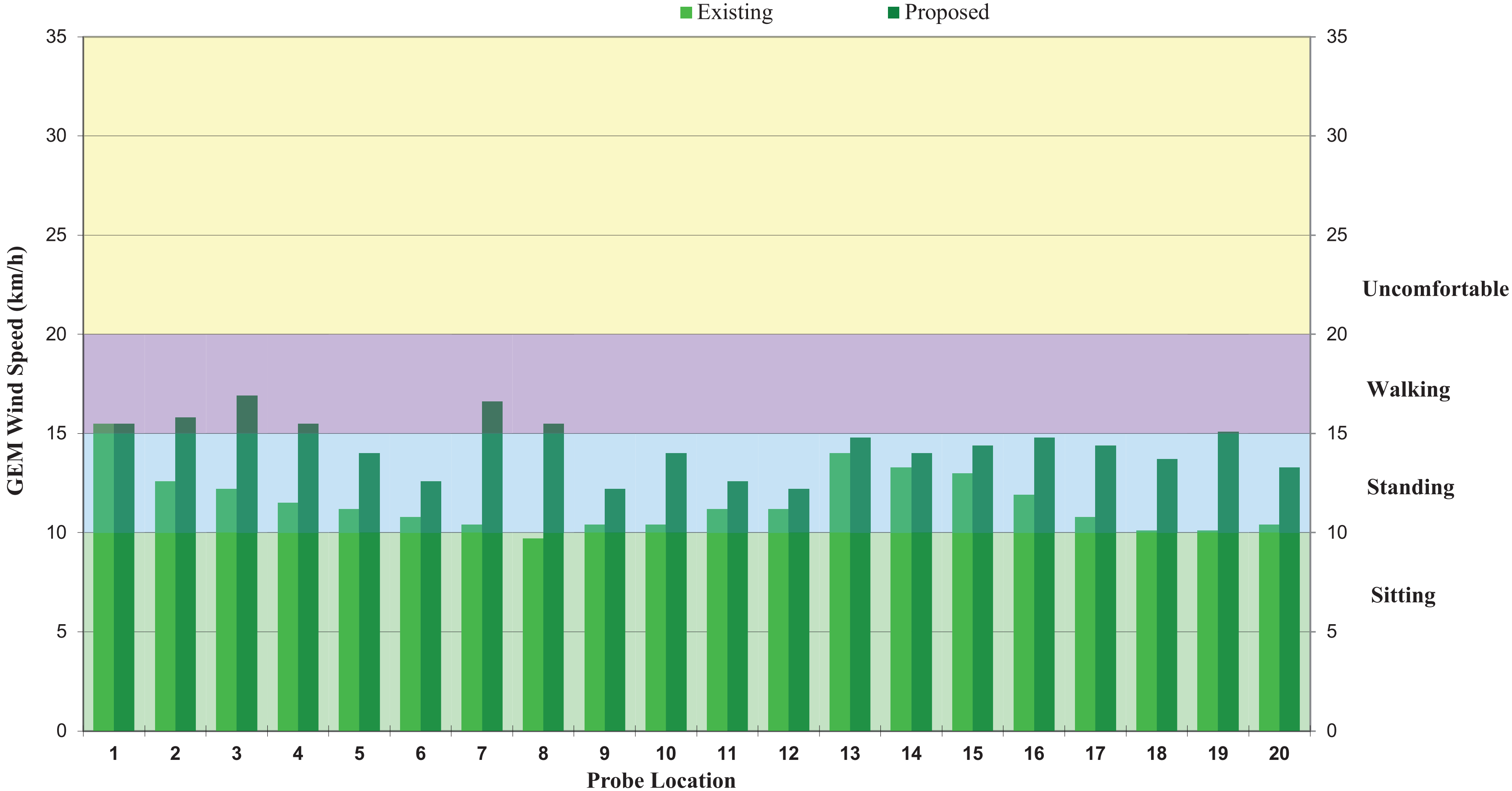


Figure 6a: WINTER - GEM Wind Speed Exceeded 20% of the Time (Locations 61 to 71).
Existing
Proposed
GEM Wind Speed (km/h)
0
5
10
15
20
25
30
35
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
Probe Location
Uncomfortable
Walking
Standing
Sitting

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



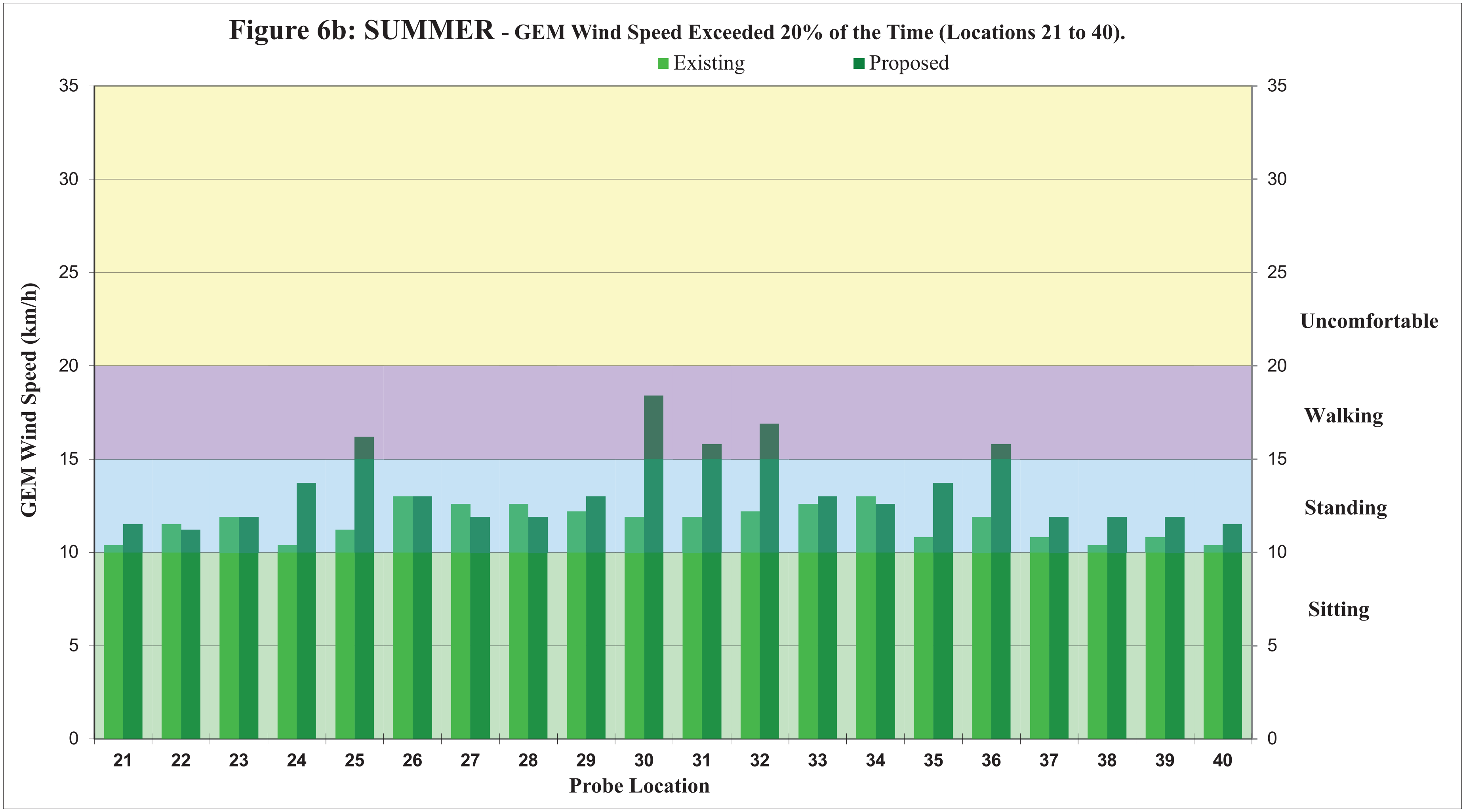


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 21 to 40).
Existing
Proposed
GEM Wind Speed (km/h)
0
5
10
15
20
25
30
35
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
Probe Location
Uncomfortable
Walking
Standing
Sitting

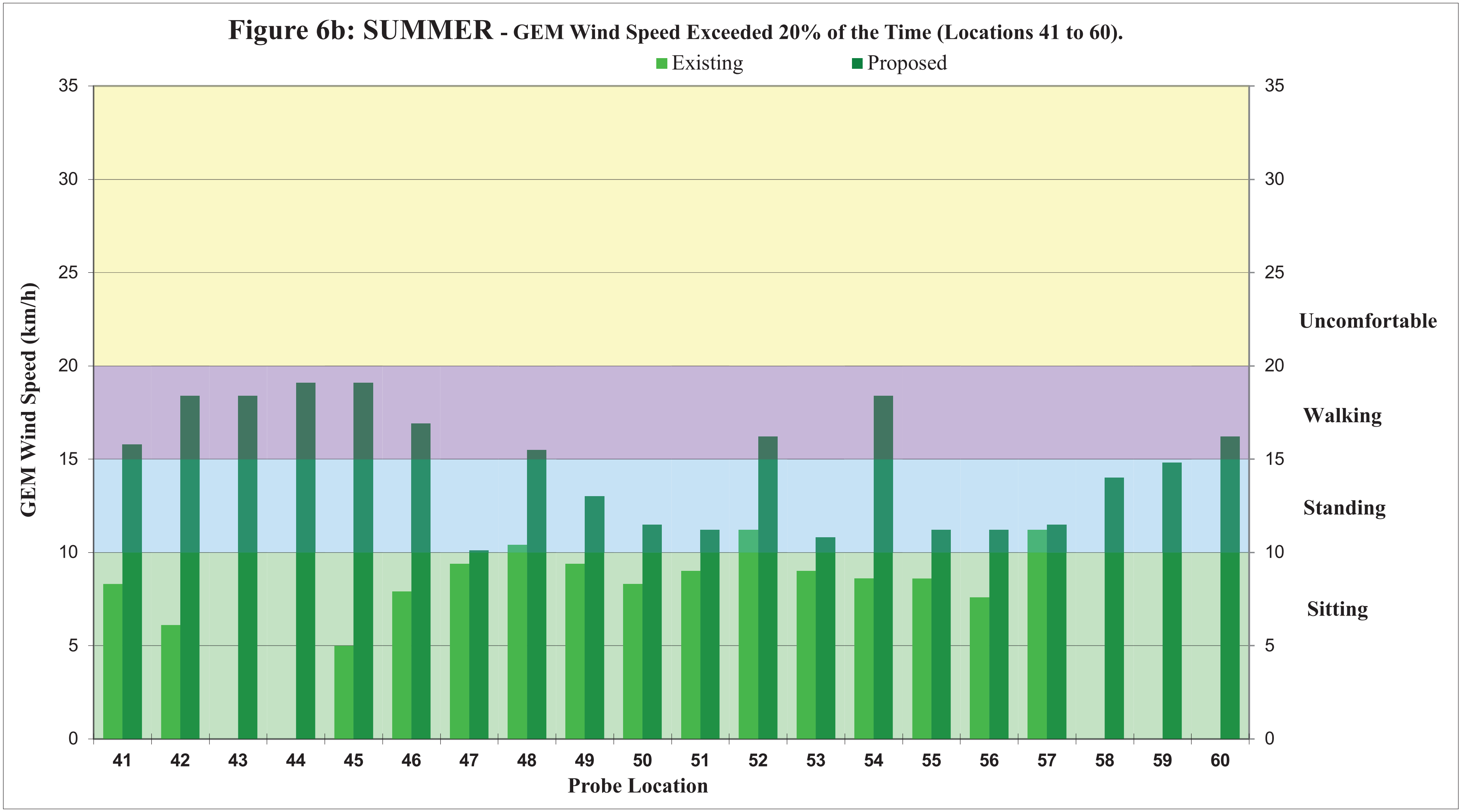


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 41 to 60).
Existing
Proposed
GEM Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

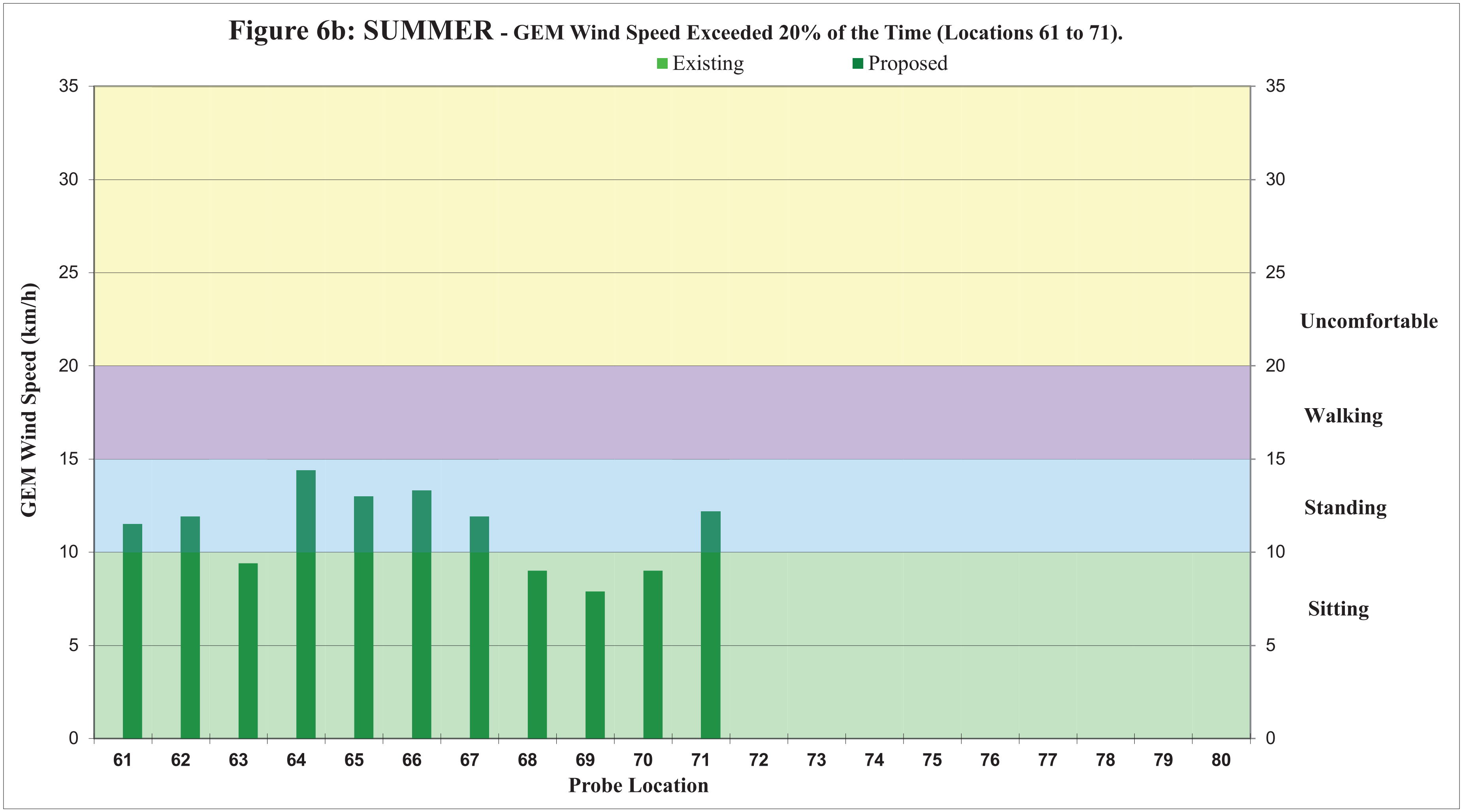


Figure 6b: SUMMER - GEM Wind Speed Exceeded 20% of the Time (Locations 61 to 71).
Existing
Proposed
GEM Wind Speed (km/h)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
5
10
15
20
25
30
35
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80

Figure 7a: Pedestrian level wind velocity comfort categories.

Comfort Categories - Winter - Existing

Sitting Standing Walking Uncomfortable

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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 - Summer - Existing

Sitting Standing Walking Uncomfortable

Figure 7d: Pedestrian level wind velocity comfort categories.

Comfort Categories - Summer - Proposed

Sitting Standing Walking Uncomfortable

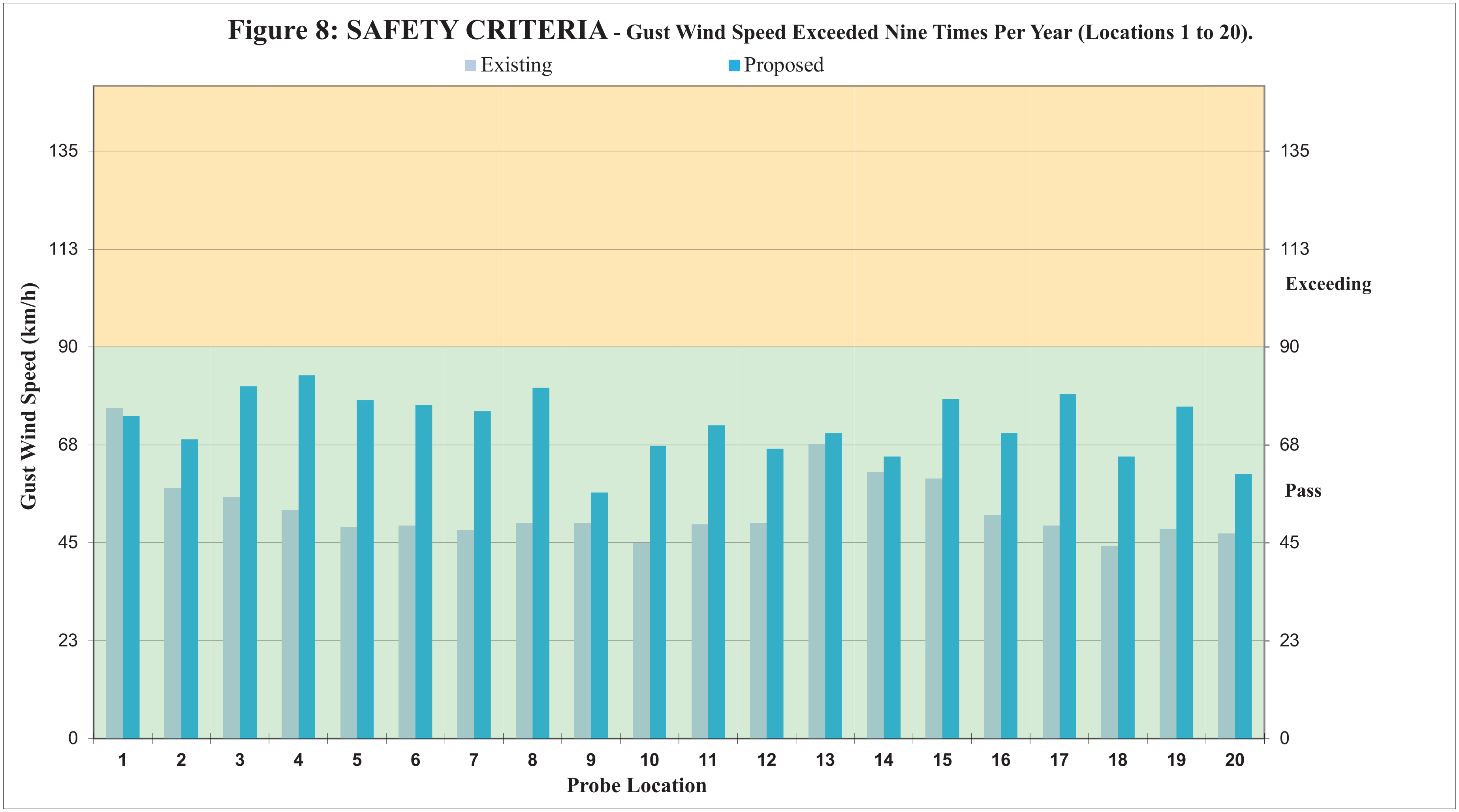
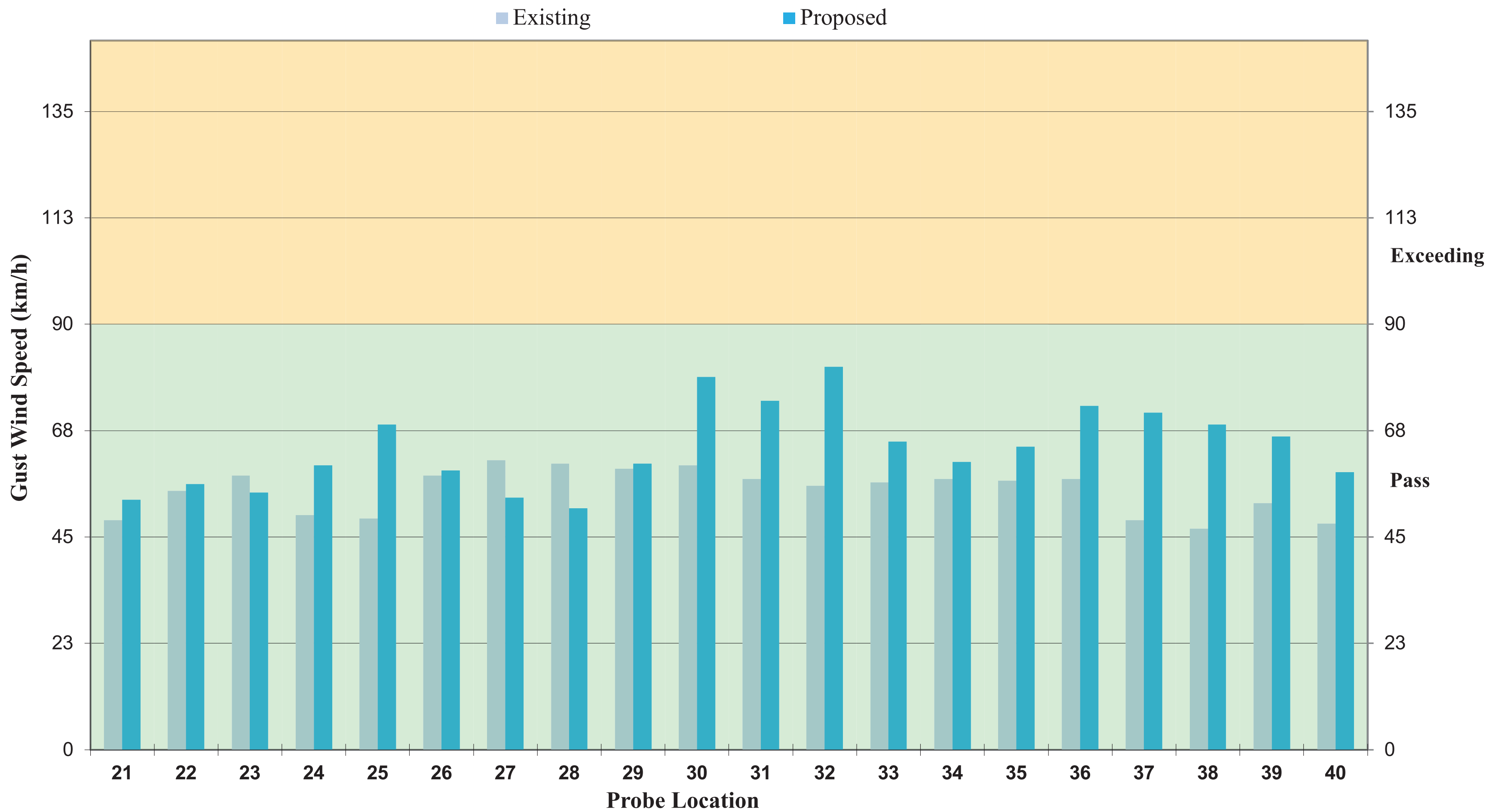


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 1 to 20).
Existing
Proposed
Gust Wind Speed (km/h)
135
113
90
68
45
23
0
Exceeding
Pass
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Probe Location

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



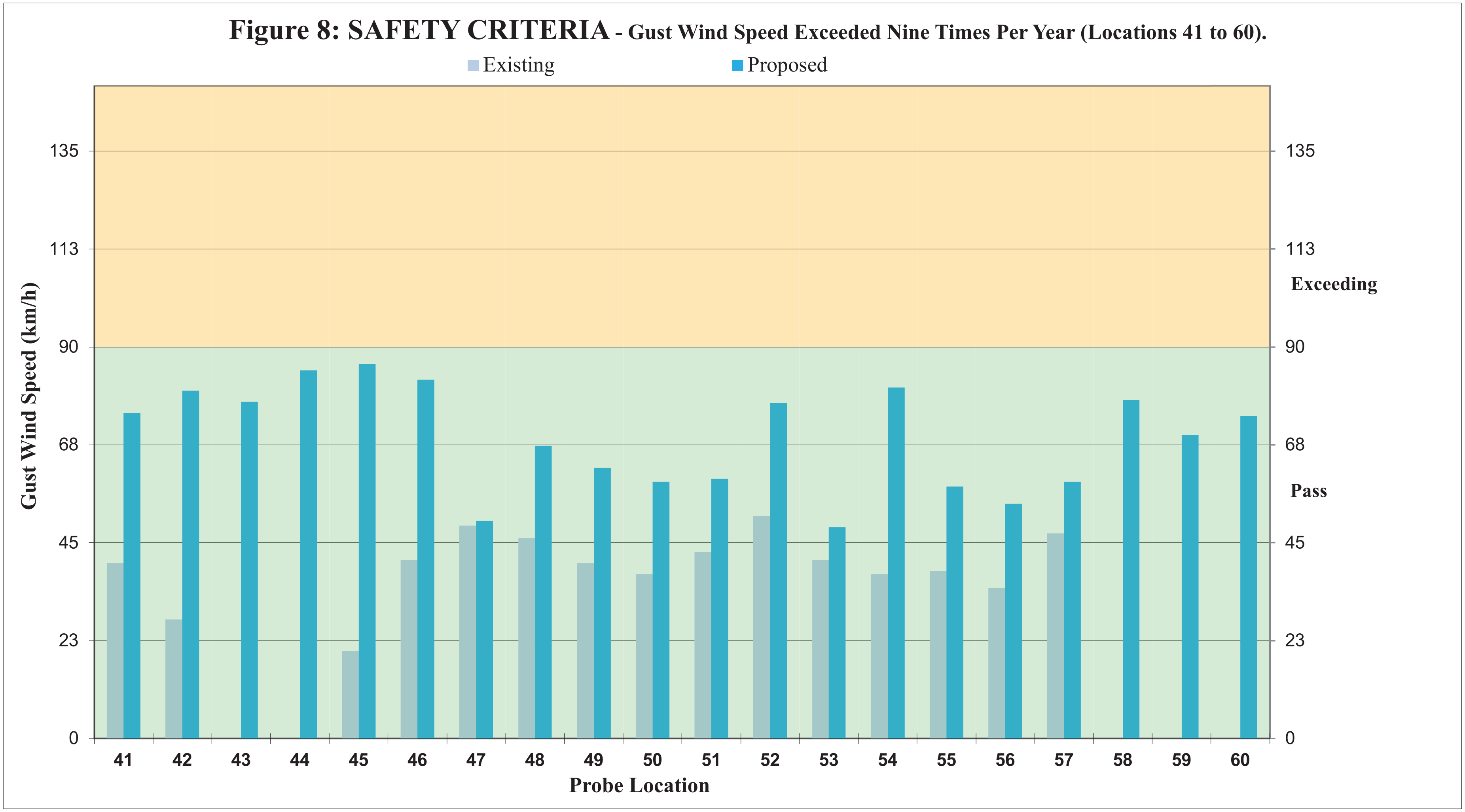


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 41 to 60).
Existing
Proposed
Gust Wind Speed (km/h)
135
113
90
68
45
23
0
Exceeding
Pass
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Probe Location

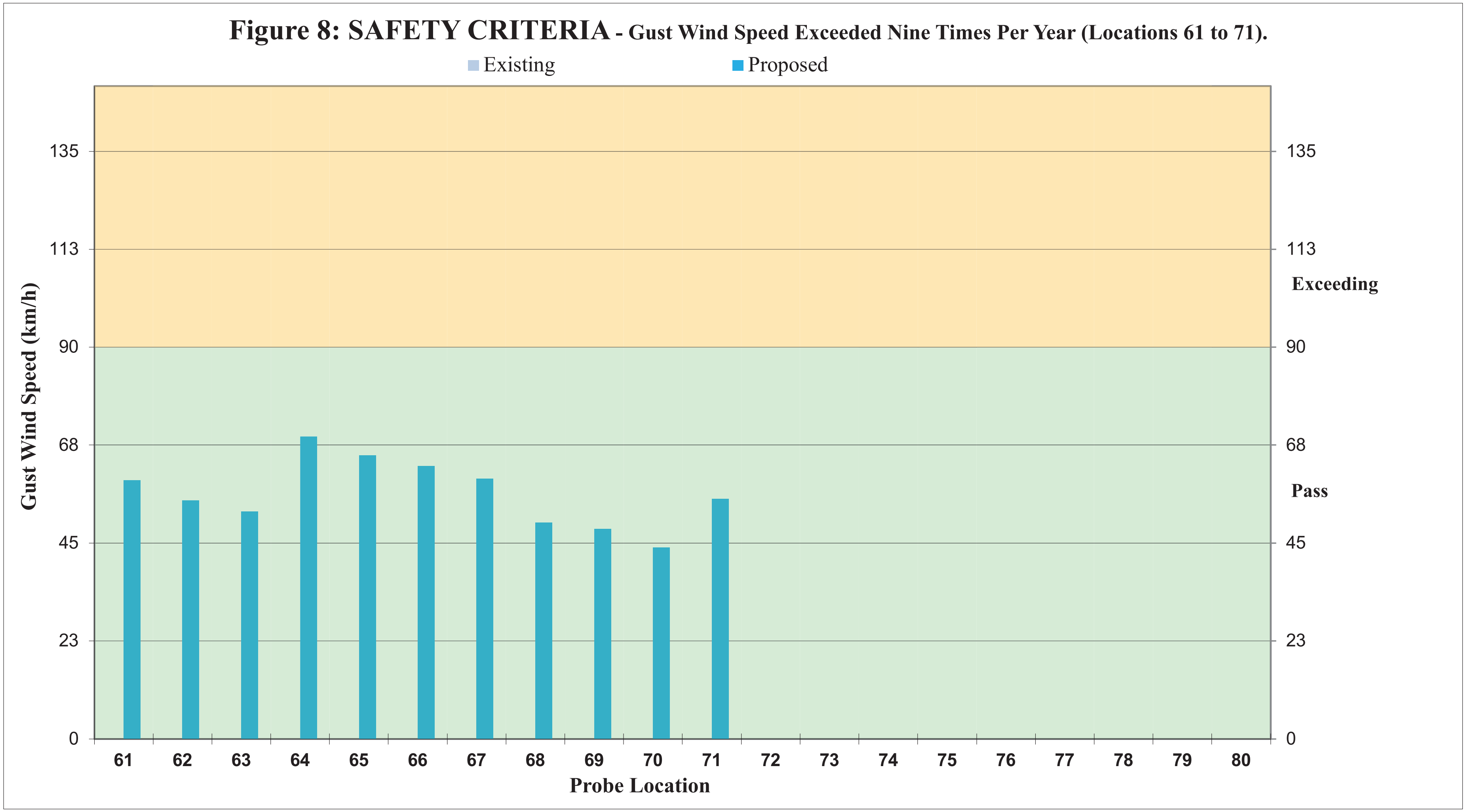


Figure 8: SAFETY CRITERIA - Gust Wind Speed Exceeded Nine Times Per Year (Locations 61 to 71).
Existing
Proposed
Gust Wind Speed (km/h)
135
113
90
68
45
23
0
Exceeding
Pass
61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
Probe Location

Figure 9a: Pedestrian level wind velocity safety criteria.

Safety Criteria - Existing

Pass Exceeding

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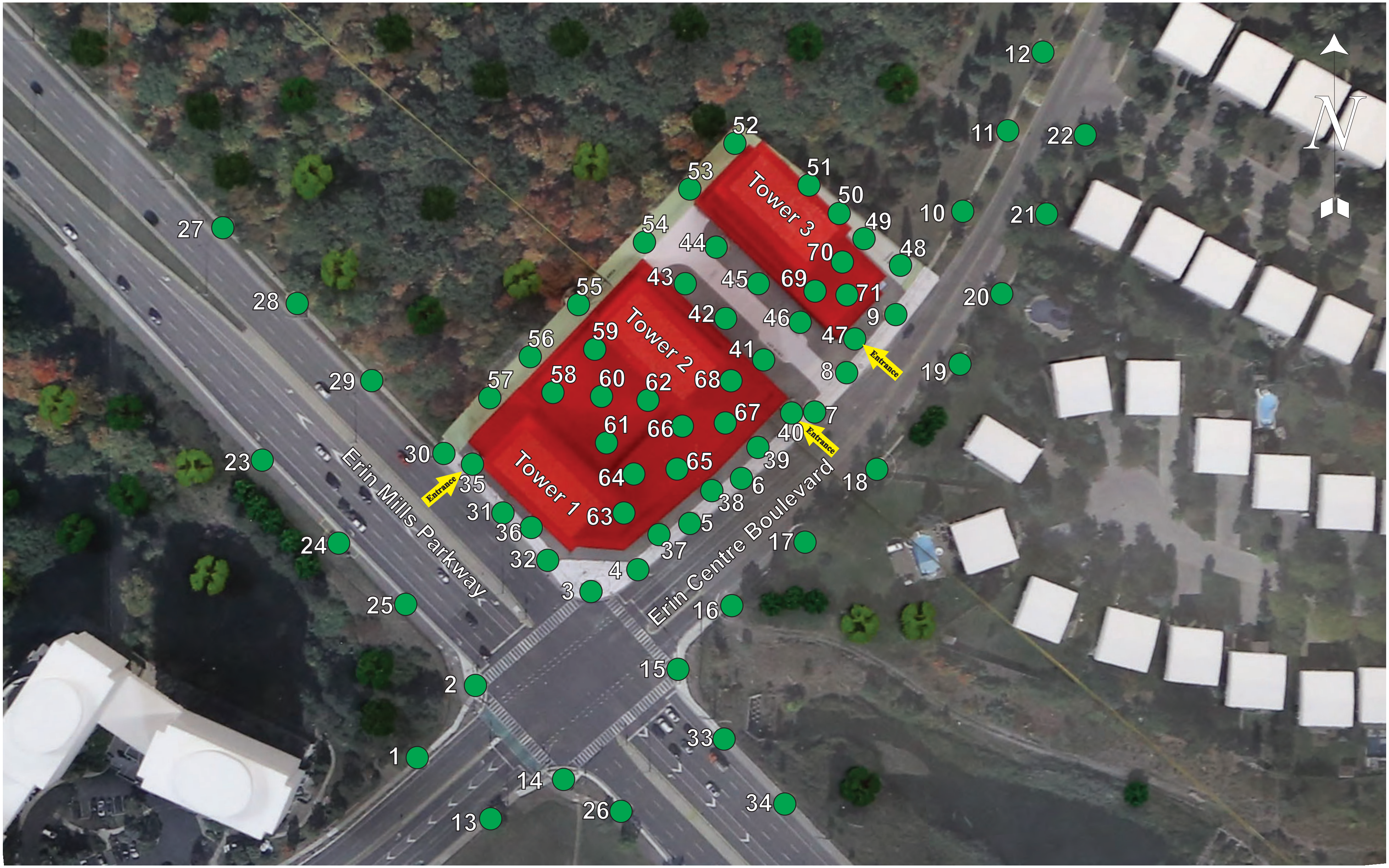
Figure 9b: Pedestrian level wind velocity safety criteria.



Safety Criteria - Proposed

Pass Exceeding

Figure 10: Pedestrian Level Wind Comfort and Safety Comparison Table

	GEM Speed (km/h)				Gust Speed (km/h)	
	Winter		Summer		Safety	
Probe	Existing	Proposed	Existing	Proposed	Existing	Proposed
1	18.7	18.4	15.5	15.5	76.0	74.2
2	14.4	18.7	12.6	15.8	57.6	68.8
3	14.0	20.5	12.2	16.9	55.4	81.0
4	13.7	19.4	11.5	15.5	52.6	83.5
5	13.0	17.6	11.2	14.0	48.6	77.8
6	13.0	15.8	10.8	12.6	49.0	76.7
7	12.6	19.1	10.4	16.6	47.9	75.2
8	12.2	18.7	9.7	15.5	49.7	80.6
9	13.0	14.0	10.4	12.2	49.7	56.5
10	12.2	16.2	10.4	14.0	45.0	67.3
11	13.7	15.1	11.2	12.6	49.3	72.0
12	13.0	14.8	11.2	12.2	49.7	66.6
13	16.9	17.3	14.0	14.8	67.7	70.2
14	15.5	16.6	13.3	14.0	61.2	64.8
15	15.5	18.4	13.0	14.4	59.8	78.1
16	13.7	17.6	11.9	14.8	51.5	70.2
17	13.0	17.6	10.8	14.4	49.0	79.2
18	11.9	16.6	10.1	13.7	44.3	64.8
19	12.2	18.4	10.1	15.1	48.2	76.3
20	12.6	15.8	10.4	13.3	47.2	60.8
21	12.6	13.3	10.4	11.5	48.6	52.9
22	14.0	13.3	11.5	11.2	54.7	56.2
23	14.4	13.7	11.9	11.9	58.0	54.4
24	11.5	15.8	10.4	13.7	49.7	60.1
25	12.6	19.1	11.2	16.2	49.0	68.8
26	15.1	15.5	13.0	13.0	58.0	59.0
27	14.8	13.7	12.6	11.9	61.2	53.3
28	14.4	13.3	12.6	11.9	60.5	51.1
29	14.0	15.1	12.2	13.0	59.4	60.5
30	13.3	20.9	11.9	18.4	60.1	78.8
31	13.3	18.0	11.9	15.8	57.2	73.8
32	13.7	19.8	12.2	16.9	55.8	81.0
33	15.1	16.2	12.6	13.0	56.5	65.2
34	15.1	15.1	13.0	12.6	57.2	60.8
35	12.2	16.2	10.8	13.7	56.9	64.1
36	13.7	19.1	11.9	15.8	57.2	72.7
37	12.6	15.1	10.8	11.9	48.6	71.3
38	12.2	14.8	10.4	11.9	46.8	68.8
39	13.3	14.0	10.8	11.9	52.2	66.2
40	12.6	13.0	10.4	11.5	47.9	58.7
41	10.1	18.4	8.3	15.8	40.3	74.9
42	7.2	21.6	6.1	18.4	27.4	79.9
43	0.0	20.9	0.0	18.4	0.0	77.4
44	0.0	23.0	0.0	19.1	0.0	84.6
45	5.8	23.0	5.0	19.1	20.2	86.0
46	10.1	19.8	7.9	16.9	41.0	82.4
47	11.9	11.9	9.4	10.1	49.0	50.0
48	12.6	16.9	10.4	15.5	46.1	67.3
49	10.8	14.0	9.4	13.0	40.3	62.3
50	9.4	12.6	8.3	11.5	37.8	59.0
51	10.4	12.2	9.0	11.2	42.8	59.8
52	13.3	19.8	11.2	16.2	51.1	77.0
53	10.8	13.0	9.0	10.8	41.0	48.6
54	10.4	22.0	8.6	18.4	37.8	80.6
55	10.4	13.7	8.6	11.2	38.5	58.0
56	9.0	13.3	7.6	11.2	34.6	54.0
57	12.6	13.3	11.2	11.5	47.2	59.0
58	0.0	18.0	0.0	14.0	0.0	77.8
59	0.0	16.9	0.0	14.8	0.0	69.8
60	0.0	19.4	0.0	16.2	0.0	74.2
61	0.0	14.0	0.0	11.5	0.0	59.4
62	0.0	13.7	0.0	11.9	0.0	54.7
63	0.0	11.9	0.0	9.4	0.0	52.2
64	0.0	16.6	0.0	14.4	0.0	69.5
65	0.0	15.1	0.0	13.0	0.0	65.2
66	0.0	15.8	0.0	13.3	0.0	62.6
67	0.0	14.0	0.0	11.9	0.0	59.8
68	0.0	10.8	0.0	9.0	0.0	49.7
69	0.0	9.4	0.0	7.9	0.0	48.2
70	0.0	10.1	0.0	9.0	0.0	43.9
71	0.0	14.0	0.0	12.2	0.0	55.1
72	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
74	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
76	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
78	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
80	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:

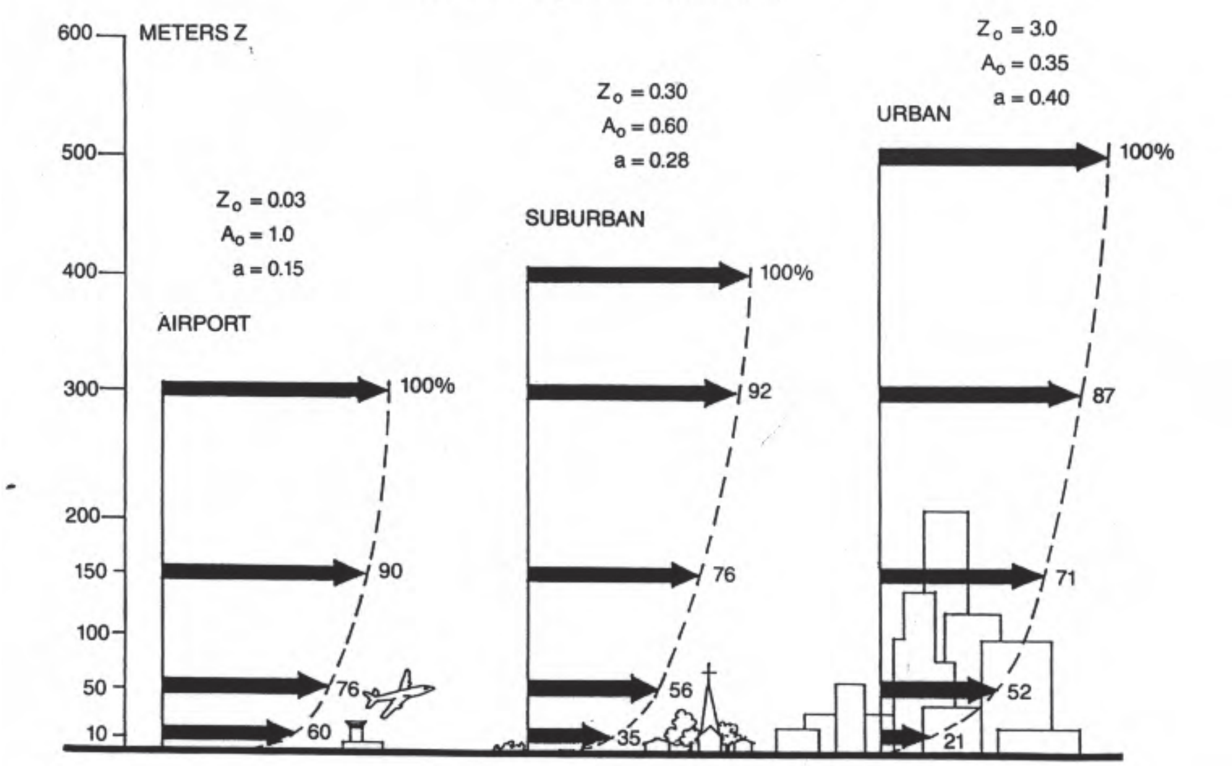


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

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.

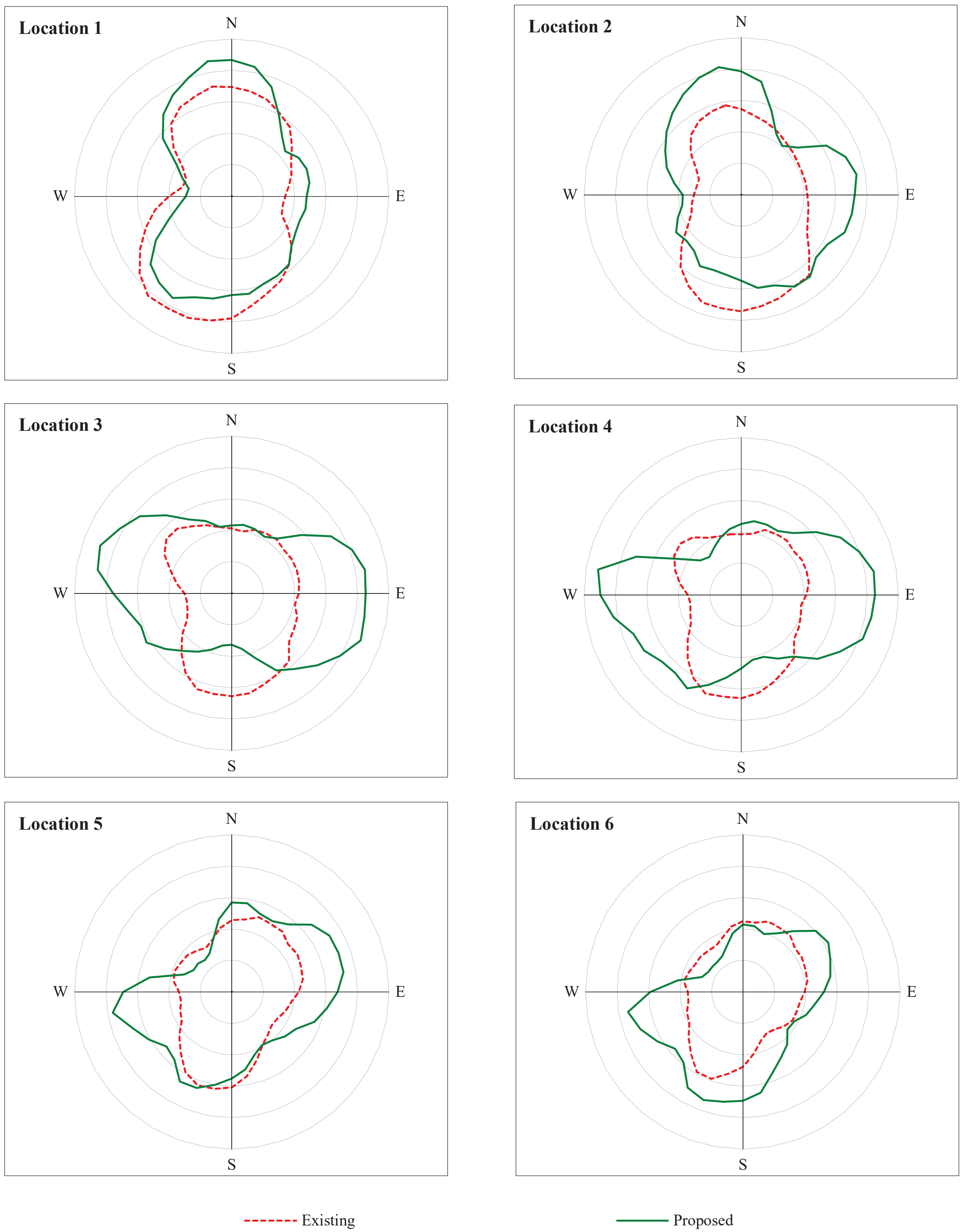
The Beaufort Scale is often used as a numerical relationship to wind speed based upon an observation of the effects of wind. Rear-Admiral Sir Francis Beaufort, commander of the Royal Navy, developed the wind force scale in 1805, and by 1838 the Beaufort wind force scale was made mandatory for log entries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



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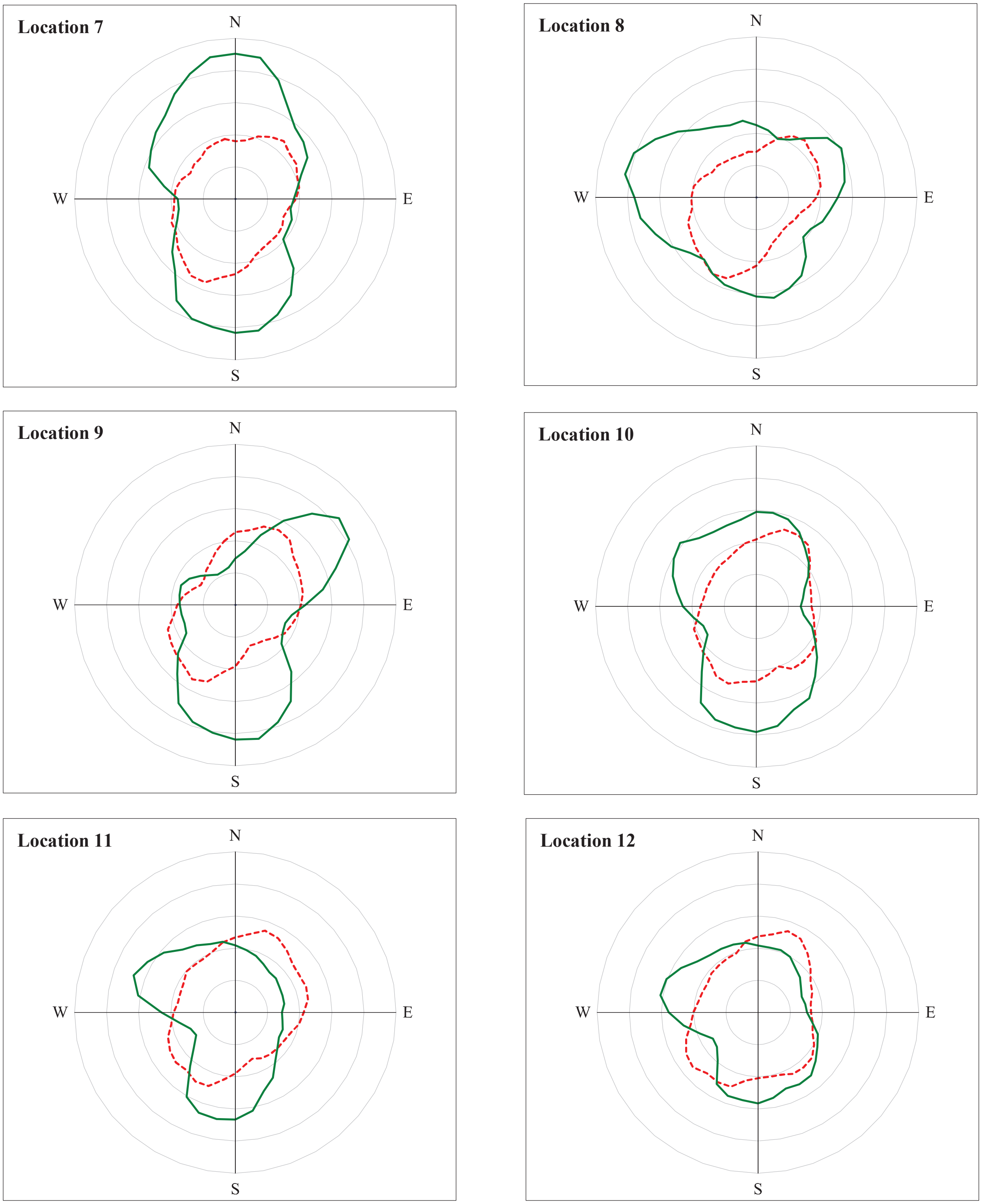

Existing
Proposed

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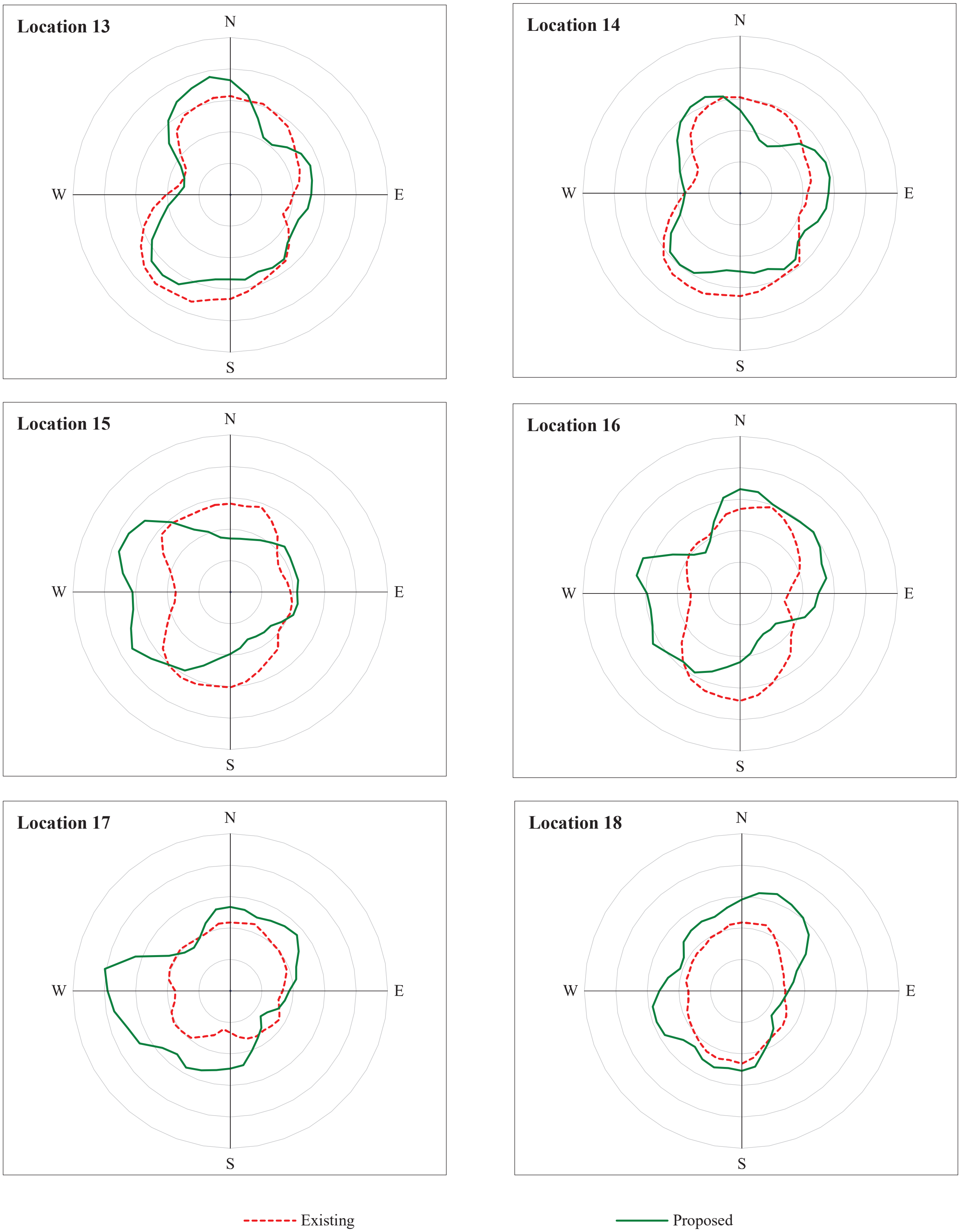

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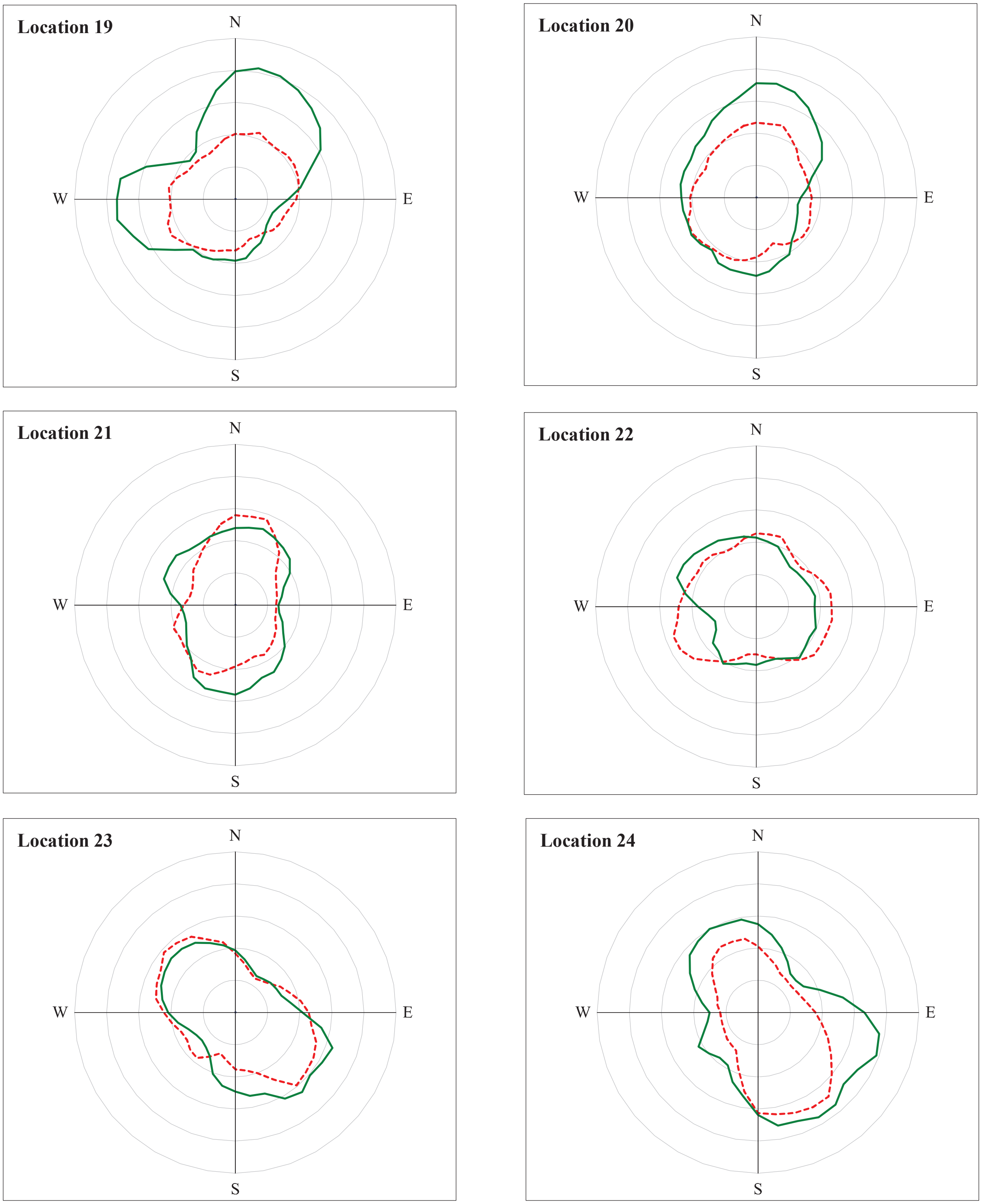

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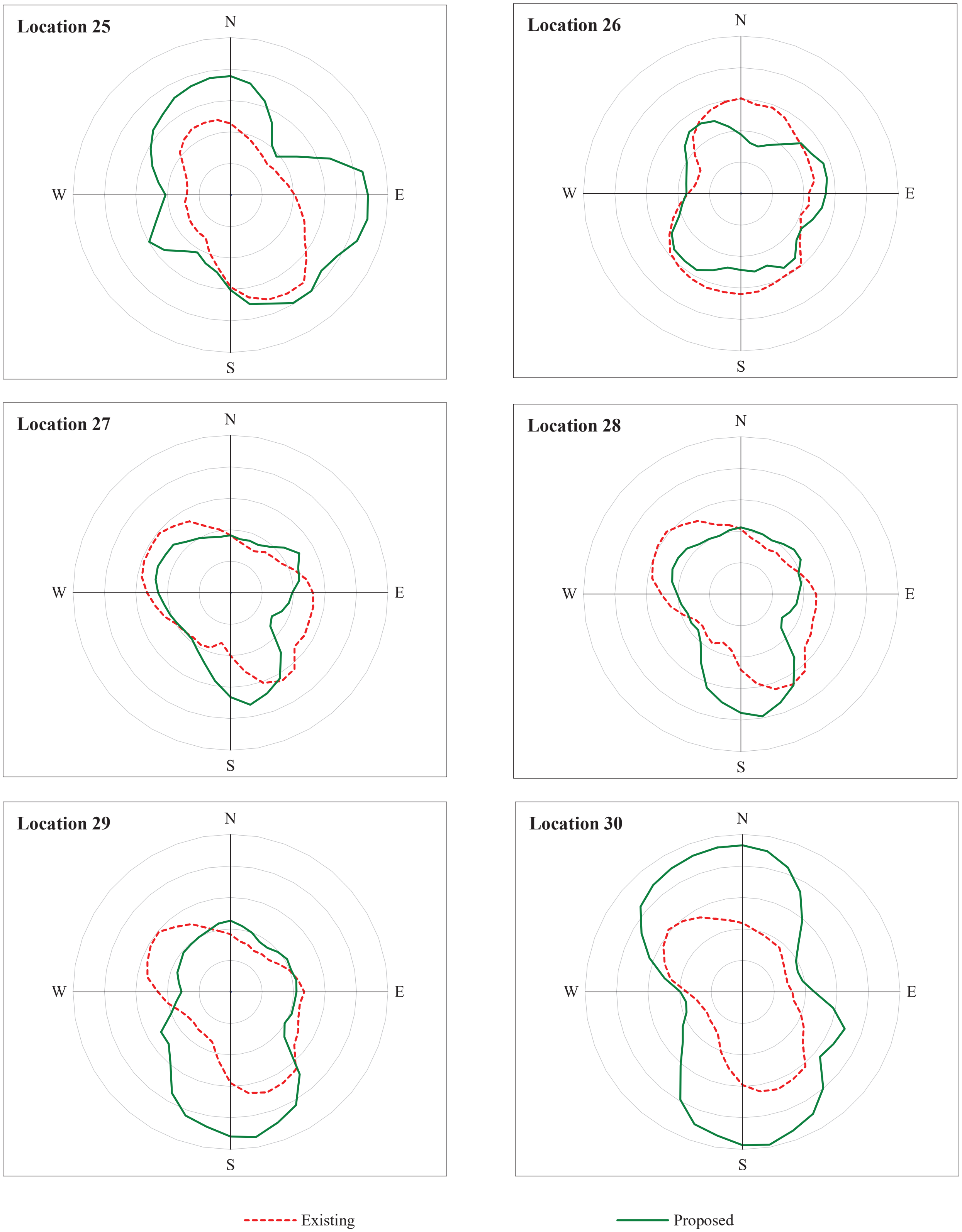

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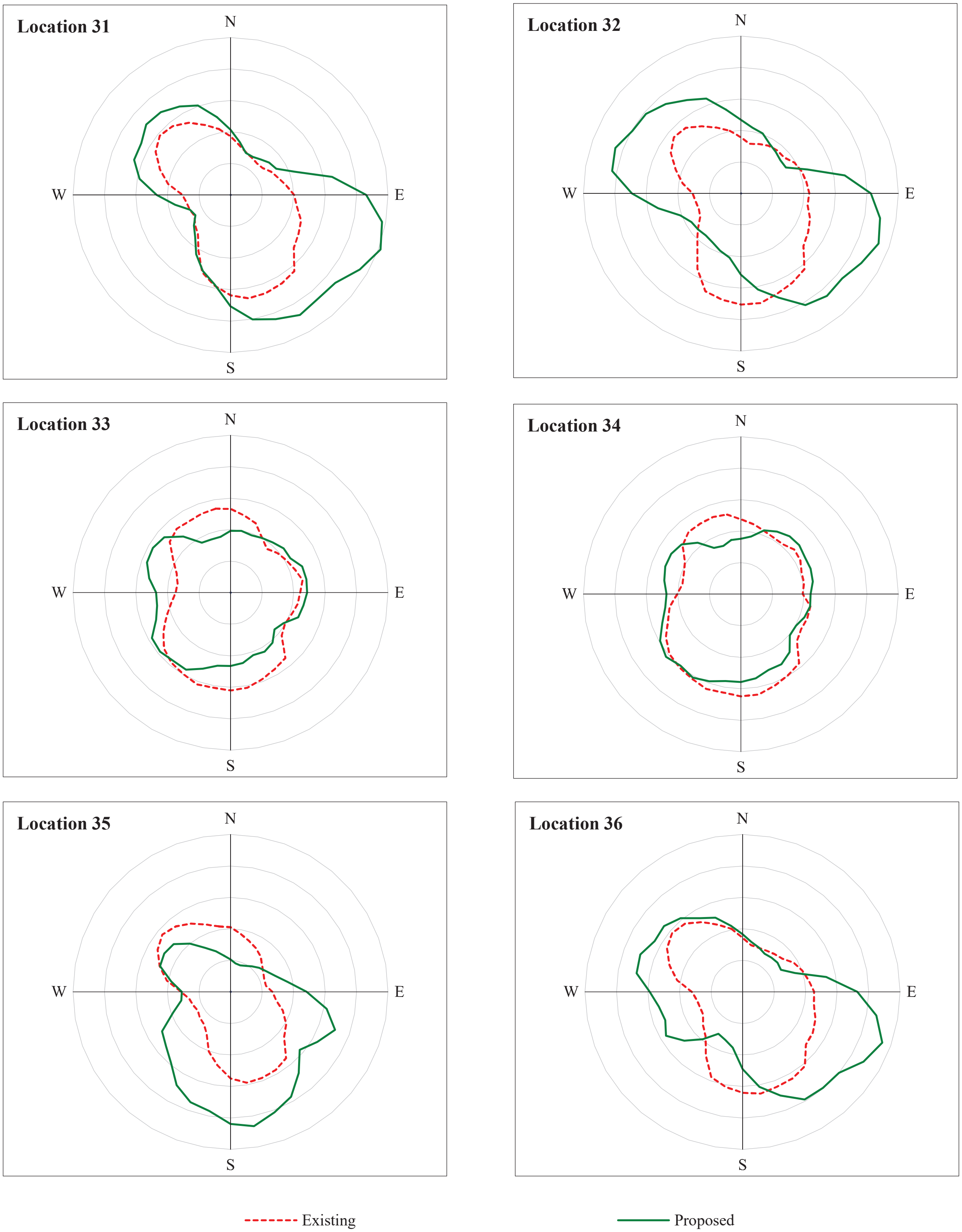

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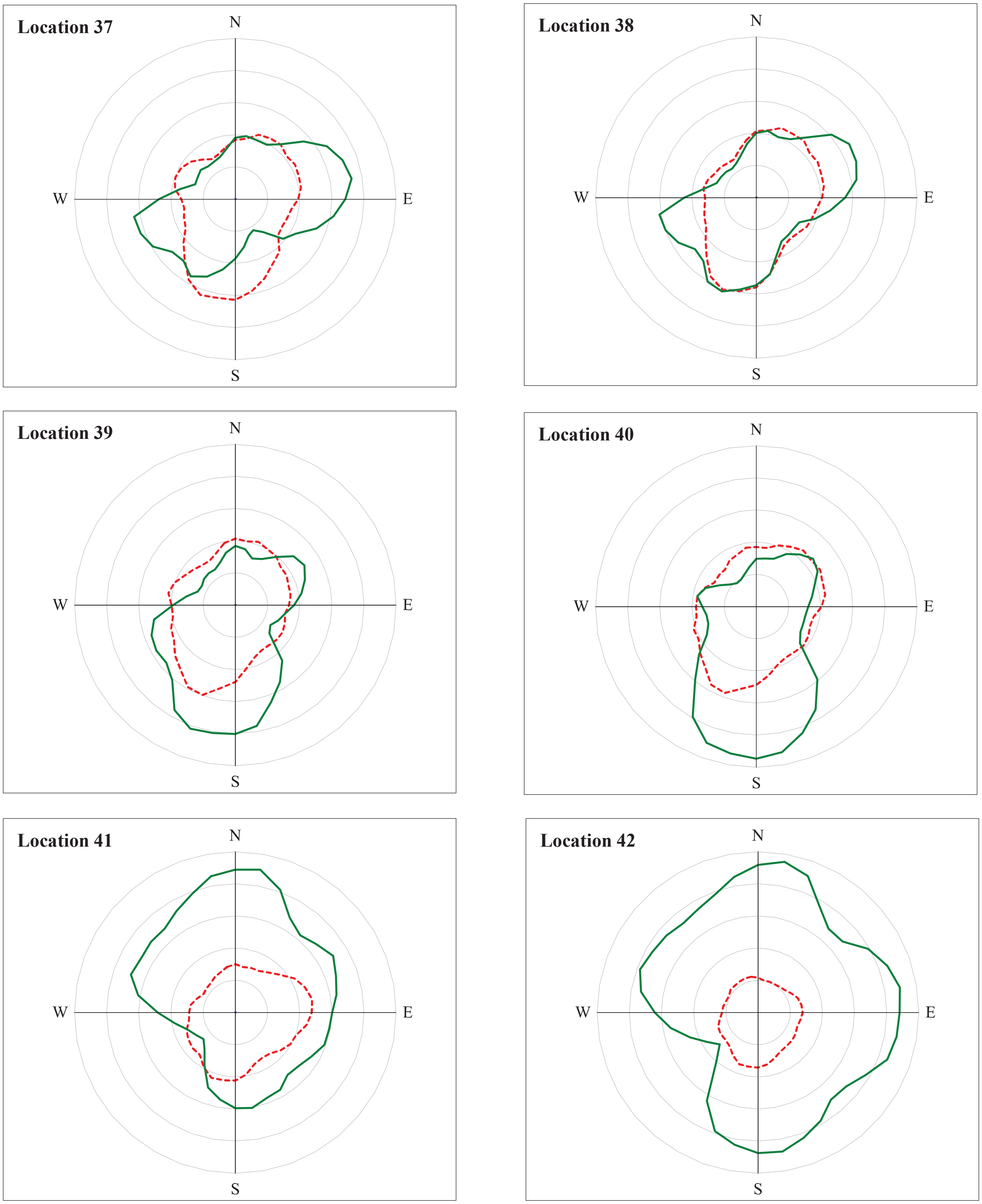

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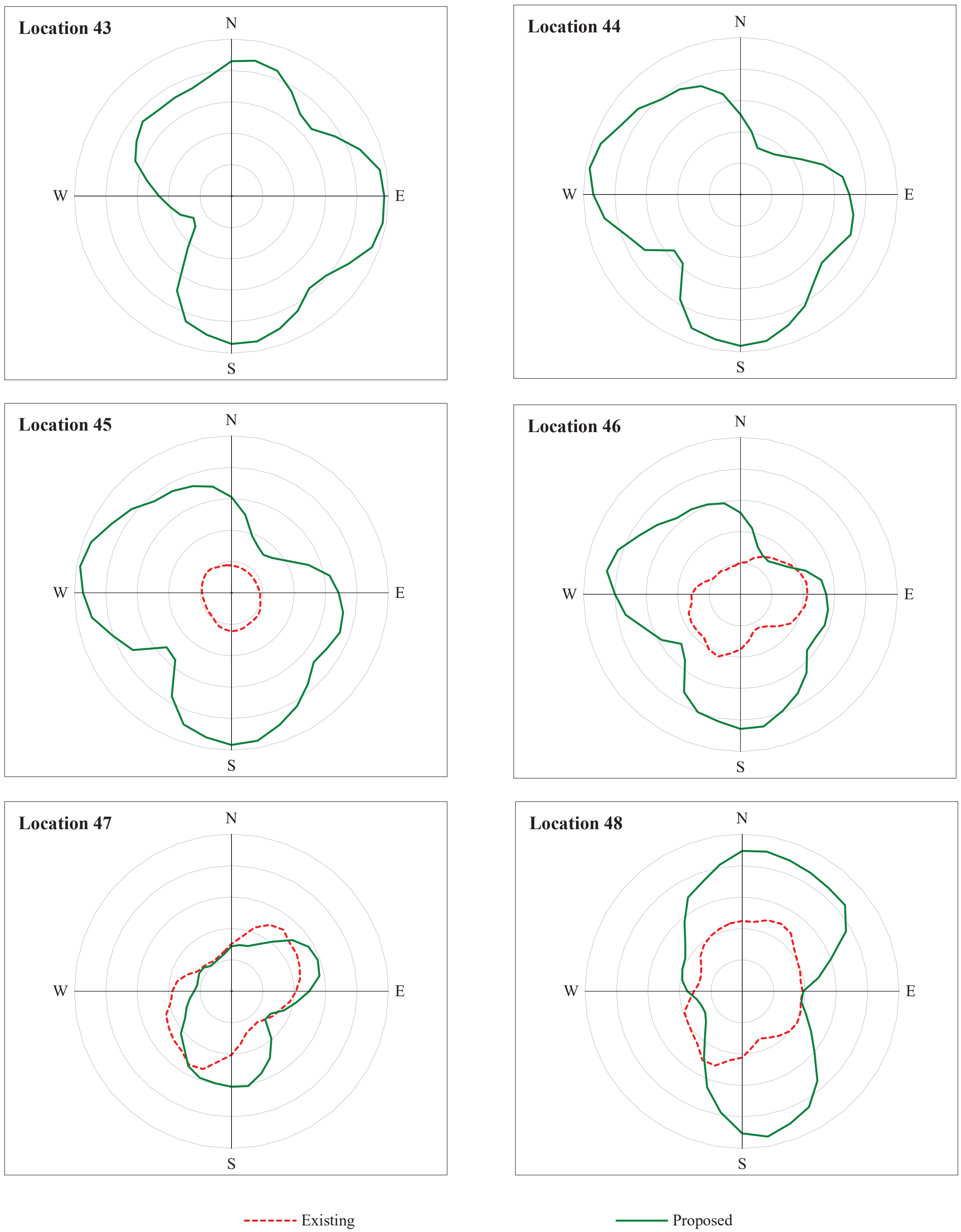

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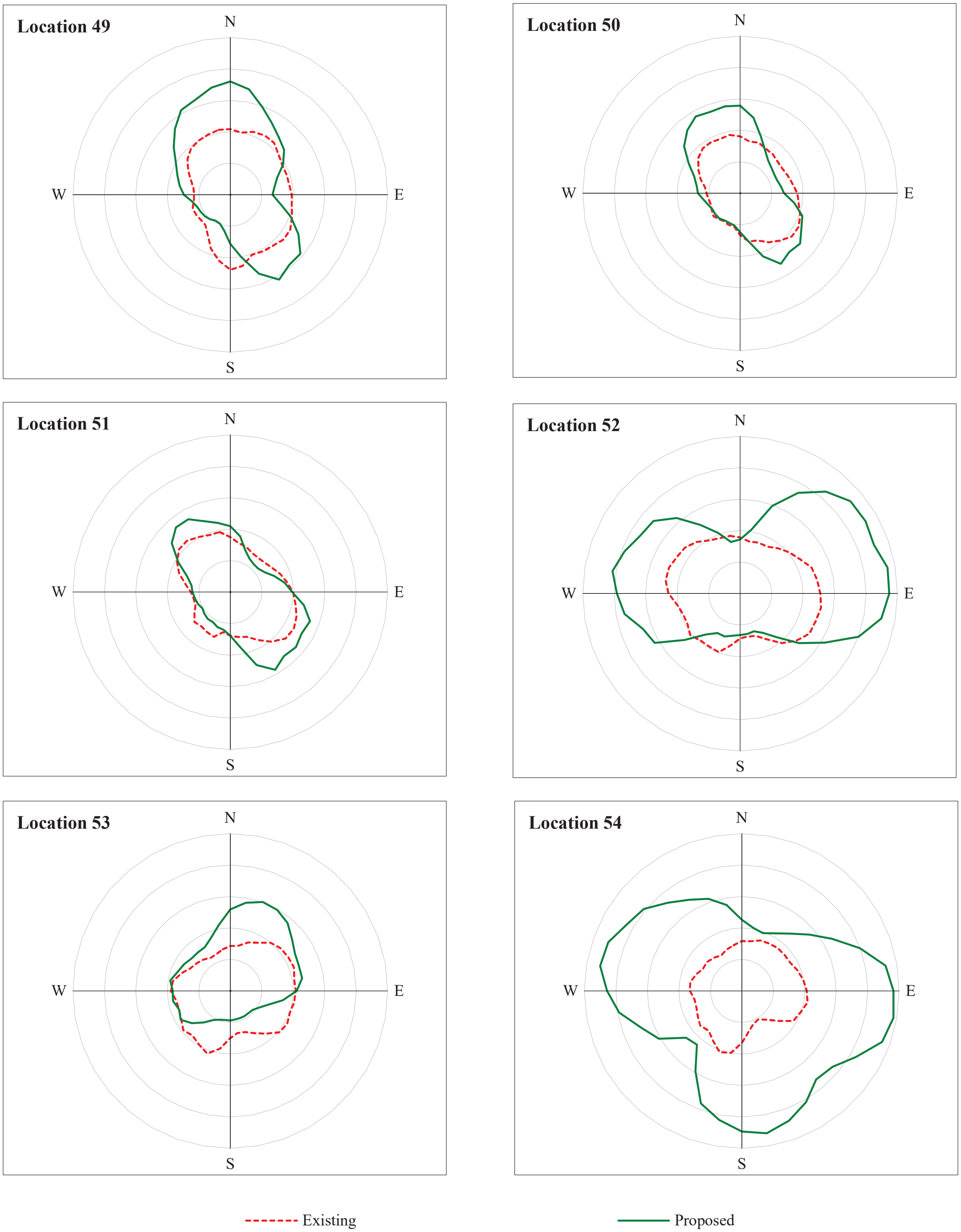

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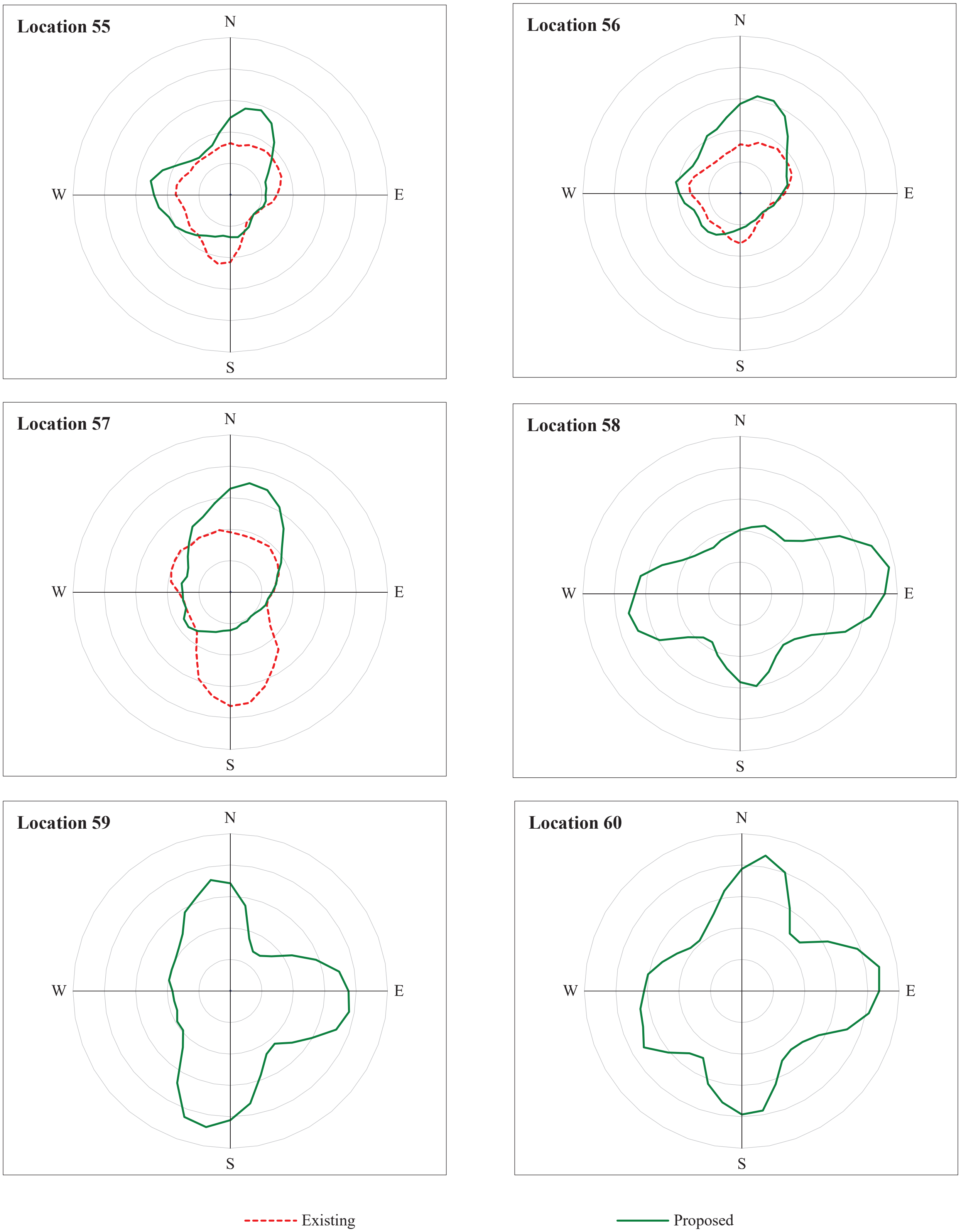

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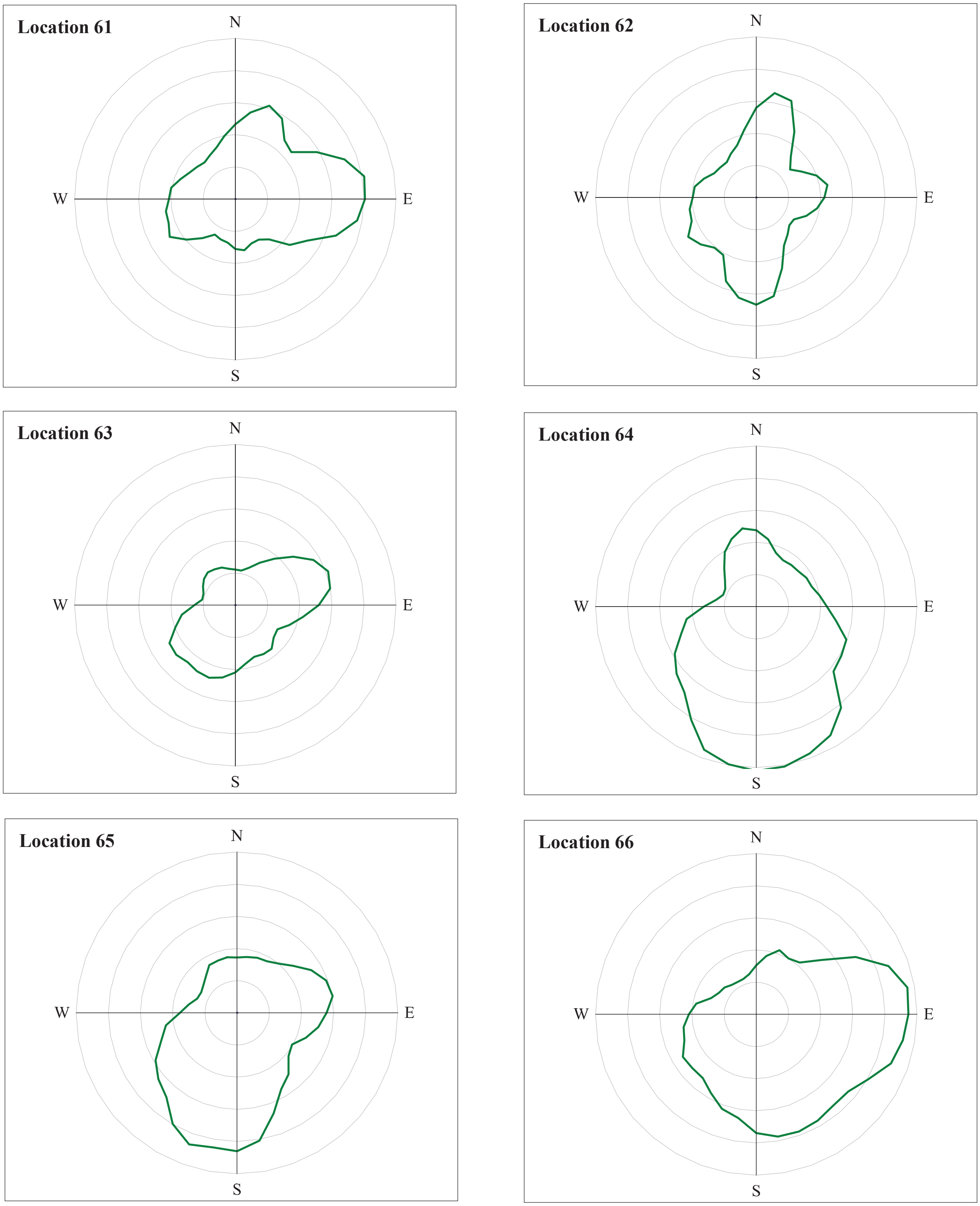

Existing   Proposed

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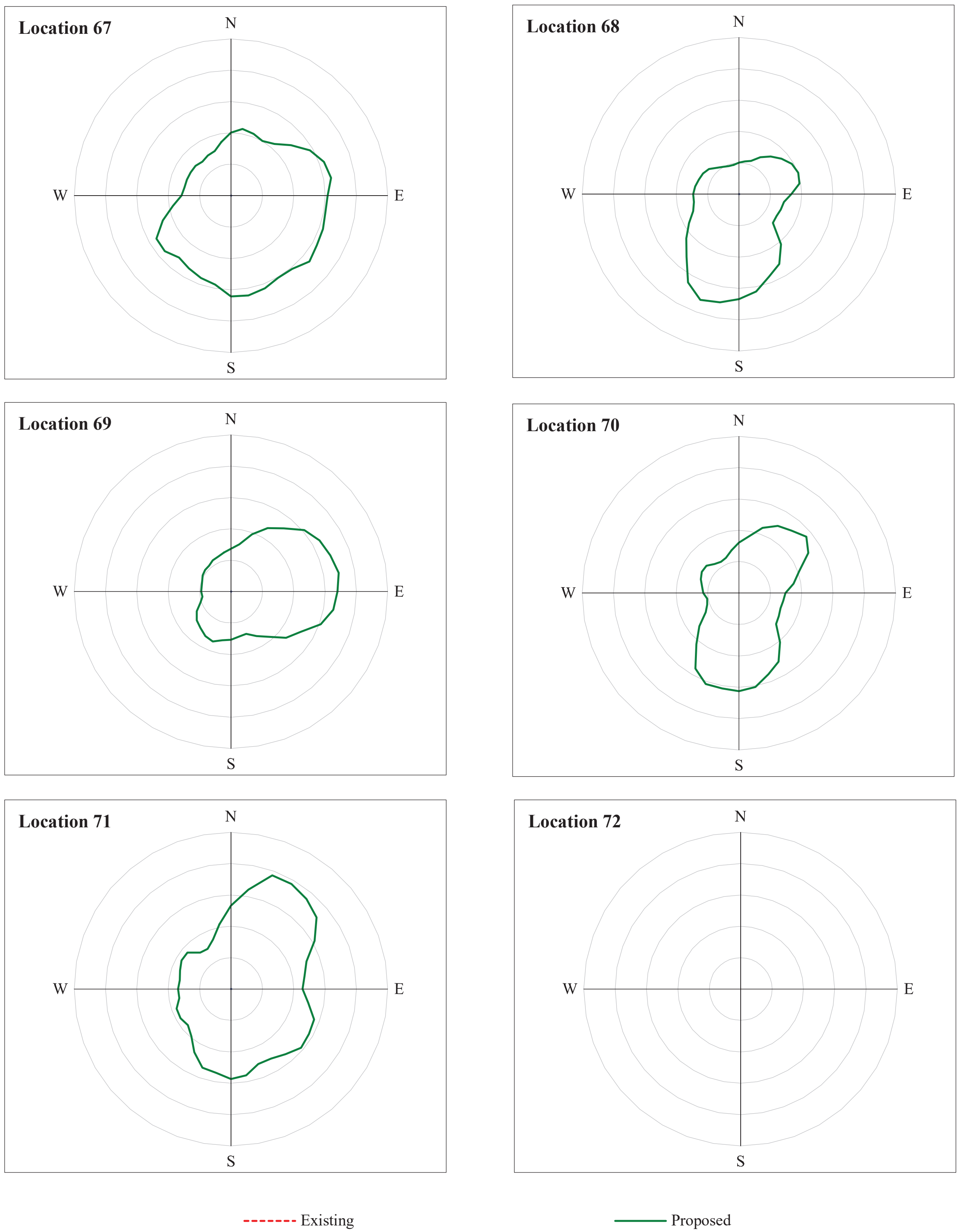

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