THEAKSTON ENVIRONMENTAL

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REPORT

FINAL PEDESTRIAN LEVEL WIND STUDY

Yee Hong Mississauga (YHMSS)

5510 Mavis Road
Mississauga, Ontario

Yee Hong Centre for Geriatric Care
c/o
Yee Hong Seniors Living

REPORT NO. 20688wind **July 20, 2021**

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1. CONCLUSIONS AND RECOMMENDATIONS

The Retirement Home & Life Lease Development proposed by Yee Hong Centre for Geriatric Care for the property municipally known as 5510 Mavis Road in the City of Mississauga, has been assessed for environmental standards regarding pedestrian level wind relative to comfort and safety. The pedestrian level wind and gust velocities predicted for the locations tested are within the safety criteria and most are within the comfort criteria described within the following report.

The Development involves a proposal to construct a building comprised of a 18 storey retirement home and a 13 storey life lease tower including 1, 6 and 7 storey podiums, the development situated to the northwest of the existing Yee Hong Centre - Mississauga. Outdoor Amenity space is proposed at grade and on the roof at the 2nd level, and the vehicular drop-off along with access to the parking garage is accessed via a driveway to the southwest of the building.

The Development is, for all intents and purposes, surrounded to prevailing windward directions by a predominantly suburban mix of institutional, residential and commercial development, related open areas, and mature vegetation. The most significant buildings in the immediate surroundings, from a wind perspective, are to the southeast of the proposed Development and comprised of the Yee Hong Centre – Mississauga, a 5 storey Long Term Care Residence, followed by the 1 - 2 storey St. Francis Xavier Church situated to the northwest. Lands to the remaining quadrants accommodate for the most part low-density residential dwellings which transitions to industrial/commercial buildings to the northwest of Matheson Boulevard West.

In general, urban development provides turbulence inducing surface roughness that can be wind friendly, while open settings afford wind the opportunity to accelerate as the wind's boundary layer profile thickens at the pedestrian level, owing to lack of surface roughness. 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 to urban, and to a lesser degree suburban, settings may prove problematic, as winds exacerbated by the relatively more open settings are redirected to flow over, around, and between urban buildings.

These phenomena were observed at the existing site with prevailing winds that have opportunity to accelerate over the relatively suburban lands associated with the site and adjacent streets. This setting accounts for the moderately windy conditions observed in the existing setting, at the Mavis Road, Father D'Souza Drive intersection to the immediate north of the site. With inclusion of the proposed Development, winds that formerly flowed over the existing lands are redirected, tending to split with portions flowing over, around and down the proposed building's façades. At the pedestrian level, the winds redirect to travel horizontally along buildings, around corners and beyond, creating minor windswept areas at or near building corners and in the gaps between. These conditions are primarily attributable to the setting, whereby the proposed Development penetrates winds that formerly flowed over the existing lands.

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

- stepped façades
- irregular façades
- canopies
- balconies
- overhangs
- parapet walls
- railings
- wind screens
- fencing
- landscaping

and others, that were included in the proposed Development's massing and landscape design. The incorporation of the mitigation features contributes to pedestrian comfort conditions that are considerably more comfortable than the existing setting, and for the most part suitable for the areas' intended uses. The proposed Development will realize wind conditions acceptable to a typical urban context and remains within the pedestrian level wind velocity safety criteria as All-Weather Areas, as described in the following.

Respectfully submitted,

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2. INTRODUCTION

Theakston Environmental Consulting Engineers, Fergus, Ontario, were retained by Yee Hong Seniors' Living Inc. on behalf of Yee Hong Centre for Geriatric Care, to study the pedestrian level wind environment for their proposed Development occupying a portion of a block of lands situated to the south of the intersection of Mavis Road with Father D'Souza Drive, municipally known as 5510 Mavis Road in the City of Mississauga and depicted on the Aerial Photo in Figure 2a.

The Development involves a proposal to construct a building comprised of 18 and 13 storey towers including 6 and 7 storey podiums adjacent to the existing Yee Hong Centre, a 5 storey Long Term Care Residence, the buildings in the configuration shown in Figure 2b.

Andy Bicanic, of Yee Hong Seniors Living, initiated the request, and Global Architect Inc. provided drawings. The co-operation and interest of the Client and their sponsors in all aspects of this study is gratefully acknowledged.

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

In order to obtain an objective analysis of the wind conditions for the property, the wind environment was tested in two configurations. The existing configuration included existing and proposed buildings in the surrounding area. The proposed configuration included the Development's subject building. Mitigation procedures were assessed during these tests to determine their impact on the various wind conditions.

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

3. OBJECTIVES OF THE STUDY

1. To quantitatively assess, by model analyses, the pedestrian level wind environment under existing conditions and future conditions with the Development in accordance with the City of Mississauga's Terms of Reference.

2. To assess mitigative solutions.

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

4. METHOD OF STUDY

4.1 General

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

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

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

The mean and gust wind speeds at the thirty-eight (38) points tested were subsequently combined with the design probability distribution of gradient wind speed and direction, (wind statistics) recorded at Airports in the vicinity, to provide predictions of the full-scale pedestrian level wind environment. Predictions of the full-scale pedestrian level wind environment are presented as the wind speed exceeded 20% of the time, based on winter and summer winds 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 2017. The meteorological data includes hourly wind records and annual extremes. The analysis of the hourly wind records provides information to develop the statistical climate model of wind speed and direction. From this model, predicted wind speeds regardless of wind direction for various return periods can be derived. The record of annual extremes was also used to predict wind speeds at various return periods. Based on the analysis of the hourly records, the predicted hourly-mean wind speed measured at 10*m* above grade, 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. Distributions for Winter and Summer are shown. From this it is apparent that winds can occur from any direction, however, historical data indicates the directional characteristics of strong winds during the winter months are north through west to southwest. Through the summer months, the winds are not as strong and are mainly from the same directions as winter winds, with the addition of winds from the southeast more often.

4.4 Wind Simulation

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

4.5 Pedestrian Level Wind Velocity Study

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

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

4.6 Pedestrian Comfort Criteria

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

Figure 6 presents results for the mean wind speed that is exceeded 20% of the time. These speeds are directly related to the pedestrian comfort at a particular point. The overall comfort rating, for existing and proposed, are depicted in Figure 7. Table 1, below, summarizes the comfort criteria used in the presentation of the results depicted in Figures 6 and 7.

Table 1: Comfort Criteria

ACTIVITY	**Gust Equivalent Mean Speed Exceeded 20% of the Time**		**Description**
COMFORT	***km/h***	***m/s*** (used in Fig. 6)	
Sitting	0-10	0-2.8	Calm or light breezes desired for outdoor restaurants and seating areas where one can read a paper without having it blown away.
Standing	0-15	0-4.2	Gentle breezes suitable for main building entrances and bus stops.
Walking	0-20	0-5.6	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering.
Uncomfortable	>20	>5.6	Strong winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended.

The activities are described as suitable for Sitting, Standing, Walking, or Uncomfortable, depending on average wind speed exceeded 20% of the time. For a point to be rated as suitable for Sitting, for example, the wind conditions must not exceed 10*km/h* (2.8*m/s*), more than 20% of the time. Thus, in the plots (Figure 6), the upper limit of each bar ends within the range described by the comfort category. For sitting, the rating would include conditions ranging from calm up to wind speeds that would rustle tree leaves or wave flags slightly, as presented in the Beaufort Scale included in the Appendices. As the name infers, the category is recommended for outdoor space where people might sit for extended periods.

The Standing category is slightly more tolerant of wind, including wind speeds from calm up to 15*km/h* (4.2 *m/s*). In this situation, the wind would rustle tree leaves and, on occasion, move smaller branches while flags flap. This category would be suitable for locations where people might sit for short periods or stand in relative comfort. The Walking category includes wind speeds from calm up to 20*km/h* (5.6*m/s*). These winds would set tree limbs in motion, lift leaves, litter and dust, and the locations are suitable for activity areas. The Uncomfortable category covers a broad range of wind conditions that are generally a nuisance for most activities, including wind speeds above 20*km/h* (5.6*m/s*).

In Figure 6, the probe locations are listed along the bottom of the chart; beneath the graphical representation of the Mean Wind Speed exceeded 20% of the time. Along the right edge of the plot the comfort categories are shown. The background of the plot is lightly shaded in colours corresponding to the categories shown in Table 1. Each category represents a 5*km/h* (or more) interval. The location is rated as suitable for Sitting, Standing, Walking, or Uncomfortable, if the bar extends into the corresponding interval.

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

4.7 Pedestrian Safety Criteria

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

Both the Comfort and Safety Criteria are based on those developed at the Allan G. Davenport Wind Engineering Group Boundary Layer Wind Tunnel Laboratory, located on the campus of The University of Western Ontario. The comfort criteria were subsequently revised for the Mississauga Urban Design Terms of Reference for Wind Comfort and Safety Studies, in consultation with RWDI and more closely respects the Lawson criteria.

Table 2: Safety Criteria

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

4.8 Pedestrian Comfort Criteria – Seasonal Variation

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

The comfort of a site is based on the "winter" or "summer" results of the study, Figures 6a and 6b and 7a through 7d. When compared to the annual average wind speed, winter winds are about 12.5% higher and summer winds are about 16% lower.

5. RESULTS

5.1 Study Site and Test Conditions

Proposed Development

The Development municipally known as 5510 Mavis Road occupies lands to the south of the intersection of Mavis Road with Father D'Souza Drive in the City of Mississauga. The Development involves a proposal to construct a building comprised of 18 and 13 storey towers including 6 and 7 storey podiums adjacent to the existing Yee Hong Centre, a 5 storey Long Term Care Residence. Outdoor Amenity space is proposed at grade and the second level. Vehicular drop-off along with access to the parking garage as well as the main entrance to the building are via a driveway to the southwest of the building.

The configuration of the proposed Development is shown in Figure 2b. The Development Site, located in the City of Mississauga, is depicted in the Aerial Photo in Figure 2a. Note: Mississauga's street orientation is relative to the Lake Ontario Shoreline resulting in east/west orientated streets in the subject area being offset by approximately 50 degrees north.

View of the Yee Hung Seniors 5510 Mavis Road Development Site Looking Southeast.

<u>Surrounding Area</u>

As mentioned, buildings in the immediate surround on the same property include the Yee Hong Centre, a 5 storey Long Term Care Residence. Beyond the subject property, to the immediate northeast beyond Mavis Road, is a 3 storey townhomes development, with a park and single-family dwellings beyond. Lands to the southwest of Mavis Road are for the most part low-density residential dwellings, and lands to the northwest of Matheson Boulevard West are comprised of industrial/commercial buildings with large open areas assigned to parking.

<u>Macroclimate</u>

For the proposed Development, the upstream wind flow during testing was conditioned to simulate an atmospheric boundary layer passing over suburban terrain. The terrain within the site's immediate vicinity was incorporated into the proximity model. Historical meteorological data recorded from the Toronto Pearson International Airport was used in this analysis. For studies in the City of Mississauga, the data is presented for two seasons and 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 10*m*. Thus, representative ground level velocities at a height of 2*m*, for an urban macroclimate, are 52% of the mean values indicated on the wind rose, (for suburban and rural macroclimates the values are 63% and 78% respectively).

Winter (November through April) 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. Summer (May through October) has the lowest mean wind velocities of the seasons with prevailing winds from north through west to southerly directions 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, thirty-eight (38) wind velocity measurement probes were located around the proposed Development, activity areas, and surrounds, 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 as well as proposed mitigation was removed and the “existing” site model retested.

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

The design probability distribution gradient wind speed and direction, taken from historical meteorological data for the area (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.

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

Venturi action, scour action, downwash and other factors, as discussed in the Appendix on wind flow phenomena, can be associated with large buildings, depending on their orientation and configuration. These serve to increase wind velocities. Open areas within a heavily developed area may also encounter high wind velocities. Consequently, wind force effects are common in heavily built-up areas. The Development site is open to a predominantly suburban setting to prevailing and remaining compass points with winds flowing over and between buildings. As such, the surroundings can be expected to influence wind at the site to varying degrees. It should be noted that the probes are positioned at points typically subject to windy conditions in order to determine the worst-case scenario.

5.3 Review of Probe Results

The probe results, as follows, were clustered into groups comprised of Public Street Conditions, Neighbouring Site Conditions, Internal Site Conditions, Pedestrian Entrance Conditions, and Outdoor Amenity Area Conditions. The measurement locations are depicted in Figure 4 and are listed in Figures 6a and 6b, for 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. The following discusses anticipated wind conditions and suitability for the points' intended use.

5.3.1 Public Street Conditions

Mavis Road

Probes 1 through 14, were located along Mavis Road within the zone of influence of the proposed Development. These probe locations indicate wind conditions that are mainly suitable for standing in the existing setting during the summer with localised areas suitable for sitting, and standing during the winter, with localised areas suitable for walking. The buildings along Mavis Road to the north, and to the south of the Development site provide blockage to dominant winds, resulting in more comfortable conditions, however slightly exacerbated conditions are noted proximate to the intersection of Mavis Road with Father D'Souza Drive, the intersection being more exposed to dominant winds approaching from over more open terrain types.

With inclusion of the proposed Development, probes in the immediate surrounds realise a notable realignment of winds, whereas probes more removed from the Development site realise more subtle changes. Many of the probe locations realised an improvement in pedestrian comfort conditions, however, only probe location 3 realised improvements sufficient to change the winter comfort category from walking to standing. The improvements realised can be attributed to the proposed development presenting increased blockage to winds, resulting in the observed leeward effect, however, the realignment of winds associated with insertion of tall buildings into a suburban setting invariably causes a realignment of winds that can result in localised windier conditions. This was the case at probe location 4, situated at the intersection of Mavis Road and Father D'Souza Drive, which changed from standing to walking during the winter, however, the rating of standing is retained during the summer. During the summer probes 6 and 8 realised an improvement to change from walking to standing.

From the mean ground level wind velocity presented as a ratio of gradient wind speed, in the plots of Figure B in the Appendix, it is apparent that many of these points realise either little change or an improvement to the existing setting with inclusion of the proposed Development for specific wind directions, however, there are directions from which the wind is exacerbated. Should that direction coincide with dominant wind directions, as indicated in Figure 5's wind roses, relatively more windy conditions can be expected. As such, the relatively more comfortable conditions predicted at probe location 6, for example, associated with southwesterly winds, are attributed to winds that formerly flowed over the relatively more open lands of the existing site realising increased resistance. The probe realised a substantial improvement to easterly winds as well, resulting in a net improvement to comfort conditions. The areas remain suitable to the intended purpose year-round.

The above-mentioned, considered in concert with massing features and landscaping that were too fine to be incorporated into the site and surroundings, and urban intensification of the surroundings will result in further improvement.

Mavis Road remains within the pedestrian level wind velocity safety criteria as All-Weather Areas, as described in Section 4.7 and depicted in Figure 9.

Volpe Avenue

Probes 15 through 17 were located along Volpe Avenue. In the existing setting, said points are mainly rated suitable for standing during the winter, with the exception of 15 which is sitting, and sitting during the summer. The reasonably comfortable conditions can be attributed to the neighbouring developments introducing roughness to the wind's approach flow, moderating the winds as they approach.

From the Appendix Figure B Wind Radar Plots, it is apparent that with inclusion of the proposed Development, the probes situated along the above captioned realise a slight realignment of winds that was insufficient to change the comfort categories, except for point 15 which changed from sitting to standing during the winter. The point was at the transition between comfort categories and as such the slight upset to winds required to affix the change will not likely be perceptible.

Volpe Avenue is predicted comfortable for the intended use year-round and within the pedestrian level wind velocity safety criteria as All-Weather Areas, as described in Section 4.7 and depicted in Figure 9.

Father D'Souza Drive and Avonwick Avenue

Probes 18 through 26 were located along Father D'Souza Drive and Avonwick Avenue, the penultimate along the northwest façade of the proposed and the ultimate across Mavis Road to the north. In the existing setting, said points are mainly rated suitable for standing during the winter, except for locations 18, 19 and 20, which are sheltered by the residential community and suitable for sitting. The reasonably comfortable conditions can be attributed to the neighbouring developments introducing roughness to the wind's approach flow, moderating the winds as they approach.

Father D'Souza Drive realised a slight to moderate increase in northerly winds that are deflected by the proposed Development to flow along the street. This results in locations 18, 19 and 20 changing from sitting to standing during the winter months. The points were at the transition from standing to walking and as such only a modest upset was required to change the ratings. A rating of walking is appropriate for sidewalks during the winter months, and as such the area remains more than suitable for the intended purpose.

Father D'Souza Drive and Avonwick Avenue are predicted comfortable for the intended use year-round and within the pedestrian level wind velocity safety criteria as All-Weather Areas, as described in Section 4.7 and depicted in Figure 9.

5.3.2 Neighbouring Site Conditions

Probe 27 was placed in the 720 Avonwick townhouse development, adjacent to a playground, and 28 was placed adjacent to the existing Yee Hong Long Term Care Residence's outdoor amenity space, to the southeast of the proposed Development site. In the existing setting, the probes were rated as suitable for sitting in the summer and winter months. With inclusion of the proposed Development the areas realise an insignificant change and retained the sitting comfort category.

The above-mentioned locations are predicted comfortable for the intended use year-round and within the pedestrian level wind velocity safety criteria as All-Weather Areas, as described in Section 4.7 and depicted in Figure 9.

5.3.3 Internal Site Conditions

Probes 29 through 37 were positioned about the proposed development site and were rated as suitable for standing during the winter and summer in the existing setting. The exceptions, probes 32 and 33, which are situated adjacent to the existing Yee Hong Seniors Centre, were slightly more comfortable, and respectively suitable for sitting and standing in winter and sitting in summer.

With inclusion of the proposed Development all but points 32, 33 and 34 realised an improvement in winter wind conditions, some slight, others substantial, and the exception, 32, remained unchanged, despite the realignment of winds indicated in Appendix Figure B.

Probes 29 through 31 were positioned along or proximate to the southwest façade of the proposed Development and became suitable for sitting during the winter and summer months.

Probes 32, 33 and 34 were situated along the southeast façade of the proposed Development, in or near the gap created between the subject and existing Yee Hong Seniors Centre. With inclusion of the proposed Development a realignment of winds is a reasonable expectation, and as such the comfort conditions changed with proximity to the gap. Probe 32, which is most distant, retained its comfort rating as suitable for sitting in winter and summer. Probe 33 went from sitting to standing in summer and standing to walking in winter, and probe 34 remained suitable for standing in summer, but went to walking in winter.

Note: The probes were situated along a walkway adjacent to terraces serving the ground floor units. The terraces will be individually fenced, however, due to the scale of the model, it was not possible to include said fencing. The fencing will moderate winds through the area resulting in conditions on the terraces that are likely suitable for sitting during the summer months.

Probe 35 was situated adjacent to an entrance along the Mavis Road façade and will be discussed in the following pedestrian entrance section.

Probes 36 and 37 were situated in the interior courtyard and respectively indicated pedestrian comfort conditions that are suitable for standing and sitting during the winter and sitting during the summer. The area is susceptible to winds deflected through downwash to flow down the flanking towers and over the space. However, this occurs with a small portion of the wind climate, and as such the area is comfortable and suitable to the intended purpose.

The above-mentioned areas about the site are rated as suitable for the intended uses and will experience more comfortable conditions with consideration of design elements and landscaping that were too fine to incorporate into the massing model. The internal site areas fall within the pedestrian level wind velocity safety criteria as All-Weather Areas.

5.3.4 Pedestrian Entrance Conditions

Probes 30 and 31 were located at the Main Residential Entrances to the proposed towers accessed via the driveway connecting with Father D'Souza Drive and probe 35 at the Mavis Road entrance. The entrances are set beneath canopies and are well protected from large portions of the wind climate by the proposed building; however, the ultimate Mavis Road entrance is exposed to easterly winds that are deflected to flow along the sidewalk, and said winds often occur during the winter months. The entrance is rated as suitable for standing during the winter and sitting during the summer, and as such will be comfortable and appropriate for the intended purpose.

Probes 30 and 31, located at the Main Residential Entrances accessed via the vehicular drop-off, were predicted suitable for sitting on an annual basis and are appropriate to their intended purpose.

Wind conditions comfortable for standing or better are preferable at building entrances while conditions suitable for walking are suitable for sidewalks. Consideration of the proposed landscape plan for the area will likely further improve the comfort ratings at the proposed Main Residential Entrances and related walkways resulting in conditions appropriate for the intended use. The proposed Development's Entrances fall within the pedestrian level wind velocity safety criteria as All-Weather Areas.

5.3.5 Outdoor Amenity Areas

Landscaped Areas are proposed at various locations about the property. Such a space was situated at the base of the proposed Development along a portion of the Mavis Road façade. Probe 6 indicates comfort conditions suitable for standing during the winter, sitting during the summer, and is appropriate to the area's intended purpose.

Similarly probes 25 and 26 were situated in the Landscaped Areas along Father D'Souza Drive and indicated comfortable conditions, suitable for sitting during summer, standing during the winter. The building's fine design elements and soft landscaping were excluded from the analysis. Consideration of said elements will result in an improvement that is likely sufficient to bring the area into the sitting category during a portion of the winter months as well. The area will be comfortable for the intended purpose and a mitigation plan beyond that proposed is not required.

An Outdoor Amenity Space is proposed on the roof of the 1 storey connective between the towers. The space is exposed to winds from the westerly quadrant, that are deflected to flow down the 13-storey tower, as well as northerly and southerly winds that are deflected to flow along the towers, however, the area realises conditions suitable for sitting through the summer season, standing during the winter. A mitigation plan that incorporated 1.8m wind/noise barriers was included into the model under test, resulting in the reported conditions being seasonally appropriate for the intended use.

The analysis was conducted without the subject and neighbouring buildings' fine design features or existing and proposed soft landscape features in place. As such, we reasonably expect prevailing pedestrian comfort conditions will be better than those predicted. The proposed mitigation plans will result in more comfortable conditions that are suitable for the intended uses at the Amenity Spaces.

The proposed Development's Outdoor Amenity Spaces fall within the pedestrian level wind velocity safety criteria as All-Weather Areas.

Summary

The observed wind velocity and flow patterns at the Development are largely influenced by approach wind characteristics that are dictated by the predominantly suburban mix of residential and commercial development, related open areas, and mature vegetation mitigating the wind, to different degrees, on approach. Historical weather data indicates that strong winds of a mean wind speed greater than 30 km/h occur approximately 13 percent of the time during the winter months and 5 percent of the time during the summer. Once the subject site is developed, ground level winds at several locations will improve, with occasional localized areas of higher pedestrian level winds. The relationship between surface roughness and wind is discussed in the Appendix and shown graphically in Figure A of the same section.

The site is predicted comfortable and generally suitable for standing, or better, under normal wind conditions annually; however, under high ambient wind conditions with winds emanating from specific directions, a few localized areas adjacent to building corners, may be windy from time to time, but the areas remain within safety criteria and appropriate to the intended purpose. The consideration of proposed surface roughness will result in conditions more comfortable than those reported herein. Consideration of existing and proposed building features too fine to incorporate into the massing model will improve the predicted comfort ratings beyond those reported.

Where windy conditions were realised, mitigation plans were made in order to achieve comfortable conditions that are suitable for the intended uses year-round. The proposed Development is predicted to realise wind conditions suitable to the context.

6. FIGURES:

Figure 1: Laboratory Testing Facility

Figure 2a: Site Aerial Photo

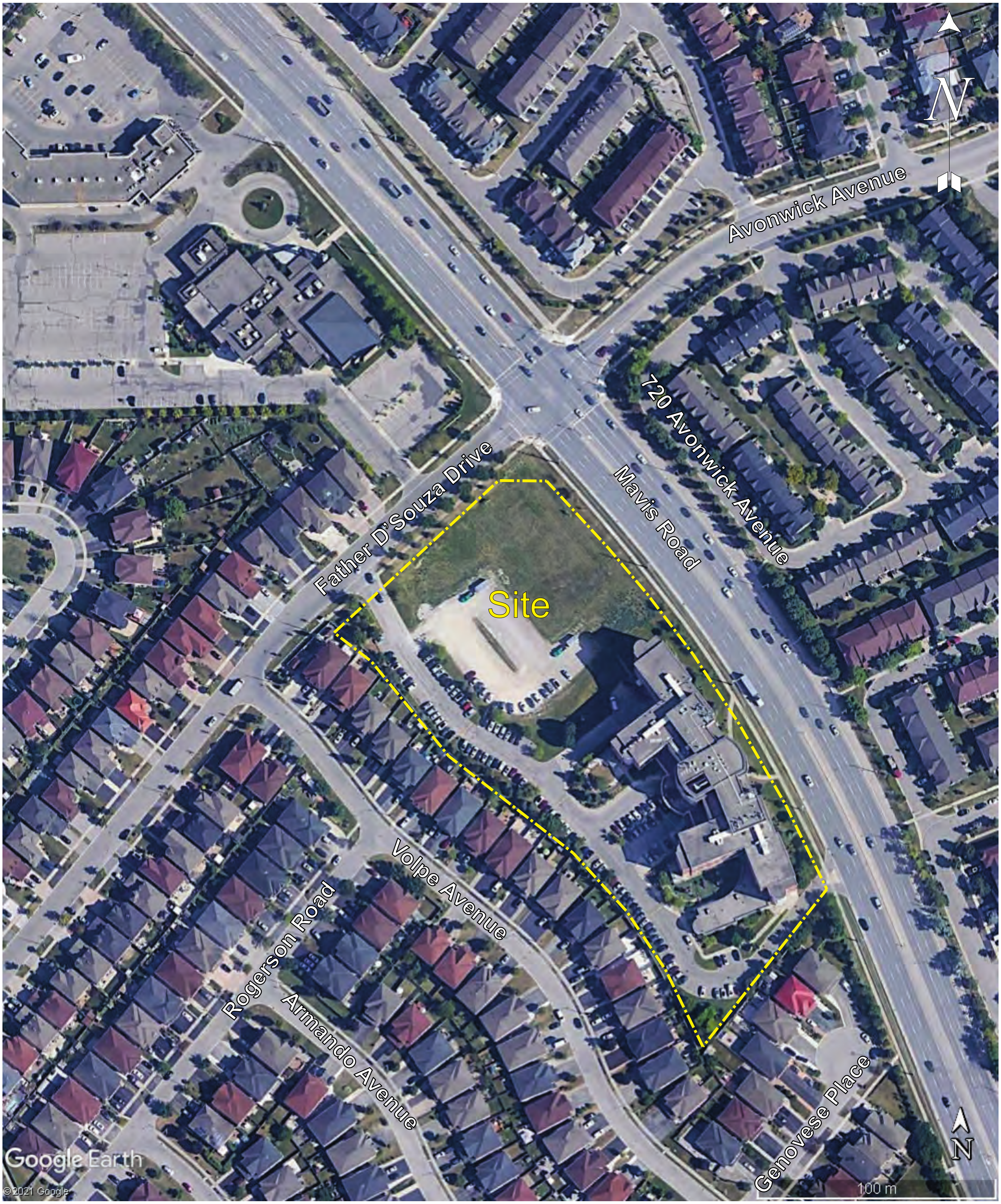


Figure 2b: Site Plan

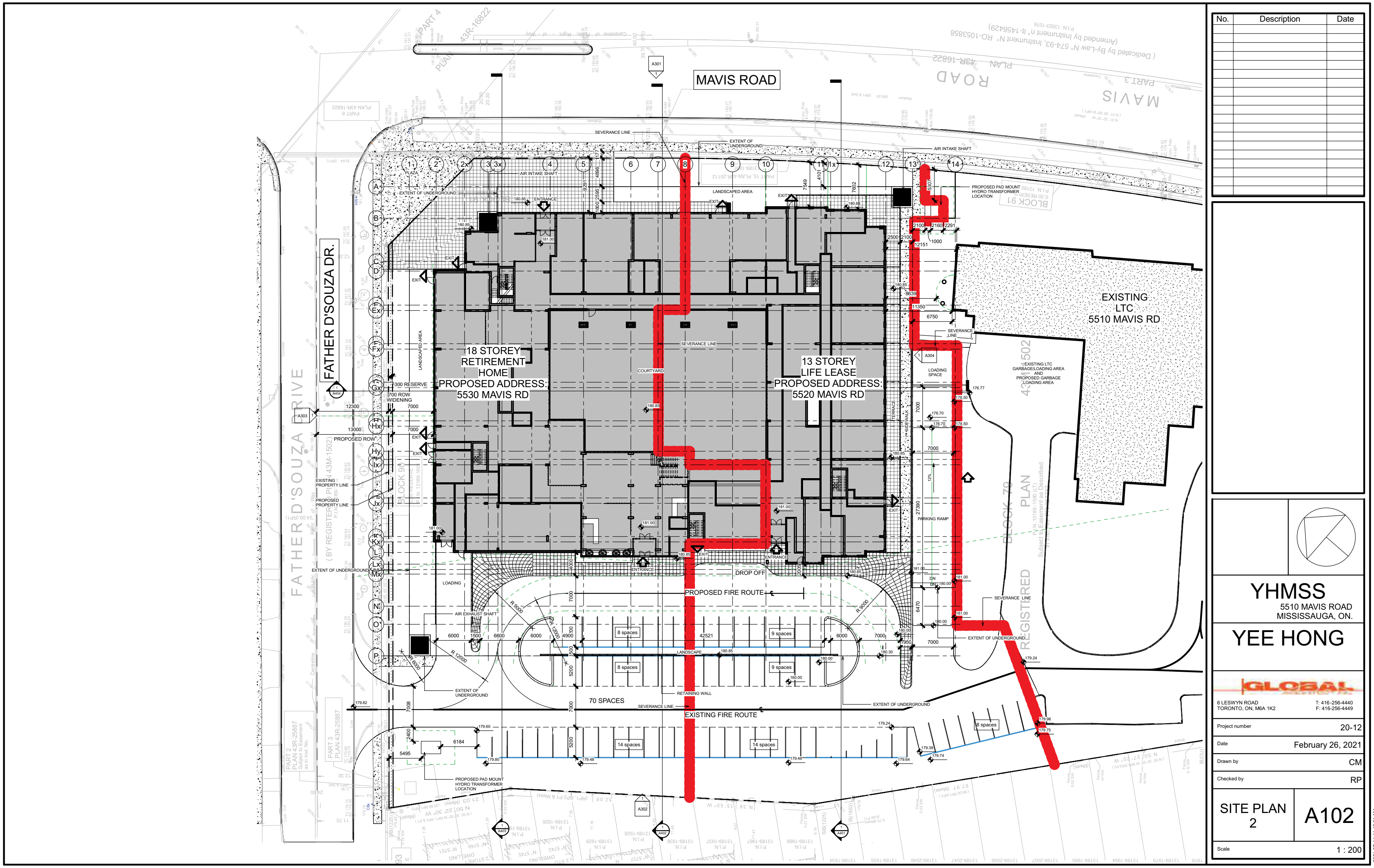
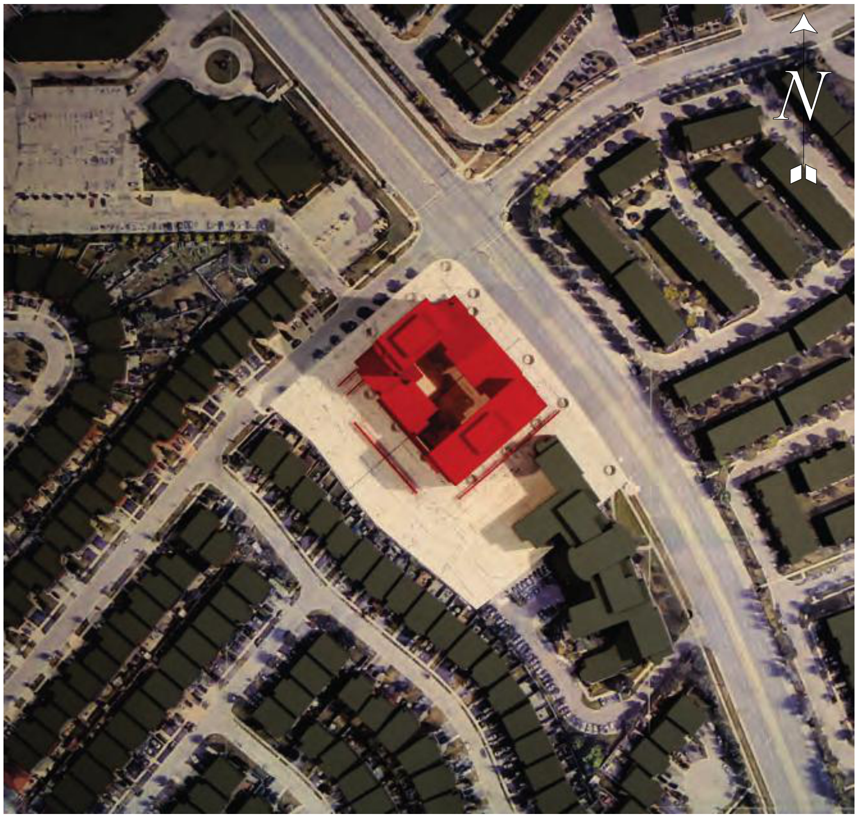
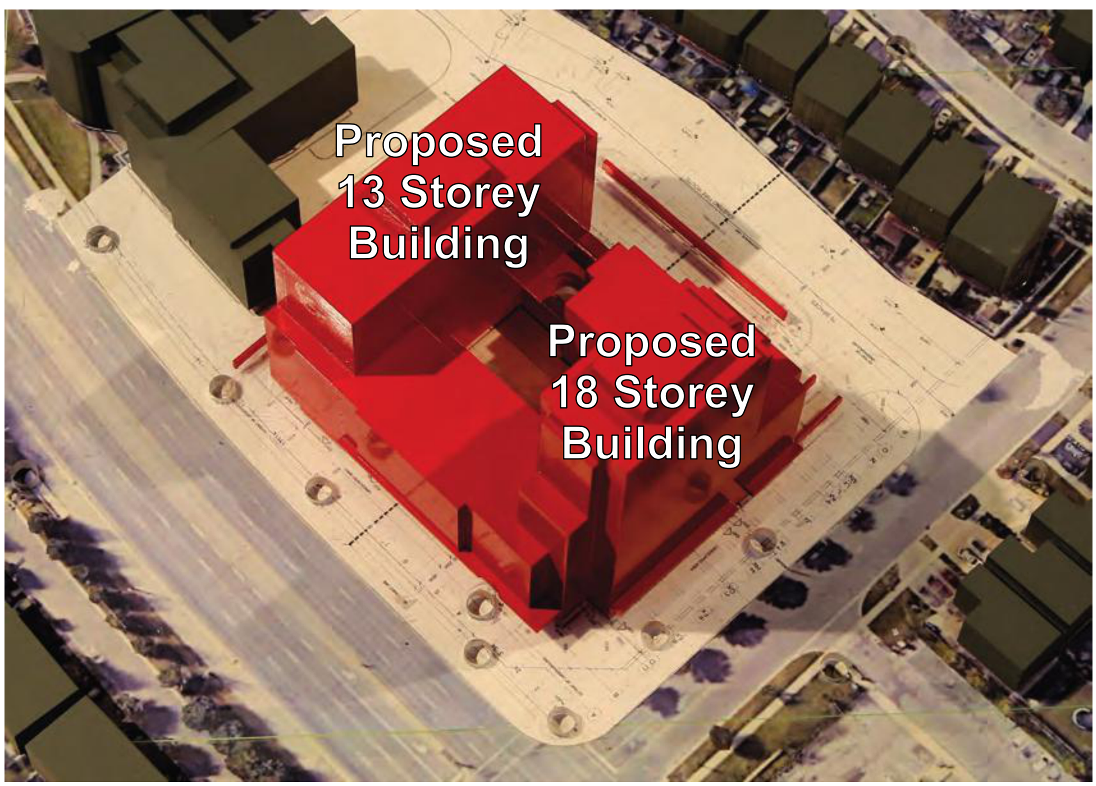


Figure 3: 1:500 Scale model of test site



a) Overall view of model - Proposed Site



b) Close-up view of model - Proposed Site

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

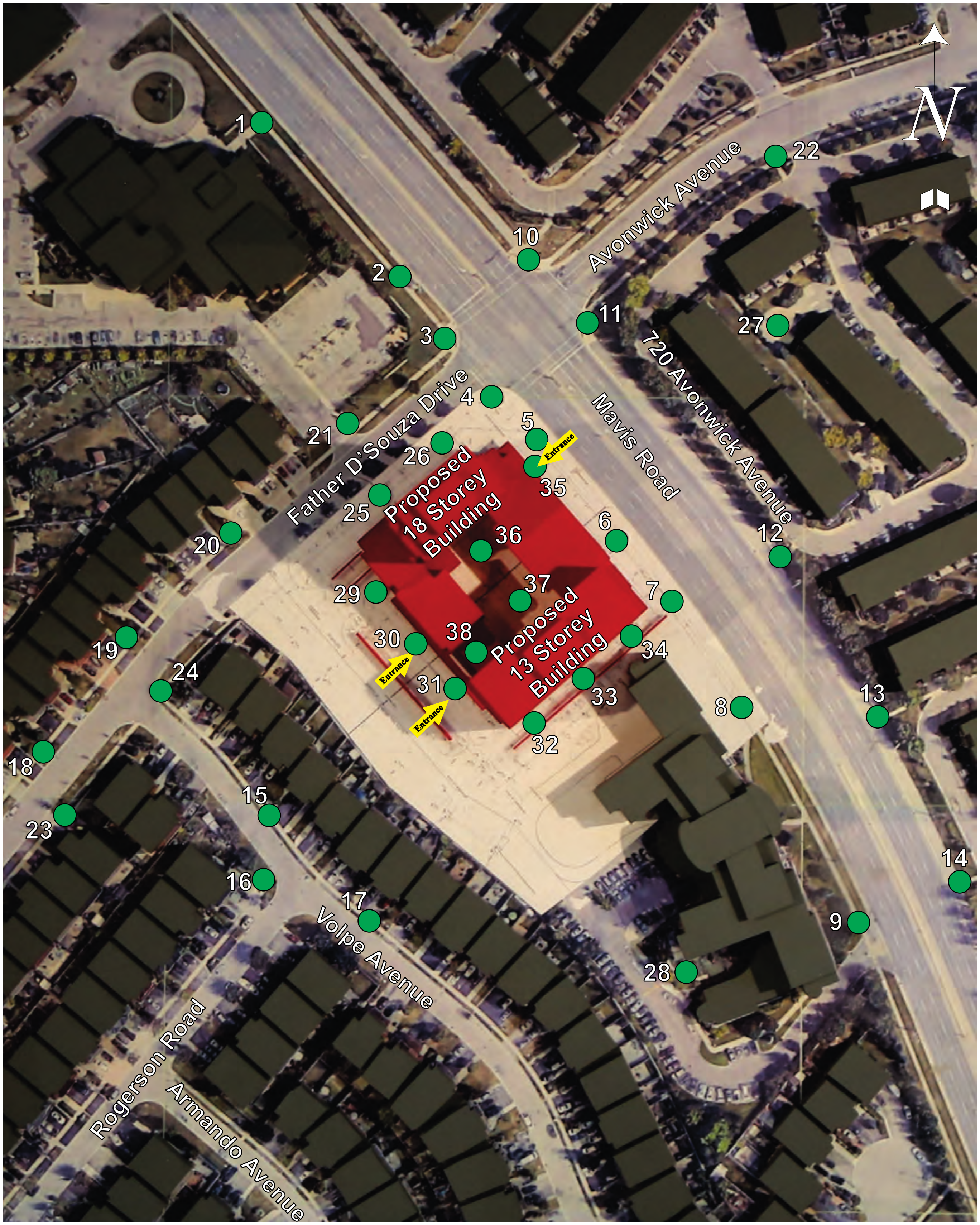
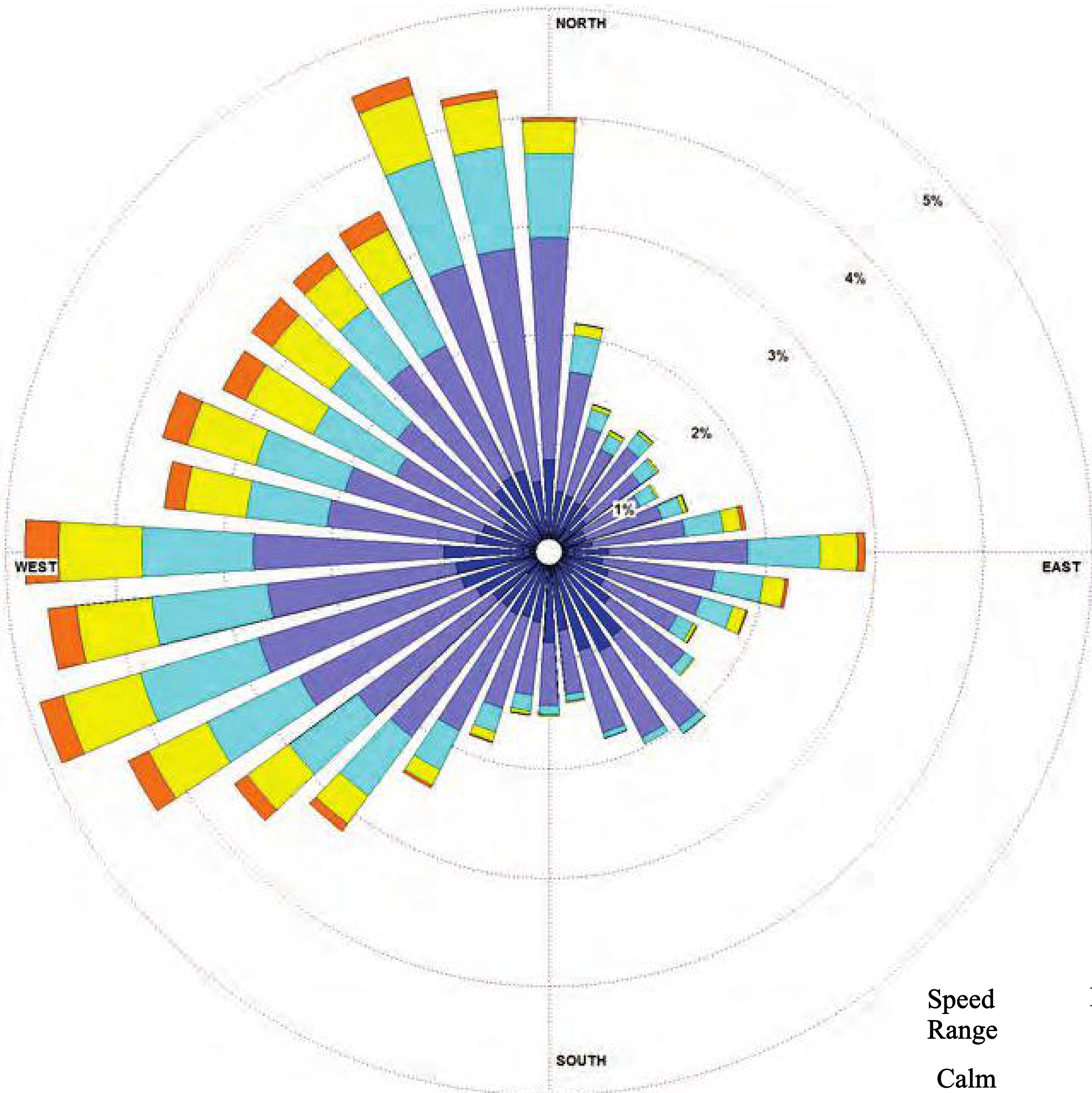


Figure 5a: Winter Wind Rose - Pearson International Airport.

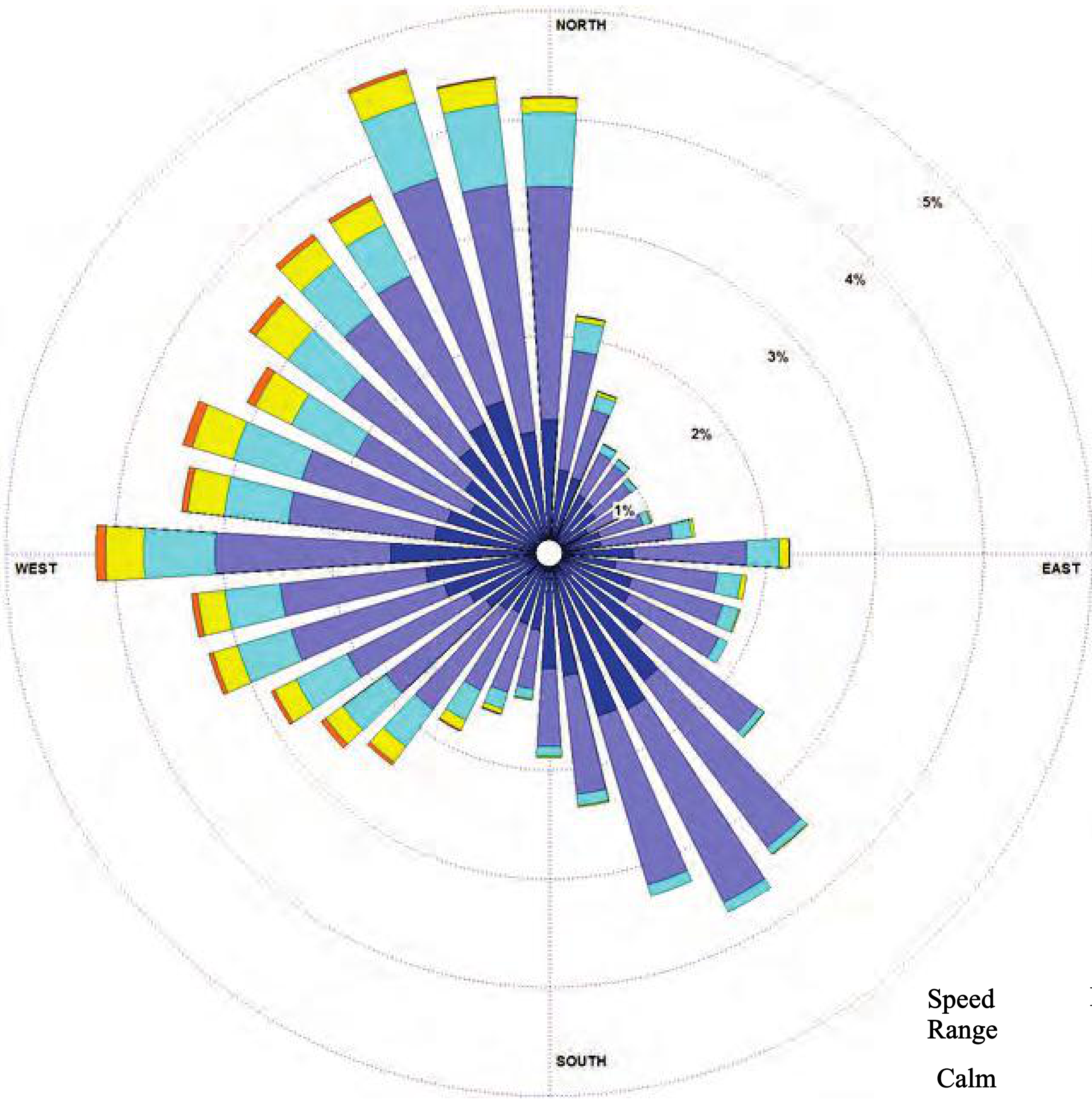
Historical Directional Distribution of Winds (@ 10*m* height)
November through April (1980 - 2017)



Speed Range	Probability (%)
Calm	5%
1 - 10*km/h*	24%
11 - 20*km/h*	41%
21 - 30*km/h*	17%
31 - 40*km/h*	10%
> 40*km/h*	3%

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

Historical Directional Distribution of Winds (@ 10*m* height)
May through October (1980 - 2017)



Speed Range	Probability (%)
Calm	8%
1 - 10*km/h*	33%
11 - 20*km/h*	42%
21 - 30*km/h*	12%
31 - 40*km/h*	5%
> 40*km/h*	<1%

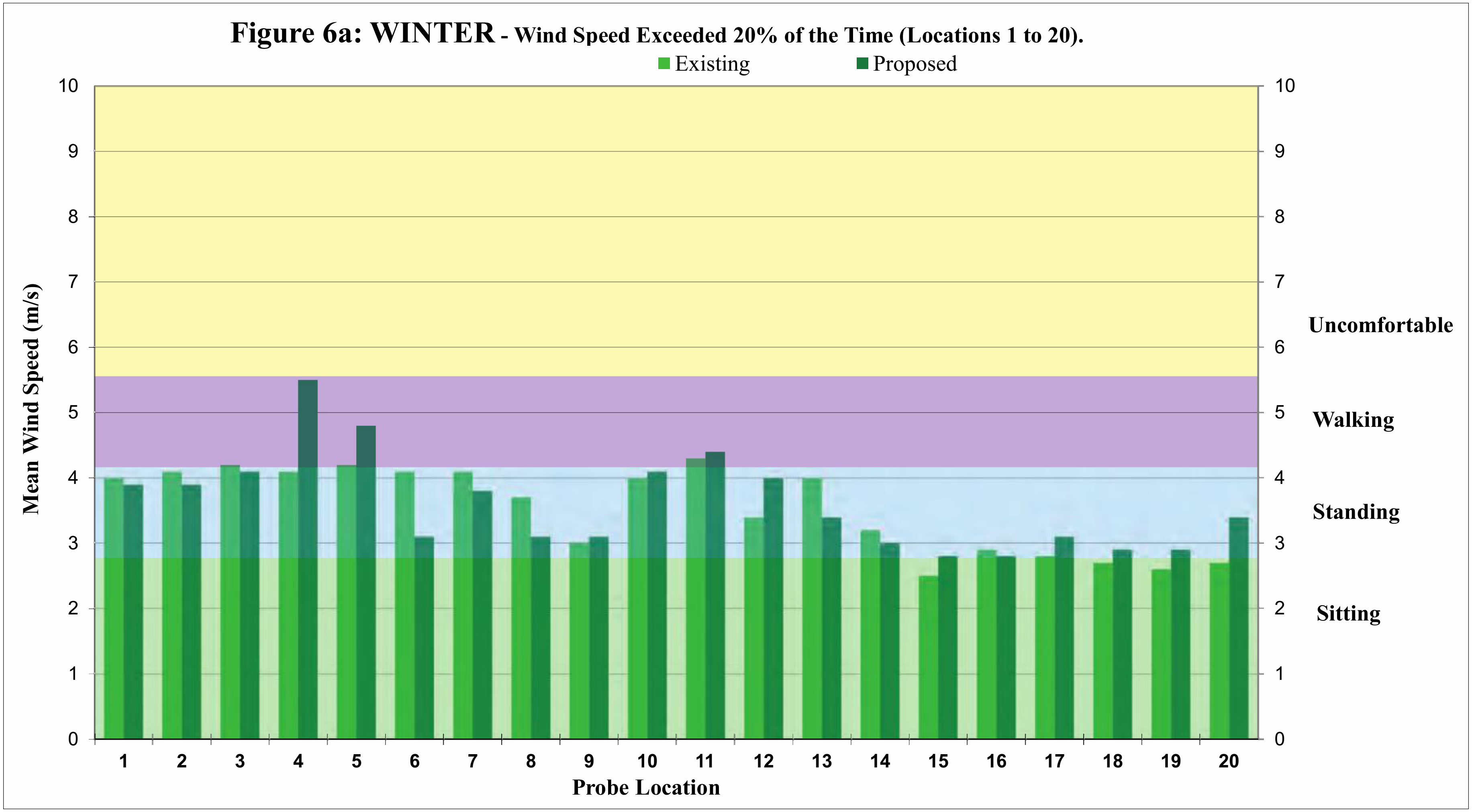
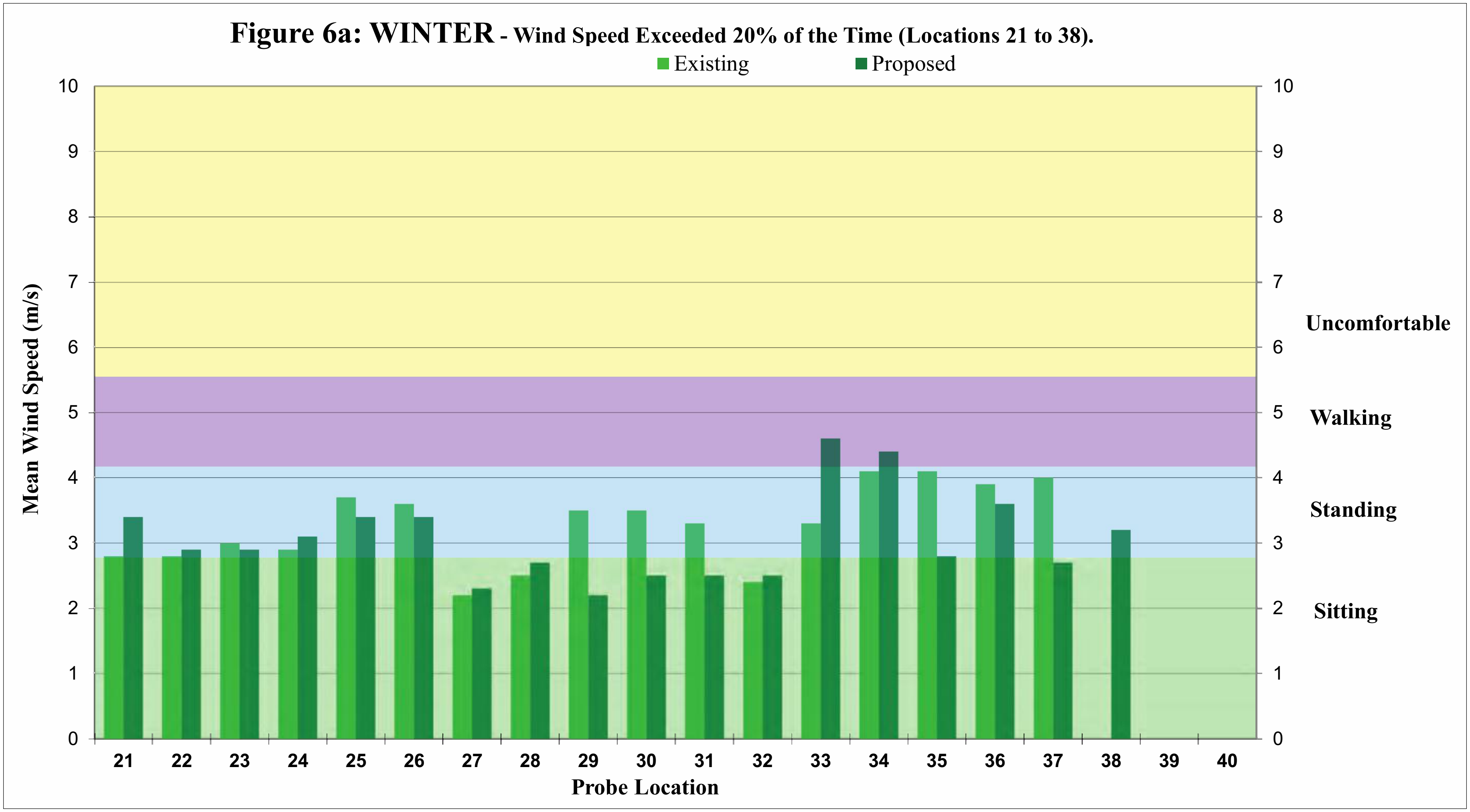


Figure 6a: WINTER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20



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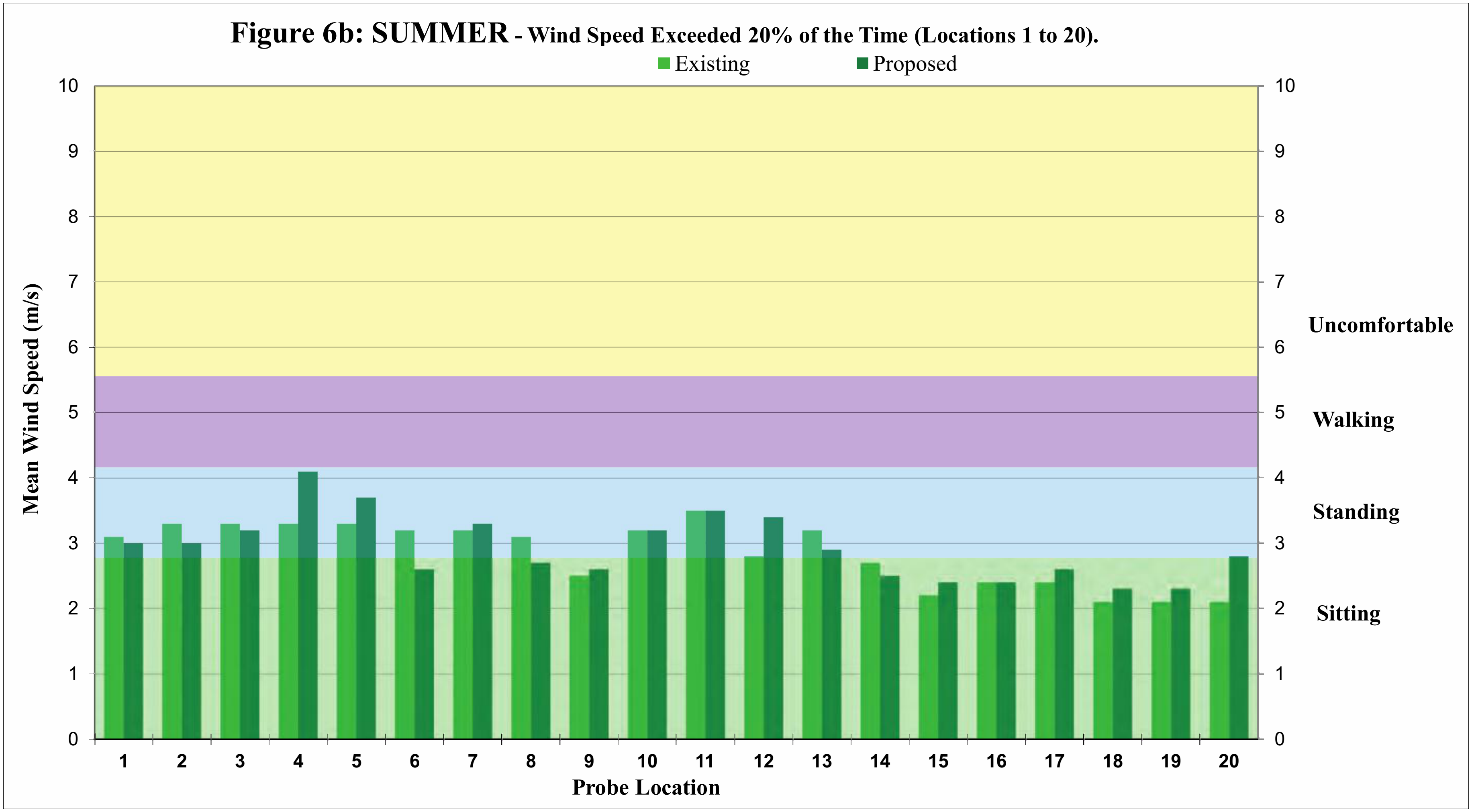

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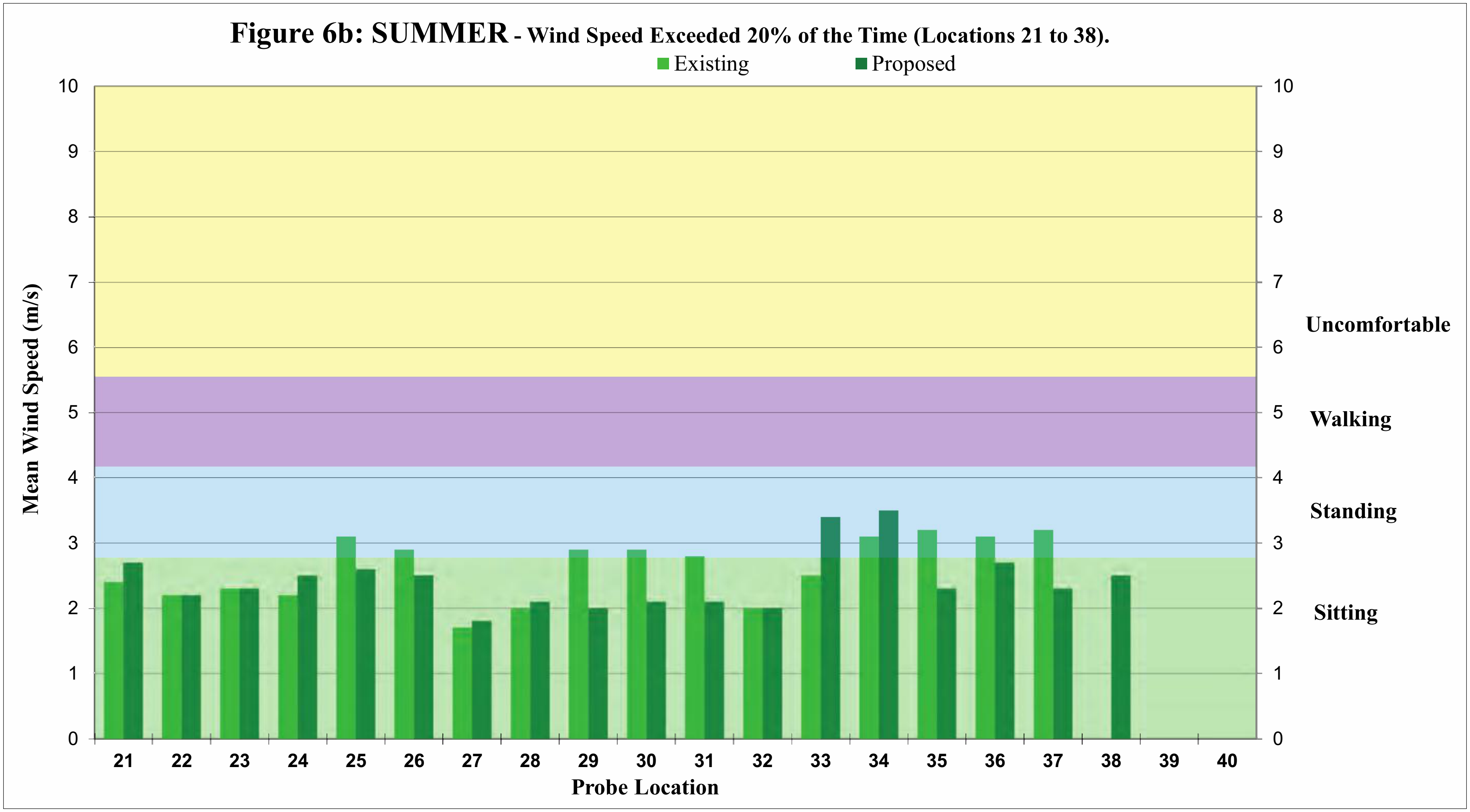
Figure 6b: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 21 to 38).
Existing
Proposed
Mean Wind Speed (m/s)
Probe Location
Uncomfortable
Walking
Standing
Sitting
0
1
2
3
4
5
6
7
8
9
10
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

Figure 7a: Pedestrian level wind velocity comfort categories.

Comfort Categories - Winter - Existing

Sitting Standing Walking Uncomfortable

Figure 7b: Pedestrian level wind velocity comfort categories.

Comfort Categories - Winter - Proposed

Sitting Standing Walking Uncomfortable

Figure 7c: Pedestrian level wind velocity comfort categories.

Comfort Categories - Summer - Existing

Sitting Standing Walking Uncomfortable

Figure 7d: Pedestrian level wind velocity comfort categories.

Comfort Categories - Summer - Proposed

Sitting Standing Walking Uncomfortable

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

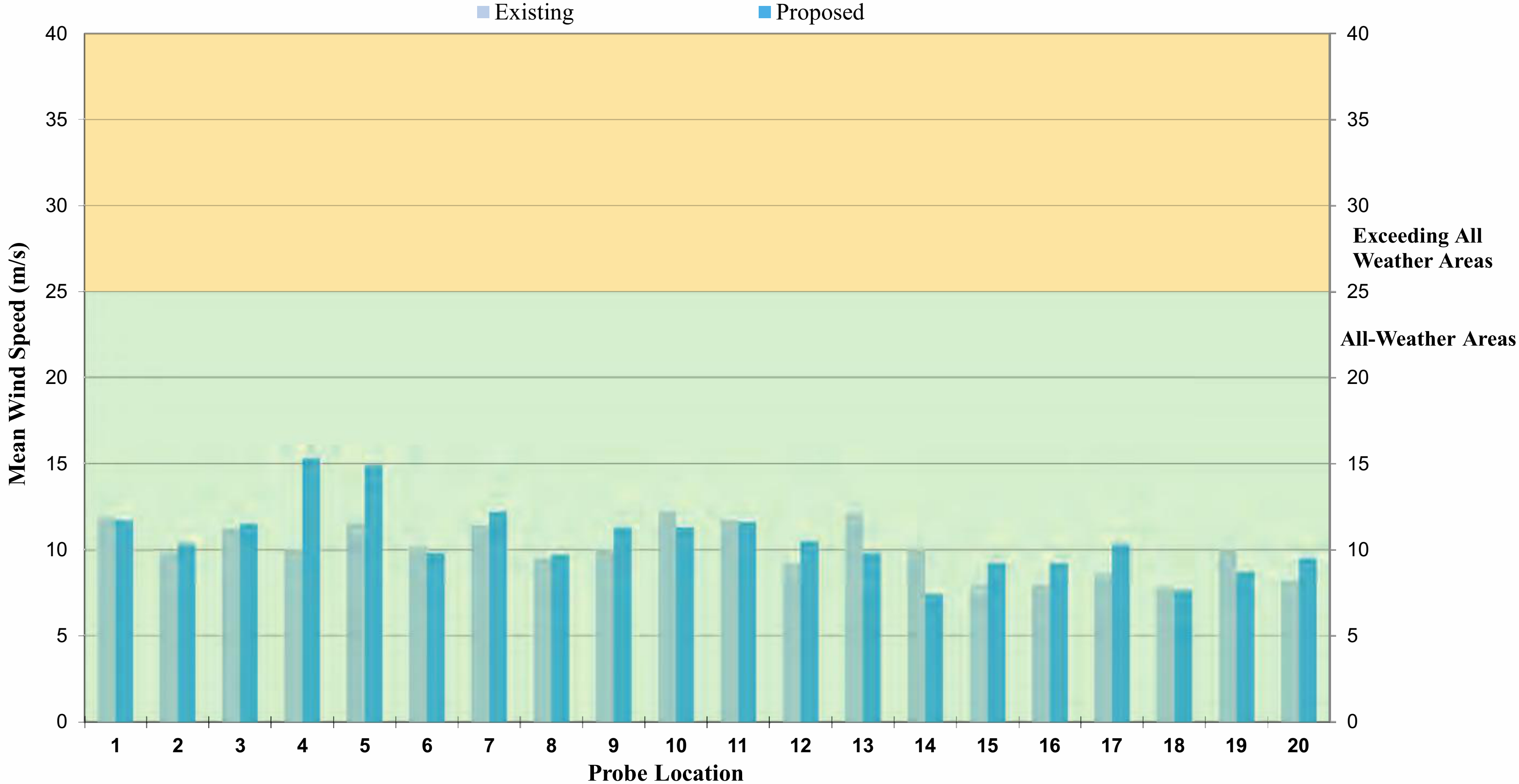


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 21 to 38).

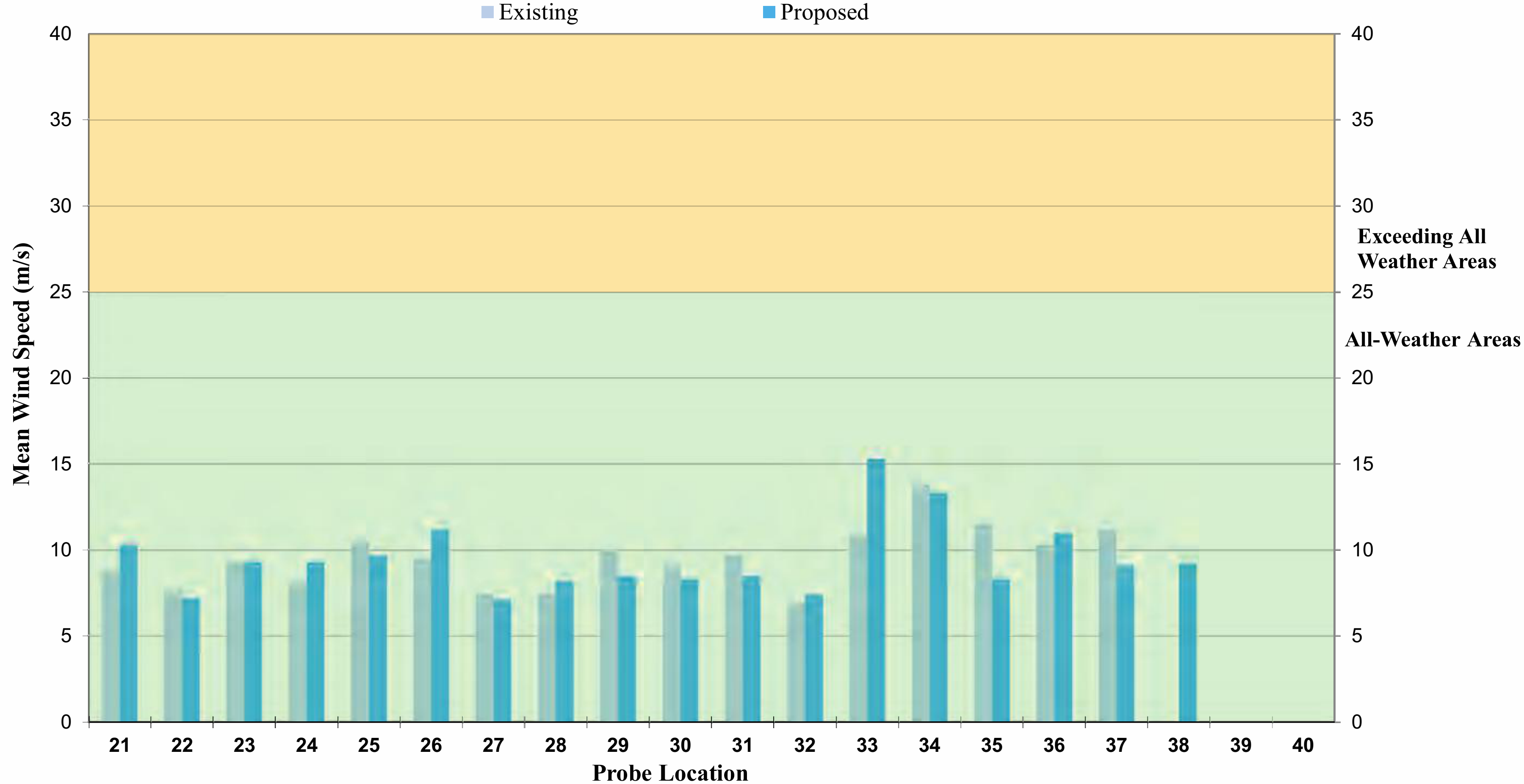
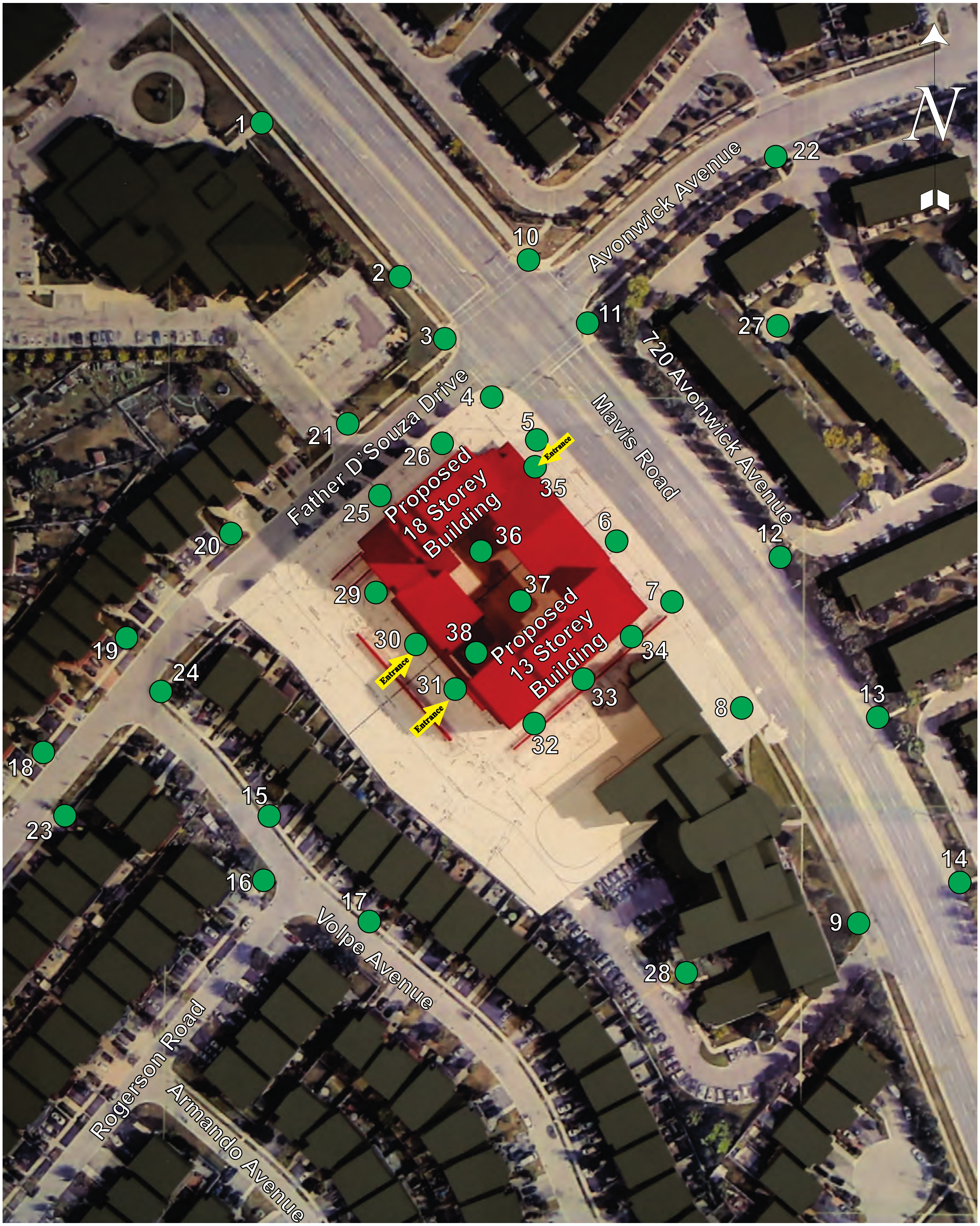


Figure 9a: Pedestrian level wind velocity safety criteria.

Safety Criteria - Existing

All-Weather Areas　Exceeding All-Weather Areas

Figure 9b: Pedestrian level wind velocity safety criteria.



Safety Criteria - Proposed

All-Weather Areas   Exceeding All-Weather Areas

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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:

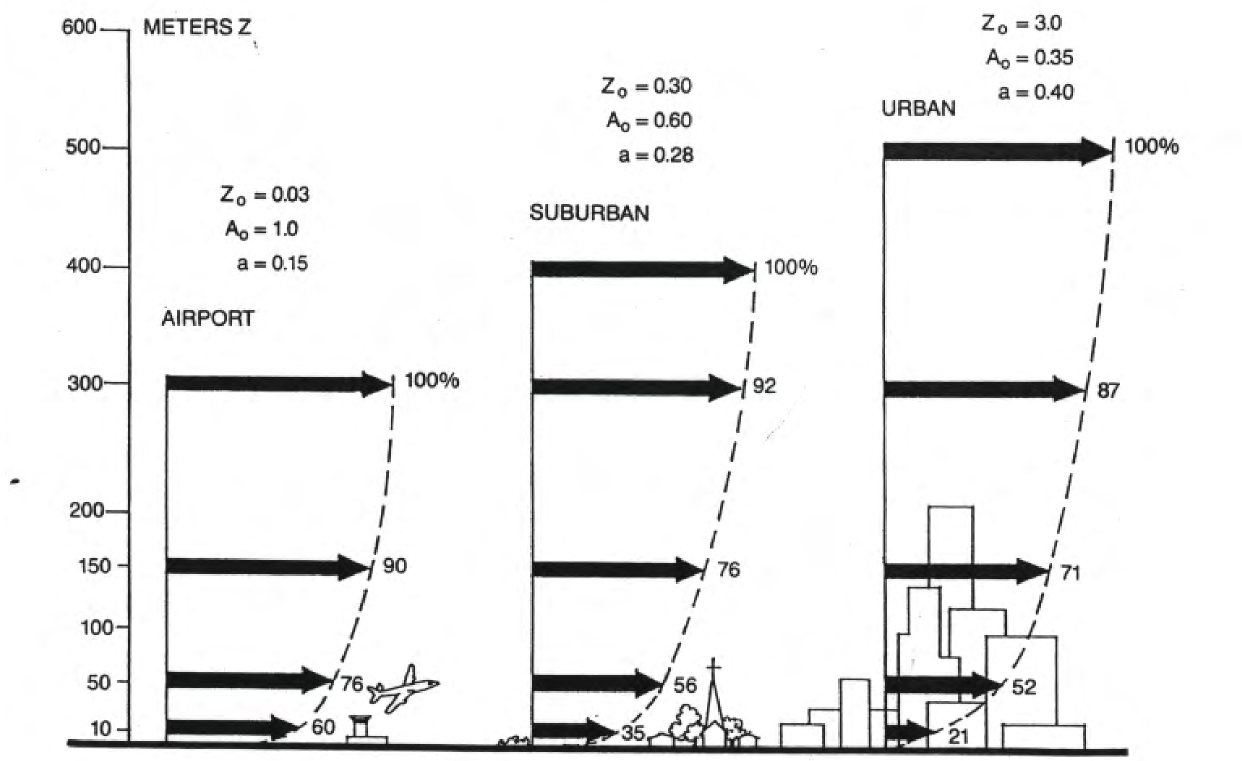


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

For the above velocity profiles, ground level velocities at a height of $z = 2\,m$, 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.

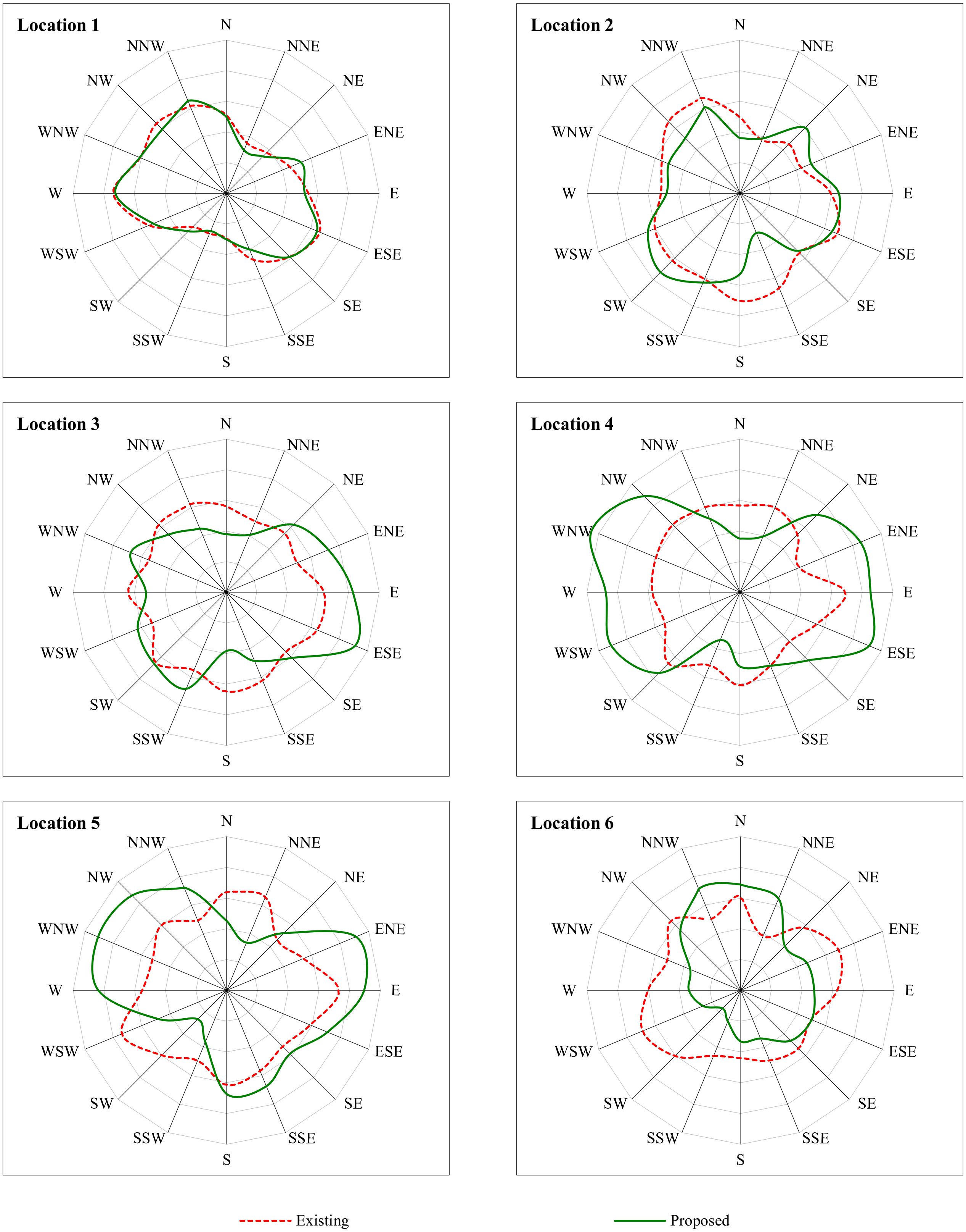
The Beaufort Scale is often used as a numerical relationship to wind speed based upon an observation of the effects of wind. Rear-Admiral Sir Francis Beaufort, commander of the Royal Navy, developed the wind force scale in 1805, and by 1838 the Beaufort wind force scale was made mandatory for log entries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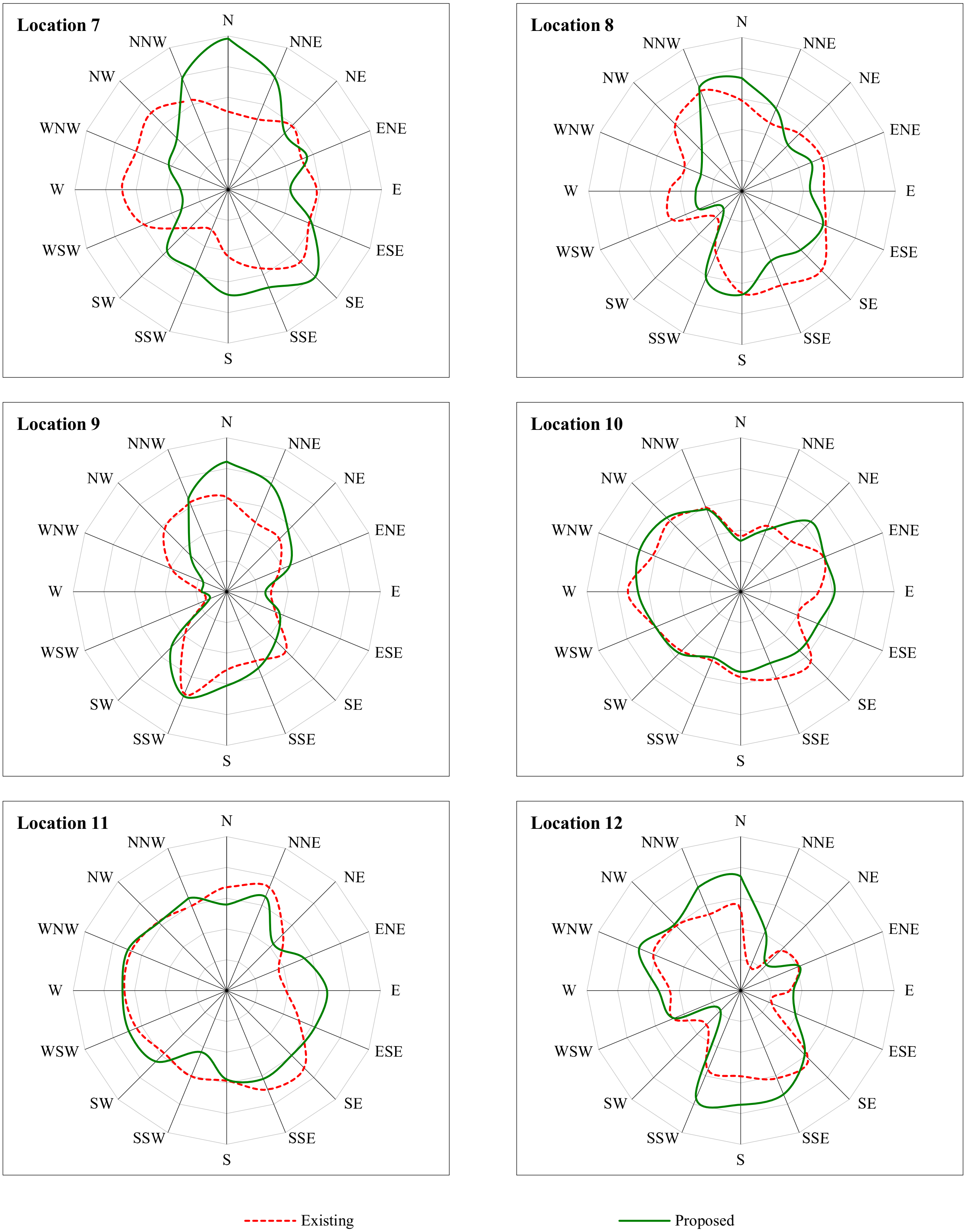

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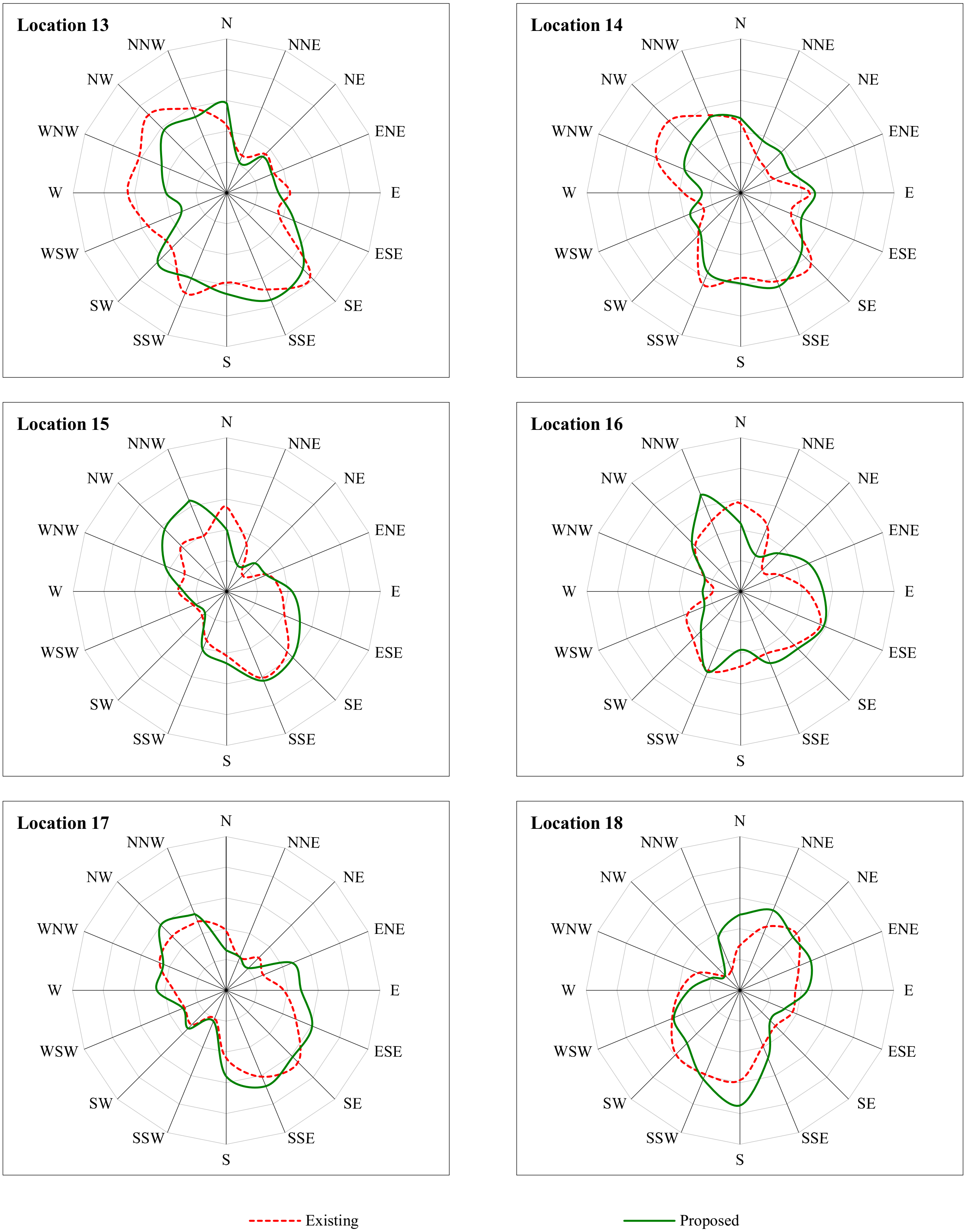

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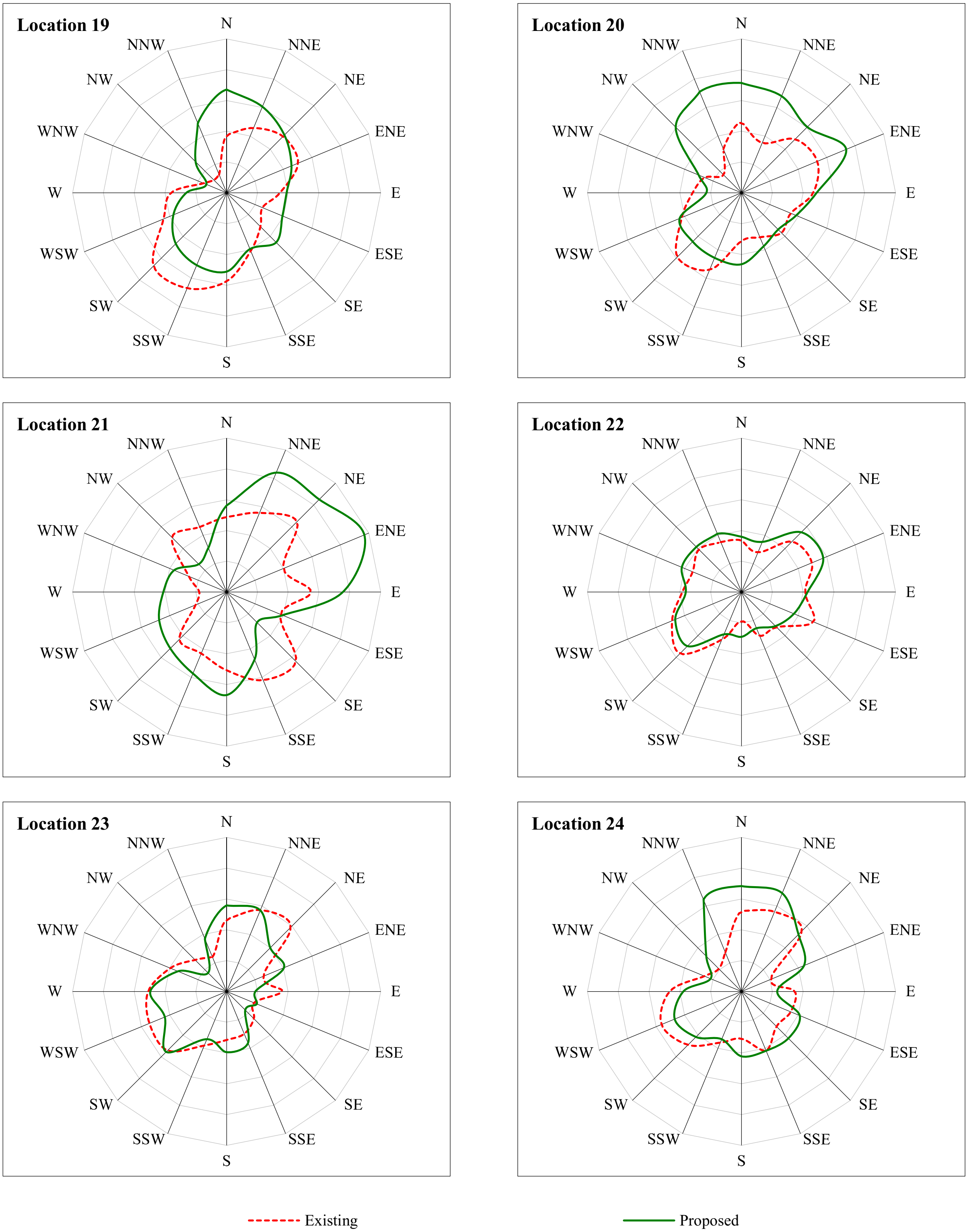

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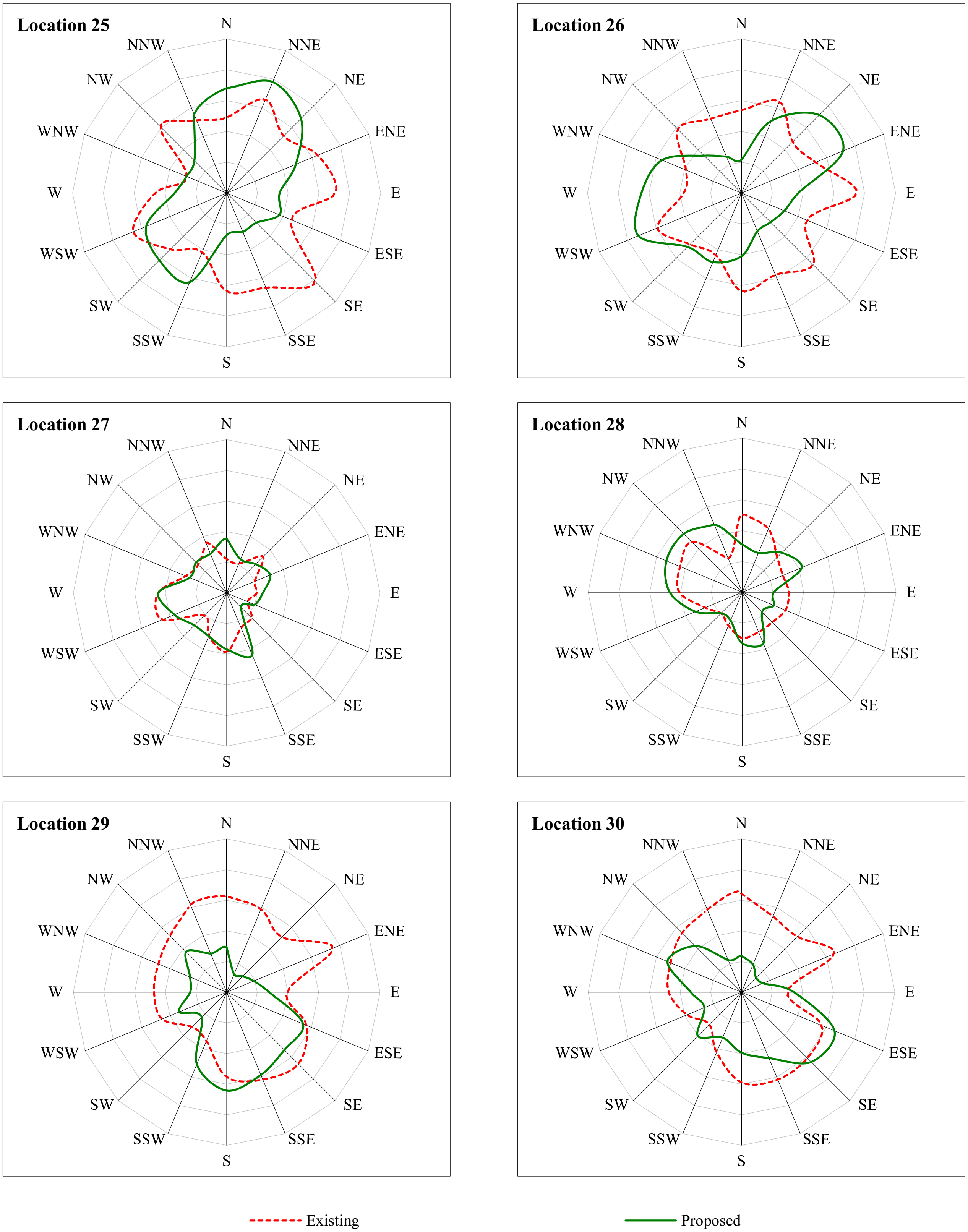

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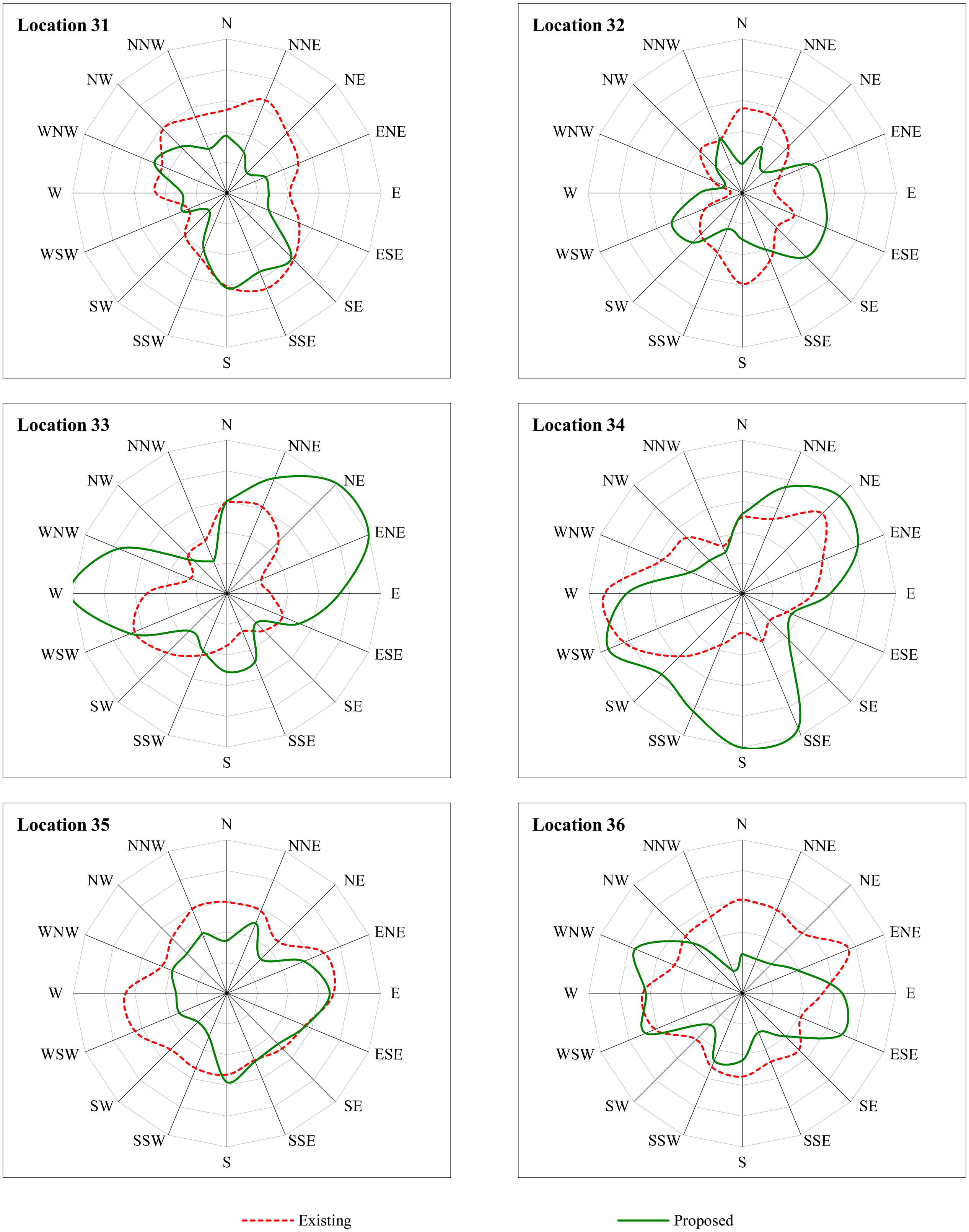

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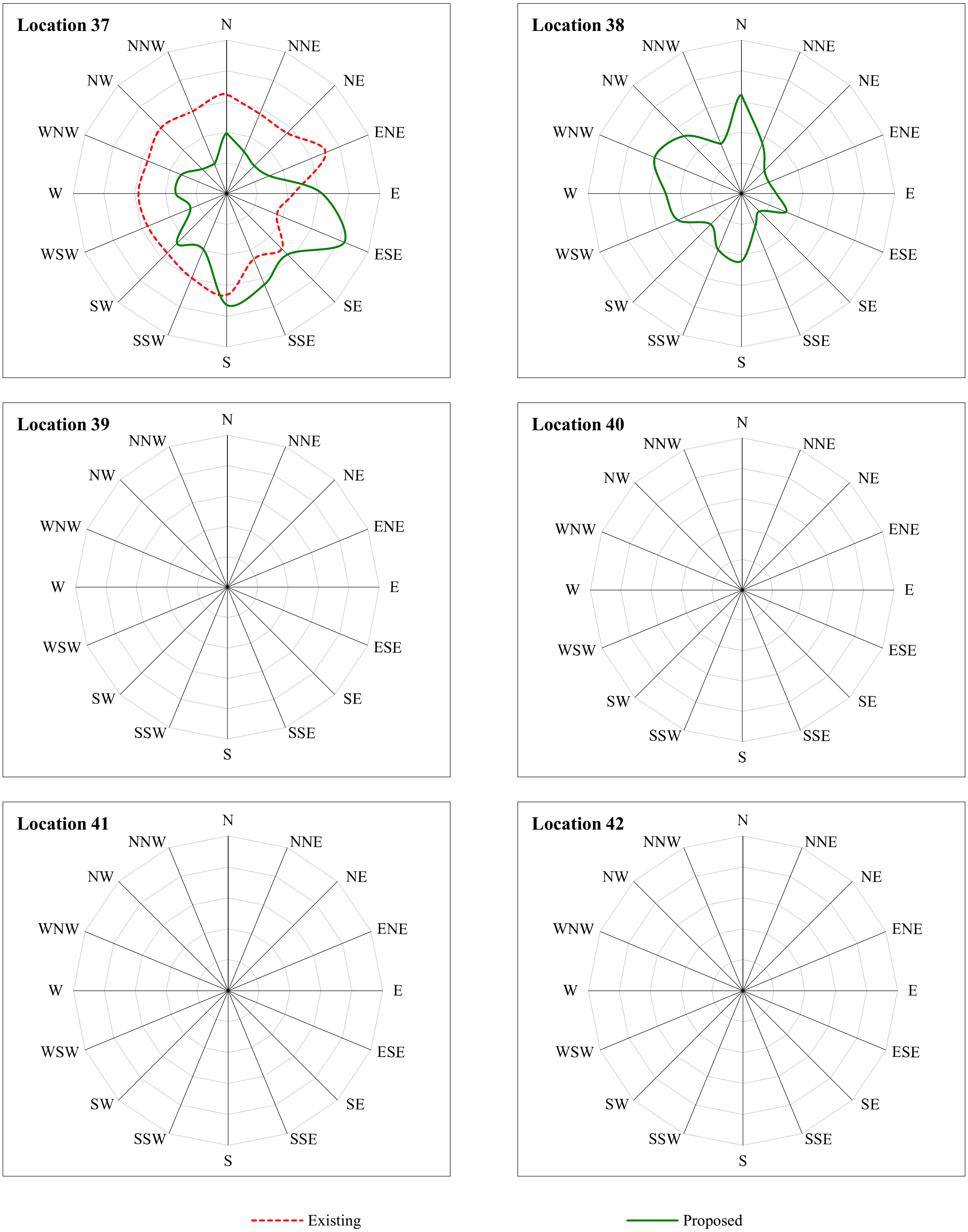

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