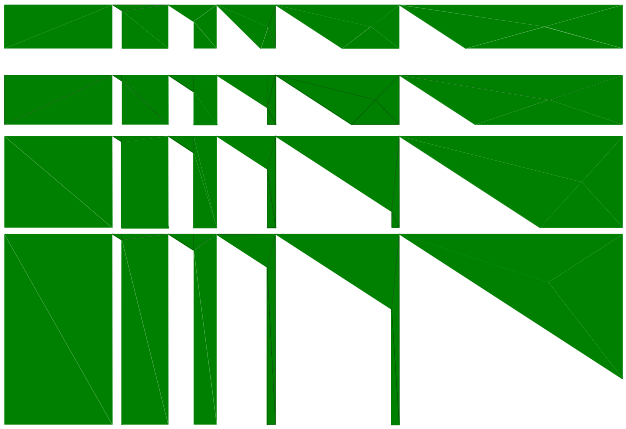
THEAKSTON ENVIRONMENTAL
Consulting Engineers • Environmental Control Specialists

REPORT

FINAL PEDESTRIAN LEVEL WIND STUDY

284 - 292 Plains Road East
Burlington, Ontario



284 Plains Road Development Inc.

REPORT NO. 20641wind **September 15, 2021**

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1 EXECUTIVE SUMMARY

The Development proposed by 284 Plains Road Development Inc. for 284 - 292 Plains Road East in Burlington, Ontario has been assessed for Environmental standards with regard to Pedestrian Level Wind Velocities relative to comfort and safety. The pedestrian level wind and gust velocities measured for the thirty-seven (37) locations tested are within the safety criteria and most are within the comfort criteria described within the following report.

The proposed Development is located in the City of Burlington and occupies a portion of the block of lands bound by Plains Road East to the northwest, Shadeland Avenue to the southwest, Filmandale Road to the northeast, and Townsend Avenue and Merle Avenue to the southeast. The site is currently occupied by two residential dwellings that will be removed. The Development involves a proposal to construct a U-shaped 9 storey residential building with rooftop amenity spaces at various levels. Based upon this analysis, wind conditions on and around the proposed Development are predicted to be mainly suitable for leisurely walking, or better, year-round, under normal to high ambient wind conditions, with localised windy conditions proximate to the southern corner of the site.

Suburban lands supporting mainly low-rise residential, commercial, and institutional buildings surround the property, with open lands supporting recreational fields to the north through northwest of the site. The site is situated approximately 1.25km north of Lake Ontario.

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. Mid to 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 urban buildings.

The proposed Development's building penetrates winds that formerly flowed over the site. The increased blockage relative to the existing setting causes wind to redirect to flow over the building, without consequence, and/or, depending upon the angle of incidence, around, or down the building towards the pedestrian level, as downwash. At the pedestrian level, the winds redirect to travel horizontally along the building, around the corners and beyond, creating windswept areas at or near the building's southern corner, however the area will remain suitable for the intended use, much of the time.

The Development is punctuated with steps, balconies, notches, and other features that discourage downwash associated with prevailing winds, deflecting a portion of said flows around the building at elevations well above the pedestrian level. This results in a moderate upset to the impending wind climate realised at the site with inclusion of the proposed Development, relative to the

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

- stepped façades
- irregular facades
- balconies
- canopies
- overhangs
- landscaping

and others, that were included in the proposed Development's massing and landscape design. The mitigation features contribute to pedestrian comfort conditions that are suitable to the context. Additional mitigation is recommended for areas near the southern corner of the site including the at-grade amenity area, as well as various rooftop Amenity Areas, in order to achieve comfortable conditions that are suitable for the intended uses. Comfort conditions expected at the proposed Development site are in many cases improved, or similar to the existing setting, and considered acceptable to the suburban context.

Note: Subsequent to testing the 284 Plains Road Development the massing was revised. Significant changes include reducing the height and footprint of the building. To this end the height went from 9 to 6 storeys, and 3, 5, and 7 storey steps along the southeast façade were removed. Based upon experience we submit reductions to height and/or footprint typically result in a reduction in winds realised at the pedestrian level. Therefore the comfort conditions predicted in the report remain valid, though are likely conservative.

Respectfully submitted,



Nicole Murrell, M.Eng.



Paul Kankainen, M.A.Sc.



Stephen Pollock, P. Eng.

2 INTRODUCTION

Theakston Environmental, Consulting Engineers, Fergus, Ontario, were retained by 284 Plains Road Development Inc. to study the pedestrian level wind environment for their proposed Development at 284 – 292 Plains Road East in the City of Burlington, Ontario. The proposed Development site is depicted on the Aerial Photo in Figure 2a. The Development involves a proposal to construct a U-shaped 9 storey residential building with rooftop amenity spaces at various levels, in the configuration shown in Figure 2b.

Architectural drawings for the proposed Development were prepared by SRM Architects. The co-operation and interest of the Client and their sponsors in all aspects of this study is gratefully acknowledged.

The specific objective of the study is to determine areas of higher than normal wind velocities induced by the shape and orientation of the proposed building and surroundings. The wind velocities are rated in accordance with the safety and comfort of pedestrians, notably at entrances to the buildings, sidewalks, courtyards on the property, as well as 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 current study site as well as existing and proposed buildings in the surrounding area. The proposed configuration included the Development's subject building. The ultimate configuration was assessed with selected mitigation strategies 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.
2. To assess mitigative solutions.
3. To publish a Consultant's report documenting the findings and recommendations.

4 METHOD OF STUDY

4.1 General

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

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

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

The mean and gust wind speeds at the thirty-seven (37) points tested were subsequently combined with the design probability distribution of gradient wind speed and direction, (wind statistics) recorded at Hamilton International Airport, to provide predictions of the full-scale pedestrian level wind environment. Predictions of the full-scale pedestrian level wind environment are presented as the wind speed exceeded 20% of the time, based on annual, and wind for the seasons in Figures 6a – 6c. 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 Burlington region that was used in the analysis was based on historical records of wind speed and direction measured at Hamilton International Airport for the period between 1988 and 2018. 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.

Note: Weather data from the Burlington Piers weather station was considered, however the data is influenced by the location under the Burlington Bay Skyway and as such was deemed inappropriate for this analysis. The weather station at Hamilton International Airport is expected to be a better representation of winds realised in the City of Burlington.

4.3 Statistical Wind Climate Model

The design probability distribution of mean-hourly wind speed and wind direction at reference height is shown for Hamilton International Airport in Figure 5. Both annual and seasonal distributions are shown. From this it is apparent that winds can occur from any direction, however, historical data indicates the directional characteristics of strong winds are northeast and southwest.

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. SRM Architects provided architectural drawings. City of Burlington 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 Wind Speed Exceeded 20% of the Time*		Description
COMFORT	***km/hr***	***m/s*** (used in Fig. 6)	
Sitting	0-10	0-2.78	Calm or light breezes for outdoor restaurants and seating areas where one can read a paper without having it blown away.
Standing	0-14	0-3.89	Gentle breezes suitable for main building entrances and bus stops.
Leisurely Walk	0-17	0-4.72	Moderate winds that would be appropriate for window shopping and strolling along a downtown street, plaza, or park.
Fast Walking	0-20	0-5.56	Relatively high speeds that can be tolerated if one's objective is to walk, run, or cycle without lingering.
Uncomfortable	>20	>5.56	Strong winds of this magnitude are considered a nuisance for most activities, and wind mitigation measures are recommended.

*Note: The Gust Equivalent Mean wind speed = maximum (mean wind, gust speed/1.85)

The activities are described as suitable for Sitting, Standing, Leisurely Walking or Fast Walking, 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/hr* (2.78*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 and in Table 1 above. 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 14*km/hr* (3.89*m/s*). In this situation, the wind would rustle tree leaves and, on occasion, move smaller branches while flags flap and ripple. This category would be suitable for locations where people might sit for short periods or stand in relative comfort. The Leisurely Walking category includes wind speeds from calm up to 17*km/hr* (4.72*m/s*). These winds would set tree limbs in motion, lift leaves, litter and dust, and the locations are suitable for activity areas. The Fast Walking category is much more tolerant of wind, including wind speeds up to 20*km/hr* (5.56*m/s*). In this case, whole trees would sway and it would be more difficult to walk. This is considered as the acceptable upper limit for comfort for the average population. The Uncomfortable category covers a broad range of wind conditions, including wind speeds above 20*km/hr* (5.56*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 3*km/h* (or more) interval. The location is rated as suitable for Sitting, Standing, Leisurely Walking or Fast Walking, if the bar extends into the corresponding interval.

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

4.7 Pedestrian Safety Criteria

Safety criteria are also included in the analysis to ensure that strong winds do not cause a loss of balance to individuals occupying the area. The safety criteria are based on wind speeds exceeded nine hours per year or 0.1% of the time for a 24 hour period, as shown in Table 2.

Both the Comfort and Safety Criteria were based on those developed at the Allan G. Davenport Wind Engineering Group Boundary Layer Wind Tunnel Laboratory. These criteria, developed for pedestrian wind studies, or versions thereof, are used in studies around the world.

Table 2: Safety Criteria

ACTIVITY	Gust Equivalent Mean Wind Speed Exceeded nine times per year		Description
SAFETY	***km/hr***	***m/s*** (used in Fig. 8)	
All-Weather Areas	0-90	0-25	Areas that need to be used in all weather conditions, such as building entrances, sidewalks, etc.
Exceeding All-Weather Areas	>90	>25	Excessive gusts that can adversely affect a pedestrian's balance and footing. Wind mitigation is required.

4.8 Pedestrian Comfort Criteria – Seasonal Variation

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

The comfort of a site is based on the "annual" results of the study, Figures 6a and 7a & b. In cases where seasonal comfort is important, results have been included for winter and summer (see Figures 6b and 6c and Figures 7c to 7f).

5 RESULTS

5.1 Study Site and Test Conditions

The proposed Development is located in the City of Burlington and occupies a portion of the block of lands bound by Plains Road East to the northwest, Shadeland Avenue to the southwest, Filmandale Road to the northeast, and Townsend Avenue and Merle Avenue to the southeast. The site is situated approximately 1.25km north of Lake Ontario and is currently occupied by two residential dwellings that will be removed.

Suburban lands supporting mainly low-rise residential, commercial, and institutional buildings surround the property to most directions. To the immediate west through northwest of the site are the low-rise Holy Rosary Church buildings and the associated Holy Rosary Catholic Elementary School, with surrounding greenfields and recreational fields to the northwest through north. To the northeast of the site are low-rise residential and commercial buildings flanking Plains Road

East, with the 6 storey Affinity Condo buildings at 318 – 348 Plains Road East. Lands to the east through southwest of the site are occupied by low-rise residential neighbourhoods supporting related mature vegetation.



View of the 284 – 292 Plains Road East Development Site Looking Southeast (Google)

Proposed Development

The Development, based upon project plans prepared by SRM Architects, involves a proposal to construct a U-shaped 9 storey residential building on site. The Main Entrance to the building is accessed via the northwestern façade, along Plains Road East. Vehicular access to the underground parking and loading areas is provided via a driveway along the northeastern side of the site. Outdoor Amenity Areas are proposed at-grade at the southern corner of the site, atop steps in the southeastern façades at the 6^{th} and 8^{th} levels, as well as atop the 10^{th} level rooftop.

Figures 2a and 2b depict the site and its immediate context and the site model, shown in Figure 3, is built to a scale of 1:500.

Macroclimate

For the proposed Development, the upstream wind flow during testing was conditioned to simulate an atmospheric boundary layer passing over suburban terrain. Historical meteorological data recorded from the Hamilton International Airport was used in this analysis. For studies in the City of Burlington, the historical weather data is depicted on an annual and winter and summer basis and the resulting wind roses are presented as mean velocity and percent frequency in Figures 5a-c. The mean velocities presented in the wind roses are measured at an elevation of 10*m*. Thus, representative ground level velocities at a height of 2*m*, for an urban macroclimate, are 52% of the mean values indicated on the wind rose, (for suburban and rural macroclimates the values are 63% and 78% respectively). The macroclimate for this area is dependent upon wind direction and varies with direction but is predominantly suburban.

Winter (November through April) has the highest mean velocities of the seasons with prevailing winds from the southwesterly quadrant, with significant components from the northeast quadrant as well, as indicated in Figure 5b. Summer (May through October) has the lowest mean wind velocities of the seasons with prevailing winds from the southwest with components from the west and northeast as well, as indicated in Figure 5c. Reported pedestrian comfort conditions generally pertain to the Annual conditions, which are depicted in Figure 5a and tend to frequent the northeast and southwest quadrants with the greatest frequency of strong winds from more southwesterly directions.

The wind climate at Hamilton International Airport is very directional and this is attributed to the City's situation between Lake Ontario, to the northeast, and Lake Erie, to the southwest. The lakes provide an energy source and the lay of the land channels winds to flow over the much lower portion of lands separating the lakes.

5.2 Pedestrian Level Wind Velocity Study

On the site model thirty-seven (37) wind velocity measurement probes were located on and around the proposed Development as well as 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 proposed scenario. For the existing setting, the subject building was removed and the "existing" site model retested with the existing buildings.

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 Figures 5a – 5c) was combined with pedestrian level mean and gust wind speeds measured at each point to provide predictions of the percentage of time a point will be comfortable for a given activity. These predictions of mean and maximum or "gust" wind speeds are provided on an annual, winter and summer basis in Figures 6a – 6c.

The ratings for a given location are conservative by design. Those ratings that are close to a transition between ratings will likely assume the more comfortable rating when the existing surroundings and proposed building's fine massing details and actual landscaping are taken into consideration. As such the actual 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 exposed to a suburban setting to prevailing and remaining compass points with winds flowing over low to mid-rise buildings that assist in mitigating the approaching wind climate. 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 an urban environment in order to determine the worst-case scenario.

5.3 Review of Probe Results

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

5.3.1 Public Street Conditions

Plains Road East
Probes 1 through 14 were located along Plains Road East, within the zone of influence of the proposed Development, as indicated in Figure 4. The probes indicate conditions in the existing setting that are suitable for standing or leisurely walking on an annual basis. In the winter months, the street realises slightly windier conditions with many of the probes rated for leisurely walking. The relatively windy conditions realised along the street are a reasonable expectation, given the street presents an open setting that allows dominant winds from the northeast and southwest that are in approximate alignment with the street to accelerate over the area.

With inclusion of the proposed Development, very similar pedestrian level wind conditions will be realised along Plains Road East, however, a realignment of winds was noted, resulting in localised changes to comfort conditions at a few locations. Probe 11, located proximate to the northern corner of the building, realised subtle increases in winds that changed the annual comfort rating from standing to leisurely walking. Conversely, probe 12 located proximate to the western corner of the site realised subtle improvements that changed the annual rating from leisurely walking to standing.

The above noted can be attributed to the proposed Development causing a realignment of winds that reduces apparent wind effects at the pedestrian level for several points for several

wind directions, but causes an increase in winds for others, as indicated in the Appendices Figure B, Ground Level Wind Velocity Plots presented as a ratio of gradient wind velocity. The subtle increases in winds can be attributed to the proposed Development redirecting winds to flow down and around the proposed building and along portions of Plains Road East, while improvements can be attributed to the proposed Development providing blockage to locations along the street for winds from specific directions.

As such, all probe locations along Plains Road East, with the above noted exceptions, retained their original annual pedestrian comfort rating. During the winter months, the subtle improvements result in generally more comfortable conditions along portions of the street, changing probes 12 and 13 from leisurely walking to standing. In the summer months the street realises more comfortable conditions, suitable for sitting or standing.

The street remains comfortable and suitable for its intended purpose and consideration of existing and proposed building elements that are too fine to incorporate into the model, and landscaping, will result in more comfortable conditions than those reported. Plains Road East remains within the pedestrian level wind velocity safety criteria as Fair-Weather Areas, as described in Section 4.7 and depicted in Figure 9.

Merle Avenue

Probes 15 through 19 were situated along Merle Avenue, within the zone of influence of the proposed Development. The street is well protected by the flanking low-rise dwellings from the majority of the wind climate and as such realises comfortable conditions in the existing setting, suitable for standing annually. With inclusion of the proposed Development the street realises subtle increases in winds from a few directions, however the probes retain their annual rating of standing. Merle Avenue remains comfortable and suitable to the area's intended purpose with inclusion of the proposed Development and the reported pedestrian comfort conditions do not pose a concern to pedestrian safety as indicated in Figure 9; the points are rated as All-Weather Areas.

Filmandale Road

Probes 20 through 25 were placed along Filmandale Road, to the east of the proposed Development. Filmandale Road is well protected from large portions of the wind climate by the low to mid-rise buildings flanking the street. As such, the probes along the street realise comfortable conditions in the existing setting, annually suitable for standing, with the exception of probes 22 and 25 that are rated for sitting.

In the proposed setting, Filmandale Road realises similar conditions, insufficient to change the annual ratings along the street. The street remains annually suitable for the intended purpose and will realise more comfortable conditions with consideration of design and landscape elements that were too fine to include in the massing model. The pedestrian level wind velocity safety criteria rates Filmandale Road as an All-Weather Area, as depicted in Figure 9.

5.3.2 Neighbouring Site Conditions

Probe 10 was situated adjacent to the Main Entrance of the neighbouring building to the immediate northeast of the proposed Development, at 300 Plains Road East. In the existing setting, the entrance is rated suitable for standing in the winter, and sitting in the summer. With inclusion of the proposed Development, the entrance realises similar conditions. The neighbouring entrance remains comfortable and suitable for the intended use year-round and will realise more comfortable conditions with consideration of proposed and existing fine design and landscape features.

Probes 26 and 27 were located proximate to the entrances to the neighbouring Holy Rosary Catholic Elementary School, located to the west of the proposed Development. In the existing setting, the entrances experience comfortable conditions and are rated suitable for sitting or standing throughout the year. With inclusion of the proposed Development, the entrances realise subtle changes in winds, however the seasonal ratings remain unchanged, with the exception of probe 26 that improves from standing to sitting through the winter months. The entrances to the neighbouring Holy Rosary Catholic Elementary School remain comfortable and suitable for the intended use year-round.

The above-noted neighbouring sites will realise similar conditions to the existing setting with inclusion of the proposed Development, and will remain comfortable and appropriate for the intended uses. Consideration of existing and proposed surface roughness features too fine to incorporate into the massing model and landscaping will likely translate into comfort ratings better than those described above. The above-noted neighbouring site areas are rated as All-Weather Areas.

5.3.3 Internal Site Conditions

Probes 28, 30, 32, 33, and 34 were situated along internal walkways within the site. Probe 28 was situated proximate to the western corner of the building, along Plains Road East, and realises sufficient blockage to winds from most directions to realise conditions suitable for sitting year-round. Probe 30 was located within the internal loading area and is protected by the proposed Development from winds from most directions. As such, probe 30 realises comfortable conditions that are rated suitable for sitting throughout the year.

Probes 32, 33, and 34 were located along the proposed building's southwestern façade and the area is exposed to portions of the wind climate that are directed to flow down and around the building and along the façade. Probes 33 and 34 realise conditions that are suitable for sitting or standing throughout the year, while probe 32 is exposed to westerly winds and as such experiences windier conditions. Probe 32 is rated suitable for leisurely walking in the summer, however it is rated uncomfortable through the winter months. The uncomfortable rating in the winter is near the transition to fast walking conditions and with consideration of design and landscape elements that were too fine to include in the massing model, the area is expected to be suitable as such. A mitigation plan is recommended for the area in order to achieve more

comfortable conditions near the southern corner of the building and at the adjacent private patio areas. The mitigation plan may include coniferous trees/shrubs, coarse plantings in raised planters, wind screens, fencing, trellises, and others that will provide roughness to winds flowing through the area from westerly directions. With inclusion of an appropriate mitigation plan, the area is expected to be comfortable and suitable for the intended use throughout the year.

The above-noted internal site areas fall within the pedestrian level safety criteria as All-Weather Areas.

5.3.4 Pedestrian Entrance Conditions

Probe 29 is situated adjacent to the Main Entrance to the proposed Development along Plains Road East. The entrance is fairly well protected from the majority of the wind climate, but is exposed to northerly winds that are uncommon in the area, as seen in the Figure 5 Wind Roses. As such, the are realises comfortable conditions that are rated suitable for standing in the winter and sitting in the summer. The entrance is set into a notch in the façade, underneath a canopy, and as such will realise more comfortable conditions than the sidewalk beyond. The Main Entrance to the proposed Development will be comfortable and suitable for the intended use, year-round.

Wind conditions comfortable for standing are preferable at building entrances, while conditions suitable for walking are suitable for walkways. Consideration of existing and proposed surface roughness features too fine to incorporate into the massing model as well as landscape features will result in more comfortable conditions than those described above. The Main Entrance to the proposed Development is rated as an All-Weather Area.

5.3.5 Outdoor Amenity Space Conditions

An Outdoor Amenity Space is proposed proximate to the southern corner of the site, at-grade, as represented by probe 31. The area is well protected by the proposed Development from the majority of the dominant wind climate, and as such is predicted comfortable and suitable for sitting, year-round. Portions of the Outdoor Amenity Area near the southern corner of the building may be exposed to westerly winds that are directed to flow around the corner of the building, resulting in windier conditions. As such, this area of the Outdoor Amenity Space would benefit from mitigative features, such as coniferous trees/shrubs, wind screens, fencing, etc. situated to the west of the area. With inclusion of a mitigative plan for the western portion of the space, the at-grade Outdoor Amenity Area is predicted to be comfortable and suitable for the intended use, year-round.

Probes 36 and 37 were situated within Outdoor Amenity Spaces atop steps in the southeastern façade at the 6th level. The more northern space, as represented by probe 36, is well protected from the majority of the wind climate and as such is predicted suitable for sitting, year-round.

The more southern space is represented by probe 37 and is exposed to larger portions of the wind climate from northerly through easterly to southerly directions. The area realises conditions suitable for leisurely walking in the winter and standing in the summer. In order to achieve comfortable conditions that are suitable for the intended use, a mitigation plan including 1.8m high perimeter wind screens, raised planters with coarse plantings, trellises, and others, is recommended for the southerly space.

Note: Probes 36 and 37 situated within Amenity Spaces at the 6th level are also representative of conditions at the Amenity Spaces at the 8th level. As such, the northerly space at the 8th level is predicted to be comfortable throughout the year, however the more southerly space is predicted to experience windier conditions, and a mitigation plan, as described above, is recommended for the space.

An Outdoor Amenity Space is also proposed for the roof of the building at the 10th level, as represented by probe 35. The area is exposed to large portions of the wind climate and as such realises conditions suitable for leisurely walking in the winter and standing through the summer months. In order to achieve comfortable conditions that are suitable for the intended use, a mitigation plan including 1.8m high perimeter wind screens, raised planters with coarse plantings, trellises, and others, is recommended for the space.

Comfort conditions generally suitable for sitting are preferred for amenity spaces during the summer months15 and 16. The northern amenity spaces at the 6th and 8th levels are predicted to be comfortable and appropriate for the intended uses, however mitigation plans are recommended for the southern spaces at the 6th and 8th levels, the 10th level rooftop space, and the at-grade Amenity Area. Consideration of appropriate mitigation plans for the spaces will result in comfortable conditions that are seasonally suitable for the intended uses. The proposed Outdoor Amenity Areas fall within the safety criteria as All-Weather Areas.

5.3.6 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 wind directions. These surroundings moderate wind flow in streamlines near the pedestrian level, resulting in generally comfortable conditions with localised windy conditions proximate to open areas. Historical weather data measured at Hamilton International Airport indicates the mean winter wind speed is 18.1 km/h with wind speeds greater than 30 km/h occurring approximately 16 percent of the time, during the winter, and less than 5 percent of the time during the summer.

Once the subject site is developed, ground level winds at several locations will improve from specific directions, with occasional localized areas of higher pedestrian level winds, resulting in wind conditions that are predicted as windy at times, but remain comfortable and generally appropriate to the areas' intended purpose throughout the year. The relationship between surface roughness and wind is discussed in the Appendix and shown graphically in Figure A of the same section.

As such, the site and surrounds are predicted mainly suitable for leisurely walking or better under normal wind conditions annually; however, under high ambient winter wind conditions with winds emanating from specific directions, the southern corner of the proposed building will be windy from time to time, but remains appropriate to the intended purpose much of the time. Additional mitigation is recommended for areas near the southern corner including the at-grade amenity area, as well as various rooftop Amenity Areas, in order to achieve comfortable conditions that are suitable for the intended uses. The consideration of proposed surface roughness will result in conditions more comfortable than those reported herein.

The site will realise conditions suitable to a typical suburban context.

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Appendix: Background and Theory of Wind Movement 42

Figure 1: Laboratory Testing Facility





Figure 2a: Site Aerial Photo

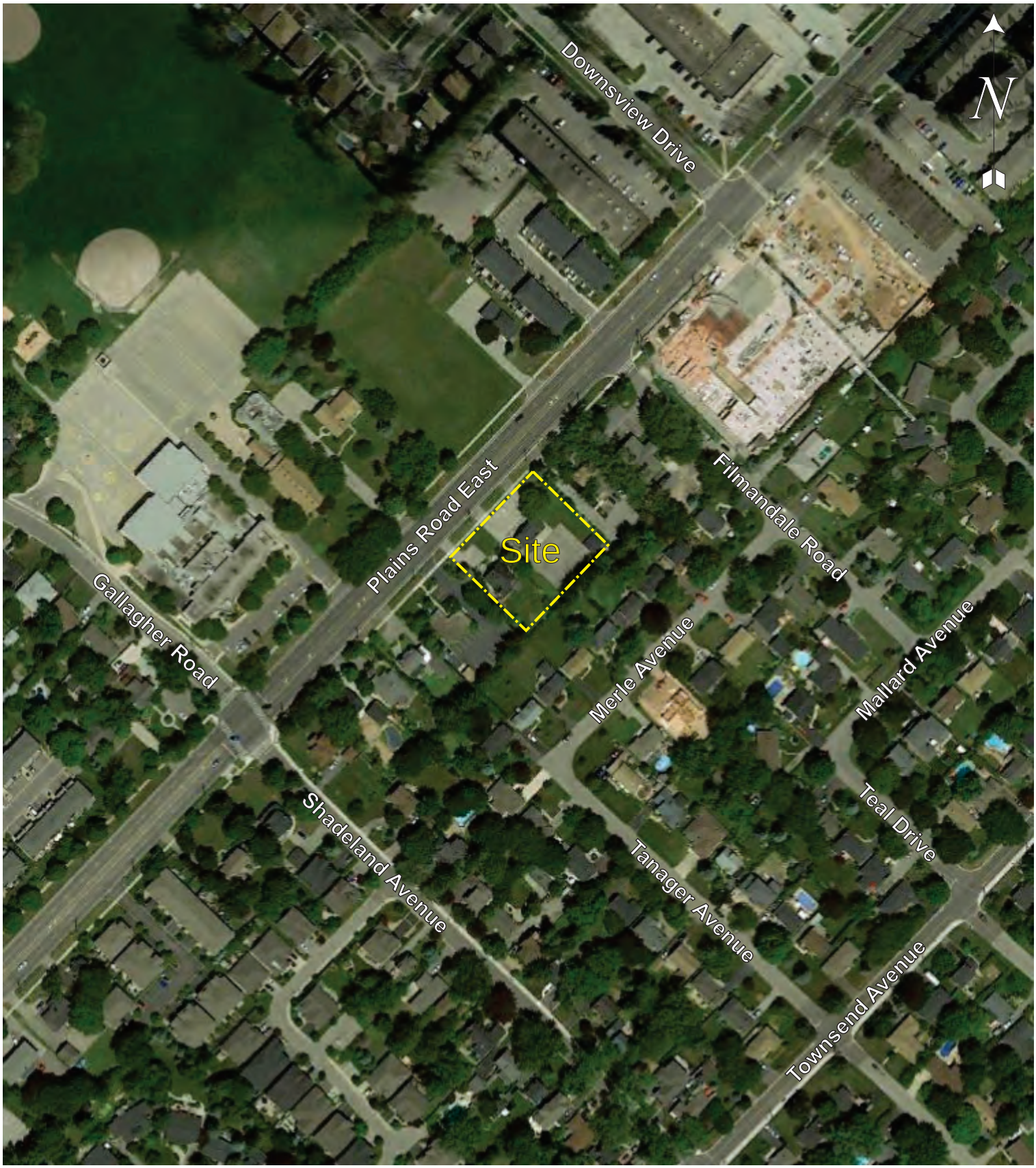
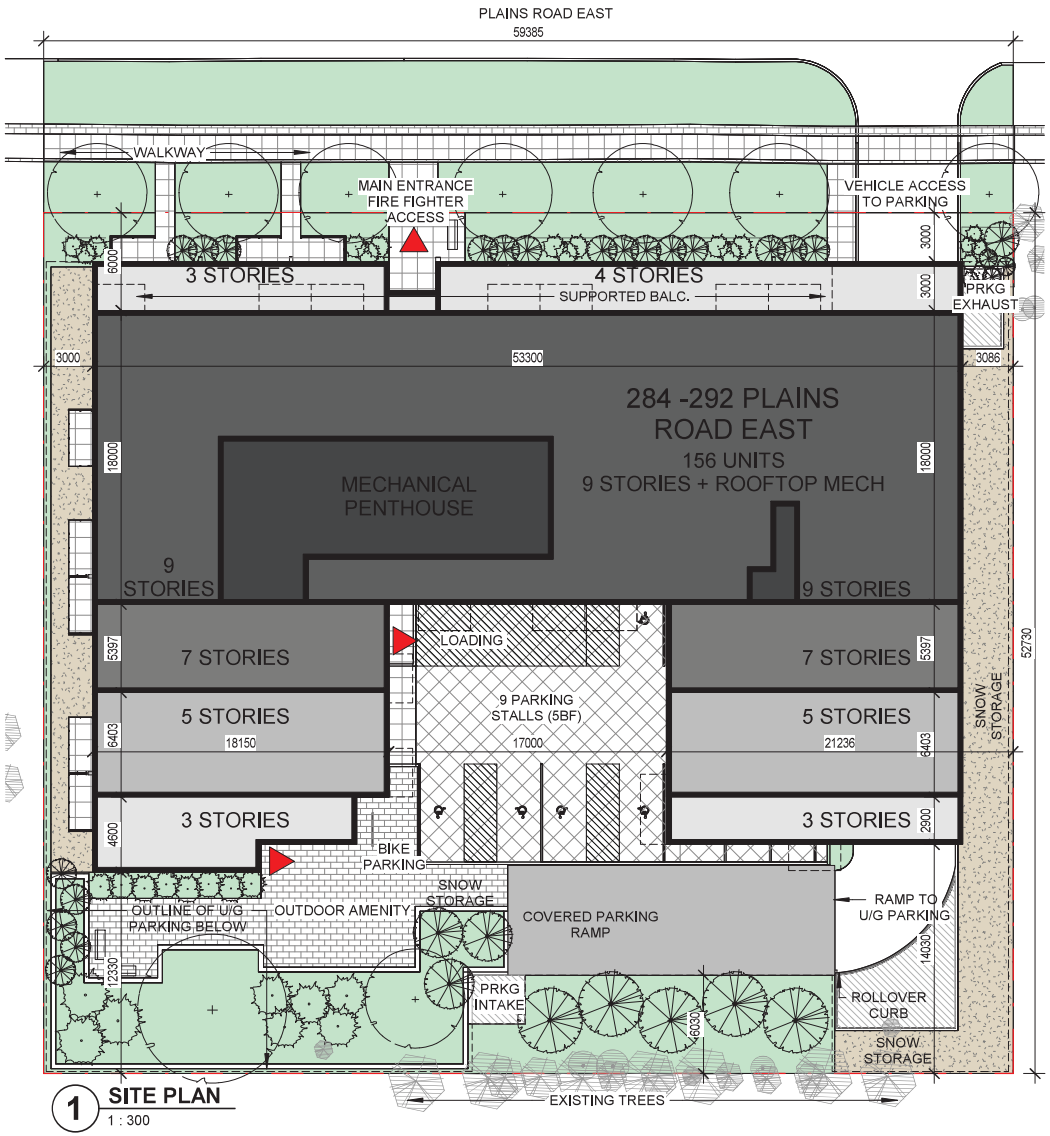


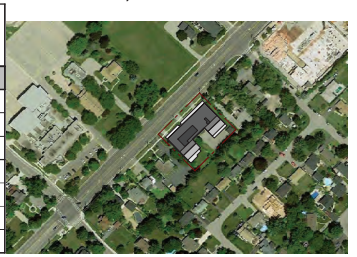
Figure 2b: Site Plan



1 SITE PLAN
1 : 300

Project North

True North



SITE DATA

284-292 Plains Rd. E, Burlington, Ontario

DATA		REQUIRED	PROVIDED
ZONING		ZONING - MXG	
PROPERTY ZONE		RM1-346	
LOT AREA (m²)		XX (m²)	3,131.4 (m²)
SETBACKS	FRONT YARD (m)	3 (m)	3 (m)
	INTERIOR SIDE YARD (m) East	3 (m)	3 (m)
	INTERIOR SIDE YARD (m) West	3 (m)	3 (m)
	REAR YARD (m)	12 (m)	12.3 (m)

BUILDING DATA

DATA	REQUIRED	PROVIDED
TOTAL DENSITY (# of units) 1 BEDROOM (INBOUND) 1 BEDROOM 2 BEDROOM 3 BEDROOM 2 BED TOWNHOUSES	XX (units)	156 (units) 40 units 90 units 14 units 4 units 8 units
BUILDING AREA (m²)	XX (m²)	1,163 m²
GROSS FLOOR AREA (m²) -not incl. parking	XX (m²)	11,997 m²
NUMBER OF STOREYS	6 MAX.	9 + Mech Rooftop
BUILDING HEIGHT (m)	XX (m) MAX.	33.5 m OVERALL
AMENITY AREA (m²) (15m² for 1B unit <60m², 20m² for 1B >60m², 35m² for 2B+)	TOTAL = 2,720 m²	= 2,032 m² = 13 m² / unit

LANDSCAPING DATA

DATA	REQUIRED	PROVIDED
LANDSCAPE AREA (percentage)	XX (%)	27.6 (%) 866 (m²)

VEHICLE PARKING DATA

DATA	REQUIRED	PROVIDED
RESIDENTIAL PARKING (3 STOREYS U/G TO DEPTH OF 8.25m ~ 62 STALLS / LEVEL + 9 SURFACE)	1.25 / UNIT TOTAL 156 UNITS = 195 STALLS REQ.	192 (1.23 / UNIT)
BARRIER FREE PARKING	3% OF STALLS = 6	6 (includ. in above)
VISITOR PARKING	INCLUDED IN TOTAL	
MAINTENANCE PARKING	1 STALL / 75 UNITS = 2.08	3
TOTAL	179 + 2 = 181	195

BICYCLE PARKING DATA

DATA	REQUIRED	PROVIDED
RESIDENTIAL BICYCLE PARKING	X	7
	TOTAL	7

SITE PLAN
284-292 PLAINS RD. E, BURLINGTON

20042
2020-08-05
PRELIMINARY

srm ARCHITECTS INC.
2020-08-06 9:41:39 AM

Theakston Environmental

Figure 3: 1:500 Scale model of test site



a) Overall view of model - Proposed Site



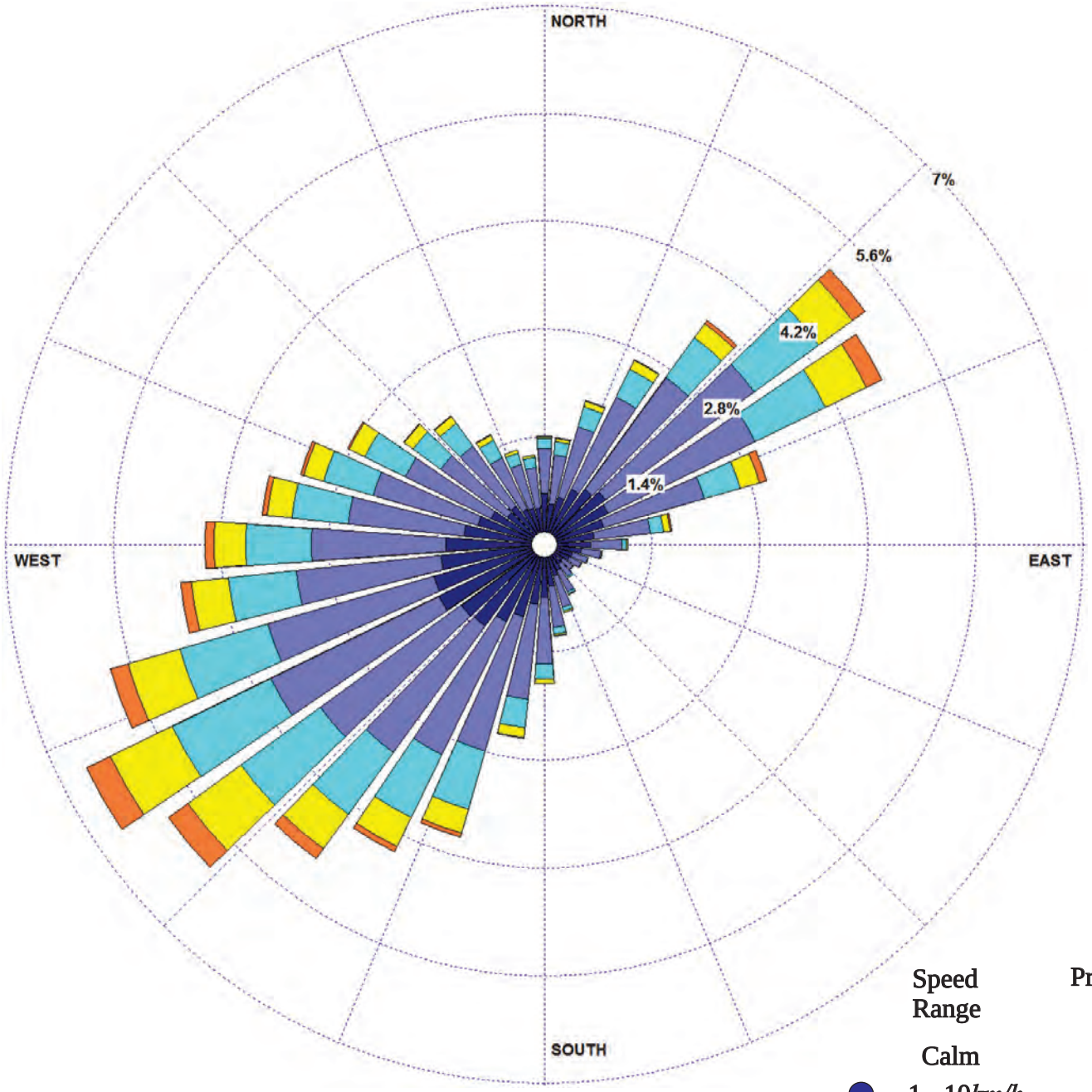
b) Close-up view of model - Proposed Site

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



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

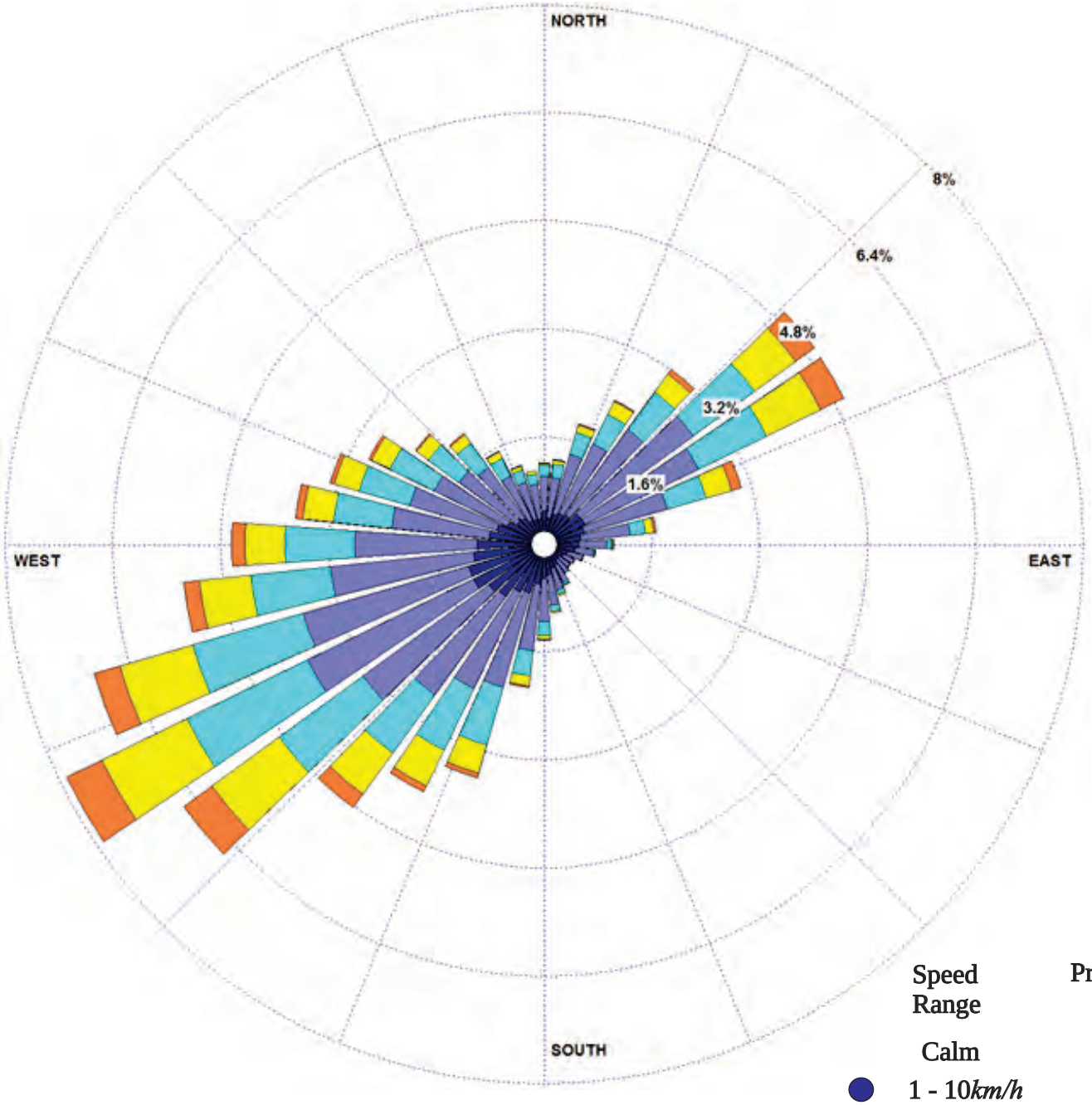
Historical Directional Distribution of Winds (@ 10*m* height)
(1988 - 2018)



Speed Range	Probability (%)
Calm	4%
1 - 10*km/h*	28%
11 - 20*km/h*	41%
21 - 30*km/h*	17%
31 - 40*km/h*	8%
> 40*km/h*	2%

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

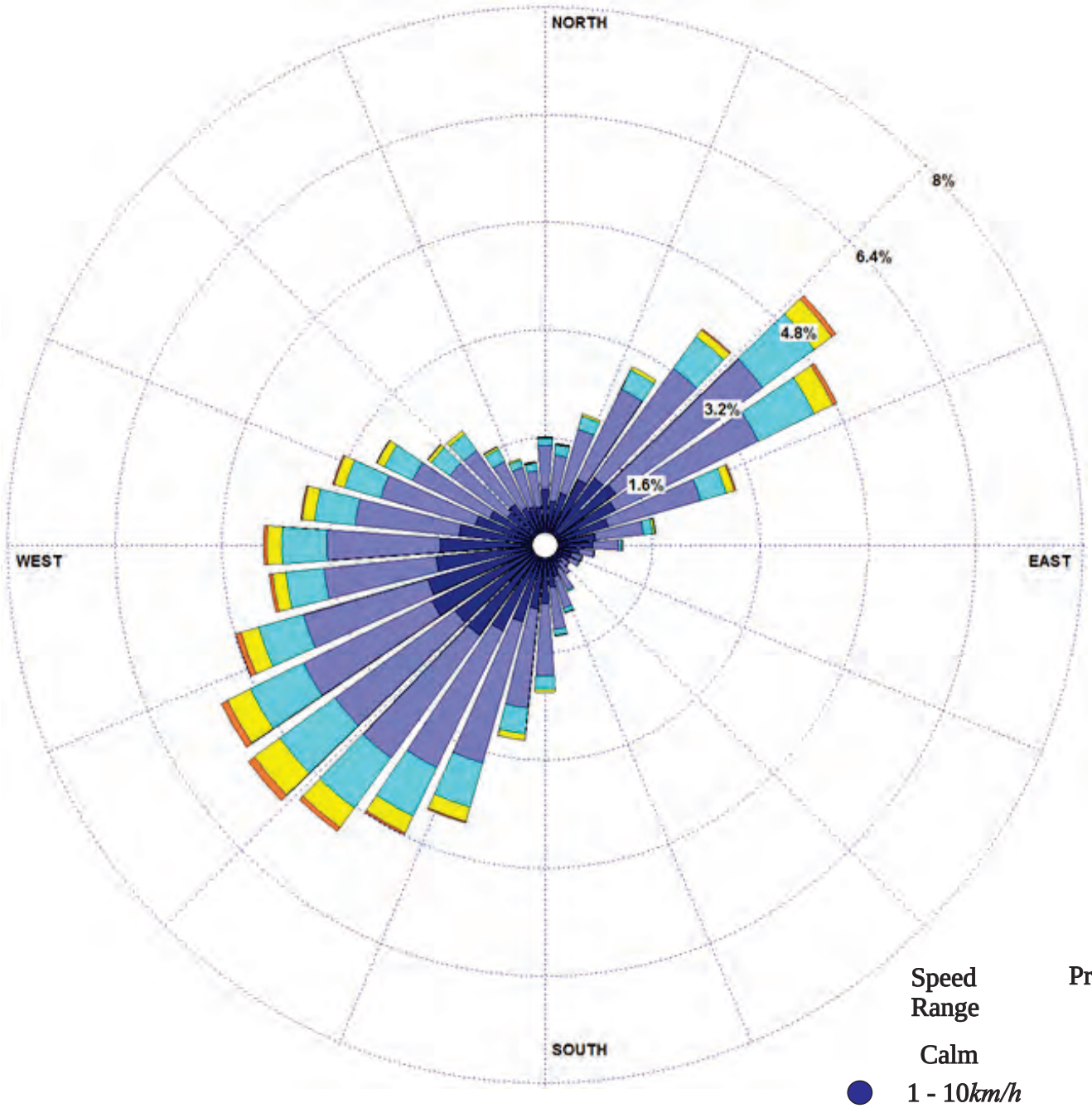
Historical Directional Distribution of Winds (@ 10*m* height)
November through April (1988 - 2018)



Speed Range	Probability (%)
Calm	3%
1 - 10*km/h*	22%
11 - 20*km/h*	39%
21 - 30*km/h*	20%
31 - 40*km/h*	12%
> 40*km/h*	4%

Figure 5c: Summer Wind Rose - Hamilton International Airport.

Historical Directional Distribution of Winds (@ 10*m* height)
May through October (1988 - 2018)



Speed Range	Probability (%)
Calm	5%
1 - 10*km/h*	34%
11 - 20*km/h*	43%
21 - 30*km/h*	13%
31 - 40*km/h*	4%
> 40*km/h*	<1%

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

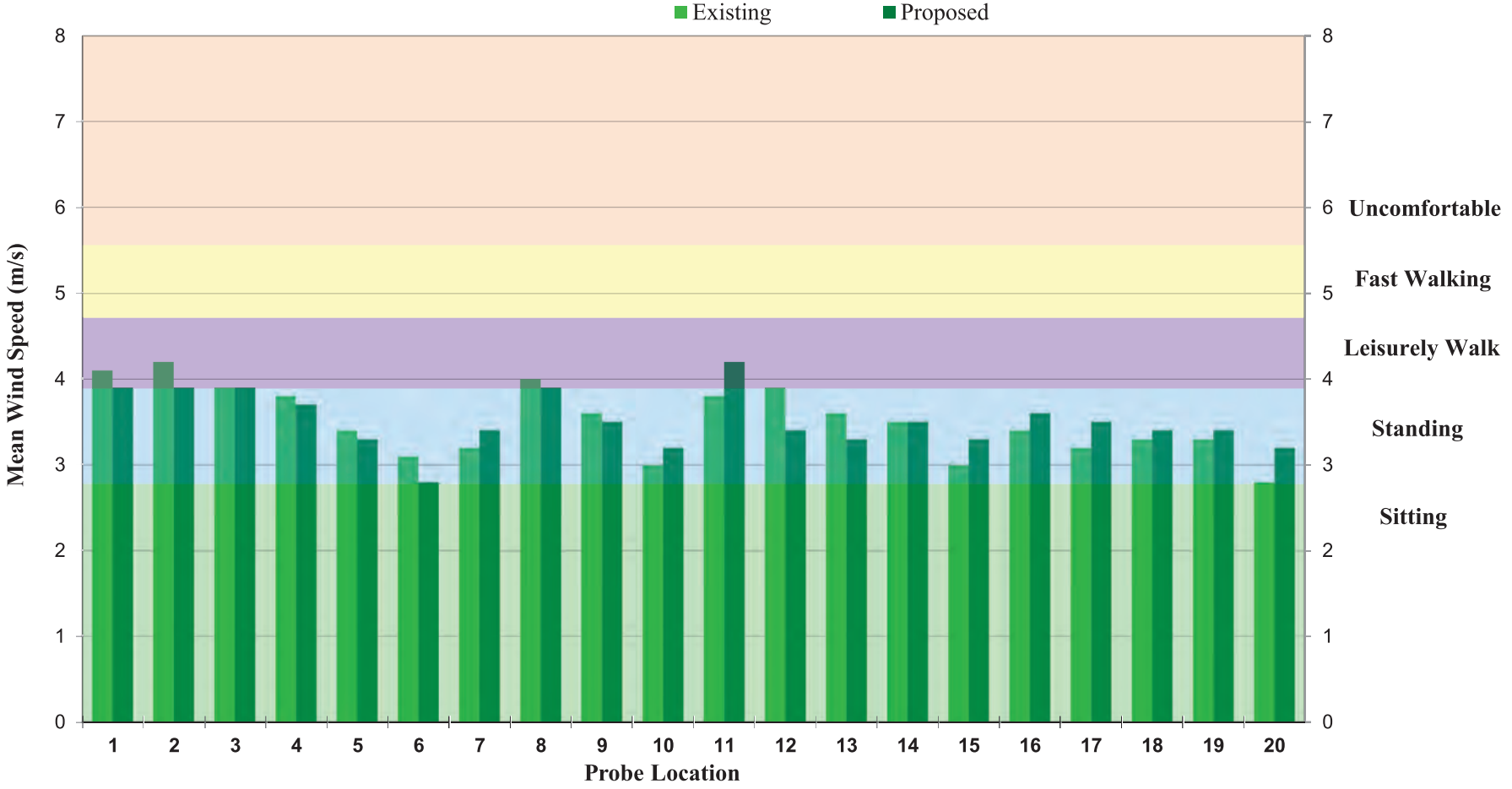


Figure 6a: ANNUAL - Wind Speed Exceeded 20% of the Time (Locations 21 to 37).

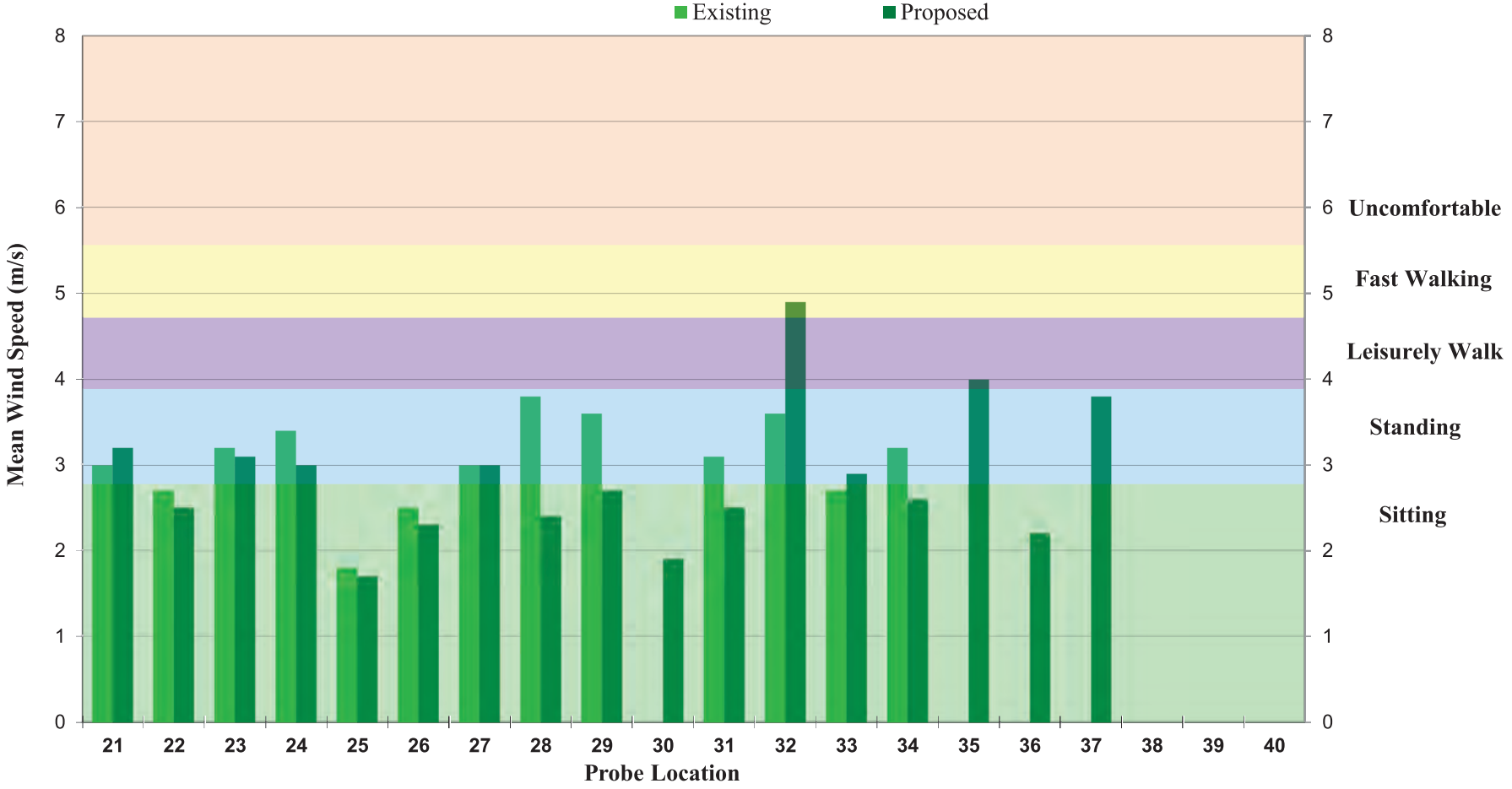


Figure 6b: WINTER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).

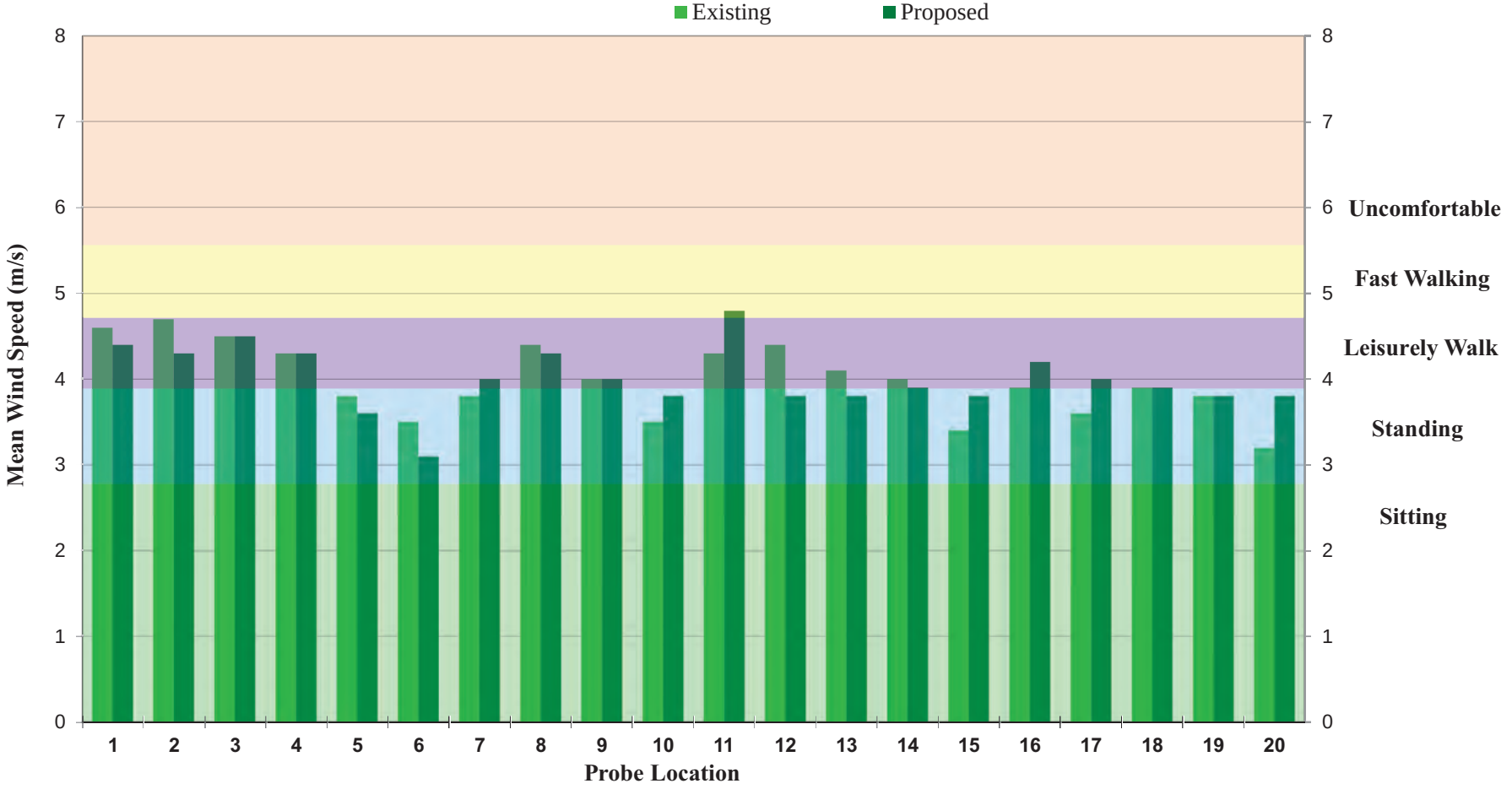


Figure 6b: WINTER - Wind Speed Exceeded 20% of the Time (Locations 21 to 37).

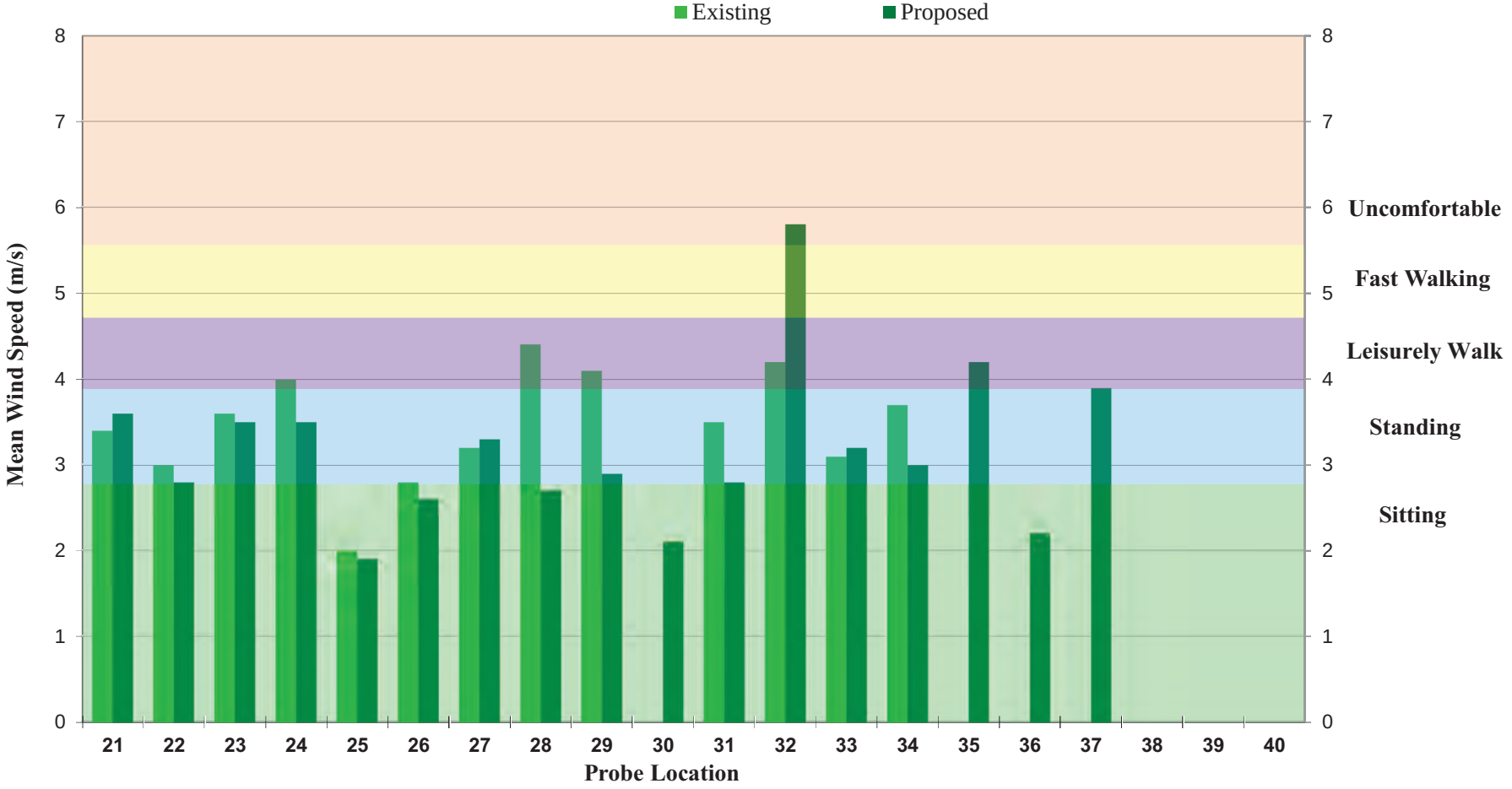


Figure 6c: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 1 to 20).

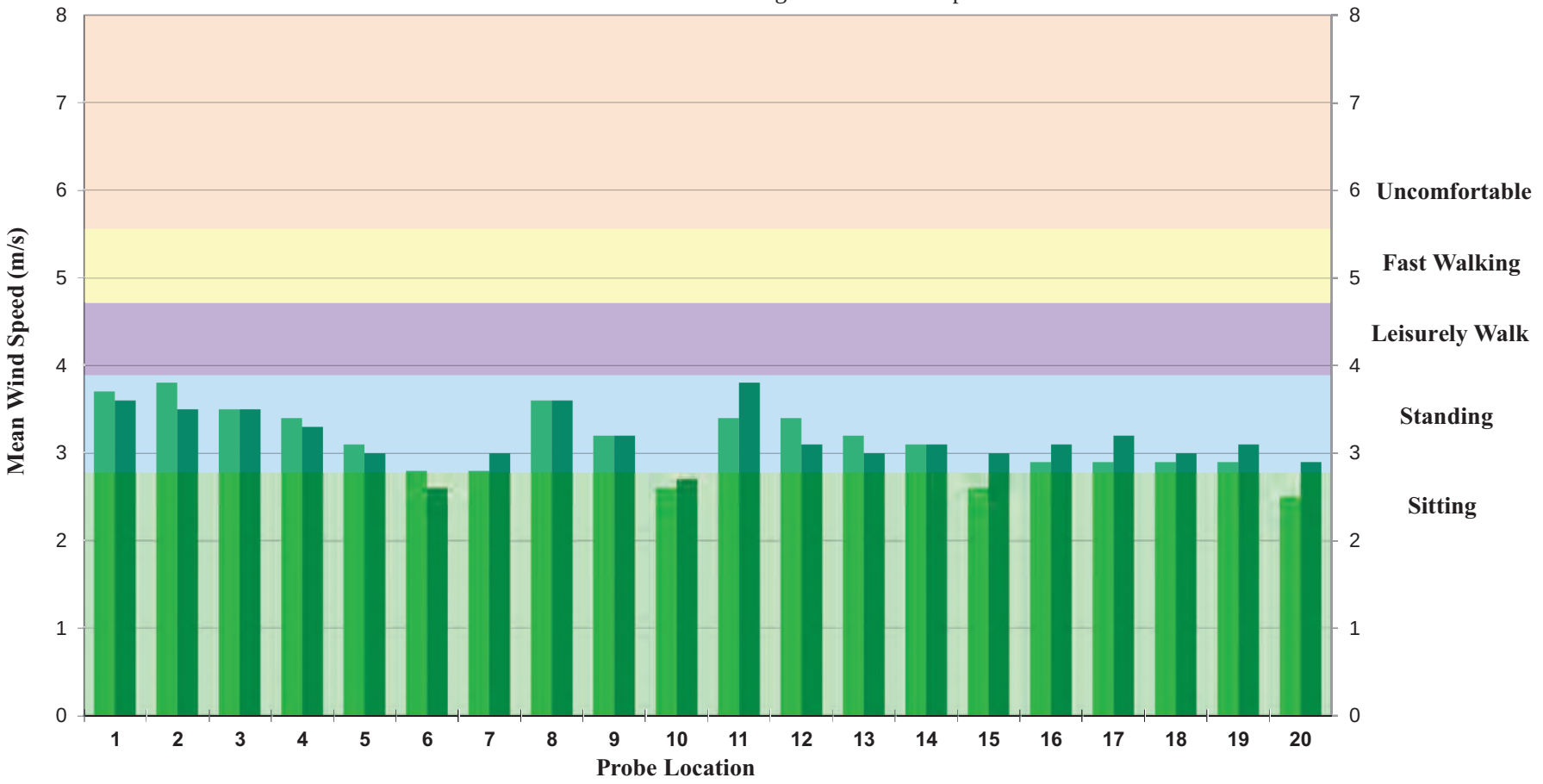


Figure 6c: SUMMER - Wind Speed Exceeded 20% of the Time (Locations 21 to 37).

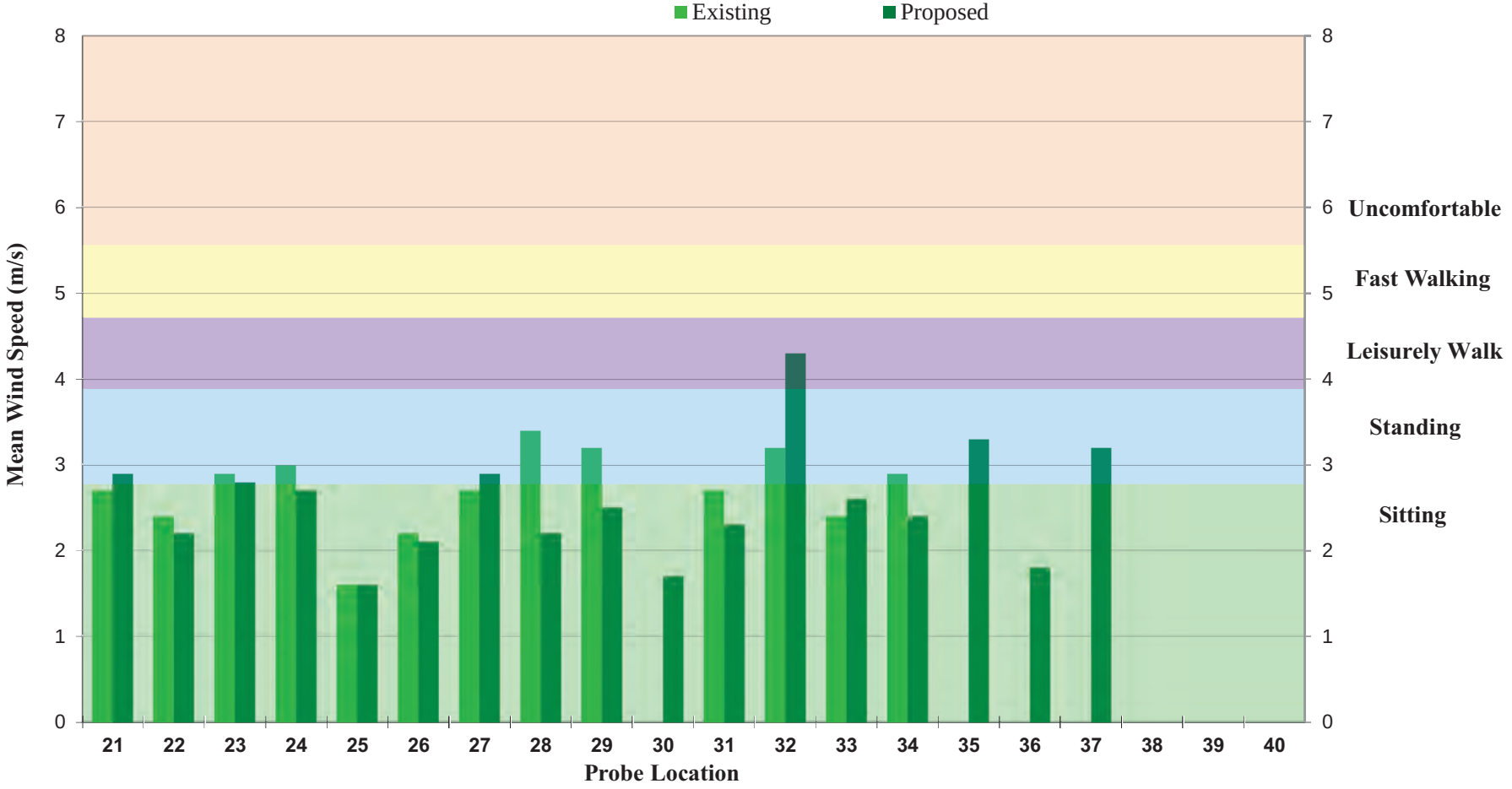


Figure 7a: Pedestrian level wind velocity comfort categories.



Comfort Categories - Annual - Existing

Sitting | Standing | Leisurely Walking | Fast Walking | Uncomfortable

Figure 7b: Pedestrian level wind velocity comfort categories.



Comfort Categories - Annual - Proposed

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

Figure 7c: Pedestrian level wind velocity comfort categories.



Figure 7d: Pedestrian level wind velocity comfort categories.



Comfort Categories - Winter - Proposed

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

Figure 7e: Pedestrian level wind velocity comfort categories.



Figure 7f: Pedestrian level wind velocity comfort categories.



Comfort Categories - Summer - Proposed

Sitting Standing Leisurely Walking Fast Walking Uncomfortable

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

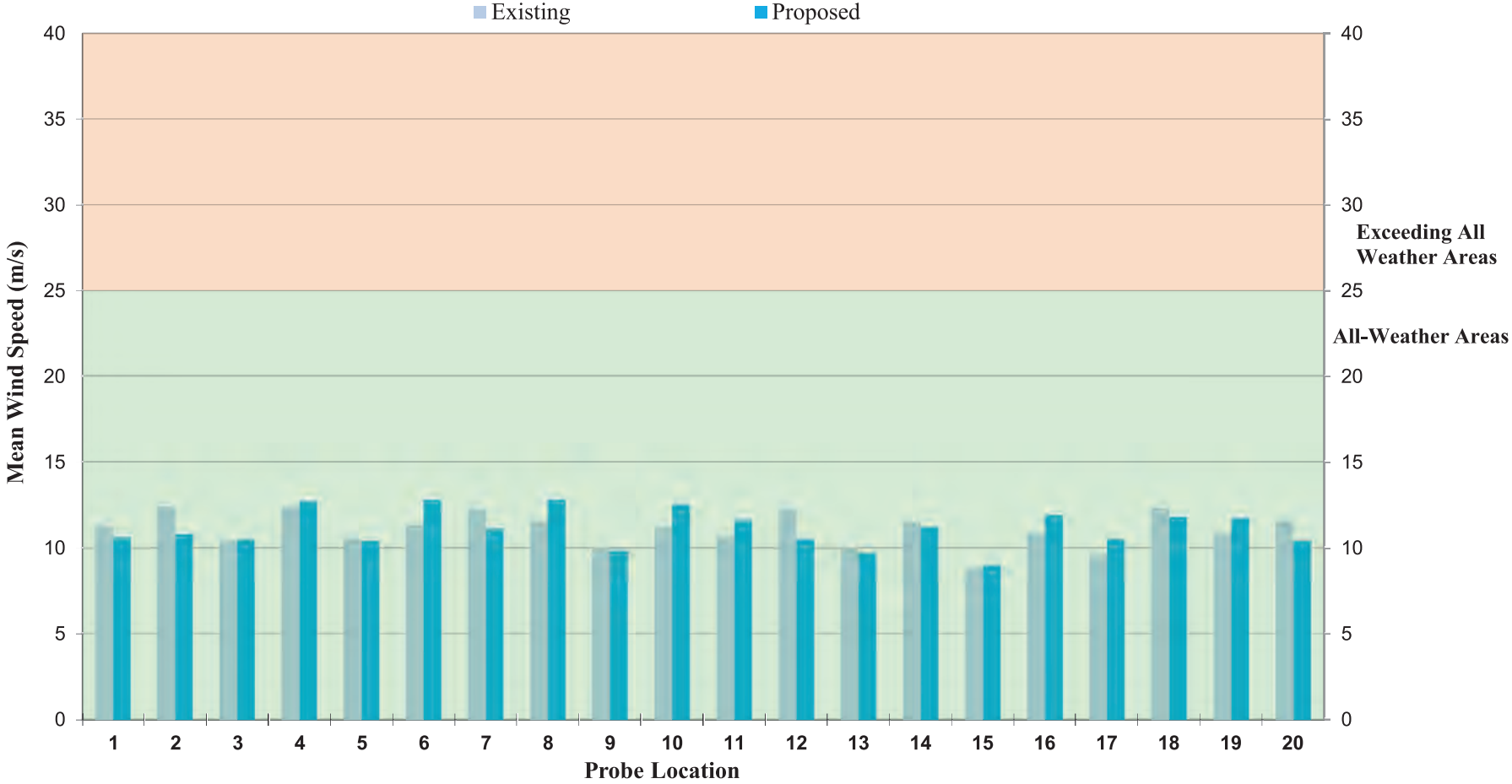


Figure 8: SAFETY CRITERIA - Wind Speed Exceeded Nine Times Per Year (Locations 21 to 37).

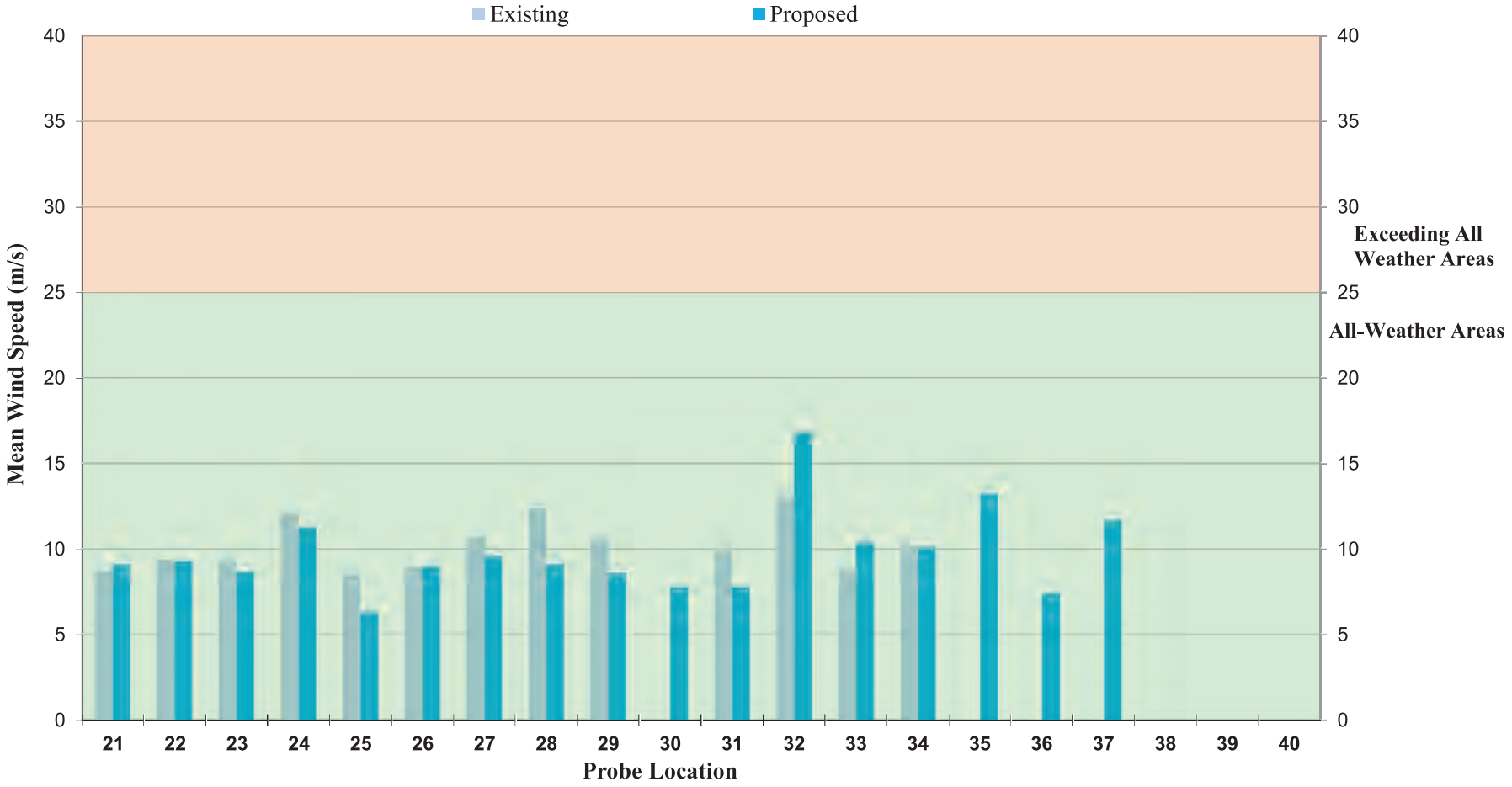


Figure 9a: Pedestrian level wind velocity safety criteria.



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

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:

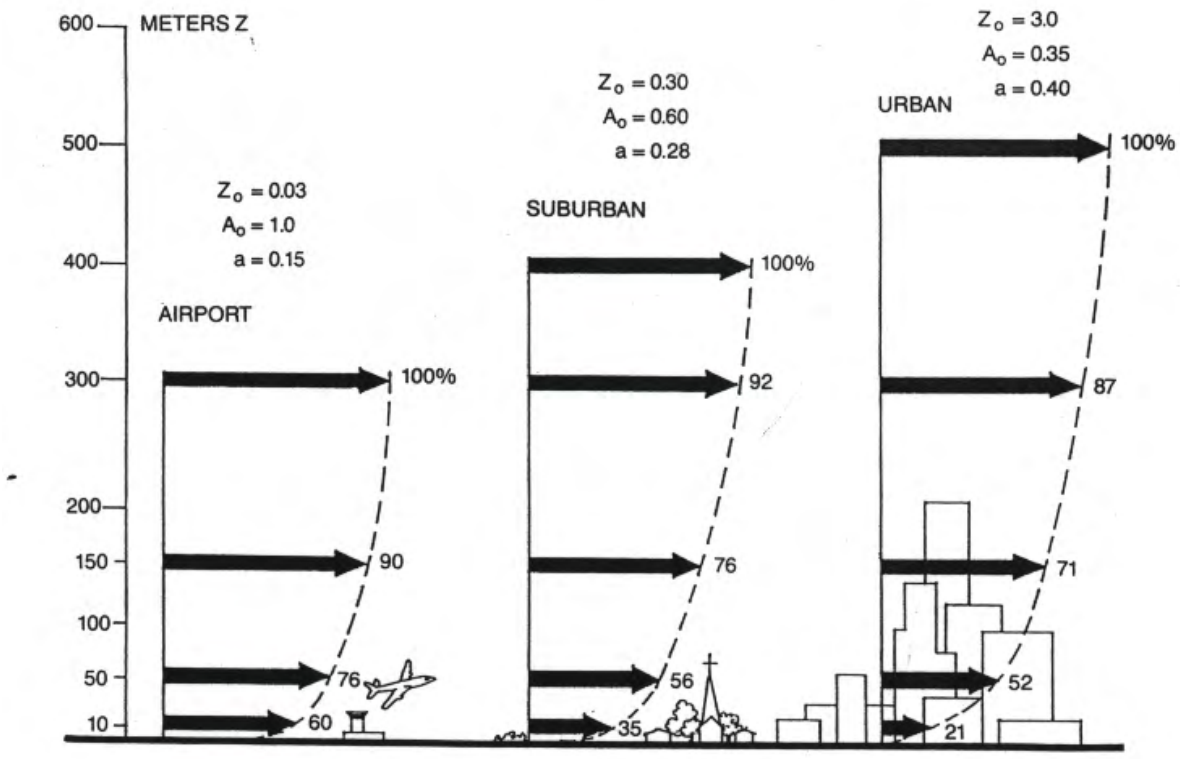


Figure A: Mean wind speed profiles for various terrain (from ASHRAE 1989).

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.

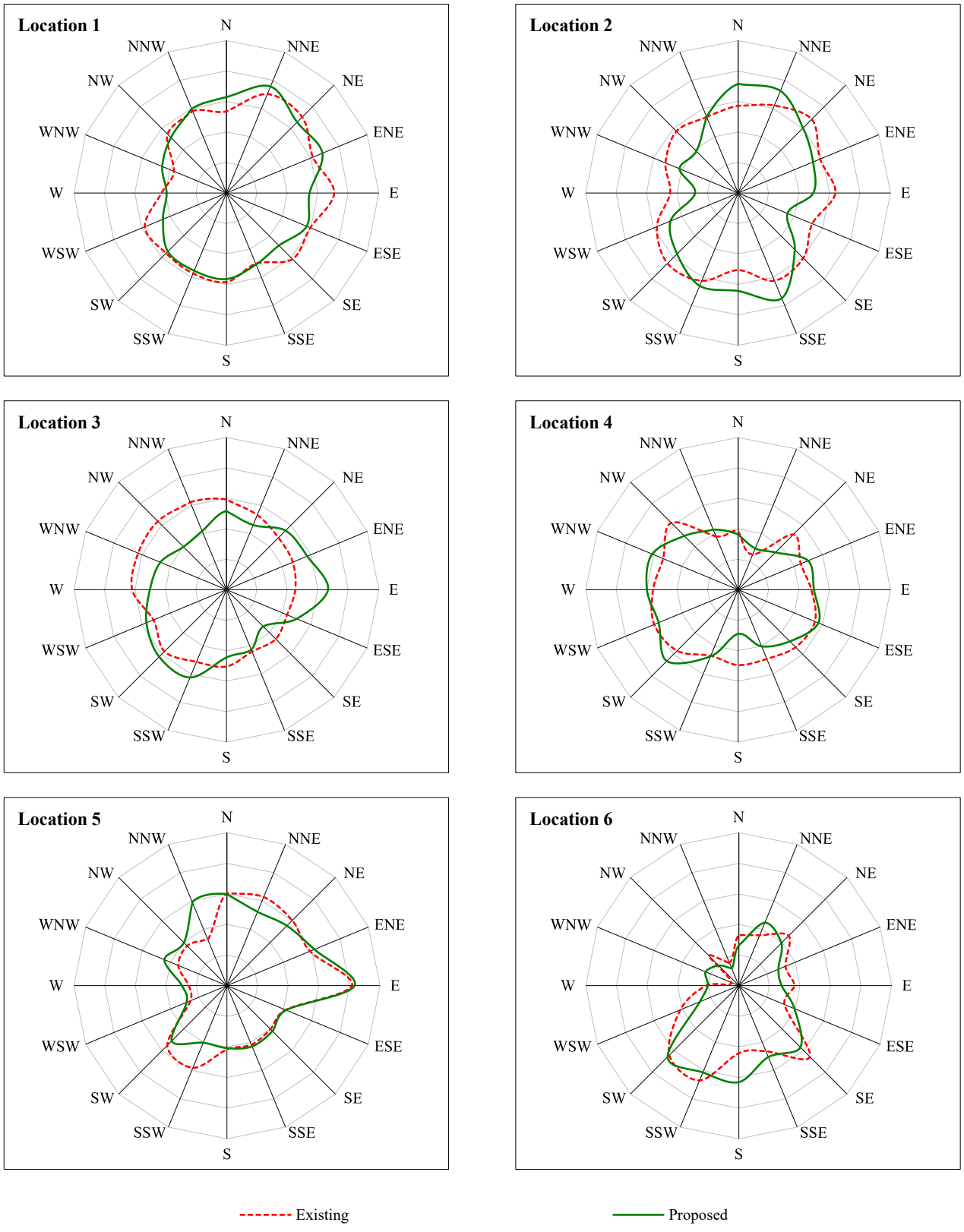


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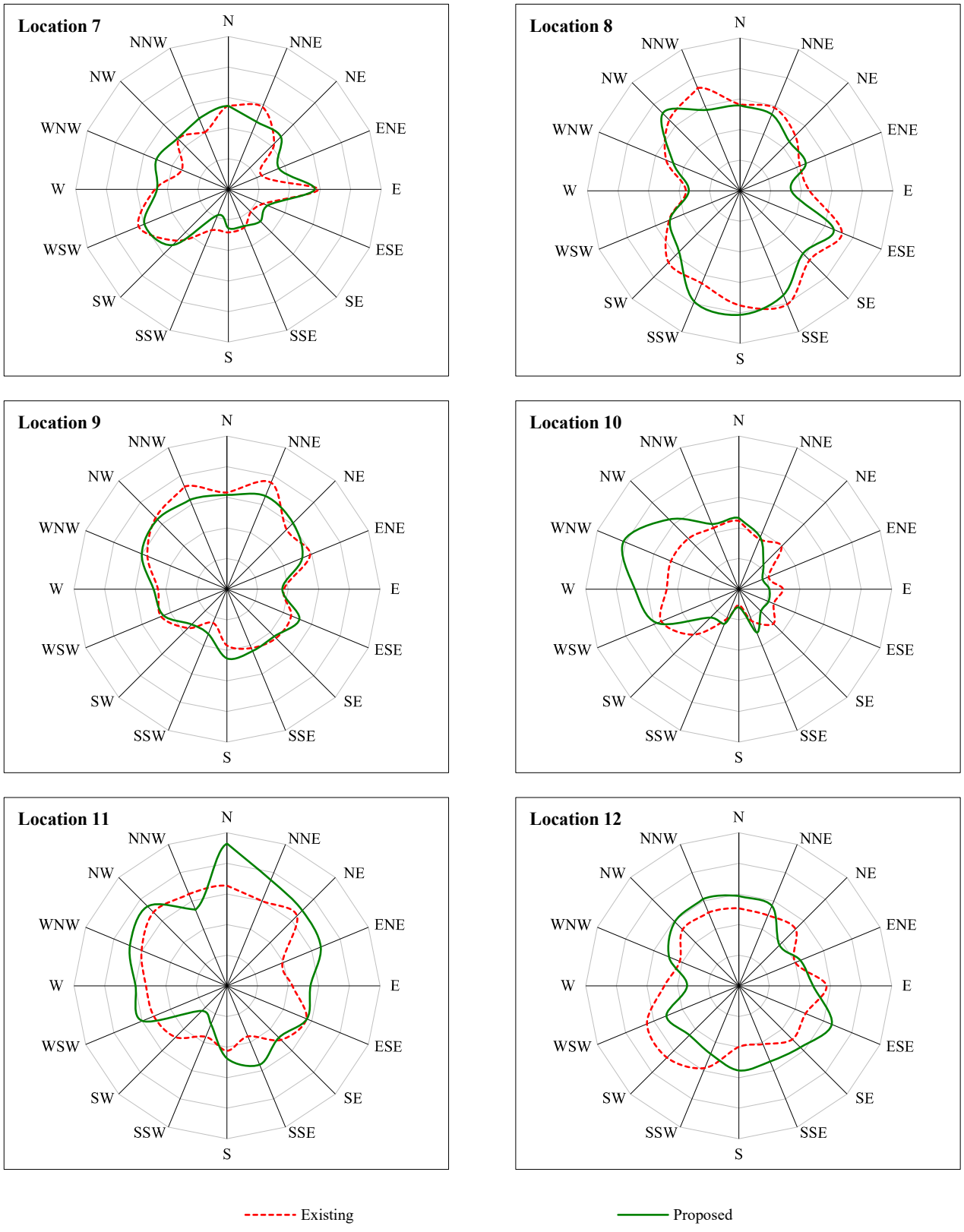


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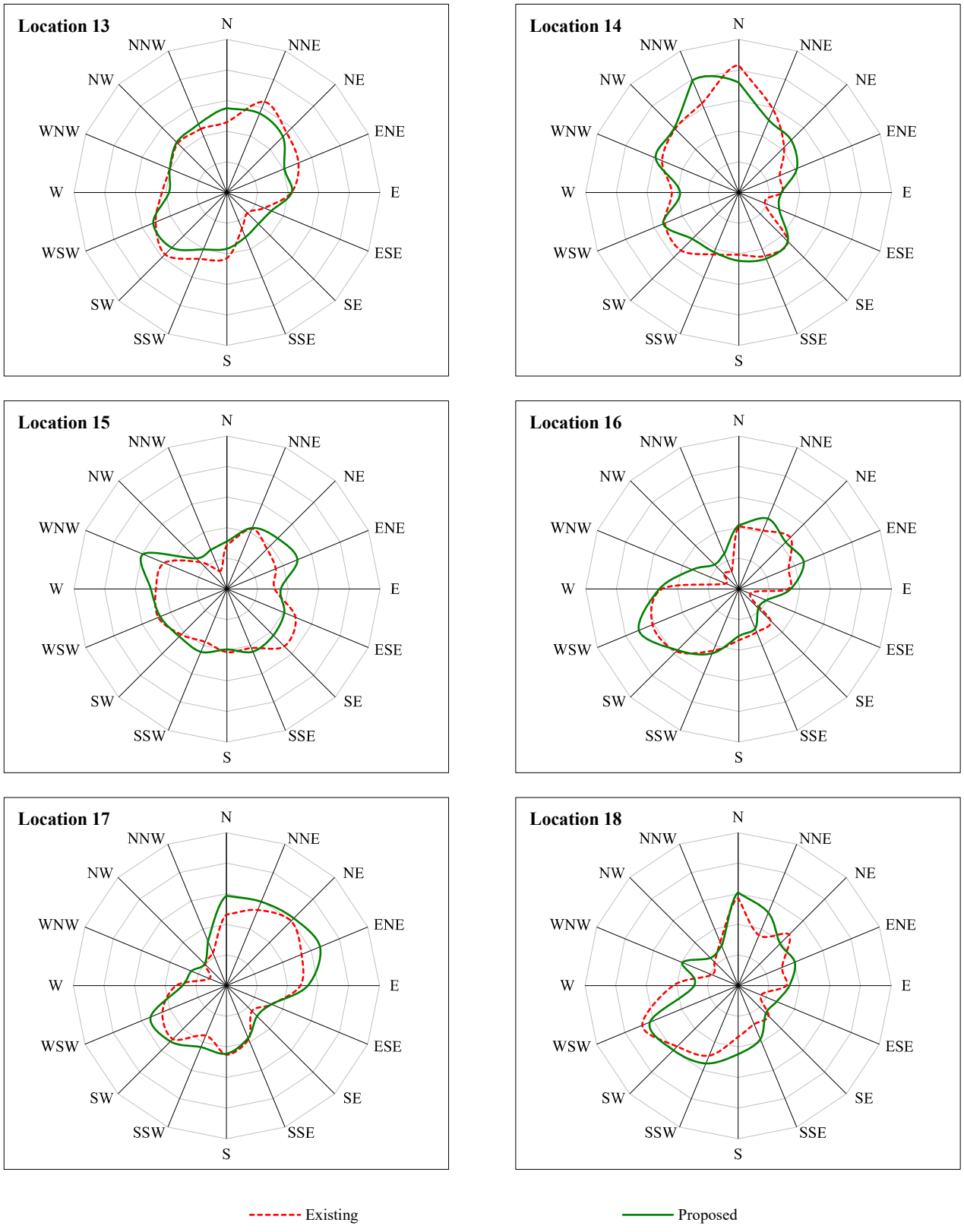


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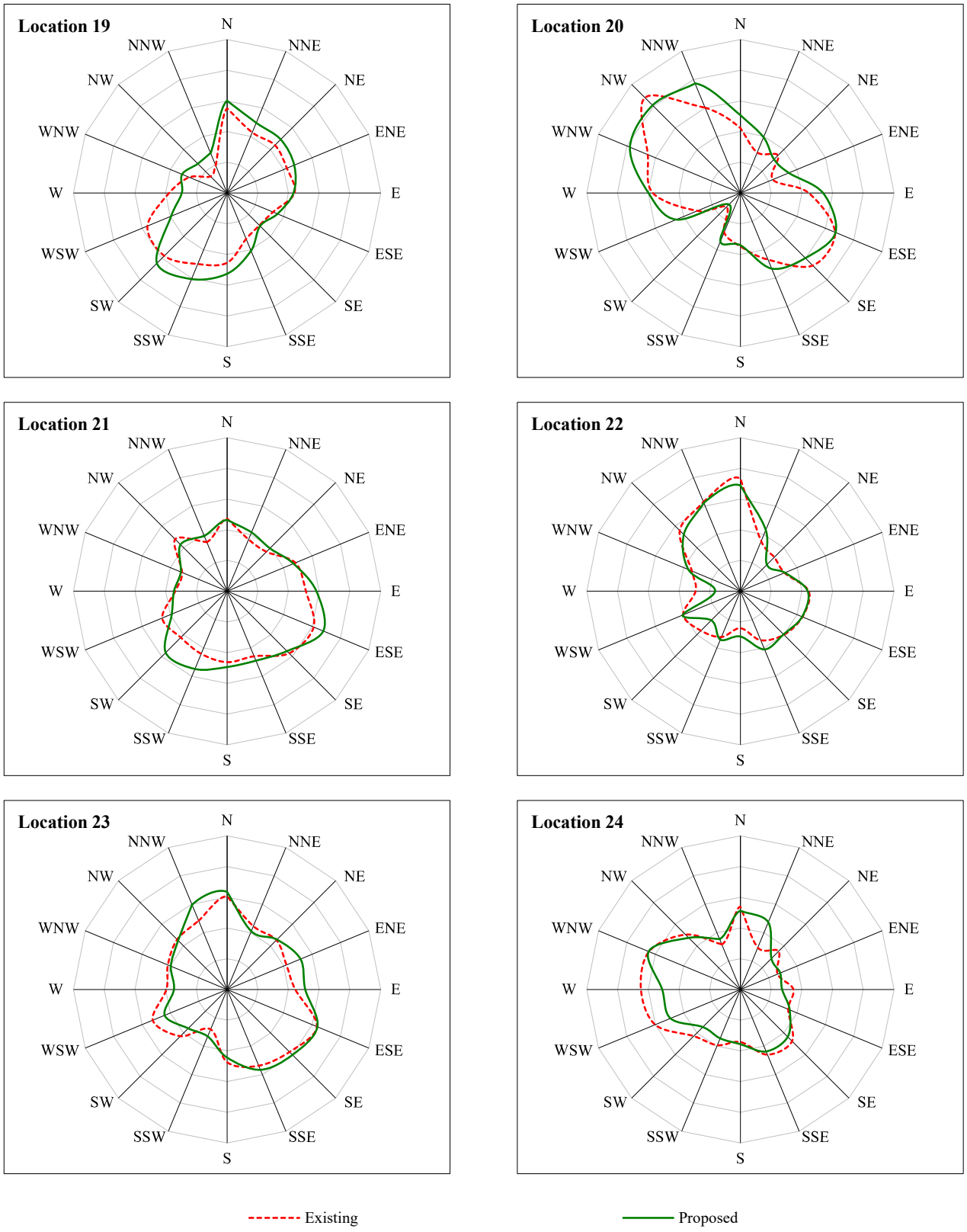


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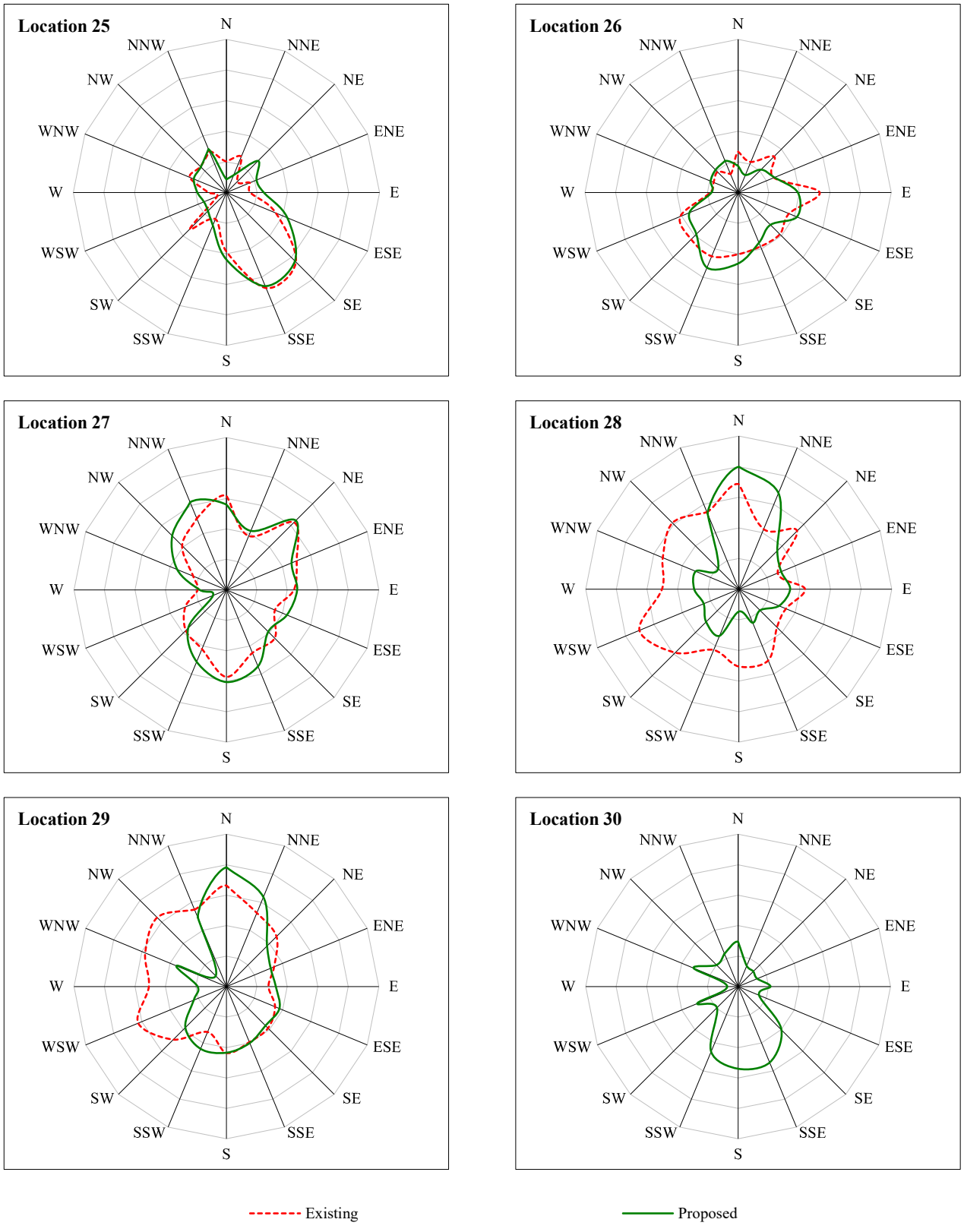


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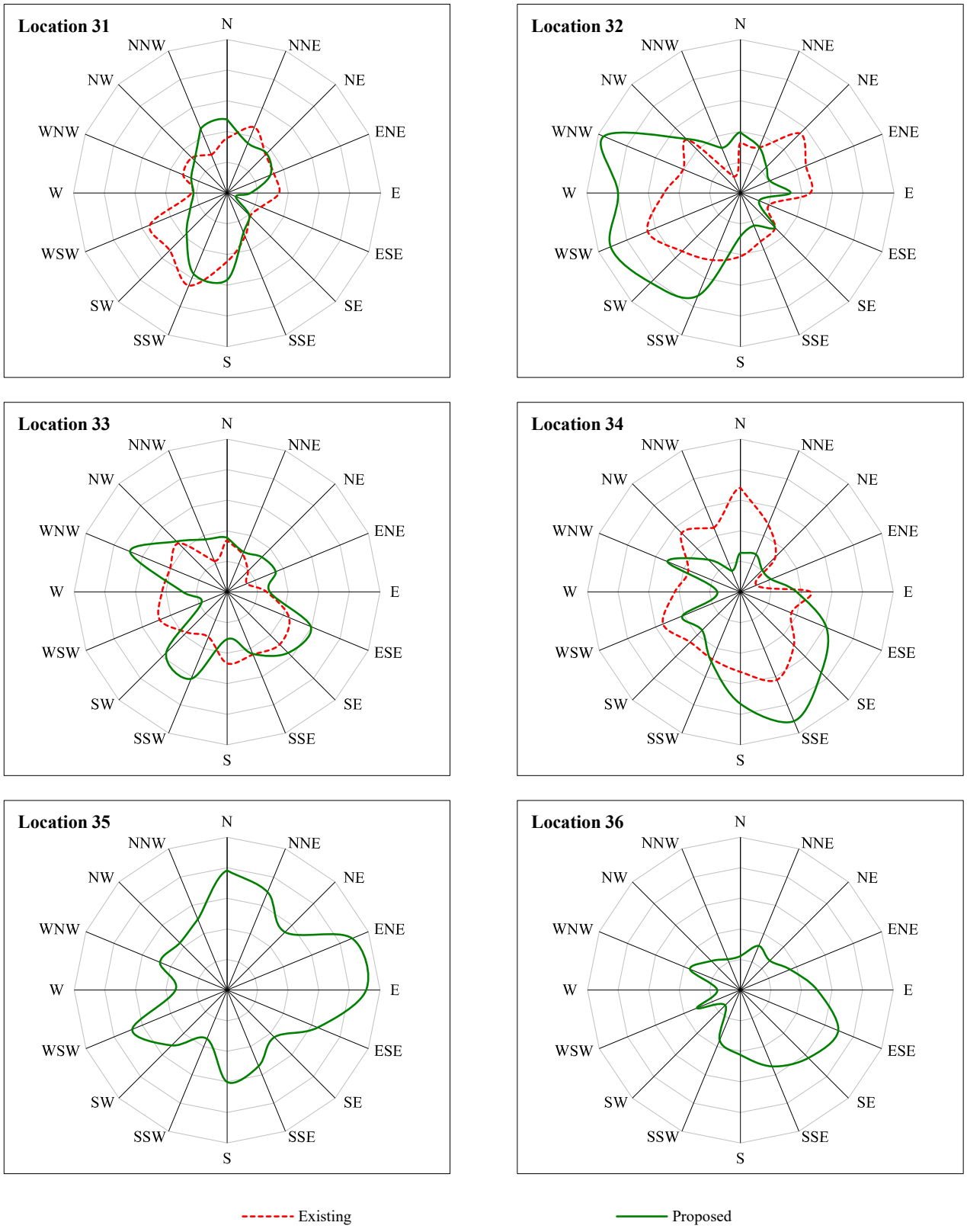
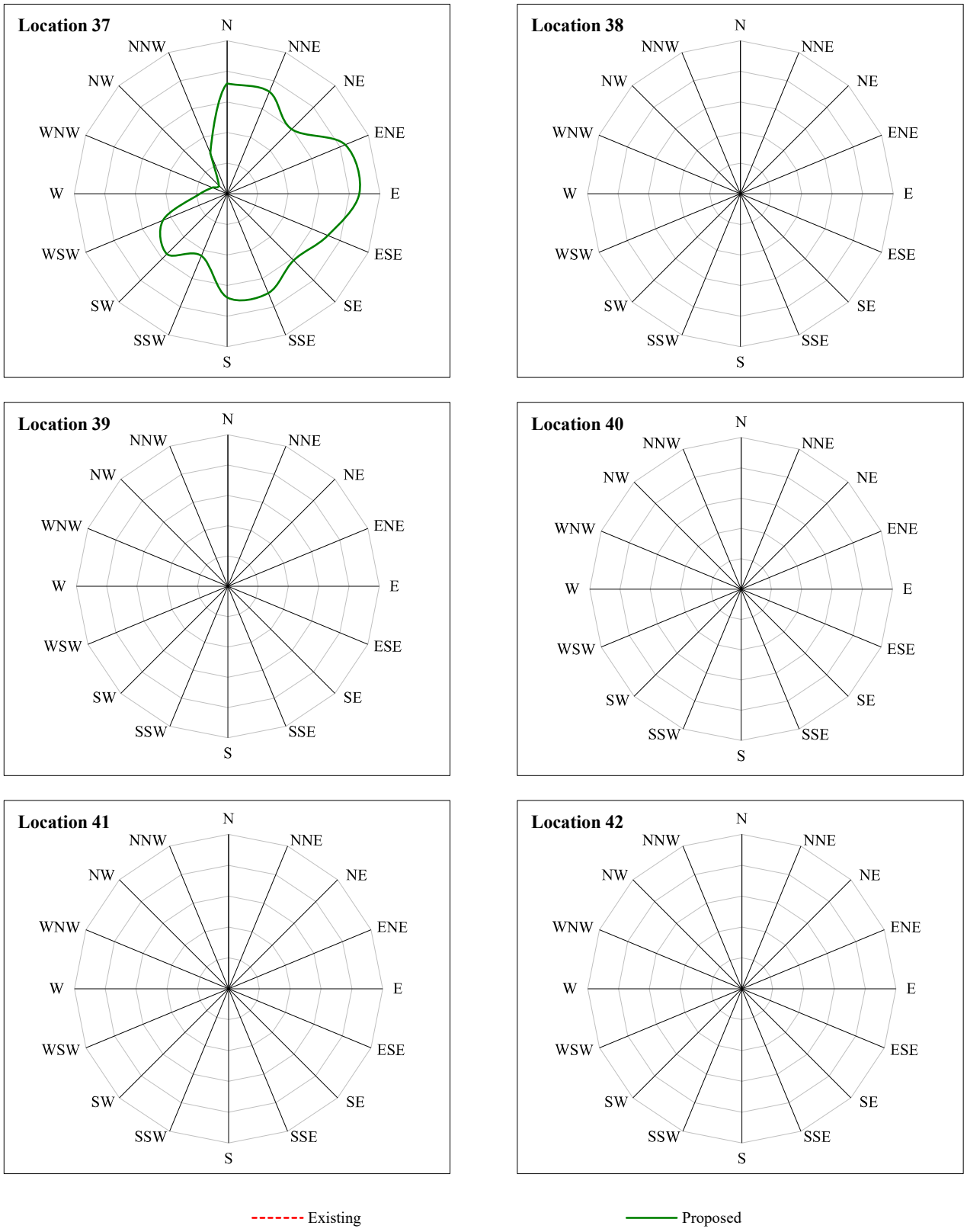


Figure B : Ground level wind velocity as a ratio of gradient wind velocity.



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