The Boundary Layer Wind Tunnel Laboratory

Pedestrian Level Wind Study

5438 Ferry Street,
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Niagara Falls, Ontario

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Submitted To:

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MAIN FINDINGS

This report describes the pedestrian-level wind study performed at the Boundary Layer Wind Tunnel Laboratory for the development at 5438 Ferry Street in Niagara Falls. The project site is located on the southwest corner of the intersection of Ferry St. and Fallsview Boulevard. A detailed discussion of the results is contained in Section 3.5. A description of the criteria used can be found in Section 3.4.

Tests were carried out for two configurations described as follows:

- Existing Site - the existing site presently consists of a bare surface parking lot with a single-storey restaurant building at the western edge. The site is surrounded by low-rise commercial / hotel buildings with open parking lots and sparsely spaced single-family homes.

- Proposed Site – the as-tested proposed site consists of a single tower development. The tower is 30 storeys, approximately 116m tall, and is residential occupancy. Since the time of testing the tower has undergone minor modifications. The tower height has increased by 3.6m and the balconies have been removed as can be seen in Figure 1.

Both configurations are described in more detail at the beginning of Section 3.5. An image of each tested configuration is shown in Figure 5. Figure 1a shows an isometric view of the tower as originally tested. Figure 1b likewise shows an isometric view of the tower's current design. While the surface details have changed, the overall massing of the tower is largely unchanged.

Figure 9 indicates the 55 locations at which wind speeds were measured.

The evaluation for safety is summarized schematically in Figure 10. Comfort results for each season are summarized schematically in Figures 11a and 11b for summer and winter seasons, respectively. These summarize the suitability of each measurement location with respect to pedestrian-level safety or comfort. The comfort and safety categories used correspond to those summarized in section 3.4.

Colour-coded diagrams further summarize the suitability of each measurement location with respect to pedestrian-level safety and pedestrian comfort for each tested configuration. Figures 12 and 13 present these for safety considerations for the existing and proposed configuration, respectively. For comfort considerations these are presented in Figures 14a and 14b for the summer and winter seasons for the existing configuration, respectively. Similarly, the seasonal comfort diagrams for the proposed configuration can be found in Figures 15a and 15b. The comfort and safety categories used in these figures correspond to those summarized in section 3.4.

The introduction of a high-rise building development in a relatively open environment will invariably create local wind speed-ups for some wind directions. With that expectation, the focus is to identify and develop strategies to make wind conditions suitable for the intended usage for negatively affected area. For example, entry areas should have a comfort category consistent with standing activities, while sidewalks should meet the condition of being comfortable for walking.

Existing Site

The immediate site surroundings are comprised of a commercial / suburban environment for the majority of wind directions, with open parkland intermixed. Directly to the north, east, and west of the development are 1-2 storey commercial buildings. Further to the west is a new development, the Stanley District Tower Condos, that consists of 8 and 30 storey towers. To the south is the 18 storey Doubletree Fallsview and beyond is the Hilton and Niagara Fallsview Casino. Beyond the immediate site, the region is largely characterized by typical suburban exposure for many directions. An aerial view of the existing site can be seen in Figure 2.

Given the mixture of open and suburban surroundings, it is not surprising that the measured wind speeds for the existing site are generally consistent with a typical suburban environment or marginally greater, while not quite achieving wind speeds expected in open environments.

For the existing configuration, all tested locations except Location 12 meet the recommended safety criterion. Location 12 is located on the west side of Fallsview Boulevard south of the proposed development and marginally exceeds the safety criteria. With respect to comfort, the results indicate that all tested locations are suitable for standing or sitting in the summer months except for Location 42 on Stanley Avenue which is suitable for walking. During the winter months most locations on Ferry Street are suitable for standing, numerous locations along Stanley Avenue and Fallsview Boulevard are also suitable for standing with others suitable for walking.

Influence of Proposed Development

The proposed development was tested without any landscaping. As a result, these results can be expected to provide somewhat conservative estimates of full-scale wind speeds, particularly in late spring through autumn months.

In general, the influence on wind speeds for measurement locations somewhat away from the proposed development is minimal for many wind directions, with the comfort categorizations at most of these offsite measurement locations remain largely unchanged from those of the existing condition. For prevailing southwesterly wind directions, the winds around the areas of the Buchanan Avenue - Forsythe Street intersection do increase. Nonetheless, the comfort classification remains at walking category in the winter season, and remain suited for the intended sidewalk usages of the respective areas.

With respect to pedestrian comfort, most locations along Stanley Avenue, Fallsview Boulevard, and Ferry Street are suitable for standing with others suitable for walking in the summer months. In winter most locations move into the walking category, while some locations remain suitable for standing. Closer to the proposed development there are observed areas of increased winds. At locations 3, 8, and 26 along Ferry Street, and Locations 16 and 17 along Fallsview Blvd. winds fall into the uncomfortable category during the winter months, and suitable for walking in the summer months. Consequently, these specific areas may be uncomfortable for typical leisurely or lingering activities at sidewalks.

Numerous other locations are classified as suitable for walking in the winter months. This reflects a variation from the existing configuration for which these locations were suitable for standing. Some of these areas remain suited for the intended usage year-round, with the summer months at such locations marginally better than winter conditions and generally suitable for standing.

With respect to pedestrian safety, ground level Location 16 (east side of Fallsview Blvd, across from site) and Location 26 (at northwest corner of Ferry Street and Buchanan Avenue) exceed the safety criteria. Location 12, located south of the site, also exceeds the safety criteria – this is unchanged from the Existing configuration.

Mitigation Strategies

Ground level Locations 3, 8, 16, 17 and 26 have been identified as having wind conditions that are expected to exceed desired comfort levels in winter and may be unsuited for their intended usage. These uncomfortable conditions generally occur for southwesterly to northwesterly wind directions. For these areas, planters with evergreen plantings or trees planted along Ferry Street and Fallsview Boulevard, immediately adjacent to the 5438 Ferry Street development will provide some improvement both locally and on adjacent properties. The influence of these features may be limited further abroad.

The effectiveness of any proposed mitigation should ultimately be explored through further wind tunnel studies.

1 THE WIND CLIMATE FOR NIAGARA FALLS, ONTARIO

1.1 General

The statistical wind climate model for Niagara Falls, Ontario consists of the probability distribution of wind speed and direction for extratropical winds developed from historical records at the Niagara Falls International Airport in Niagara Falls, New York. This airport is approximately 11 km from the site of the project. The statistical wind climate model will ultimately be combined with aerodynamic data measured in the wind tunnel for the prediction of wind loads and pedestrian level wind speeds. The methodology for its development is detailed in Reference 1.

1.2 Meteorological Data

The Integrated Surface Data records are maintained by the National Climatic Data Center (NCDC), and provides a climatological database of approximately 20,000 stations around the world (Reference 2). The ISD contains a number of meteorological variables typically recorded at intervals of 1 hour. An analysis of historical wind data from the Niagara Falls International Airport (ISD Station No. 725287) was carried out to develop a wind climate model for Niagara Falls, Ontario. The historical data consists of the time period 1973 – 2016.

For evaluating wind speeds, separate wind climates were used for the Comfort and Safety criteria. The development of the Safety climate utilized the complete set of historical wind data (i.e., 24 hours), while the development of the Comfort climate utilized a subset of historical wind data (i.e., between 06:00 and 23:00). The wind climate data are grouped on a four-season basis as follows:

- Summer: May through October
- Winter: November through April

The results of the two analyses yielded similar estimates of wind speed, which is not unexpected given that most wind events persist over a several hour period are therefore observed during daylight hours.

Based on the analysis of the hourly wind records, the predicted hourly mean wind speeds at 10m corrected for standard open exposure are 21.3 m/s and 23.8 m/s for return periods of 10 years and 50 years, respectively. This is referred to as the Parent Wind Climate and is plotted for various return periods in Figure 3a.

Based on the analysis of hourly wind records a probability distribution of wind speed and wind direction is developed for Safety and Comfort purposes. This model predicts annual hourly mean wind speeds at 10 m, corrected for standard open country exposure, of 13.6 m/s and 17.7 m/s for return periods of 1 month and 1 year, respectively. Wind speeds corresponding to each model are plotted in Figure 3a for various return periods.

1.3 Statistical Wind Climate Model

For the analysis of the wind tunnel data, the wind climate models are converted to a reference height of 500 m using a standard open country exposure profile. Each of the wind climate models described above are converted to a 500 m reference height; the corresponding wind speeds are shown in Figure 3b. The predicted 1 year return period hourly mean wind speeds at the 500 m reference height, used in the analysis and reporting of pedestrian-level wind speeds, are 24.9 m/s and 32.2 m/s for the comfort and safety climates respectively.

The directional characteristics of winds associated with various return periods are plotted in terms of Relative Importance (%) in Figures 4a and 4b for the Safety (Annual) and Comfort (Seasonal) climates, respectively. Each wind climate model indicates that westerly winds are the most important.

The design probability distribution of hourly mean wind speed at 500 m reference height and wind direction is shown in Appendix A.

2 THE MODELLING OF THE SITE AND THE WIND

2.1 Overall Approach

The basic tool used is the Laboratory's boundary layer wind tunnel. The tunnel is designed with a very long test section, which allows extended models of upwind terrain to be placed in front of the model of the building under test. The modelling is done in more detail close to the site. The wind flow then develops characteristics which are similar to the wind over the terrain approaching the actual site. This methodology has been highly developed (see References 2 and 3) and is detailed below.

2.2 Model Design

Close-up views of the tested 1:400 scale model are shown in Figure 5.

Aerodynamic model components:

The model of the 5438 Ferry Street development model built in detail from foam.

1. A detailed proximity model of the surrounding city built in block outline, including the local topography, from Styrofoam for a radius of approximately 500m.
2. Generic models of upstream terrain, modelled by setting appropriate heights of generic roughness blocks and by turbulence-generating spires to produce wind characteristics representative of those at the project site.

The building model and the proximity model are rotated to simulate different wind directions with the upstream terrain being changed as appropriate. Testing was carried out for 2 configurations of the surroundings, namely the existing and proposed:

- The existing configuration included bare surface parking lot with a single storey restaurant building at the western edge.
- the proposed configuration sees the demolition of the restaurant and includes the addition of the single 30 storey 120m tall residential tower.

Photographs of the configurations are shown in Figure 5. Two different terrain models were used, as shown in Figure 6. The azimuth ranges over which these were used are shown in Figure 7.

2.3 Characteristics of the Modelled Wind

Figure 8 presents vertical profiles of the mean speed and of the intensity of the longitudinal component of turbulence, measured just upstream of the centre of the turntable, for each upstream terrain exposure.

The model profiles are good representations of the expected variation of full-scale wind speed and turbulence over the building height. The reference wind speed measured in the wind tunnel has been scaled such that the expected full-scale wind speeds at roof height are achieved.

3 THE DETERMINATION OF PEDESTRIAN-LEVEL WIND SPEEDS

3.1 Overall Approach

Detailed measurements were made of pedestrian-level wind speeds at locations of interest around the project. Views of the model in the wind tunnel are shown in Figure 5 for each of the tested configurations. The wind-tunnel findings were then combined with the parent wind climate to provide statistical predictions of expected pedestrian-level wind speeds around the site.

Assessment for pedestrian safety is based on the gust wind speed predicted to occur 0.1% of time (approximately 9 hours in a year). Assessment for pedestrian comfort is based on the gust equivalent mean wind speed predicted to occur 80% of the time.

General descriptions of the testing and analysis procedure are given in Reference 1.

3.2 Model Instrumentation

Figure 9 indicates the 55 locations at which wind speeds were measured.

Locations were placed systematically along the sidewalk areas around the proposed development and on existing neighbouring pedestrian traffic routes.

Measurements were made using omni-directional pressure sensors which measure both mean and fluctuating components of the wind speed parallel to the ground at a height of about 1.5 to 2m in full scale.

3.3 Aerodynamic Data

Measurements were taken at 10° intervals for the full range of azimuths. Measured coefficients of mean and gust wind speeds at all measuring locations are presented in Appendix B, and presented as a ratio of the mean wind speed at reference (500m) height. The gust equivalent mean (GEM) wind speed is defined as the maximum of the mean wind speed or the gust wind speed divided by 1.85.

The polar plots in Appendix B show the gust equivalent mean wind speed at each of the sensors, expressed as a ratio of the mean wind speed at reference height. The angular coordinate gives the direction of the approach wind, relative to true North. These are presented for the Existing and Proposed Configurations.

The radial magnitudes and the shapes of the polar plots in Appendix B provide valuable indications of the relative magnitudes of wind speeds at different locations and their sensitivity to the direction of the approach wind.

These plots can be useful to identify important wind directions that can influence conditions at a particular location. In turn, this information can be used to inform and develop mitigation strategies.

3.4 Statistical Prediction of Pedestrian-Level Winds

The directional characteristics of the extratropical wind climate are shown in Figure 4.

The predicted wind speeds are obtained by combining the statistical wind climate model of wind speed and direction with the aerodynamic data measured in the wind tunnel. Two types of prediction are provided:

1. Wind speeds exceeded 20% of the time on a seasonal basis.
2. Wind speeds exceeded during 0.1% of the time on an annual basis.

These predictions are compared against the following specified criteria to evaluate pedestrian comfort and safety:

CRITERIA	DESCRIPTION	GEM WIND SPEED EXCEEDED 20% OF THE TIME
Comfort level 4	**Sitting**	**≤ 10 km/h**
Comfort level 3	**Standing**	**≤ 15 km/h**
Comfort level 2	**Walking**	**≤ 20 km/h**
Comfort level 1	**Uncomfortable**	**> 20 km/h**

CRITERIA	DESCRIPTION	GUST WIND SPEED EXCEEDED 0.1% OF THE TIME
Safety level	**Exceeded**	**> 90 km/h**

The comfort categories are described as follows:

- **Comfort Level 4 - Sitting:** Calm or light breezes desired at outdoor restaurants and seating areas where one can read a paper without having it blown away
- **Comfort Level 3 - Standing:** Gentle breezes suitable for main building entrances and bus stops
- **Comfort Level 2 - Walking:** Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering
- **Comfort Level 1 - Uncomfortable:** Strong winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended

The safety category is described as follows:

- **Areas which exceed the Safety Level**: Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required.

These criteria are consistent with Terms of References used for the Niagara Region [Ref. 7]

3.5 Tests Results and Discussion

The tested configurations are as follows:

1. Existing Site - the existing site presently consists of a bare surface parking lot with a single-storey restaurant building at the western edge.

2. Proposed Site – the proposed site consists of a single tower development. The tower is 30 storeys, approximately 116m tall, and is residential occupancy. Since the time of testing the tower has undergone minor modifications. The tower height has increased by 3.6m and the balconies have been removed

Landscaping was not included for these tested configurations. Results can therefore be expected to reflect a somewhat conservative representation of expected wind conditions and aid in understanding flow patterns around the development.

Figure 10 compares the predicted wind speeds at the various locations for these configurations along with the criteria for pedestrian safety. Similar plots of predicted wind speeds compared to the criteria for pedestrian comfort can be found in Figures 11a and 11b for summer and winter seasons, respectively.

Colour-coded diagrams are also used to summarize the suitability of each measurement location with respect to pedestrian-level safety and pedestrian comfort for each of the tested configurations. Figures 12 and 13 present these for safety considerations for the Existing and Proposed configurations, respectively. For comfort considerations these are presented in Figures 14 and 15 for

the Existing and Proposed configurations, respectively, with results provided separately for each season.

Results are discussed below for each of the tested configurations.

3.5.1 Existing Site Configuration

Results for the existing configuration reflect current expected wind conditions at the existing 5438 Ferry Street site. This configuration is referred to as the 'Existing Site'.

With respect to pedestrian safety:

1. All tested locations except Location 12 meet the recommended safety criterion. Location 12 is located on the west side of Fallsview Boulevard south of the proposed development site and marginally exceeds the criteria for pedestrian safety.

With respect to pedestrian comfort:

1. All tested locations are generally suited for standing or sitting activities in the summer months except Location 42 on Stanley Avenue which is suitable for walking.
2. Most tested locations along Ferry Street remain suitable for standing activities in the winter months. Numerous locations along Stanley Avenue and Fallsview Boulevard are also suitable for standing with others suitable for walking during the winter months.

As expected, and given the sites combination of suburban surroundings with some nearby open areas, the measured wind speeds for the existing site are generally consistent with or marginally greater than a typical suburban environment, while typically less windy than a typical open country exposure.

3.5.2 Proposed Development Configuration

Tests of the proposed development were carried out with the existing restaurant building replaced by the proposed tower and associated podium structure; all other details of the surroundings are consistent with the existing configuration.

With respect to pedestrian safety:

1. Location 12, located on the west side of Fallsview Boulevard south of the proposed development, exceeds the safety criterion – this is unchanged from the Existing conditions.
2. Ground-level Location 16 (east side of Fallsview Blvd, across from site) and Location 26 (at northwest corner of Ferry Street and Buchanan Avenue) both exceed the safety criteria. These are on sidewalk areas and may be difficult to control through localized on-site mitigation.
3. All other test locations meet the criteria for safety.

With respect to pedestrian comfort:

1. In summertime, the comfort categorization at most measurement locations remains unchanged from the existing condition. Nearby summertime exceptions to this are Locations 3, 8, 9, 16, and 17. With the presence of the proposed tower, these locations are rated suitable for walking, remaining within the categorization for sidewalk usage.
2. In the wintertime, numerous locations see their comfort classification increase to walking; this remains suitable for the intended sidewalk usage of most locations. Nonetheless, the are exceptions as noted below.
3. Locations 3, 8, 16, 17, and 26 are uncomfortable in the winter months. Some mitigation around the ground level areas would be beneficial to improve the comfort category to walking at ground level locations. Where practical, controlling access during wind events is also an effective strategy.

4. In general, the influence on wind speeds for measurement locations somewhat away from the proposed development is minimal for many wind directions, with the comfort categorizations at most of these offsite measurement locations remain largely unchanged from those of the existing condition. For prevailing southwesterly wind directions (and with proposed development upstream), the winds around the areas of the Buchanan Avenue - Forsythe Street intersection do increase. Nonetheless, the comfort classification remains at walking category in the winter season, and remain suited for the intended sidewalk usages of the respective areas.
5. Main entries at Location 4 and 7 are expected to be suited for standing or better year-round, consistent with usage requirements.
6. Remaining areas either see minimal change or an improvement in comfort class.
7. With respect to all other tested locations, these are expected to be suitable for the intended usage.

3.6 Seasonal Differences

The amount and type of activity for a given location can vary by season. For example, a terrace or outdoor amenity area may have limited or restricted usage during the winter season. Thus, in some cases it is valuable to look at the wind speeds and the corresponding classification of pedestrian comfort on a more detailed season-by-season basis.

In general, compared to annual wind speeds, wind speeds during the winter months are about 7% higher, in the summer they are about 12% lower.

3.7 Summary Remarks

The inclusion of the proposed development causes localized increases to wind speeds, especially at adjacent and nearby sidewalk areas. Areas further from the site are less affected by the development in terms of usage. The local speedups are observed to be largely influenced by the frequent southwesterly winds.

With the expectation of increased local winds, the focus should not be to return wind conditions to an ‘as-it-was’ state, but rather identify and develop strategies to make wind conditions suitable for the intended usage. For example, entry areas should have a comfort category consistent with standing activities or better, while sidewalks should meet the condition of being comfortable for walking.

The comfort in the affected areas along Ferry Street and Fallsview Boulevard, in the vicinity of Locations 3, 8, 16, 17, and 26, can be improved with the installation of street line trees in conjunction with planters with tall evergreen shrubbery. The effectiveness of these strategies would need to be assessed with further wind tunnel testing for future submissions.

Examples of effective pedestrian level wind mitigation options can be seen in Figure 16.

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FIGURES

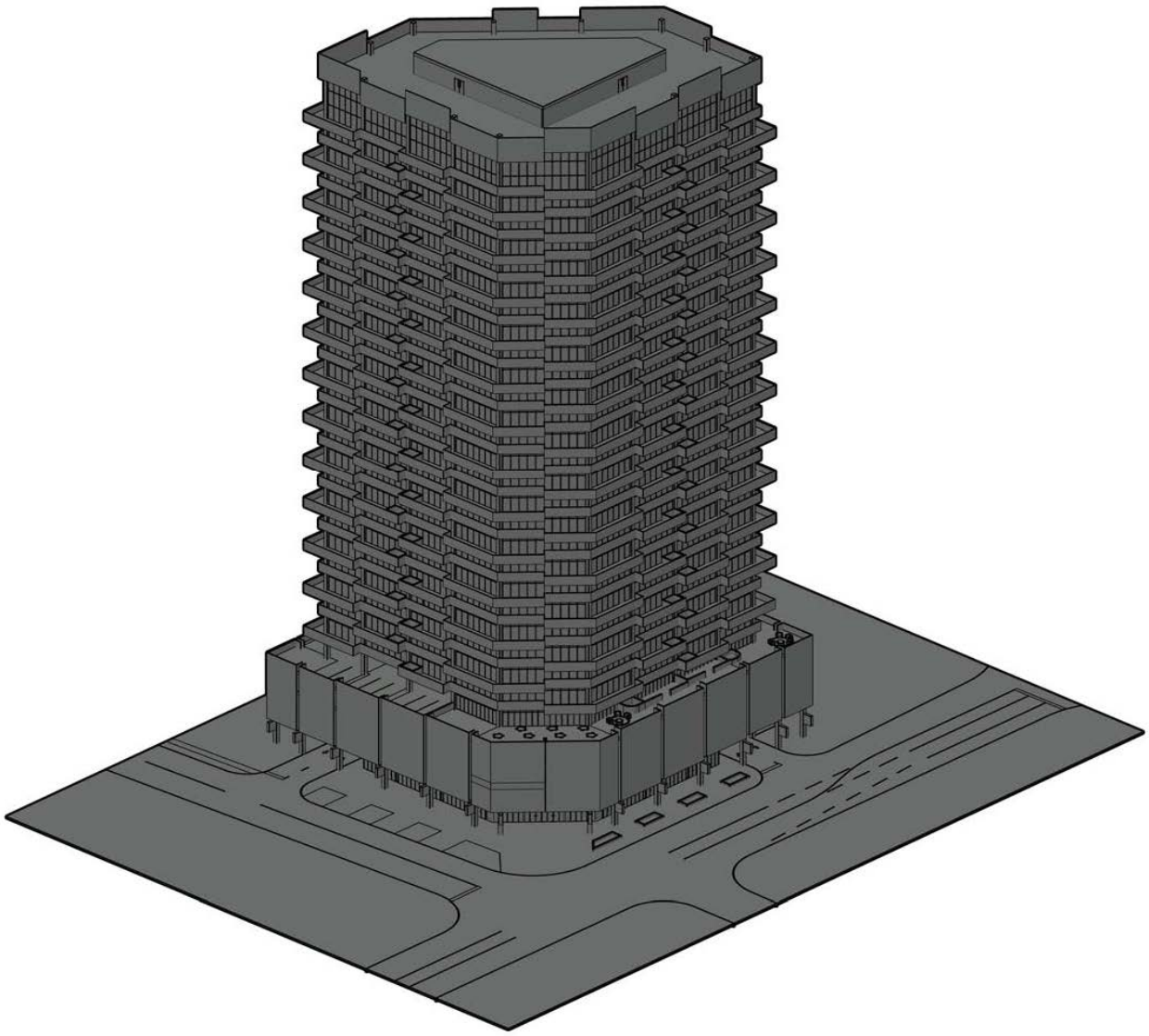


FIGURE 1a PERSPECTIVE VIEW OF THE AS-TESTED DEVELOPMENT

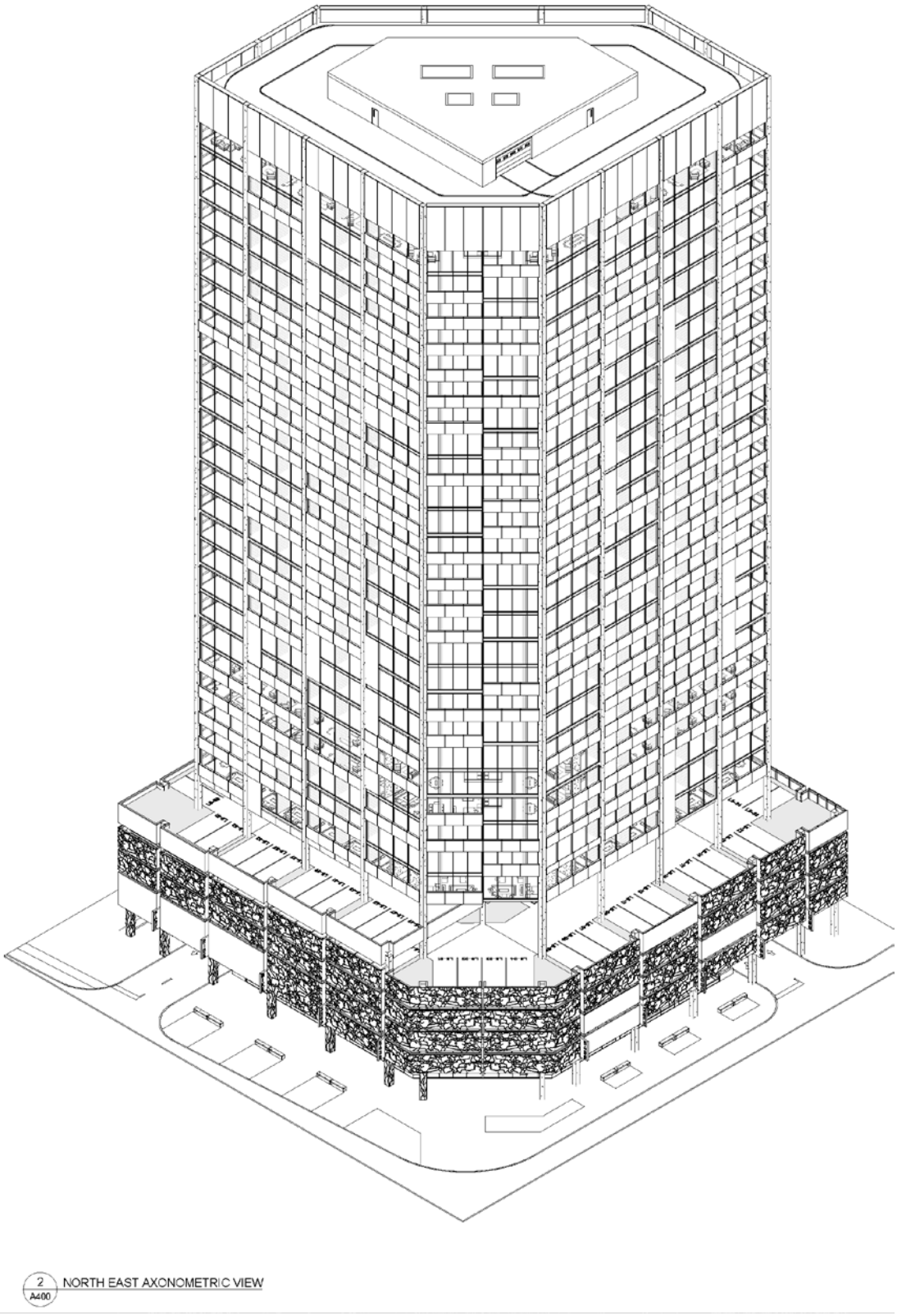


FIGURE 1b PERSPECTIVE VIEW OF THE DEVELOPMENT – CURRENT DESIGN

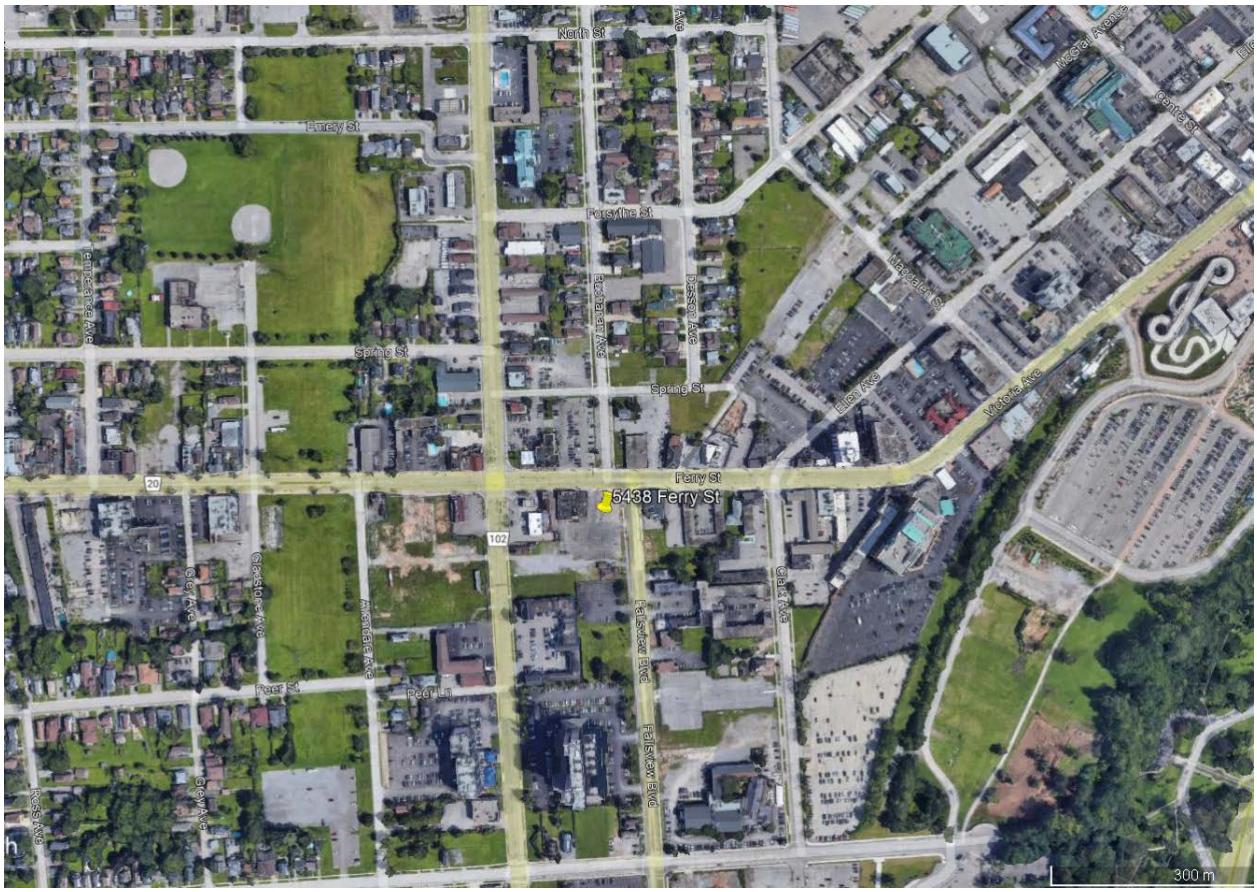


FIGURE 2 AERIAL VIEW OF EXISTING SITE LOCATION

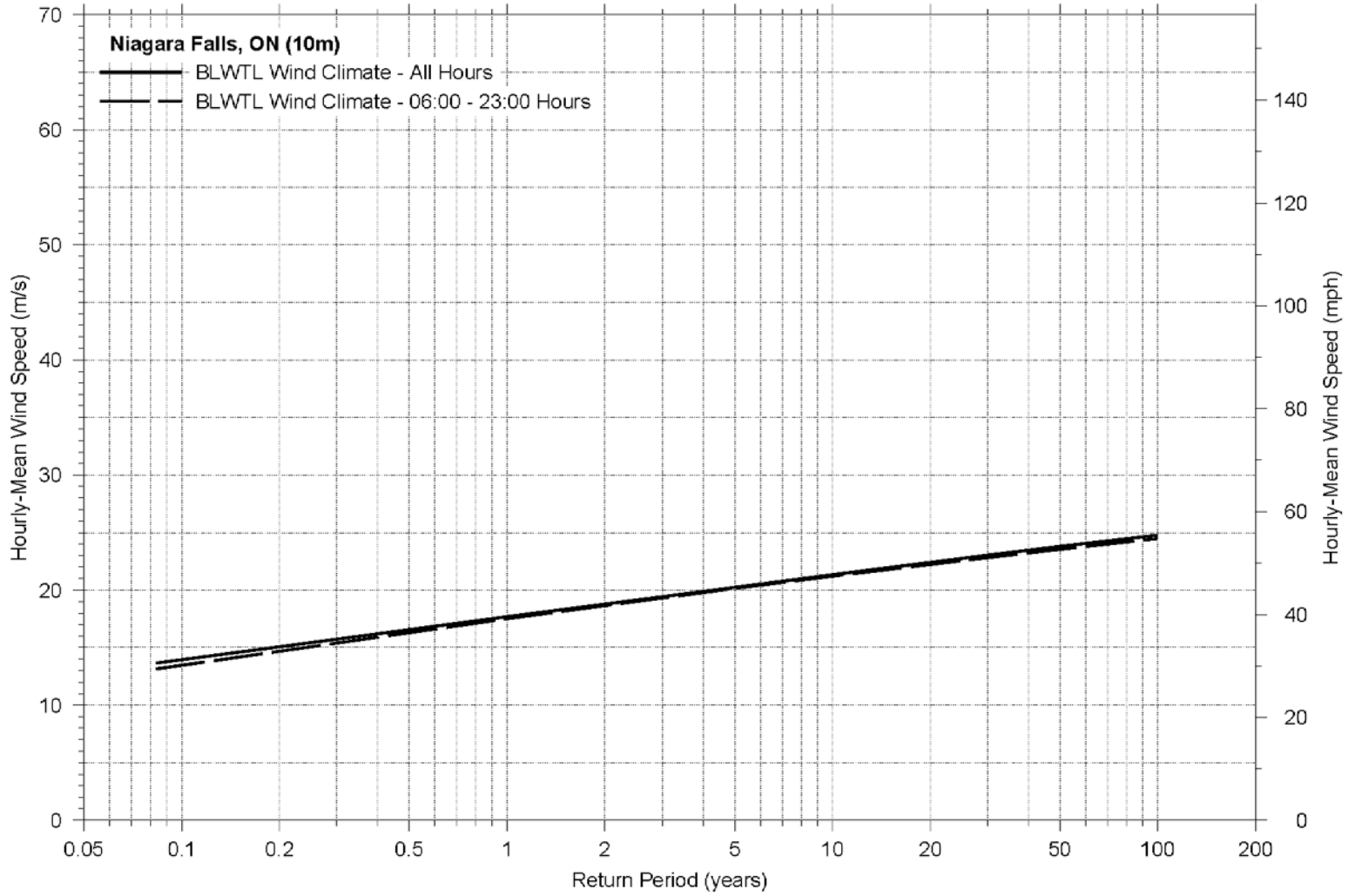


FIGURE 3a PREDICTED ANNUAL EXTREME REFERENCE WIND SPEEDS AT 10 m HEIGHT FOR VARIOUS RETURN PERIODS

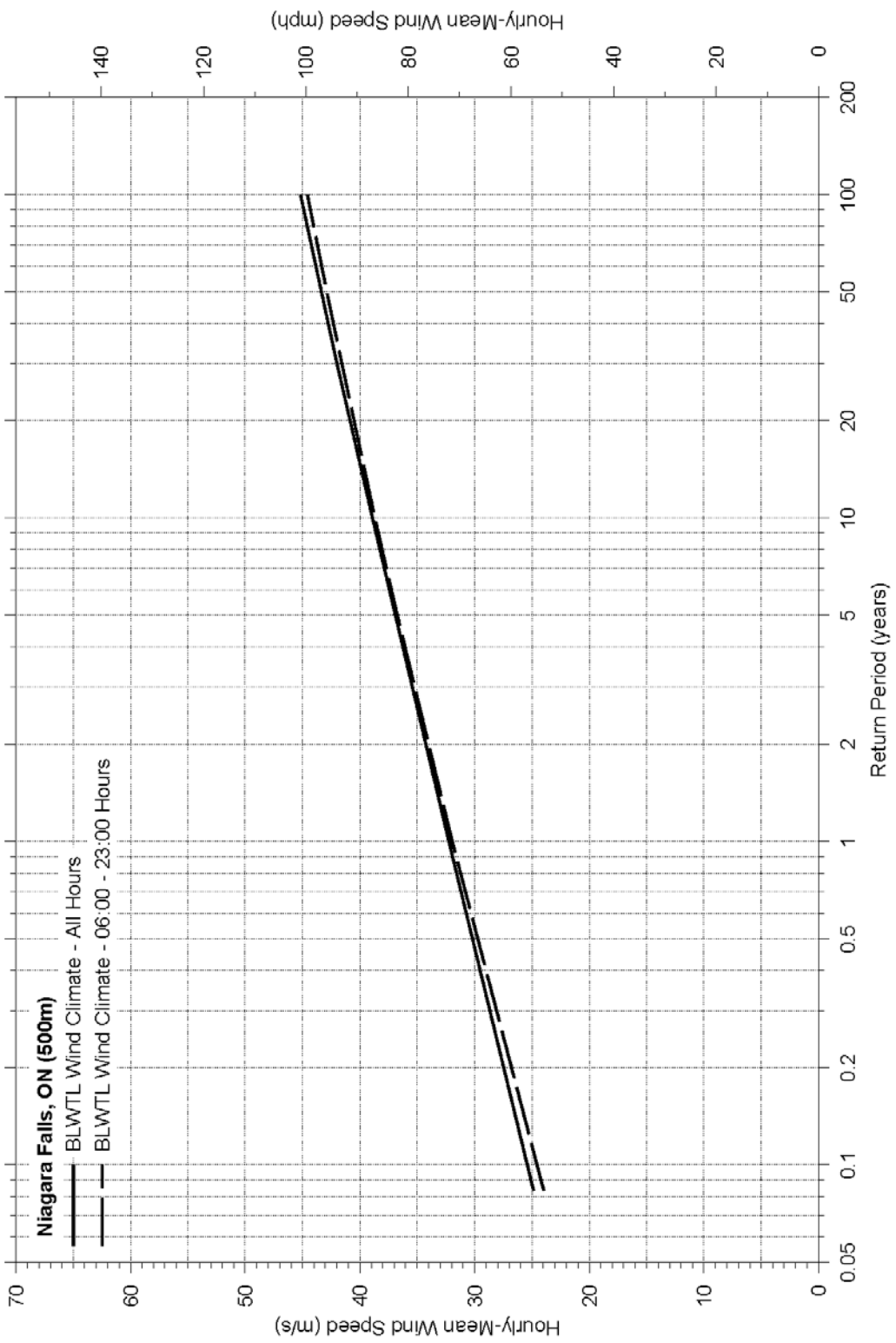


FIGURE 3b PREDICTED ANNUAL EXTREME REFERENCE WIND SPEEDS AT 500m HEIGHT FOR VARIOUS RETURN PERIODS

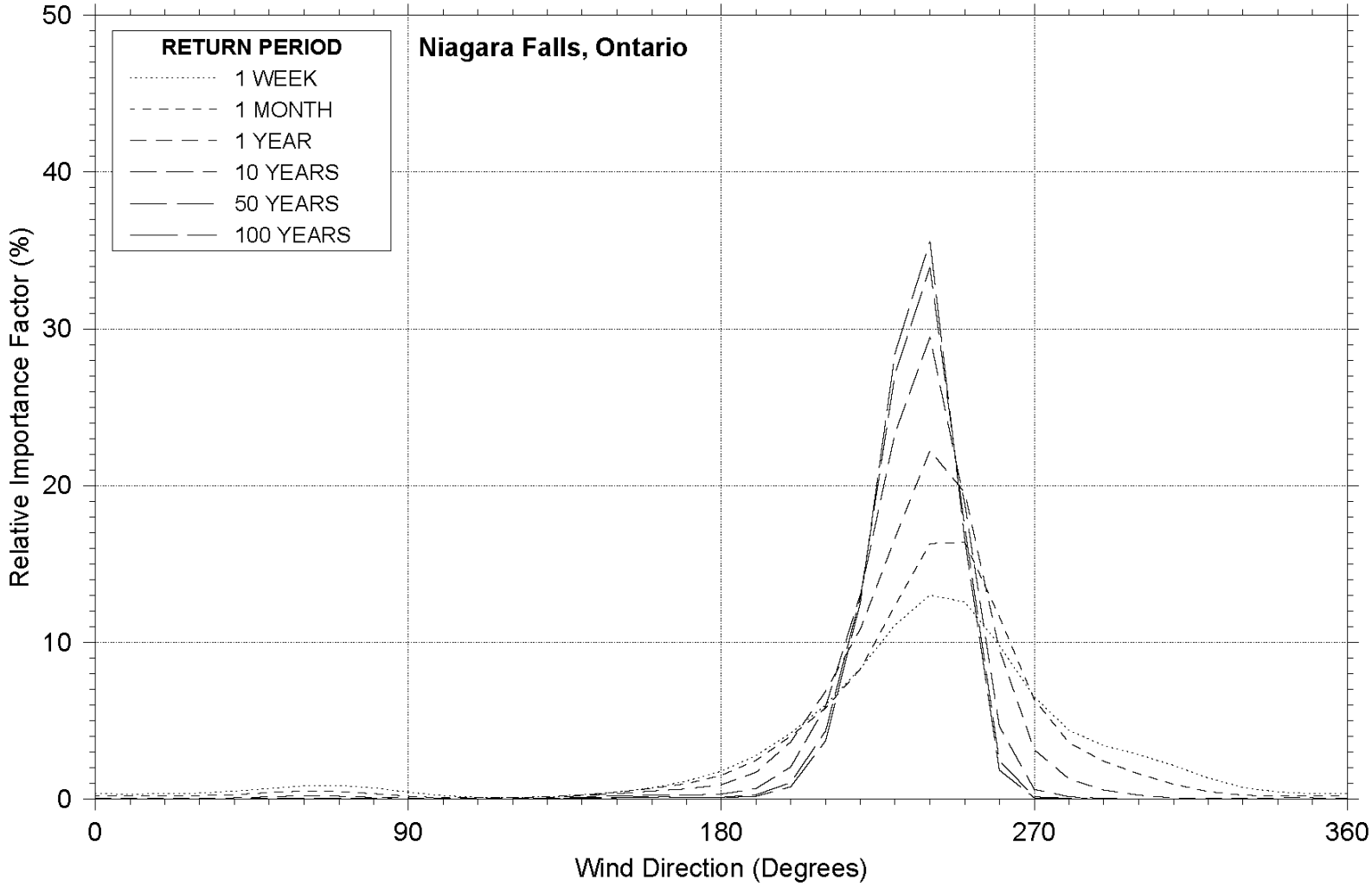
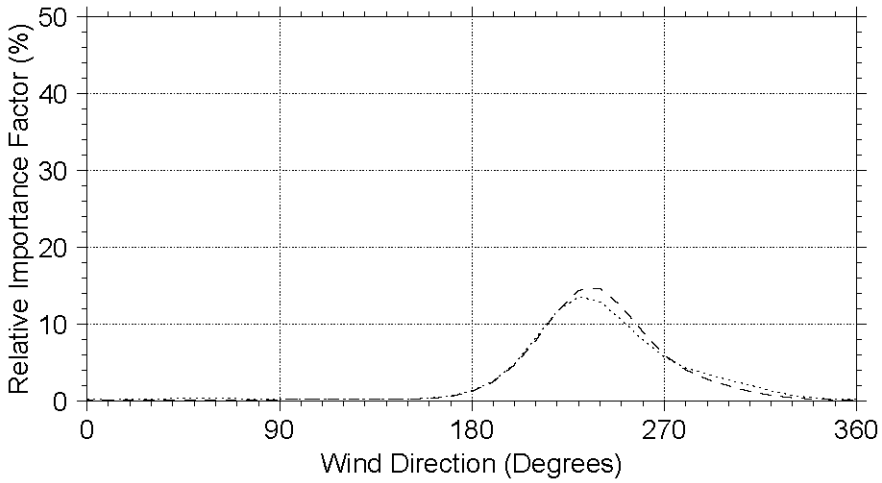
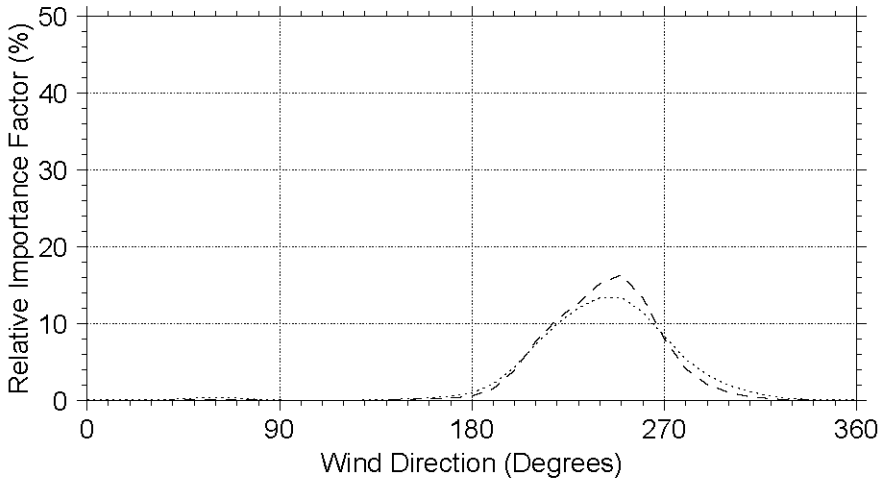


FIGURE 4a RELATIVE IMPORTANCE OF AZIMUTHAL SECTOR TO THE PROBABILITY OF EXCEEDING VARIOUS RETURN-PERIOD WIND SPEEDS



SUMMER



WINTER

FIGURE 4b RELATIVE IMPORTANCE OF AZIMUTHAL SECTOR TO THE PROBABILITY OF EXCEEDING VARIOUS RETURN-PERIOD WIND SPEEDS (SEASONAL)

EXISTING CONFIGURATION

PROPOSED CONFIGURATION

FIGURE 5a CLOSE UP VIEWS OF THE PEDESTRIAN LEVEL WIND SPEED MODELS AND CONFIGURATIONS TESTED

PROPOSED CONFIGURATION CONT'D

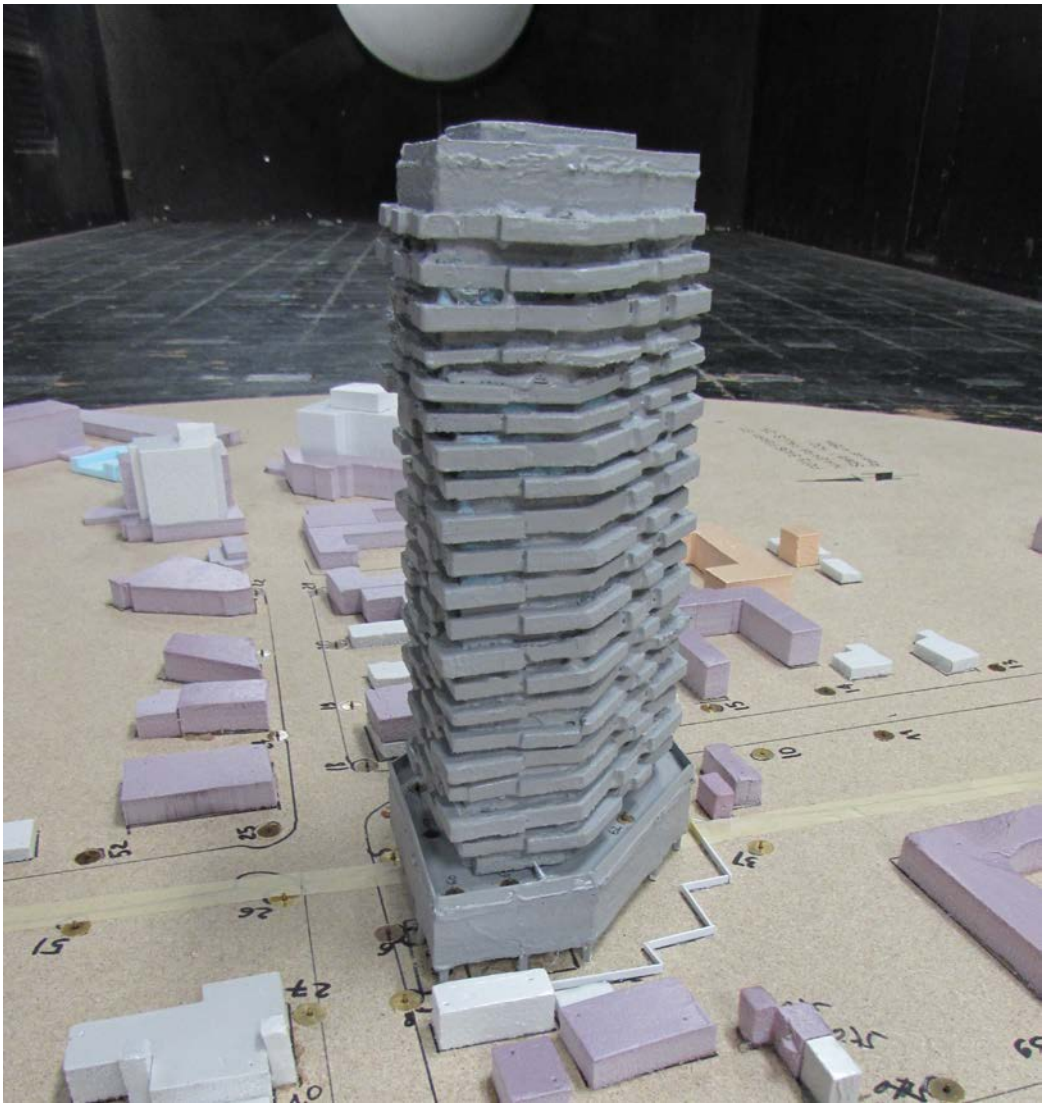


FIGURE 5b CLOSE UP VIEWS OF THE PEDESTRIAN LEVEL WIND SPEED MODELS AND CONFIGURATIONS TESTED

EXPOSURE 1 - EXISTING

EXPOSURE 2 - PROPOSED

FIGURE 6 PHOTOGRAPHS OF THE MODEL IN THE WIND TUNNEL SHOWING THE UPSTREAM TERRAIN MODELS (EXPOSURES) USED

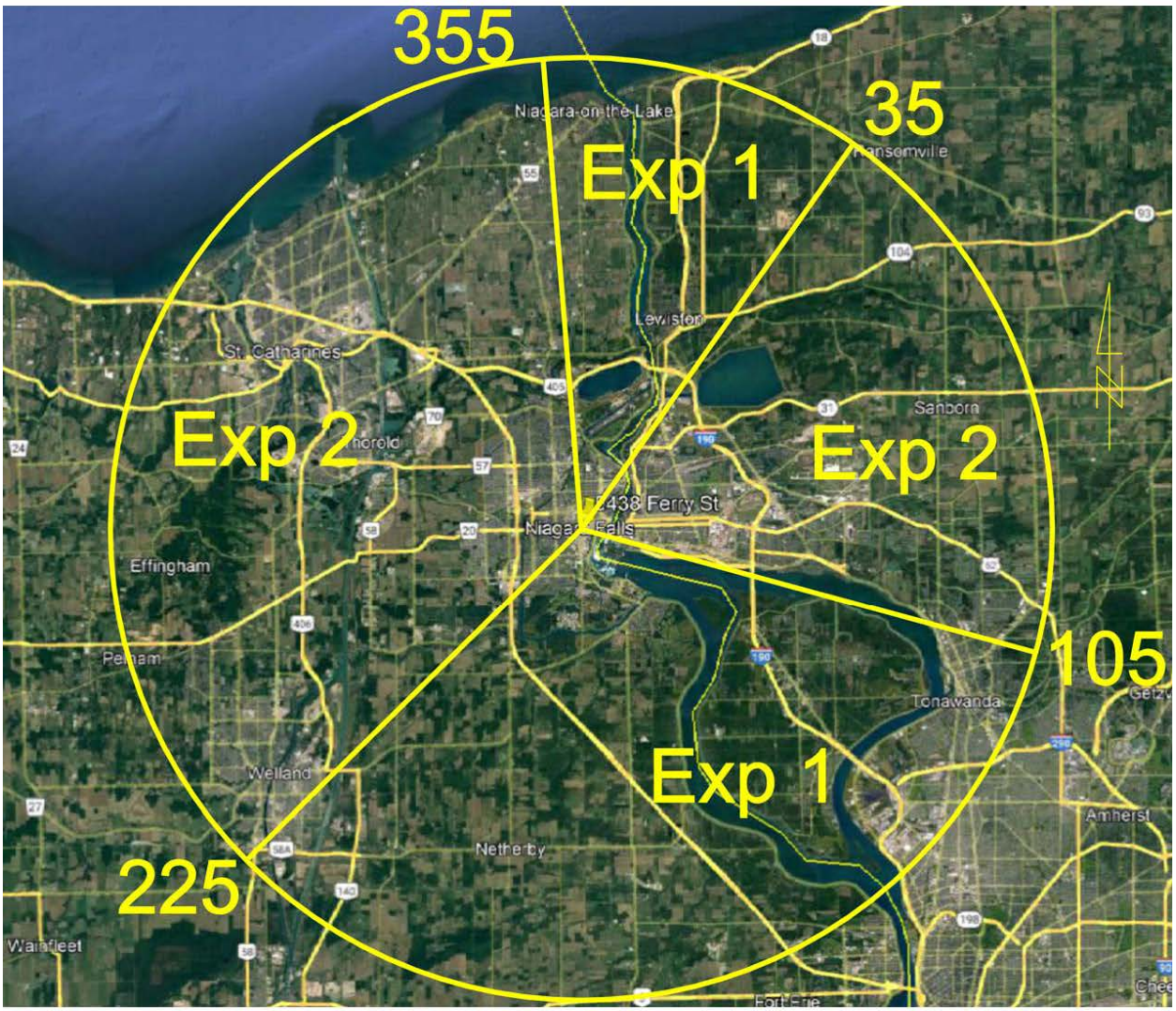


FIGURE 7 AZIMUTH RANGES OVER WHICH THE UPSTREAM TERRAIN MODELS WERE USED

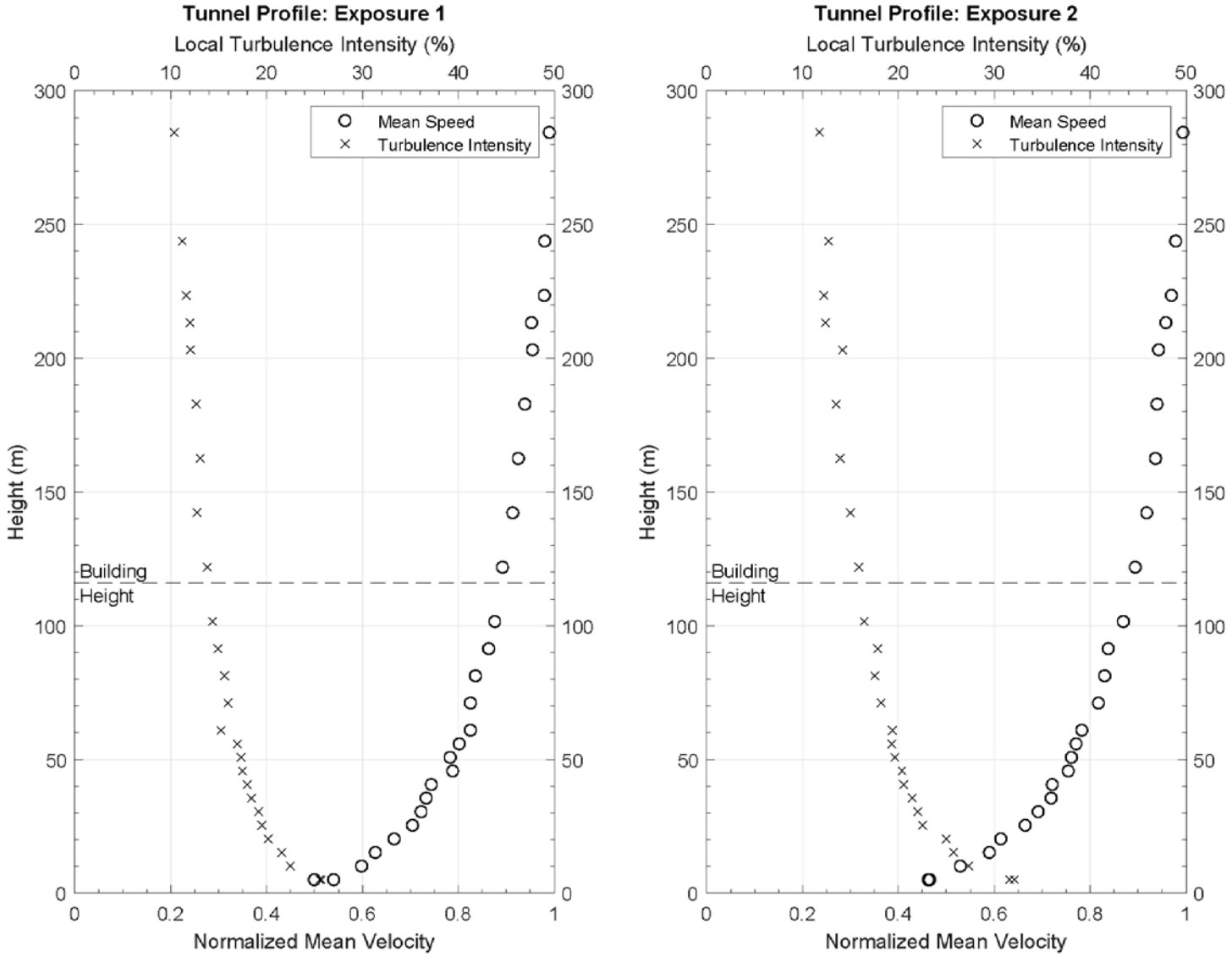


FIGURE 8 VERTICAL PROFILES OF MEAN WIND SPEED AND LONGITUDINAL TURBULENCE INTENSITY MEASURED JUST UPSTREAM OF THE PROXIMITY MODEL.

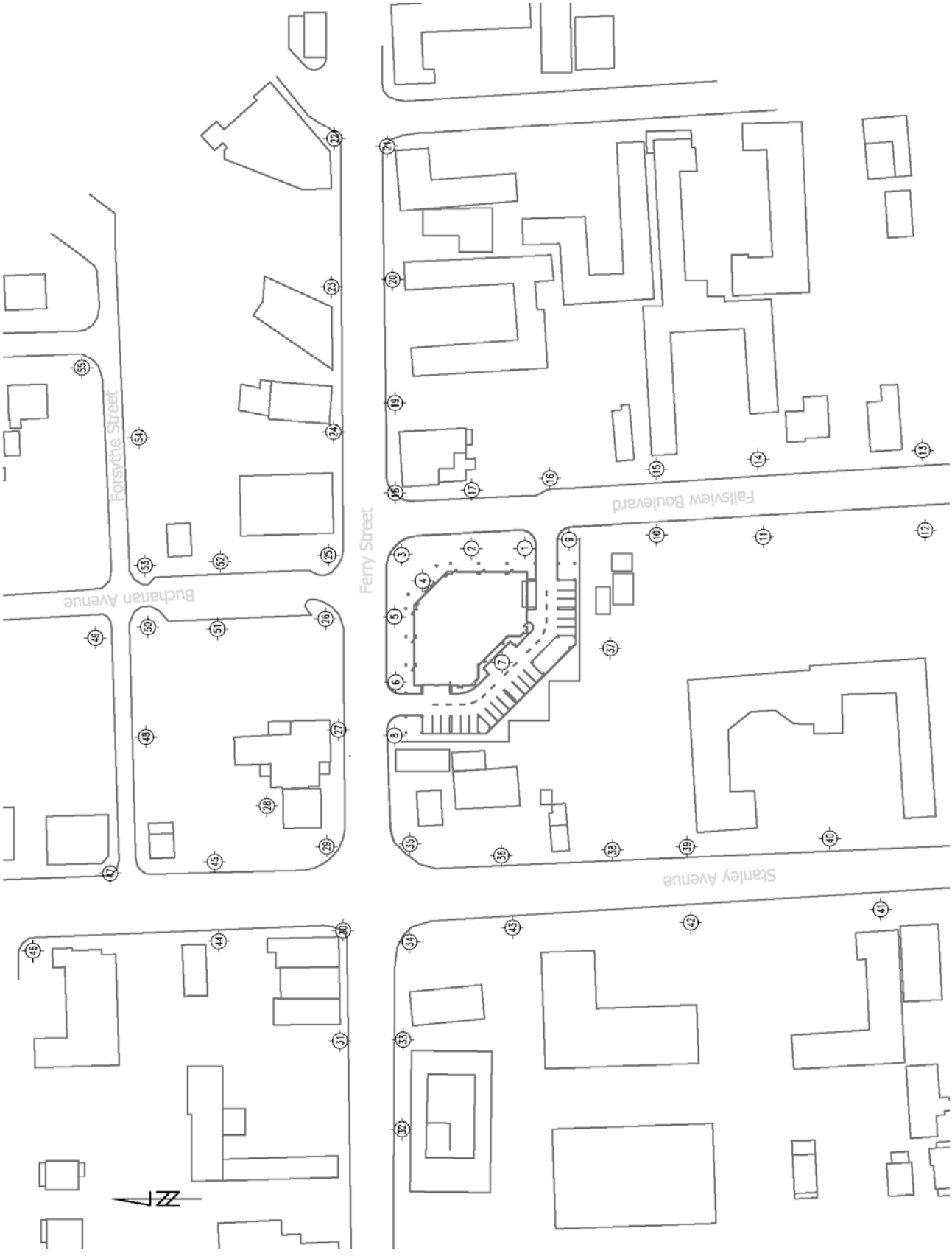


FIGURE 9 MEASUREMENT LOCATIONS FOR PEDESTRIAN-LEVEL WIND SPEEDS

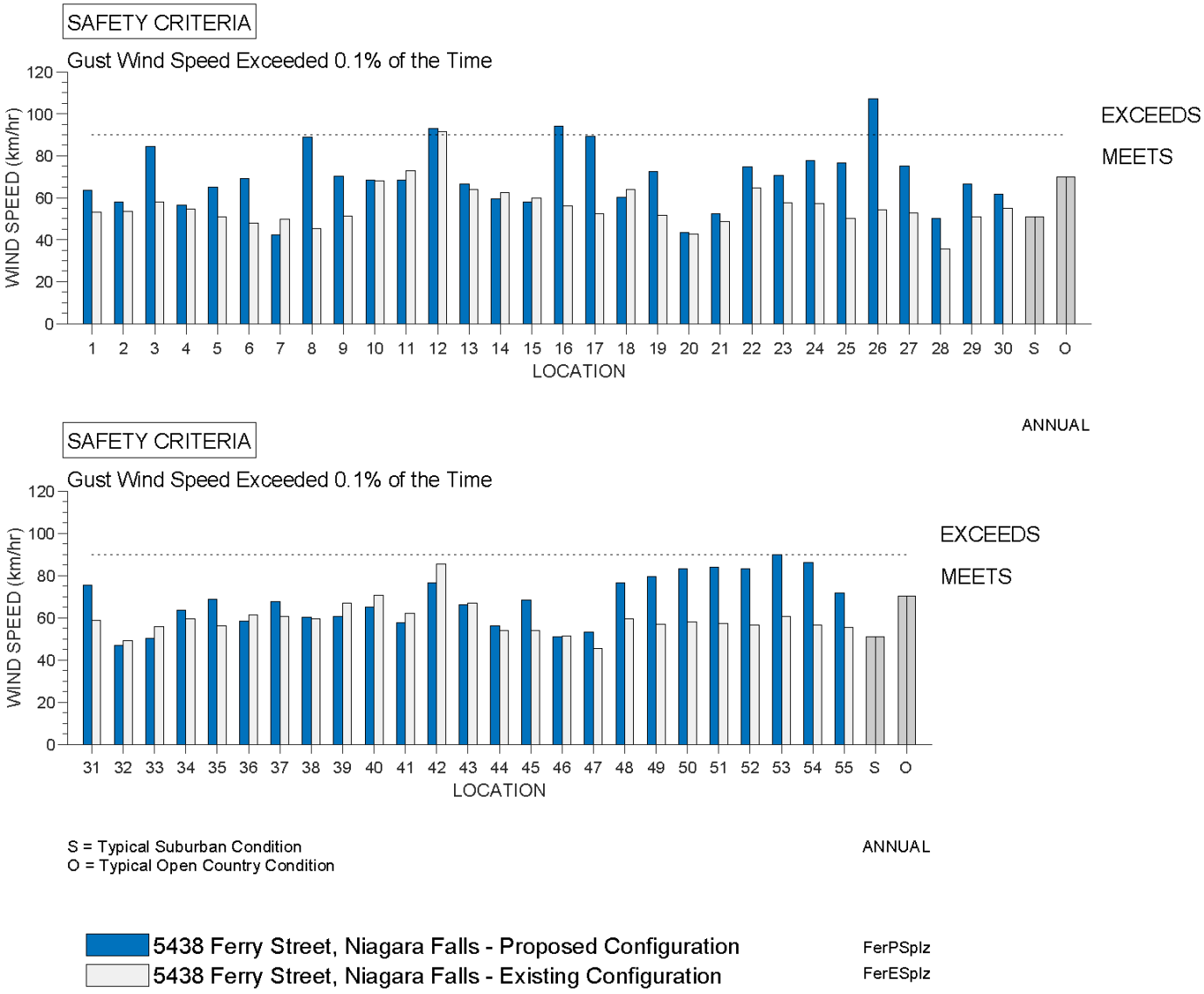


FIGURE 10 PREDICTED WIND SPEEDS COMPARED WITH CRITERIA FOR PEDESTRIAN SAFETY

FIGURE 11a PREDICTED WIND SPEEDS COMPARED WITH CRITERIA FOR PEDESTRIAN COMFORT – SUMMER

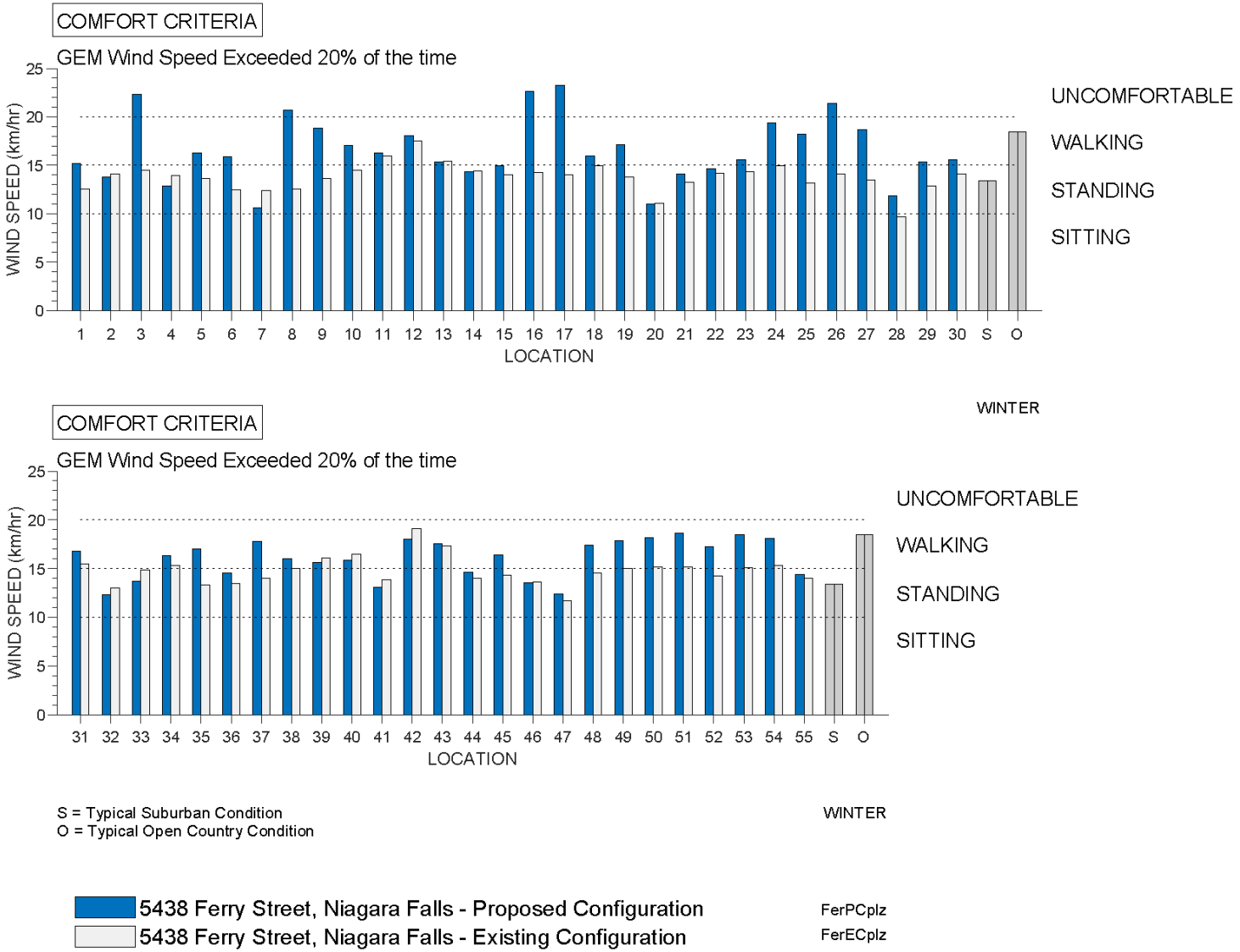


FIGURE 11b PREDICTED WIND SPEEDS COMPARED WITH CRITERIA FOR PEDESTRIAN COMFORT – WINTER

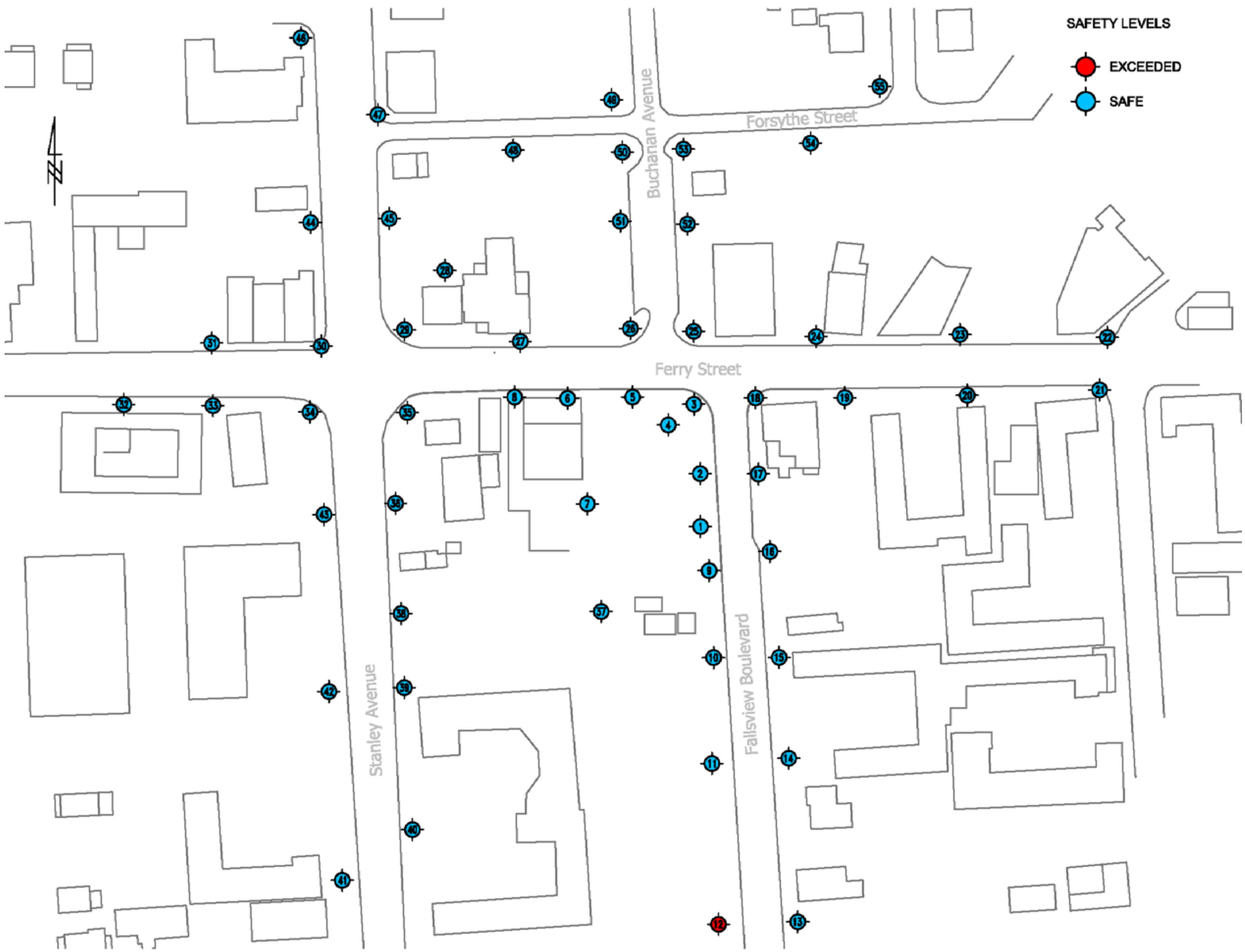


FIGURE 12 **SUMMARY OF PREDICTED <u>SAFETY</u> LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – EXISTING DEVELOPMENT**

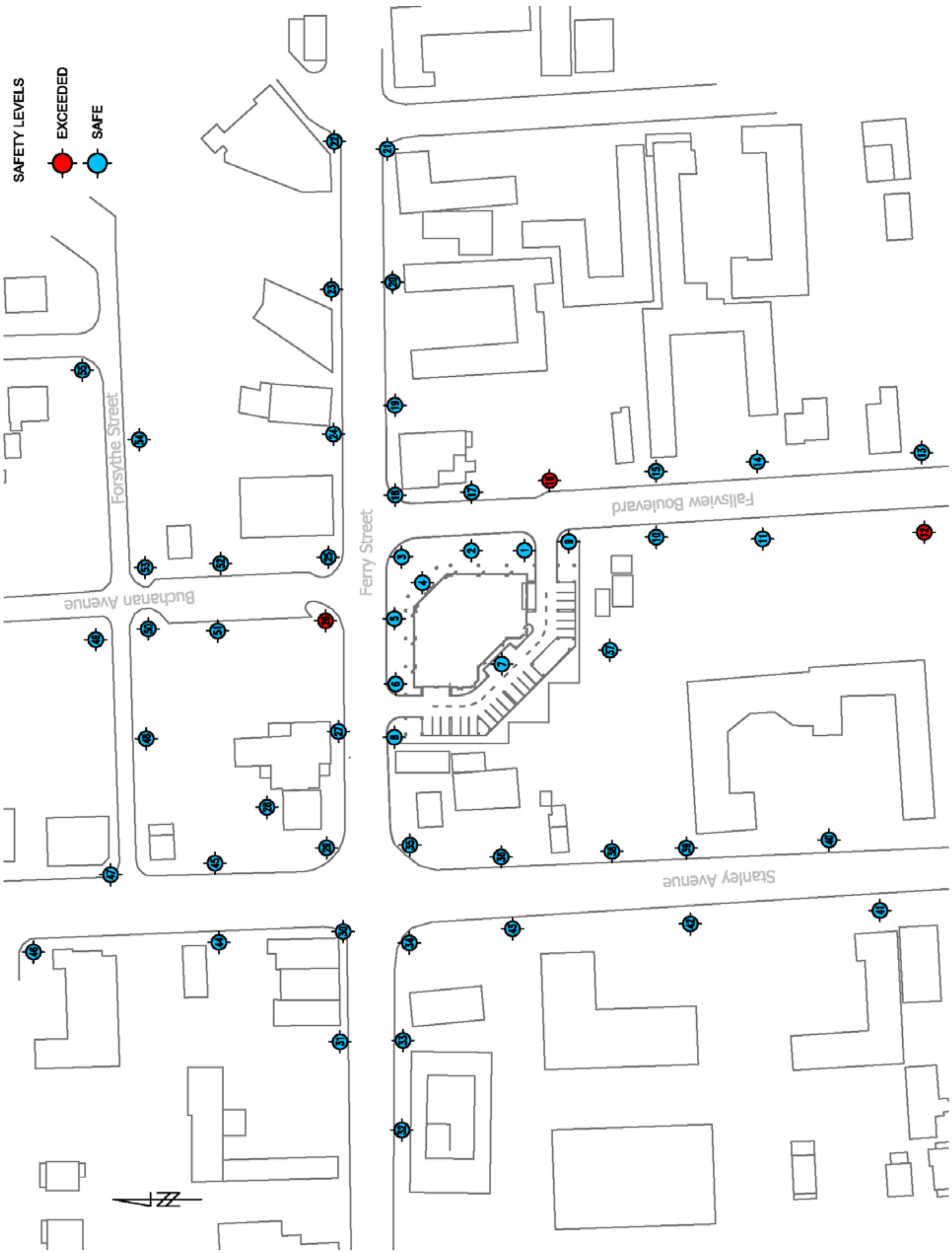


FIGURE 13 SUMMARY OF PREDICTED SAFETY LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT

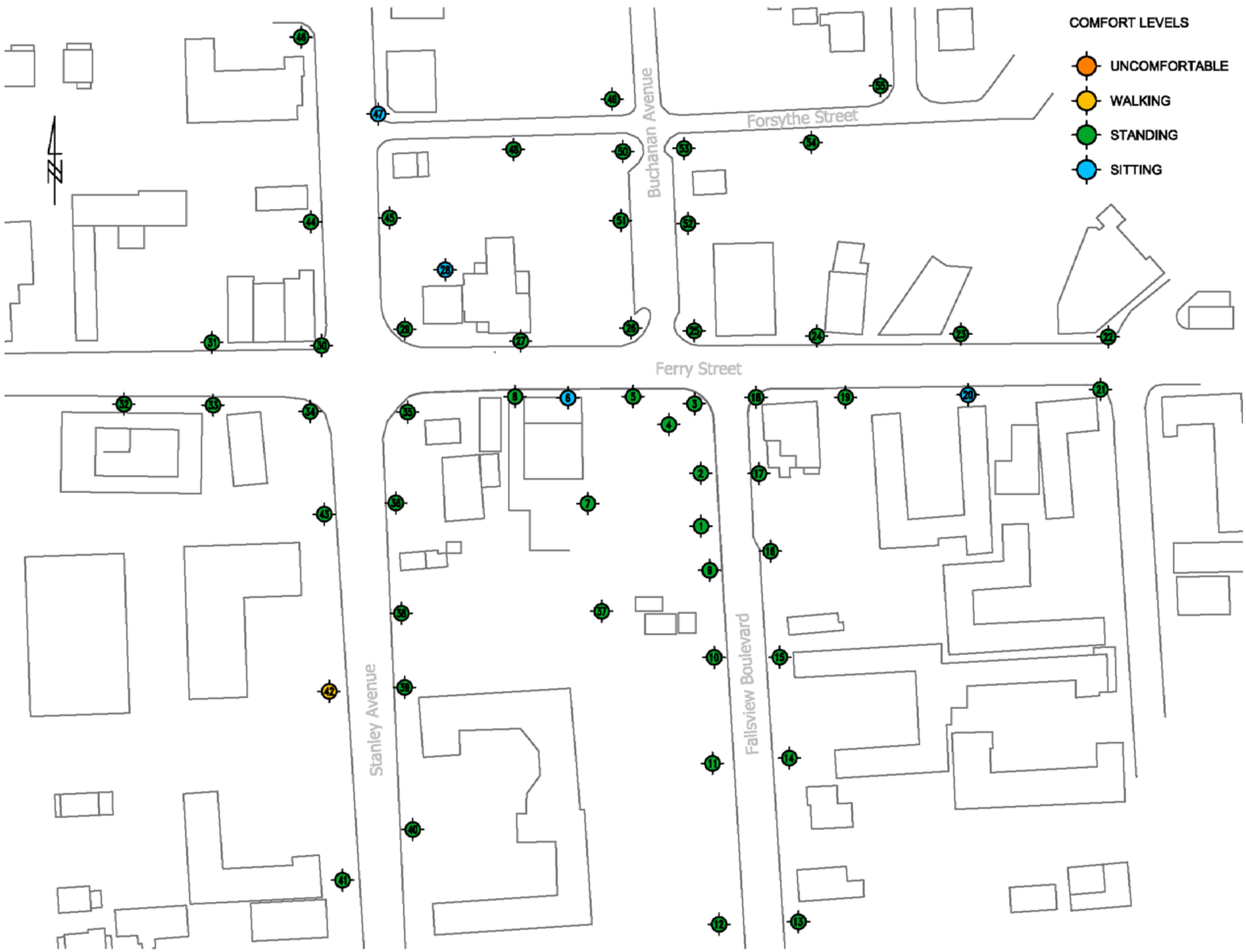


FIGURE 14a SUMMARY OF PREDICTED COMFORT LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – EXISTING SITE - SUMMER

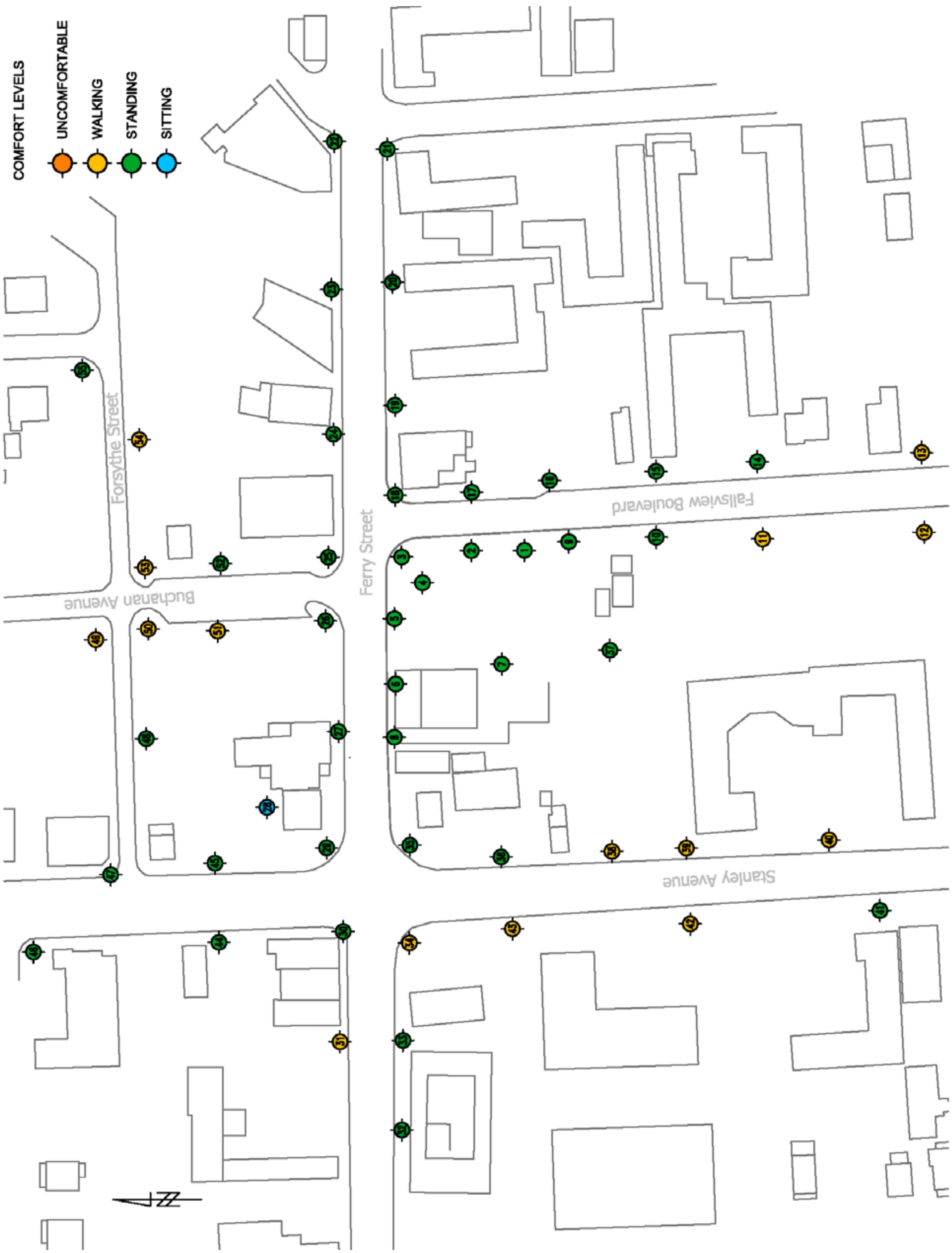


FIGURE 14b SUMMARY OF PREDICTED COMFORT LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – EXISTING SITE - WINTER

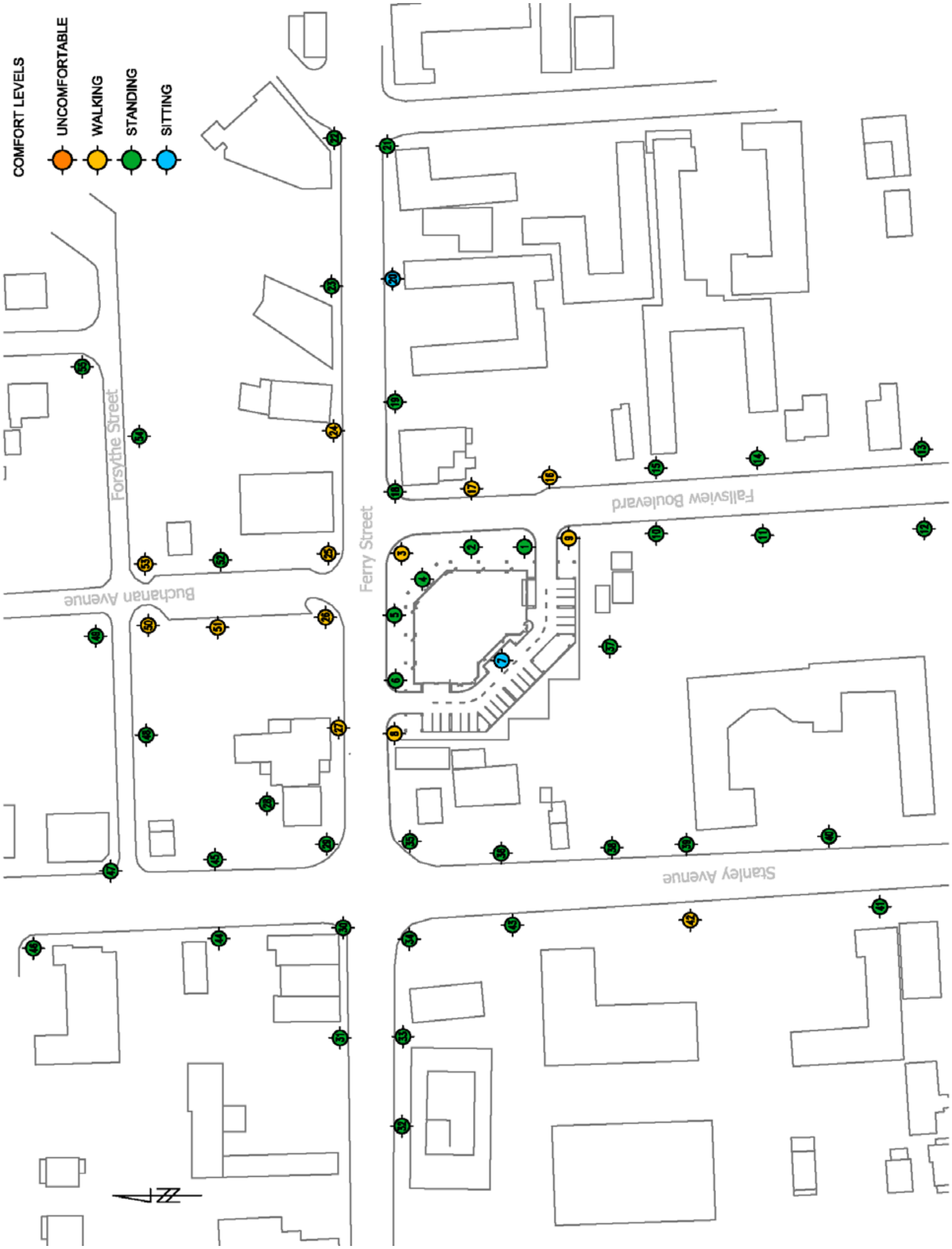


FIGURE 15a SUMMARY OF PREDICTED COMFORT LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT– SUMMER

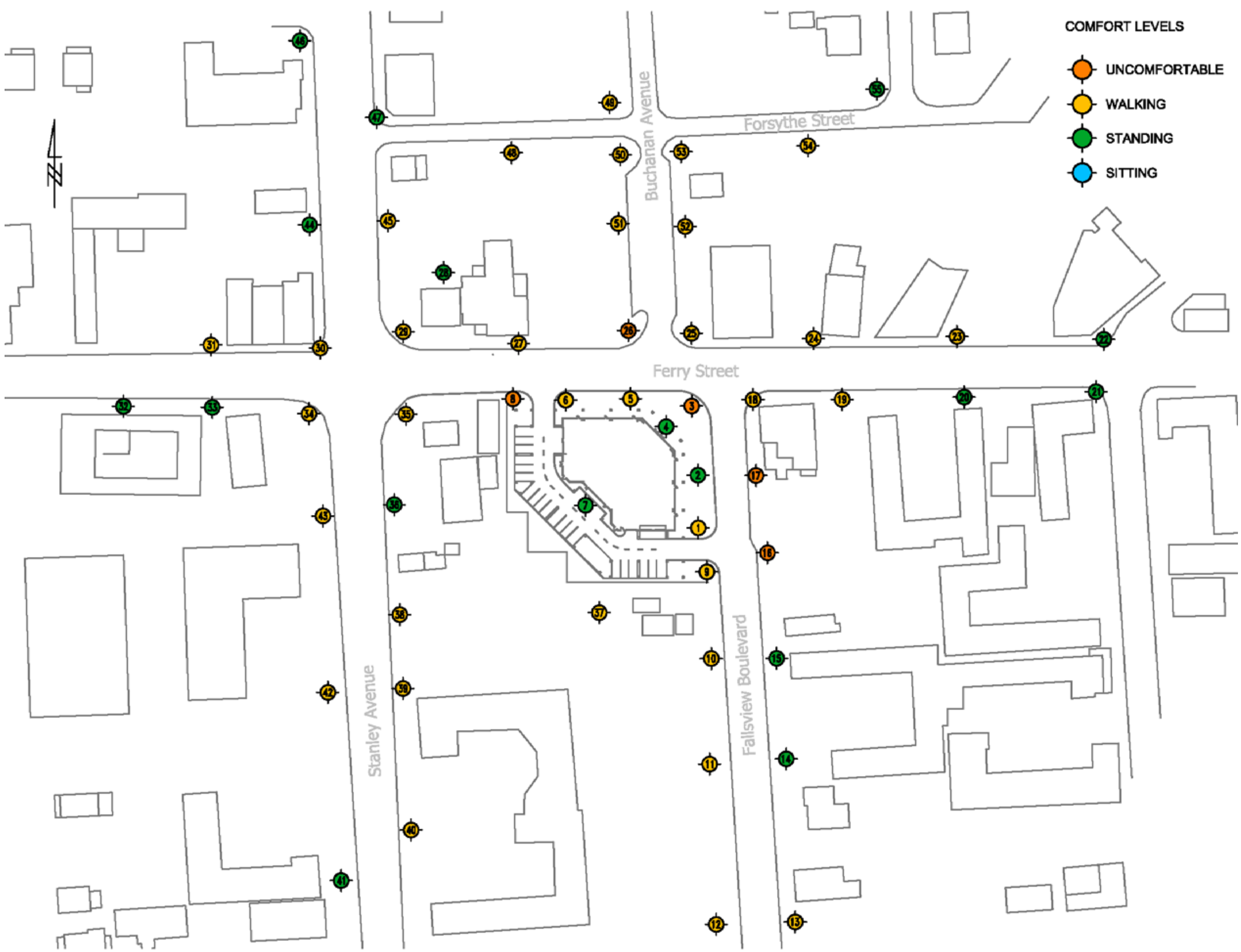


FIGURE 15b SUMMARY OF PREDICTED COMFORT LEVELS FOR PEDESTRIAN-LEVEL WIND SPEEDS – PROPOSED DEVELOPMENT - WINTER

Mitigation concepts for sidewalk area along Ferry Street and Fallsview Blvd adjacent to site

Mitigation concepts for 5th floor parking area

FIGURE 16 EXAMPLES OF VARIOUS MITIGATION OPTIONS

APPENDIX A

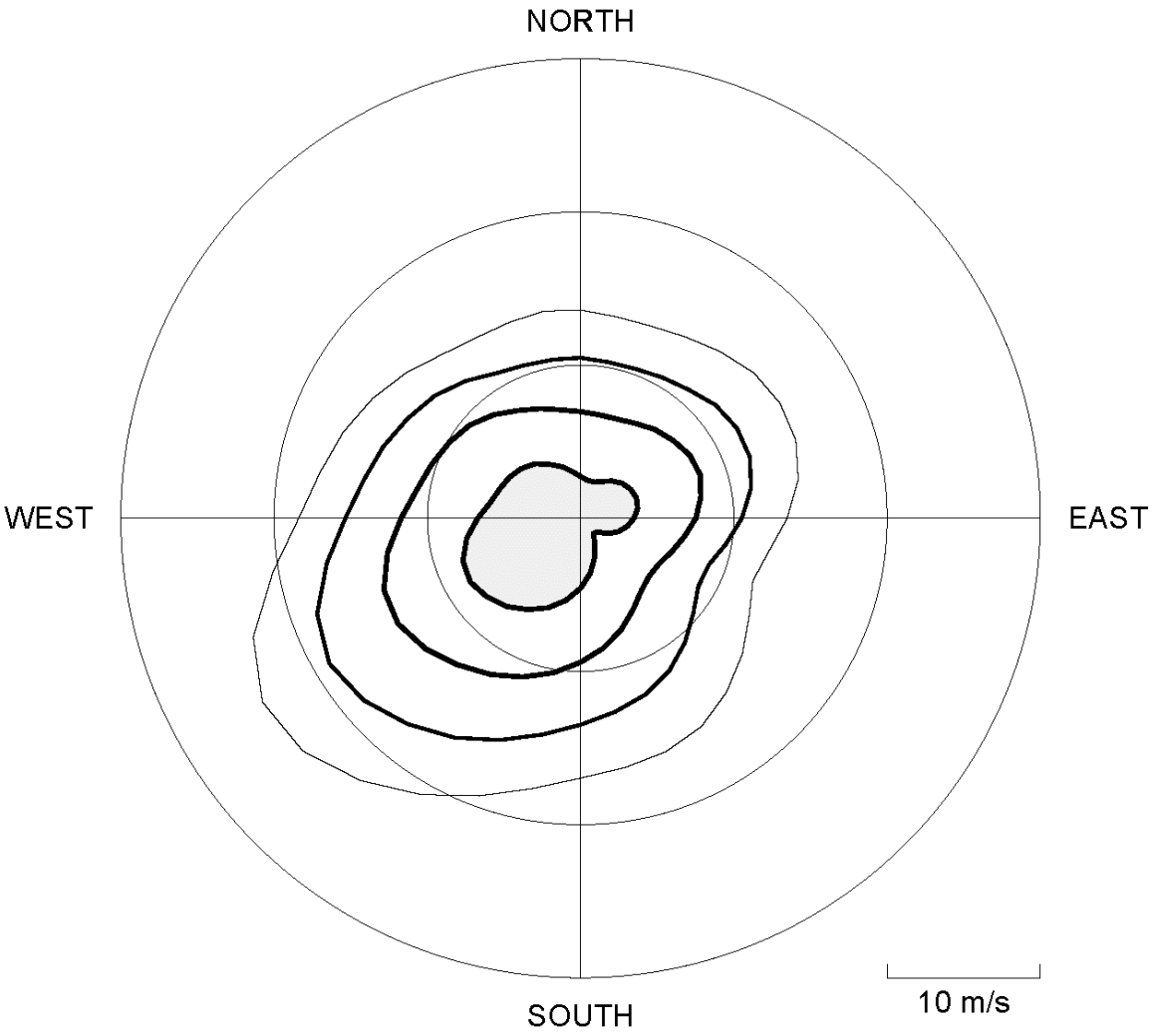
PROBABILITY DISTRIBUTIONS OF WIND SPEED AND DIRECTION

In the plots, the radial distance represents the wind speed at a reference height of 500 m in standard open country exposure. Contours are plotted for four probability levels: the innermost contour is for a probability level of 0.01 or 1% of the time. The other contours represent 0.1%, 0.01% and 0.001% of the time. Thus, the more-common winds are represented by the inner contours and the more-rare winds by the outer contours.

These plots have been derived using data at 16 compass directions, which were interpolated to every 10°. Thus, a point on the innermost contour would represent the wind speed that is exceeded 1% of the time within a 10° sector centred on that wind direction.

To determine the probability of exceeding a particular wind speed at a particular direction, interpolate between the contour levels. For example, to determine the probability of exceeding 20 m/s from the west, find the point on the plot corresponding to this speed and direction. In this case (for 20 m/s at 270°), the probability of exceeding 20 m/s from the west falls between the 1% and 0.1% contours, and is approximately 0.35%.

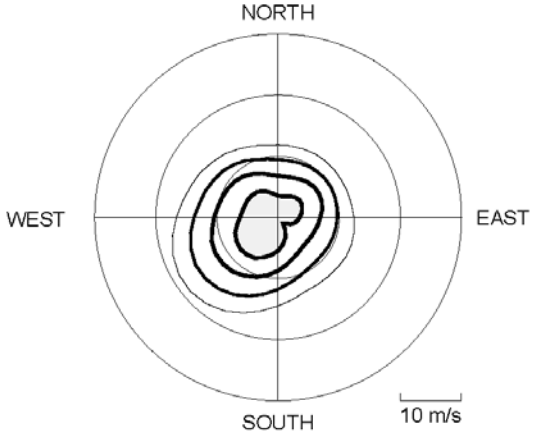
The probability of a particular wind speed being exceeded regardless of direction can be obtained by summing the probabilities of exceeding that wind speed at every 10° over the full 360° azimuth range.



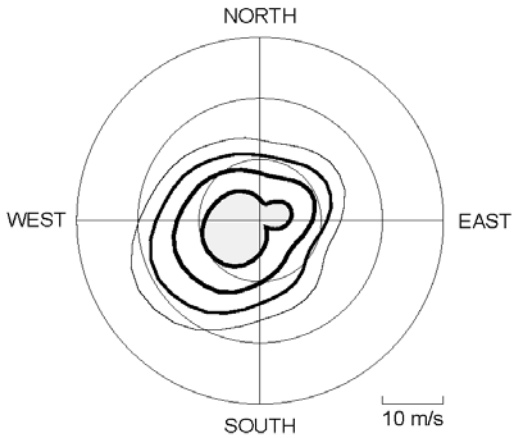
ANNUAL

A point on the innermost contour represents the wind speed exceeded
1% of the time within a 10 degree sector centred on that direction.
Other contours represent probability levels of:
0.1%, 0.01% and 0.001% respectively.

Niagara Falls, Ontario (Wind at 10m)



SUMMER



WINTER

A point on the innermost contour represents the wind speed exceeded 1% of the time within a 10 degree sector centred on that direction. Other contours represent probability levels of: 0.1%, 0.01% and 0.001% respectively.

Niagara Falls, ON (10m)

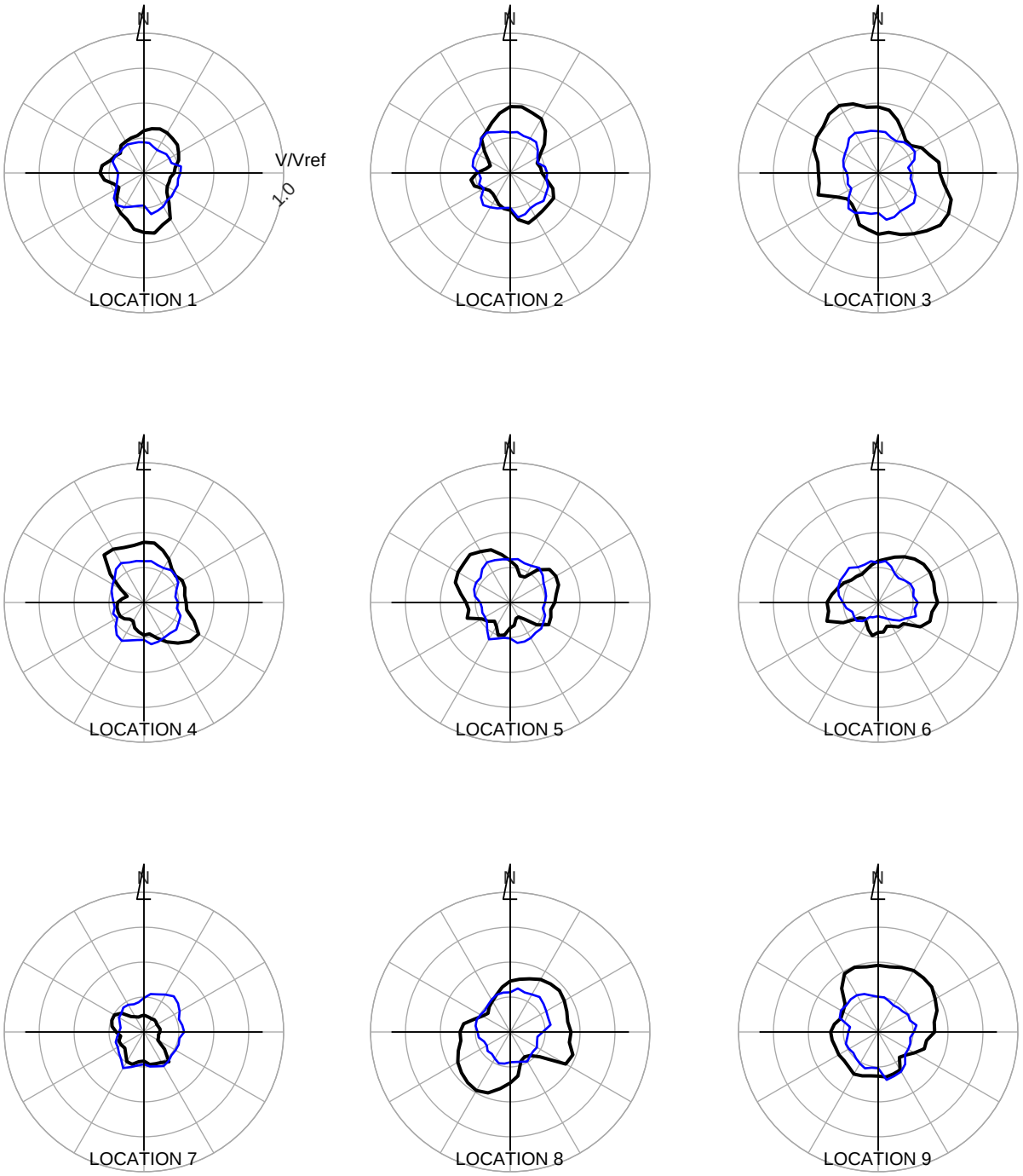
APPENDIX B

POLAR PLOTS OF SPEED COEFFICIENTS

Speed ratios are the speed at the probe height divided by the speed at reference height (see Figure 3b).

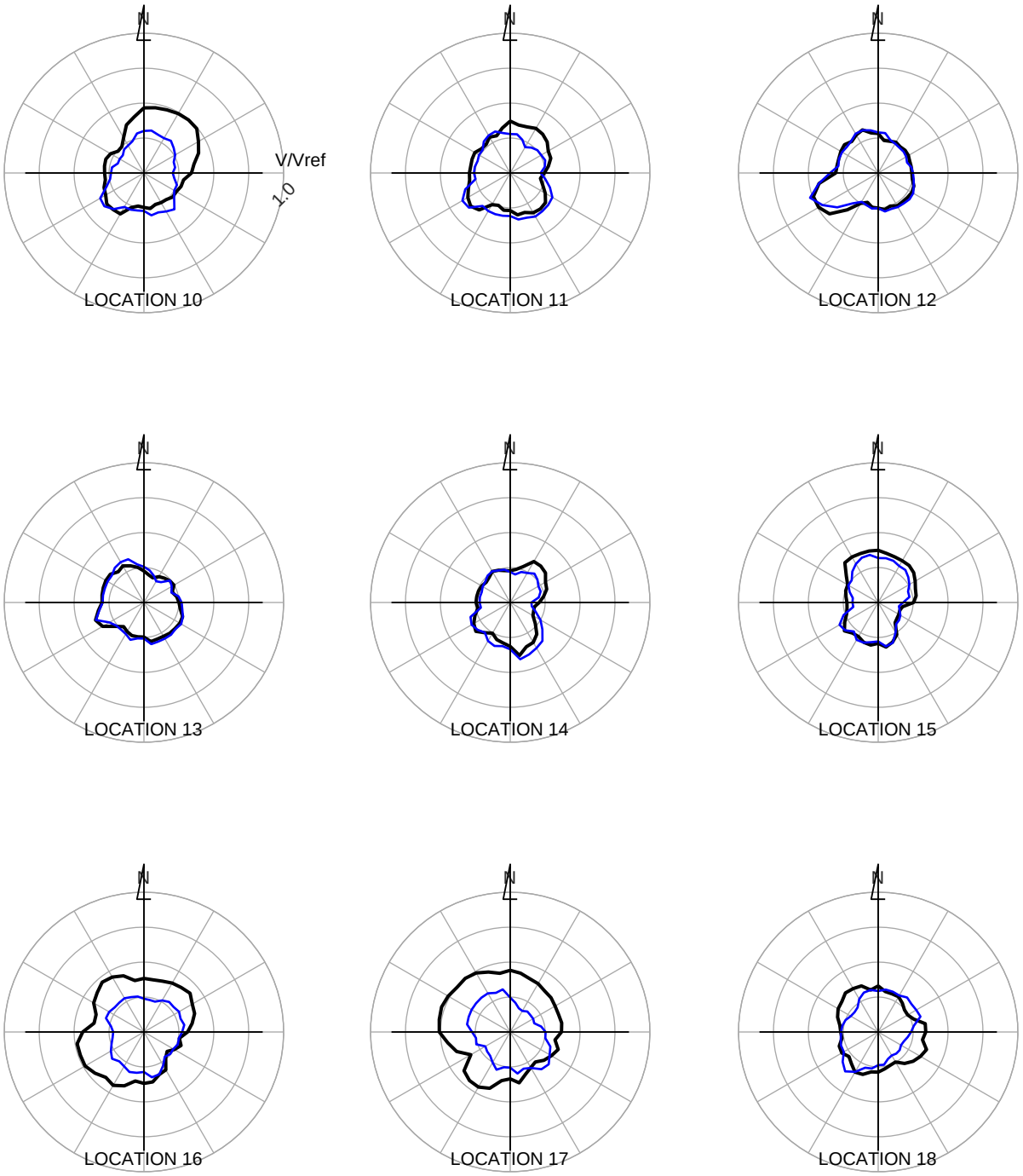
The azimuth indicated refers to the direction of the oncoming reference-height wind flow, measured from true North. Surface wind directions may vary considerably from these.

Note: GEM = Maximum of either mean wind speed or the gust wind speed divided by 1.85



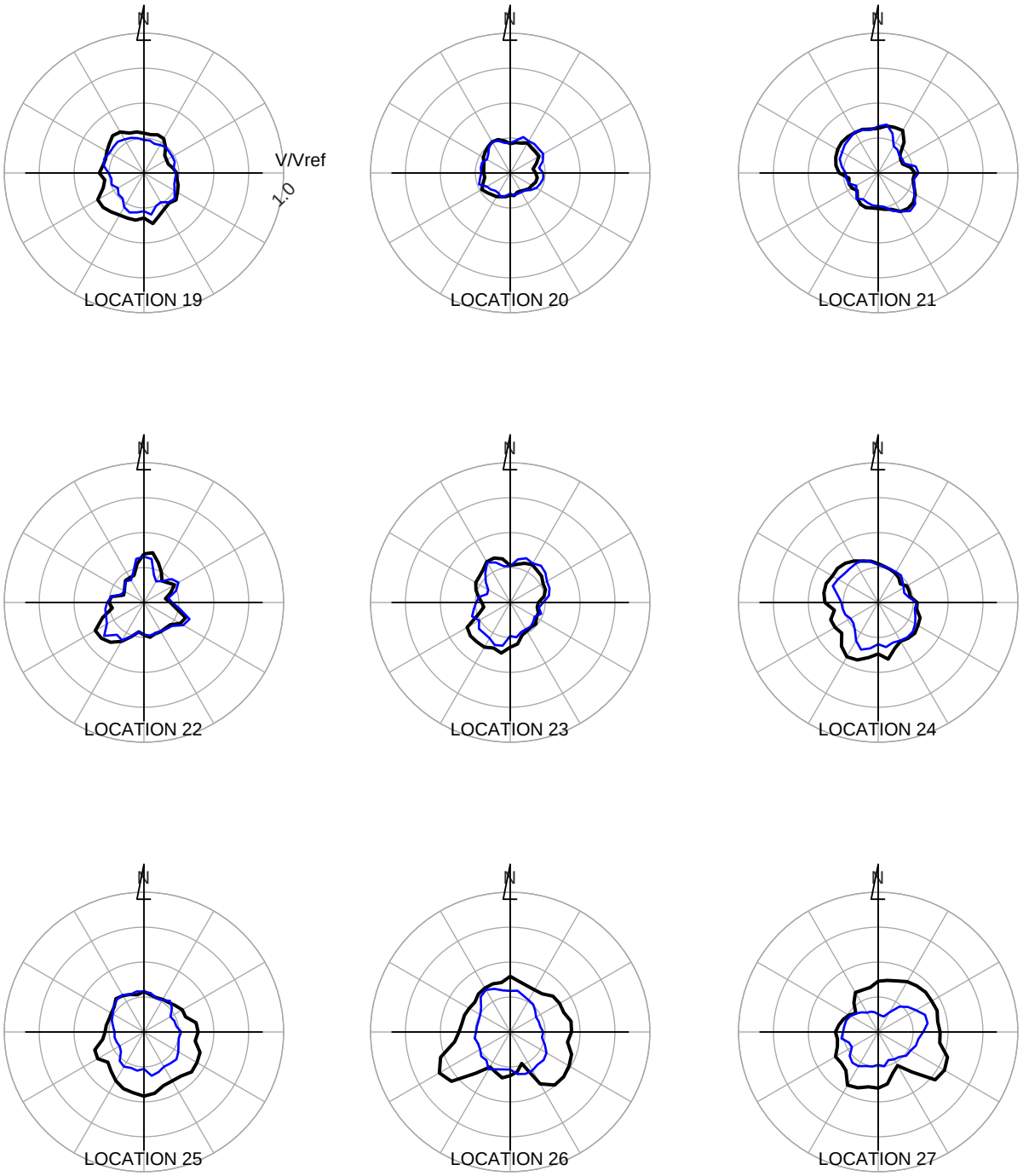
5438 Ferry Street, Niagara Falls - Proposed Configuration FerPCplz/GEMean

5438 Ferry Street, Niagara Falls - Existing Configuration FerECplz/GEMean



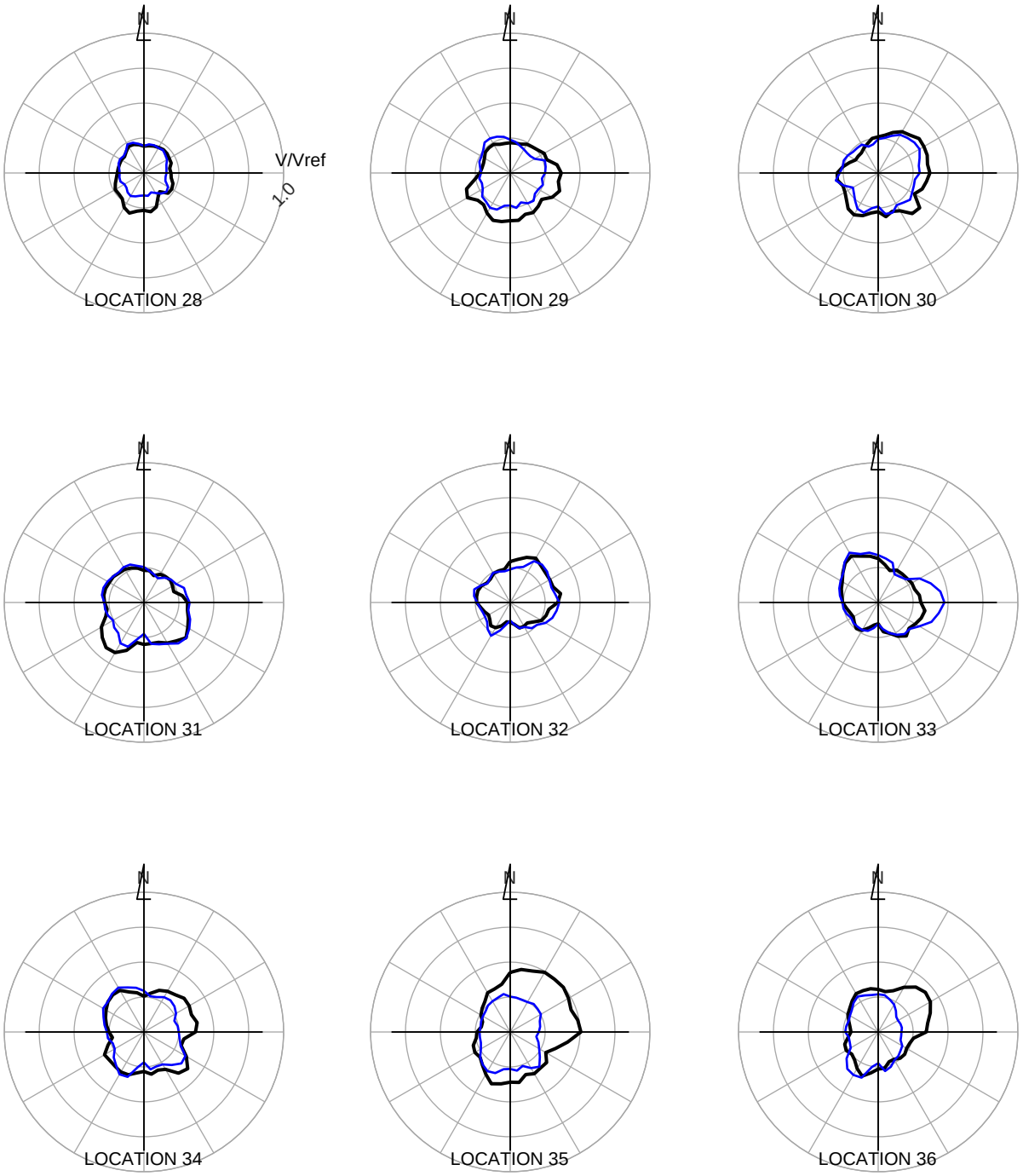
5438 Ferry Street, Niagara Falls - Proposed Configuration FerPCplz/GEMean

5438 Ferry Street, Niagara Falls - Existing Configuration FerECplz/GEMean



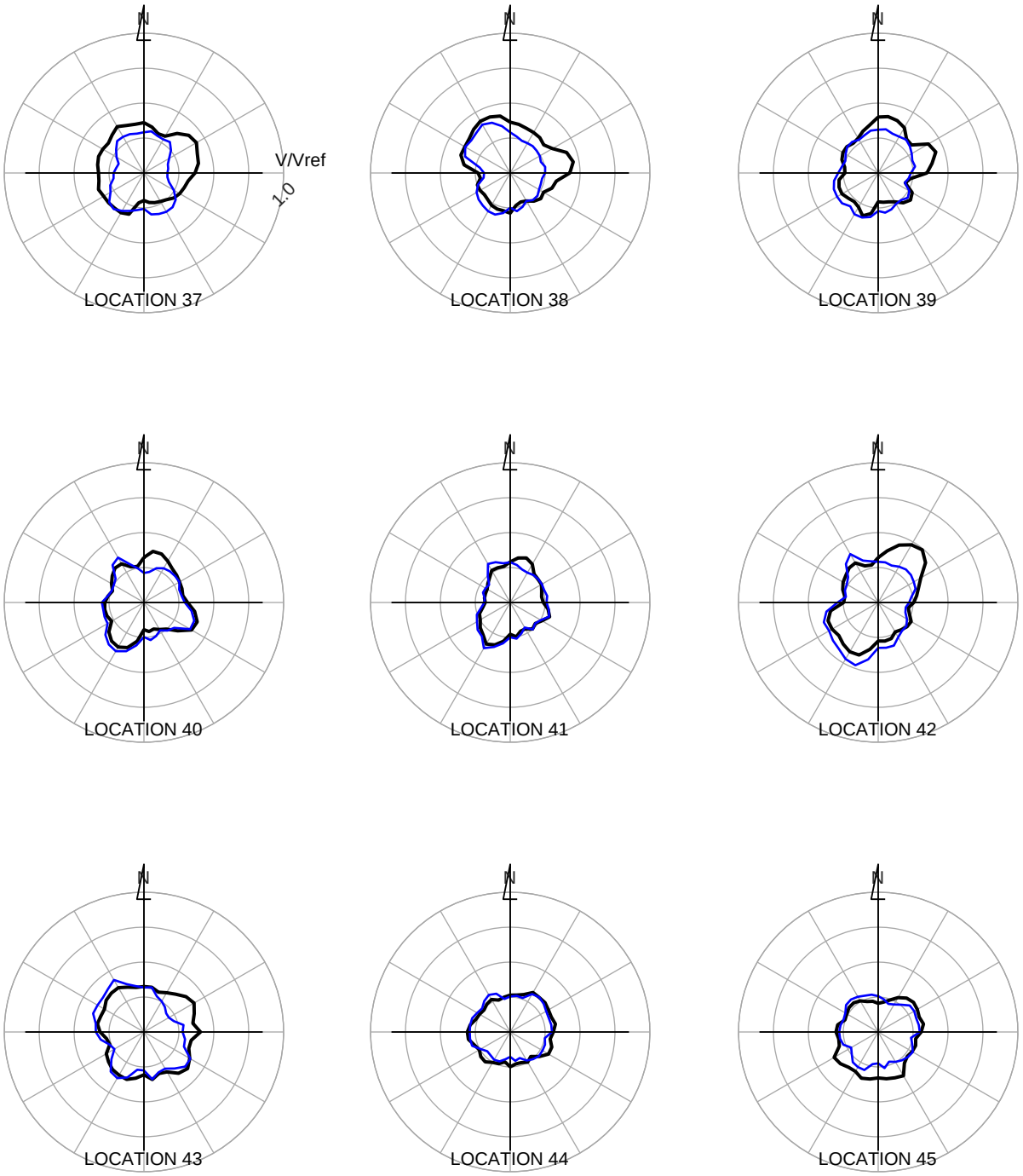
5438 Ferry Street, Niagara Falls - Proposed Configuration FerPCplz/GEMean

5438 Ferry Street, Niagara Falls - Existing Configuration FerECplz/GEMean



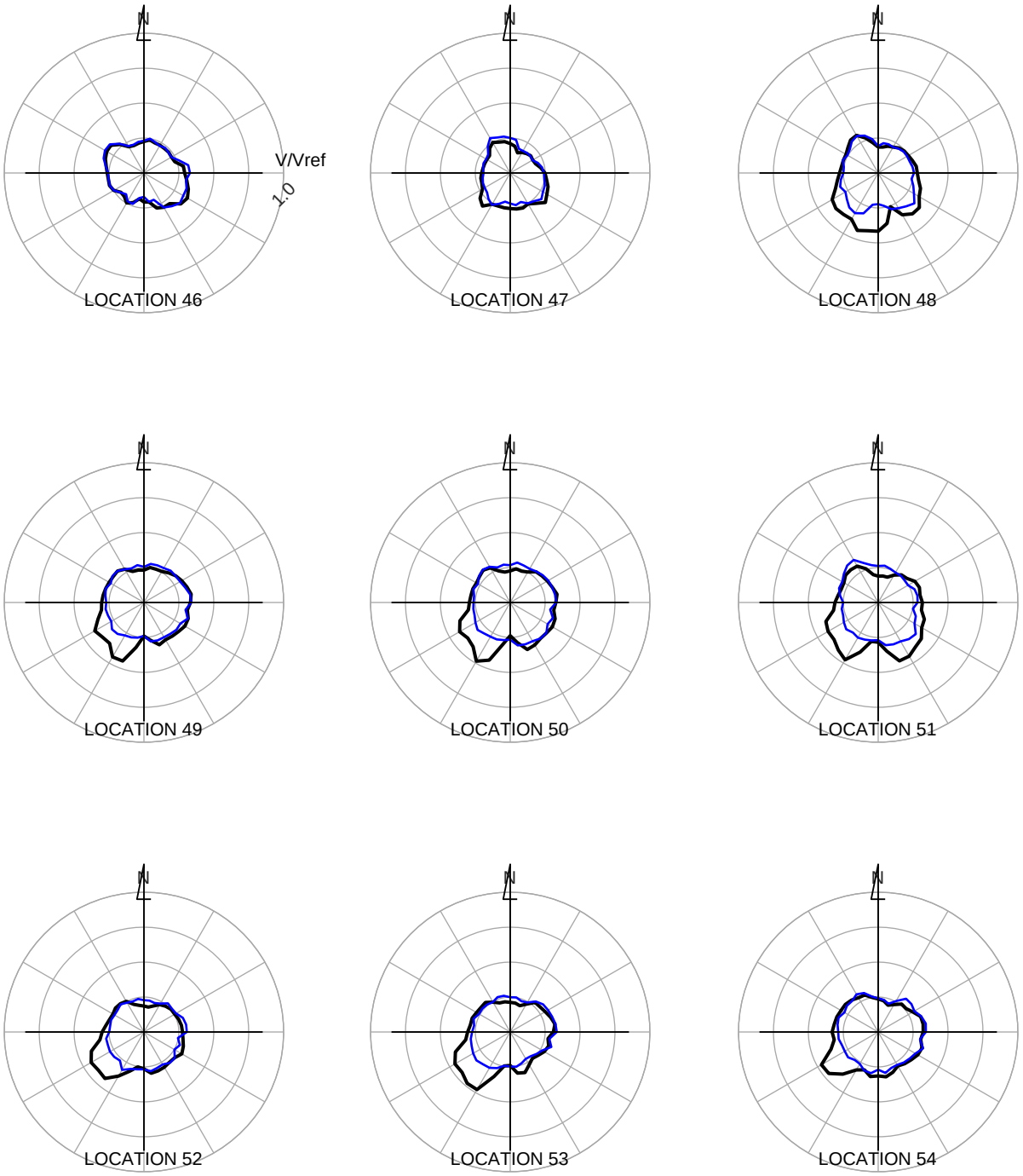
5438 Ferry Street, Niagara Falls - Proposed Configuration FerPCplz/GEMean

5438 Ferry Street, Niagara Falls - Existing Configuration FerECplz/GEMean



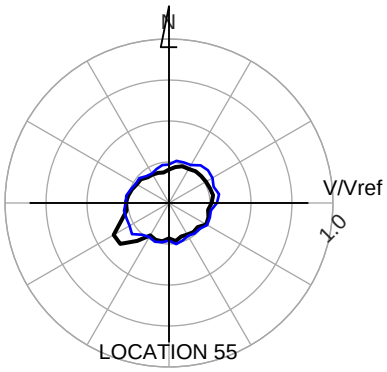
5438 Ferry Street, Niagara Falls - Proposed Configuration FerPCplz/GEMean

5438 Ferry Street, Niagara Falls - Existing Configuration FerECplz/GEMean



5438 Ferry Street, Niagara Falls - Proposed Configuration FerPCplz/GEMean

5438 Ferry Street, Niagara Falls - Existing Configuration FerECplz/GEMean



5438 Ferry Street, Niagara Falls - Proposed Configuration FerPCplz/GEMean

5438 Ferry Street, Niagara Falls - Existing Configuration FerECplz/GEMean