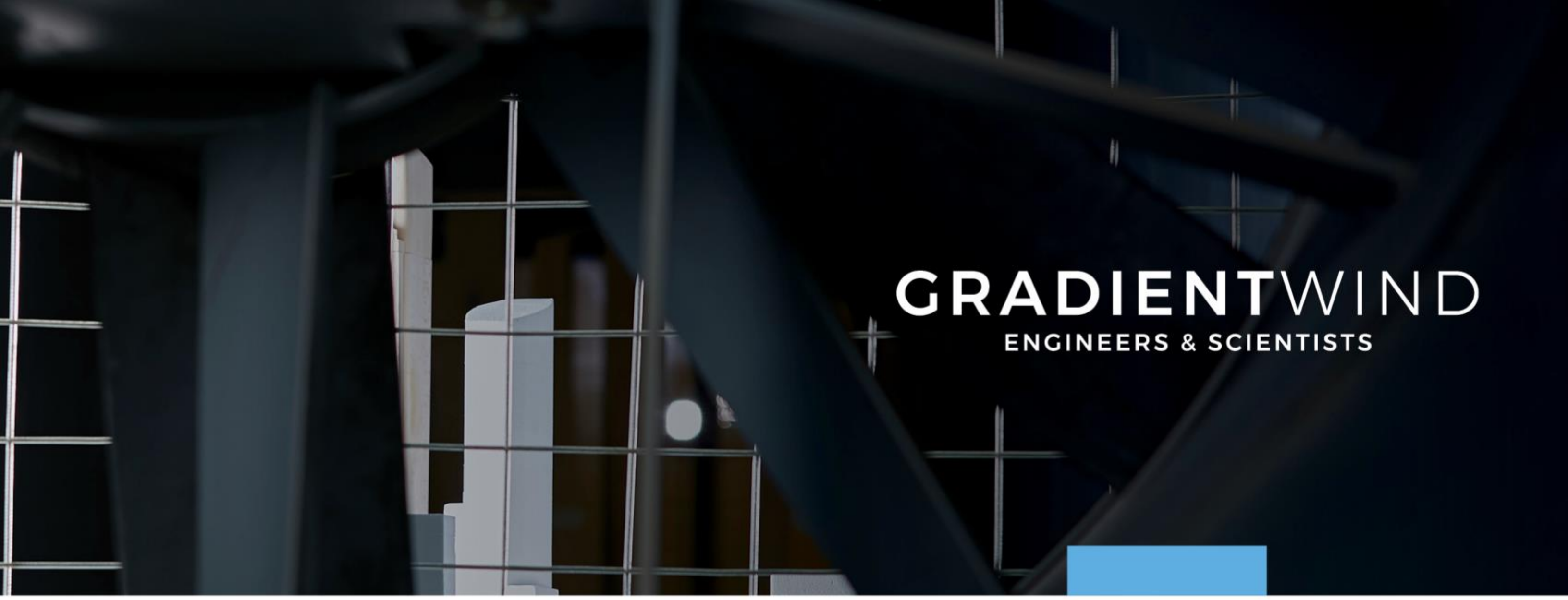

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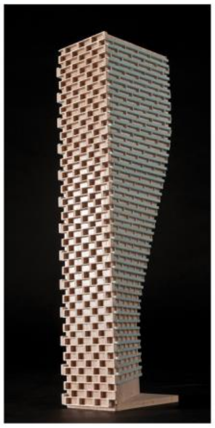
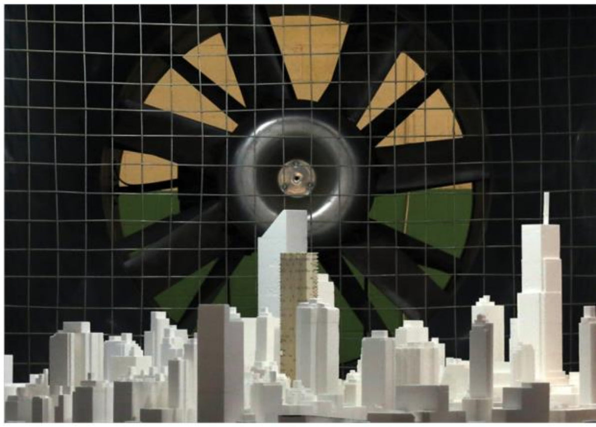
ENGINEERS & SCIENTISTS

PEDESTRIAN LEVEL WIND STUDY

36 Robinson Avenue
Ottawa, Ontario

REPORT: GWE19-016-CFDPLW





March 7, 2019

PREPARED FOR
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EXECUTIVE SUMMARY

This report describes a pedestrian level wind study undertaken to assess wind conditions for a proposed residential development located at 36 Robinson Avenue in Ottawa, Ontario. The study involves simulation of wind speeds for selected wind directions in a three-dimensional (3D) computer model using the Computational Fluid Dynamics (CFD) technique, combined with meteorological data integration, to assess pedestrian comfort and safety within and surrounding the development site. The results and recommendations derived from these considerations are summarized in the following paragraphs and detailed in the subsequent report.

Our work is based on industry standard CFD simulation and data analysis procedures, architectural drawings provided by Hobin Architecture Incorporated in February 2019, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, as well as recent site imagery.

A complete summary of the predicted wind conditions is provided in Section 5 of this report and illustrated in Figures 3A-6B following the main text. Based on CFD test results, interpretation, experience with similar developments, and City of Ottawa pedestrian wind speed criteria, we conclude that wind conditions over all pedestrian sensitive grade-level locations within and surrounding the study site will be acceptable for the intended uses on a seasonal basis.

The majority of the rooftop amenity area will be suitable for sitting during the summer without mitigation. If seating is desired at limited windy areas, mitigation is recommended in the form of barriers, as described in Section 5.

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience conditions too windy for walking, or that could be considered unsafe.

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1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Robinson Village LP IV Limited Partnership to undertake a computer-based pedestrian level wind study for a residential development to be located at 36 Robinson Avenue in Ottawa, Ontario. Our mandate within this study, as outlined in GWE proposal #19-003P, dated January 15, 2019, is to investigate pedestrian wind comfort and safety within and surrounding the development site, and to identify any areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where necessary.

Our work is based on industry standard computer simulations using the Computational Fluid Dynamics (CFD) technique and data analysis procedures, architectural drawings provided by Hobin Architecture Incorporated in February 2019, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, as well as recent site imagery.

2. TERMS OF REFERENCE

The focus of this detailed pedestrian level wind study is a proposed residential development at 36 Robinson Avenue in Ottawa, Ontario. The study site is located on a larger parcel of land bounded by Hurdman Road to the west and Robinson Avenue at all remaining sides.

The proposed development is a nine-storey building of rectangular planform. A sheltered ramp at the northwest corner of the building provides access to two levels of underground parking. Ground floor contains a lobby at the northwest corner, an adjacent gym, and residential units in the remaining space, while residential units occupy the floors above. Stairwell exits are also located at the east and west elevations, whereas the north and south elevations feature private patios. The building maintains a consistent planform from Levels 1 through 9, apart from variations in the façade detailing over the east two-thirds of the building, and a slight setback in the floorplate at Level 8. The roof slab of the building overhangs the floors below at the southwest and northeast corners. A central section of the building rooftop features an outdoor amenity area, northeast of the rooftop mechanical enclosure.

Following completion of the CFD simulations, changes have been made to the design plan for the rooftop amenity area that are not reflected in the figures of this report. Notably, the massing of the mechanical penthouse has expanded to the south and west, and the rooftop amenity area has expanded to encompass the remaining east and south sections of the rooftop. Based on knowledge of wind flows and our experience performing simulations and wind tunnel testing for similar projects, we conclude that these changes will not have an appreciable effect on the predicted pedestrian comfort classifications presented in this report. The results of the present study therefore remain applicable to the updated design plan.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre radius of the site) comprise low-rise buildings in all directions, followed by the Rideau River to the north and east, Highway 417 to the south, and Robinson Field to the northwest. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius) comprise primarily low-rise residential buildings with several isolated taller buildings to the north, a moderate density concentration of low- and medium-rise commercial and institutional buildings to the east along the Highway 417 corridor, open park space and the Rideau River as well as several high-rise buildings to the south, and a mix of low- medium-, and high-rise buildings beyond Highway 417 towards downtown Ottawa to the west.

Key areas under consideration for pedestrian wind comfort include surrounding sidewalks, building access points, and the rooftop outdoor amenity area. Figure 1 illustrates the study site and surrounding context. Figures 2A and 2B illustrate the computational model used to conduct the study.

3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind comfort and safety conditions at key areas within and surrounding the development site; (ii) identify areas where wind conditions may interfere with the intended uses of outdoor spaces; and (iii) recommend suitable mitigation measures, where required.

4. METHODOLOGY

The approach followed to quantify pedestrian wind conditions over the site is based on Computational Fluid Dynamics (CFD) simulations of wind speeds across the study site within a virtual environment, meteorological analysis of the Ottawa area wind climate, and synthesis of computational data with industry-accepted guidelines[1]. The following sections describe the analysis procedures, including a discussion of the pedestrian comfort guidelines.

4.1 Computer-Based Context Modelling

A computer-based PLW study was performed to determine the influence of the wind environment on pedestrian comfort over the proposed development site. Pedestrian comfort predictions, based on the mechanical effects of wind, were determined by combining measured wind speed data from CFD simulations with statistical weather data obtained from Ottawa's Macdonald-Cartier International Airport.

The general concept and approach to CFD modelling is to represent building and topographic details in the immediate vicinity of the study site on the surrounding model, and to create suitable atmospheric wind profiles at the model boundary. The wind profiles are designed to have similar mean and turbulent wind properties consistent with actual site exposures.

An industry standard practice is to omit trees, vegetation, and other existing and planned landscape elements from the model due to the difficulty of providing accurate seasonal representation of vegetation. The omission of trees and other landscaping elements produces slightly more conservative wind speed values.

4.2 Wind Speed Measurements

The PLW analysis was performed by simulating wind flows and gathering velocity data over a CFD model of the site for 12 wind directions. The CFD simulation model was centered on the study building, complete with surrounding massing within a diameter of approximately 840 metres.

Mean and peak wind speed data obtained over the study site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 metres above local grade were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. The gradient height represents the theoretical depth of the boundary layer of the Earth's atmosphere, above which the mean

[1] City of Ottawa Terms of References: Wind Analysis

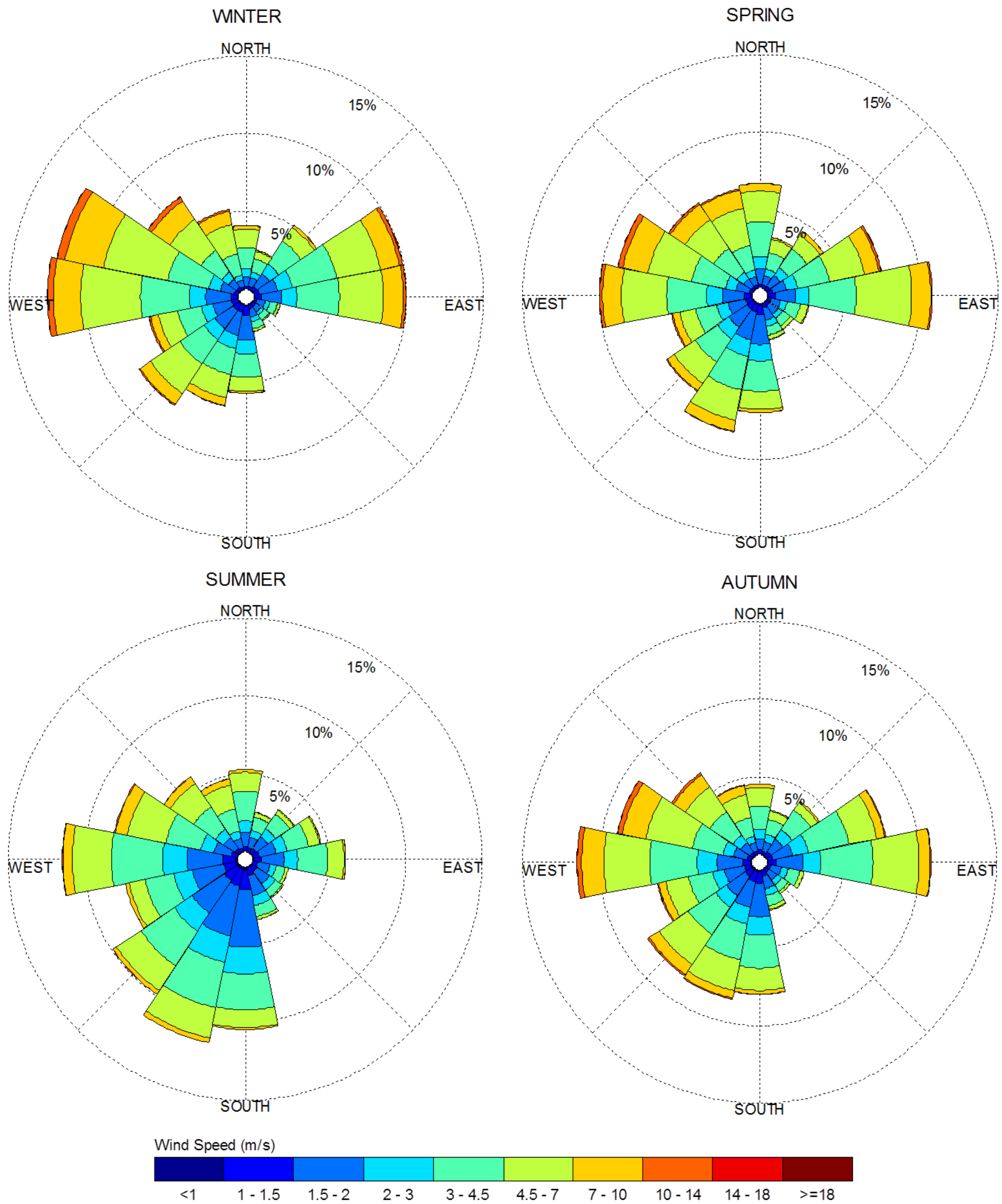
wind speed remains constant. Appendices A and B provide greater detail of the theory behind wind speed measurements.

4.3 Meteorological Data Analysis

A statistical model for winds in Ottawa was developed from approximately 40-years of hourly meteorological wind data recorded at Macdonald-Cartier International Airport and obtained from the local branch of Atmospheric Environment Services of Environment Canada. Wind speed and direction data were analyzed for each month of the year in order to determine the statistically prominent wind directions and corresponding speeds, and to characterize similarities between monthly weather patterns. Based on this portion of analysis, the four seasons are represented by grouping data from consecutive months based on similarity of weather patterns, and not according to the traditional calendar method.

The statistical model of the Ottawa area wind climate, which indicates the directional character of local winds on a seasonal basis, is illustrated on the following page. The plots illustrate seasonal distribution of measured wind speeds and directions in m/s. Probabilities of occurrence of different wind speeds are represented as stacked polar bars in sixteen azimuth divisions. The radial direction represents the percentage of time for various wind speed ranges per wind direction during the measurement period. The preferred wind speeds and directions can be identified by the longer length of the bars. For Ottawa, the most common winds occur for westerly wind directions, followed by those from the east, while the most common wind speeds are below 10 metres per second (m/s). The directional preference and relative magnitude of wind speed changes somewhat from season to season. By convention in microclimate studies, wind direction refers to the wind origin (e.g., a north wind blows from north to south).

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES
MACDONALD-CARTIER INTERNATIONAL AIRPORT, OTTAWA, ONTARIO



Notes:

1. Radial distances indicate percentage of time of wind events.
2. Wind speeds are mean hourly in m/s, measured at 10 m above the ground.

4.4 Pedestrian Comfort and Safety Guidelines

Pedestrian comfort and safety guidelines are based on the mechanical effects of wind without consideration of other meteorological conditions (i.e. temperature, relative humidity). The comfort guidelines assume that pedestrians are appropriately dressed for a specified outdoor activity during any given season. Five pedestrian comfort classes are based on 80% non-exceedance gust wind speed ranges, which include (i) Sitting; (ii) Standing; (iii) Strolling; (iv) Walking; and (v) Uncomfortable. More specifically, the comfort classes and associated mean wind speed ranges are summarized as follows:

(i) **Sitting:** Mean wind speeds less than or equal to 10 kilometers per hour (km/h).

(ii) **Standing:** Mean wind speeds less than or equal to 14 km/h (i.e. 10-14 km/h).

(iii) **Strolling:** Mean wind speeds less than or equal to 17 km/h (i.e. 14-17 km/h).

(iv) **Walking:** Mean wind speeds less than or equal to 20 km/h (i.e. 16-20 km/h).

(v) **Uncomfortable:** Uncomfortable conditions are characterized by predicted values that fall below the 80% target for walking. Brisk walking and exercise, such as jogging, would be acceptable for moderate excesses of this guideline.

The pedestrian safety wind speed guideline is based on the approximate threshold that would cause a vulnerable member of the population to fall. A 0.1% exceedance gust wind speed of greater than 90 km/h is classified as dangerous.

The gust speed, and equivalent mean speed, ranges are selected based on 'The Beaufort Scale', presented on the following page, which describes the effects of forces produced by varying wind speed levels on objects.

THE BEAUFORT SCALE

NUMBER	DESCRIPTION	WIND SPEED (KM/H)	DESCRIPTION
2	Light Breeze	4-8	Wind felt on faces
3	Gentle Breeze	8-15	Leaves and small twigs in constant motion; Wind extends light flags
4	Moderate Breeze	15-22	Wind raises dust and loose paper; Small branches are moved
5	Fresh Breeze	22-30	Small trees in leaf begin to sway
6	Strong Breeze	30-40	Large branches in motion; Whistling heard in electrical wires; Umbrellas used with difficulty
7	Moderate Gale	40-50	Whole trees in motion; Inconvenient walking against wind
8	Gale	50-60	Breaks twigs off trees; Generally impedes progress

Experience and research on people's perception of mechanical wind effects has shown that if the wind speed levels are exceeded for more than 80% of the time, the activity level would be judged to be uncomfortable by most people. For instance, if wind speeds of 10 km/h were exceeded for more than 20% of the time most pedestrians would judge that location to be too windy for sitting or more sedentary activities. Similarly, if 20 km/h at a location were exceeded for more than 20% of the time, walking or less vigorous activities would be considered uncomfortable. As most of these criteria are based on subjective reactions of a population to wind forces, their application is partly based on experience and judgment.

Once the pedestrian wind speed predictions have been established at tested locations, the assessment of pedestrian comfort involves determining the suitability of the predicted wind conditions for their associated spaces. This step involves comparing the predicted comfort class to the desired comfort class, which is dictated by the location type represented by the sensor (i.e. a sidewalk, building entrance, amenity space, or other). An overview of common pedestrian location types and their desired comfort classes are summarized on the following page.

DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES

Location Types	Desired Comfort Classes
Major Building Entrances	Standing
Secondary Building Access Points	Walking
Primary Public Sidewalks	Strolling
Secondary Public Sidewalks / Bicycle Paths	Walking
Outdoor Amenity Spaces	Sitting
Cafés / Patios / Benches / Gardens	Sitting
Transit Shelters	Standing
Public Parks / Plazas	Strolling
Garage / Service Entrances	Walking
Parking Lots	Walking
Vehicular Drop-Off Zones	Walking

5. RESULTS AND DISCUSSION

The foregoing discussion of predicted pedestrian wind conditions is accompanied by Figures 3A through 6B (following the main text) illustrating the seasonal wind conditions at grade-level and the rooftop amenity space. The colour contours indicate various comfort classes predicted for certain regions. Wind conditions comfortable for sitting or more sedentary activities are represented by the colour green, standing are represented by yellow, and conditions suitable for strolling are represented by orange.

Robinson Avenue Sidewalk and Adjacent Lobby Entrance (Tags A & B): The Robinson Avenue sidewalk in proximity to the study building (Tag A) will experience conditions suitable for sitting during the summer and sitting or standing for the remainder of the year. The adjacent lobby entrance (Tag B) will experience conditions suitable for sitting throughout the year. These conditions are acceptable for the intended uses.

Private Entrances (Tag C): The private entrances at the north and south sides of the building, as well as the adjacent patio spaces, will be suitable for sitting throughout the year, which is acceptable.

Stairwell Exits (Tag D): The stairwell exits at the east and west elevations will experience conditions suitable for sitting throughout the year, which is acceptable.

Rooftop Amenity Area (Tags E & F): The majority of the rooftop amenity area (Tag E) will be suitable for sitting during the summer. The exception is a north section of the space (Tag F), which will experience conditions suitable for standing. For the remaining seasons, the rooftop amenity area will largely experience conditions suitable for standing during the autumn and strolling or better for the remainder of the year, with the windier conditions occurring towards the central north section (Tag F).

These conditions are acceptable for an intended use period of summer provided that seating is limited to calm areas denoted by green in Figure 4B. If seating is desired for the windier north location, or if the use period is intended to extend into the shoulder seasons of spring and autumn, it is recommended to raise the parapet guards along the full perimeter of the space to 1.8 metres above the walking surface.

Influence of the Proposed Development on Existing Wind Conditions near the Study Site: Wind conditions over surrounding sidewalks beyond the development site, as well as at nearby building entrances and the nearby Robinson Field, will be comfortable for their intended pedestrian uses during each seasonal period upon the introduction of the proposed development.

Wind Safety: Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience wind conditions that are considered unsafe.

6. CONCLUSIONS AND RECOMMENDATIONS

This report summarizes the methodology, results, and recommendations related to a pedestrian level wind study for the proposed residential development located at 36 Robinson Avenue in Ottawa, Ontario. The study was performed in accordance with the scope of work described in GWE proposal #19-003P, dated January 15, 2019, as well as industry standard CFD simulation and data analysis procedures.

A complete summary of the predicted wind conditions is provided in Section 5 of this report and illustrated in Figures 3A-6B following the main text. Based on CFD test results, meteorological data analysis and experience with similar developments in Ottawa, we conclude that wind conditions over all pedestrian sensitive grade-level locations within and surrounding the study site will be acceptable for the intended uses on a seasonal basis.

The majority of the rooftop amenity area will be suitable for sitting during the summer without mitigation. If seating is desired at limited windy areas, mitigation is recommended in the form of barriers, as described in Section 5.

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience conditions too windy for walking, or that could be considered unsafe.

This concludes our pedestrian level wind study and report. Please advise the undersigned of any questions or comments.

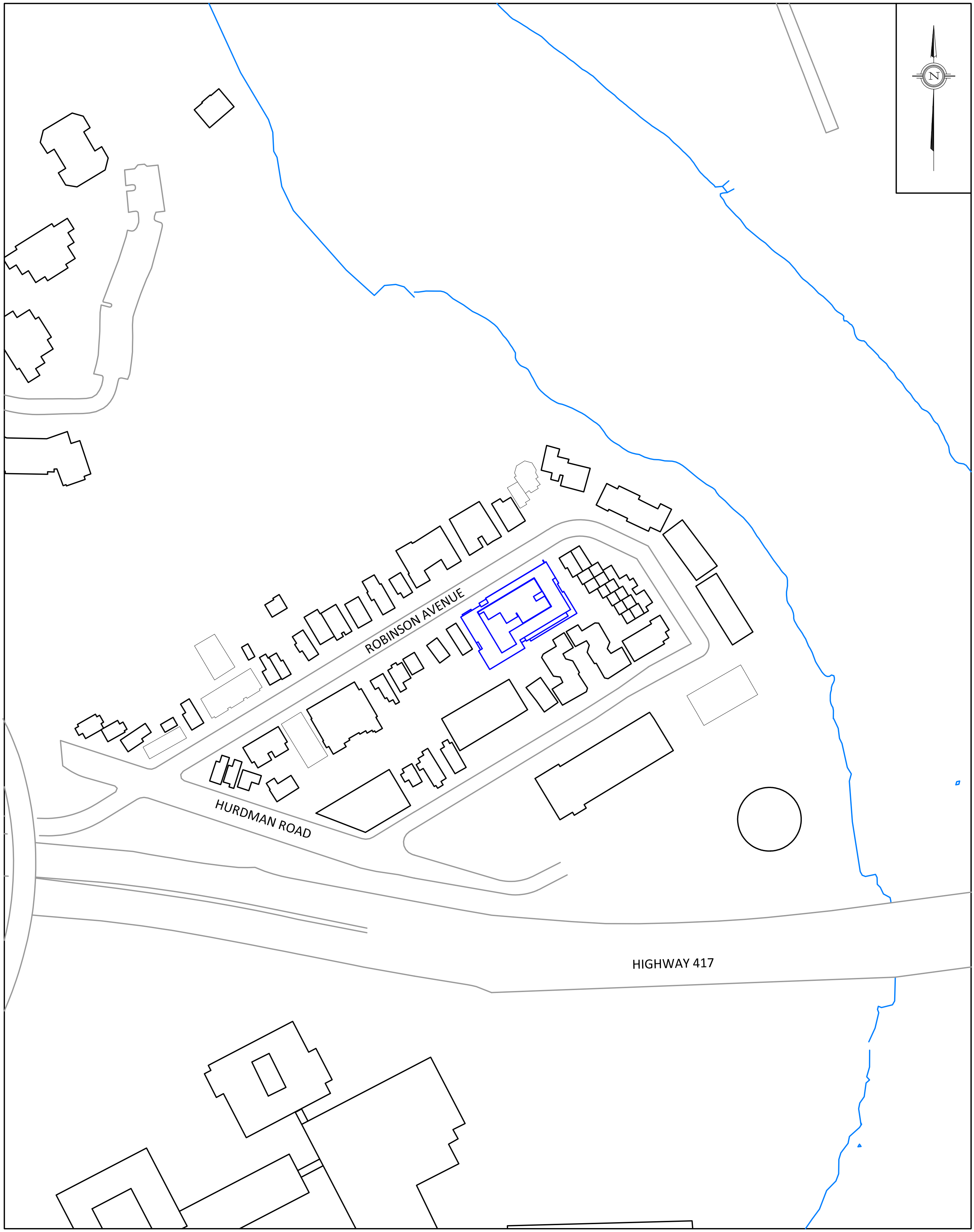
Sincerely,

Gradient Wind Engineering Inc.

Megan Prescott, MESc.,
Project Manager

Andrew Sliasas, M.A.Sc., P.Eng.,
Principal

GWE19-016-CFDPLW



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PROJECT	36 ROBINSON AVENUE, OTTAWA PEDESTRIAN LEVEL WIND STUDY
SCALE	1:2500 (APPROX.)
DRAWING NO.	GWE19-016-PLW-1
DATE	FEBRUARY 28, 2019
DRAWN BY	K.A.
DESCRIPTION	FIGURE 1: SITE PLAN AND SURROUNDING CONTEXT

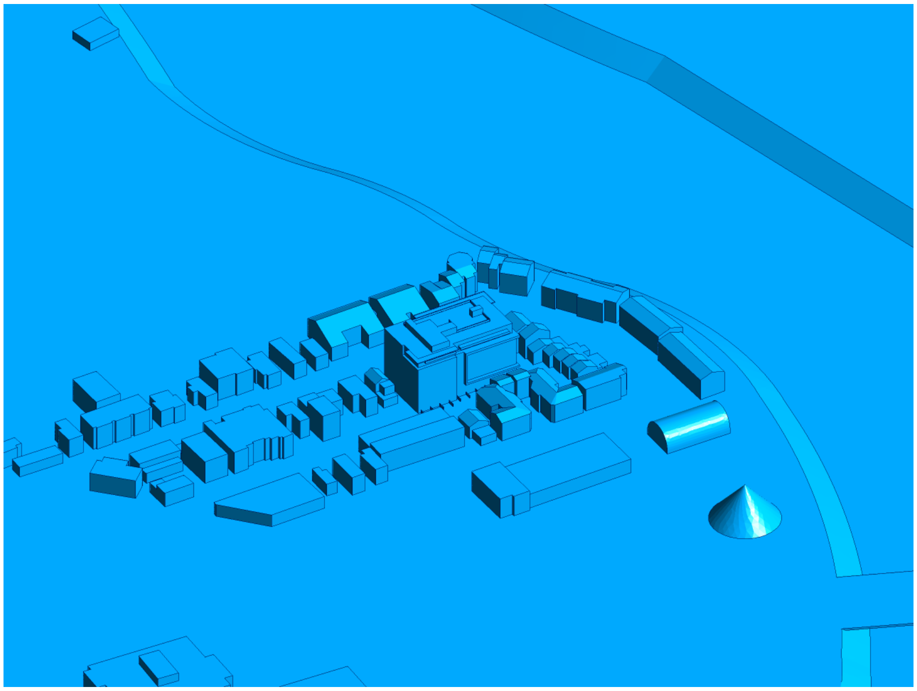


FIGURE 2A: COMPUTATIONAL MODEL, SOUTH PERSPECTIVE

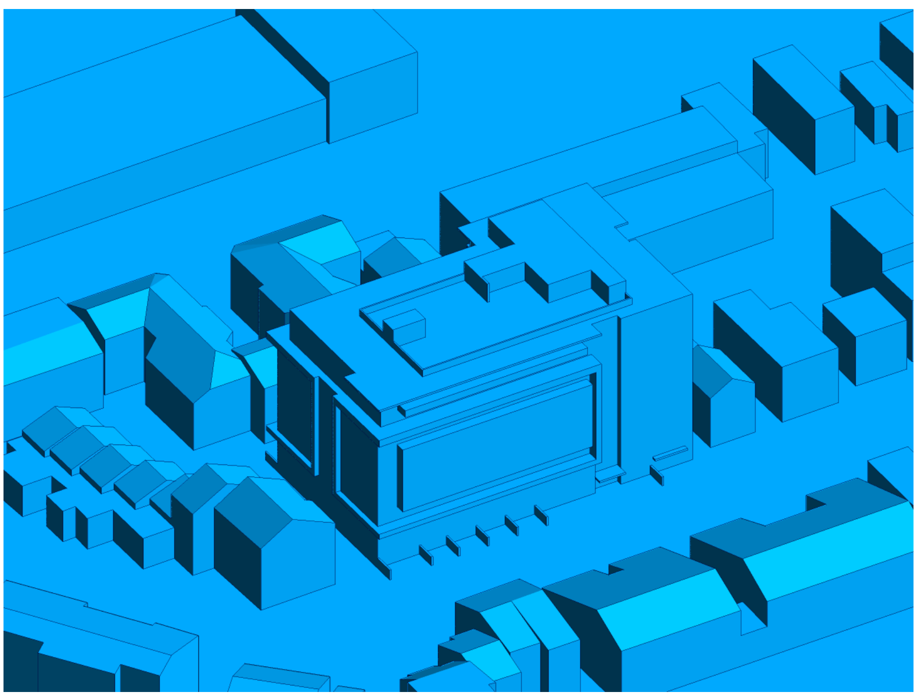


FIGURE 2B: STUDY BUILDING, NORTH PERSPECTIVE

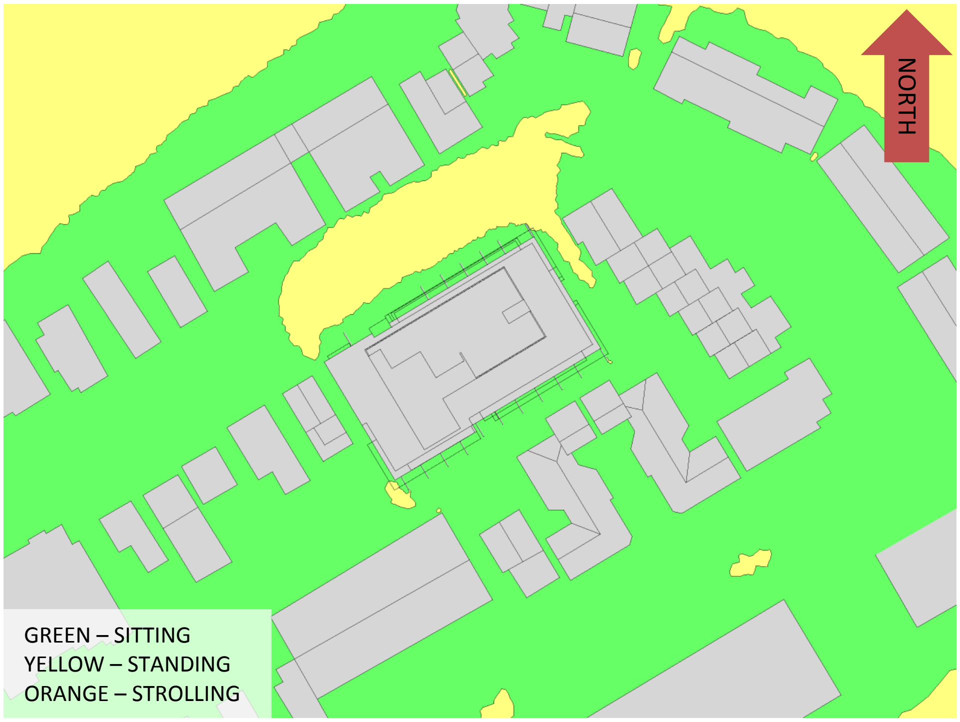


FIGURE 3A: SPRING – GRADE-LEVEL PEDESTRIAN WIND CONDITIONS

36 ROBINSON AVENUE – GRADE REFERENCE MARKER LOCATIONS

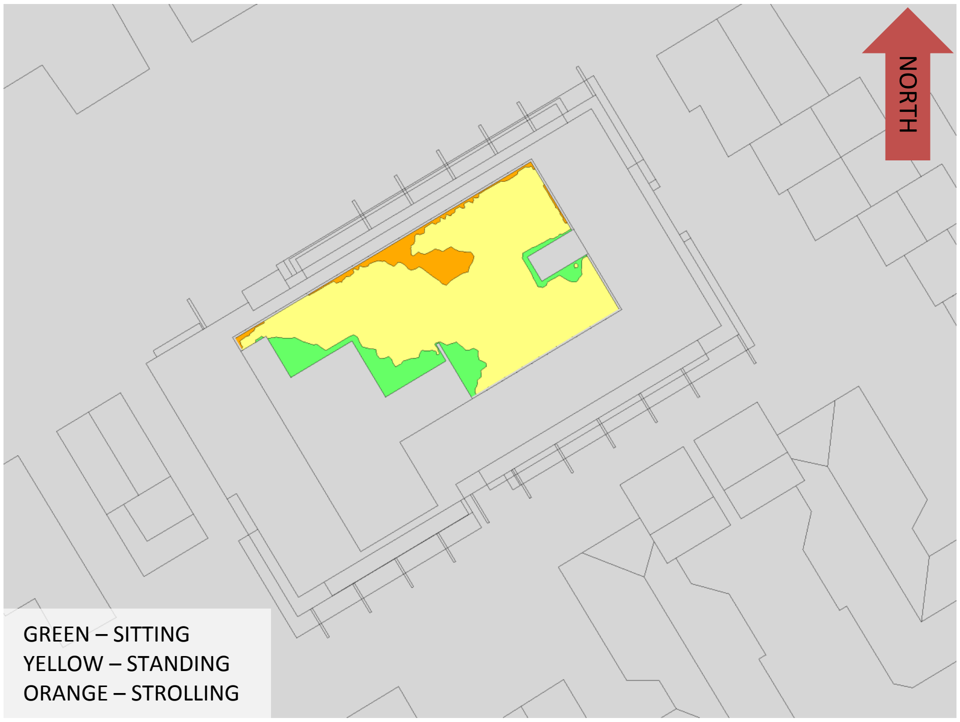


FIGURE 3B: SPRING – OUTDOOR AMENITY AREA WIND CONDITIONS

36 ROBINSON AVENUE – ROOFTOP AMENITY REFERENCE MARKER LOCATIONS

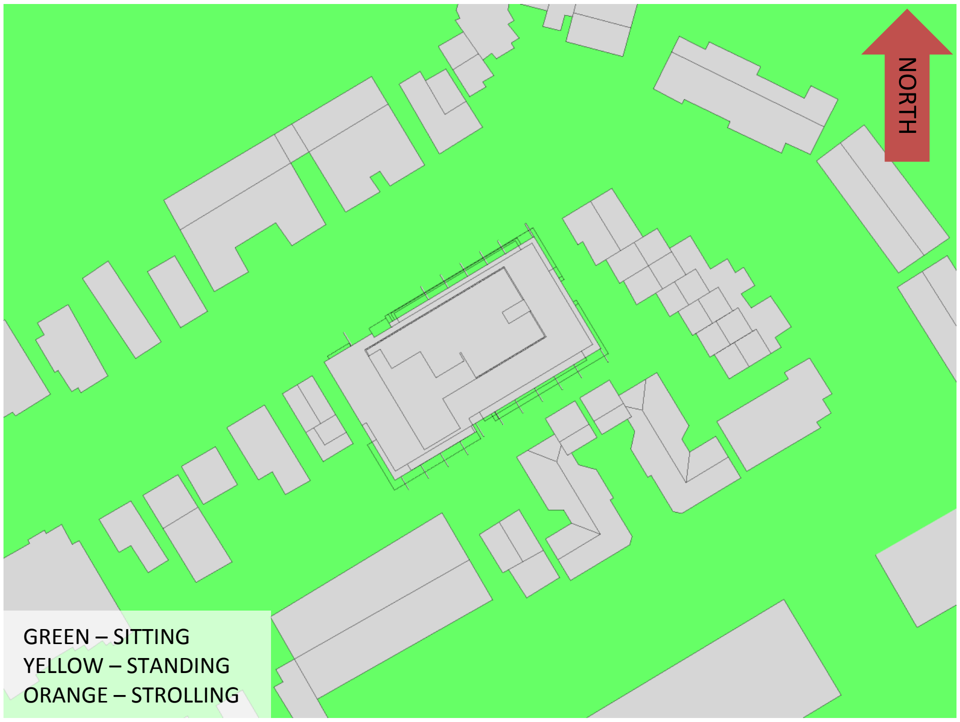


FIGURE 4A: SUMMER – GRADE-LEVEL PEDESTRIAN WIND CONDITIONS

36 ROBINSON AVENUE – GRADE REFERENCE MARKER LOCATIONS

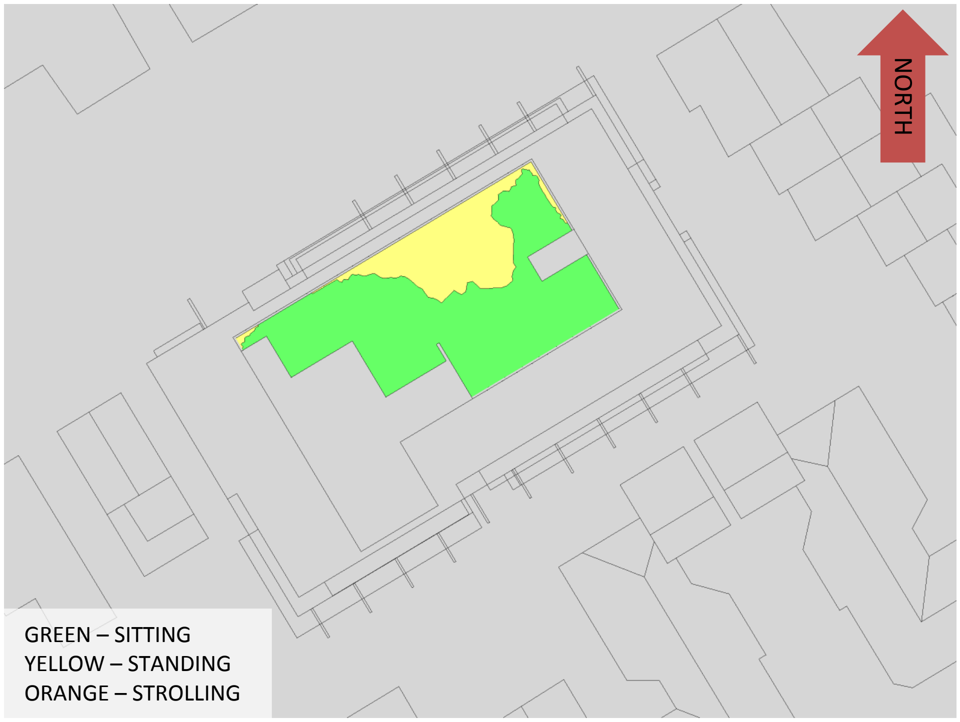


FIGURE 4B: SUMMER – OUTDOOR AMENITY AREA WIND CONDITIONS

36 ROBINSON AVENUE – ROOFTOP AMENITY REFERENCE MARKER LOCATIONS

FIGURE 5A: AUTUMN – GRADE-LEVEL PEDESTRIAN WIND CONDITIONS

36 ROBINSON AVENUE – GRADE REFERENCE MARKER LOCATIONS

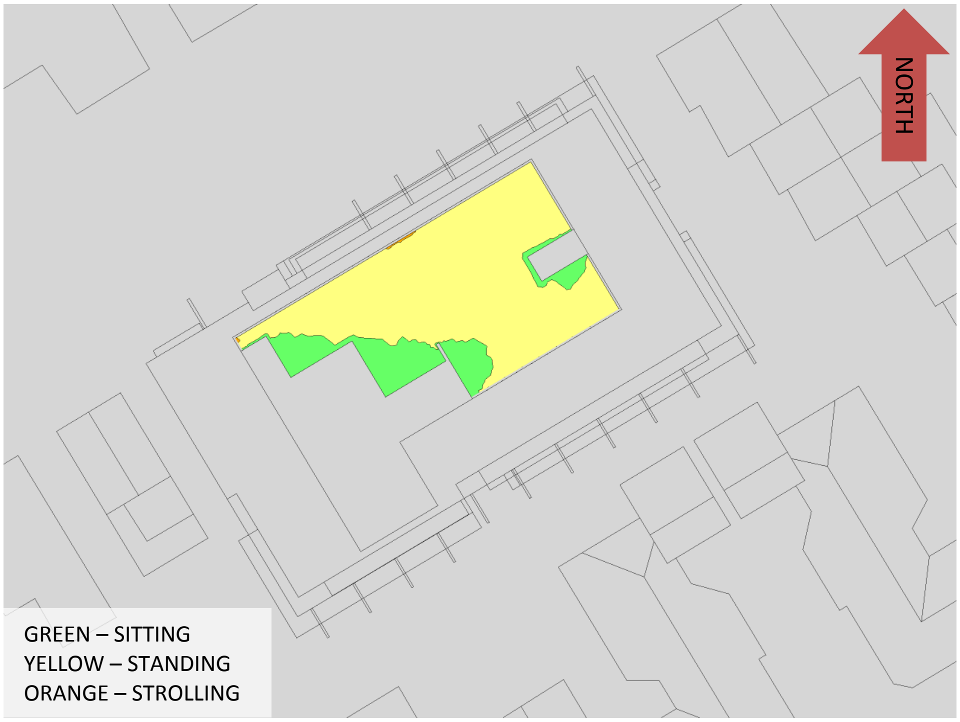


FIGURE 5B: AUTUMN – OUTDOOR AMENITY AREA WIND CONDITIONS

36 ROBINSON AVENUE – ROOFTOP AMENITY REFERENCE MARKER LOCATIONS

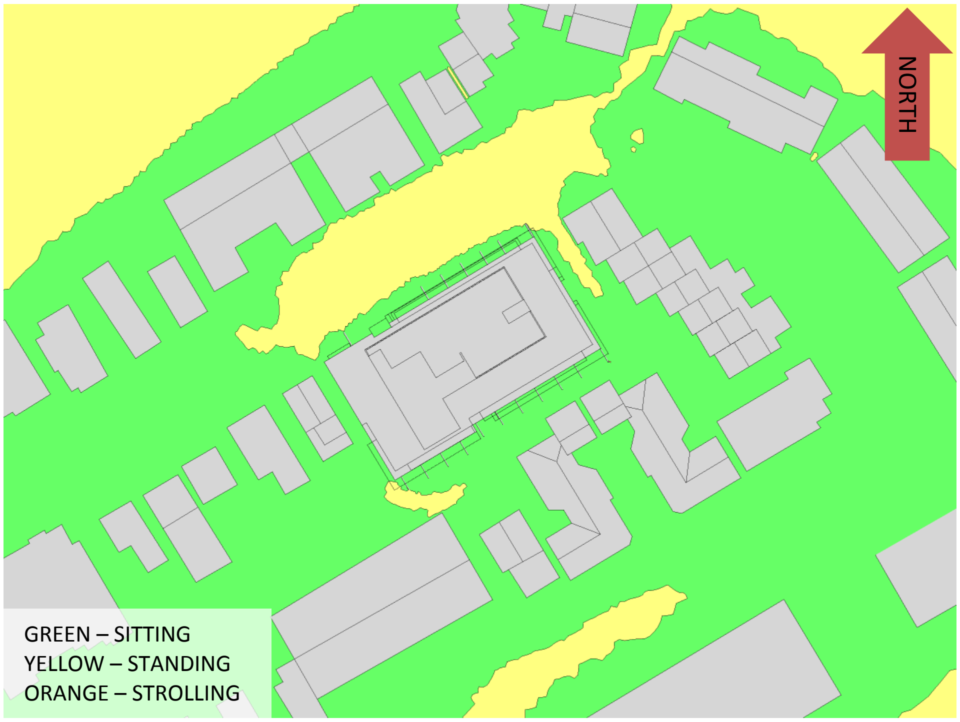


FIGURE 6A: WINTER – GRADE-LEVEL PEDESTRIAN WIND CONDITIONS

36 ROBINSON AVENUE – GRADE REFERENCE MARKER LOCATIONS

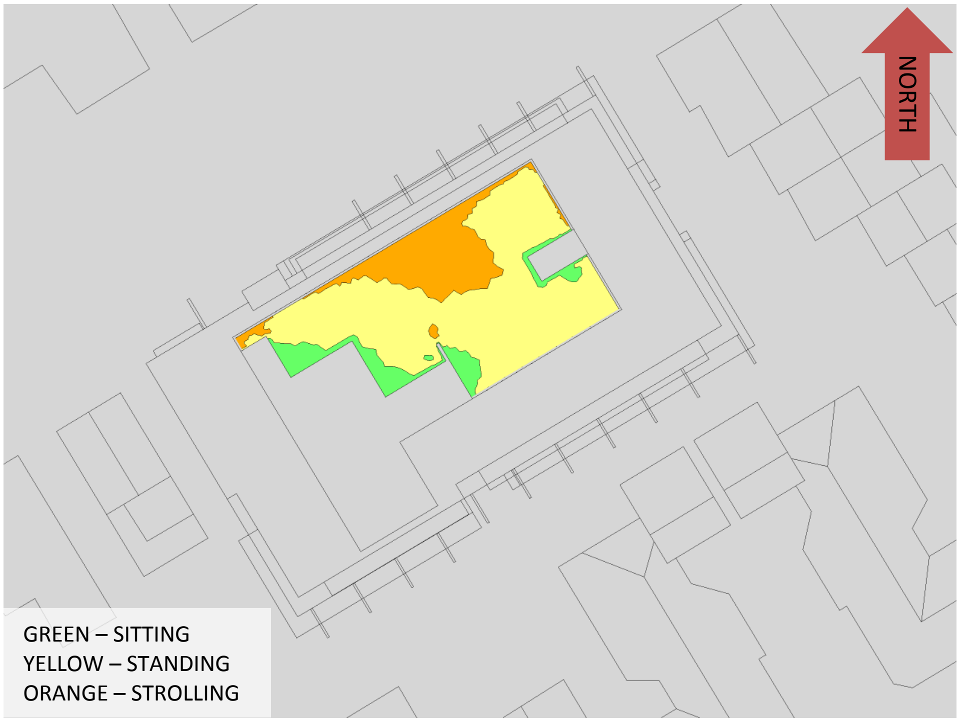
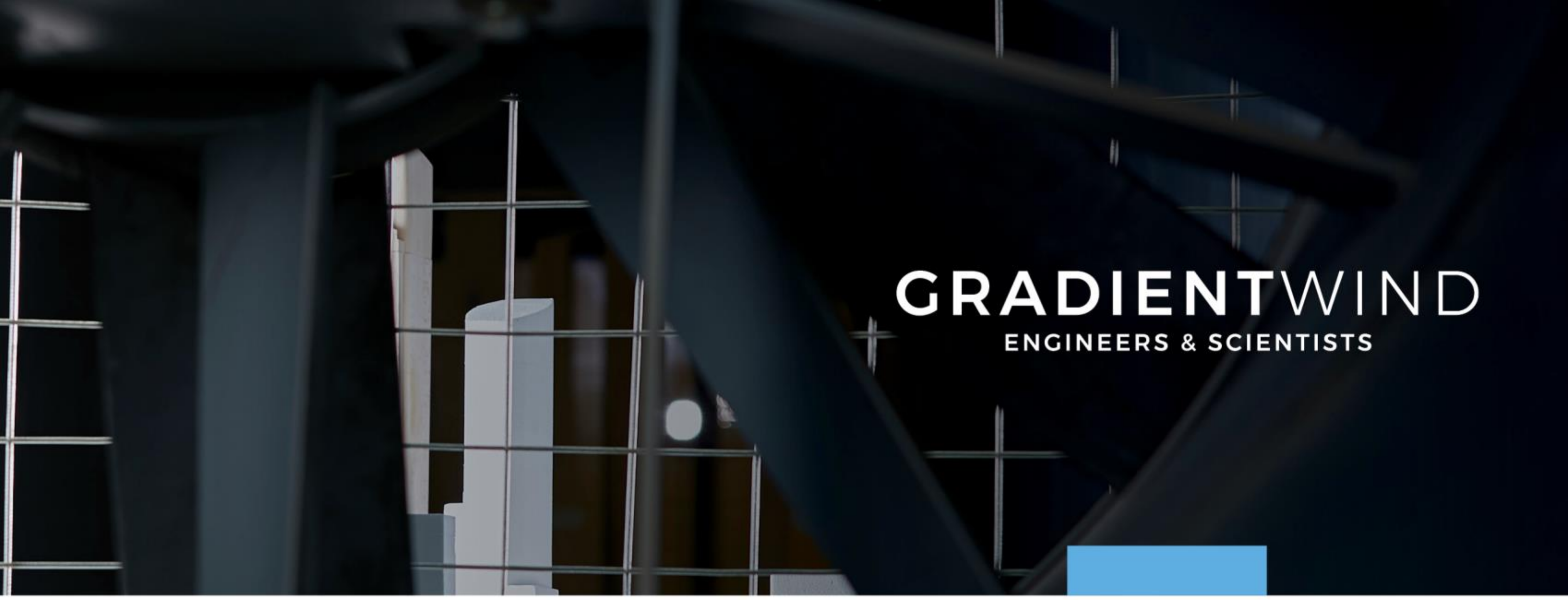
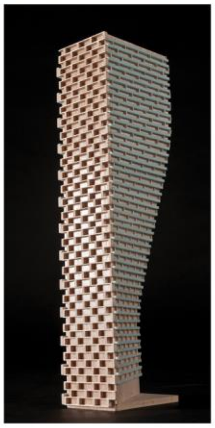
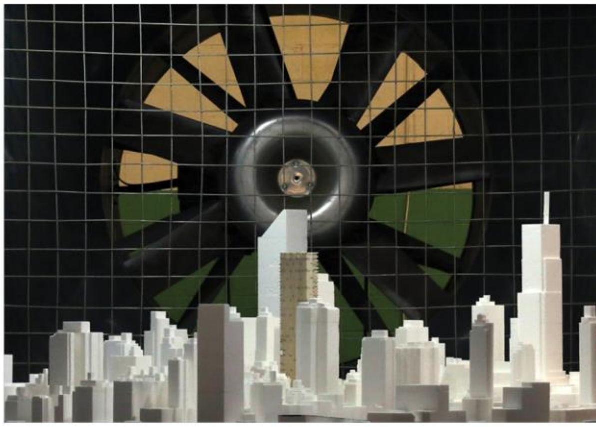


FIGURE 6B: WINTER – OUTDOOR AMENITY AREA WIND CONDITIONS

36 ROBINSON AVENUE – ROOFTOP AMENITY REFERENCE MARKER LOCATIONS







APPENDIX A

WIND TUNNEL SIMULATION OF THE NATURAL WIND

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WIND TUNNEL SIMULATION OF THE NATURAL WIND

Wind flowing over the surface of the earth develops a boundary layer due to the drag produced by surface features such as vegetation and man-made structures. Within this boundary layer, the mean wind speed varies from zero at the surface to the gradient wind speed at the top of the layer. The height of the top of the boundary layer is referred to as the gradient height, above which the velocity remains more-or-less constant for a given synoptic weather system. The mean wind speed is taken to be the average value over one hour. Superimposed on the mean wind speed are fluctuating (or turbulent) components in the longitudinal (i.e. along wind), vertical and lateral directions. Although turbulence varies according to the roughness of the surface, the turbulence level generally increases from nearly zero (smooth flow) at gradient height to maximum values near the ground. While for a calm ocean the maximum could be 20%, the maximum for a very rough surface such as the center of a city could be 100%, or equal to the local mean wind speed. The height of the boundary layer varies in time and over different terrain roughness within the range of 400 metres (m) to 600 m.

Simulating real wind behaviour in a wind tunnel requires simulating the variation of mean wind speed with height, simulating the turbulence intensity, and matching the typical length scales of turbulence. It is the ratio between wind tunnel turbulence length scales and turbulence scales in the atmosphere that determines the geometric scales that models can assume in a wind tunnel. Hence, when a 1:200 scale model is quoted, this implies that the turbulence scales in the wind tunnel and the atmosphere have the same ratios. Some flexibility in this requirement has been shown to produce reasonable wind tunnel predictions compared to full scale. In model scale the mean and turbulence characteristics of the wind are obtained with the use of spires at one end of the tunnel and roughness elements along the floor of the tunnel. The fan is located at the model end and wind is pulled over the spires, roughness elements and model. It has been found that, to a good approximation, the mean wind profile can be represented by a power law relation, shown below, giving height above ground versus wind speed.

$$U = U_g \left(\frac{Z}{Z_g} \right)^{\alpha}$$

Where; $\boldsymbol{U}$ = mean wind speed, $\boldsymbol{U_g}$ = gradient wind speed, $\boldsymbol{Z}$ = height above ground, $\boldsymbol{Z_g}$ = depth of the boundary layer (gradient height) and α is the power law exponent.

Figure B1 on the following page plots three velocity profiles for open country, and suburban and urban exposures.

The exponent α varies according to the type of upwind terrain; α ranges from 0.14 for open country to 0.33 for an urban exposure. Figure B2 illustrates the theoretical variation of turbulence for open country, suburban and urban exposures.

The integral length scale of turbulence can be thought of as an average size of gust in the atmosphere. Although it varies with height and ground roughness, it has been found to generally be in the range of 100 m to 200 m in the upper half of the boundary layer. Thus, for a 1:300 scale, the model value should be between 1/3 and 2/3 of a metre. Integral length scales are derived from power spectra, which describe the energy content of wind as a function of frequency. There are several ways of determining integral length scales of turbulence. One way is by comparison of a measured power spectrum in model scale to a non-dimensional theoretical spectrum such as the Davenport spectrum of longitudinal turbulence. Using the Davenport spectrum, which agrees well with full-scale spectra, one can estimate the integral scale by plotting the theoretical spectrum with varying L until it matches as closely as possible the measured spectrum:

$$f \times S(f) = \frac{\dfrac{4(Lf)^2}{U_{10}{}^2}}{\left[1 + \dfrac{4(Lf)^2}{U_{10}{}^2}\right]^{\frac{4}{3}}}$$

Where, f is frequency, S(f) is the spectrum value at frequency f, U10 is the wind speed 10 m above ground level, and L is the characteristic length of turbulence.

Once the wind simulation is correct, the model, constructed to a suitable scale, is installed at the center of the working section of the wind tunnel. Different wind directions are represented by rotating the model to align with the wind tunnel center-line axis.

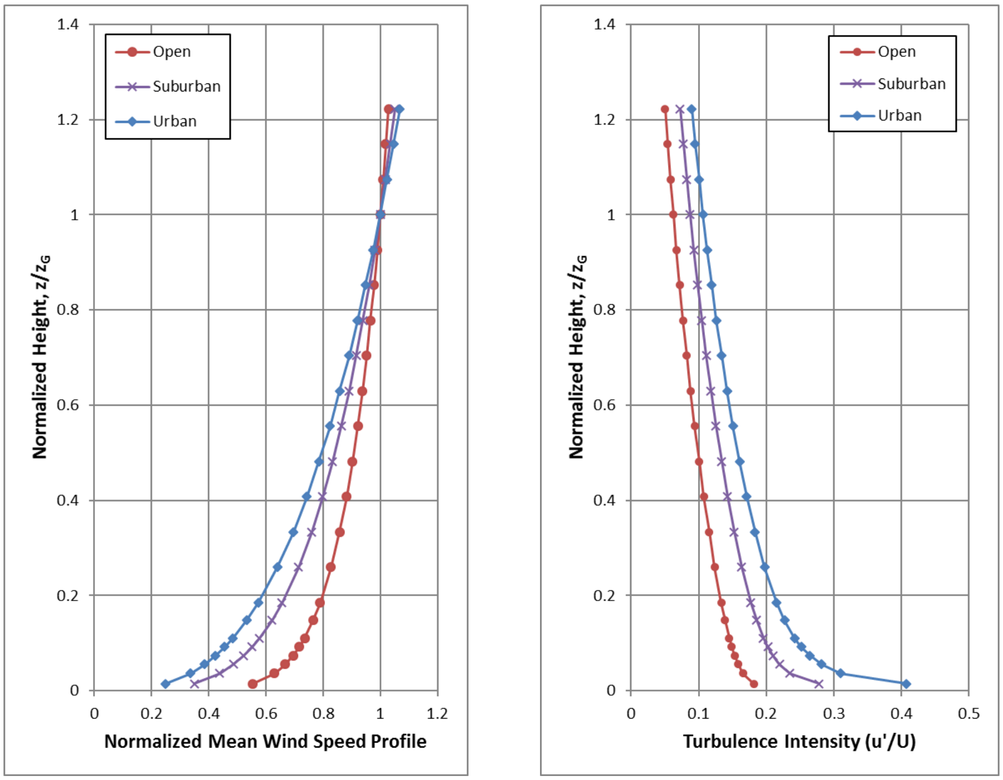

FIGURE A1 (LEFT): MEAN WIND SPEED PROFILES;
FIGURE A2 (RIGHT): TURBULENCE INTENSITY PROFILES

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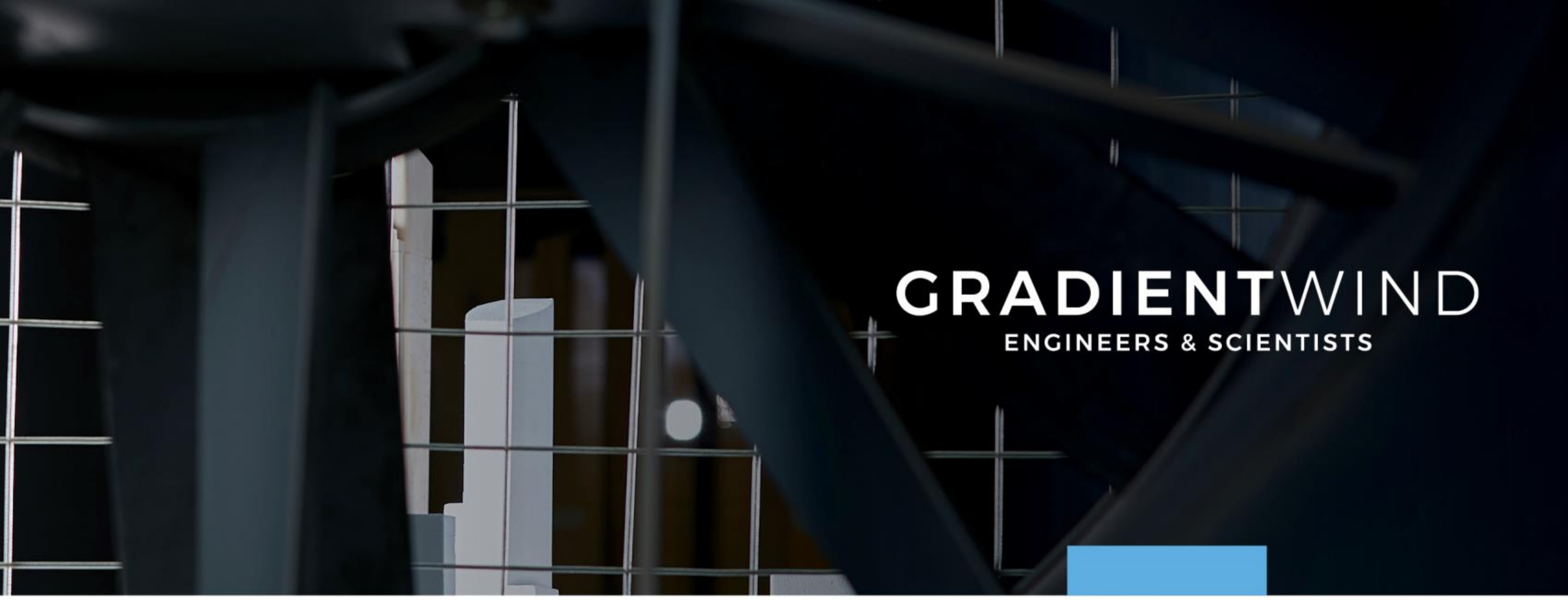

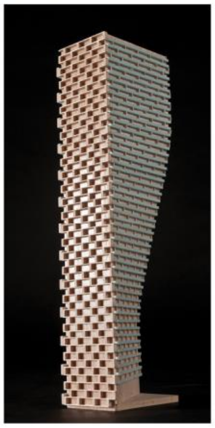

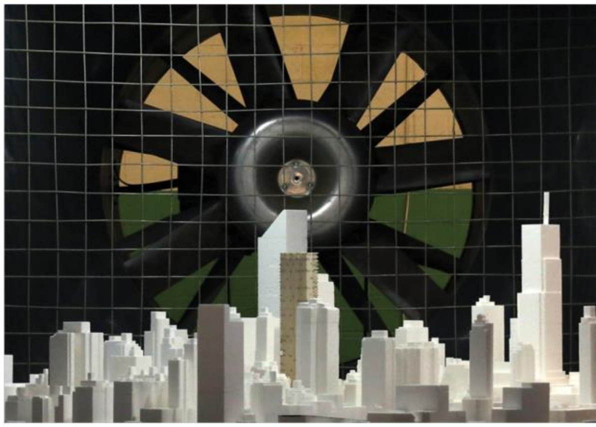

APPENDIX B

PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

The information contained within this appendix is offered to provide a greater understanding of the relationship between the physical wind tunnel testing method and virtual computer-based simulations

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PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

Pedestrian level wind studies are performed in a wind tunnel on a physical model of the study buildings at a suitable scale. Instantaneous wind speed measurements are recorded at a model height corresponding to 1.5 m full scale using either a hot wire anemometer or a pressure-based transducer. Measurements are performed at any number of locations on the model and usually for 36 wind directions. For each wind direction, the roughness of the upwind terrain is matched in the wind tunnel to generate the correct mean and turbulent wind profiles approaching the model.

The hot wire anemometer is an instrument consisting of a thin metallic wire conducting an electric current. It is an omni-directional device equally sensitive to wind approaching from any direction in the horizontal plane. By compensating for the cooling effect of wind flowing over the wire, the associated electronics produce an analog voltage signal that can be calibrated against velocity of the air stream. For all measurements, the wire is oriented vertically so as to be sensitive to wind approaching from all directions in a horizontal plane.

The pressure sensor is a small cylindrical device that measures instantaneous pressure differences over a small area. The sensor is connected via tubing to a transducer that translates the pressure to a voltage signal that is recorded by computer. With appropriately designed tubing, the sensor is sensitive to a suitable range of fluctuating velocities.

For a given wind direction and location on the model, a time history of the wind speed is recorded for a period of time equal to one hour in full-scale. The analog signal produced by the hot wire or pressure sensor is digitized at a rate of 400 samples per second. A sample recording for several seconds is illustrated in Figure B1. This data is analyzed to extract the mean, root-mean-square (rms) and the peak of the signal. The peak value, or gust wind speed, is formed by averaging a number of peaks obtained from sub-intervals of the sampling period. The mean and gust speeds are then normalized by the wind tunnel gradient wind speed, which is the speed at the top of the model boundary layer, to obtain mean and gust ratios. At each location, the measurements are repeated for 36 wind directions to produce normalized polar plots, which will be provided upon request.

In order to determine the duration of various wind speeds at full scale for a given measurement location the gust ratios are combined with a statistical (mathematical) model of the wind climate for the project site. This mathematical model is based on hourly wind data obtained from one or more meteorological stations (usually airports) close to the project location. The probability model used to represent the data is the Weibull distribution expressed as:

$$P\left(>U_g\right) = A_\theta \bullet \exp\left[\left(-\frac{U_g}{C\theta}\right)^{K\theta}\right]$$

Where,

P (> U_g) is the probability, fraction of time, that the gradient wind speed ***U_g*** is exceeded; ***θ*** is the wind direction measured clockwise from true north, ***A***, ***C***, ***K*** are the Weibull coefficients, (Units: A - dimensionless, C - wind speed units [km/h] for instance, K - dimensionless). ***A_θ*** is the fraction of time wind blows from a 10° sector centered on ***θ***.

Analysis of the hourly wind data recorded for a length of time, on the order of 10 to 30 years, yields the ***A_θ, C_θ*** and ***K_θ*** values. The probability of exceeding a chosen wind speed level, say 20 km/h, at sensor *N* is given by the following expression:

$$P_N(>20) = \Sigma_\theta P\left[\frac{(>20)}{\left(\frac{U_N}{U_g}\right)}\right]$$

$$P_N(>20) = \Sigma_\theta P\{>20/(U_N/Ug)\}$$

Where, ***U_N/U_g*** is the gust velocity ratios, where the summation is taken over all 36 wind directions at 10° intervals.

If there are significant seasonal variations in the weather data, as determined by inspection of the C_θ and K_θ values, then the analysis is performed separately for two or more times corresponding to the groupings of seasonal wind data. Wind speed levels of interest for predicting pedestrian comfort are based on the comfort guidelines chosen to represent various pedestrian activity levels as discussed in the main text.

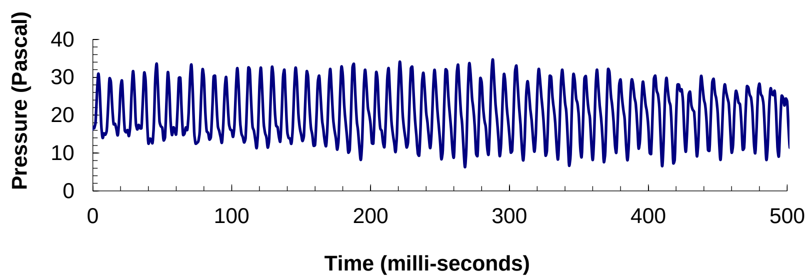

FIGURE B1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR

REFERENCES

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