# GRADIENTWIND
## ENGINEERS & SCIENTISTS

## PEDESTRIAN LEVEL WIND STUDY

50 The Driveway
Ottawa, Ontario

Report: 21-200-PLW

June 30, 2021

PREPARED FOR
Canadian Nurses Association
50 The Driveway
Ottawa, ON  K2P 1E2

PREPARED BY
Daniel Davalos, MESc., Junior Wind Scientist
Justin Ferraro, P.Eng., Principal

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# EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study undertaken to satisfy concurrent Official Plan Amendment (OPA) and Zoning By-law Amendment (ZBLA) application submissions for the proposed residential development located at 50 The Driveway in Ottawa (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind comfort and safety within and surrounding the subject site, and to identify any areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, as required.

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 wind comfort and safety within and surrounding the subject site according to City of Ottawa wind comfort and safety criteria. The results and recommendations derived from these considerations are detailed in the main body of the report (Section 5), illustrated in Figures 3A-3D, and summarized as follows:

1) All grade-level areas within and surrounding the subject site are predicted to be acceptable for the intended pedestrian uses throughout the year. Specifically, wind conditions over surrounding sidewalks, building access points, the exterior lobby lounge, and the surrounding greenspace are considered acceptable for the intended pedestrian uses throughout the year.

2) Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas within or surrounding the subject site at grade level were found to experience conditions that could be considered dangerous.

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## 1.    INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by the Canadian Nurses Association to undertake a pedestrian level wind (PLW) study to satisfy concurrent Official Plan Amendment (OPA) and Zoning By-law Amendment (ZBLA) application submissions for the proposed residential development located at 50 The Driveway in Ottawa (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind comfort and safety within and surrounding the subject site, and to identify any areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, as required.

Our work is based on industry standard computer simulations using the computational fluid dynamics (CFD) technique and data analysis procedures, City of Ottawa wind comfort and safety criteria, architectural drawings provided by Hobin Architecture Incorporated in June 2021, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, recent satellite imagery, and experience with similar numerous developments in Ottawa.

## 2.    TERMS OF REFERENCE

The subject site is located at 50 The Driveway in Ottawa, on a parcel of land bounded by Queen Elizabeth Driveway and the Rideau Canal the north, Lewis Street to the west, and existing low-rise dwellings to the south and east.

The proposed development comprises a 9-storey residential building rising approximately 30.4 meters (m) above the ground floor to the top of the main roof slab serving the mechanical penthouse. Above two levels of underground parking, the ground floor comprises a main residential entrance served by a vestibule at the northwest corner of building, which provides access to an interior lobby lounge, among other building services. Private residential suites are located along the south and east elevations, as well as within the northwest corner of the floorplate, while an interior amenity area is provided at the north elevation. An exterior lobby lounge is also provided at the north elevation, flanked by the main residential entrance to the west and the interior amenity area to the east. The parking entrance is provided at the southwest corner of the proposed development, providing access to two above grade parking levels. At Level 3, the building steps back from the northeast corner and rises with a uniform floorplate to Level 5.

At Levels 6 and 8, the floorplates step back from the east elevation to accommodate private terraces. A total of three penthouse suites are provided at Level 9, complete with balconies and terraces.

The near-field surroundings (defined as an area within 200 m of the subject site) are characterized by a mix of low-rise buildings, mostly residential, to the east-southeast clockwise to west-southwest, two 17-storey buildings to the west (40 The Driveway and 20 The Driveway), and open exposures on account of the Rideau Canal for the remaining compass directions. The far-field surroundings (defined as an area beyond the near-field but within a 2-kilometre (km) radius of the subject site) are characterized by mostly suburban low- and mid-rise massing for all directions. Additionally, the open exposure of the Central Experimental Farm lies between the north-northeast clockwise to the northwest approximately 1 km from the subject site. Further, the massing along Clyde Avenue to the south-southeast is predominantly low-rise commercial massing. Highway 417 runs southwest to northeast approximately 1.7 km to the northwest of the subject site.

Mostly low-rise dwellings with isolated mid-rise buildings from southeast clockwise to west-southwest, the dense downtown core consisting of mid-rise and high-rise buildings from the west-southwest clockwise to west-northwest, a mix of mid-rise and high-rise buildings from the west-northwest clockwise to north-northwest, and low-rise dwellings for the remaining compass directions. The subject site is situated approximately 62 m south of the Rideau Canal, which extends nominally east-to-west in the vicinity of the proposed development with a return to the south along the east side of the subject site.

Key areas under consideration include surrounding sidewalks, walkways, and building access points. The site plan for the proposed massing scenario is illustrated in Figure 1, while Figures 2A-2D illustrate the computational model used to conduct the study.

## 3.    OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian 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 CFD simulations of wind speeds across the subject site within a virtual environment, meteorological analysis of the Ottawa area wind climate, and synthesis of computational data with City of Ottawa wind comfort and safety criteria[1]. The following sections describe the analysis procedures, including a discussion of the noted pedestrian wind criteria.

### 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 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 subject 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 (i.e., windier) wind speed values.

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[1] City of Ottawa Terms of References: Wind Analysis
https://documents.ottawa.ca/sites/default/files/torwindanalysis_en.pdf

## 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 650 m.

Mean and peak wind speed data obtained over the subject 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 m 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. Gradient height represents the theoretical depth of the boundary layer of the earth's atmosphere, above which the mean wind speed remains constant. Further details of the wind flow simulation technique are presented in Appendix A.

## 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 Ottawa Macdonald-Cartier International Airport and obtained from Environment and Climate Change Canada. Wind speed and direction data were analyzed for each month of the year to determine the statistically prominent wind directions and corresponding speeds, and to characterize similarities between monthly weather patterns.

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 kilometers per hour (km/h). 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 36 km/h. The directional preference and relative magnitude of wind speed changes somewhat from season to season.

## SEASONAL DISTRIBUTION OF WIND
## OTTAWA MACDONALD-CARTIER INTERNATIONAL AIRPORT
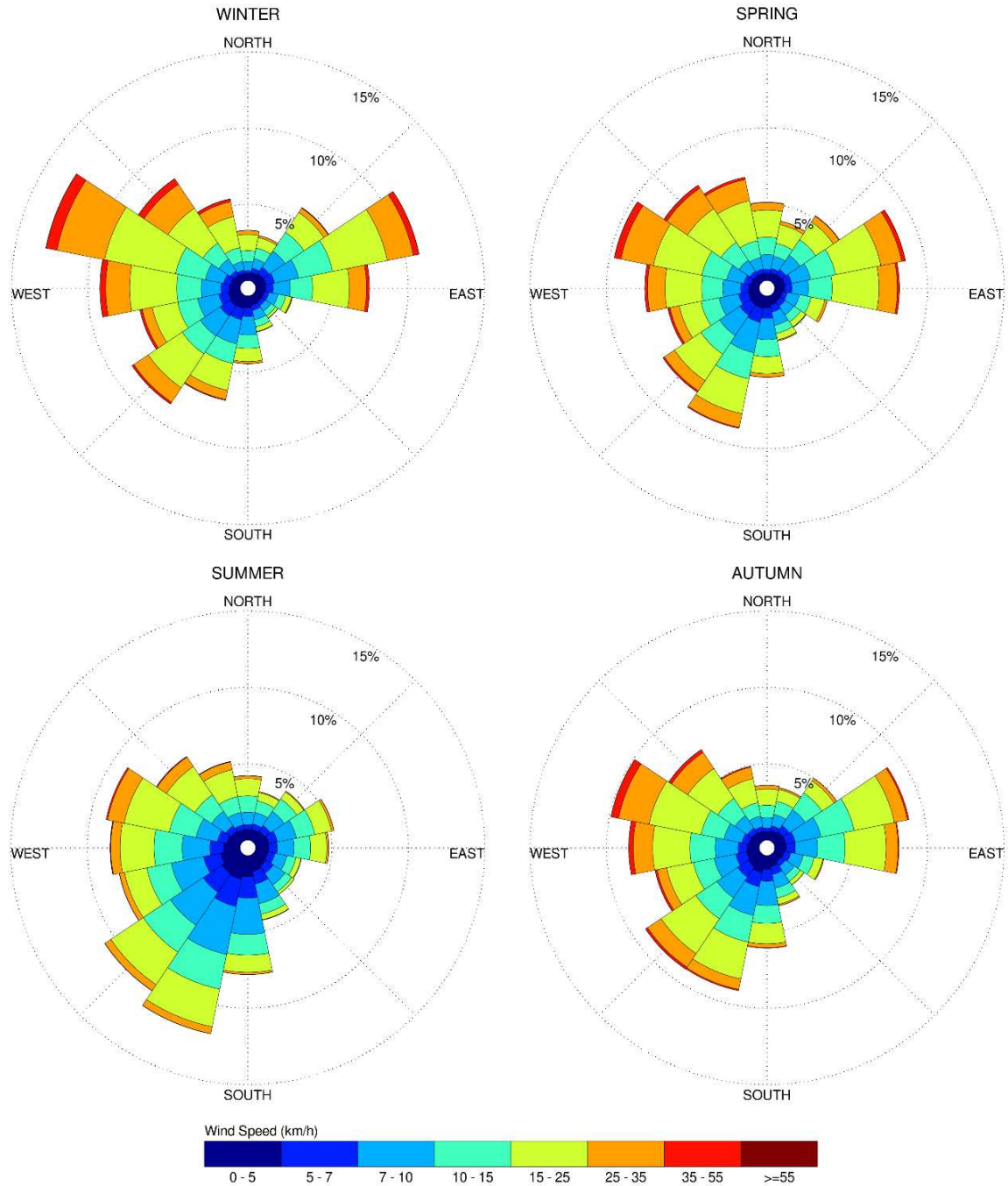


**Notes:**
1. Radial distances indicate percentage of time of wind events.
2. Wind speeds are mean hourly in km/h, measured at 10 m above the ground.

## 4.4 Pedestrian Comfort and Safety Criteria – City of Ottawa

Pedestrian comfort and safety criteria are based on the mechanical effects of wind without consideration of other meteorological conditions (i.e., temperature and relative humidity). The comfort criteria assume that pedestrians are appropriately dressed for a specified outdoor activity during any given season. Five pedestrian comfort classes are based on 20% non-exceedance mean wind speed ranges, which include (1) Sitting; (2) Standing; (3) Strolling; (4) Walking; and (5) Uncomfortable. More specifically, the comfort classes and associated mean wind speed ranges are summarized as follows:

1) **Sitting:** Mean wind speeds no greater than 10 km/h occurring at least 80% of the time. The equivalent gust wind speed is approximately 16 km/h.

2) **Standing:** Mean wind speeds no greater than 14 km/h occurring at least 80% of the time. The equivalent gust wind speed is approximately 22 km/h.

3) **Strolling:** Mean wind speeds no greater than 17 km/h occurring at least 80% of the time. The equivalent gust wind speed is approximately 27 km/h.

4) **Walking:** Mean wind speeds no greater than 20 km/h occurring at least 80% of the time. The equivalent gust wind speed is approximately 32 km/h.

5) **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 criterion.

The pedestrian safety wind speed criterion 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 90 km/h is classified as dangerous. The gust speeds, and equivalent mean speeds, 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. Gust speeds are included because pedestrians tend to be more sensitive to wind gusts than to steady winds for lower wind speed ranges. For strong winds approaching dangerous levels, this effect is less important because the mean wind can also create problems for pedestrians.

## THE BEAUFORT SCALE

| Number | Description | Wind Speed (km/h) | | Description |
|--------|-------------|------|------|-------------|
| | | Mean | Gust | |
| 2 | Light Breeze | 6-11 | 9-17 | Wind felt on faces |
| 3 | Gentle Breeze | 12-19 | 18-29 | Leaves and small twigs in constant motion; wind extends light flags |
| 4 | Moderate Breeze | 20-28 | 30-42 | Wind raises dust and loose paper; small branches are moved |
| 5 | Fresh Breeze | 29-38 | 43-57 | Small trees in leaf begin to sway |
| 6 | Strong Breeze | 39-49 | 58-74 | Large branches in motion; Whistling heard in electrical wires; umbrellas used with difficulty |
| 7 | Moderate Gale | 50-61 | 75-92 | Whole trees in motion; inconvenient walking against wind |
| 8 | Gale | 62-74 | 93-111 | 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 20% of the time, the activity level would be judged to be uncomfortable by most people. For instance, if a mean wind speed 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. Similarly, if a mean wind speed of 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 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 throughout the site, the assessment of pedestrian comfort involves determining the suitability of the predicted wind conditions for discrete regions within and surrounding the subject site. This step involves comparing the predicted comfort classes to the desired comfort classes, which are dictated by the location type for each region (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 |
|---|---|
| Primary Building Entrance | Standing |
| Secondary Building Access Point | Standing / Strolling / Walking |
| Primary Public Sidewalk | Strolling / Walking |
| Secondary Public Sidewalk / Bicycle Path | Walking |
| Outdoor Amenity Space | Sitting / Standing / Strolling |
| Café / Patio / Bench / Garden | Sitting |
| Transit Stop | Sitting / Standing |
| Public Park / Plaza | Standing / Strolling |
| Garage / Service Entrance | Walking |
| Parking Lot | Strolling / Walking |
| Vehicular Drop-Off Zone | Standing / Strolling / Walking |

## 5.    RESULTS AND DISCUSSION

The following discussion of predicted pedestrian wind conditions is accompanied by Figures 3A-3D, which illustrate seasonal wind conditions at grade level for the proposed massing scenario. Wind conditions are presented as continuous contours of wind comfort within and surrounding the subject site. The colour contours indicate various wind comfort classes predicted for certain regions, which correspond to the City of Ottawa wind comfort criteria in Section 4.4. Wind conditions comfortable for sitting or more sedentary activities are represented by the colour green, standing are represented by yellow, strolling by orange, and walking by blue. Uncomfortable conditions are represented by magenta.

In all locations studied, wind conditions are predicted to be acceptable following the introduction of the proposed development. The details of these conditions are summarized in the following pages for each area of interest.

## 5.1    Wind Comfort Conditions – Grade Level

Following the introduction of the proposed development, wind conditions within all public areas surrounding the subject site are predicted to be acceptable throughout the year according to the City of Ottawa wind comfort criteria. Specifically, conditions are predicted to be suitable for sitting during the summer season, becoming suitable for a mix of sitting and standing during the remaining three seasons.

Wind conditions within the property line of the subject site are predicted to be suitable for sitting throughout the year. The only exception is the southwest corner of the proposed development, adjacent to Lewis Street, which is predicted to be suitable for standing during the spring, autumn, and winter seasons. During the summer season, the area is predicted to be suitable for sitting. The noted conditions are considered acceptable according to the City of Ottawa wind criteria.

## 5.2    Wind Safety

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas within or surrounding the subject site at grade level were found to experience conditions that could be considered dangerous, as defined in Section 4.4.

## 5.3    Applicability of Results

Wind conditions over surrounding sidewalks beyond the subject site, as well as at nearby primary building entrances, are predicted to be acceptable for their intended pedestrian uses during each seasonal period upon the introduction of the proposed development. Pedestrian wind comfort and safety have been quantified for the specific configuration of existing and foreseeable construction around the subject site. Future changes (i.e., construction or demolition) of these surroundings may cause changes to the wind effects in two ways, namely: (i) changes beyond the immediate vicinity of the site would alter the wind profile approaching the site; and (ii) development in proximity to the site would cause changes to local flow patterns. For example, development in urban centers generally creates reduction in the mean wind speeds and localized increases in the gustiness of the wind.

Regarding primary and secondary building access points, wind conditions predicted in this study are only applicable to pedestrian comfort and safety. As such, the results should not be construed to indicate wind loading on doors and associated hardware.

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## 6. CONCLUSIONS AND RECOMMENDATIONS

A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-3B. Based on computer simulations using the CFD technique, meteorological data analysis of the Ottawa wind climate, City of Ottawa wind comfort and safety criteria, and experience with numerous similar developments in Ottawa, the study concludes the following:

1) All grade-level areas within and surrounding the subject site are predicted to be acceptable for the intended pedestrian uses throughout the year. Specifically, wind conditions over surrounding sidewalks, building access points, the exterior lobby lounge, and the surrounding greenspace are considered acceptable for the intended pedestrian uses throughout the year.

2) Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no pedestrian areas within or surrounding the subject site at grade level were found to experience conditions that could be considered dangerous.
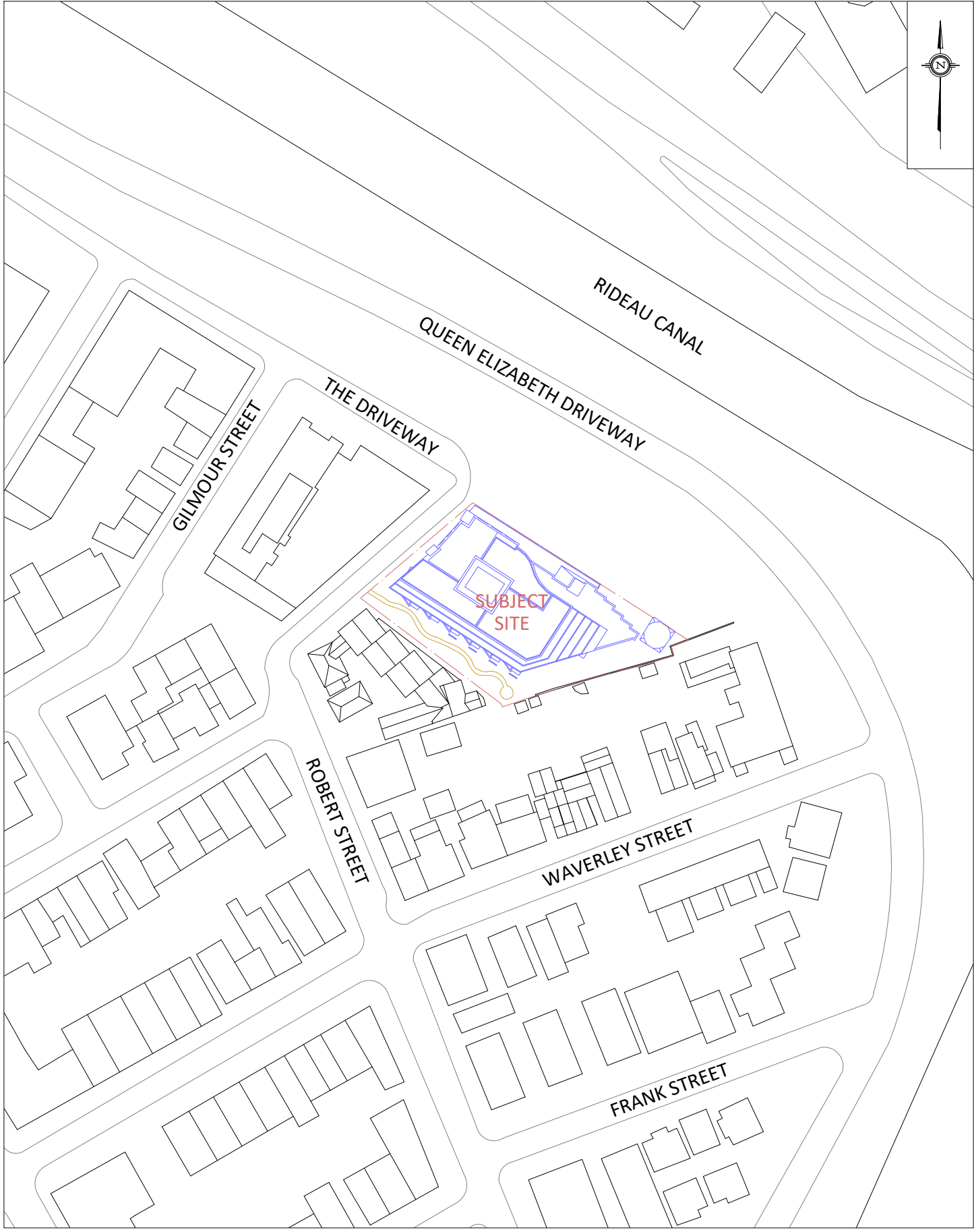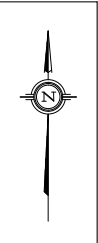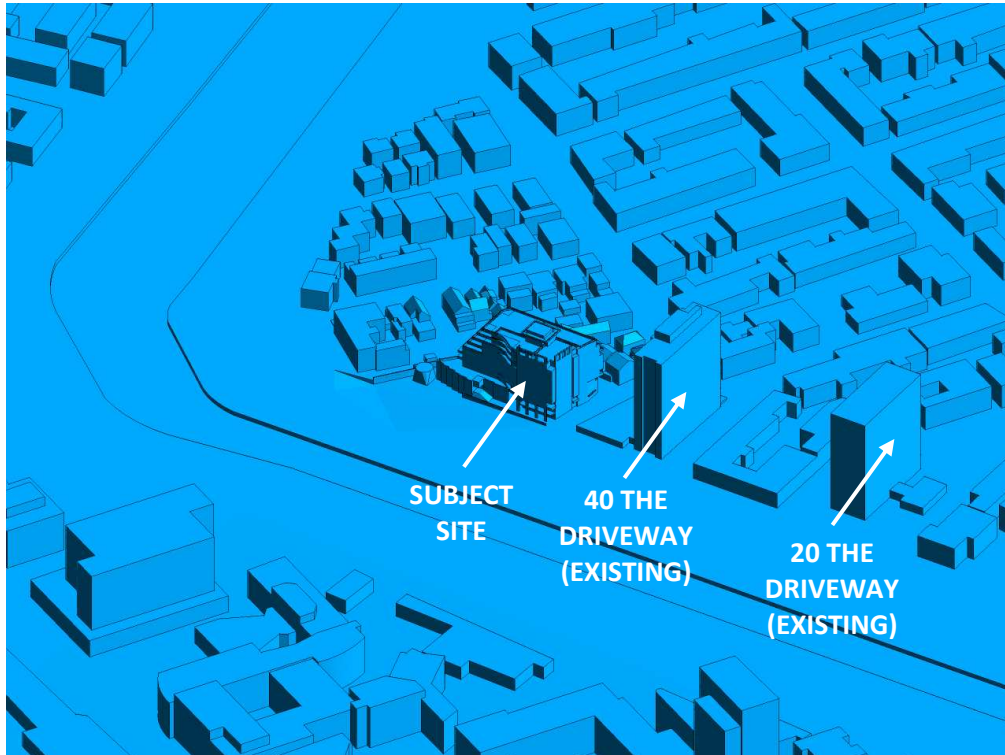
Sincerely,

*Gradient Wind Engineering Inc.*

Daniel Davalos, MESc.
Junior Wind Scientist

LICENSED PROFESSIONAL ENGINEER
J. D. FERRARO
100158495
PROVINCE OF ONTARIO

June 30, 2021

Justin Ferraro, P.Eng.
Principal

RIDEAU CANAL

QUEEN ELIZABETH DRIVEWAY

GILMOUR STREET

THE DRIVEWAY

SUBJECT SITE

ROBERT STREET

WAVERLEY STREET

FRANK STREET



**GRADIENT**WIND
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127 WALGREEN ROAD, OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

| PROJECT | 50 THE DRIVEWAY, OTTAWA PEDESTRIAN LEVEL WIND STUDY | | DESCRIPTION | |
|---|---|---|---|---|
| SCALE 1:1500 | | DRAWING NO. 21-200-PLW-1 | | FIGURE 1: SITE PLAN AND SURROUNDING CONTEXT |
| DATE JUNE 30, 2021 | | DRAWN BY O.R. | | |

**FIGURE 2A:  COMPUTATIONAL MODEL, PROPOSED MASSING, NORTH PERSPECTIVE**
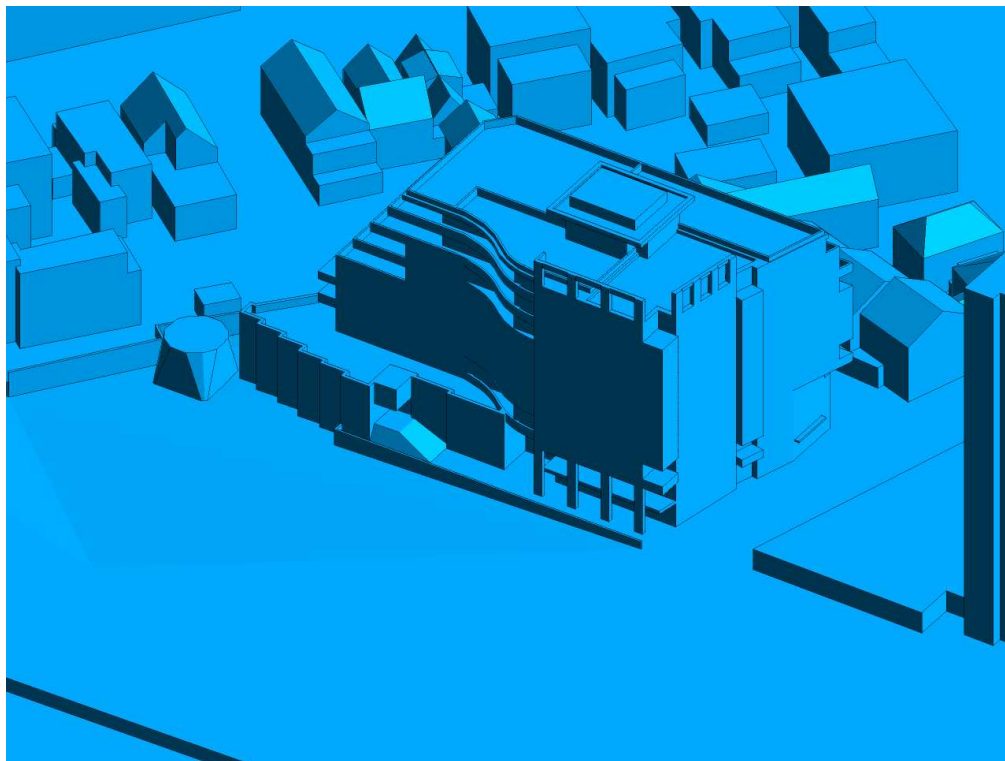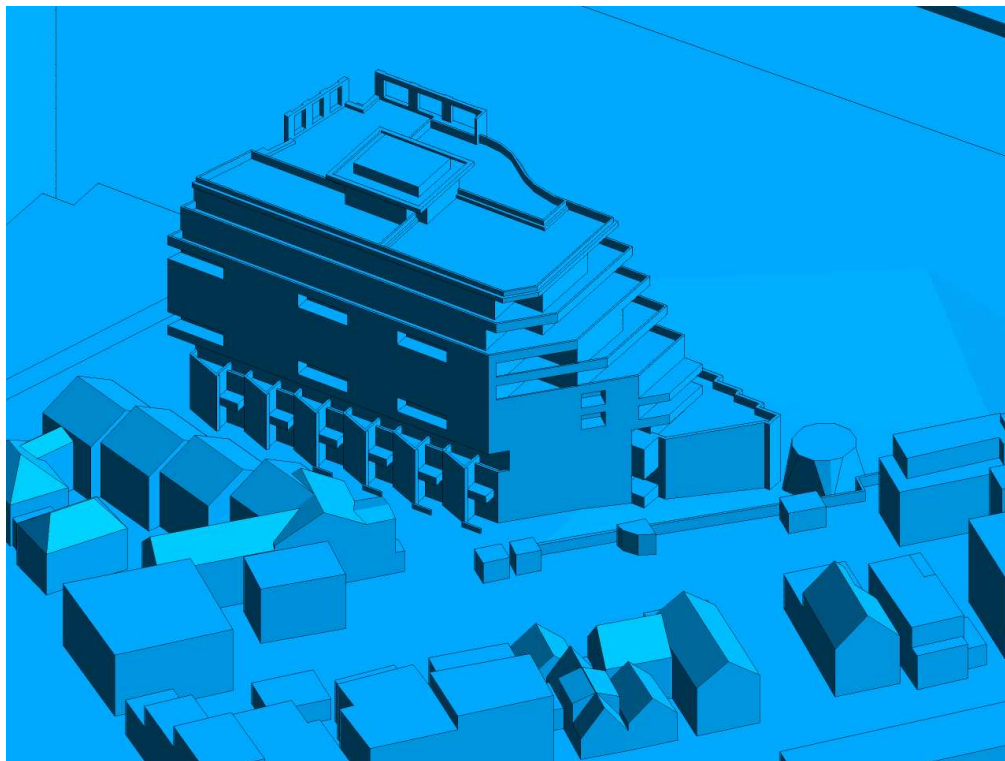

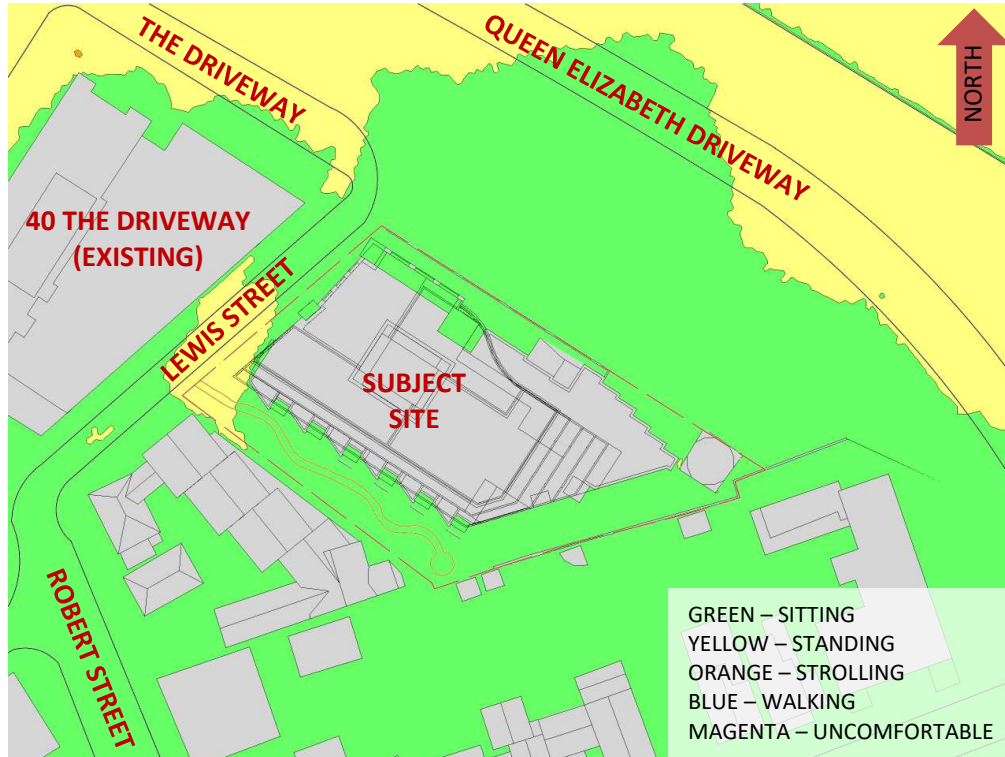
**FIGURE 2B:  CLOSE UP OF FIGURE 2A**
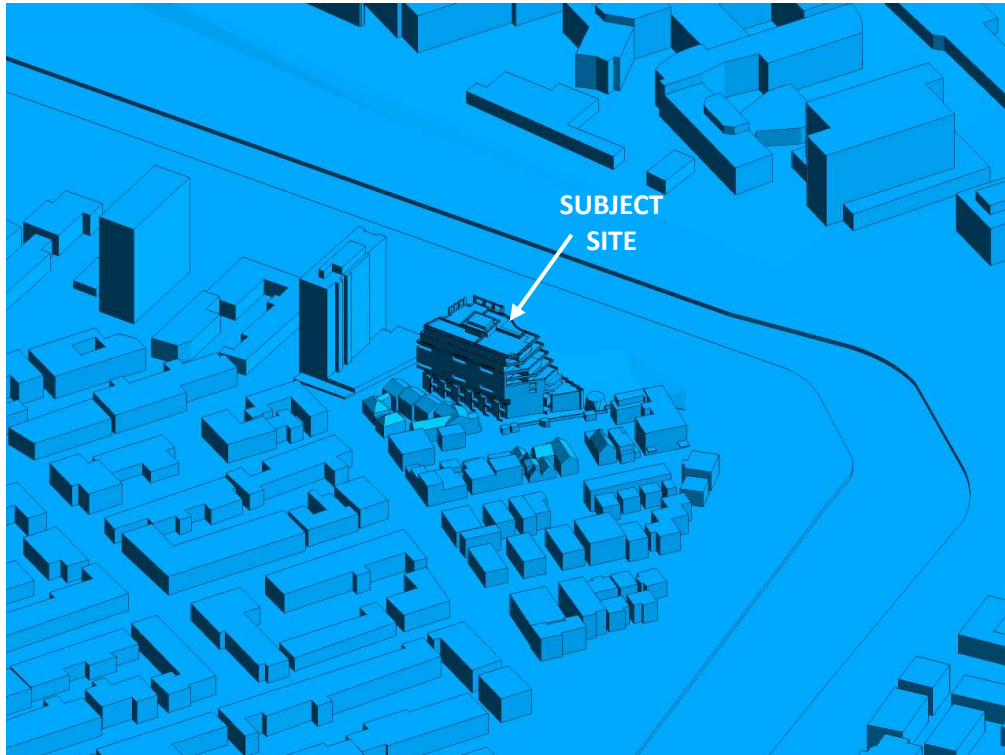
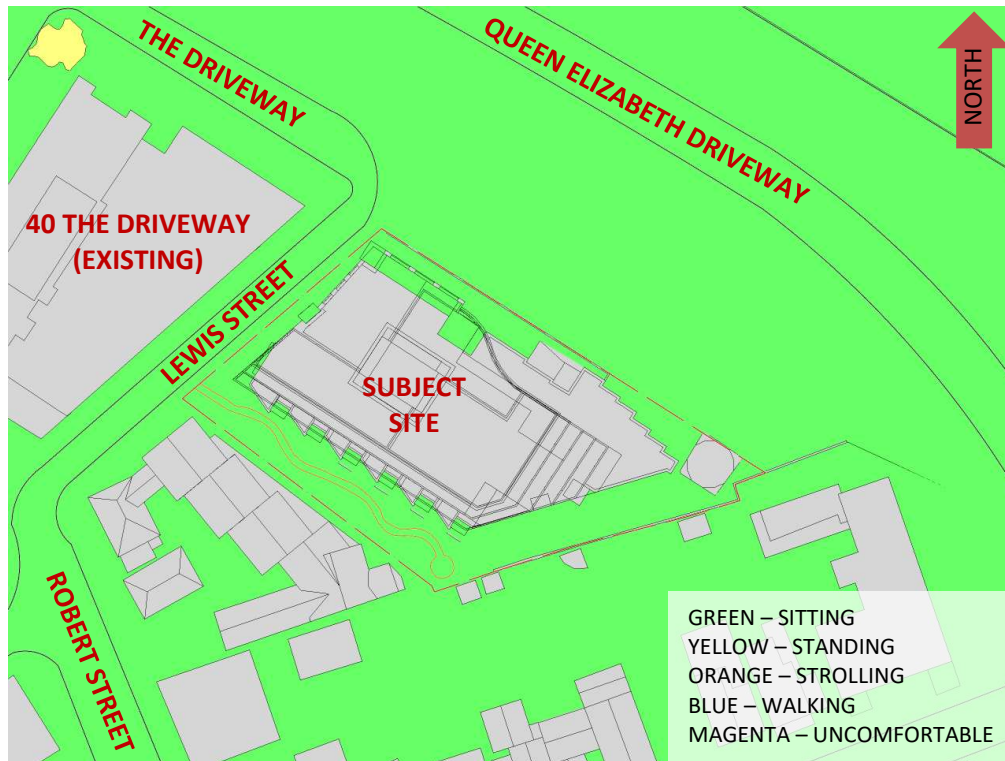**FIGURE 2C: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTH PERSPECTIVE**
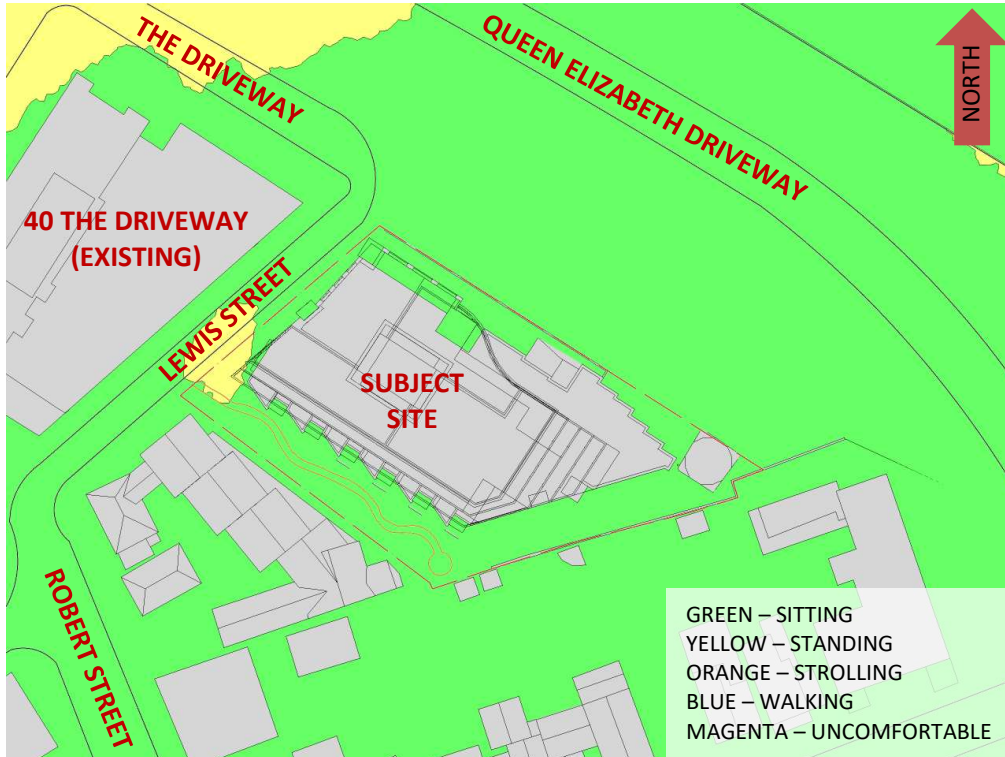


**FIGURE 2D: CLOSE UP OF FIGURE 2C**

**FIGURE 3A: SPRING – WIND COMFORT CONDITIONS, GRADE LEVEL**

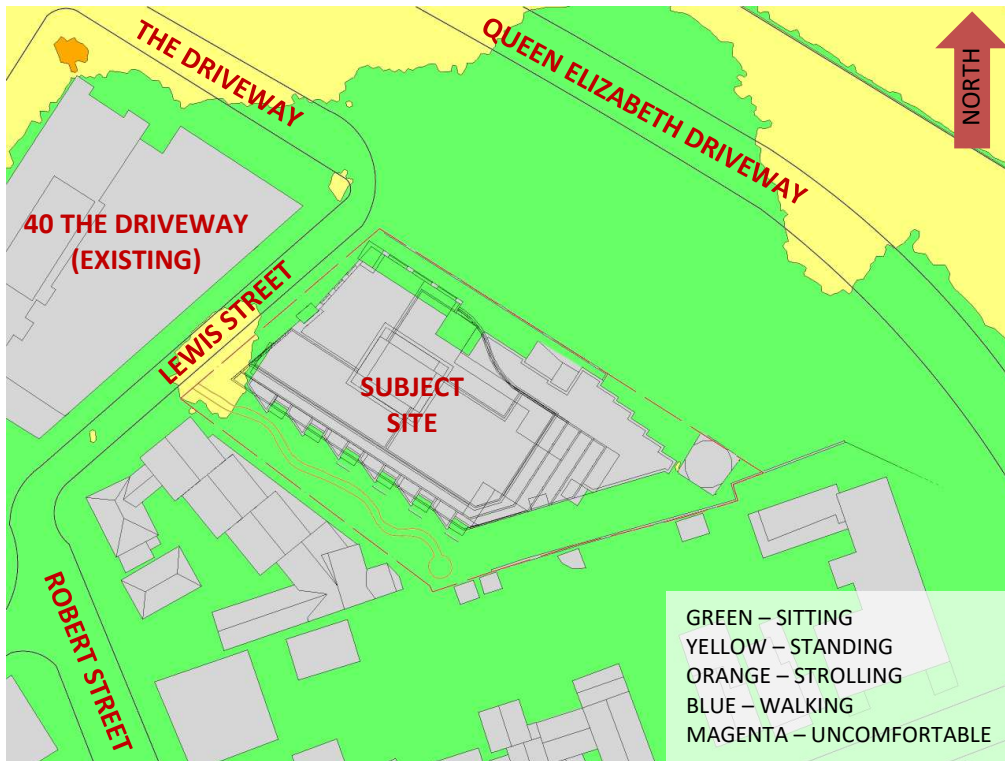GREEN – SITTING
YELLOW – STANDING
ORANGE – STROLLING
BLUE – WALKING
MAGENTA – UNCOMFORTABLE



**FIGURE 3B: SUMMER – WIND COMFORT CONDITIONS, GRADE LEVEL**

GREEN – SITTING
YELLOW – STANDING
ORANGE – STROLLING
BLUE – WALKING
MAGENTA – UNCOMFORTABLE

**FIGURE 3C: AUTUMN – WIND COMFORT CONDITIONS, GRADE LEVEL**



**FIGURE 3D: WINTER – WIND COMFORT CONDITIONS, GRADE LEVEL**

# APPENDIX A

## SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

# SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

The atmospheric boundary layer (ABL) is defined by the velocity and turbulence profiles according to industry standard practices. The mean wind profile can be represented, to a good approximation, by a power law relation, Equation (1), giving height above ground versus wind speed [1], [2].

$$U = U_g \left(\frac{Z}{Z_g}\right)^\alpha \qquad \text{Equation (1)}$$

where, $U$ = mean wind speed, $U_g$ = gradient wind speed, $Z$ = height above ground, $Z_g$ = depth of the boundary layer (gradient height), and $\alpha$ is the power law exponent.

For the model, $U_g$ is set to 6.5 metres per second (m/s), which approximately corresponds to the 60% mean wind speed for Ottawa based on historical climate data and statistical analyses. When the results are normalized by this velocity, they are relatively insensitive to the selection of gradient wind speed.

$Z_g$ is set to 540 m. The selection of gradient height is relatively unimportant, so long as it exceeds the building heights surrounding the subject site. The value has been selected to correspond to our physical wind tunnel reference value.

$\alpha$ is determined based on the upstream exposure of the far-field surroundings (i.e., the area that it not captured within the simulation model).

Table 1 presents the values of α used in this study, while Table 2 presents several reference values of α. When the upstream exposure of the far-field surroundings is a mixture of multiple types of terrain, the α values are a weighted average with terrain that is closer to the subject site given greater weight.

### TABLE 1:  UPSTREAM EXPOSURE (ALPHA VALUE) VS TRUE WIND DIRECTION

| Wind Direction (Degrees True) | Alpha Value ($\alpha$) |
|---|---|
| 0 | 0.26 |
| 49 | 0.26 |
| 74 | 0.24 |
| 103 | 0.23 |
| 167 | 0.25 |
| 197 | 0.26 |
| 217 | 0.26 |
| 237 | 0.26 |
| 262 | 0.28 |
| 282 | 0.30 |
| 302 | 0.26 |
| 324 | 0.26 |

**TABLE 2: DEFINITION OF UPSTREAM EXPOSURE (ALPHA VALUE)**

| Upstream Exposure Type | Alpha Value ($\alpha$) |
|---|---|
| Open Water | 0.14-0.15 |
| Open Field | 0.16-0.19 |
| Light Suburban | 0.21-0.24 |
| Heavy Suburban | 0.24-0.27 |
| Light Urban | 0.28-0.30 |
| Heavy Urban | 0.31-0.33 |

The turbulence model in the computational fluid dynamics (CFD) simulations is a two-equation shear-stress transport (SST) model, and thus the ABL turbulence profile requires that two parameters be defined at the inlet of the domain. The turbulence profile is defined following the recommendations of the Architectural Institute of Japan for flat terrain [3].

$$
I(Z) = \begin{cases} 0.1 \left( \dfrac{Z}{Z_g} \right)^{-\alpha-0.05}, & Z > 10 \text{ m} \\[2mm] 0.1 \left( \dfrac{10}{Z_g} \right)^{-\alpha-0.05}, & Z \leq 10 \text{ m} \end{cases} \qquad \text{Equation (2)}
$$

$$
L_t(Z) = \begin{cases} 100 \text{ m} \sqrt{\dfrac{Z}{30}}, & Z > 30 \text{ m} \\[2mm] 100 \text{ m}, & Z \leq 30 \text{ m} \end{cases} \qquad \text{Equation (3)}
$$

where, $I$ = turbulence intensity, $L_t$ = turbulence length scale, $Z$ = height above ground, and $\alpha$ is the power law exponent used for the velocity profile in Equation (1).

Boundary conditions on all other domain boundaries are defined as follows: the ground is a no-slip surface; the side walls of the domain have a symmetry boundary condition; the top of the domain has a specified shear, which maintains a constant wind speed at gradient height; and the outlet has a static pressure boundary condition.

# REFERENCES

[1] P. Arya, "Chapter 10: Near-neutral Boundary Layers," in *Introduction to Micrometeorology*, San Diego, California, Academic Press, 2001.

[2] S. A. Hsu, E. A. Meindl and D. B. Gilhousen, "Determining the Power-Law WInd Profile Exponent under Near-neutral Stability Conditions at Sea," vol. 33, no. 6, 1994.

[3] Y. Tamura, H. Kawai, Y. Uematsu, K. Kondo and T. Okhuma, "Revision of AIJ Recommendations for Wind Loads on Buildings," in *The International Wind Engieering Symposium, IWES 2003*, Taiwan, 2003.