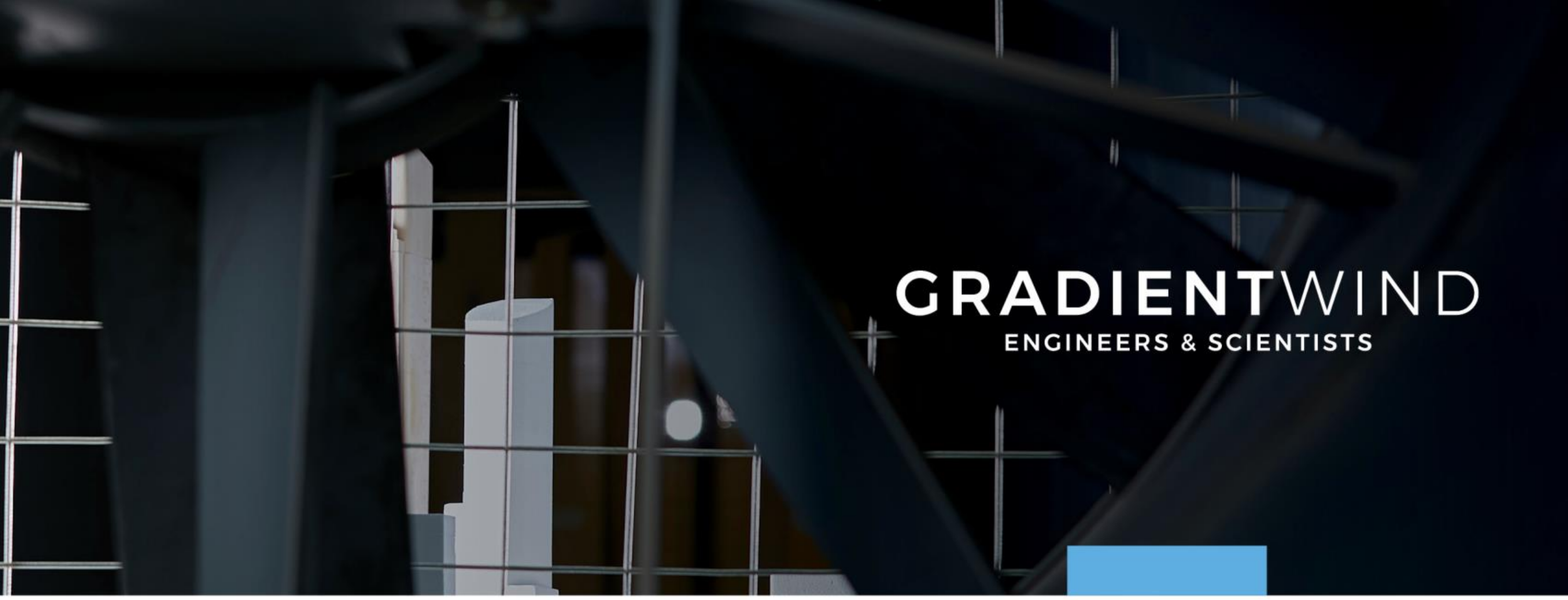
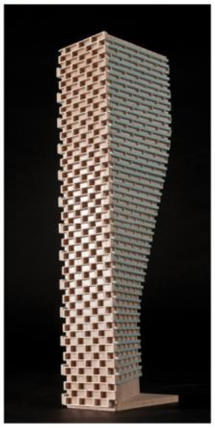
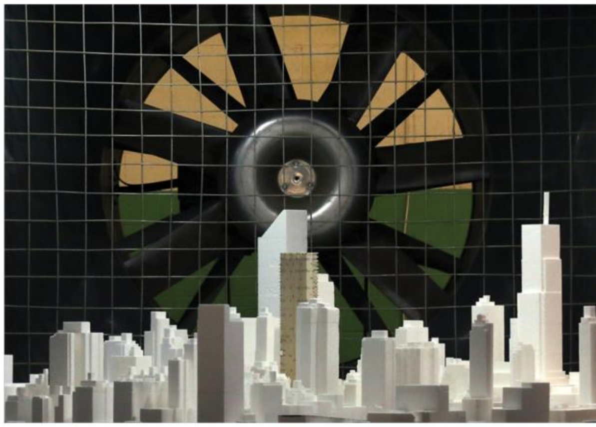



# PEDESTRIAN LEVEL WIND STUDY

5000 Robert Grant Avenue
Ottawa, Ontario

Report: 23-225-PLW





November 2, 2023

PREPARED FOR
Canadian Rental Development Services Inc.
206-555 Legget Drive (Tower A)
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PREPARED BY
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# EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study undertaken to satisfy Site Plan Control application submission requirements for the proposed multi-building development located at 5000 Robert Grant Avenue in Ottawa, Ontario (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind conditions within and surrounding the subject site, and to identify areas where conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where 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-7, and summarized as follows:

1) Most grade-level areas within and surrounding the subject site are predicted to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. Specifically, conditions over surrounding sidewalks, driveways, laneway, walkways, drop-off areas, surface parking, the common amenity terrace serving the proposed development, and in the vicinity of building access points, are considered acceptable. The areas that are predicted to experience windy conditions are described as follows:

    a. **Primary Building Entrances fronting the Drive Aisle Between Pavilions B and C.** Windy conditions are predicted along the drive aisle between Pavilions B and C during the colder months of the year. Wind conditions in the vicinity of the primary building entrances along the south elevation of Pavilion C and at the northwest corner of Pavilion B are predicted to be suitable for standing, or better, during the summer, becoming suitable for strolling, or better, throughout the remainder of the year.

    It is recommended that the commercial entrances along the south elevation of Pavilion C and the main residential entrance at the northwest corner of Pavilion B be recessed into the building façade by at least 2 m.

2) The foregoing statements and conclusions apply to common weather systems, during which no dangerous wind conditions, as defined in Section 4.4, are expected anywhere over the subject site. During extreme weather events (for example, thunderstorms, tornadoes, and downbursts), pedestrian safety is the main concern. However, these events are generally short-lived and infrequent and there is often sufficient warning for pedestrians to take appropriate cover.

**Addendum**: The PLW study was completed based on architectural drawings prepared by NEUF architect(e)s in September 2023. Updated drawings were distributed to the consultant team on October 25, 2023, which include the mitigation recommendations for the primary building entrance serving Pavilion B at the northwest corner and the primary building entrance serving the retail spaces along the south elevation of Pavilion C. Specifically, a nominally triangular notch has been applied at the northwest corner of Pavilion B and the primary building access is now recessed into the building façade by 3.46 m and also includes a vestibule, which is accessed by a sliding door. The main entrance serving Pavilion C along the south elevation has been recessed into the building façade by 2.2 m.

The noted changes are expected to increase wind comfort conditions in the vicinity of the noted primary building entrances serving Pavilions B and C. Additional simulations to confirm the expected wind conditions are not required.

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# 1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Canadian Rental Development Services Inc. to undertake a pedestrian level wind (PLW) study to satisfy Site Plan Control application submission requirements for the proposed multi-building residential development located at 5000 Robert Grant Avenue in Ottawa, Ontario (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind conditions within and surrounding the subject site, and to identify areas where conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where 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 prepared by NEUF architect(e)s in September 2023, surrounding street layouts and existing and approved future building massing information obtained from the City of Ottawa, as well as recent satellite imagery.

# 2. TERMS OF REFERENCE

The subject site is located at 5000 Robert Grant Avenue in Ottawa, situated approximately 140 metres (m) southeast of the intersection of Robert Grant Avenue and Abbott Street East, on a parcel of land bounded by Robert Grant Avenue to the southwest, Livery Street to the northeast, and green spaces and vacant lots to the northwest and southeast. The proposed development comprises three nearly rectangular buildings: Pavilion A (6 storeys), Pavilion B (9 storeys), and Pavilion C (18 storeys), situated to the northeast, southeast, and west of the subject site, respectively. The three buildings share three below-grade parking levels. The subject site comprises a downwards slope towards the northeast; therefore, the ground floor is at the level of Robert Grant Avenue and the P1 Level is level with Livery Street. The roof of the underground parking comprises a central roundabout with drop-off areas for each building and walking pathways between the buildings. Throughout this report, Robert Grant Avenue is considered as project west.

At the P1 Level, Pavilion A includes a main entrance and residential units along the east elevation, a garbage room at the southwest corner, a bike room, electrical room, and locker room along the west elevation, and a bike room at the northwest corner. Access to the underground parking is provided by a ramp to the south of Pavilion A via a driveway from Livery Street. Level 1 of Pavilion A includes a main entrance, lounge, and a drop-off area nearly central along the west elevation and residential units throughout the remainder of the level. Levels 2-5 are reserved for residential occupancy. The building steps back from the south elevation at Level 5.

The ground floor of Pavilion B includes a main entrance, lounge, and drop-off area at the northwest corner and residential units throughout the remainder of the level. Access to underground parking is provided by a ramp near the southwest corner via a driveway from Robert Grant Avenue. Levels 2-9 are reserved for residential occupancy. The building steps back from the west and east elevations at Levels 8 and 9.

The ground floor of Pavilion C includes a main entrance and lounge to the east, an administration office at the southeast corner, commercial spaces to the south, a gym room and yoga area to the west, a pool room at the northwest corner, a party room at the northeast corner, and shared building support spaces throughout the remainder of the level. A common amenity terrace is provided near the northeast corner. Levels 2-18 are reserved for residential occupancy. The building steps back from all elevations at Level 4, from the north and south elevations at Levels 16 and 17, and from the southwest and southeast corners at Level 18.

The near-field surroundings, defined as an area within 200-metres (m) of the subject site, include low-rise residential dwellings from the northeast clockwise to the southeast, a mix of green space and mid-rise residential buildings from the southeast clockwise to the south, low-rise residential buildings from the southwest clockwise to the west, a low-rise school building to the northwest, and green space in the remaining directions. Notably, a development comprising four six-storey residential buildings and a single two-storey commercial building is approved at 360 Bobolink Ridge, approximately 100 m to the southeast, and a development comprising ten blocks of stacked townhomes is approved at 723 Putney Crescent, to the immediate southwest across Robert Grant Avenue. 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 a mix of low-rise suburban massing and green spaces and vacant lots from the north-northwest clockwise to the west-northwest, with green spaces and fields to the northwest and from the east clockwise to the south.

Site plans for the proposed and existing massing scenarios are illustrated in Figures 1A and 1B, while Figures 2A-2H illustrate the computational models used to conduct the study. The existing massing scenario includes the existing massing and any future developments approved by the City of Ottawa.

## 3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind 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.

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

## 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 stronger wind speeds.

## 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 proposed development, complete with surrounding massing within a radius of 550 m. The process was performed for two context massing scenarios, as noted in Section 2.

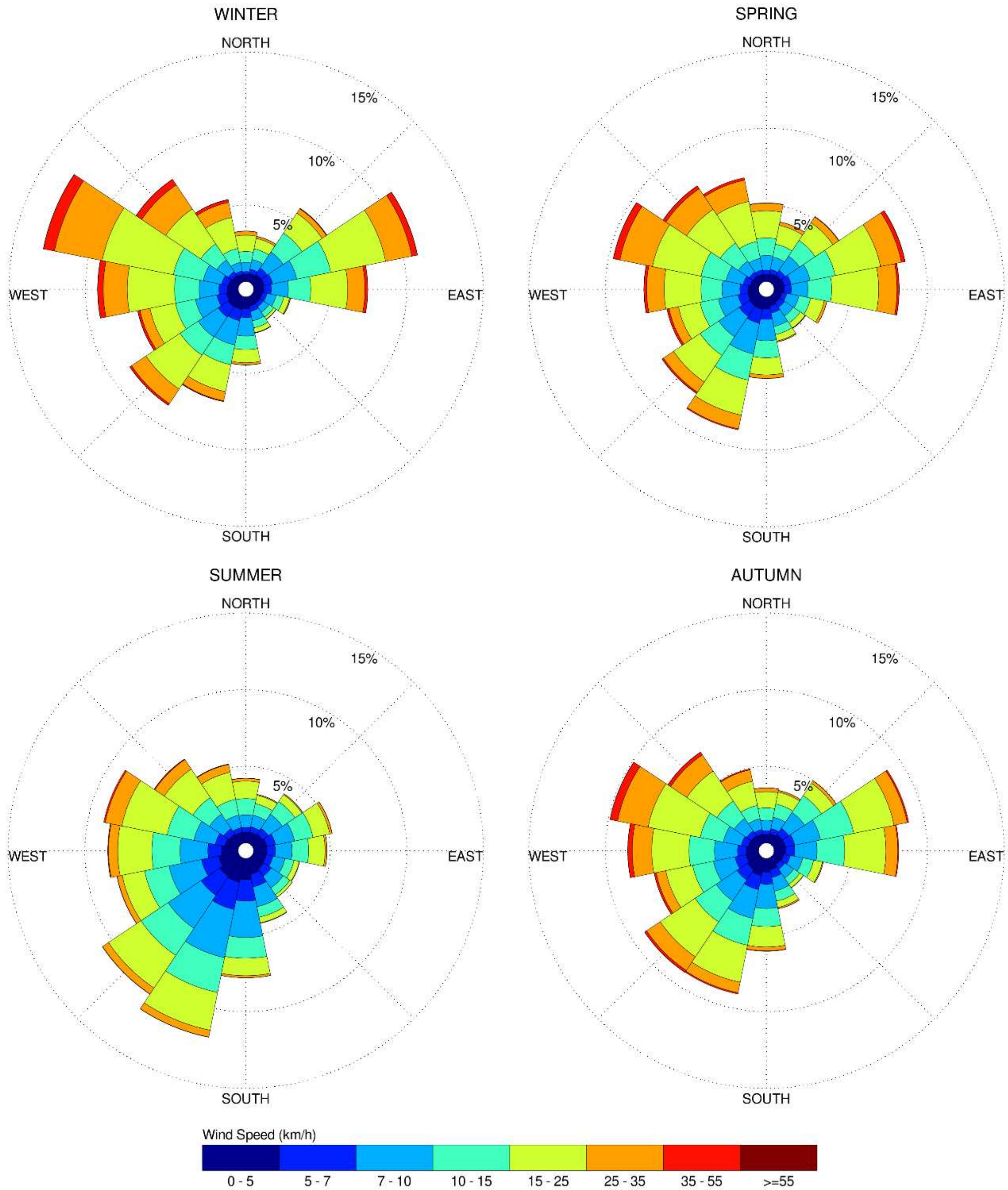
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade were referenced to the wind speed at gradient height to generate 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 Historical Wind Speed and Direction Data

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 prominent 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 prominence 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 Wind Comfort and Safety Criteria – City of Ottawa

Pedestrian wind comfort and safety criteria are based on the mechanical effects of wind without consideration of other meteorological conditions (that is, 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 based on 20% non-exceedance mean wind speed ranges are used to assess pedestrian comfort: (1) Sitting; (2) Standing; (3) Strolling; (4) Walking; and (5) Uncomfortable. The gust speeds, and equivalent mean speeds, are selected based on the Beaufort scale, which describes the effects of forces produced by varying wind speed levels on objects. Wind conditions suitable for sitting are represented by the colour blue, standing by green, strolling by yellow, and walking by orange; uncomfortable conditions are represented by the colour magenta. Specifically, the comfort classes, associated wind speed ranges, and limiting criteria are summarized as follows:

**PEDESTRIAN WIND COMFORT CLASS DEFINITIONS**

| Wind Comfort Class | GEM Speed (km/h) | Description |
|---|---|---|
| SITTING | ≤ 10 | 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. |
| STANDING | ≤ 14 | 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. |
| STROLLING | ≤ 17 | 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. |
| WALKING | ≤ 20 | 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. |
| UNCOMFORTABLE | > 20 | 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. |

Regarding wind safety, 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. From calculations of stability, it can be shown that gust wind speeds of 90 km/h would be the approximate threshold wind speed that would cause an average elderly person in good health to fall. Notably, 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.

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 (equivalent gust wind speed of approximately 16 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 mean wind speed of 20 km/h (equivalent gust wind speed of approximately 32 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 subject 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 target comfort classes, which are dictated by the location type for each region (that is, a sidewalk, building entrance, amenity space, or other). An overview of common pedestrian location types and their typical windiest target comfort classes are summarized on the following page. Depending on the programming of a space, the desired comfort class may differ from this table.

### TARGET PEDESTRIAN WIND COMFORT CLASSES FOR VARIOUS LOCATION TYPES

| Location Types | Comfort Classes |
|---|---|
| Primary Building Entrance | Standing |
| Secondary Building Access Point | Walking |
| Public Sidewalk / Bicycle Path | Walking |
| Outdoor Amenity Space | Sitting / Standing |
| Café / Patio / Bench / Garden | Sitting / Standing |
| Transit Stop (Without Shelter) | Standing |
| Transit Stop (With Shelter) | Walking |
| Public Park / Plaza | Sitting / Standing |
| Garage / Service Entrance | Walking |
| Parking Lot | Walking |
| Vehicular Drop-Off Zone | Walking |

## 5. RESULTS AND DISCUSSION

The following discussion of the predicted pedestrian wind conditions for the subject site is accompanied by Figures 3A-6B, illustrating wind conditions at grade level for the proposed and existing massing scenarios. Conditions are presented as continuous contours of wind comfort throughout the subject site and correspond to the comfort classes presented in Section 4.4.

Wind comfort conditions at grade level are also reported for the typical use period, which is defined as May to October, inclusive. Figure 7 illustrates comfort conditions consistent with the comfort classes in Section 4.4. The details of these conditions are summarized in the following pages for each area of interest.

## 5.1 Wind Comfort Conditions – Grade Level

**Sidewalks along Robert Grant Avenue:** Following the introduction of the proposed development, wind comfort conditions over the nearby public sidewalks along Robert Grant Avenue are predicted to be suitable for standing, or better, during the summer, becoming suitable for strolling, or better, throughout the remainder of the year. The noted conditions are considered acceptable.

Wind conditions over the sidewalks along Robert Grant Avenue with the existing massing are predicted to be suitable for standing, or better, during the summer, becoming suitable for strolling, or better, throughout the remainder of the year. While the introduction of the proposed development produces windier conditions along Robert Grant Avenue, wind conditions with the proposed development are nevertheless considered acceptable for public sidewalks.

**Sidewalks along Livery Street:** Prior to the introduction of the proposed development, wind comfort conditions over the public sidewalks along Livery Street are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing during the autumn, and suitable for standing, or better, during the winter and spring. Following the introduction of the proposed development, conditions over the noted sidewalks are predicted to be suitable for sitting during the summer and standing, or better, throughout the remainder of the year. The noted wind conditions are considered acceptable.

**Common Aemenity Terrace Northeast of Pavilion C**: Wind conditions over the common amenity terrace near the northeast corner of Pavilion C are predicted to be suitable for sitting during the typical use period, as illustrated in Figure 7. The noted conditions are considered acceptable.

**Driveways, Laneways, Drop-off Areas, and Surface Parking Within Subject Site**: Conditions over the driveway to the south of Pavilion A are predicted to be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing throughout the remainder of the year. Conditions over the laneway and roundabout central to the subject site are predicted to be suitable for strolling, or better, during the summer, becoming suitable for a mix of standing, strolling, and walking, throughout the remainder of the year. Conditions over the drop-off area serving Pavilion A are predicted to be suitable for mostly standing throughout the year, while conditions over the drop-off area serving Pavilion B are predicted to be suitable for strolling during the summer, becoming suitable for walking throughout the remainder of the year. Conditions over the surface parking along the central laneway and roundabout are predicted to be suitable for standing, or better, during the summer, becoming suitable for a mix of standing and strolling throughout the remainder of the year. The noted conditions are considered acceptable.

**Walkways Within Subject Site:** Conditions over the walkways along the north elevation of the subject site are predicted to be suitable for standing, or better, during the summer and autumn, becoming suitable for strolling, or better, during the winter and spring. Conditions over the remaining walkways within the subject site are predicted to be suitable for strolling, or better, during the summer, becoming suitable for walking, or better, throughout the remainder of the year. The noted conditions are considered acceptable for pedestrian walkways.

**Building Access Points**: Wind comfort conditions in the vicinity of the primary building entrance at the northwest corner of Pavilion B are predicted to be suitable for standing during the summer and autumn, becoming suitable for strolling, or better, during the winter and spring. Conditions in the vicinity of the entrances along the south elevation of Pavilion C are predicted to be suitable for standing during the summer, becoming suitable for a mix of standing and strolling throughout the remainder of the year. It is recommended that the primary building entrance serving Pavilion B at the northwest corner and the primary building entrances serving the retail spaces along the south elevation of Pavilion C be recessed into the building façade by at least 2 m.

Conditions in the vicinity of the remaining primary building access points are predicted to be suitable for standing, or better, throughout the year. Conditions in the vicinity of the secondary building access points serving the proposed development are predicted to be suitable for standing, or better, during the summer, becoming suitable for strolling, or better, throughout the remainder of the year. The noted conditions are considered acceptable.

## 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 are expected to experience conditions that could be considered dangerous, as defined in Section 4.4.

## 5.3 Applicability of Results

Pedestrian wind comfort and safety have been quantified for the specific configuration of existing and foreseeable construction around the subject site. Future changes (that is, 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 subject site would alter the wind profile approaching the subject site; and (ii) development in proximity to the subject site would cause changes to local flow patterns.

# 6. CONCLUSIONS AND RECOMMENDATIONS

A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-7. 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, the study concludes the following:

1) Most grade-level areas within and surrounding the subject site are predicted to experience conditions that are considered acceptable for the intended pedestrian uses throughout the year. Specifically, conditions over surrounding sidewalks, driveways, laneway, walkways, drop-off areas, surface parking, the common amenity terrace serving the proposed development, and in the vicinity of building access points, are considered acceptable. The areas that are predicted to experience windy conditions are described as follows:

    a. **Primary Building Entrances fronting the Drive Aisle Between Pavilions B and C.** Windy conditions are predicted along the drive aisle between Pavilions B and C during the colder months of the year. Wind conditions in the vicinity of the primary building entrances along the south elevation of Pavilion C and at the northwest corner of Pavilion B are predicted to be suitable for standing, or better, during the summer, becoming suitable for strolling, or better, throughout the remainder of the year.

It is recommended that the commercial entrances along the south elevation of Pavilion C and the main residential entrance at the northwest corner of Pavilion B be recessed into the building façade by at least 2 m.

2) The foregoing statements and conclusions apply to common weather systems, during which no dangerous wind conditions, as defined in Section 4.4, are expected anywhere over the subject site. During extreme weather events (for example, thunderstorms, tornadoes, and downbursts), pedestrian safety is the main concern. However, these events are generally short-lived and infrequent and there is often sufficient warning for pedestrians to take appropriate cover.

Sincerely,

***Gradient Wind Engineering Inc.***

LICENSED PROFESSIONAL ENGINEER
J. D. FERRARO
100158495
Nov 2, 2023
PROVINCE OF ONTARIO

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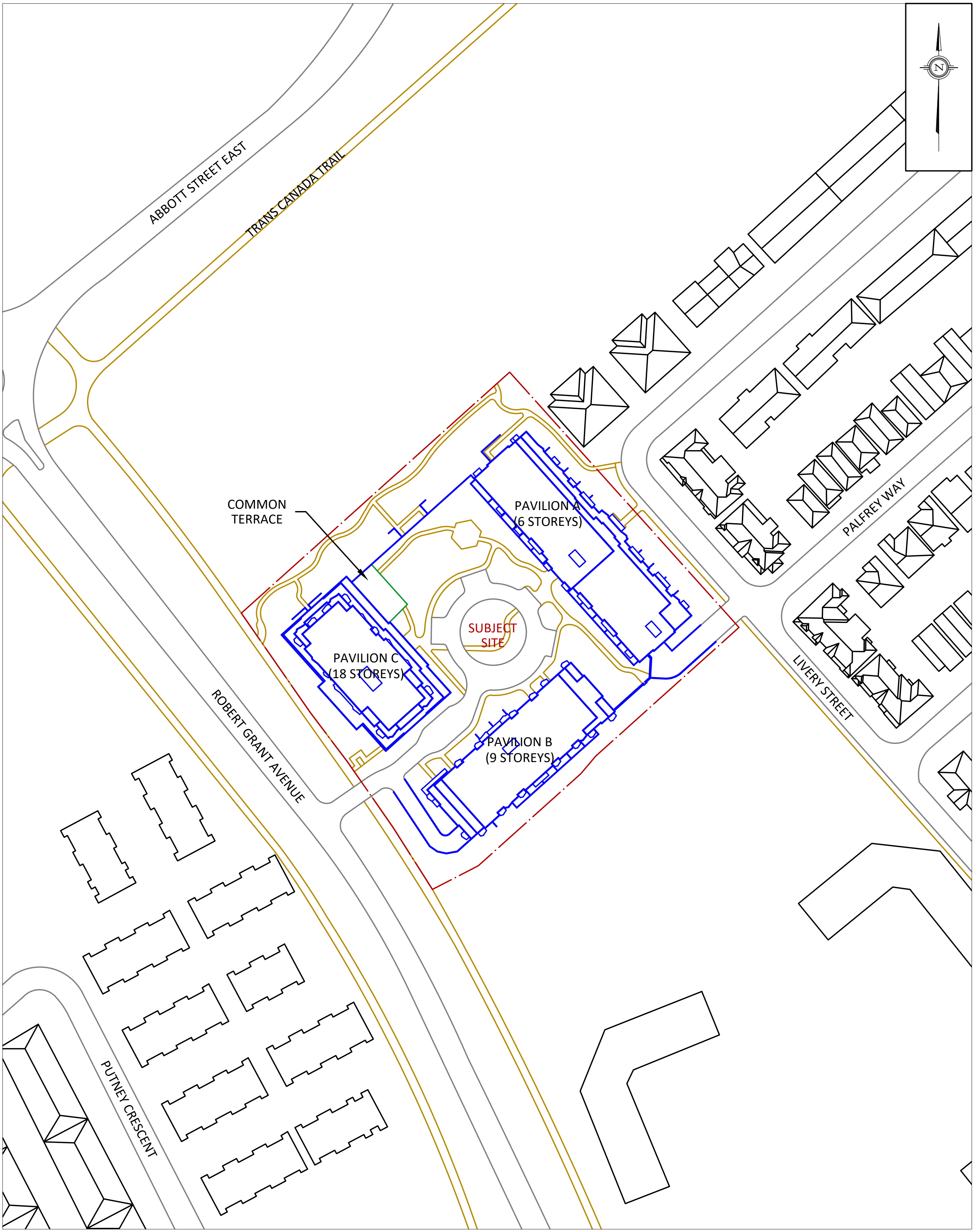
Project Coordinator

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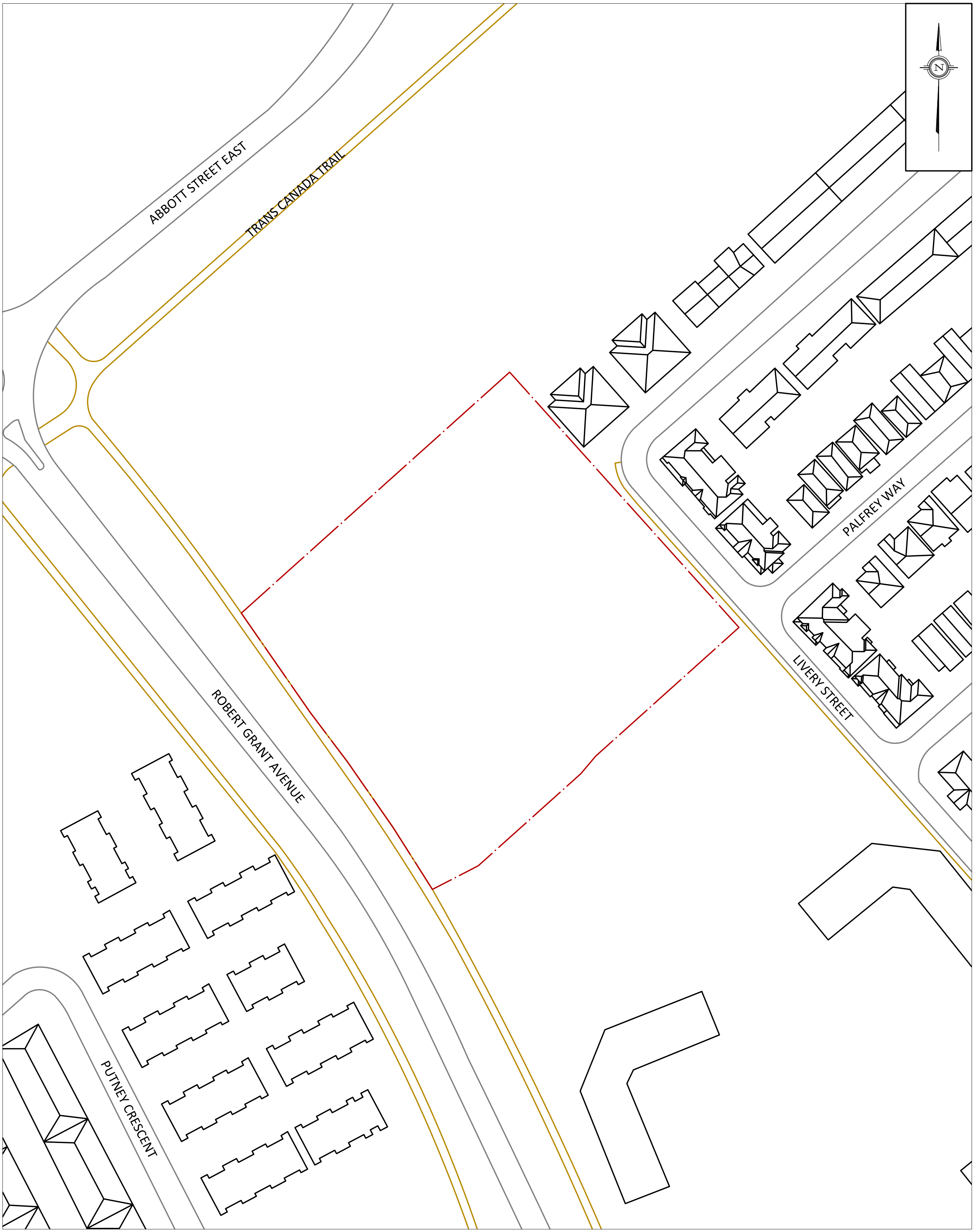
| | | |
|---|---|---|
| PROJECT: 5000 ROBERT GRANT AVENUE, OTTAWA<br>PEDESTRIAN LEVEL WIND STUDY | | DESCRIPTION: FIGURE 1A:<br>PROPOSED SITE PLAN AND SURROUNDING CONTEXT |
| SCALE: 1:2000 | DRAWING NO.: 23-225-PLW-1A | |
| DATE: NOVEMBER 1, 2023 | DRAWN BY: S.K. | |

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| PROJECT | 5000 ROBERT GRANT AVENUE, OTTAWA<br>PEDESTRIAN LEVEL WIND STUDY | | |
| SCALE | 1:2000 | DRAWING NO. | 23-225-PLW-1B |
| DATE | NOVEMBER 1, 2023 | DRAWN BY | S.K. |

DESCRIPTION

FIGURE 1B:
EXISTING SITE PLAN AND SURROUNDING CONTEXT

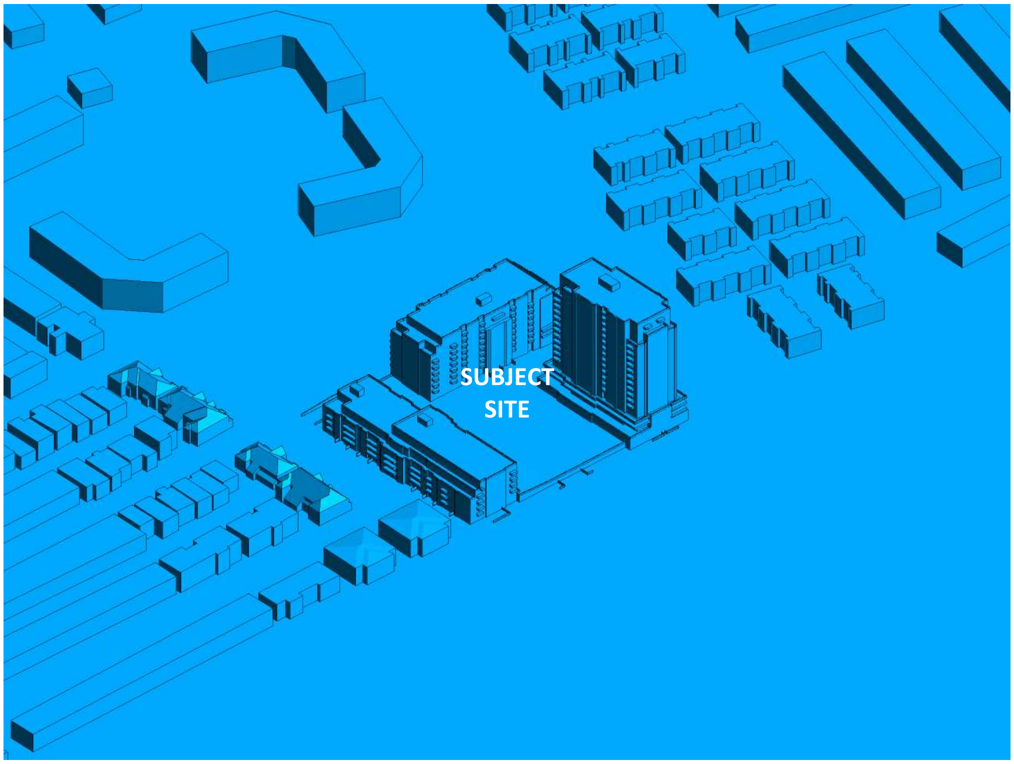



**FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTH PERSPECTIVE**

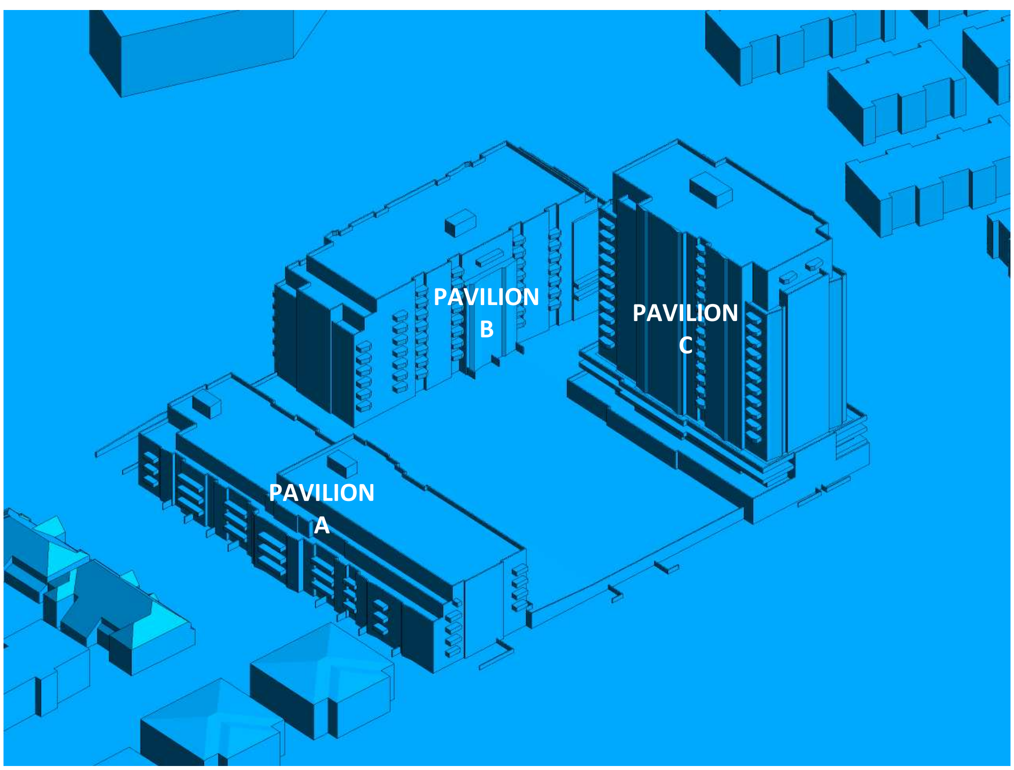



**FIGURE 2B: CLOSE UP OF FIGURE 2A**

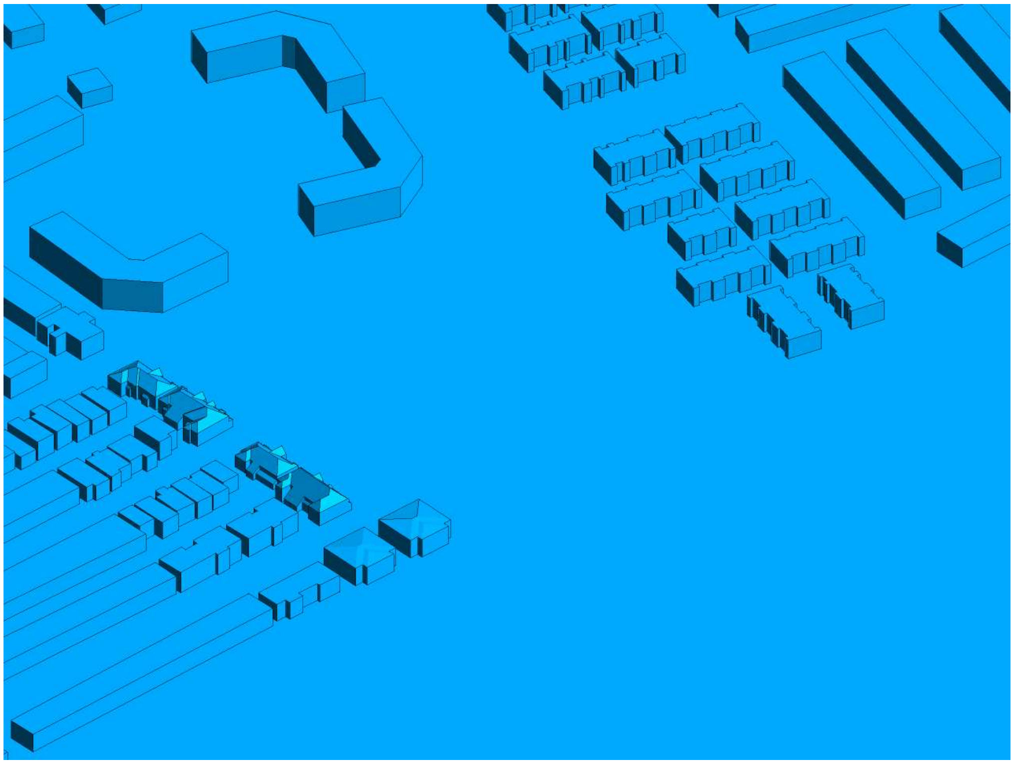


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTH PERSPECTIVE

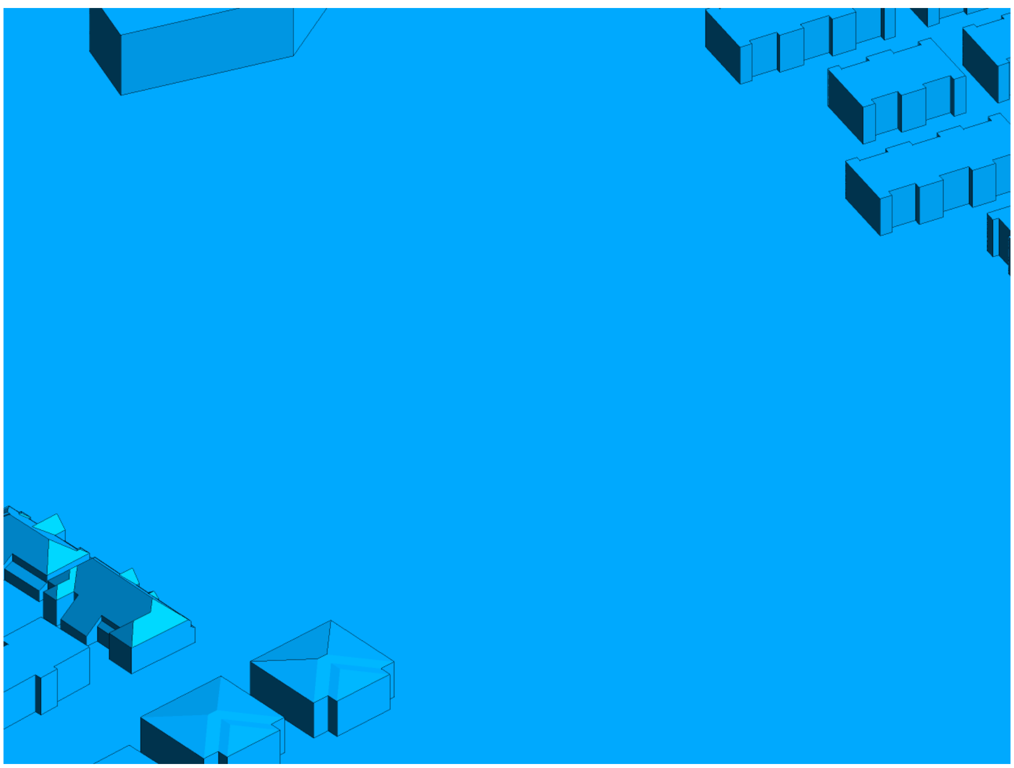


FIGURE 2D: CLOSE UP OF FIGURE 2C

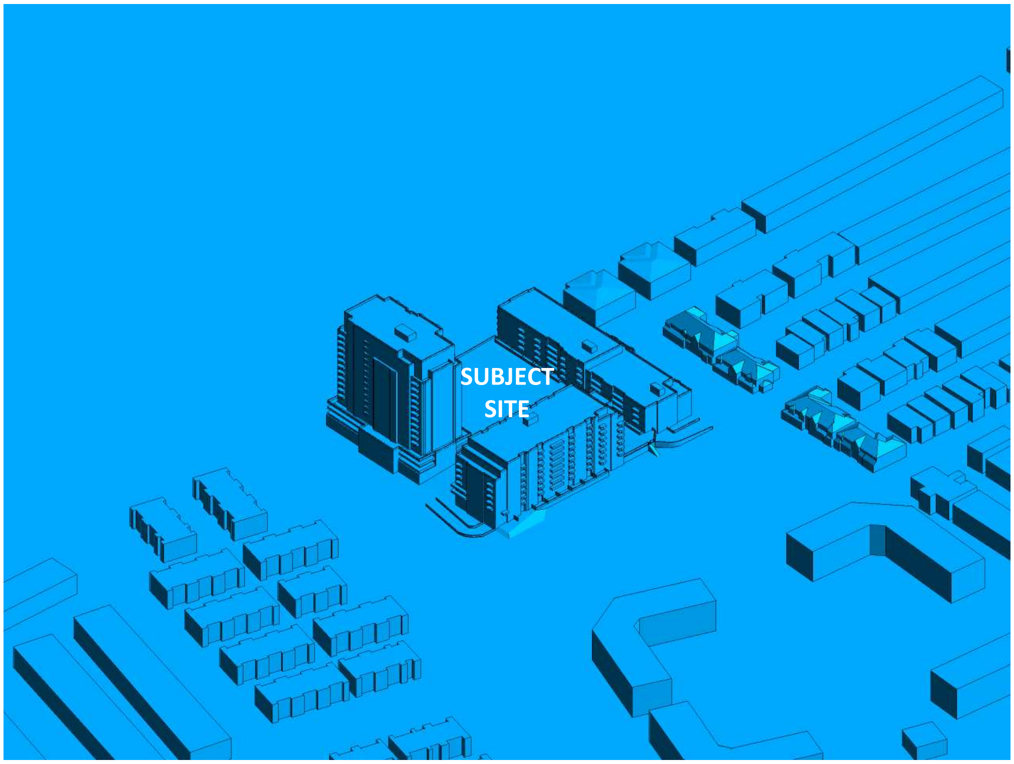



FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTH PERSPECTIVE

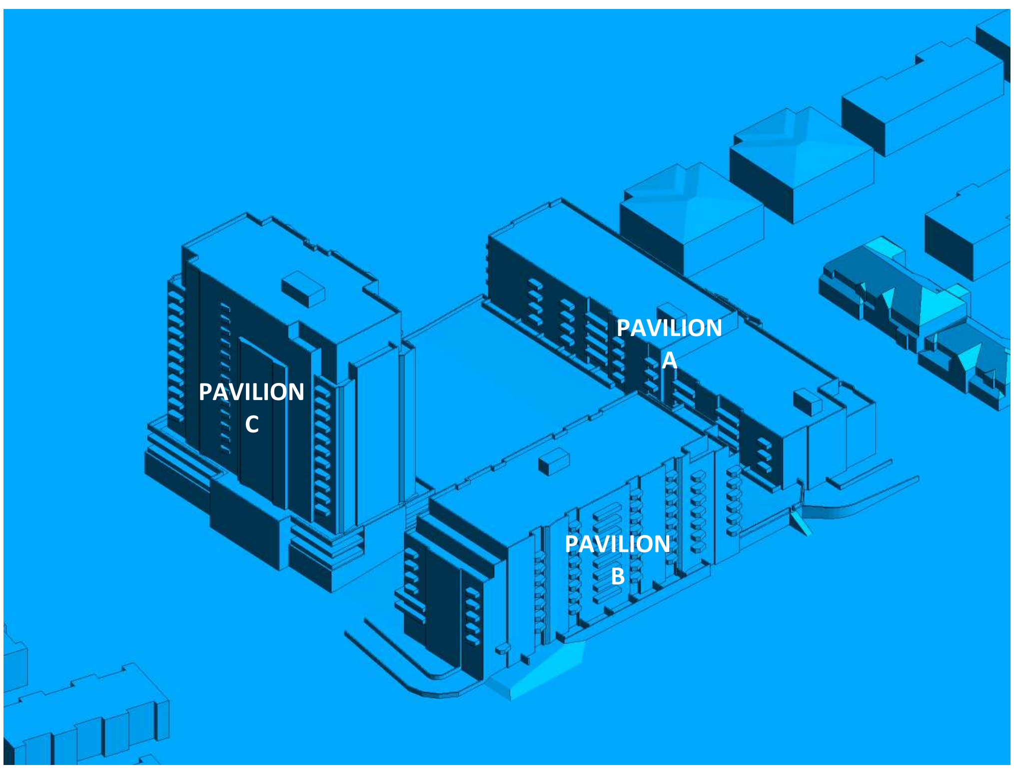



FIGURE 2F: CLOSE UP OF FIGURE 2E

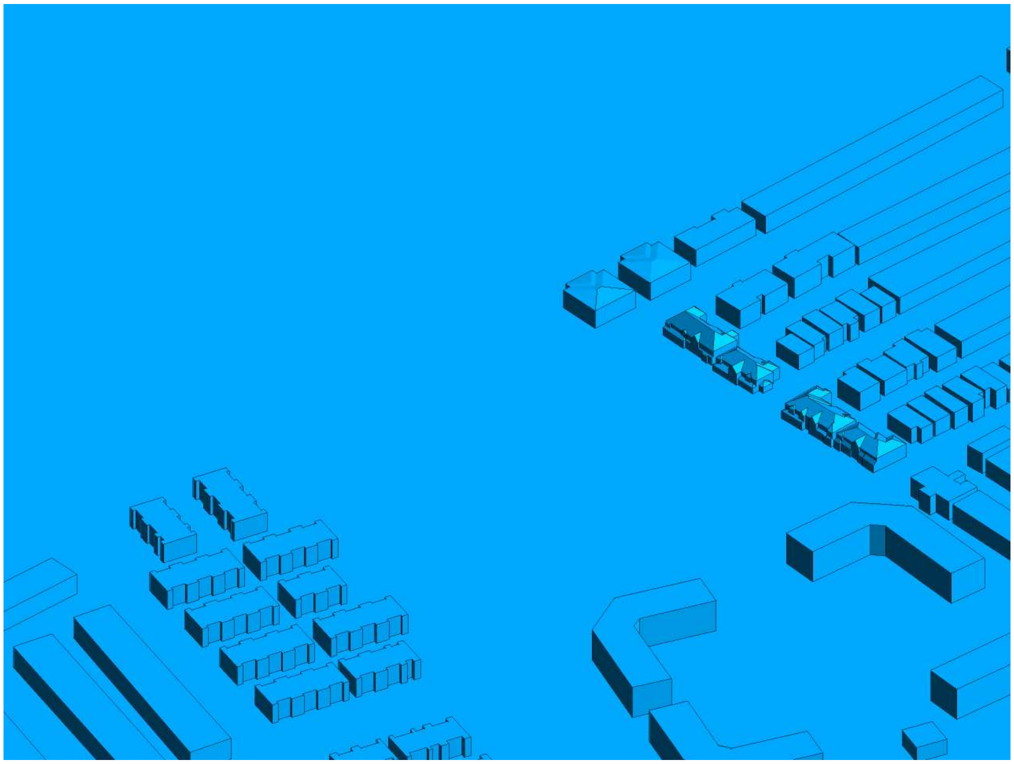


**FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, SOUTH PERSPECTIVE**

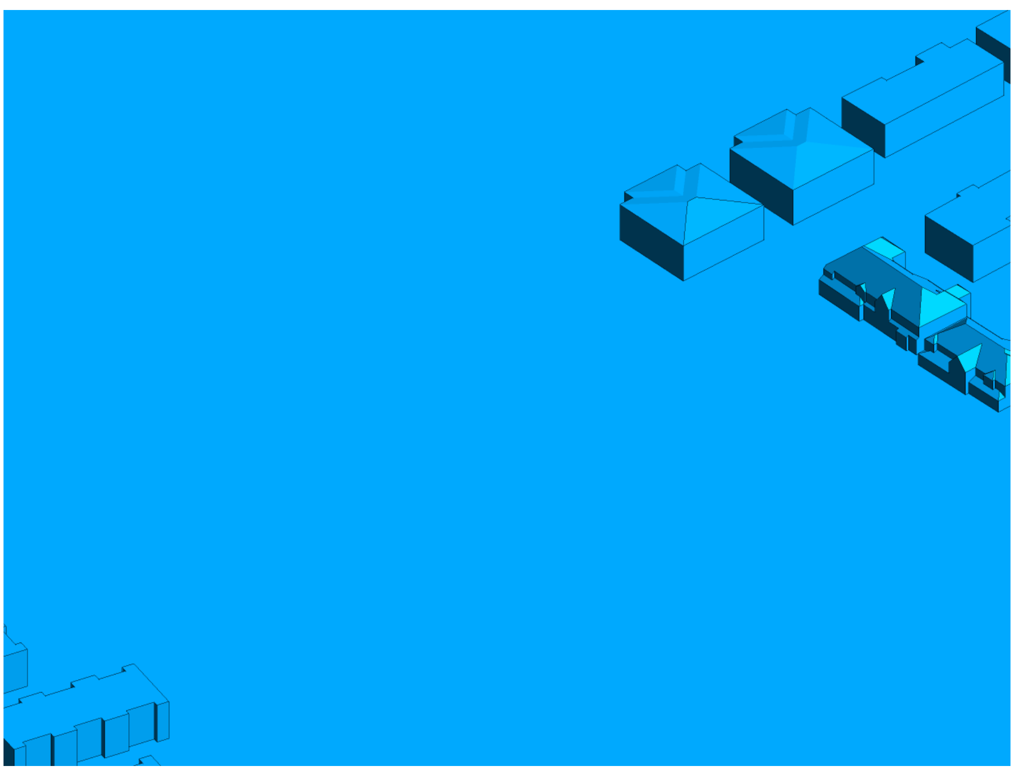


**FIGURE 2H: CLOSE UP OF FIGURE 2G**

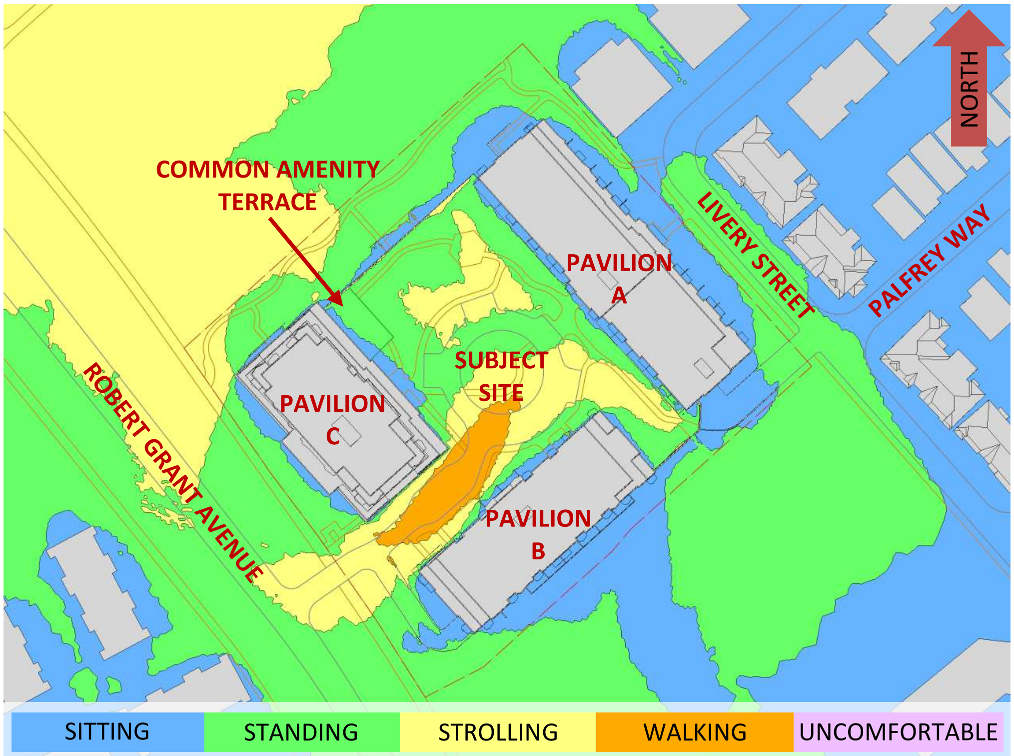



**FIGURE 3A: SPRING – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING**

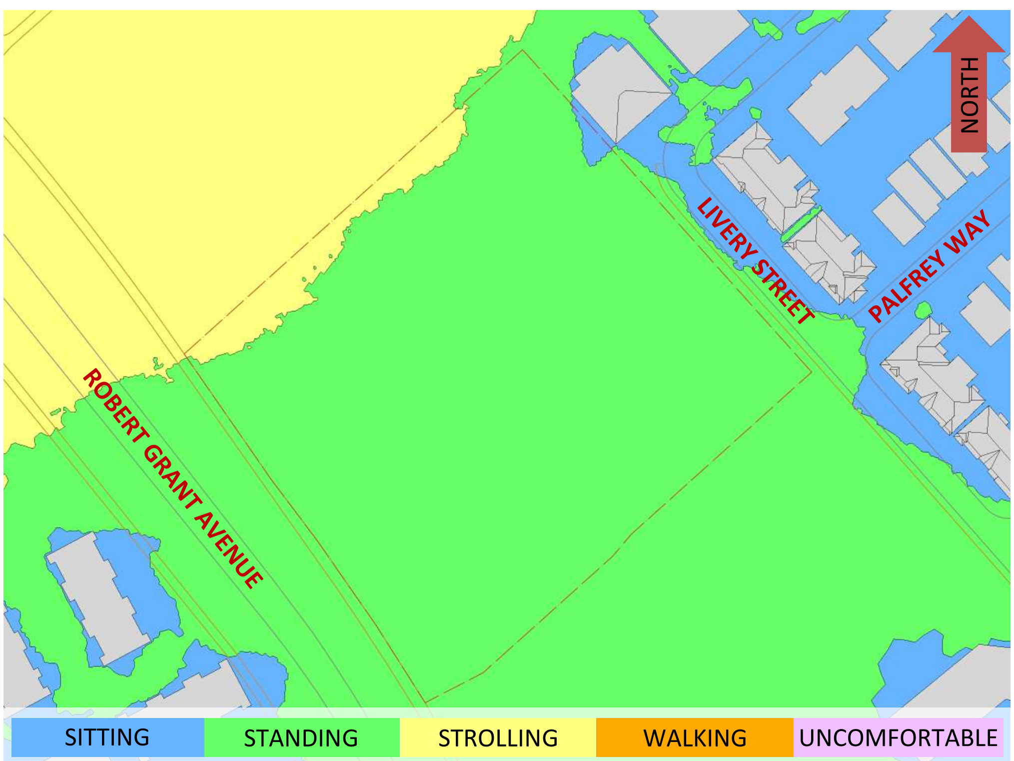



**FIGURE 3B: SPRING – WIND COMFORT, GRADE LEVEL – EXISTING MASSING**

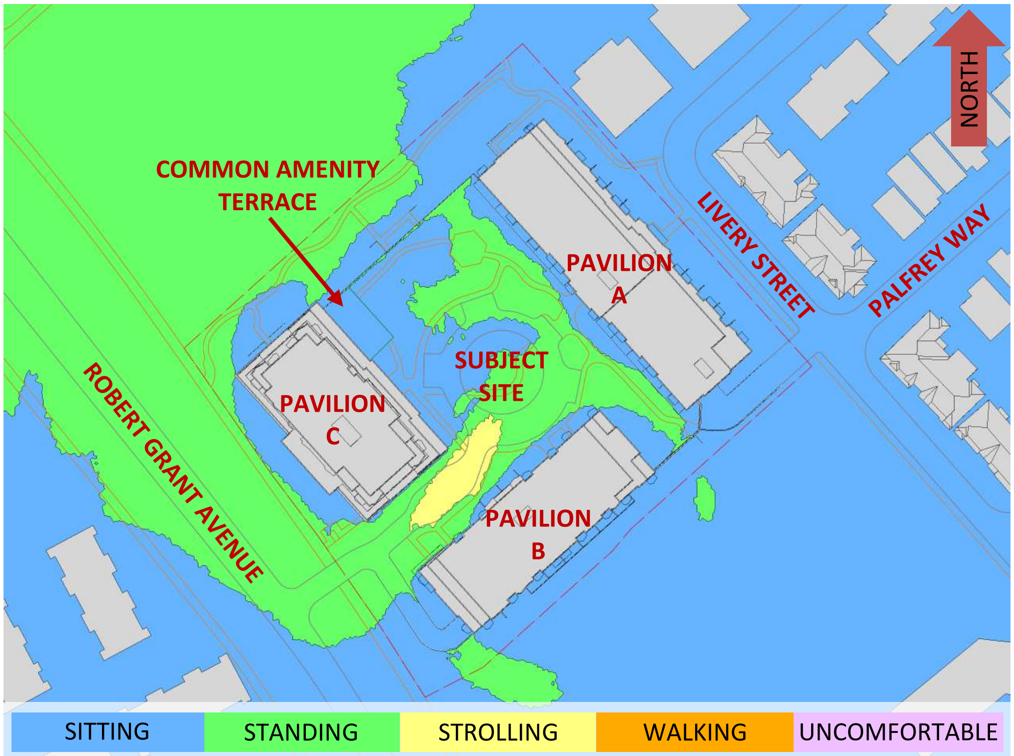



**FIGURE 4A: SUMMER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING**

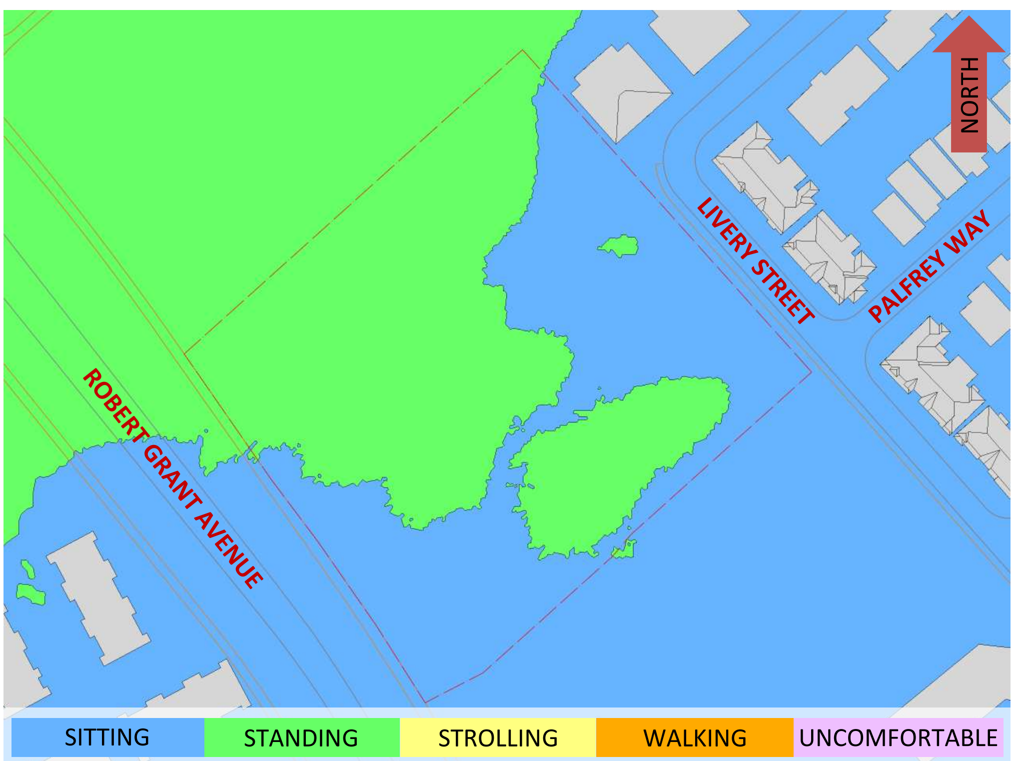



**FIGURE 4B: SUMMER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING**

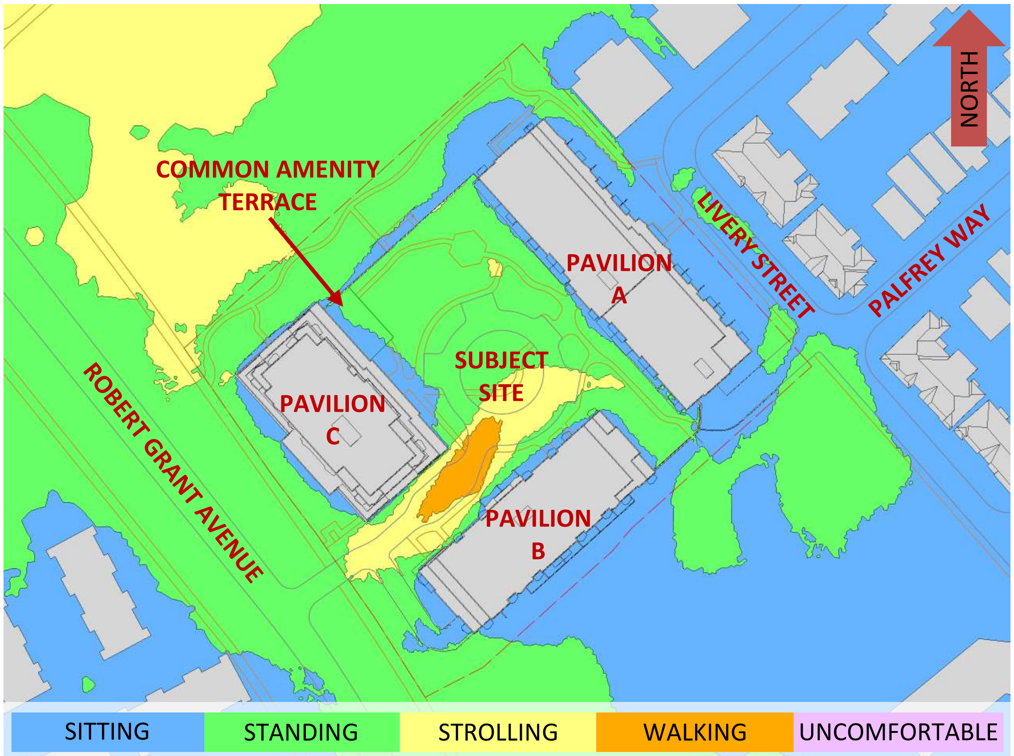



**FIGURE 5A: AUTUMN – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING**

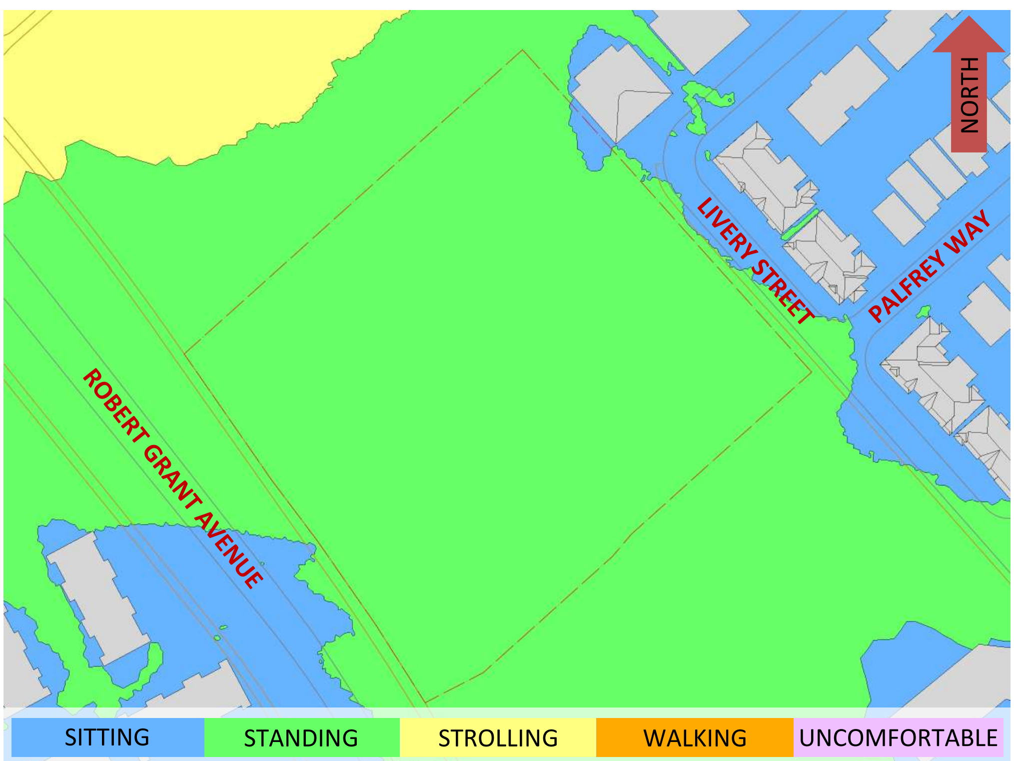



**FIGURE 5B: AUTUMN – WIND COMFORT, GRADE LEVEL – EXISTING MASSING**

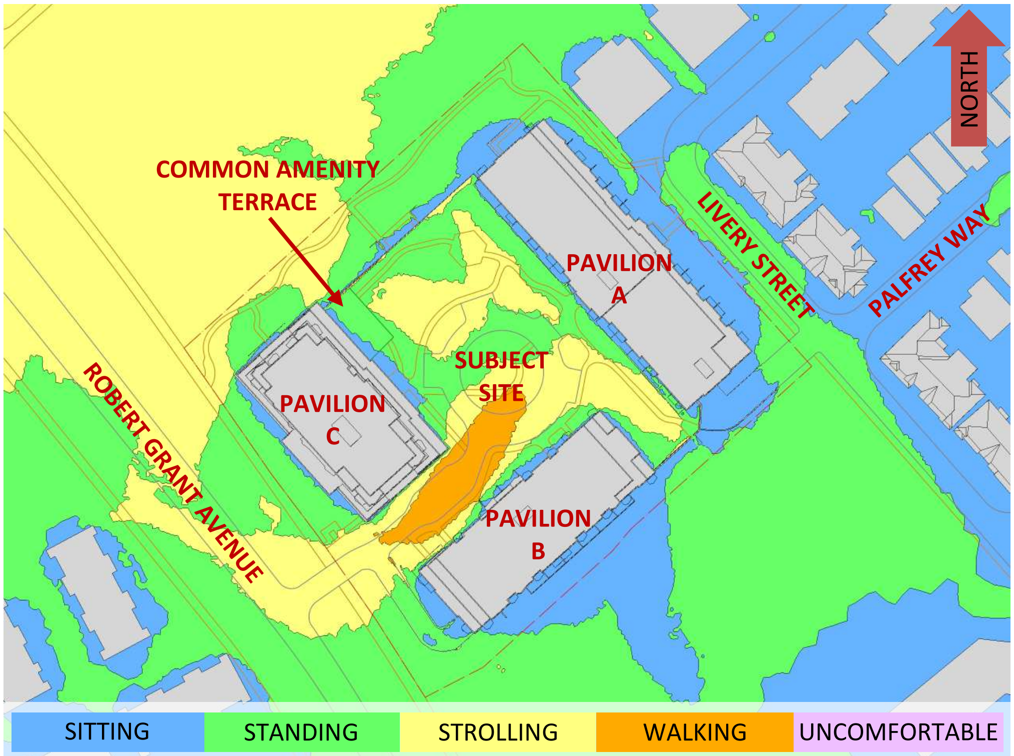



**FIGURE 6A: WINTER – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING**

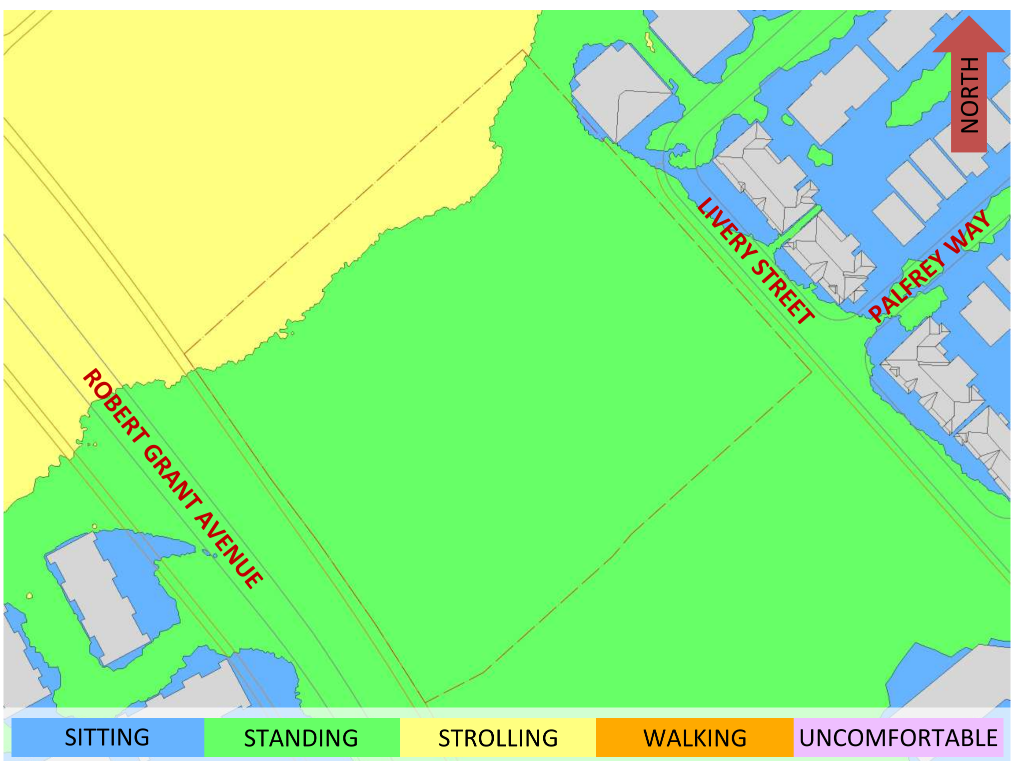



**FIGURE 6B: WINTER – WIND COMFORT, GRADE LEVEL – EXISTING MASSING**

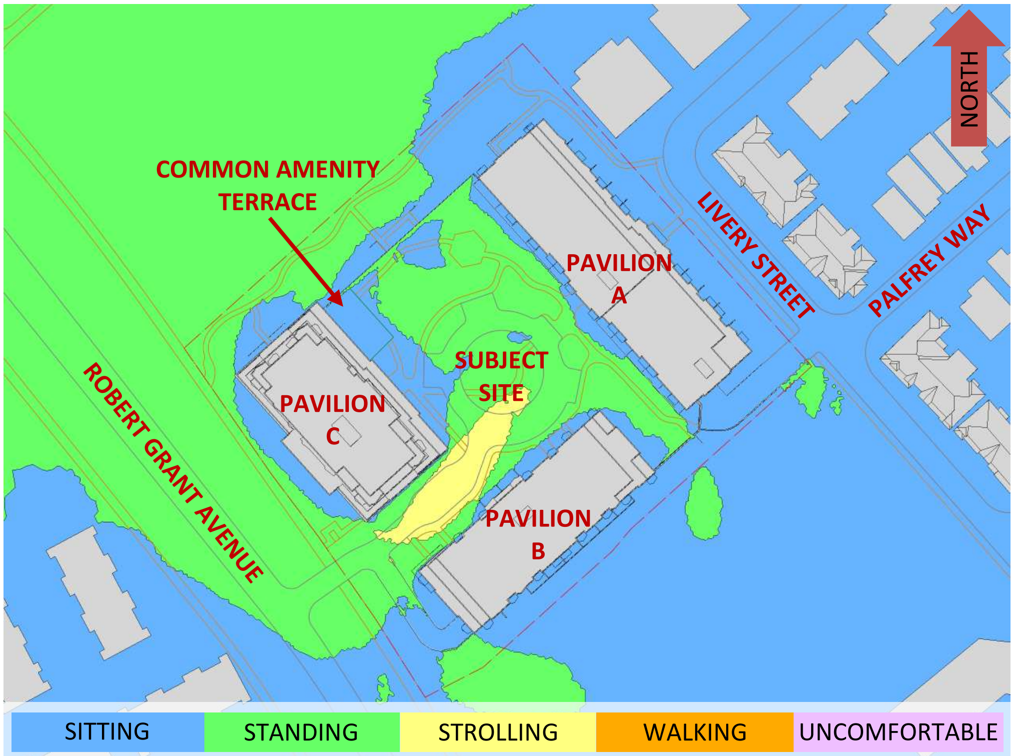
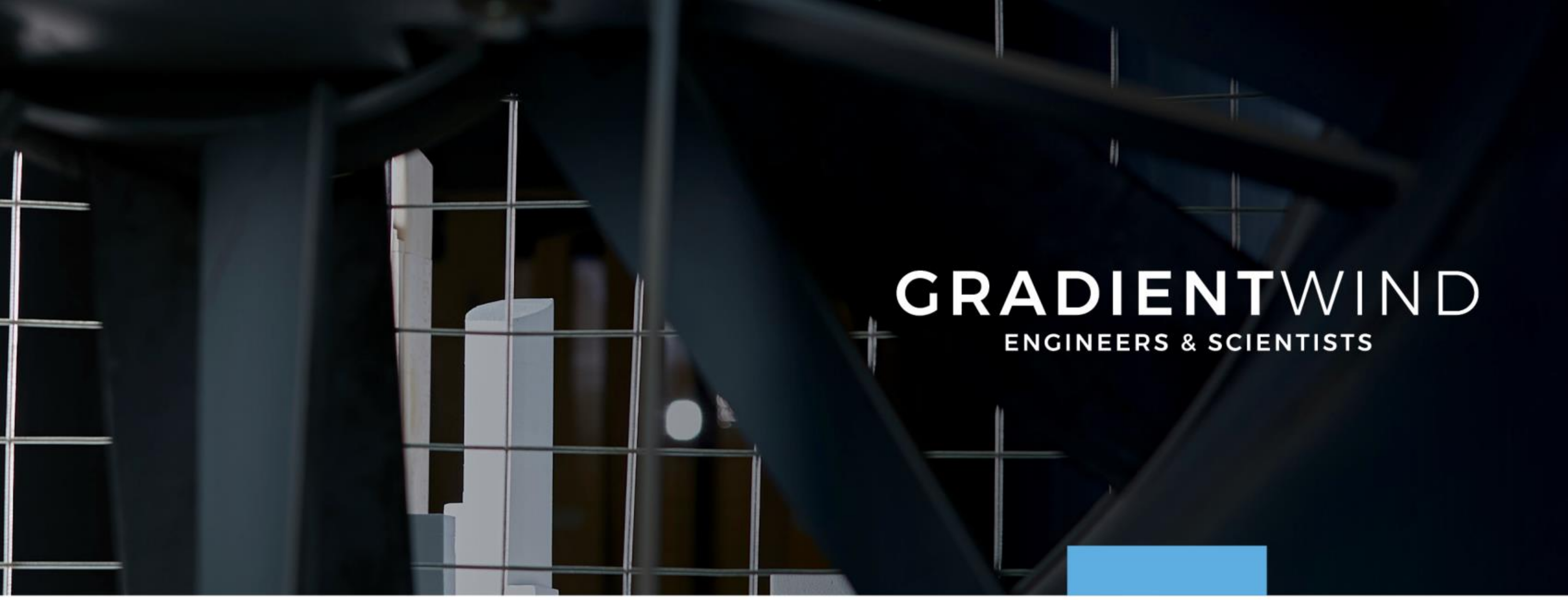
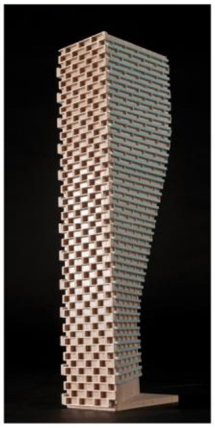
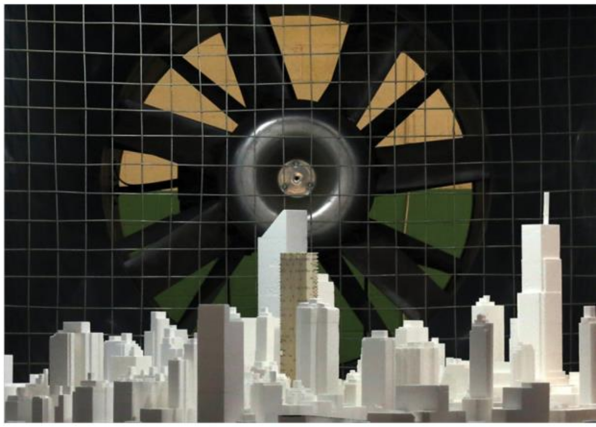



**FIGURE 7: TYPICAL USE PERIOD – WIND COMFORT, GRADE LEVEL – PROPOSED MASSING**





# APPENDIX A

## SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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## 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, $\boldsymbol{U}$ = 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 $\alpha$ is the power law exponent.

For the model, $U_g$ is set to 6.5 metres per second, 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 (that is, 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 (α) |
|---|---|
| 0 | 0.23 |
| 49 | 0.23 |
| 74 | 0.23 |
| 103 | 0.21 |
| 167 | 0.19 |
| 197 | 0.23 |
| 217 | 0.22 |
| 237 | 0.22 |
| 262 | 0.23 |
| 282 | 0.23 |
| 301 | 0.21 |
| 324 | 0.20 |

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

| Upstream Exposure Type | Alpha Value (α) |
|---|---|
| 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).

$$I(Z) = \begin{cases} 0.1\left(\frac{Z}{Z_g}\right)^{-\alpha-0.05}, & Z > 10\text{ m} \\ 0.1\left(\frac{10}{Z_g}\right)^{-\alpha-0.05}, & Z \leq 10\text{ m} \end{cases}$$

Equation (2)

$$L_t(Z) = \begin{cases} 100\text{ m}\sqrt{\frac{Z}{30}}, & Z > 30\text{ m} \\ 100\text{ m}, & Z \leq 30\text{ m} \end{cases}$$

Equation (3)

where, ***I*** = turbulence intensity, $\boldsymbol{L_t}$ = 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.

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[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 Engineering Symposium, IWES 2003*, Taiwan, 2003.