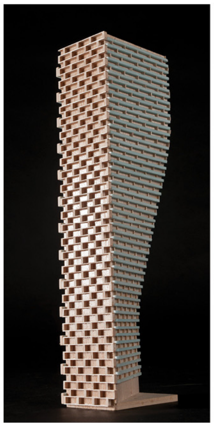
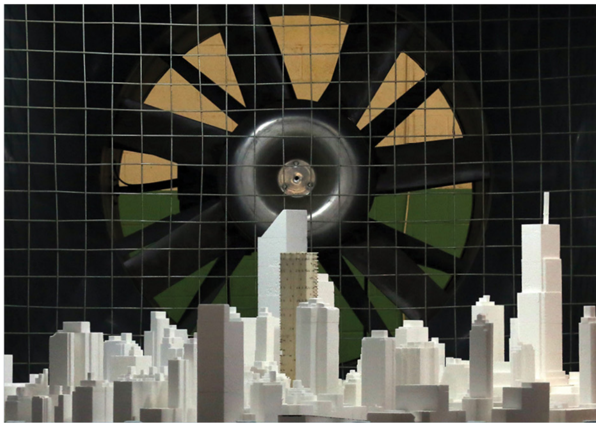
PEDESTRIAN LEVEL WIND STUDY

1740-1760 St. Laurent Boulevard
Ottawa, Ontario

Report: 20-142-PLW





July 31, 2020

PREPARED FOR
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EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study to satisfy the requirements for a joint Zoning By-law Amendment (ZBA) and Site Plan Control Application (SPA) submission for the proposed mixed-use, multi-building development located at 1740-1760 St. Laurent Boulevard in Ottawa, Ontario (hereinafter referred to as "subject site"). 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-5D, and summarized as follows:

1) Conditions throughout the site at grade are expected to be suitable for the intended uses throughout the year. This includes most primary and secondary building entrances, sidewalks, walkways, parking lots, the garden to the northeast of Building 4, and the grade-level terrace at the south of Building 1.

2) The only exception to item (1) relates to the entrance at the north of Building 4 where conditions are predicted to be windier than desirable for a primary building entrance, as noted in Section 4.4. To ensure suitable conditions at this entrance, we recommend either:

    a. Recessing the entrance by a minimum of 2 m into the building façade.

       OR

    b. Locating the entrance on the east side of the building, where conditions are predicted to be calm throughout the year.

If the proposed Everest development, to the west of the subject site, is included in the simulation, conditions for the noted entrance are acceptable. If the Everest development is approved, mitigation for the noted entrance will not be required.

3) All exterior amenity terraces at Levels 2-4 will be mostly suitable for sitting during the typical use period of late spring to early autumn, which is acceptable.

4) 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 associate hardware.

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

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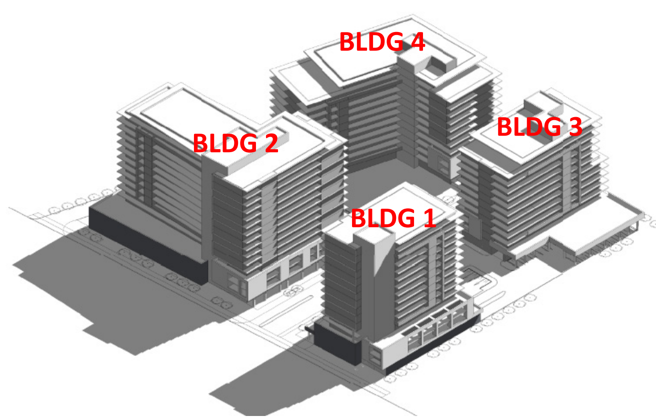
1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Heafey Group to undertake a pedestrian level wind (PLW) study to satisfy the requirements for a joint Zoning By-Law Amendment (ZBA) and Site Plan Control application (SPA) submission for the proposed mixed-use development located at 1740-1760 St Laurent Boulevard in Ottawa, Ontario (hereinafter referred to as “subject site”). 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 prepared by Lapalme Rheault Architectes + Associés and Pierre Martin & Associés Architectes, in July 2020, 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 on a parcel of land to the west of St Laurent Boulevard and to the south of Industrial Avenue. The site comprises 4 proposed buildings: Building 1 and 2, at the northeast and southeast of the site, of 15 storeys, and Buildings 3 and 4, at the northwest and southwest of the site, of 12 storeys.



Rendering, Northeast Perspective
(Courtesy Lapalme Rheault Architectes + Associés and Pierre Martin & Associés|Architectes)

Building 1 has a roughly rectangular planform at grade. The first level comprises commercial space and a lobby at the northeast corner. A grade-level terrace is planned along the south elevation of the building, and the main entrance is located at the north of the east elevation. At

Level 2, the floorplate extends over grade at the west and south, providing for terraces. Level 2 comprises common indoor and outdoor amenity areas. The terrace along the west elevation extends along the north elevation as well, where it is overhung by the building above. The building steps back form the southeast corner at Level 3 and from the north elevation at Level 4 and rises with a consistent planform from Level 3 to Level 15, where its steps back from the west elevation. Levels 3 and above comprise residential units.

Building 2, at the southeast of the site, has a roughly L-shaped planform at grade, comprising mostly commercial space and a lobby and common area at the northeast corner. The main entrance is located at the north of the east elevation. At Level 2, the building steps out to the north to overhang the grade-level area below. Level 2 comprises an indoor common area along the east of the building, and residential units elsewhere. At Level 3 the building steps back from the east elevation, providing a large outdoor terrace. The building steps back again from all sides of the north section at Level 4, and rises with a consistent planform to Level 15, where it steps back from the west and south elevations. Levels 3 and above comprise residential units.

Building 3, at the northwest of the site, has a roughly rectangular planform at grade. The grade level comprises common areas, with the main entrance located near the centre of the south elevation. At Level 2, a large terrace extends to the north over the parking lot below. The building rises with a consistent planform to Level 7, where it steps back from the west elevation. At Level 12, the building steps back from the east elevation.

Building 4, at the southwest of the site, has a roughly L-shaped planform at grade. The grade level comprises a lobby at the north and residential units elsewhere. The main entrance is located near the east side of the north elevation. The building steps over the grade along all elevations at Level 2 and rises with a roughly consistent planform to Level 12, where it steps back from the north and east elevations.

Due to the preliminary nature of the architectural drawings provided, and the lack of identified elevated outdoor amenity terraces, this report will provide wind conditions within all elevated terraces at Levels 2, 3, and 4 that may be outdoor amenity terraces.

At grade, parking lots are located between Buildings 1 and 3 and between Buildings 2 and 4, as well as to the north of Building 3. A garden is located to the northeast of Building 4. Buildings 1 and 3 are separated from Buildings 2 and 4 by the proposed Everest Private.

The near-field surroundings (defined as an area within 200 metres (m) of the subject site) include the 8-storey building at 1730 St Laurent Boulevard and low-rise buildings to the east and south. Two 8-storey buildings have been proposed to the immediate west of the subject site (Everest North and South) which, if approved, will reduce wind exposures to the west and lead to somewhat calmer wind conditions throughout the site. The far-field surroundings (defined as an area beyond the near-field but within a 2 kilometre (km) radius of the subject site) comprise mostly low-rise commercial buildings from the northwest clockwise to the southeast, several mid-rise residential buildings to the south-southeast, and low-rise suburban dwellings from the south clockwise to northwest.

Key areas under consideration include surrounding sidewalks, walkways, the garden to the northeast of Building 4, the grade-level terrace at the south of Building 1, building access points, and elevated terraces. Figure 1 illustrates the subject site and surrounding context, 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 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 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 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 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 (i.e., windier) wind speed values.

4.2 Wind Speed Measurements

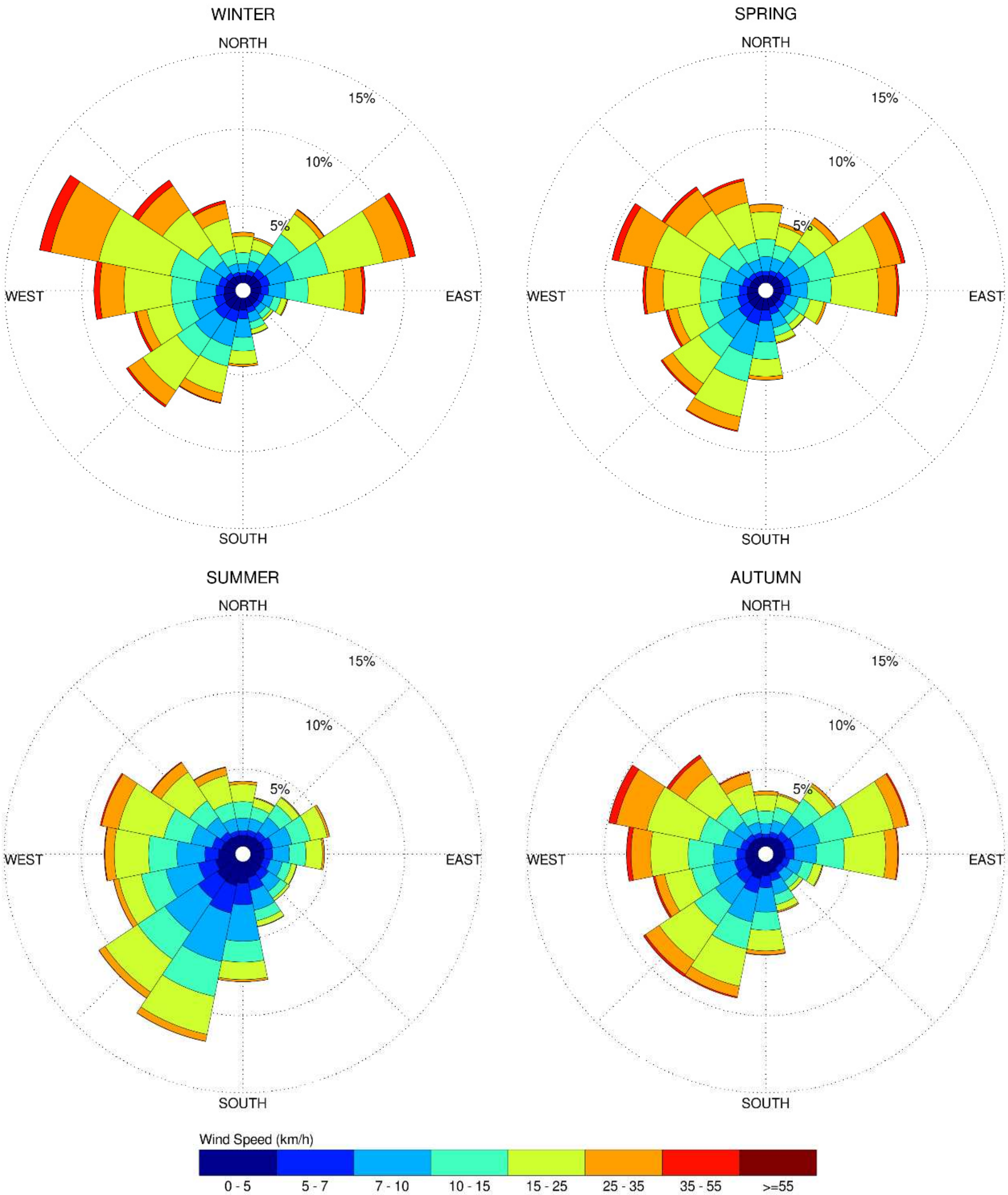
The PLW analysis was performed by simulating wind flows and gathering velocity data over a CFD model of the site for 12 wind directions. The CFD simulation model was centered on the study building, complete with surrounding massing within a diameter of approximately 1260 m. Mean and peak wind speed data 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 m above local grade, and above the elevated amenity terraces, was 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. 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 winter season is defined as December-March, spring as April-May, summer as June-September, and autumn as October-November.

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, 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 80% 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 mean gust speed ranges are selected based on 'The Beaufort Scale', which describes the effect of forces produced by varying wind speeds on levels on objects.

THE BEAUFORT SCALE

Number	Description	Wind Speed (km/h)		Description
		Mean	Gust (Peak)	
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 80% 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 (gust equivalent mean wind speed of 16 km/h) was 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 (gust equivalent mean wind speed of 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 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 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	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 the predicted pedestrian wind conditions for the subject site is accompanied by Figures 3A-3D, which illustrate seasonal wind conditions at grade level, and Figures 4A-5D, which illustrate seasonal wind conditions on the elevated amenity terraces. The wind conditions are presented as continuous contours of wind comfort within and surrounding the subject site.

The colour contours indicate predicted regions of the various comfort classes noted in Section 4.4. Wind conditions suitable for sitting are represented by the colour green, standing by yellow, walking by blue, while conditions considered uncomfortable for walking are represented by the colour magenta.

5.1 Wind Comfort Conditions – Grade Level

St. Laurent Boulevard: Conditions along St. Laurent Boulevard are predicted to be mostly suitable for sitting during the summer, becoming suitable for standing along portions of the sidewalk that are exposed to wind channelling effects between Buildings 1 and 2, as well as between Building 1 and the existing 8-storey building at 1730 St. Laurent Boulevard. Conditions during the autumn will be similar but slightly windier as a function of the historical climate data. During the spring and winter, conditions will be suitable for strolling near the northeast corners of Buildings 1 and 2, and suitable for standing or better elsewhere. The noted conditions are considered acceptable with respect to the wind comfort criteria.

Everest Private: Conditions along Everest Private will be mostly suitable for sitting during the summer, becoming suitable for standing near the southeast corners of Buildings 1 and 3, where prominent northwesterly winds accelerate around the building corners. During the autumn, conditions will be mostly suitable for standing, while winter and spring conditions will be suitable for strolling or better. The orientation of the road with respect to prominent westerly winds causes moderate channelling effects between Buildings 1 and 2 and between Buildings 3 and 4. The noted conditions are considered acceptable with respect to the wind comfort criteria.

Garden: The garden to the northeast of Building 4 will be suitable for sitting during the summer, becoming suitable for a mix of sitting and standing during the remaining colder seasons. Given that the garden is expected to be mostly suitable for sitting during the typical use period of late spring to early autumn, the noted conditions are considered acceptable with respect to the wind comfort criteria in Section 4.4.

If sitting conditions are desired to extend into the spring and autumn seasons, we recommend wind mitigation measures placed to block southerly winds, which channel between Buildings 2 and 4. Mitigation could include tall coniferous plantings in a dense formation along the eastern extent of the garden.

Grade-Level Terrace, South of Building 1: The grade-level terrace will be mostly suitable for sitting during the summer. Slightly windier conditions, suitable for standing, are expected near the southwest corner of Building 1 around which northwesterly winds tend to accelerate. During the autumn, conditions will be mostly suitable for sitting, with standing conditions developing near the western and eastern extents of the terrace. Winter and spring conditions will be suitable for a mix of sitting and standing, with the possibility for strolling conditions to develop over parts of the terrace. Given that the terrace is expected to be mostly suitable for sitting during the typical use period of late spring to early autumn, the noted conditions are acceptable with respect to the wind comfort criteria. However, we suggest locating designated seating areas away from the southwestern corner of Building 1, where conditions are windy.

Parking Lots Throughout Subject Site: The parking lots throughout the site are expected to be suitable for standing or better during the summer and autumn, and suitable for strolling or better during the winter and spring. The noted conditions are acceptable with respect to the wind comfort criteria.

Building Entrances: The building entrance at the north of Building 4 is predicted to be suitable for strolling during the winter. To satisfy the recommended comfort class for a primary building entrance (standing), the entrance could be recessed by a minimum of 2 m into the building façade. Alternatively, the entrance could be located on the east side of the building, where conditions are predicted to be suitable for sitting throughout the year. If the proposed Everest development, to the west of the subject site, is included in the simulation, conditions for the noted entrance are acceptable. If the Everest development is approved, mitigation for the noted entrance will not be required.

All other primary building entrances will be suitable for standing or better throughout the year, which is acceptable.

5.2 Wind Comfort Conditions – Elevated Amenity Terraces

Level 2 Terraces: Conditions within all Level 2 terraces will be suitable for sitting during the summer. During the spring and autumn, the terraces will mostly be suitable for sitting, although standing conditions will develop throughout the western portion of the terrace serving Building 3, the southern portion of the terrace on the west side of Building 1, and the southern portion of the terrace along the south elevation of Building 1. During the winter, the terrace serving Building 3 will be mostly suitable for standing, while the two terraces serving Building 1 will be suitable for a mix of sitting and standing. Given that the terraces are expected to be mostly suitable for sitting during the typical use period, the noted conditions are considered acceptable with respect to the wind comfort criteria.

Level 3 Terrace, Building 1: The terrace at the southeast corner of Building 1 will be suitable for sitting during the summer. During the colder seasons standing conditions are expected to develop near the southeast corner of the terrace, while most of the terrace will remain suitable for sitting. Given that the terrace is expected to be mostly suitable for sitting during the typical use period, the noted conditions are acceptable with respect to the wind comfort criteria.

Level 4 Terrace, Building 1: The terrace at Level 4 of Building 1 will be mostly suitable for sitting during the summer, becoming mostly suitable for standing during the autumn, and suitable for strolling or better during the winter and spring. Given that the terrace is expected to be mostly suitable for sitting during the typical use period, the noted conditions are acceptable with respect to the wind comfort criteria.

Level 4 Terrace, Building 2: The terrace along the east elevation of Building 2 will be suitable for sitting during the summer. During the colder seasons standing conditions will develop near the south of the terrace. Given that the terrace is expected to be mostly suitable for sitting during the typical use period, the noted conditions are acceptable with respect to the wind comfort criteria.

5.3 Applicability of Results

Wind conditions over surrounding sidewalks beyond the subject site, as well as at nearby primary building entrances, will be acceptable for their intended pedestrian uses during each seasonal period upon the introduction of the subject site. Pedestrian wind comfort and safety have been quantified for the specific configuration of existing and foreseeable construction around the study 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. In general, 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.

6. CONCLUSIONS AND RECOMMENDATIONS

A complete summary of the predicted wind comfort and safety conditions is provided in Section 5 and illustrated in Figures 3A-5D. 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 similar developments in Ottawa, we conclude the following:

1) Conditions throughout the site at grade are expected to be suitable for the intended uses throughout the year. This includes most primary and secondary building entrances, sidewalks, walkways, parking lots, the garden to the northeast of Building 4, and the grade-level terrace at the south of Building 1.

2) The only exception to item (1) relates to the entrance at the north of Building 4 where conditions are predicted to be windier than desirable for a primary building entrance, as noted in Section 4.4. To ensure suitable conditions at this entrance, we recommend either:

   a. Recessing the entrance by a minimum of 2 m into the building façade.

   OR

   b. Locating the entrance on the east side of the building, where conditions are predicted to be calm throughout the year.

   If the proposed Everest development, to the west of the subject site, is included in the simulation, conditions for the noted entrance are acceptable. If the Everest development is approved, mitigation for the noted entrance will not be required.

3) All exterior amenity terraces at Levels 2-4 will be mostly suitable for sitting during the typical use period of late spring to early autumn, which is acceptable.

4) 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 associate hardware.

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

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

Sincerely,

Gradient Wind Engineering Inc.

LICENSED PROFESSIONAL ENGINEER
J. D. FERRARO
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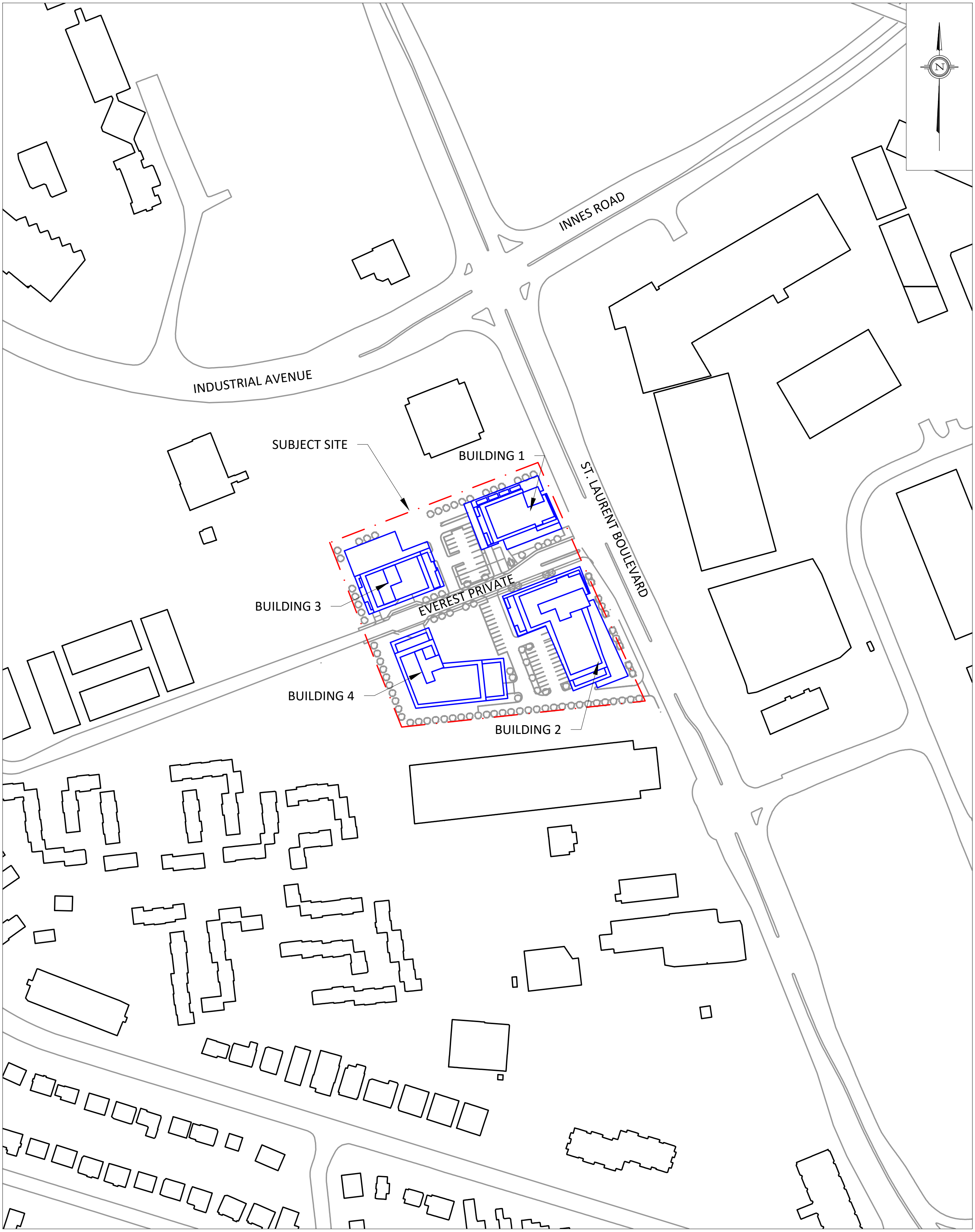

GRADIENTWIND ENGINEERS & SCIENTISTS 127 WALGREEN ROAD , OTTAWA, ON 613 836 0934 • GRADIENTWIND.COM	PROJECT 1740-1760 ST. LAURENT BOULEVARD, OTTAWA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION FIGURE 1: SITE PLAN AND SURROUNDING CONTEXT
	SCALE 1:3000 (APPROX.)	DRAWING NO. 20-142-PLW-1	
	DATE JULY 28, 2020	DRAWN BY S.P.	

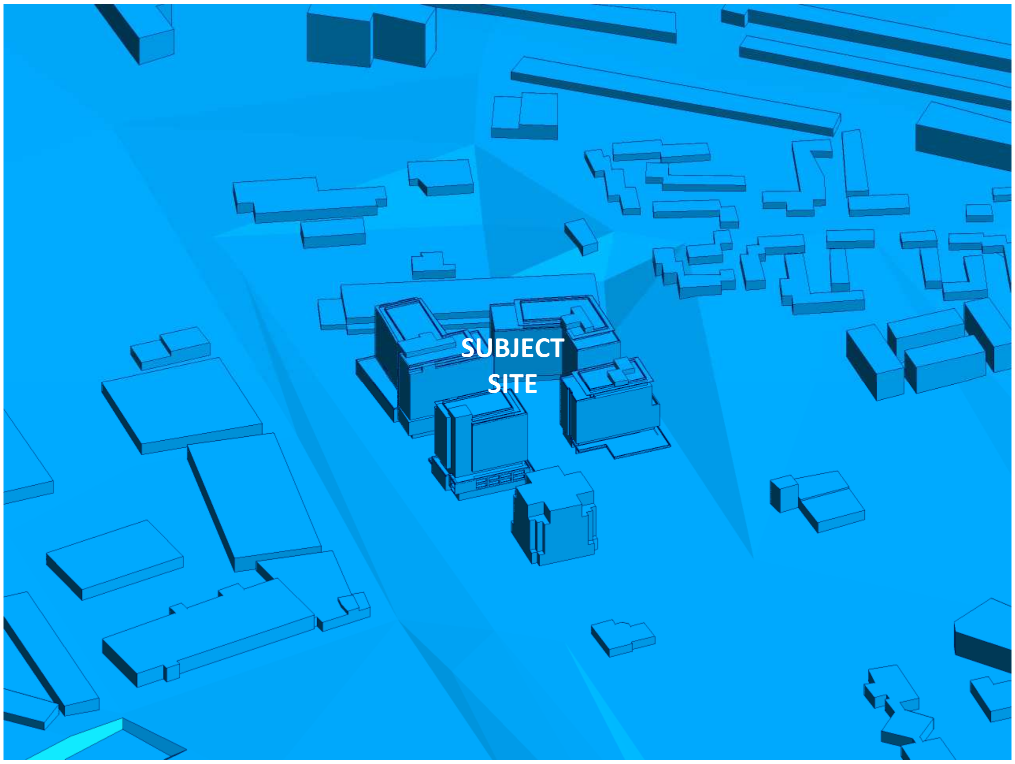

FIGURE 2A: COMPUTATIONAL MODEL, NORTH PERSPECTIVE

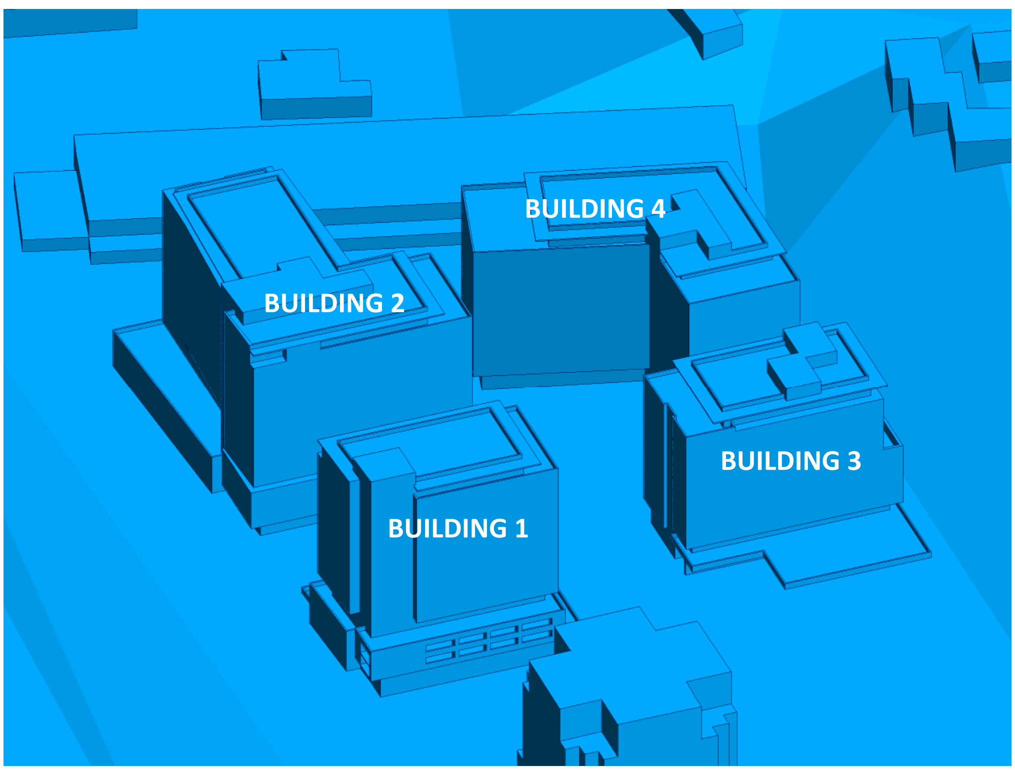

FIGURE 2B: CLOSE UP OF FIGURE 2A

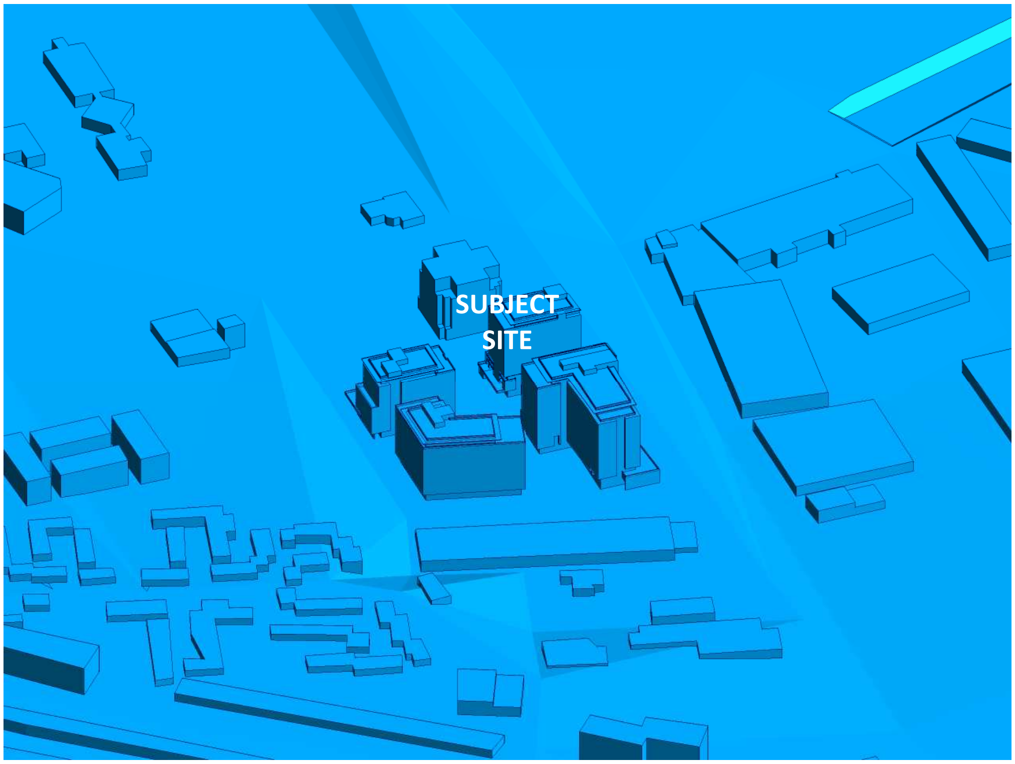

FIGURE 2C: COMPUTATIONAL MODEL, SOUTH PERSPECTIVE

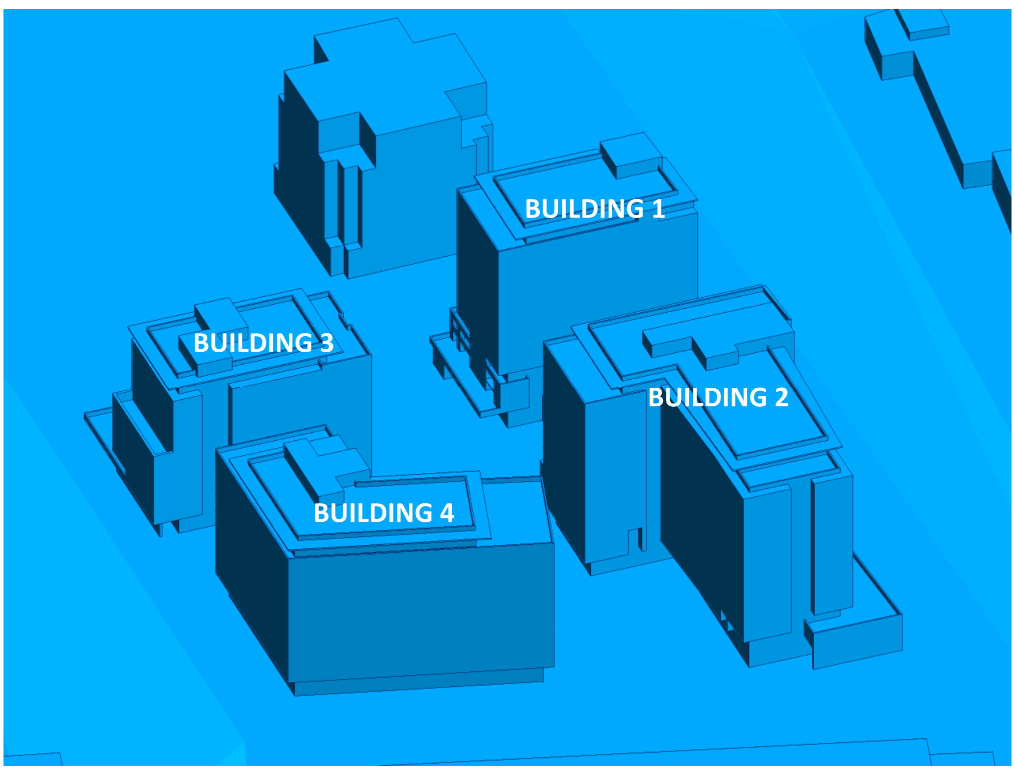

FIGURE 2D: CLOSE UP OF FIGURE 2C

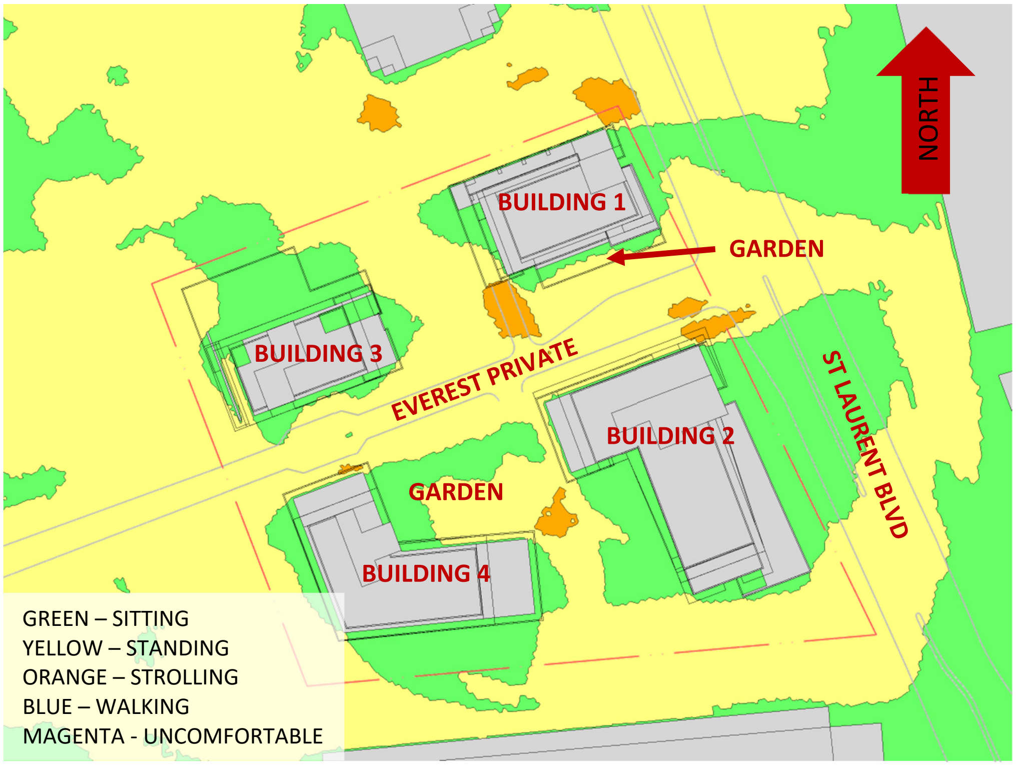

FIGURE 3A: SPRING – WIND CONDITIONS AT GRADE LEVEL

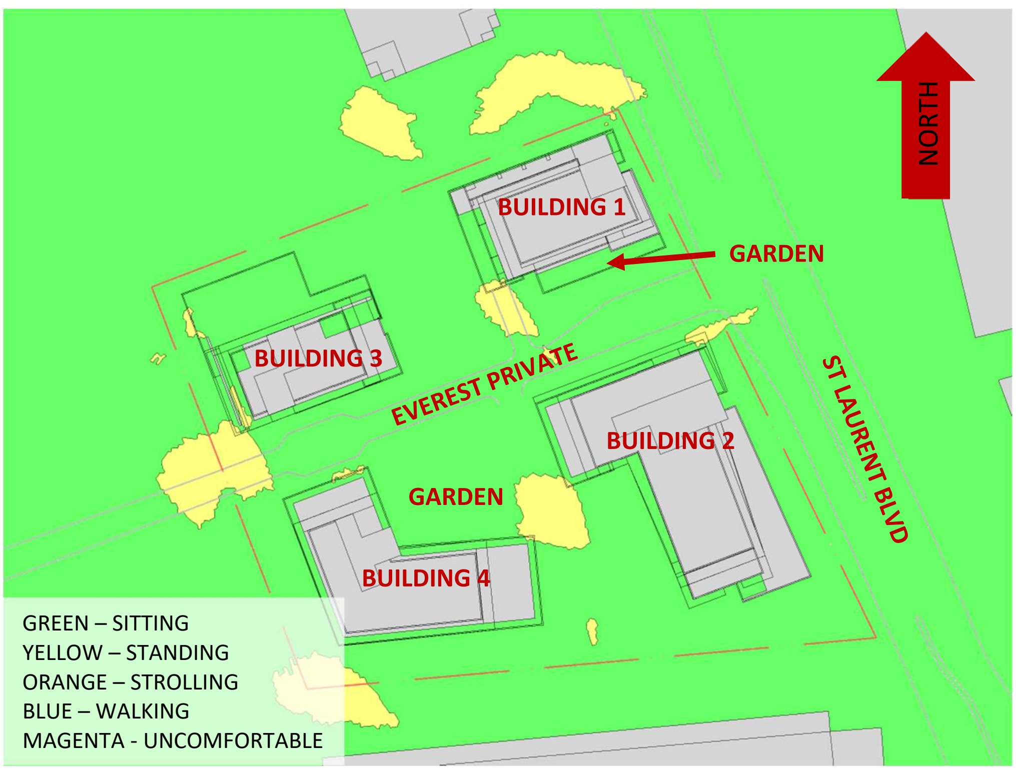

FIGURE 3B: SUMMER – WIND CONDITIONS AT GRADE LEVEL

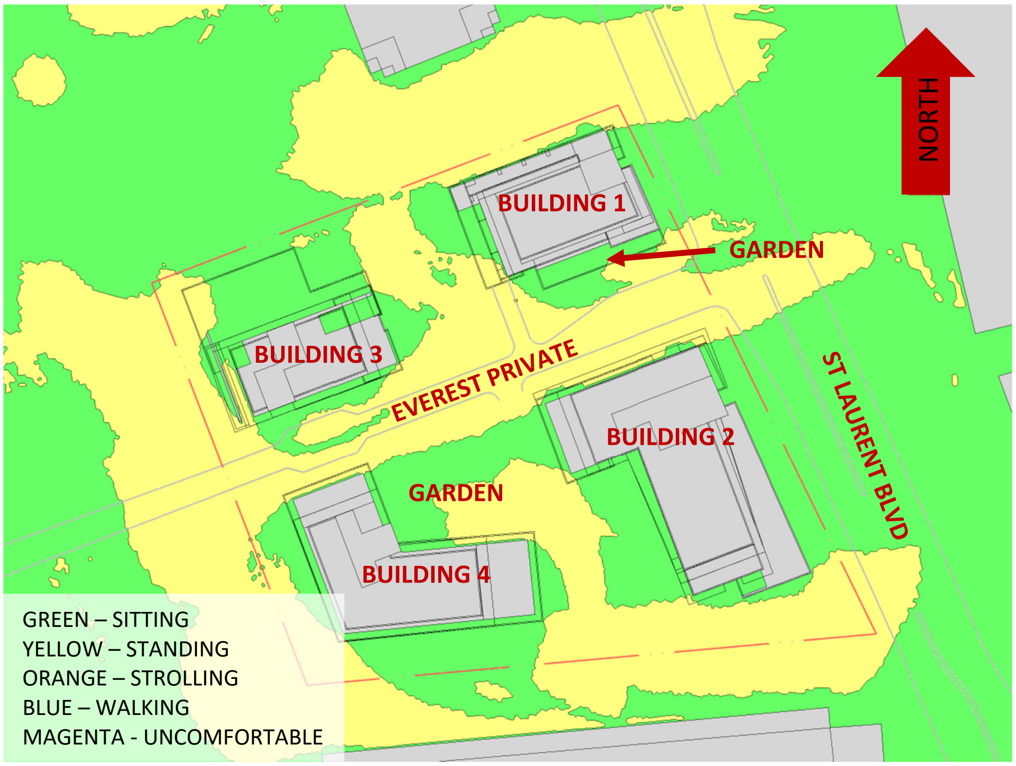

FIGURE 3C: AUTUMN – WIND CONDITIONS AT GRADE LEVEL

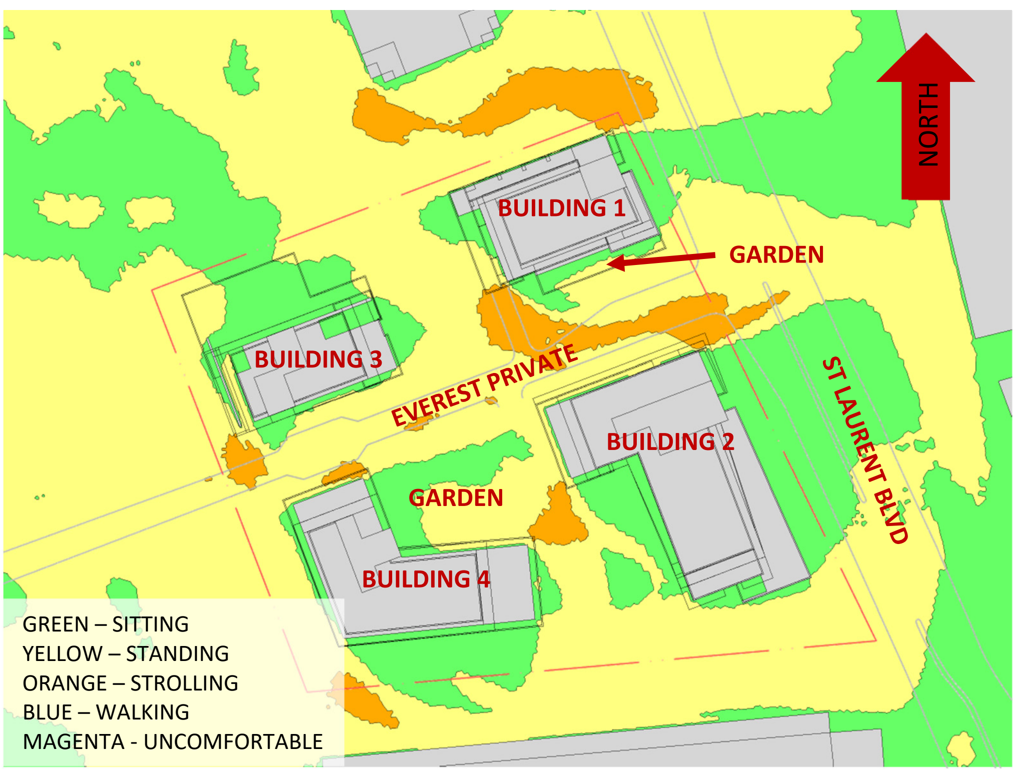

FIGURE 3D: WINTER – WIND CONDITIONS AT GRADE LEVEL

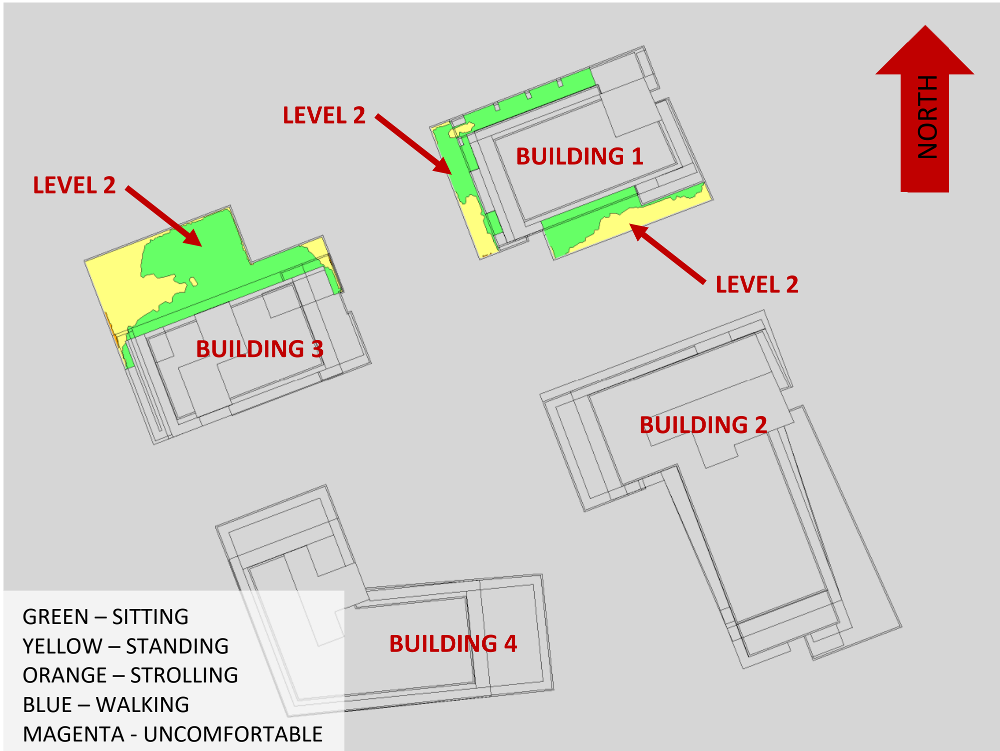

FIGURE 4A: SPRING – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES

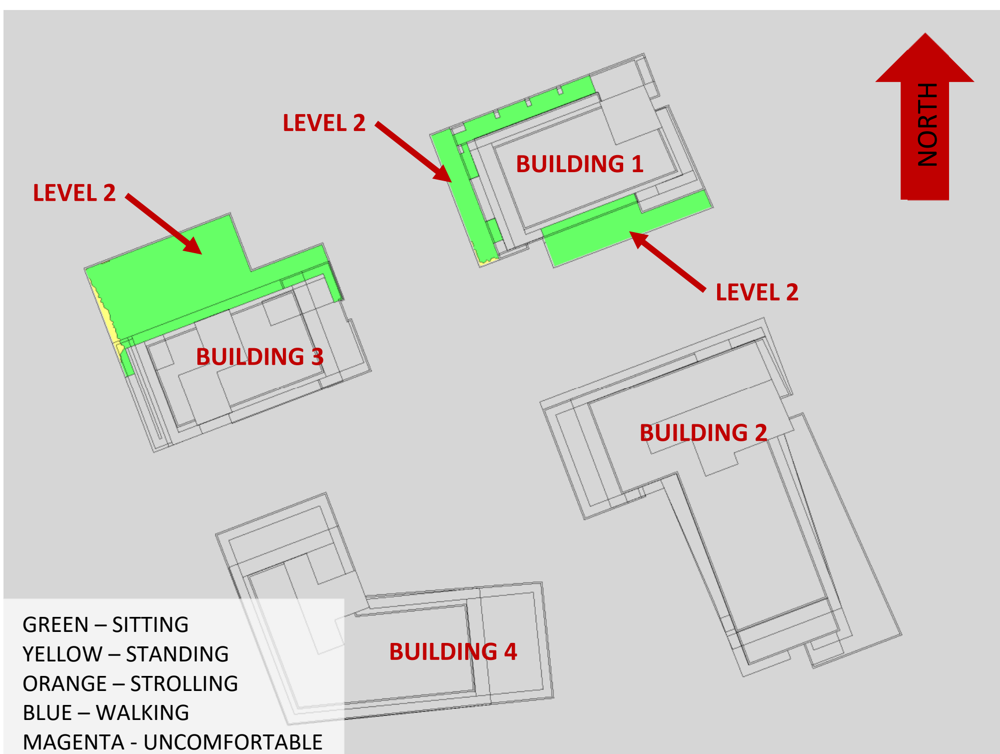

FIGURE 4B: SUMMER – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES

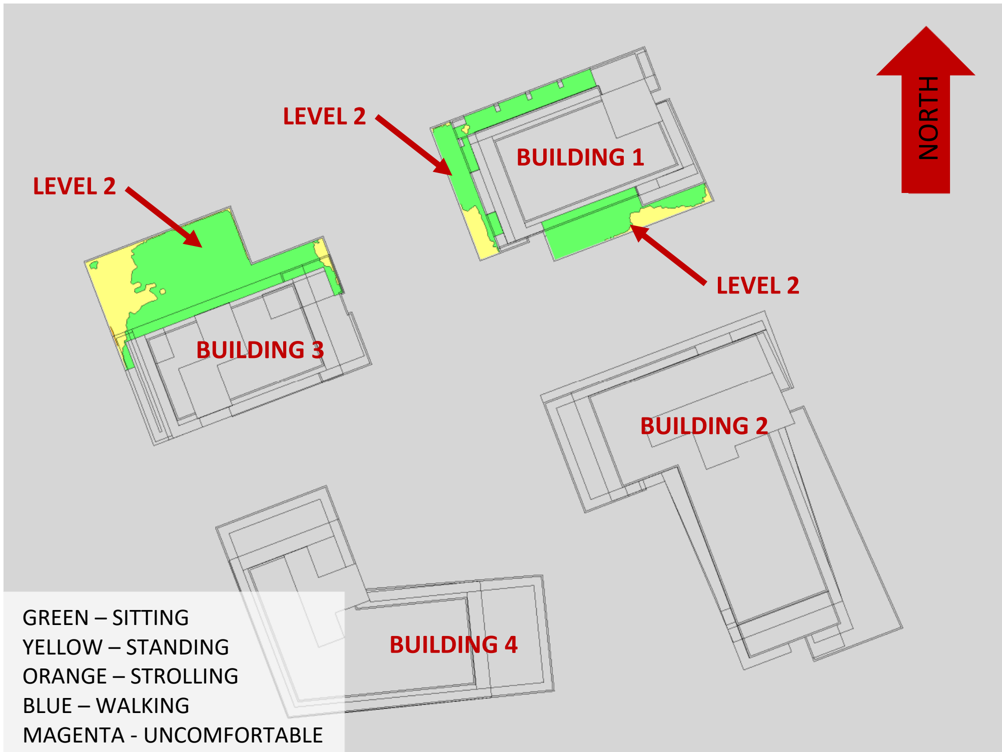

FIGURE 4C: AUTUMN – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES

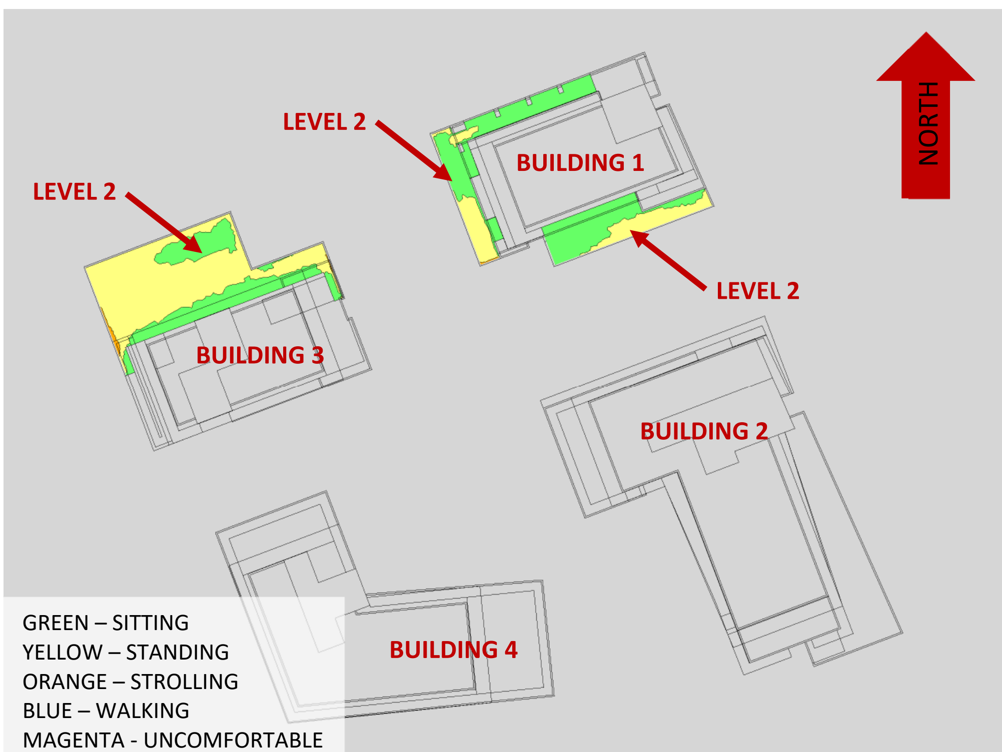

FIGURE 4D: WINTER – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES

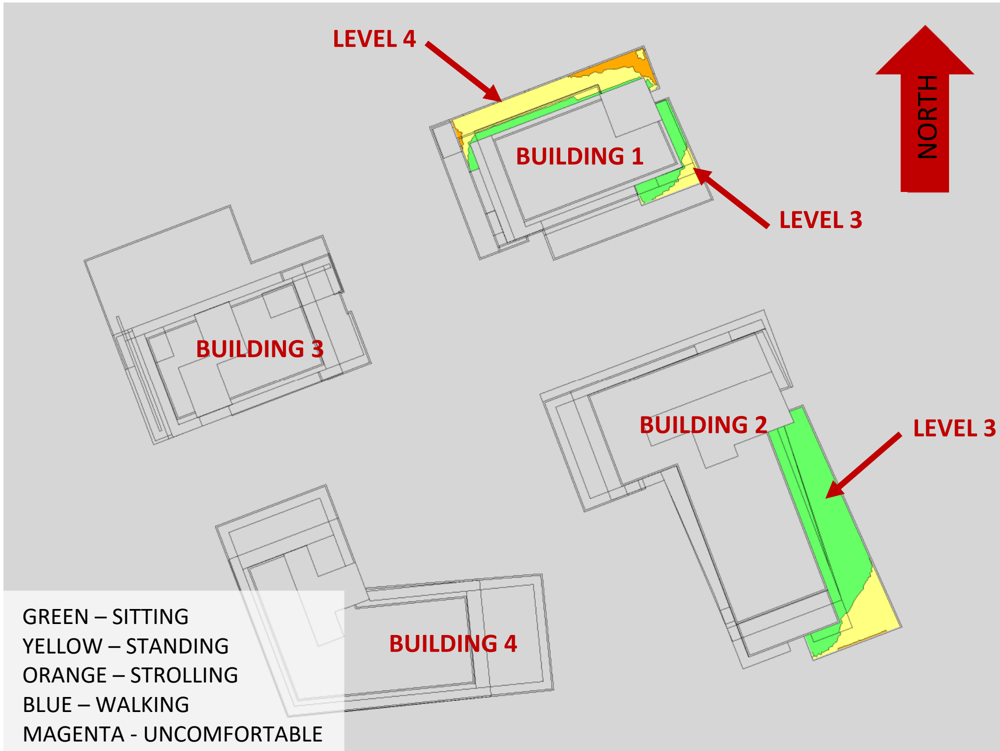

FIGURE 5A: SPRING – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES

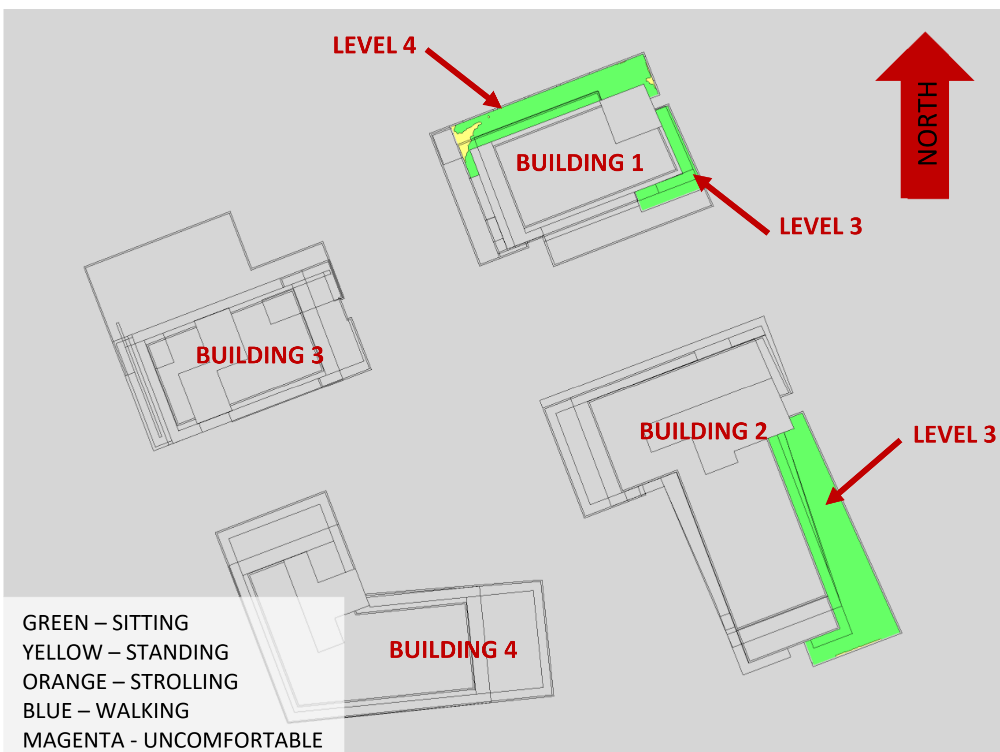

FIGURE 5B: SUMMER – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES

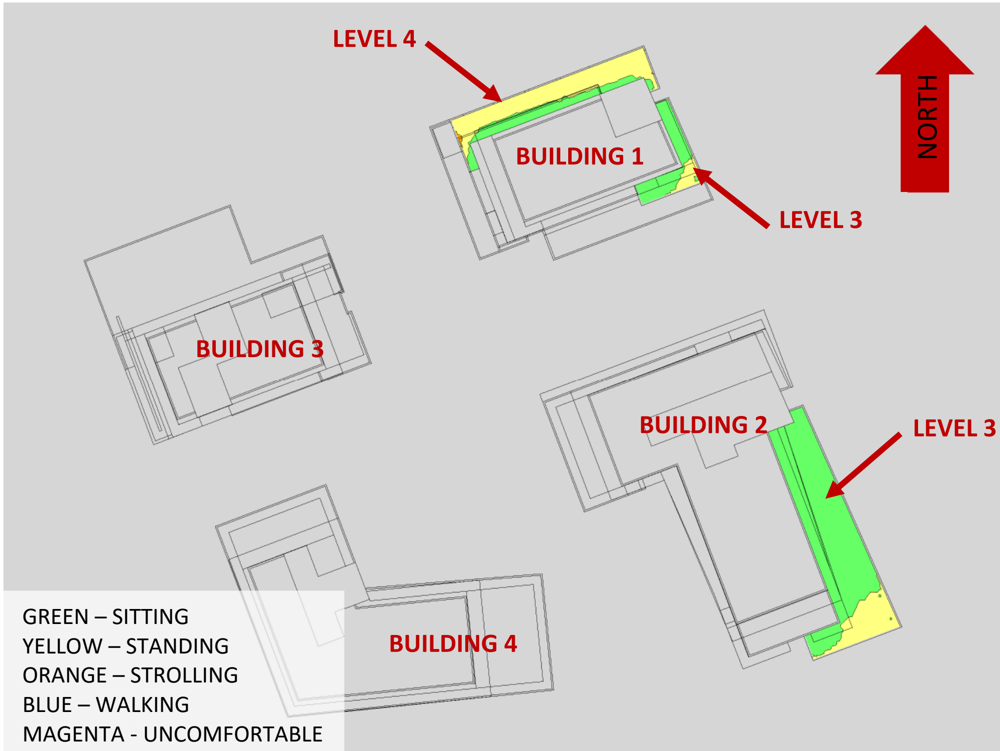

FIGURE 5C: AUTUMN – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES

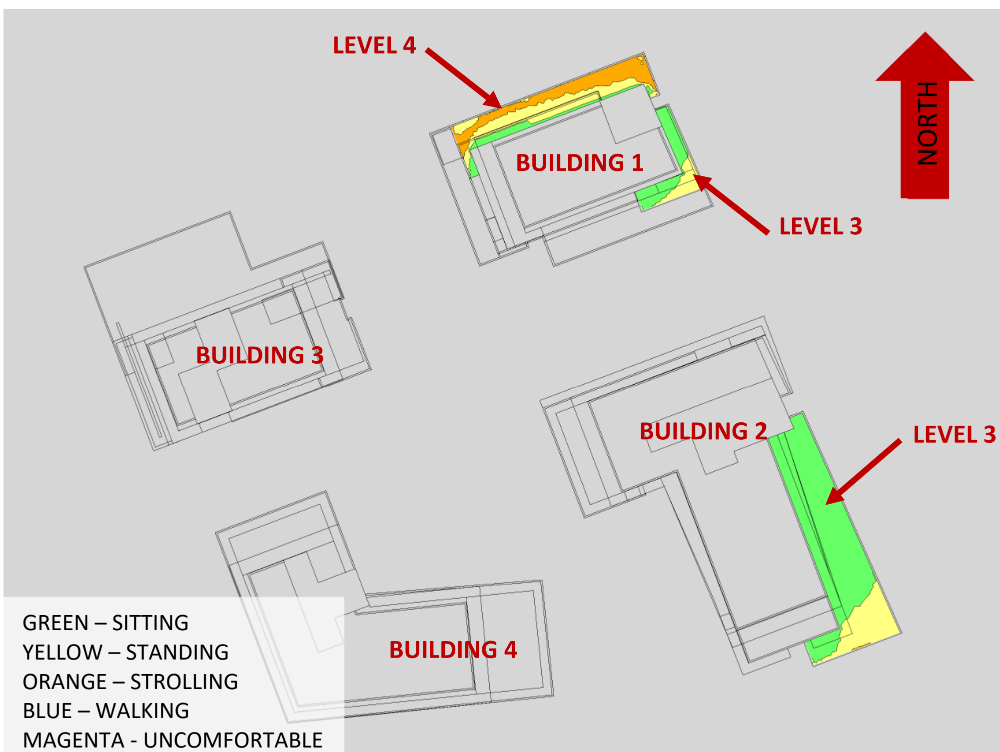

FIGURE 5D: WINTER – WIND CONDITIONS WITHIN COMMON AMENITY TERRACES

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 α 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.

α 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 (° True)	Alpha (α) Value
0	0.23
49	0.22
74	0.22
103	0.22
167	0.23
197	0.23
217	0.23
237	0.23
262	0.23
282	0.24
302	0.22
324	0.23

TABLE 2: DEFINITION OF UPSTREAM EXPOSURE (ALPHA VALUE)

Upstream Exposure Type	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].

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

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

where, ***I*** = turbulence intensity, L_t = turbulence length scale, ***Z*** = height above ground, and α 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.