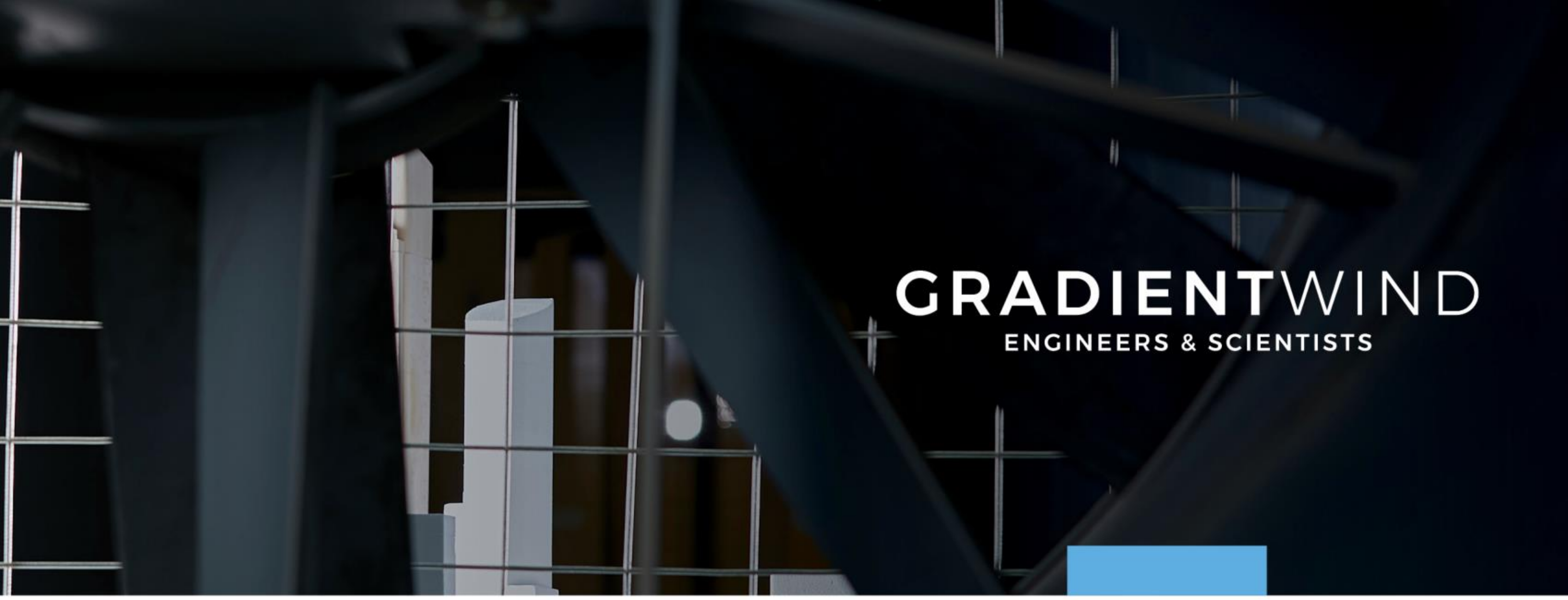
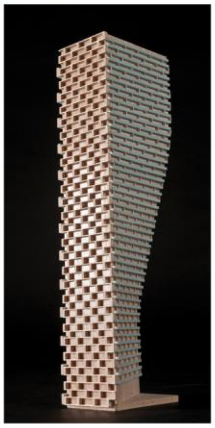
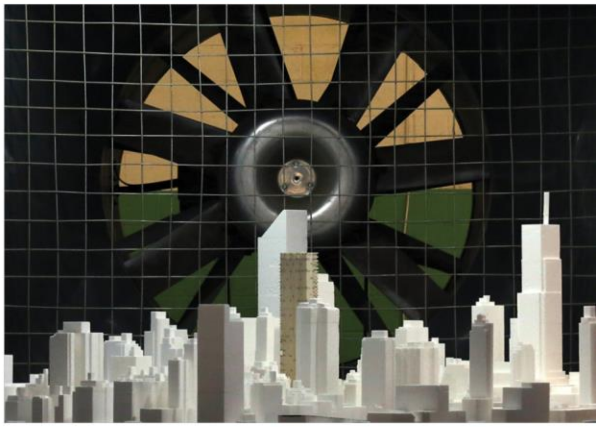


PEDESTRIAN LEVEL WIND AND MICROCLIMATE STUDY

41-43 Essa Road and 259 Innisfil Street
Barrie, Ontario

Report: 21-138-PLW





September 21, 2021

PREPARED FOR
Tonlu Holdings Ltd.
401 Vaughan Valley Boulevard
Woodbridge, ON L4H 3B5

PREPARED BY
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EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) and microclimate study to satisfy Zoning By-law Amendment (ZBLA) application requirements for the proposed development located at 41-43 Essa Road and 259 Innisfil Street in Barrie, Ontario (hereinafter referred to as the "subject site" or "proposed development"). Our mandate within this study is to investigate wind conditions within and surrounding the subject site, and to identify areas where wind 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. A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-8B, and is summarized as follows:

1) All 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, walkways, transit stops, parking lots, and building access points are considered acceptable, without mitigation.

2) Depending on the programming, conditions over the Level 7 amenity terraces may be suitable for the intended pedestrian uses. Importantly, large areas are predicted to be suitable for sitting along the south and east elevations of Towers 1 and 2, the south elevation of Tower 3, and the south and north elevations of Tower 4. If necessary, sitting conditions may be extended to other areas of the terrace with a combination of perimeter guards, typically glazed, in-board wind barriers, or canopies, located around seating areas. Mitigation strategies will be developed in collaboration with the design team for the future Site Plan Control application.

3) 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, (e.g., 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.

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1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Tonlu Holdings Ltd. to undertake a pedestrian level wind (PLW) and microclimate study to satisfy Zoning By-law Amendment (ZBLA) application requirements for the proposed development located at 41-43 Essa Road and 259 Innisfil Street in Barrie, Ontario (hereinafter referred to as the “subject site” or “proposed development”). Our mandate within this study is to investigate wind conditions within and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered.

The study is based on industry standard computer simulations using the computational fluid dynamics (CFD) technique and data analysis procedures, architectural drawings provided by Architecture Unfolded, in June 2021 and updated in September 2021, surrounding street layouts and existing and approved future building massing information obtained from the City of Barrie, and recent site imagery.

2. TERMS OF REFERENCE

The subject site is situated on an irregular parcel of land bordering Innisfil Street to the west, Essa Road to the east, and the Barrie Colllingwood Railway (BCRY) to the north. Throughout this report, the Innisfil Street elevation is referred to as the west elevation.

The proposed development comprises four towers between 20-37 storeys atop a shared 6-storey podium. From the southwest clockwise to the northeast, the towers are referred to as Tower 1 through 4, and reach heights of 29, 35, 37, and 20 storeys. At grade, the podium is divided by a driveway into a portion to the west serving Towers 1, 2, and 3, and a portion to the east serving Tower 4. The grade level for the west portion of the podium comprises residential units and a residential lobby along the west elevation, a second residential lobby at the northeast, and parking spaces throughout the remainder of the level. The grade level for the east portion of the podium comprises retail units along the southeast elevation, a residential lobby and office/mail room at the northwest corner, and parking spaces at the southwest corner. At Level 2, the east and west portions of the podium are connected. Level 2 comprises retail space at the northeast corner, residential units along the west elevation, and parking space and storage spaces throughout the remainder of the level. Levels 3 through 6 comprise residential units along the west elevation and at the northeast corner, and parking spaces and storage spaces throughout the remainder of the level. At Level 7, the towers step back from the podium to accommodate amenity spaces on the podium roof. For Towers 1 and 2, Level 7 comprises indoor amenity space along the east elevation and residential units along the west elevation. For Towers 3 and 4, Level 7 comprises indoor amenity space along the south elevation and residential units along the north elevation. Levels 8 and above are reserved for residential occupancy for all four towers.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre (m) radius of the subject site) comprise mostly low-rise massing in all directions. Additionally, there is a proposed 17-storey tower to the immediate west-southwest at 272 Innisfil Street, which has been approved for rezoning, as well as a proposed development which comprises two towers of 24- and 26-storeys on a shared 4-storey podium located approximately 130 m to the west-southwest at 17 Jacob’s Terrace. The far-field surroundings (defined as the area beyond the near field and within a 2-kilometre (km) radius) are characterized by a mix of mostly low-rise massing and the open exposure of Kempenfelt Bay from the north clockwise to the east, and mostly low-rise massing in the remaining compass direction. Notably, Kempenfelt Bay lies approximately 550 m to the northeast, and Highway 400 runs northwest-southeast approximately 1.0 km to the southwest.

Site plans for the proposed and existing massing scenarios are illustrated in Figures 1A and 1B, respectively, while Figures 2A-2F illustrate the computational models used to conduct the study. The “existing massing scenario” is defined to include both the massing that has already been constructed and any changes to the massing which have been approved by the City of Barrie for future construction. The development at 17 Jacob’s Terrace has been included in the proposed massing scenario, but not the existing massing scenario, while the development at 272 Innisfil Street has been included in both the proposed and existing massing scenarios.

3. OBJECTIVES

The principal objectives of this study are to: (i) determine comparative pedestrian level wind comfort and safety conditions at key outdoor areas; (ii) identify areas where future 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 Barrie wind climate, and synthesis of computational data with industry-accepted guidelines. The following sections describe the analysis procedures, including a discussion of the comfort guidelines.

4.1 Computer-Based Context Modelling

A computer-based PLW and microclimate wind study was performed to determine the influence of the wind environment on pedestrian comfort over the subject 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 Lake Simcoe Regional 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[1]. The omission of trees and other landscaping elements produces slightly more conservative (i.e., windier) wind speed values.

[1] City of Barrie, Wind Study: Terms of Reference

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 and two massing scenarios, as noted in Section 2. The CFD simulation models were centered on the subject site, complete with surrounding massing within a diameter of approximately 1.3 km.

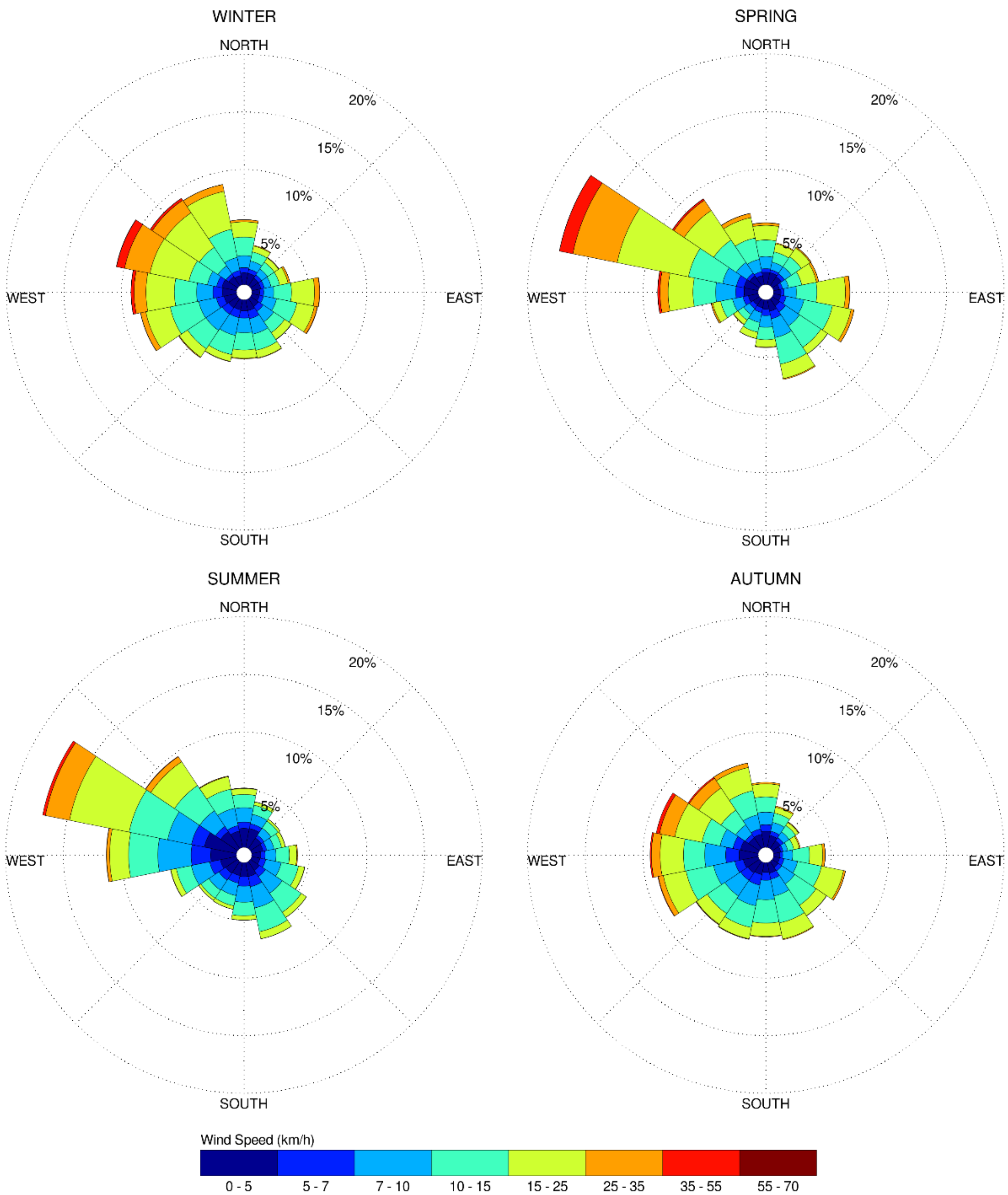
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds on a continuous measurement plane 1.5 m above local grade and the common amenity terraces were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. The gradient height represents the theoretical depth of the boundary layer of the earth's atmosphere, above which the mean wind speed remains constant. Further details of the CFD wind flow simulation technique are presented in Appendix A.

4.3 Meteorological Data Analysis

A statistical model for winds in Barrie was developed from approximately 12 years of hourly wind data recorded at Lake Simcoe Regional 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 Barrie 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 km/h. Probabilities of occurrence of different wind speeds are represented as stacked polar bars in sixteen azimuth divisions. The radial direction shows the frequency distribution of wind speeds for each wind direction during the measurement period. The preferred wind speeds and directions can be identified by the longer length of the bars. For Barrie, the most common winds concerning pedestrian comfort occur from the west clockwise to the north. The directional preference and relative magnitude of the wind speed varies somewhat from season to season with the summer months displaying the calmest winds relative to the remaining seasonal periods.

SEASONAL DISTRIBUTION OF WIND
LAKE SIMCOE REGIONAL AIRPORT, ORO STATION, ONTARIO



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 Guidelines

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

(i) **Sitting** – A gust wind speed no greater than 16 km/h is considered acceptable for sedentary activities, including sitting.

(ii) **Standing** – A gust wind speed greater than 16 km/h but no greater than 22 km/h is considered acceptable for activities such as standing or leisurely strolling.

(iii) **Walking** – A gust wind speed greater than 22 km/h but no greater than 30 km/h is considered acceptable for walking or more vigorous activities.

(iv) **Uncomfortable** – A gust wind speed greater than 30 km/h is classified as uncomfortable from a pedestrian comfort standpoint. Brisk walking and exercise, such as jogging, would be acceptable for moderate excesses of this comfort class.

The pedestrian safety wind speed guideline is based on the approximate threshold that would cause a vulnerable member of the population to fall. A 0.1% exceedance gust wind speed of greater than 90 km/h is classified as dangerous. The wind speeds associated with the above categories are gust wind speeds. 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 wind speeds of 16 km/h were exceeded for more than 20% of the time most pedestrians would judge that location to be too windy for sitting or more sedentary activities. Similarly, if 30 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 guidelines 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 / Walking
Public Sidewalks / Pedestrian Walkways	Walking
Outdoor Amenity Spaces	Sitting / Standing
Cafés / Patios / Benches / Gardens	Sitting / Standing
Transit Stops	Sitting / Standing
Transit Stops (with Shelter)	Sitting / Standing / Walking
Public Parks	Sitting / Standing / Walking
Garage / Service Entrances	Walking
Vehicular Drop-Off Zones	Standing / Walking
Laneways / Loading Zones	Walking

5. RESULTS AND DISCUSSION

The following discussion of the predicted pedestrian wind conditions for the subject site is accompanied by Figures 3A-6B, which illustrate seasonal wind conditions at grade level for the proposed and approved massing scenarios, and Figures 7A-7D, which illustrate seasonal wind conditions over the amenity terraces. Conditions are presented as continuous contours of wind comfort within and surrounding the subject site and correspond to the various comfort classes noted in Section 4.4. Wind conditions suitable for sitting are represented by the colour green, standing by yellow, and walking by blue; uncomfortable conditions are represented by the colour magenta.

Wind conditions over amenity terraces are also reported for the typical use period, which is defined as May to October, inclusive. Figure 8A illustrates wind comfort conditions, consistent with the comfort classes in Section 4.4, while Figure 8B illustrates contours indicating the percentage of time the terraces are predicted to be suitable for sitting.

In all grade-level 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

Sidewalk, Transit Stop, and Building Entrances along Innisfil Street: Following the introduction of the proposed development, the sidewalk along Innisfil Street is predicted to be suitable for a mix of sitting and standing during the summer and autumn, becoming suitable for a mix of standing and walking during the spring and winter. In the vicinity of the nearby transit stop along Innisfil Street, conditions are predicted to be suitable for a mix of sitting and standing during the summer and autumn, becoming suitable for standing during the spring and winter. Owing to the protection of the building façade, conditions in the vicinity of building entrances along Innisfil Street are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the comfort guidelines in Section 4.4.

Conditions over the Innisfil Street sidewalk with the approved massing are predicted to be mostly suitable for sitting during the summer and autumn, becoming suitable for a mix of sitting and standing during the spring and winter. In the vicinity of the nearby transit stop, conditions are predicted to be suitable for sitting during the summer and autumn, becoming suitable for a mix of sitting and standing during the spring and winter. While the introduction of the proposed development results in slightly windier conditions along the Innisfil Street sidewalk in comparison to existing conditions, conditions with the proposed development are considered acceptable.

Sidewalk and Building Entrances along North Elevation: Conditions over the sidewalk along the north elevation are predicted to be suitable for a mix of sitting and standing during the summer and autumn, becoming suitable for mostly standing during the winter, and suitable for a mix of standing and walking during the spring. Owing to the protection of the building façade, conditions in the vicinity of building entrances along the north elevation are predicted to be suitable for sitting during the summer, autumn, and winter, becoming suitable for a mix of sitting and standing during the spring. The noted conditions are considered acceptable according to the comfort guidelines in Section 4.4.

Drop-Off Area along North Elevation: Conditions over the drop-off area along the north elevation are predicted to be suitable for a mix of sitting and standing during the summer and autumn, becoming suitable for a mix of sitting, standing, and walking during the spring and winter. Notably, the walking conditions during the spring and winter are located near the parking access serving Tower 4. Owing to the protection of the building façade, conditions in the vicinity of building entrances along the drop-off area are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the comfort guidelines in Section 4.4.

Sidewalk and Building Entrances along Essa Road: Following the introduction of the proposed development, the sidewalk along Essa Road is predicted to be suitable for a mix of sitting and standing during the summer, autumn, and winter, becoming suitable for a mix of sitting, standing, and walking during the spring. Owing to the protection of the building façade, conditions in the vicinity of building entrances along Essa Road are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the comfort guidelines in Section 4.4.

Conditions over the sidewalk along Essa Road with the approved massing are predicted to be suitable for sitting throughout the year. While the introduction of the proposed development results in slightly windier conditions in comparison to existing conditions, wind conditions with the proposed development are considered acceptable.

Walkway along Southeast Elevation: Conditions over the walkway along the southeast elevation are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable according to the comfort guidelines in Section 4.4.

5.2 Wind Comfort Conditions – Common Amenity Terraces

Level 7 Amenity Terrace Serving Towers 1, 2, and 3: Conditions over the Level 7 amenity terrace serving Towers 1, 2, and 3 are predicted to be suitable for mostly a mix of sitting and standing during the typical use period with an area near the southwest corner of Tower 3 being suitable for walking. Conditions between the towers are generally windier than the areas along the broad faces of the towers. Importantly, there are large areas predicted to be suitable for sitting along the south and east elevations of Towers 1 and 2 and along the south elevation of Tower 3. If the programming of the space locates any seating areas within the areas identified as being suitable for sitting in Figure 8A, these conditions may be considered acceptable. If seating areas are desired in the windier areas of the terrace, mitigation may be used to ensure conditions are suitable for sitting. This mitigation may include a combination of perimeter guards, typically glazed, in-board wind barriers, or canopies, located around seating areas. Mitigation strategies will be developed in collaboration with the design team for the future Site Plan Control application.

Level 7 Amenity Terrace Serving Tower 4: Conditions over the Level 7 amenity terrace serving Tower 4 are predicted to be suitable for mostly sitting during the typical use period, with conditions near the southwest corner of Tower 4 being suitable for a mix of standing and walking. If the programming of the space locates any seating areas within the areas identified as being suitable for sitting in Figure 8A, these conditions may be considered acceptable. If seating areas are desired to the southwest of Tower 4, mitigation may be used to ensure conditions are suitable for sitting. This mitigation may include a combination of perimeter guards, typically glazed, in-board wind barriers, or canopies, located around seating areas. Mitigation strategies will be developed in collaboration with the design team for the future Site Plan Control application.

5.3 Wind Safety

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, (e.g., 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.

5.4 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 (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 subject site would alter the wind profile approaching the site; and (ii) development in proximity to the subject site would cause changes to local flow patterns.

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. SUMMARY AND RECOMMENDATIONS

A complete summary of the predicted wind conditions is provided in Section 5 of this report and illustrated in Figures 3A-8B. Based on computer simulations using the CFD technique, meteorological data analysis, and experience with numerous similar developments, the study concludes the following:

1) All 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, walkways, transit stops, parking lots, and building access points are considered acceptable, without mitigation.

2) Depending on the programming, conditions over the Level 7 amenity terraces may be suitable for the intended pedestrian uses. Importantly, large areas are predicted to be suitable for sitting along the south and east elevations of Towers 1 and 2, the south elevation of Tower 3, and the south and north elevations of Tower 4. If necessary, sitting conditions may be extended to other areas of the terrace with a combination of perimeter guards, typically glazed, in-board wind barriers, or canopies, located around seating areas. Mitigation strategies will be developed in collaboration with the design team for the future Site Plan Control application.

3) 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, (e.g., 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
S. R. HALL
100197168
Sept. 21, 2021
PROVINCE OF ONTARIO

David Huitema, M.Eng.
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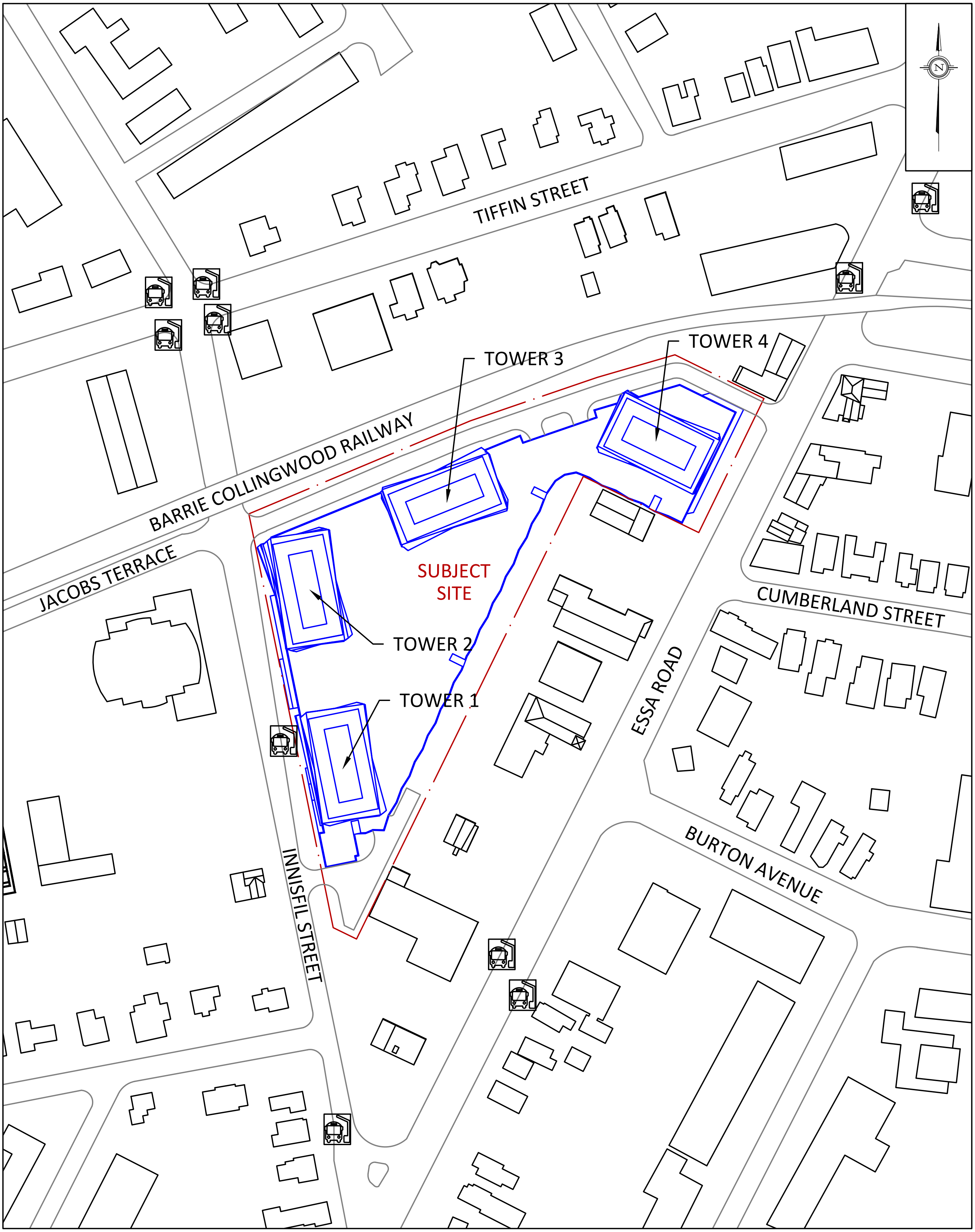
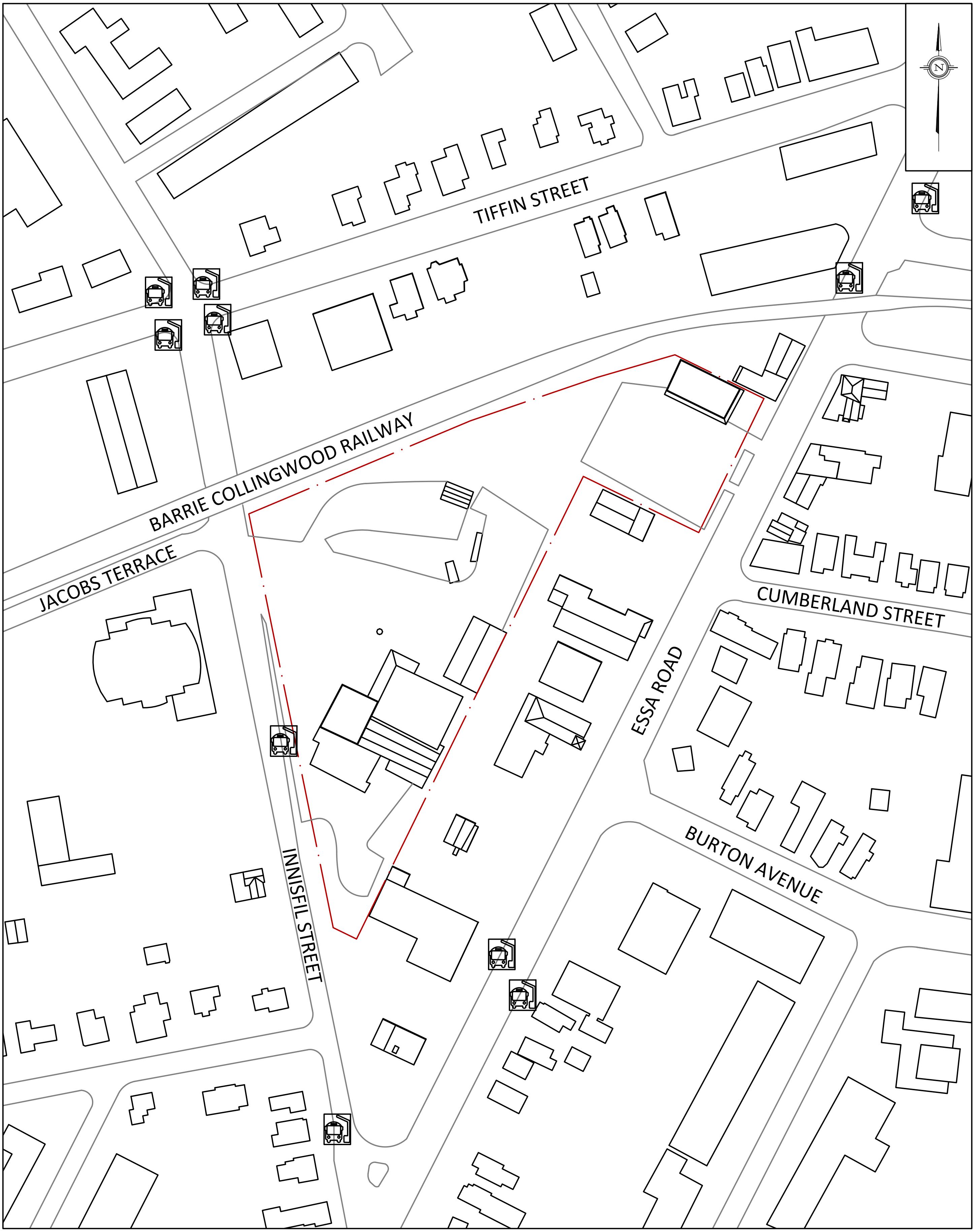
Senior Wind Engineer



GRADIENTWIND
ENGINEERS & SCIENTISTS

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

PROJECT: 41-43 ESSA ROAD & 259 INNISFIL STREET, BARRIE PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1A: PROPOSED SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:2000	DRAWING NO.: 21-138-PLW-1A	
DATE: JULY 30, 2021	DRAWN BY: N.M.P.	



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PROJECT		DESCRIPTION
41-43 ESSA ROAD & 259 INNISFIL STREET, BARRIE PEDESTRIAN LEVEL WIND STUDY		FIGURE 1B: EXISTING SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:2000	DRAWING NO.: 21-138-PLW-1B	
DATE: JULY 30, 2021	DRAWN BY: N.M.P.	

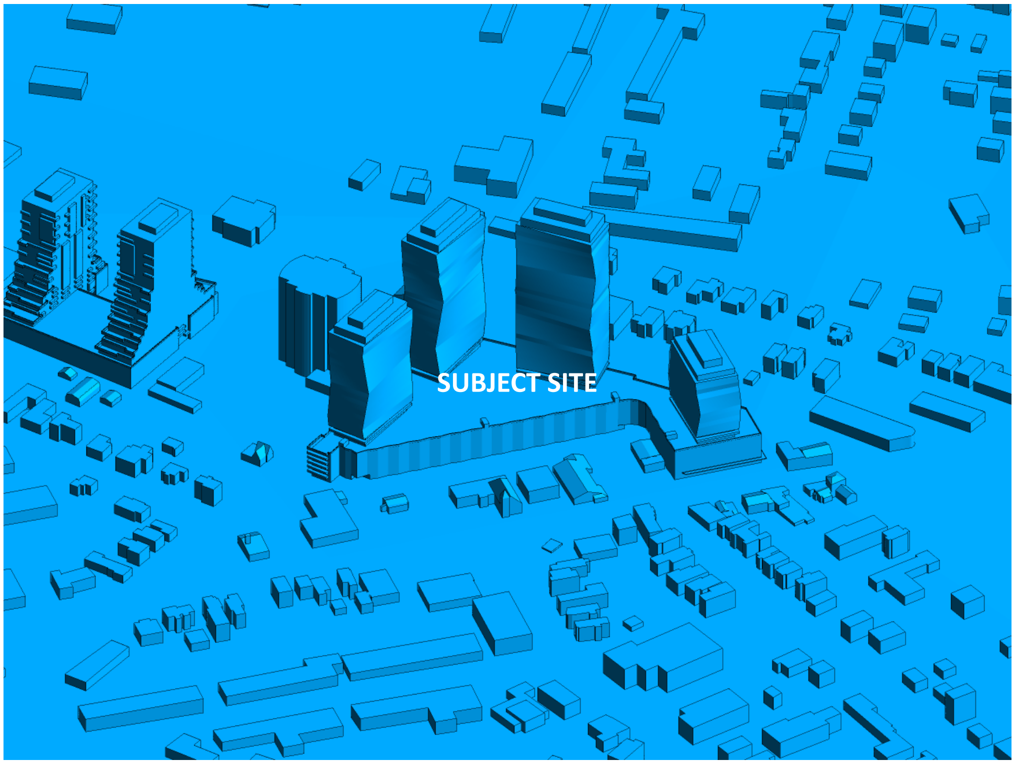


FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTHEAST PERSPECTIVE

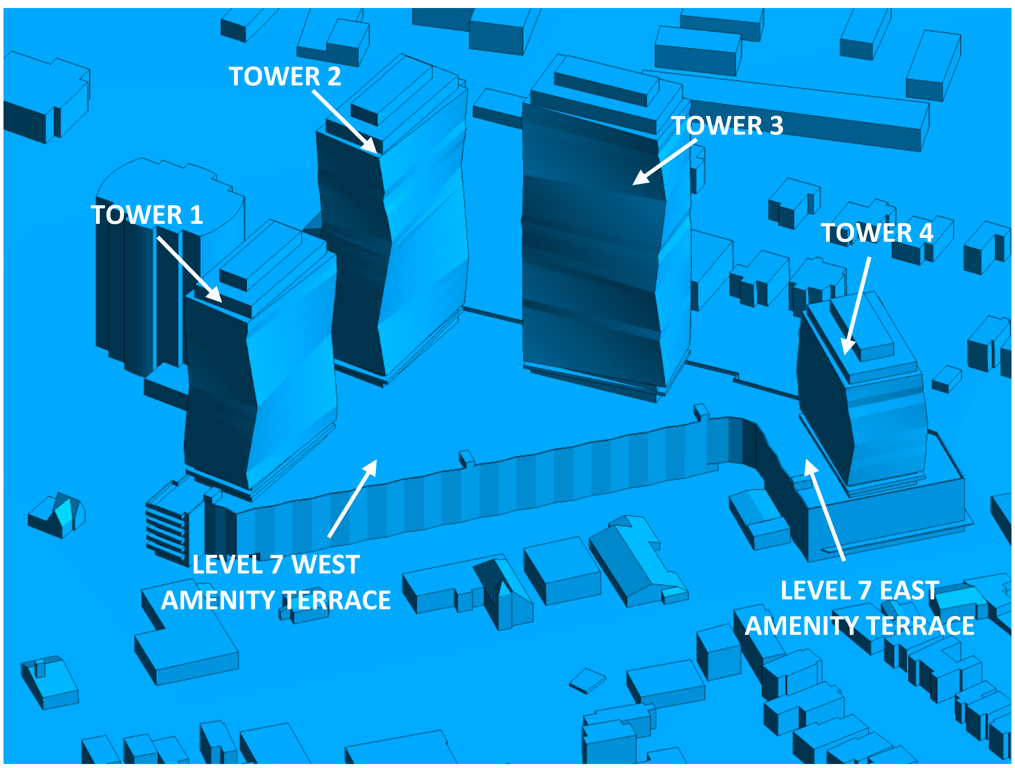


FIGURE 2B: CLOSE-UP VIEW OF FIGURE 2A

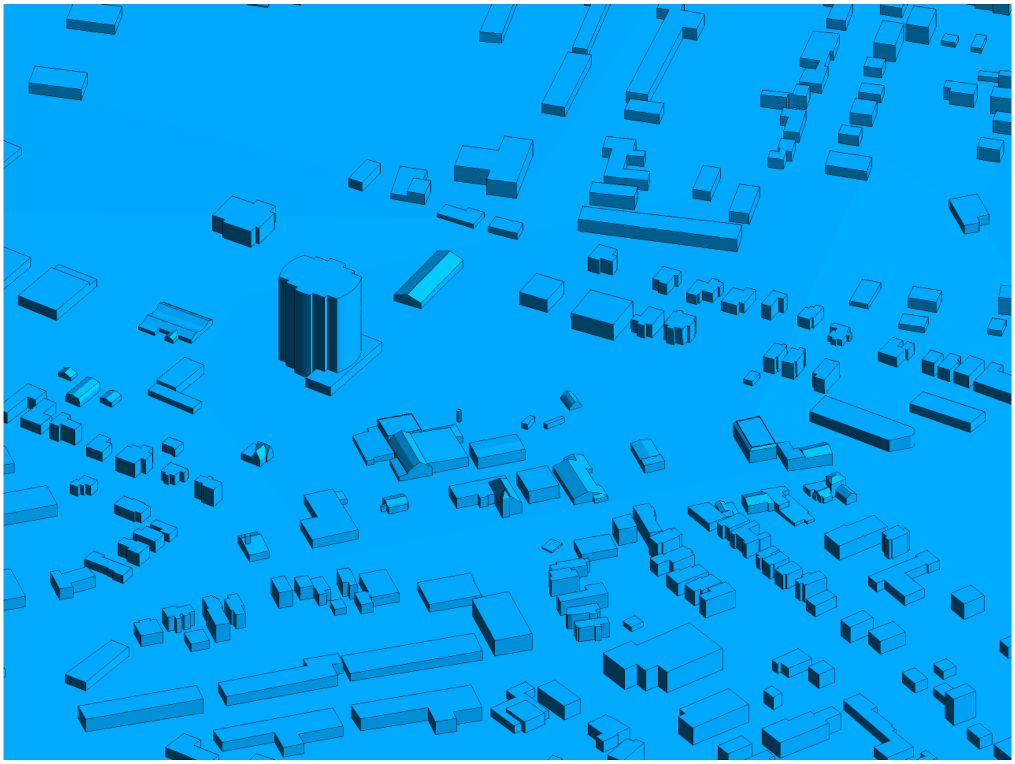


FIGURE 2C: COMPUTATIONAL MODEL, APPROVED MASSING, SOUTHEAST PERSPECTIVE

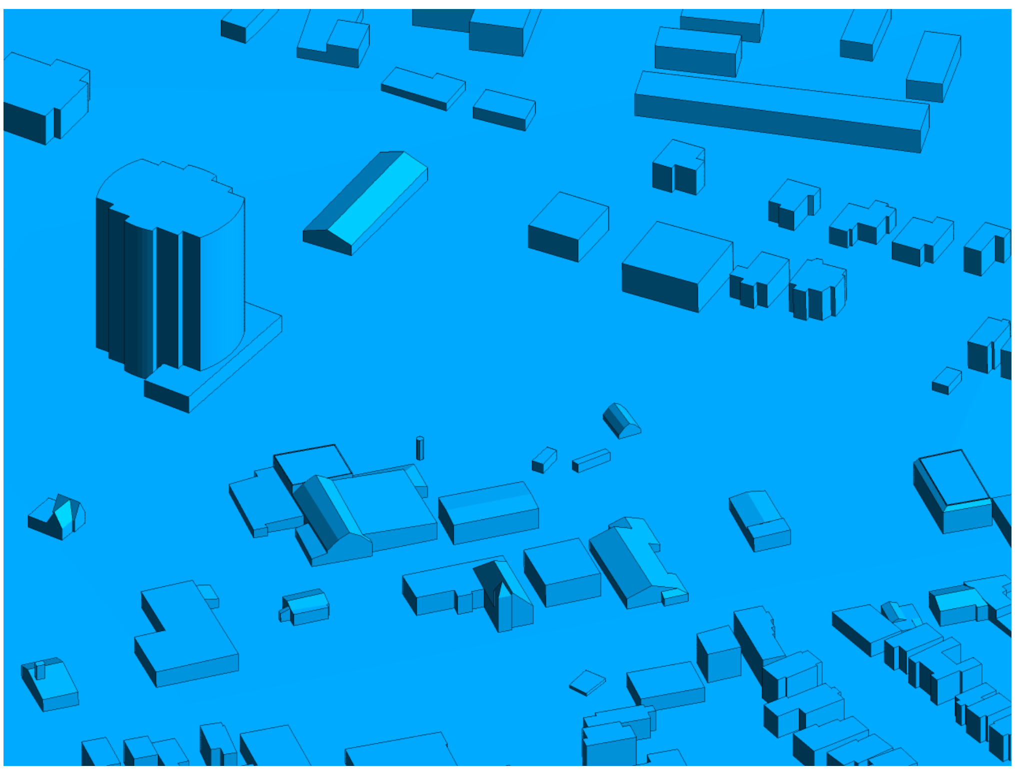


FIGURE 2D: CLOSE-UP VIEW OF FIGURE 2C

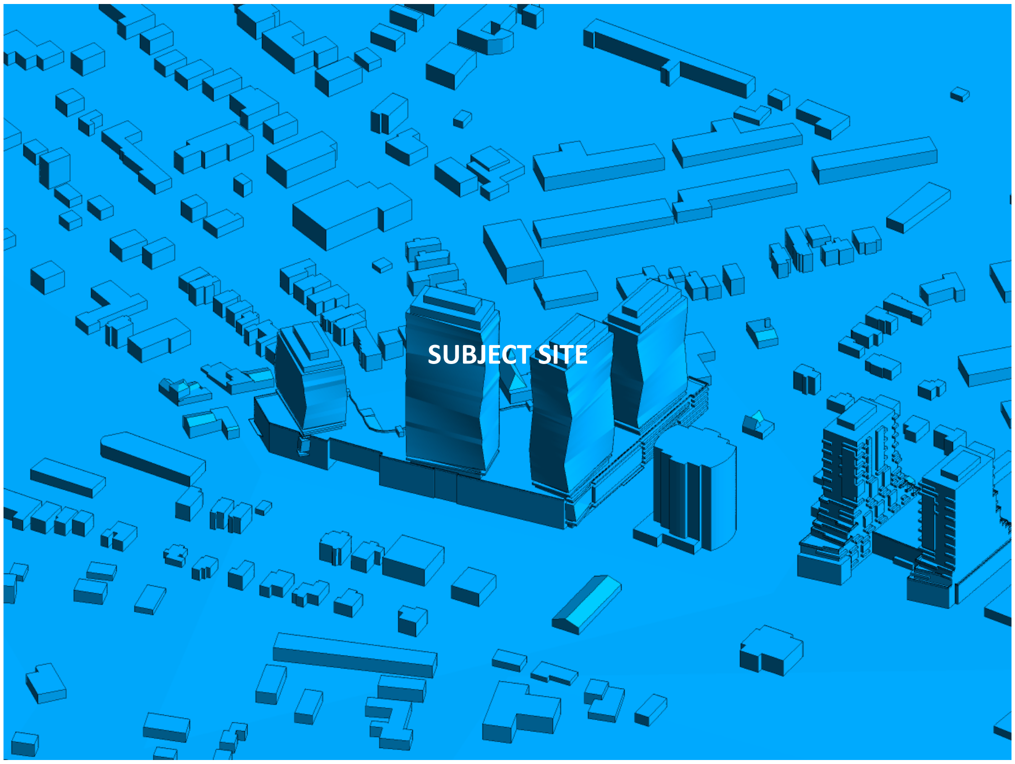


FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTHWEST PERSPECTIVE

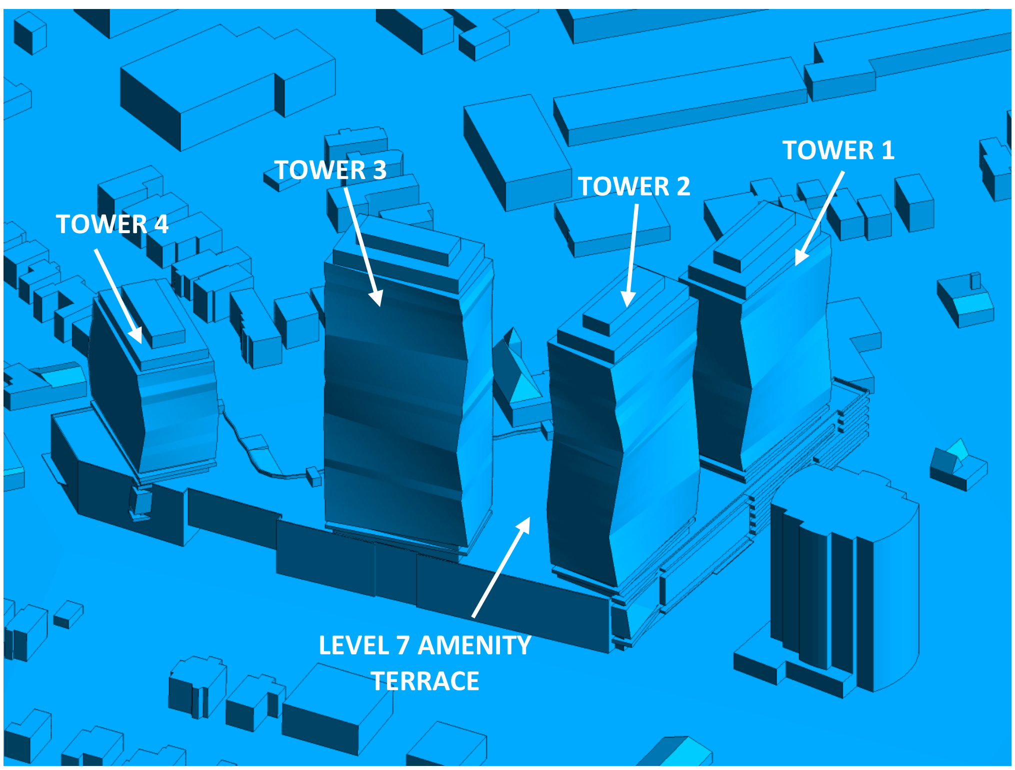


FIGURE 2F: CLOSE-UP VIEW OF FIGURE 2E

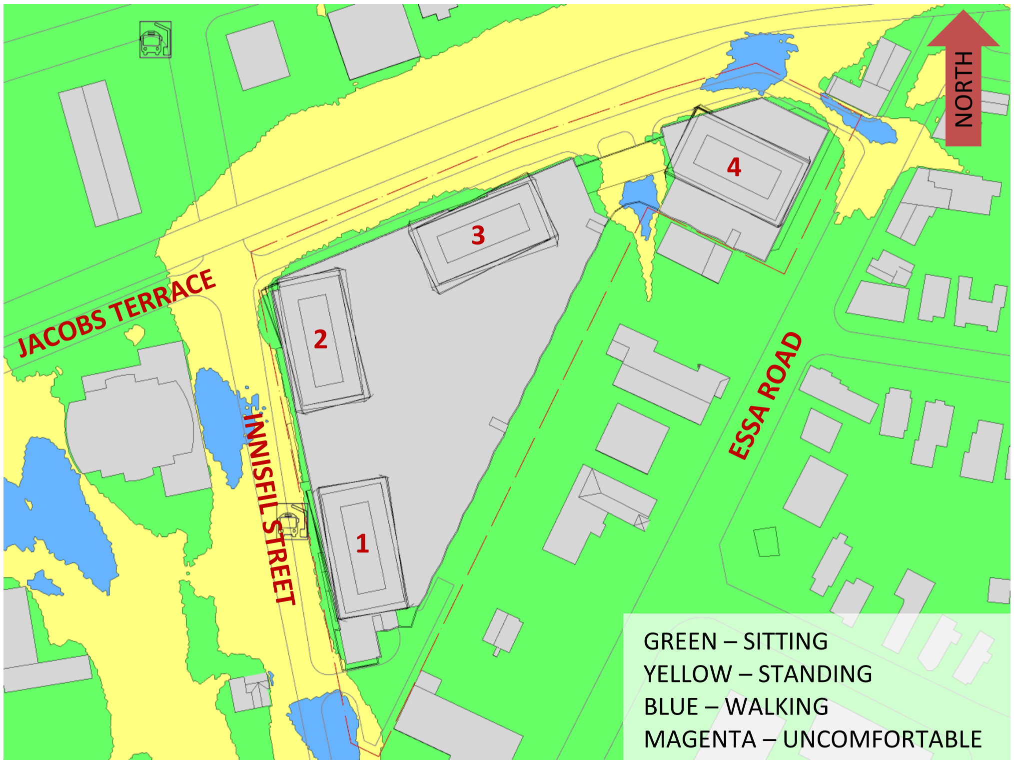


FIGURE 3A: SPRING – PROPOSED MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

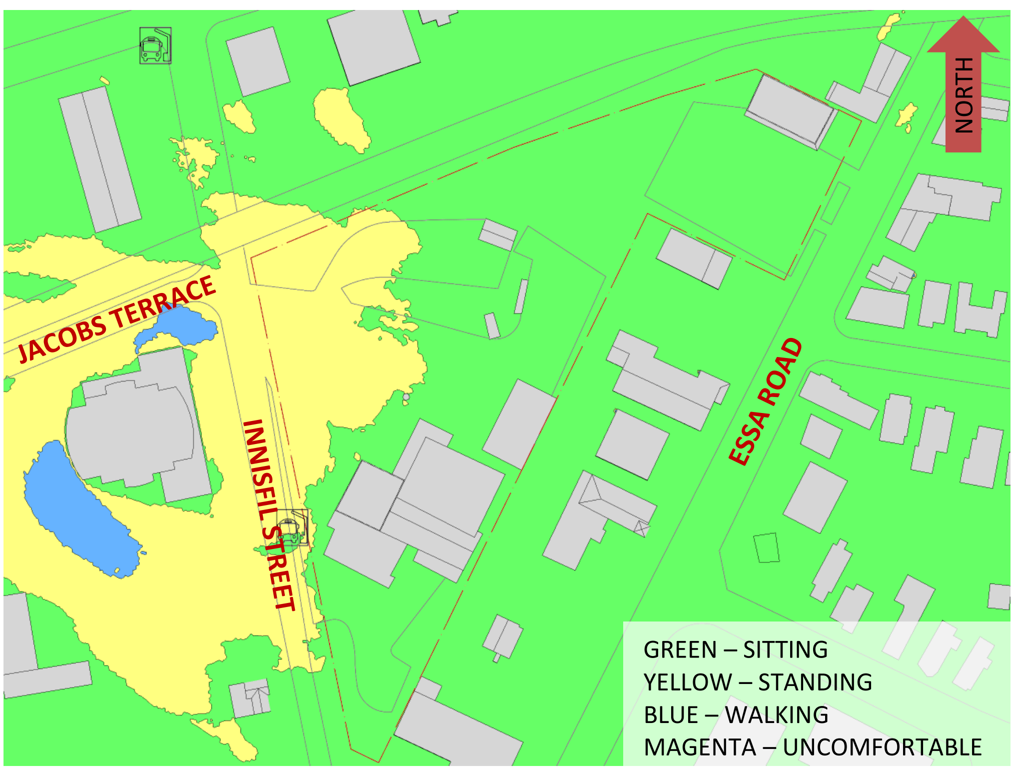


FIGURE 3B: SPRING – EXISTING MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

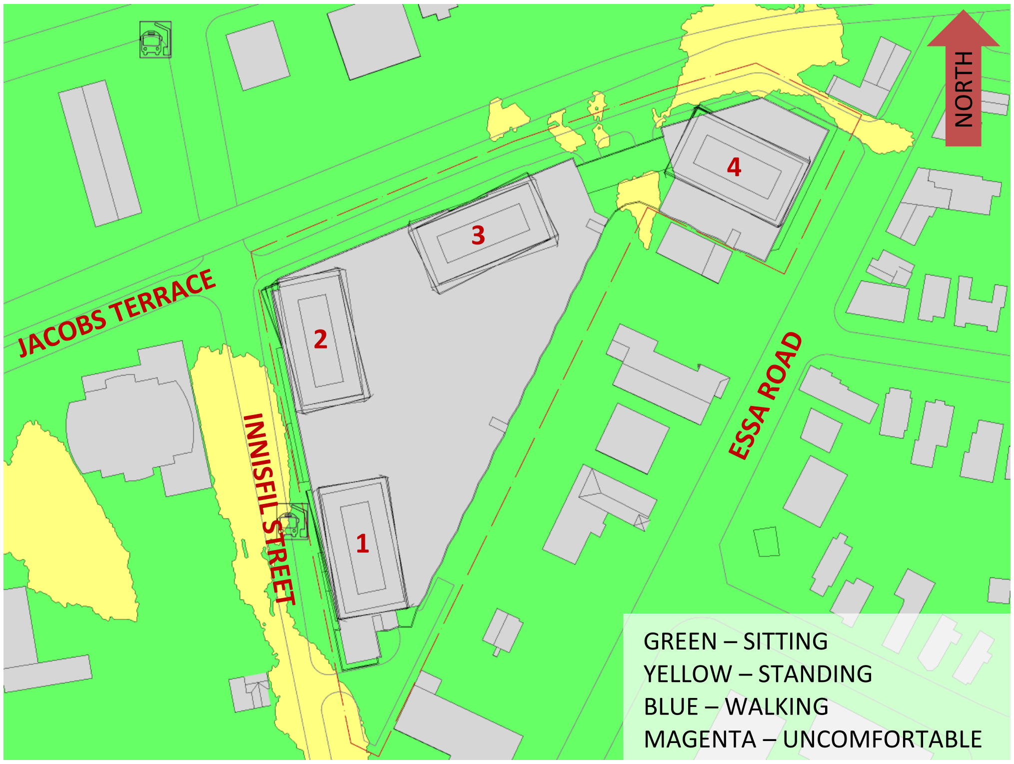


FIGURE 4A: SUMMER – PROPOSED MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

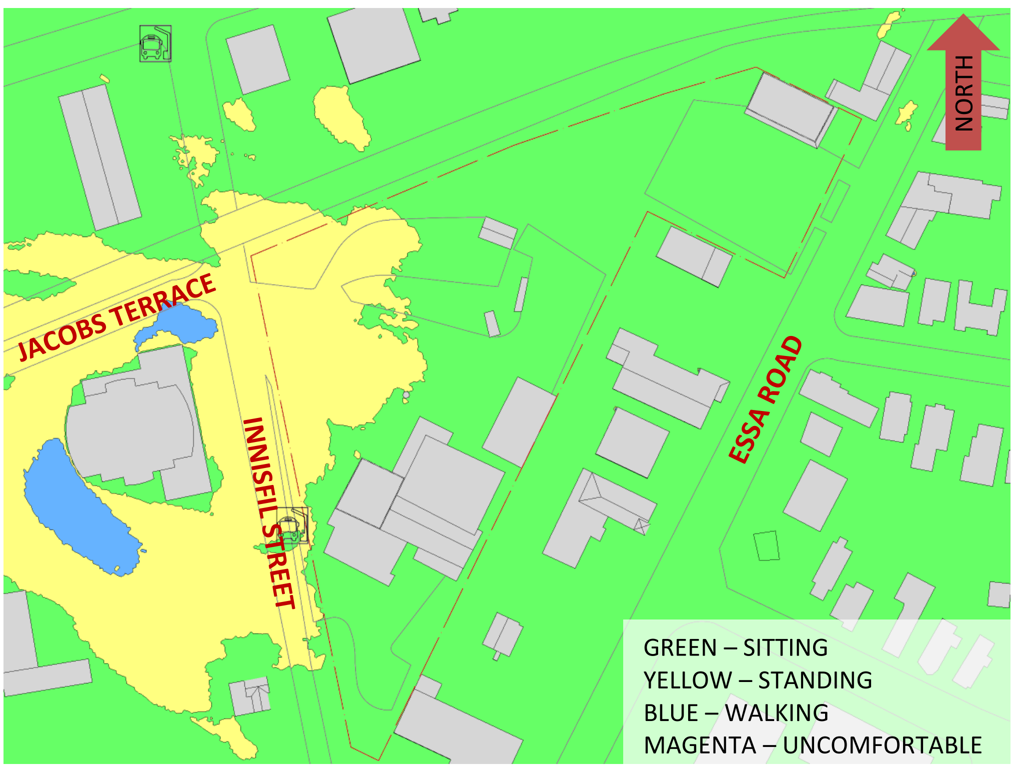


FIGURE 4B: SUMMER – APPROVED MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

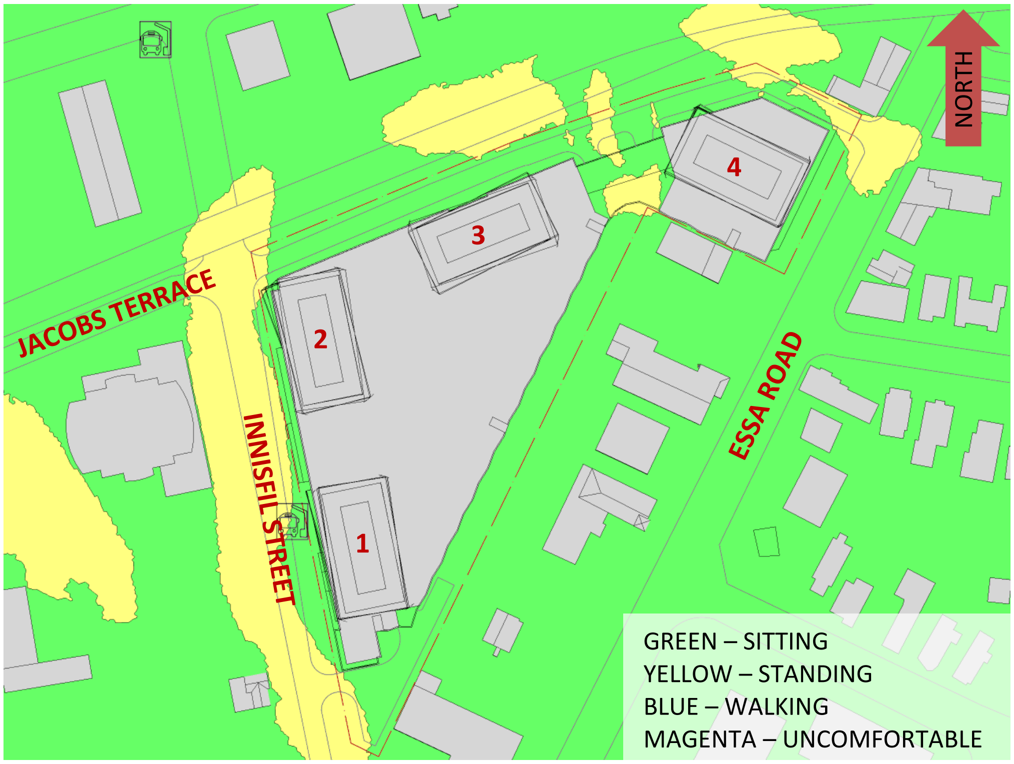


FIGURE 5A: AUTUMN – PROPOSED MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

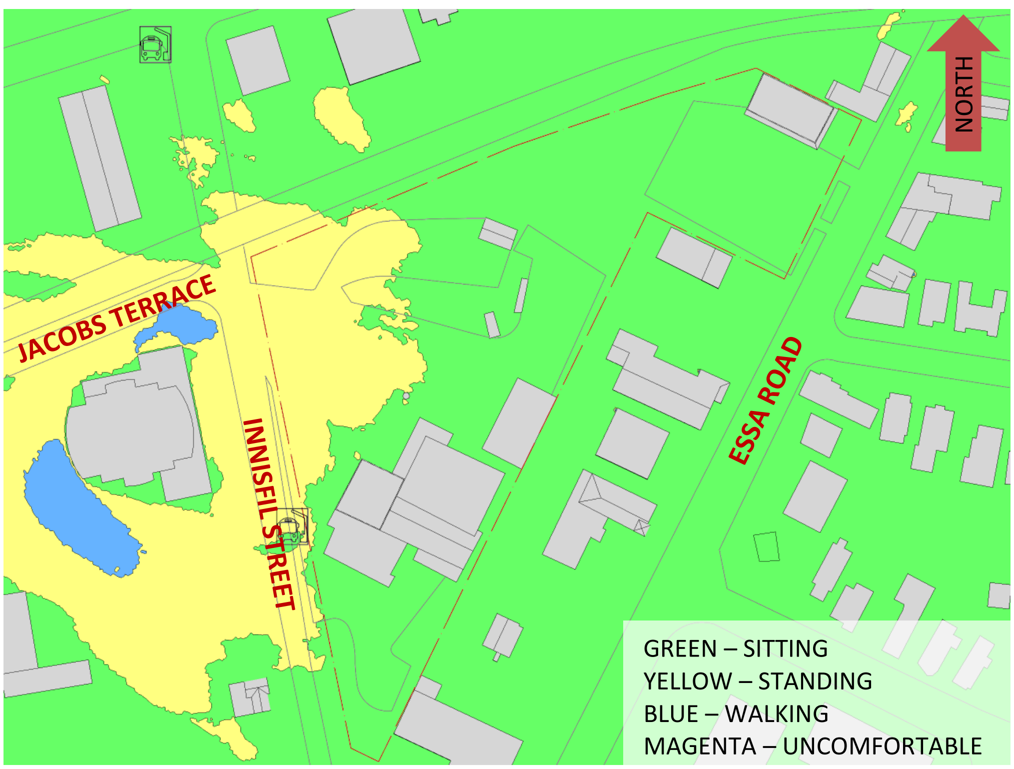


FIGURE 5B: AUTUMN – APPROVED MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

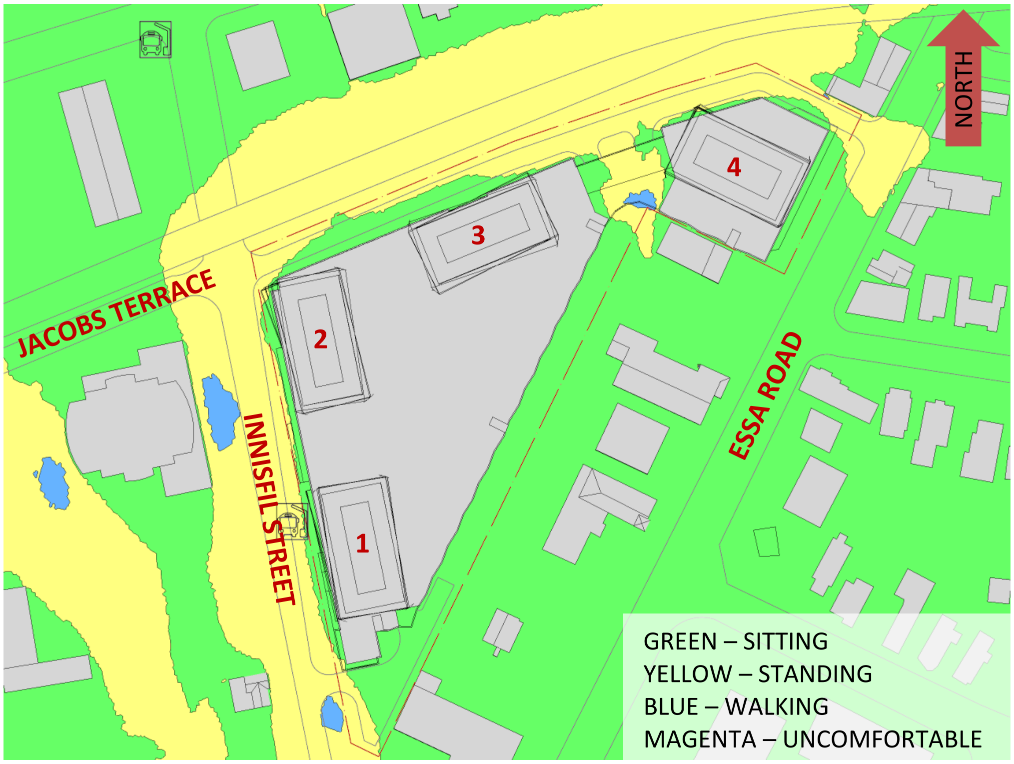


FIGURE 6A: WINTER – PROPOSED MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

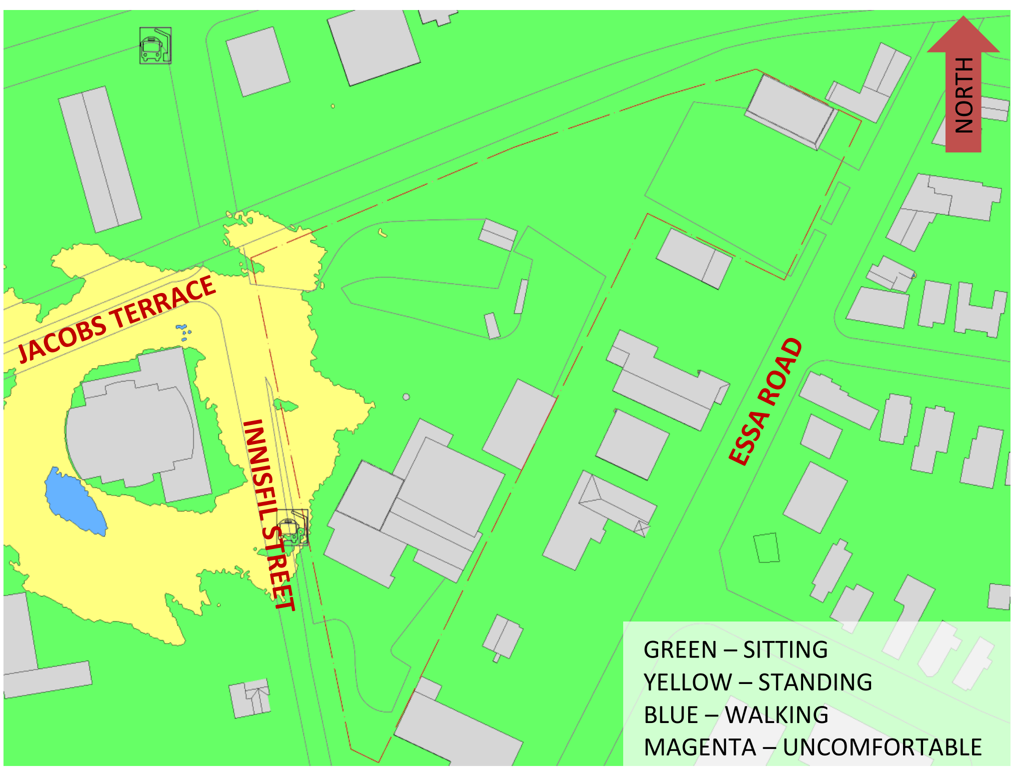


FIGURE 6B: WINTER – APPROVED MASSING – WIND COMFORT CONDITIONS, GRADE LEVEL

FIGURE 7A: SPRING – WIND COMFORT CONDITIONS, ROOFTOP AMENITY TERRACES

FIGURE 7B: SUMMER – WIND COMFORT CONDITIONS, ROOFTOP AMENITY TERRACES

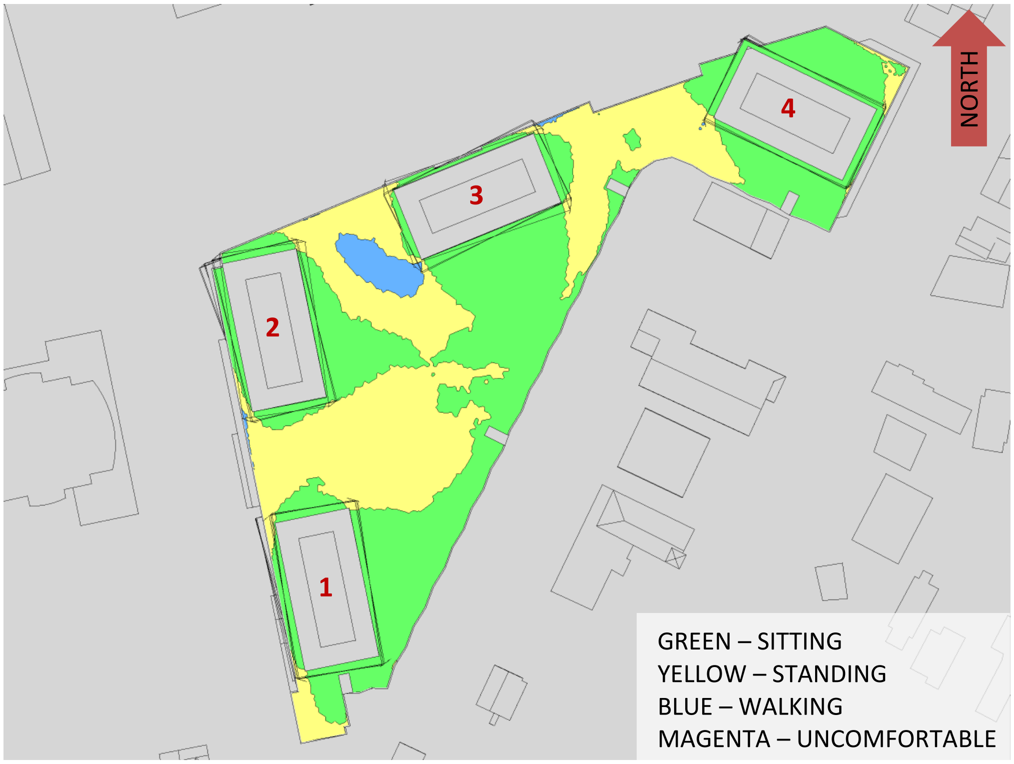


FIGURE 7C: AUTUMN – WIND COMFORT CONDITIONS, ROOFTOP AMENITY TERRACES

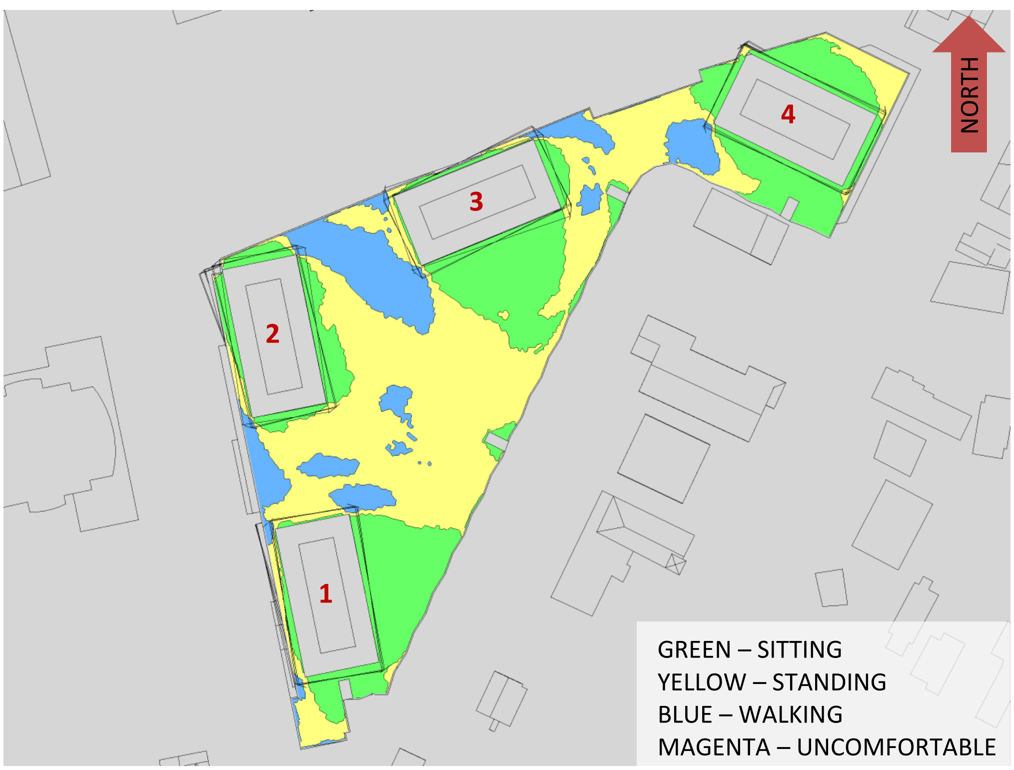


FIGURE 7D: WINTER – WIND COMFORT CONDITIONS, ROOFTOP AMENITY TERRACES

FIGURE 8A: TYPICAL USE PERIOD – WIND COMFORT CONDITIONS, AMENITY TERRACES

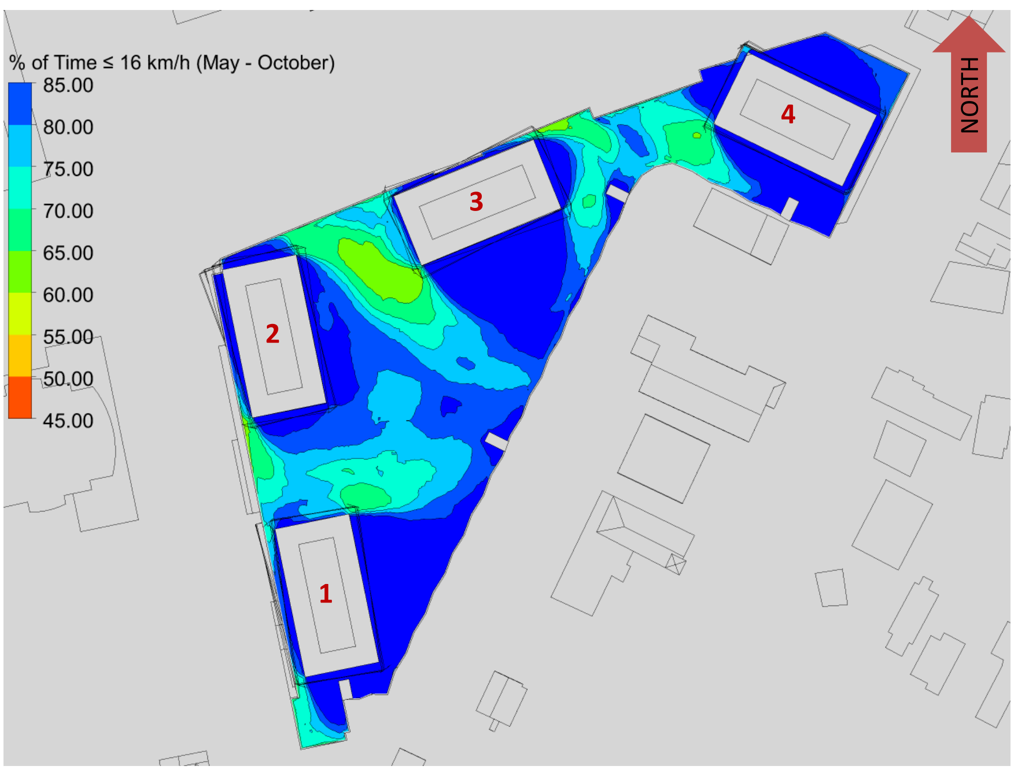
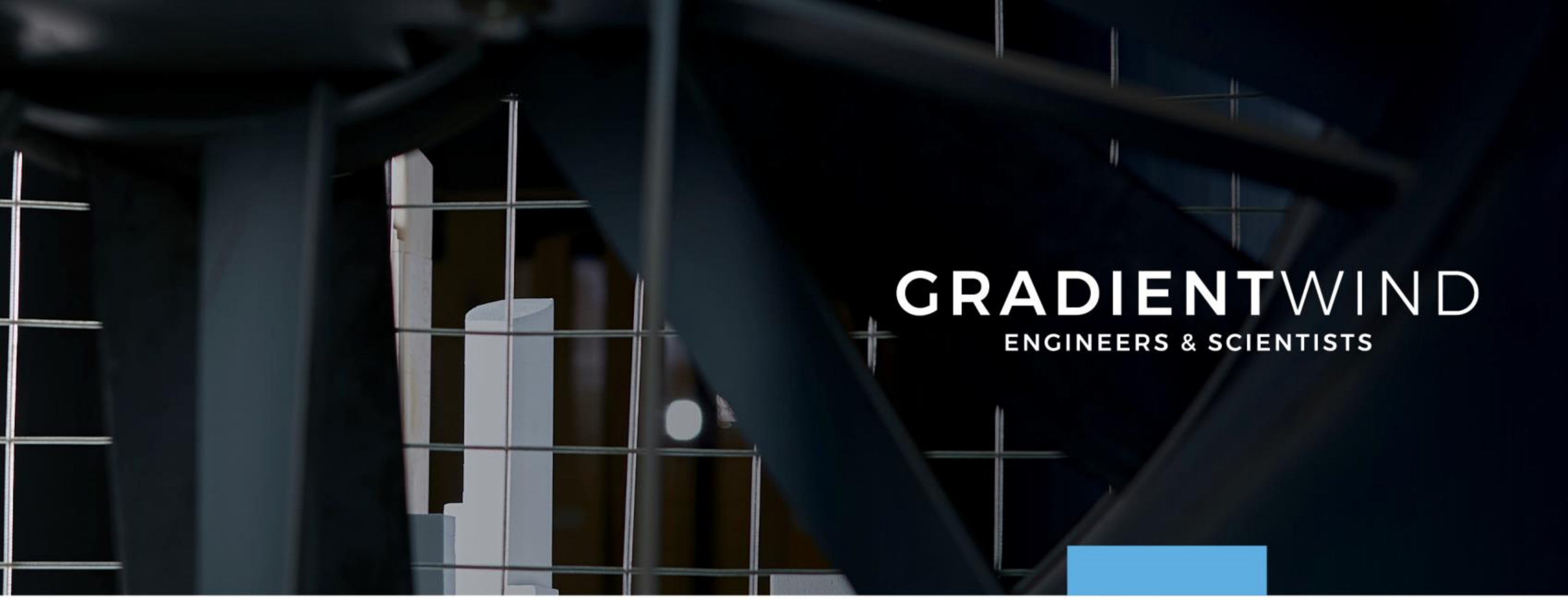
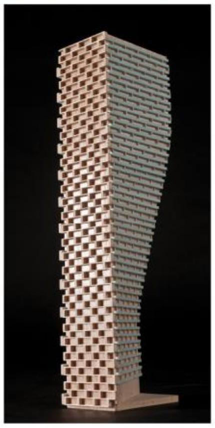
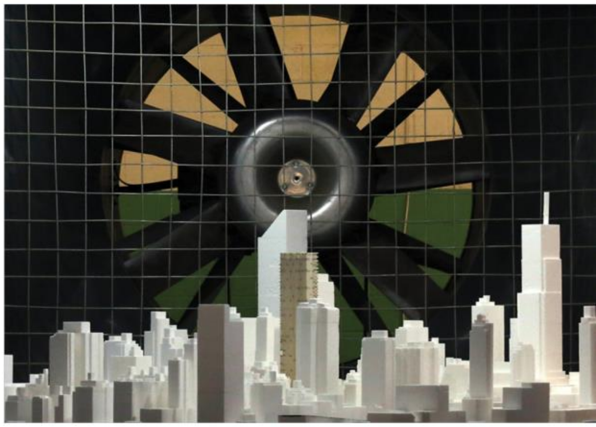


FIGURE 8B: TYPICAL USE PERIOD – % OF TIME SUITABLE FOR SITTING, AMENITY TERRACES





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 50% mean wind speed for Toronto 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 is 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	0.20
98	0.22
132	0.23
164	0.23
200	0.23
237	0.22
263	0.22
280	0.23
295	0.23
310	0.24
331	0.24

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].

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

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

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