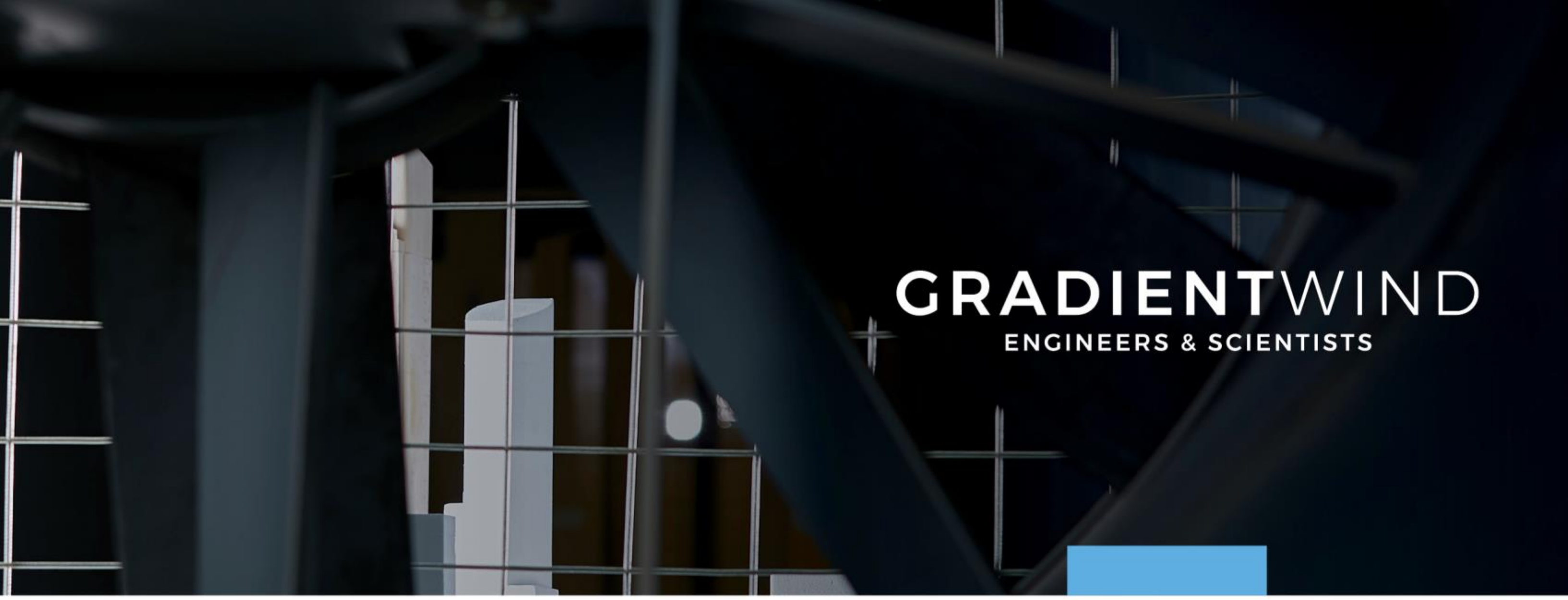
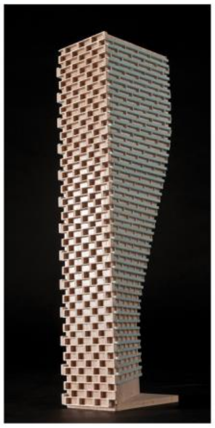
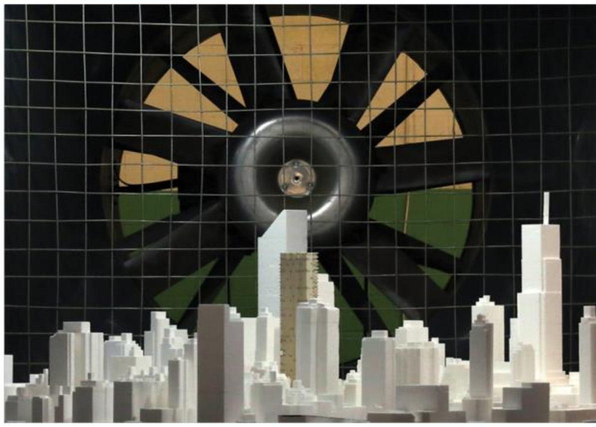


PEDESTRIAN LEVEL WIND STUDY

1437-1455 Queen Street West
Toronto, Ontario

Report: 23-029-PLW





April 20, 2023

PREPARED FOR
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EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study to satisfy concurrent Zoning By-Law Amendment (ZBLA) and Site Plan Control application submission requirements for the proposed mixed-use residential development located at 1437-1455 Queen Street West in Toronto, 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 sixteen (16) 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 Toronto wind comfort and safety criteria. A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-9, 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, transit stops, surface parking, laneways, the existing patio serving 1498 Queen Street West, the proposed outdoor amenity at grade, and in the vicinity of building access points, are considered acceptable.

2) Regarding the Level 9 common amenity terrace serving the proposed development, wind comfort conditions during the typical use period are predicted to be calm and suitable for sitting, which is considered acceptable.

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 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 performed based on architectural drawings received in March 2023. An updated set of drawings were distributed to the consultant team by RAW Design Inc. in April 2023. Notably, a canopy has been added over the residential entrance along the north façade, and the setbacks from the southwest, west, and northeast elevations at Level 5 have increased while the setbacks at Level 6 from these same elevations have been removed. Additionally, the balconies projecting from the façade at Level 5 and above have changed from nominally rectangular in shape to a continuous waveform pattern along the façade. Overall, the updates are not expected to change the main conclusions of the PLW study.

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Jameson Plaza Limited to undertake a pedestrian level wind (PLW) study to satisfy concurrent Zoning By-Law Amendment (ZBLA) and Site Plan Control application submission requirements for the proposed mixed-use residential development located at 1437-1455 Queen Street West in Toronto, 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 is based on industry standard computer simulations using the computational fluid dynamics (CFD) technique and data analysis procedures, City of Toronto wind comfort and safety criteria, architectural drawings provided by RAW Design Inc. in March 2023, surrounding street layouts and existing and approved future building massing information obtained from the City of Toronto, and recent site imagery.

2. TERMS OF REFERENCE

The subject site is located at 1437-1455 Queen Street West in Toronto, situated at the southwest intersection of Queen Street West and Jameson Avenue, on a parcel of land bounded by Queen Street West to the north, Jameson Avenue and a low-rise building to the east, a mid-rise building and a high-rise building to the south, and a low-rise building to the west. The proposed development comprises a nominally rectangular 12-storey mixed-use building, topped a mechanical penthouse (MPH).

Above a below-grade parking level, the ground floor of the proposed development includes a residential main entrance to the north, retail spaces at the northwest and northeast corners, an indoor amenity to the south, and a loading space to the west. An outdoor amenity is situated along the south elevation of the subject site. Access to the underground parking is provided by a ramp at the southwest corner via a laneway along the west elevation of the subject site from Queen Street West. Levels 2-12 comprise residential units, and the building steps back from the north elevation at Level 2, from the northwest, west, and southwest elevations at Level 3, and from all elevations at Levels 6 and 11 to accommodate private terraces. Additionally, the building steps back from the west elevation at Level 9 to accommodate a common amenity terrace.

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) are characterized by low-rise massing in all compass directions with mid-rise buildings to the southwest, west, north-northeast, and east, the Parkdale Collegiate Institute to the southeast, and high-rise residential buildings to the south. Notably, a six-storey mixed-use residential building is approved (ZBLA) at 1488 Queen Street West, to the immediate north, and a seven-storey mixed-use residential building is approved (ZBLA) at 1375 Queen Street West, approximately 140 m to the east-northeast. The far-field surroundings (defined as the area beyond the near field and within a two-kilometre (km) radius) are characterized by mostly low-rise massing and isolated mid- and high-rise buildings from the west clockwise to the southeast, with clusters of high-rise buildings to the east and east-southeast, and a mix of low-, mid-, and high-rise massing followed by the open exposure of Lake Ontario in the remaining compass directions. Notably, Humber Bay is located approximately 650 m to the southwest.

A site plan for the proposed massing scenario is illustrated in Figure 1A, while the existing scenario is illustrated in Figure 1B. Figures 2A-2H illustrate the computational models used to conduct the study.

3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind conditions at key areas within and surrounding the subject 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 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 Toronto area wind climate, and synthesis of computational data with City of Toronto wind criteria[1]. The following sections describe the analysis procedures, including a discussion of the noted pedestrian wind criteria.

4.1 Computer-Based Context Modelling

A computer based PLW study was performed to determine the influence of the wind environment on pedestrian comfort over the proposed development site. Pedestrian comfort predictions, based on the mechanical effects of wind, were determined by combining measured wind speed data from CFD simulations with statistical weather data obtained from Billy Bishop Toronto City Airport in Toronto, Ontario. 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 proposed 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 stronger 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 subject site for 16 wind directions. The CFD simulation model was centered on the proposed development, complete with surrounding massing within a radius of 480 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 and the Level 9 common amenity terrace serving the proposed

[1] Toronto, *Pedestrian Level Wind Study Terms of Reference Guide*, 2022
https://www.toronto.ca/wp-content/uploads/2022/03/8f9c-CityPlanning-ToR-Wind-Guide.pdf

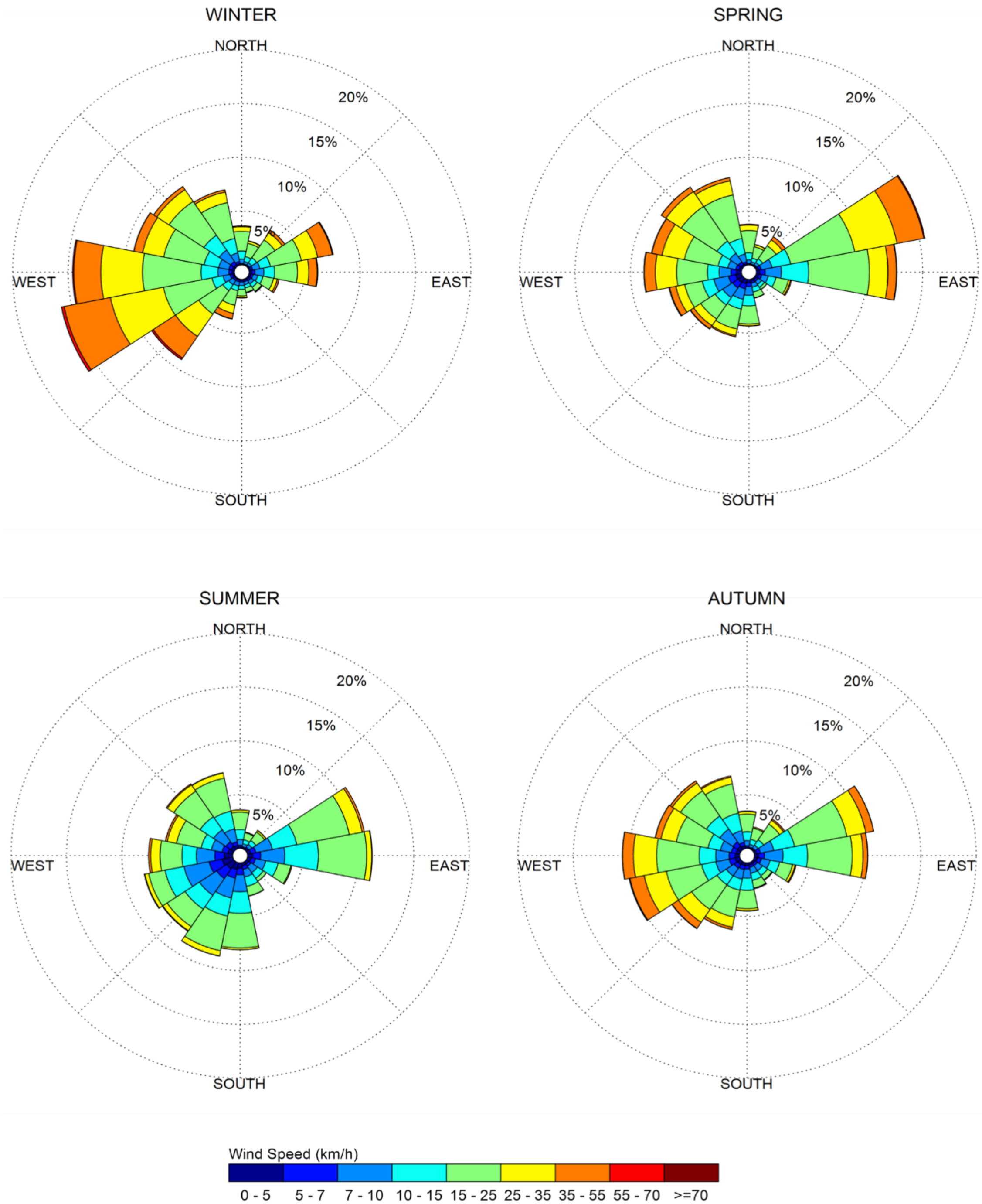
development were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. Gradient height represents the theoretical depth of the boundary layer of the earth's atmosphere, above which the mean wind speed remains constant. 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 Toronto was developed from approximately 50 years of hourly meteorological wind data recorded at Billy Bishop Toronto City Airport and obtained from Environment and Climate Change Canada. Wind speed and direction data were analyzed during the appropriate hours of pedestrian usage (i.e., between 06:00 and 23:00) and divided into four distinct seasons, as stipulated in the wind criteria. Specifically, the spring season is defined as March through May, the summer season is defined as June through August, the autumn season is defined as September through November, and the winter season is defined as December through February, inclusive.

The statistical model of the Toronto 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 Toronto, 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
BILLY BISHOP TORONTO CITY AIRPORT, TORONTO, 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 Wind Comfort and Safety Criteria – City of Toronto

Pedestrian wind comfort and safety criteria are based on the mechanical effects of wind without consideration of other meteorological conditions (i.e., temperature and relative humidity). The comfort criteria assume that pedestrians are appropriately dressed for a specified outdoor activity during any given season. Since both mean and gust wind speeds affect pedestrian comfort, their combined effect is defined in the City of Toronto Pedestrian Level Wind Study Terms of Reference Guide. Specifically, the criteria are defined as a Gust Equivalent Mean (GEM) wind speed, which is the greater of the mean wind speed or the gust wind speed divided by 1.85.

The wind speed ranges are selected based on 'The Beaufort Scale' (presented on the following page), which describes the effects of forces produced by varying wind speed levels on objects. Four pedestrian comfort classes and corresponding gust wind speed ranges are used to assess pedestrian comfort: (1) Sitting; (2) Standing; (3) Walking; and (4) Uncomfortable. Specifically, the comfort classes, associated wind speed ranges, and limiting criteria are summarized as follows:

1) **Sitting:** GEM wind speeds no greater than 10 km/h occurring at least 80% of the time would be considered acceptable for sedentary activities, including sitting.

2) **Standing:** GEM wind speeds no greater than 15 km/h occurring at least 80% of the time are acceptable for activities such as standing, strolling or more vigorous activities.

3) **Walking:** GEM wind speeds no greater than 20 km/h occurring at least 80% of the time are acceptable for walking or more vigorous activities.

4) **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.

Regarding wind safety, gust wind speeds greater than 90 km/h, occurring more than 0.1% of the time on an annual basis (based on wind events recorded for 24 hours a day), are 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.

THE BEAUFORT SCALE

Number	Description	Gust Wind Speed (km/h)	Description
2	Light Breeze	9-17	Wind felt on faces
3	Gentle Breeze	18-29	Leaves and small twigs in constant motion; wind extends light flags
4	Moderate Breeze	30-42	Wind raises dust and loose paper; small branches are moved
5	Fresh Breeze	43-57	Small trees in leaf begin to sway
6	Strong Breeze	58-74	Large branches in motion; Whistling heard in electrical wires; umbrellas used with difficulty
7	Moderate Gale	75-92	Whole trees in motion; inconvenient walking against wind
8	Gale	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 GEM wind speeds of 10 km/h were exceeded for more than 20% of the time most pedestrians would judge that location to be too windy for sitting. Similarly, if GEM wind speeds of 20 km/h at a location were exceeded for more than 20% of the time, walking or less vigorous activities would be considered uncomfortable. As these criteria are based on subjective reactions of a population to wind forces, their application is partly based on experience and judgment.

Once the pedestrian wind speed predictions have been established throughout the 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 desired comfort classes, which are dictated by the location type for each region (e.g., a sidewalk, building entrance, amenity space, or other). An overview of common pedestrian location types and their typical windiest desired comfort classes are summarized on the following table. Depending on the programming of a space, the desired comfort class may differ from this table.

DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES

Location Types	Desired 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, which illustrate wind conditions at grade level for the proposed and existing massing scenarios, and by Figures 8A-8D, which illustrate wind conditions over the common amenity terrace serving the proposed development at Level 9. 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 blue, standing by green, and walking by yellow; uncomfortable conditions are represented by the colour orange, consistent with the City of Toronto Terms of Reference.

Wind comfort conditions are also reported for the typical use period, which is defined as May to October, inclusive. Figures 7 and 9 illustrate comfort conditions at grade and within the Level 9 amenity terrace serving the proposed development, respectively, consistent with the comfort classes in Section 4.4. Conditions at all areas studied are considered acceptable for the intended pedestrian uses. The details of these conditions are summarized in the following pages for each area of interest.

5.1 Wind Comfort Conditions – Grade Level

Sidewalks and Transit Stop Along Queen Street West: Following the introduction of the proposed development, wind comfort conditions over the public sidewalks along Queen Street West 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 in the vicinity of the nearby transit stop are predicted to be suitable for sitting during the summer and autumn, becoming suitable for standing during the winter and spring. The noted conditions are considered acceptable.

Conditions over the sidewalks and in the vicinity of the nearby transit stop along Queen Street West with the existing massing are predicted to be suitable for sitting throughout the year with an isolated region suitable for standing during the winter at the intersection of Macdonell Avenue and Queen Street West. While the introduction of the proposed development produces windier conditions in comparison to existing conditions, wind conditions with the proposed development are considered acceptable.

Sidewalks and Transit Stop Along Macdonell Avenue: Following the introduction of the proposed development, wind conditions over the public sidewalks along Macdonell Avenue are predicted to be suitable for sitting during the summer, suitable mostly for sitting during the spring and autumn, and suitable for a mix of sitting and standing during the winter. Conditions in the vicinity of the nearby transit stop along Macdonell Avenue are predicted to be suitable for sitting during the spring, summer, and autumn, becoming suitable for standing during the winter. The noted conditions are considered acceptable.

Conditions over the sidewalks along Macdonell Avenue and in the vicinity of the nearby transit stop with the existing massing are predicted to be suitable for sitting during the spring, summer, and autumn, becoming suitable for a mix of sitting and standing during the winter. While the introduction of the proposed development produces slightly windier conditions in comparison to existing conditions, wind conditions with the proposed development are considered acceptable.

1498 Queen Street West Existing Patio: Conditions over the existing patio serving 1498 Queen Street West are predicted to be suitable for sitting during the typical use period prior to and following the introduction of the proposed development. The noted conditions are considered acceptable.

Sidewalks Along Jameson Avenue: Following the introduction of the proposed development, conditions over the public sidewalks along Jameson Avenue are predicted to be suitable for sitting during the spring, summer, and autumn, becoming suitable for a mix of sitting and standing during the winter. The noted conditions are considered acceptable.

Conditions over the noted public sidewalks with the existing massing are predicted to be suitable for sitting during the spring, summer, and autumn, and suitable for mostly sitting during the winter, with isolated regions of conditions suitable for standing. While the introduction of the proposed development produces slightly windier conditions in comparison to existing conditions during the winter season, wind conditions throughout the year are considered acceptable.

Existing Surface Parking South and Southeast of Subject Site: Following the introduction of the proposed development, wind conditions over the existing parking lots to the south and southeast of the subject site are predicted to be suitable for sitting during the spring, summer, and autumn, becoming suitable for a mix of sitting and standing during the winter. The noted conditions are considered acceptable.

Conditions over the noted surface parking with the existing massing are predicted to be suitable for sitting during the summer and autumn, becoming suitable for standing, or better, during the winter and spring. Notably, the introduction of the proposed development is predicted to improve comfort levels over the surface parking to the southeast, in comparison to existing conditions. Wind conditions over the noted areas with the proposed development are considered acceptable.

Outdoor Amenity South of Subject Site: During the typical use period, as illustrated in Figure 7, wind comfort conditions over the outdoor amenity along the south elevation of the subject site are predicted to be suitable for sitting. The noted conditions are considered acceptable.

Laneway West of Subject Site: Wind conditions over the laneway along the west elevation of the subject site are predicted to be suitable for sitting during the spring, summer, and autumn, becoming suitable for a mix of sitting and standing during the winter. The noted conditions are considered acceptable.

Building Access Points: Conditions in the vicinity of all building access points serving the proposed development are predicted to be suitable for standing, or better, throughout the year. The noted conditions are considered acceptable.

5.2 Wind Comfort Conditions – Common Amenity Terrace

Level 9 Amenity Terrace: During the typical use period, as illustrated in Figure 9, wind comfort conditions within the amenity terrace serving the proposed development at Level 9 are predicted to be calm and suitable for sitting. The noted conditions are considered acceptable.

5.3 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.

5.4 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 (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. SUMMARY AND RECOMMENDATIONS

A complete summary of the predicted wind conditions is provided in Section 5 of this report and illustrated in Figures 3A-9. 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, transit stops, surface parking, laneways, the existing patio serving 1498 Queen Street West, the proposed outdoor amenity at grade, and in the vicinity of building access points, are considered acceptable.

2) Regarding the Level 9 common amenity terrace serving the proposed development, wind comfort conditions during the typical use period are predicted to be calm and suitable for sitting, which is considered acceptable.

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 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
Apr 20, 2023
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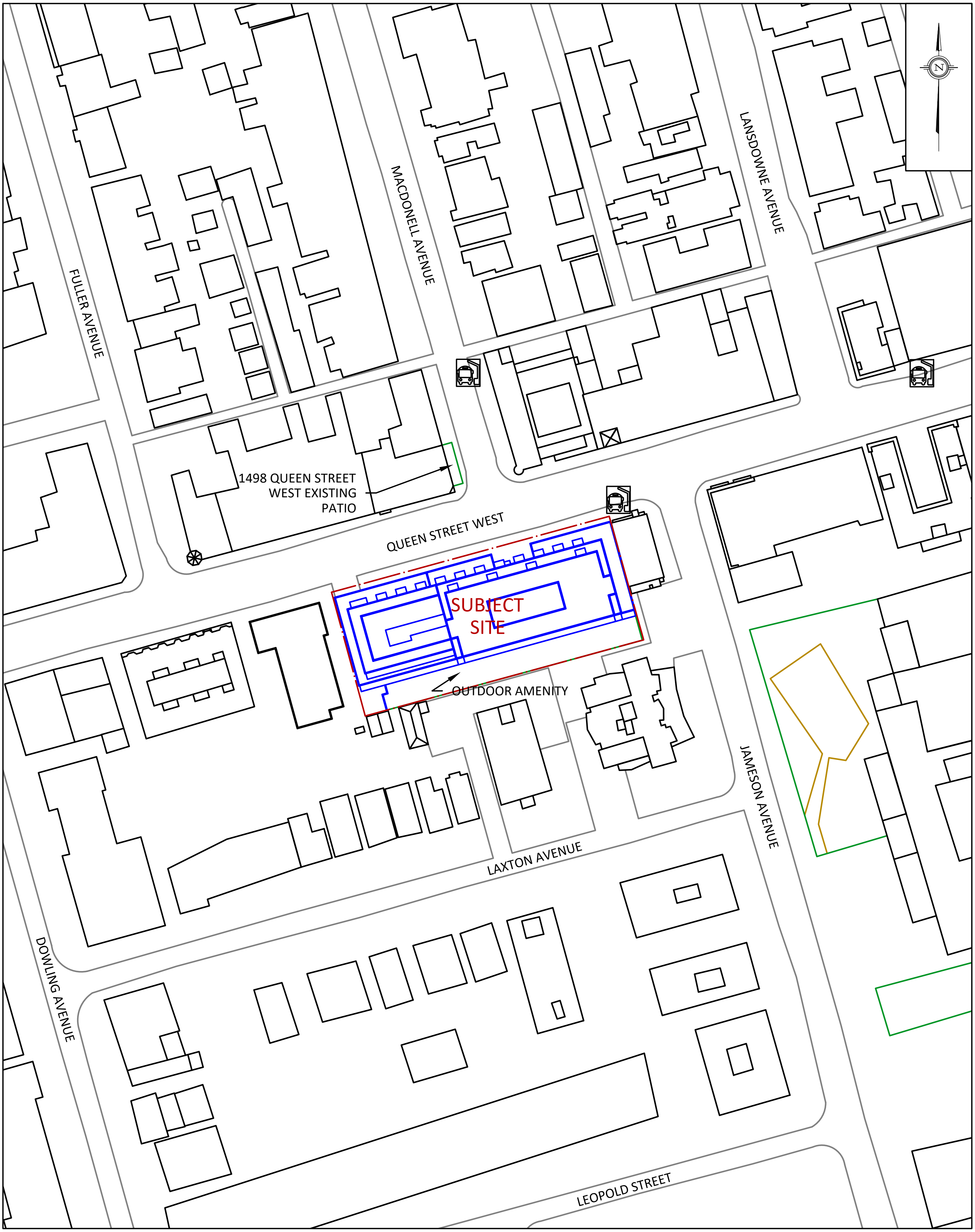

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ENGINEERS & SCIENTISTS

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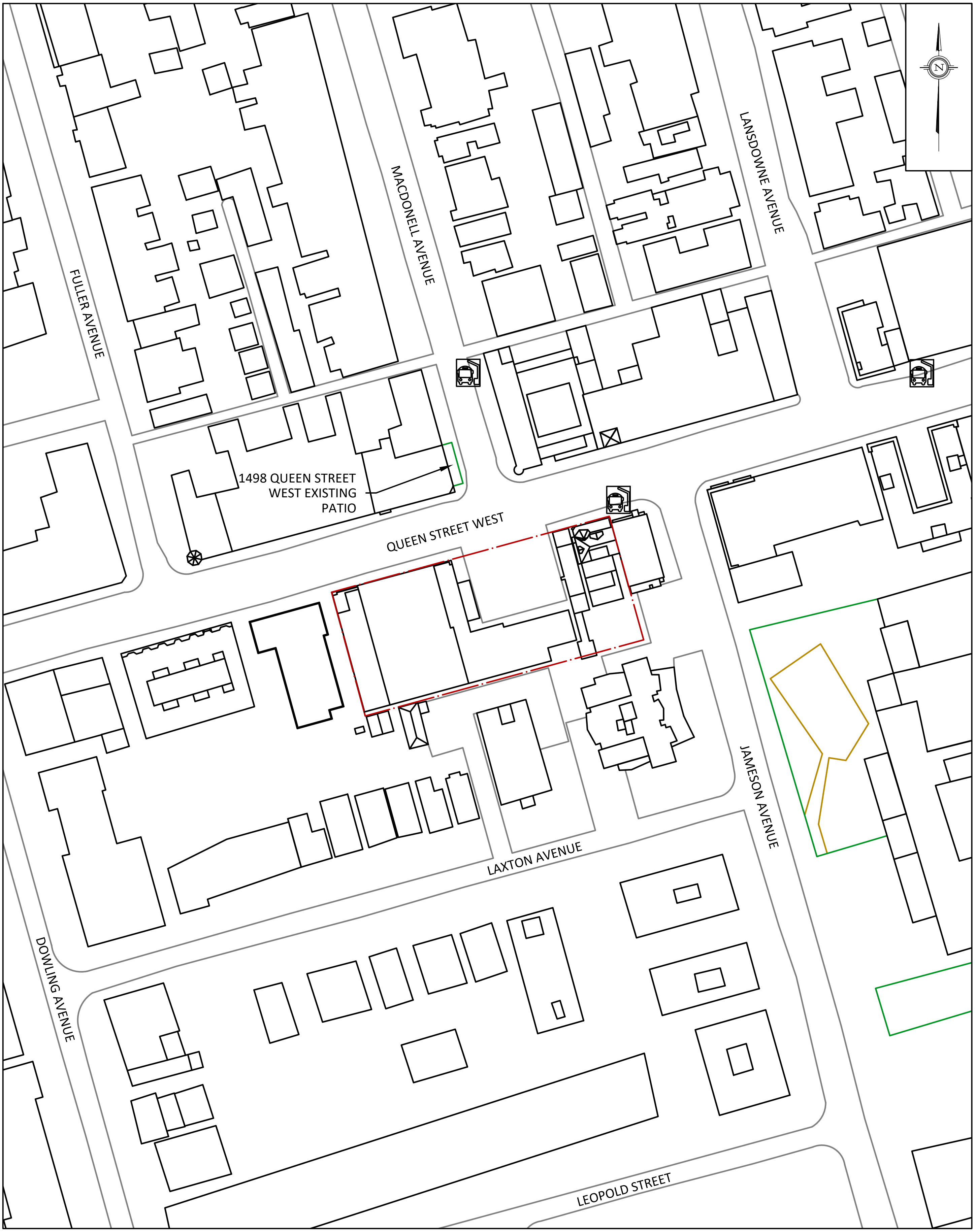
PROJECT	1437-1455 QUEEN STREET WEST, TORONTO PEDESTRIAN LEVEL WIND STUDY
SCALE	1:1500
DRAWING NO.	23-029-PLW-1A
DATE	MARCH 31, 2023
DRAWN BY	T.K.
DESCRIPTION	FIGURE 1A: PROPOSED SITE PLAN AND SURROUNDING CONTEXT



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PROJECT: 1437-1455 QUEEN STREET WEST, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1B: EXISTING SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:1500	DRAWING NO.: 23-029-PLW-1B	
DATE: MARCH 31, 2023	DRAWN BY: T.K.	

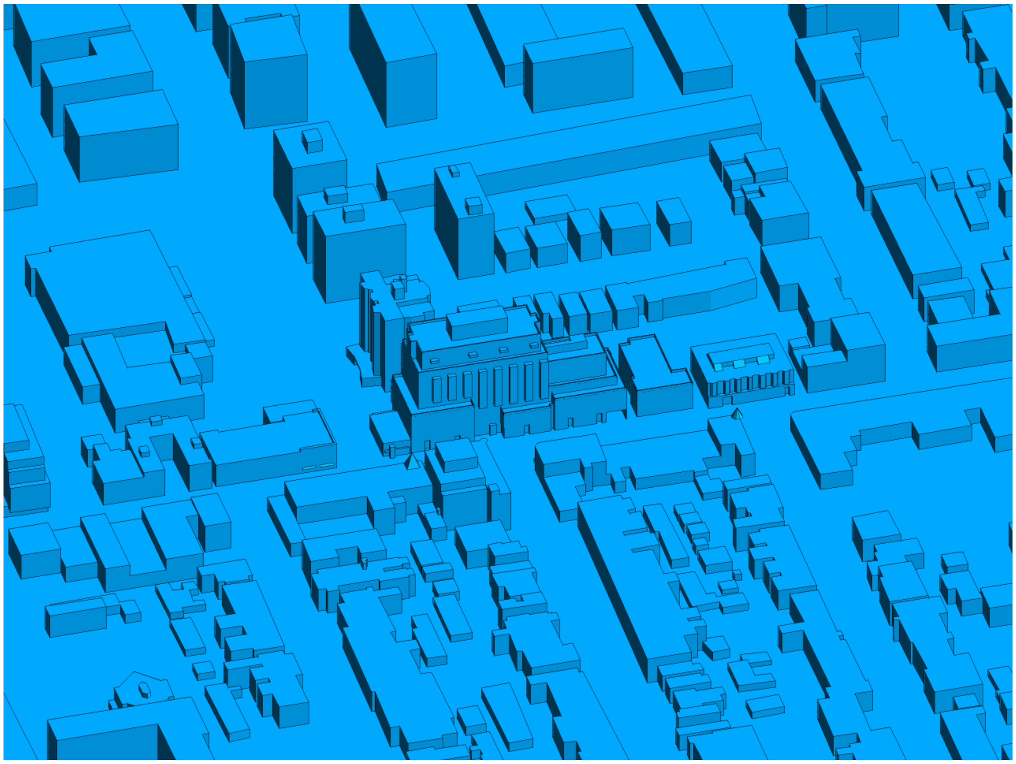


FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTH PERSPECTIVE

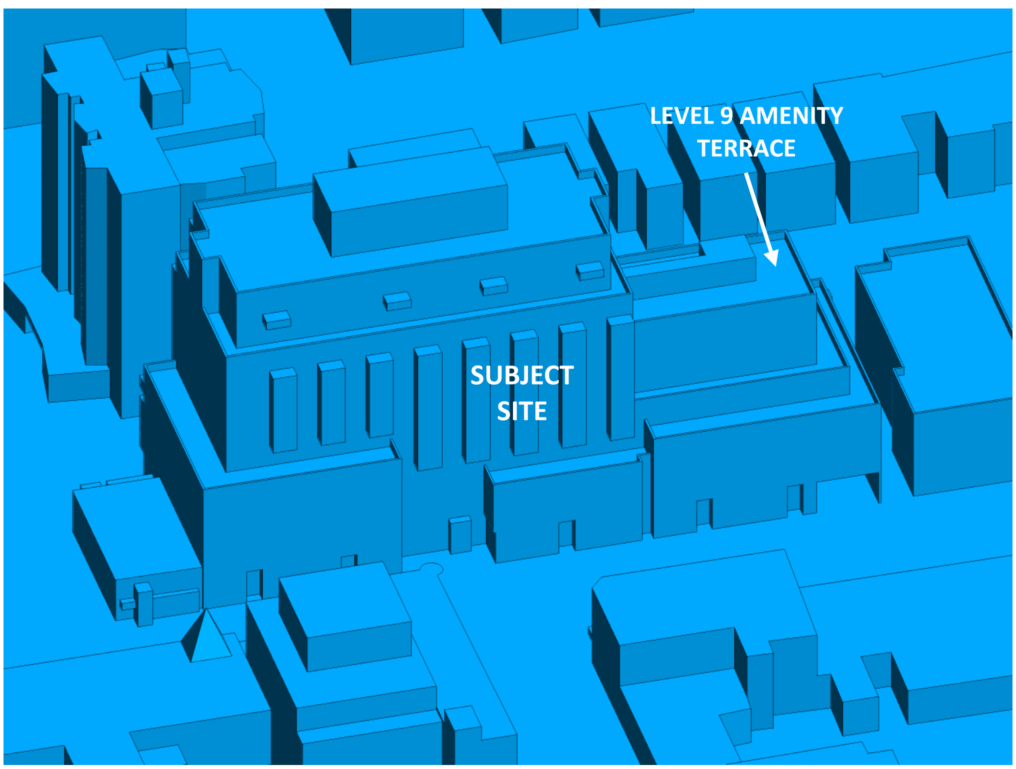


FIGURE 2B: CLOSE-UP VIEW OF FIGURE 2A

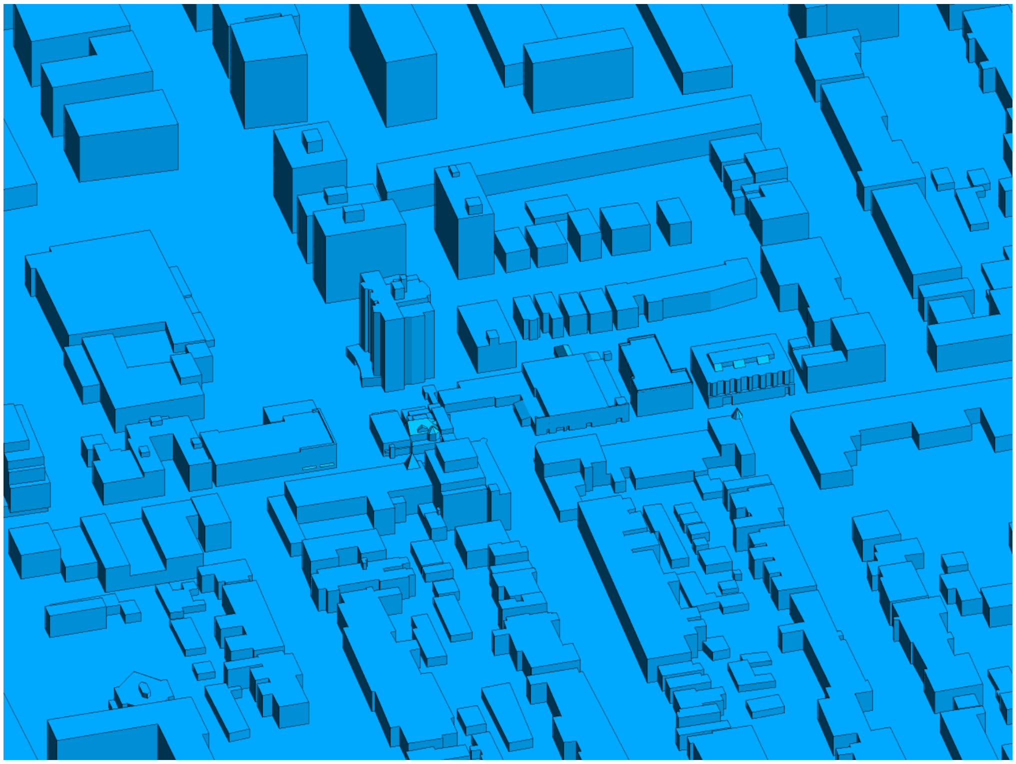


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTH PERSPECTIVE

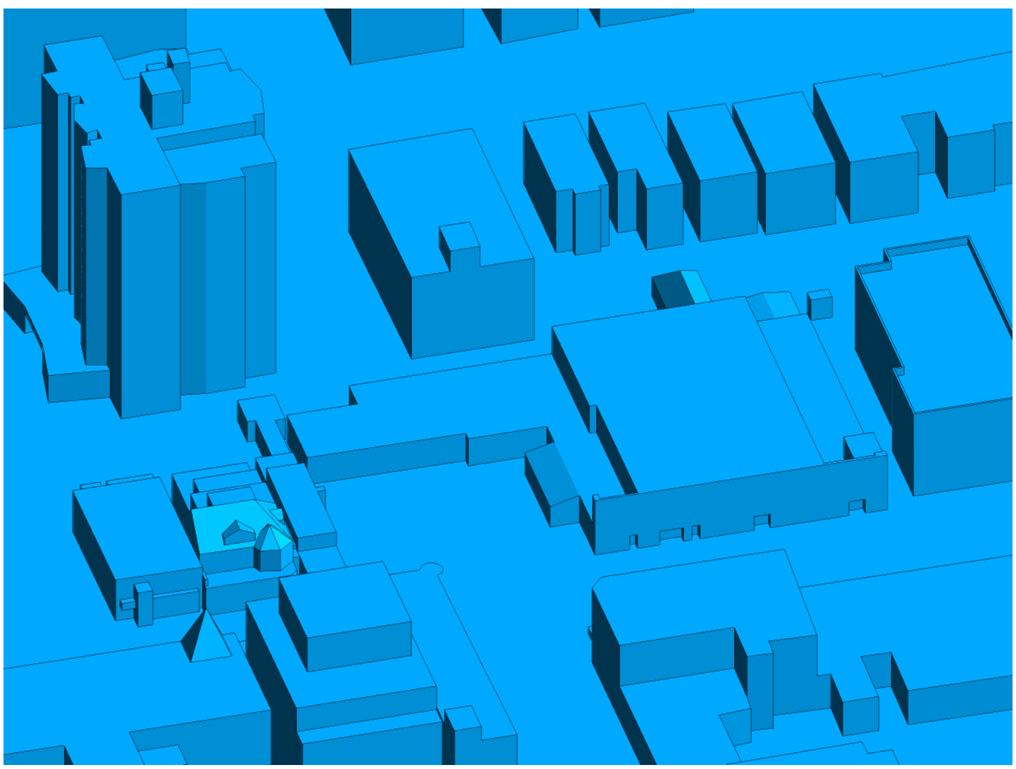


FIGURE 2D: CLOSE-UP VIEW OF FIGURE 2C

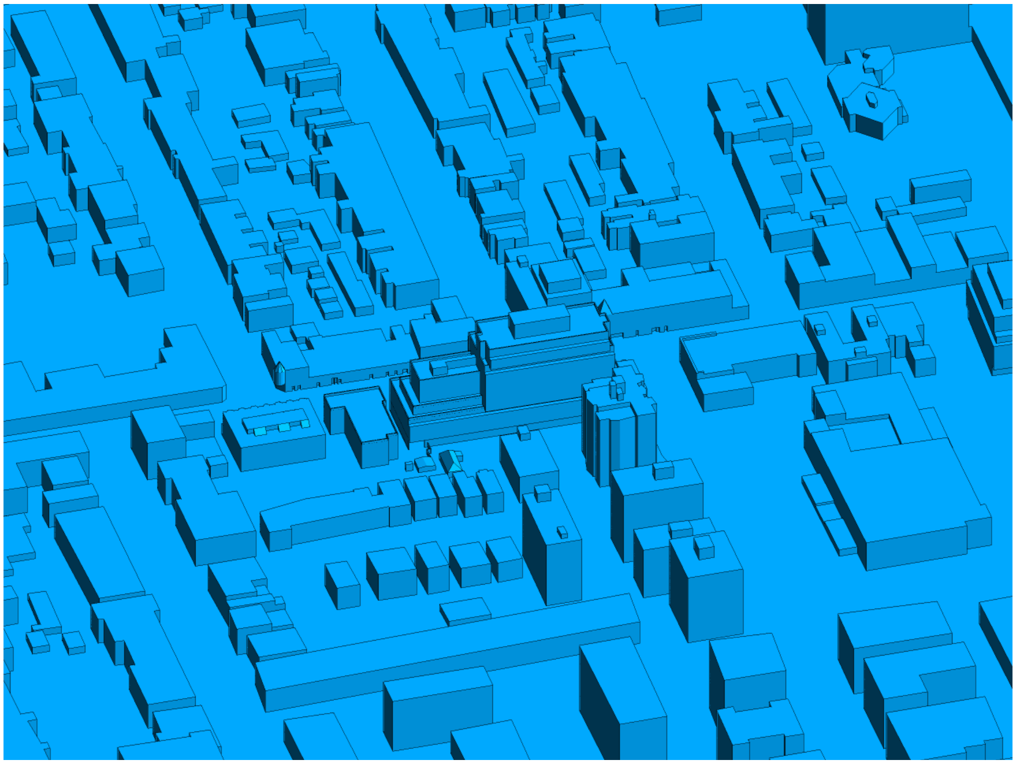


FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTH PERSPECTIVE

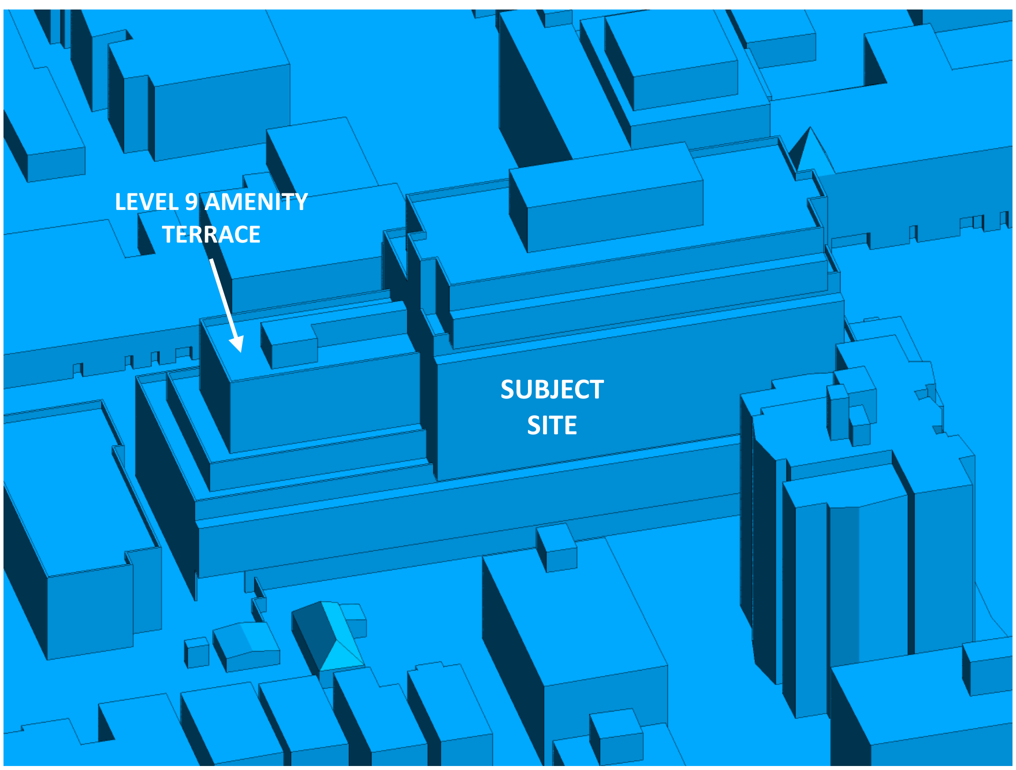


FIGURE 2F: CLOSE-UP VIEW OF FIGURE 2E

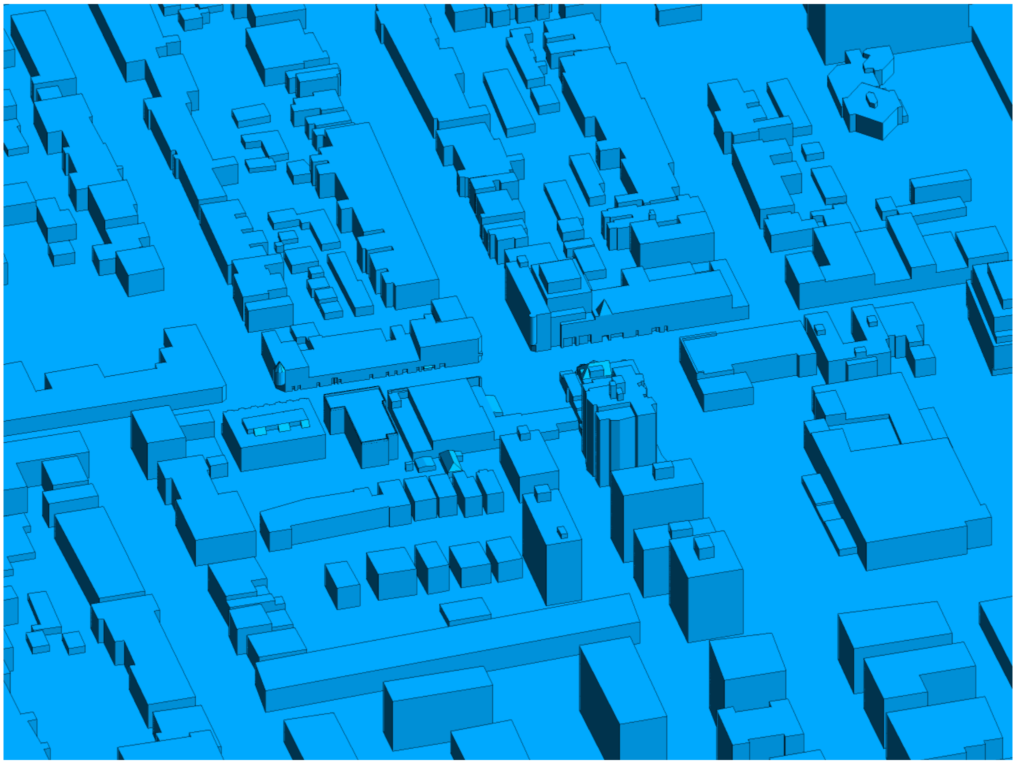


FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, SOUTH PERSPECTIVE

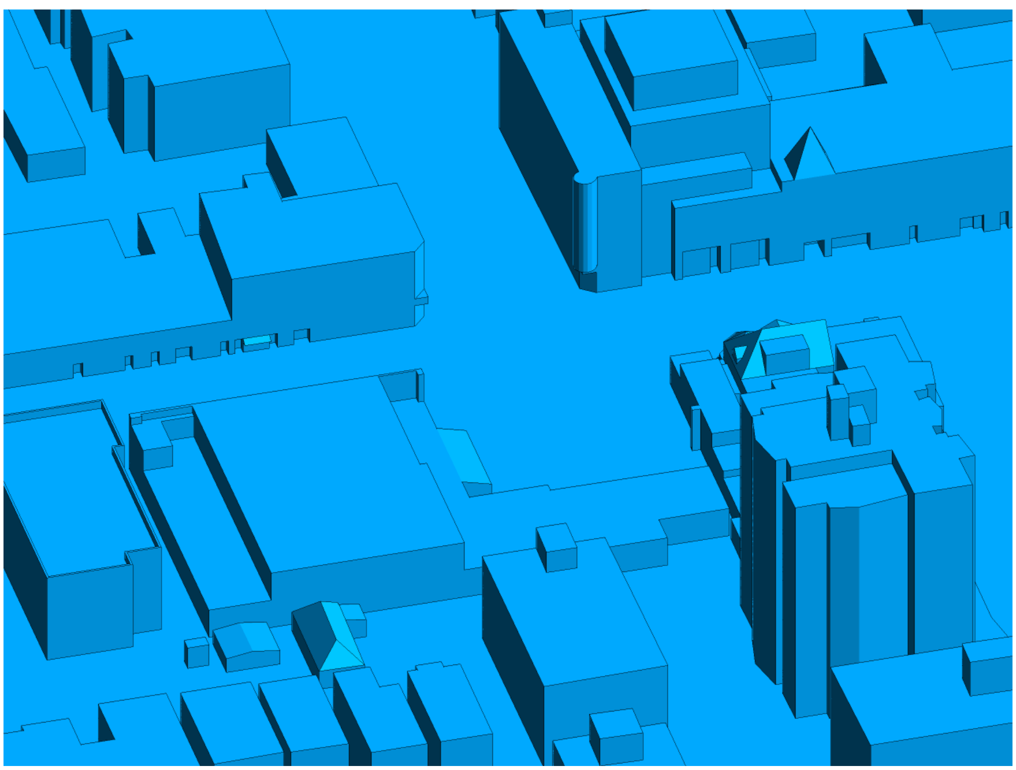


FIGURE 2H: CLOSE-UP VIEW OF FIGURE 2G

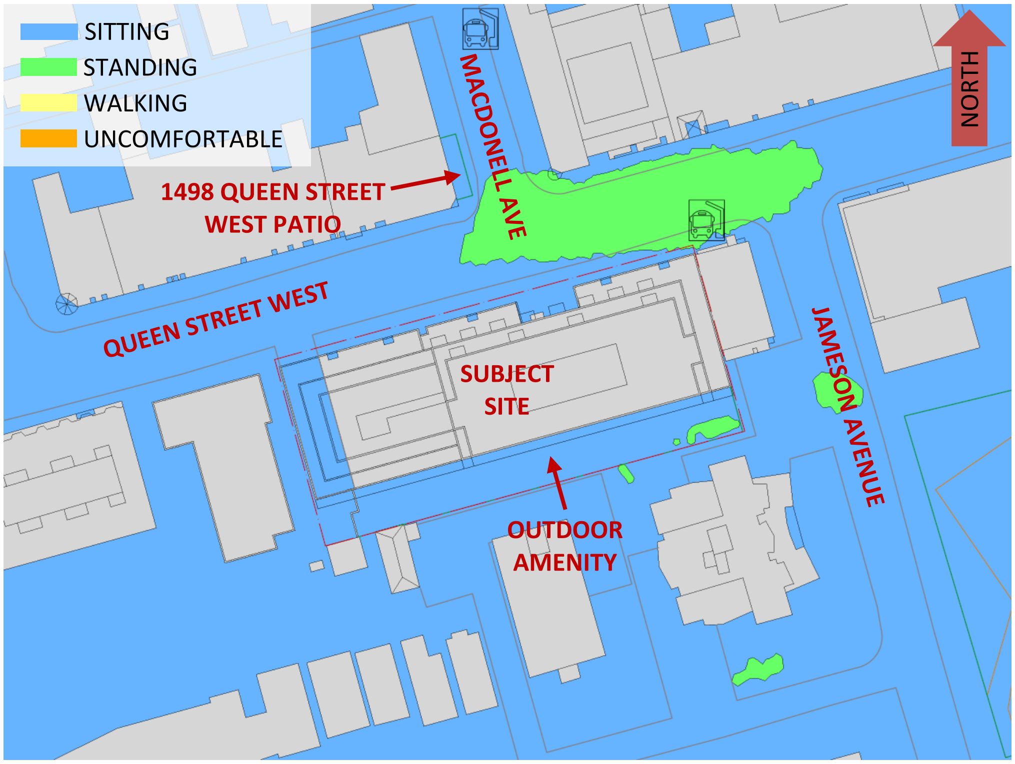


FIGURE 3A: SPRING – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

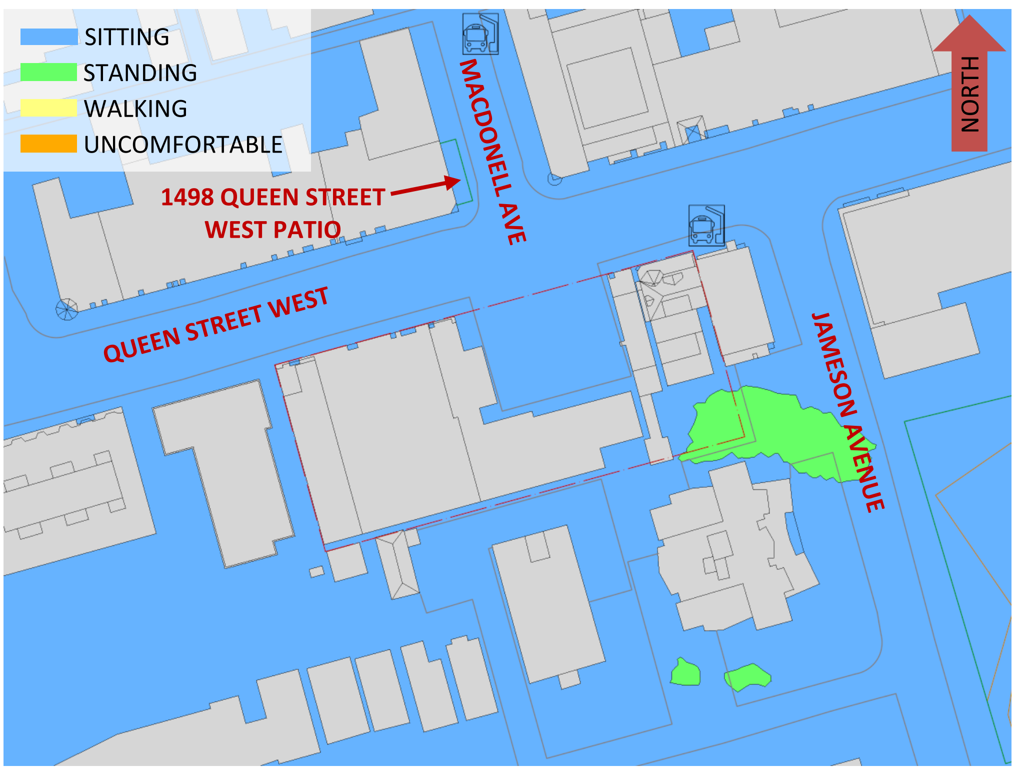


FIGURE 3B: SPRING – EXISTING MASSING – WIND COMFORT, GRADE LEVEL

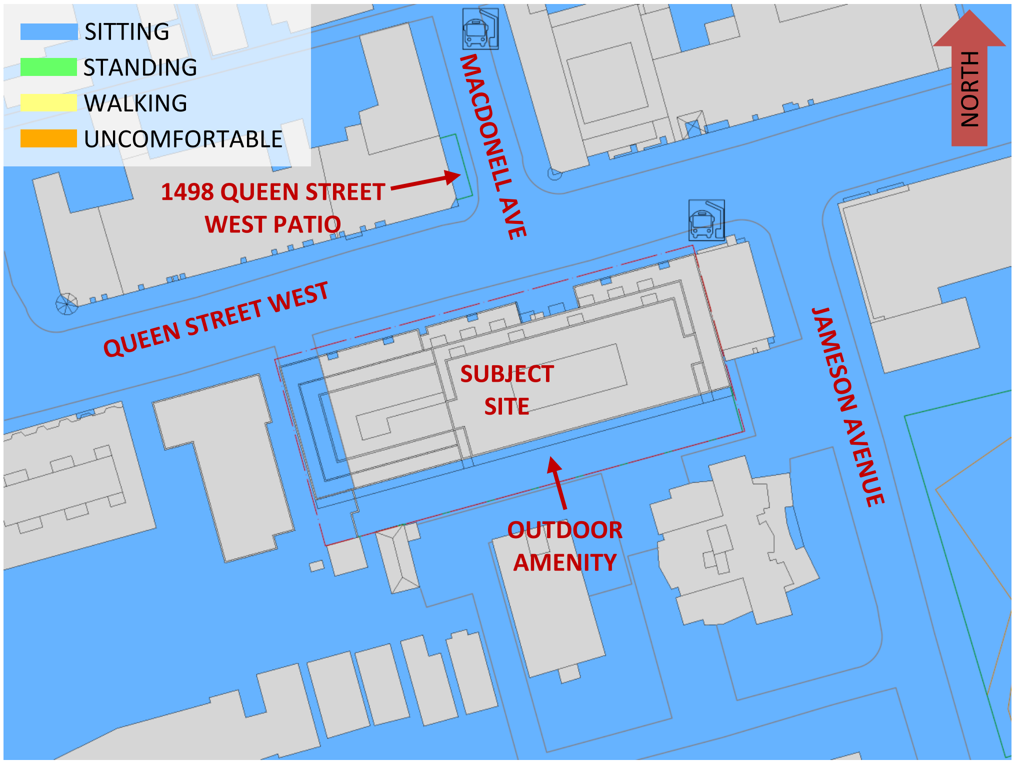


FIGURE 4A: SUMMER – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

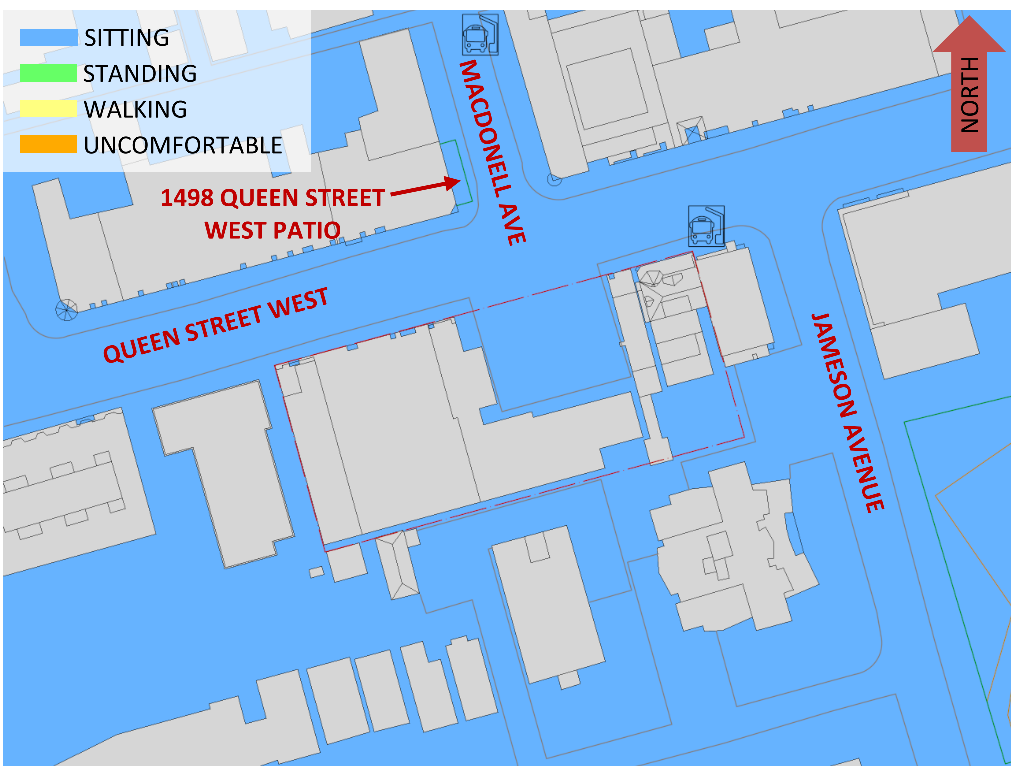


FIGURE 4B: SUMMER – EXISTING MASSING – WIND COMFORT, GRADE LEVEL

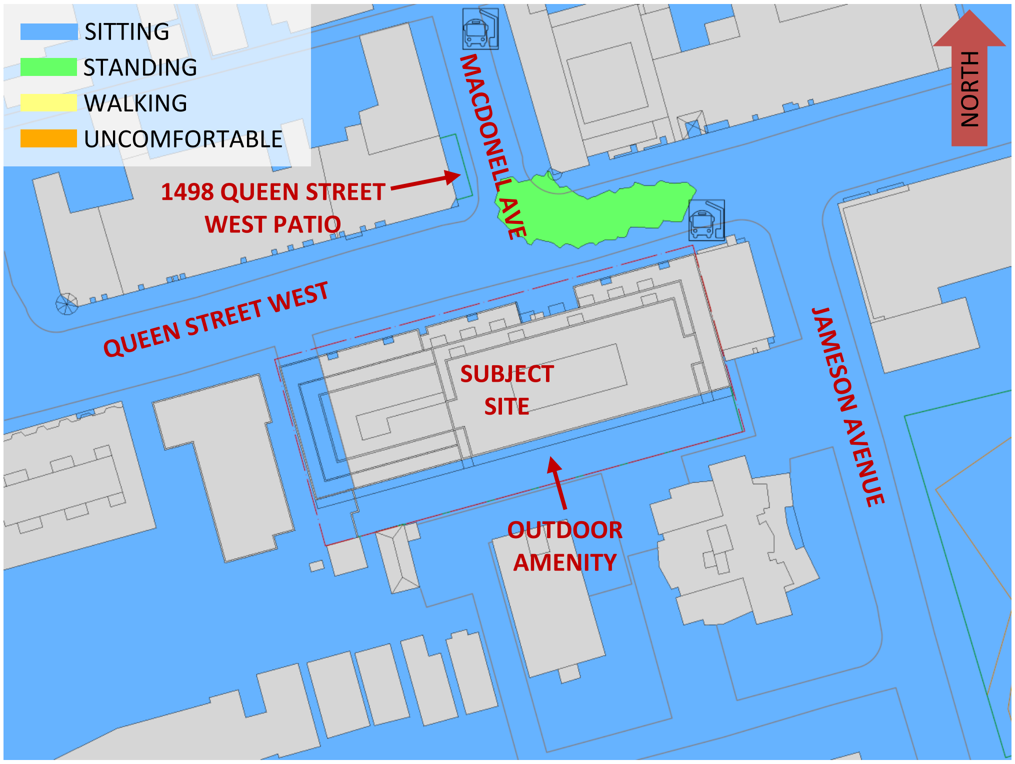


FIGURE 5A: AUTUMN – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

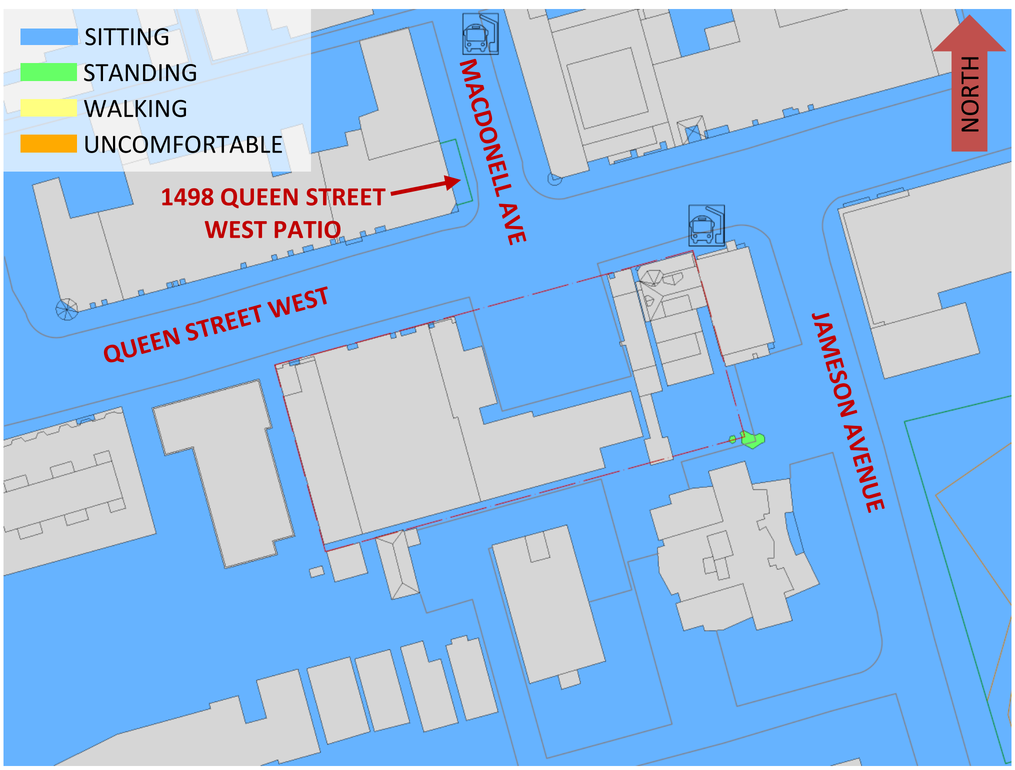


FIGURE 5B: AUTUMN – EXISTING MASSING – WIND COMFORT, GRADE LEVEL

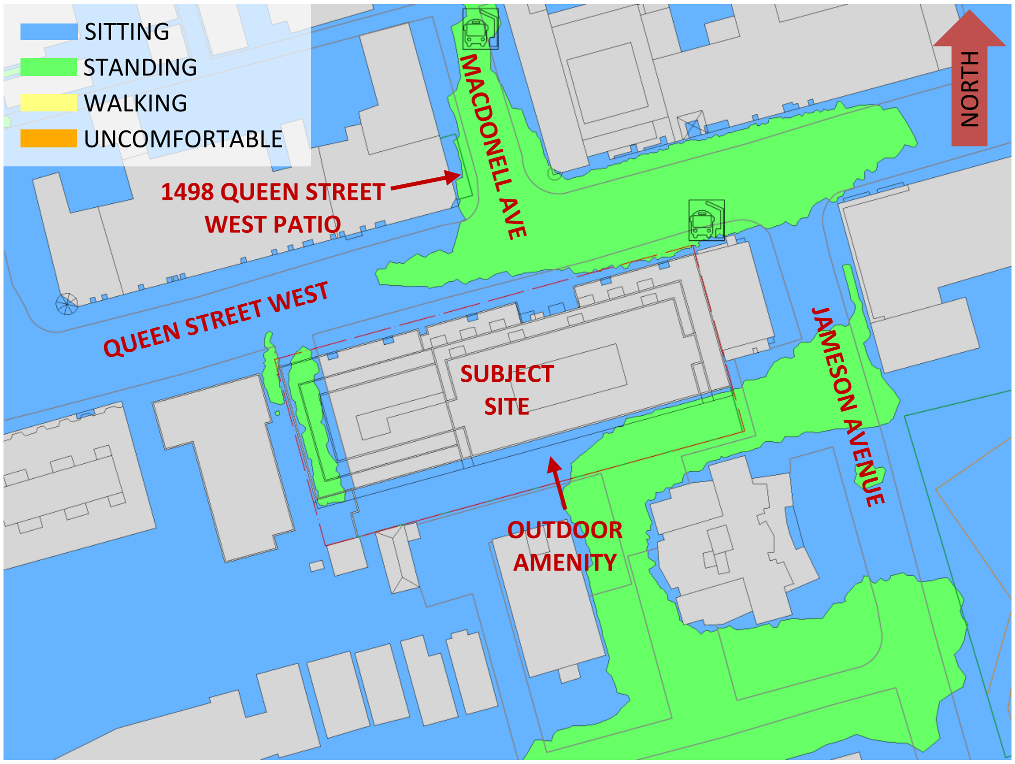


FIGURE 6A: WINTER – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

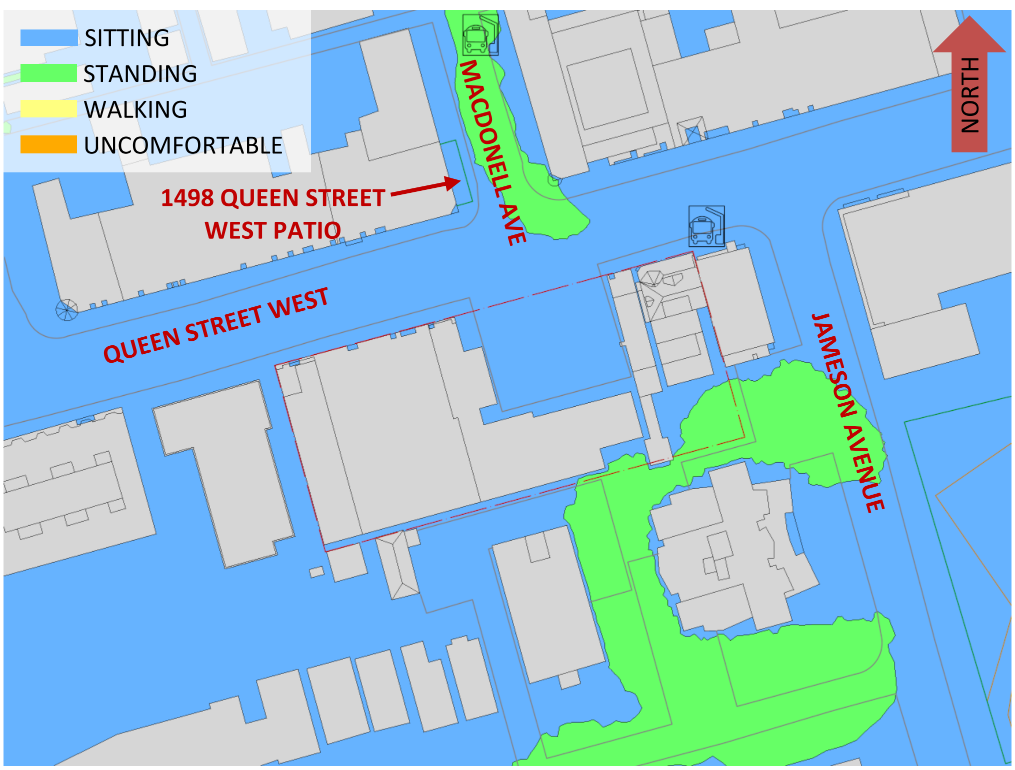


FIGURE 6B: WINTER – EXISTING MASSING – WIND COMFORT, GRADE LEVEL

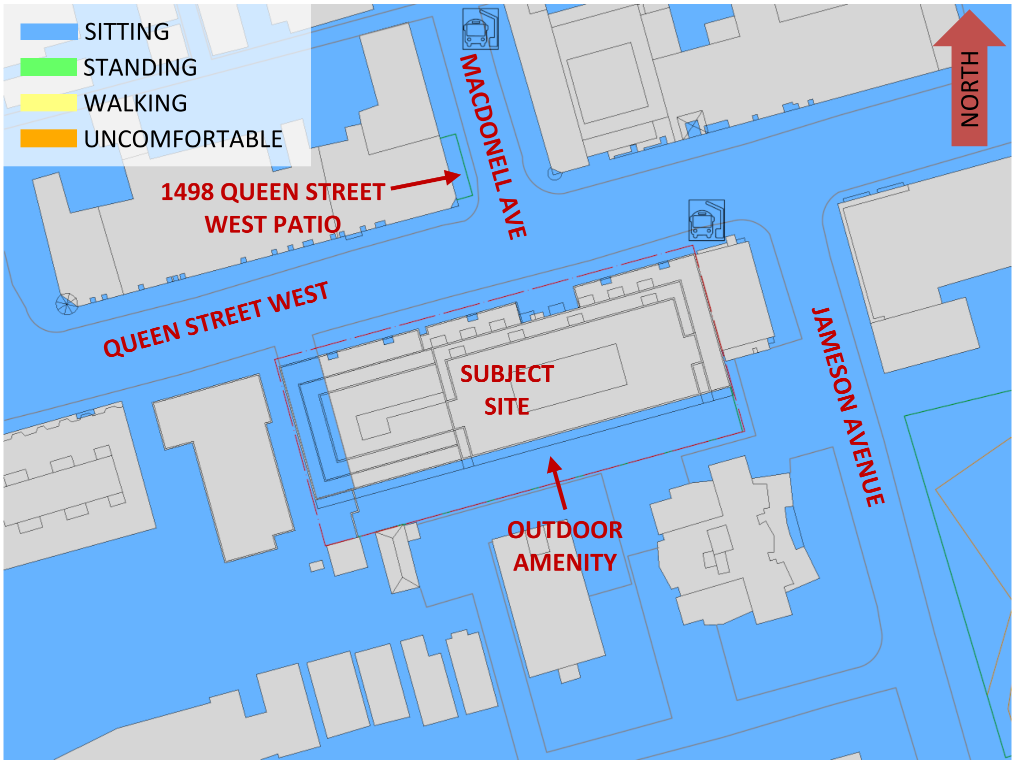


FIGURE 7: TYPICAL USE PERIOD – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

FIGURE 8A: SPRING – WIND COMFORT, LEVEL 9 COMMON AMENITY TERRACE

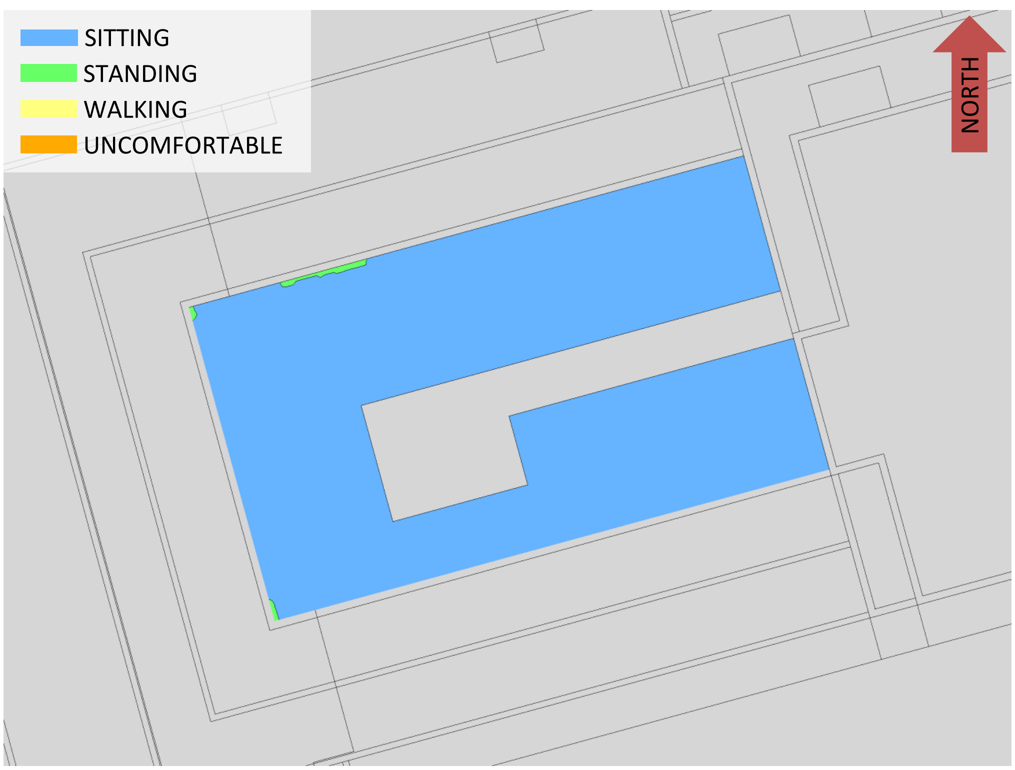


FIGURE 8B: SUMMER – WIND COMFORT, LEVEL 9 COMMON AMENITY TERRACE

FIGURE 8C: AUTUMN – WIND COMFORT, LEVEL 9 COMMON AMENITY TERRACE

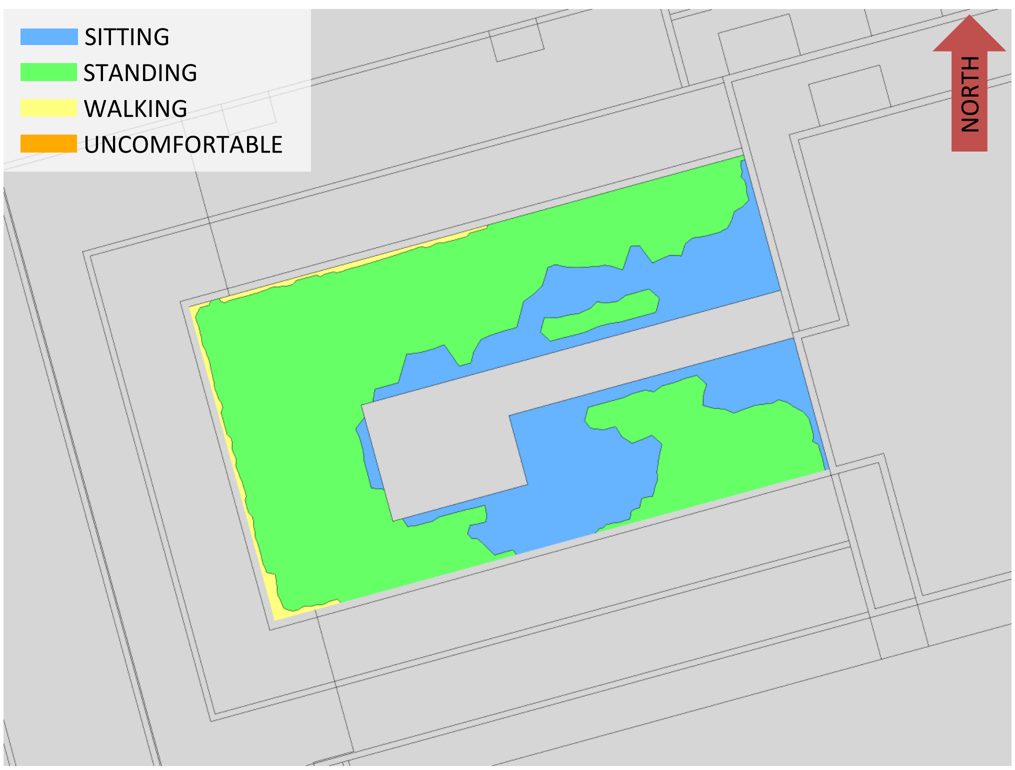


FIGURE 8D: WINTER – WIND COMFORT, LEVEL 9 COMMON AMENITY TERRACE

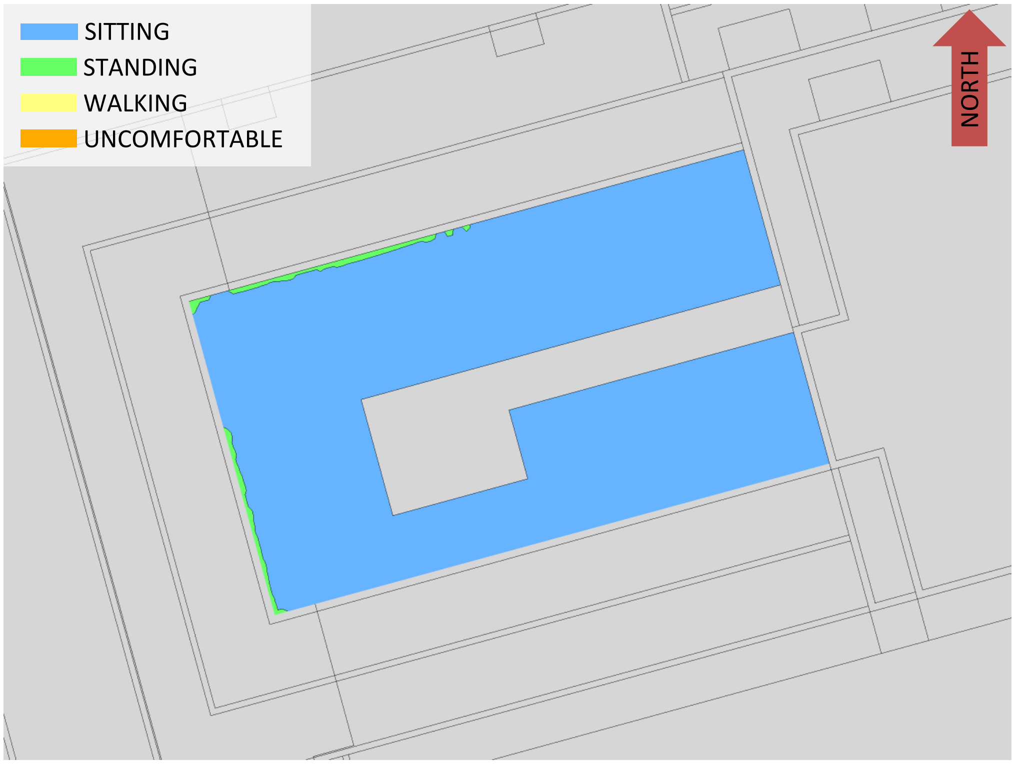
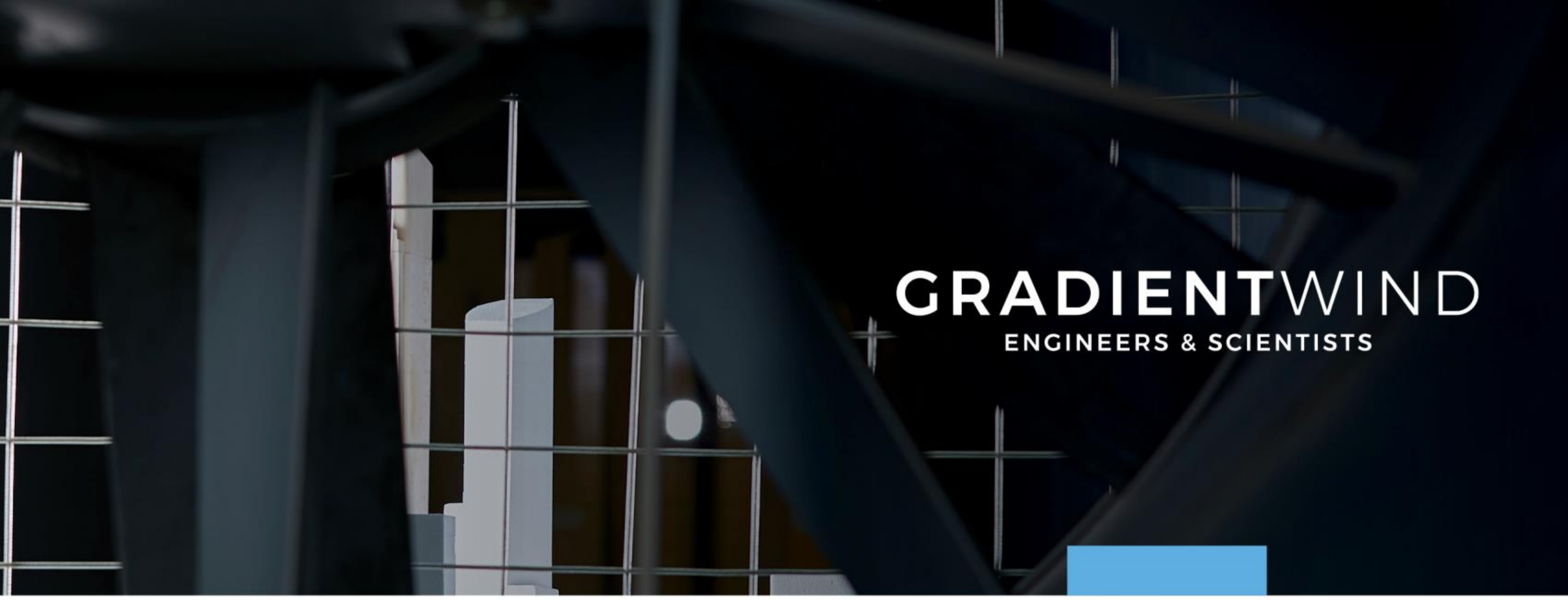
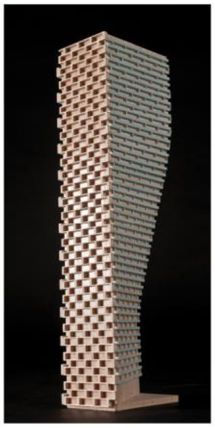
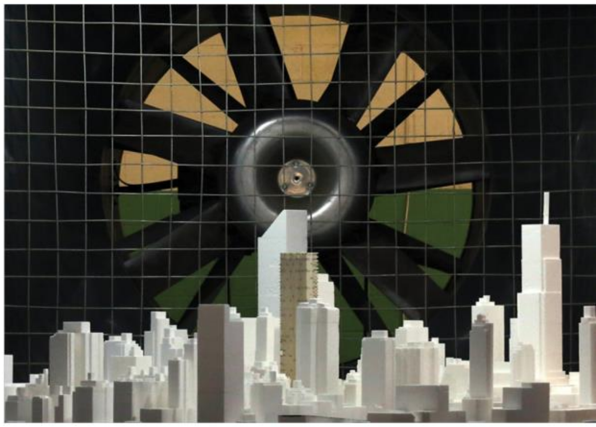


FIGURE 9: TYPICAL USE PERIOD – WIND COMFORT, LEVEL 9 COMMON AMENITY TERRACE







APPENDIX A

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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

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

where, $\boldsymbol{U}$ = 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 (that is, 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	0.26
22.5	0.26
45	0.26
67.5	0.27
90	0.28
112.5	0.26
135	0.23
157.5	0.20
180	0.18
202.5	0.17
225	0.17
247.5	0.20
270	0.24
292.5	0.25
315	0.25
337.5	0.26

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, $\boldsymbol{I}$ = turbulence intensity, $\boldsymbol{L_t}$ = turbulence length scale, $\boldsymbol{Z}$ = 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 Engineering Symposium, IWES 2003*, Taiwan, 2003.