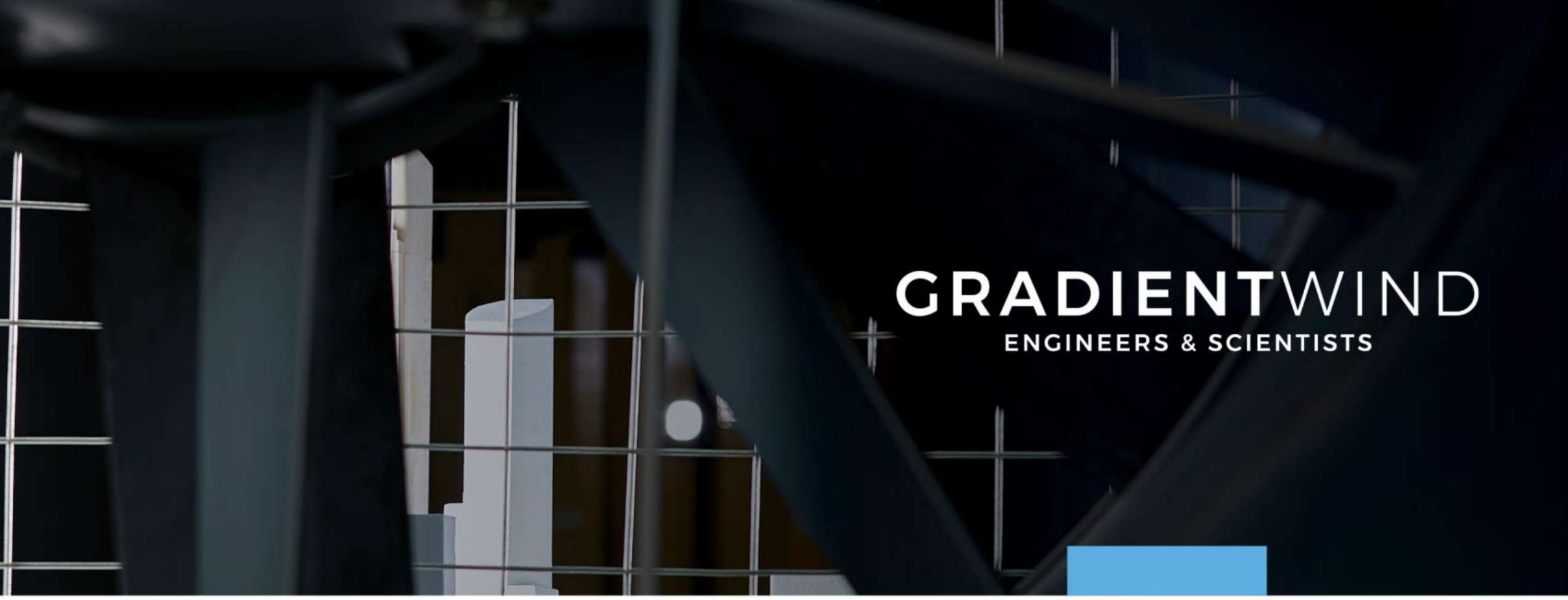
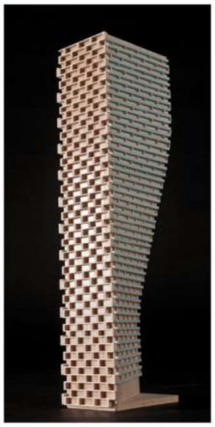


PEDESTRIAN LEVEL WIND STUDY

48 Isabella Street
Toronto, Ontario

Report: 25-060-PLW



June 11, 2025

PREPARED FOR
Land's Edge Properties Ltd.
203-1155 W Pender Street
Vancouver, BC V6E 2P4

PREPARED BY
Sunny Kang, B.A.S., Project Coordinator
Justin Denne, M.A.Sc., Junior Wind Scientist
David Huitema, M.Eng., P.Eng., CFD Lead Engineer

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study to satisfy Official Plan Amendment and Zoning By-Law Amendment application submission requirements for the proposed residential development located at 48 Isabella Street in Toronto, Ontario (hereinafter referred to as the “subject site” or “proposed development”). Our mandate within this study is to investigate pedestrian wind conditions within and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where required.

The PLW study involves the 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 conditions 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-13B, 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 public sidewalks, nearby laneways and drive aisles, the neighbouring outdoor amenity serving 45 Charles Street East, proposed PUDO areas, walkways, and grade-level outdoor amenity, and in the vicinity of building access points, are considered acceptable.

2) Regarding the common amenity terrace serving the proposed development at Level 3, conditions during the typical use period (that is, May to October, inclusive) are predicted to be suitable for sitting, which is considered acceptable.

3) Wind comfort conditions within the common amenity terraces serving 55 Charles Street East are predicted to remain practically unchanged prior to and following the introduction of the proposed development.

4) 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.

GRADIENTWIND
ENGINEERS & SCIENTISTS

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Land's Edge Properties Ltd. to undertake a pedestrian level wind (PLW) study to satisfy Official Plan Amendment and Zoning By-Law Amendment application submission requirements for the proposed residential development located at 48 Isabella Street in Toronto, Ontario (hereinafter referred to as the "subject site" or "proposed development"). Our mandate within the current study is to investigate pedestrian wind conditions within and surrounding the subject site for the current architectural design, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where required.

The PLW 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 Kirkor Architects and Planners in March 2025, 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 48 Isabella Street in Toronto, situated approximately 100 metres (m) to the west of the intersection of Isabella Street and Church Street on a parcel of land bordered by Isabella Street to the south, a low-rise residential building to the west, Macy DuBois Lane to the north, and a high-rise mixed-use residential building to the east. The proposed development comprises a rectangular 69-storey residential tower, topped with a mechanical penthouse (MPH). Above four levels of below-grade parking, the ground floor of the proposed development includes a primary access point along the south elevation to a main lobby and a mail parcel room, an indoor amenity at the southwest corner, a loading space and shared building support spaces to the north, and bicycle parking to the east. An outdoor amenity is proposed along the west elevation of the subject site and connects with a pickup/drop-off (PUDO) area at the northwest corner. Access to the underground parking levels is provided by a ramp at the northwest corner from Macy DuBois Lane. Level 2 is open to below at the northeast corner and includes a garbage room to the east and bicycle parking throughout the remainder of the level. Level 3 is reserved for indoor amenities and steps back from all elevations to accommodate a common amenity terrace atop the podium. The remaining levels of the tower are reserved for residential occupancy.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-m-radius of the subject site) are characterized by a mix of mid- to high-rise building in all compass directions with high-rise massing primarily located to the southwest clockwise to the east, and a mix of low- and tall mid-rise massing to the southeast. Notably, the high-rise tower at 45 Charles Street East to the immediate northwest includes a grade-level outdoor amenity and the high-rise tower at 55 Charles Street East to the immediate north includes amenity terraces at Levels 9 and 52. Future high-rise mixed-use residential developments are approved at 625 Church Street (56 storeys), 90 Isabella Street (69 storeys), 88 Isabella Street (62 storeys), 619 Yonge Street (57 storeys), 645 Yonge Street (76 storeys), and 15 Charles Street East (66 storeys).

The far-field surroundings (defined as the area beyond the near field and within a two-kilometre (km) radius) comprise mid- and high-rise buildings from the southeast clockwise to the southwest, which define the Toronto downtown core, and a mix of low-to high-rise buildings followed by suburban massing in all remaining compass directions. Queen's Park is located approximately 750 m to the southwest and isolated areas of green spaces and parks are located to the north clockwise to the east within the Rosedale Valley and Don River Valley.

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 approximately 480 m. The process was performed for two context massing scenarios, as noted in Section 2.

[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

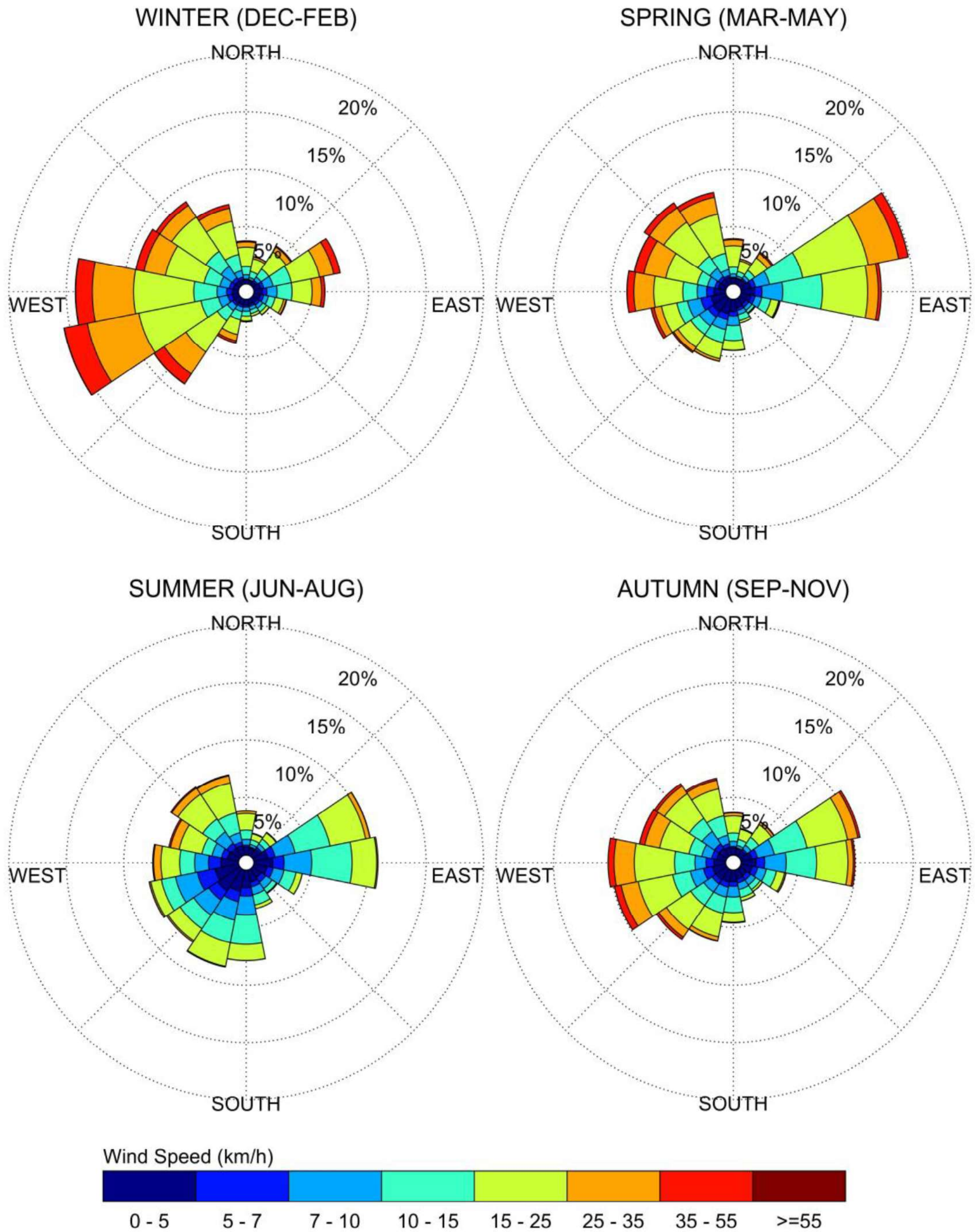
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade, the common amenity terrace serving the proposed development at Level 3, and the common amenity terraces serving the neighbouring development at 55 Charles Street East 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 (that is, 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 preferred 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 preference 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 (that is, 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 based on the Beaufort scale, 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. 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. Specifically, the comfort classes, associated wind speed ranges, and limiting criteria are summarized as follows:

PEDESTRIAN WIND COMFORT CLASS DEFINITIONS

Wind Comfort Class	GEM Speed (km/h)	Description
SITTING	≤ 10	GEM wind speeds no greater than 10 km/h occurring at least 80% of the time are considered acceptable for sedentary activities, including sitting.
STANDING	≤ 15	GEM wind speeds no greater than 15 km/h occurring at least 80% of the time are considered acceptable for activities such as standing, strolling, or more vigorous activities.
WALKING	≤ 20	GEM wind speeds no greater than 20 km/h occurring at least 80% of the time are considered acceptable for walking or more vigorous activities.
UNCOMFORTABLE	> 20	Uncomfortable conditions are characterized by predicted values that fall below the 80% target for walking. Brisk walking and exercise, such as jogging, are considered 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.

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 target comfort classes, which are dictated by the location type for each region (that is, a sidewalk, building entrance, amenity space, or other). An overview of common pedestrian location types and their typical windiest target comfort classes are summarized below. Depending on the programming of a space, the desired comfort class may differ from this table.

TARGET PEDESTRIAN WIND COMFORT CLASSES FOR VARIOUS LOCATION TYPES

Location Types	Target Comfort Classes
Primary Building Entrance	Standing
Secondary Building Access Point	Walking
Public Sidewalk / Bicycle Path	Walking
Café / Patio / Bench / Garden	Sitting / Standing
Transit/Bus Stop (Without Shelter)	Standing
Transit/Bus Stop (With Shelter)	Walking
Public Park / Plaza / Amenity Space	Sitting / Standing
Garage / Service Entrance / Parking Lot	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, by Figures 7A-D, which illustrate wind conditions over the common amenity terrace serving the proposed development at Level 3, and by Figures 9A-12B, which illustrate comparative wind conditions over the amenity terraces serving the neighbouring development at 55 Charles Street East. 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 comfort conditions are also reported for the typical use period, which is defined as May to October, inclusive. Figures 8 and 13A-B illustrate wind comfort conditions over the noted common amenity terraces serving the proposed development and 55 Charles Street East, respectively, during this period, consistent with the comfort classes in Section 4.4.

The details of these conditions are summarized in the following pages for each area of interest.

5.1 Wind Comfort Conditions – Grade Level

Sidewalks along Isabella Street and Macy DuBois Lane: Prior to and following the introduction of the proposed development, wind comfort conditions over the nearby public sidewalks along Isabella Street and over Macy DuBois Lane are predicted to be suitable for sitting during the summer and autumn, with small, isolated regions suitable for standing during the autumn, becoming suitable for a mix of sitting and standing during the spring and winter with an isolated region suitable for walking to the southwest of the subject site during the winter. The noted conditions are considered acceptable.

Neighbouring Drive Aisles East and South of Subject Site: Prior to and following the introduction of the proposed development, wind comfort conditions over the nearby drive aisles to the east and south of the subject site are predicted to be suitable for standing, or better, throughout the year. The noted conditions are considered acceptable.

Neighbouring Outdoor Amenity Serving 45 Charles Street East: Prior to and following the introduction of the proposed development, wind comfort conditions over the outdoor amenity serving 45 Charles Street East to the northwest of the subject site are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable.

Proposed Outdoor Amenity West of Subject Site: Wind conditions over the outdoor amenity located along the west elevation of the subject site are predicted to be suitable for sitting throughout the year, which is considered acceptable.

Proposed Pickup/Drop-off (PUDO) Area and Walkways: Conditions over the PUDO area at the northwest corner of the subject site and the walkways serving the proposed development are predicted to be suitable for standing, or better, throughout the year. The noted conditions are considered acceptable.

Building Access Points: Owing to the protection provided by the building façade, all primary and secondary building access points serving the proposed development are predicted to be suitable for sitting throughout the year, which is considered acceptable.

5.2 Wind Comfort Conditions – Common Amenity Terraces

Wind comfort conditions within the common amenity terrace serving the proposed development at Level 3 are predicted to be suitable for sitting during the typical use period. The noted conditions are considered acceptable.

Prior to the introduction of the proposed development, conditions over the common amenity terraces serving 55 Charles Street East at Levels 9 and 52 are predicted to be suitable for sitting during the typical use period. Following the introduction of the proposed development, conditions are predicted to remain suitable for mostly sitting within the noted terraces, as illustrated in Figures 13A and 13B.

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-13B. 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 public sidewalks, nearby laneways and drive aisles, the neighbouring outdoor amenity serving 45 Charles Street East, proposed PUDO areas, walkways, and grade-level outdoor amenity, and in the vicinity of building access points, are considered acceptable.

2) Regarding the common amenity terrace serving the proposed development at Level 3, conditions during the typical use period (that is, May to October, inclusive) are predicted to be suitable for sitting, which is considered acceptable.

3) Wind comfort conditions within the common amenity terraces serving 55 Charles Street East are predicted to remain practically unchanged prior to and following the introduction of the proposed development.

4) 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,

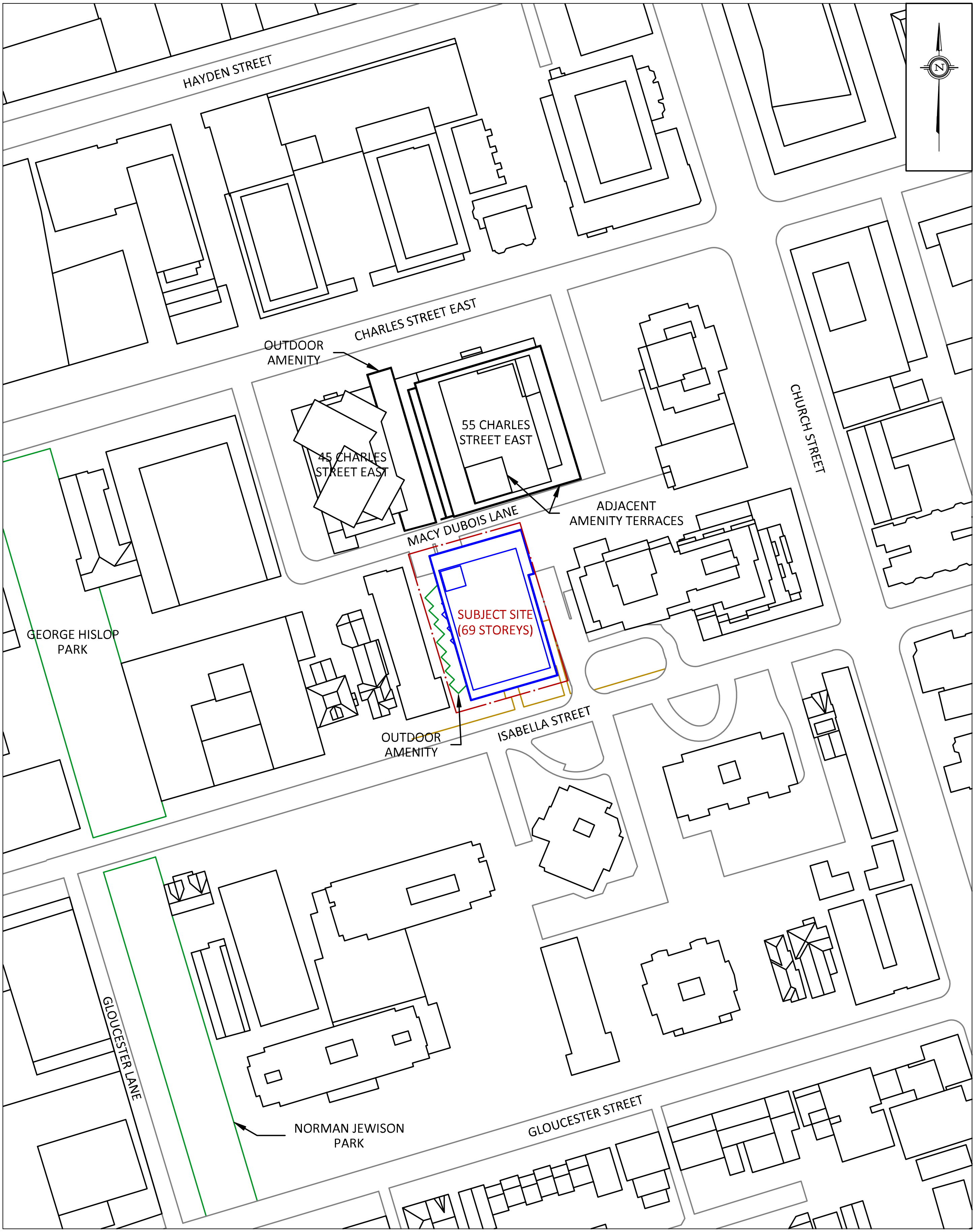
Gradient Wind Engineering Inc.

LICENSED PROFESSIONAL ENGINEER
D. T. HUITEMA
100561777
June 11, 2025
PROVINCE OF ONTARIO

Justin Denne, M.A.Sc.
Junior Wind Scientist

David Huitema, M.Eng., P.Eng.
CFD Lead Engineer

Sunny Kang, B.A.S.
Project Coordinator



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127 WALGREEN ROAD, OTTAWA, ON
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PROJECT: 48 ISABELLA STREET, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1A: PROPOSED SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:1500	DRAWING NO.: 25-060-PLW-1A	
DATE: MARCH 31, 2025	DRAWN BY: S.K.	

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PROJECT	48 ISABELLA STREET, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1B: EXISTING SITE PLAN AND SURROUNDING CONTEXT
SCALE	1:1500	DRAWING NO.	25-060-PLW-1B
DATE	MARCH 31, 2025	DRAWN BY	S.K.

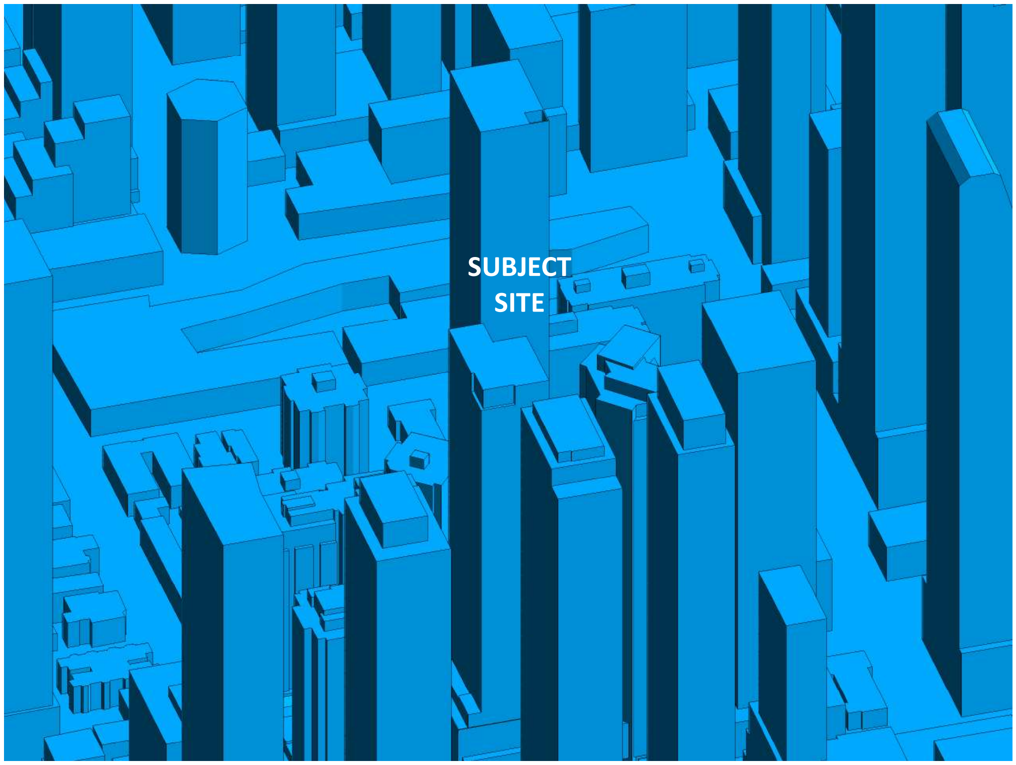


FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTH PERSPECTIVE

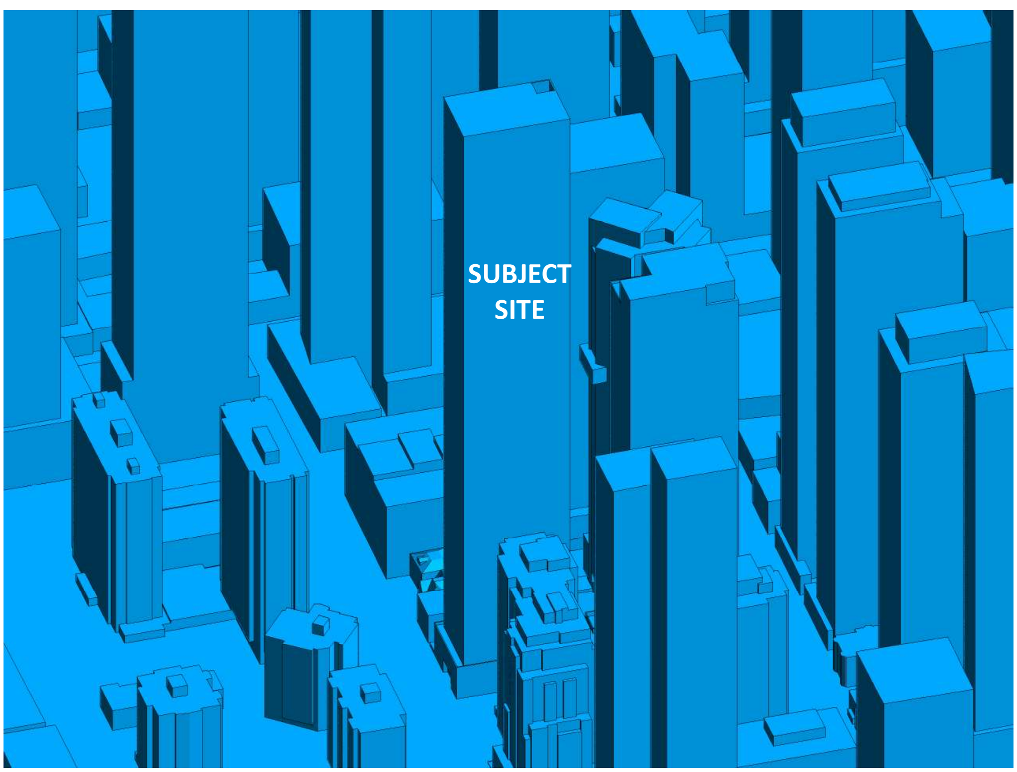


FIGURE 2B: COMPUTATIONAL MODEL, PROPOSED MASSING, EAST PERSPECTIVE

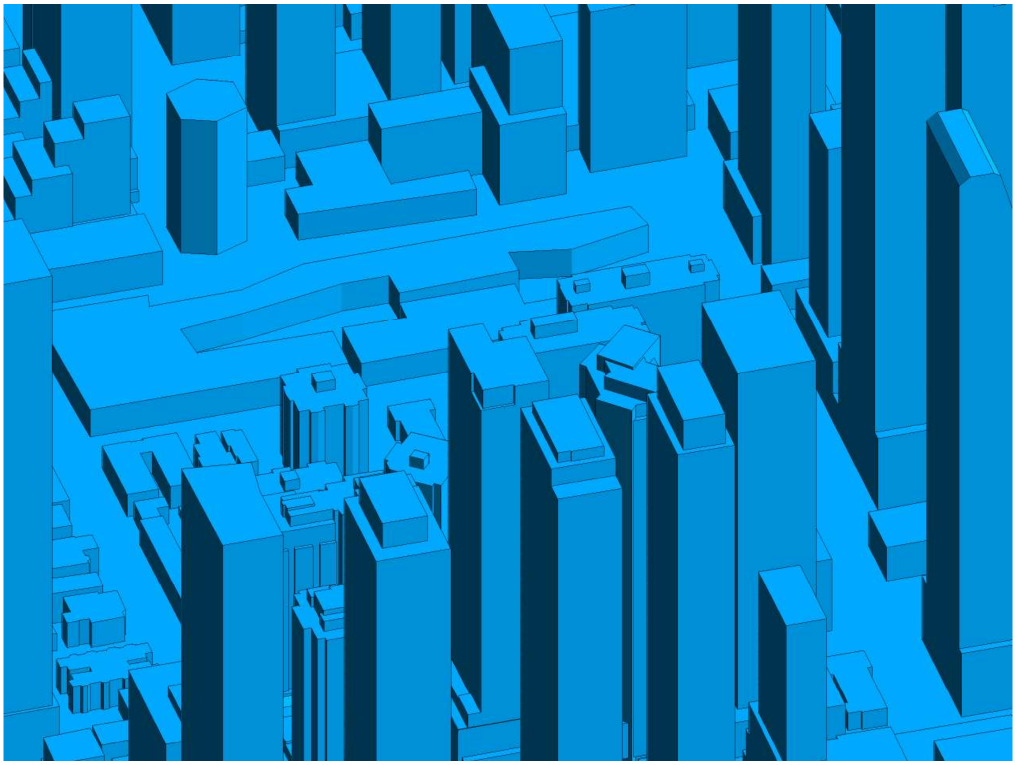


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTH PERSPECTIVE

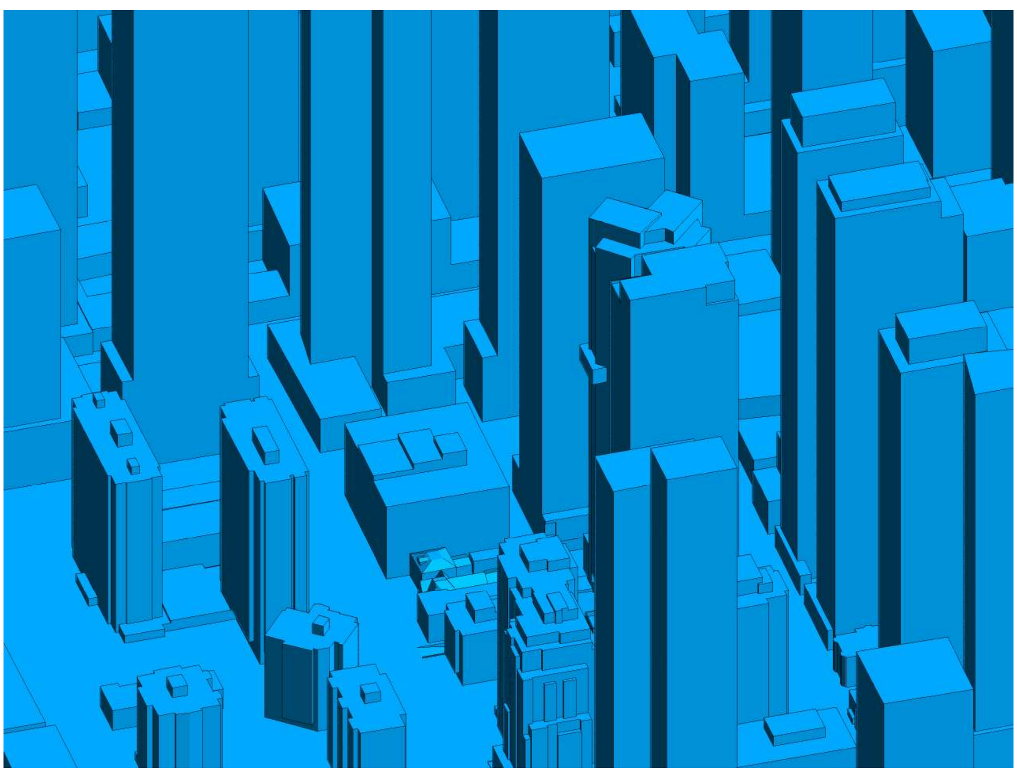


FIGURE 2D: COMPUTATIONAL MODEL, EXISTING MASSING, EAST PERSPECTIVE

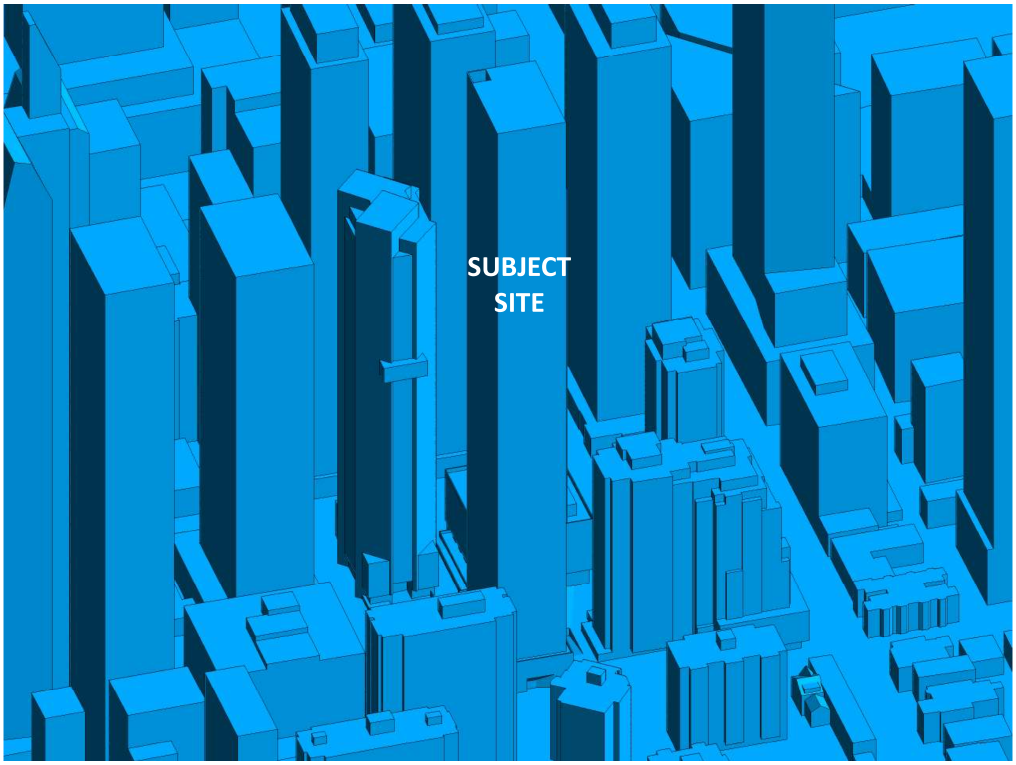


FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTH PERSPECTIVE

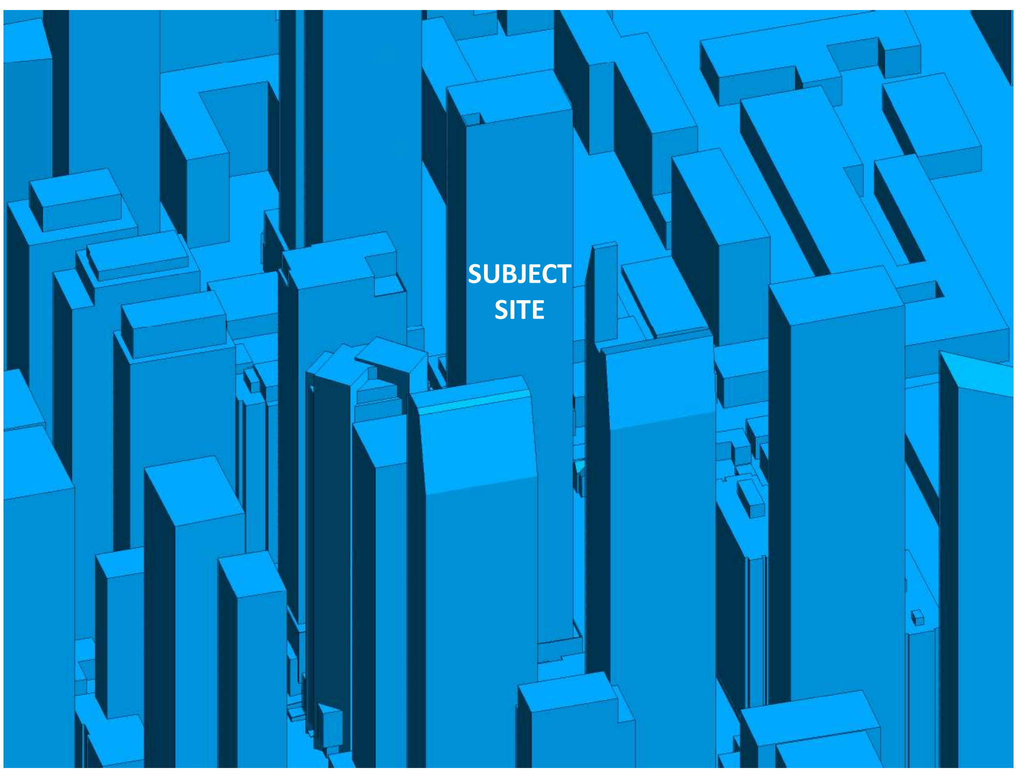


FIGURE 2F: COMPUTATIONAL MODEL, PROPOSED MASSING, WEST PERSPECTIVE

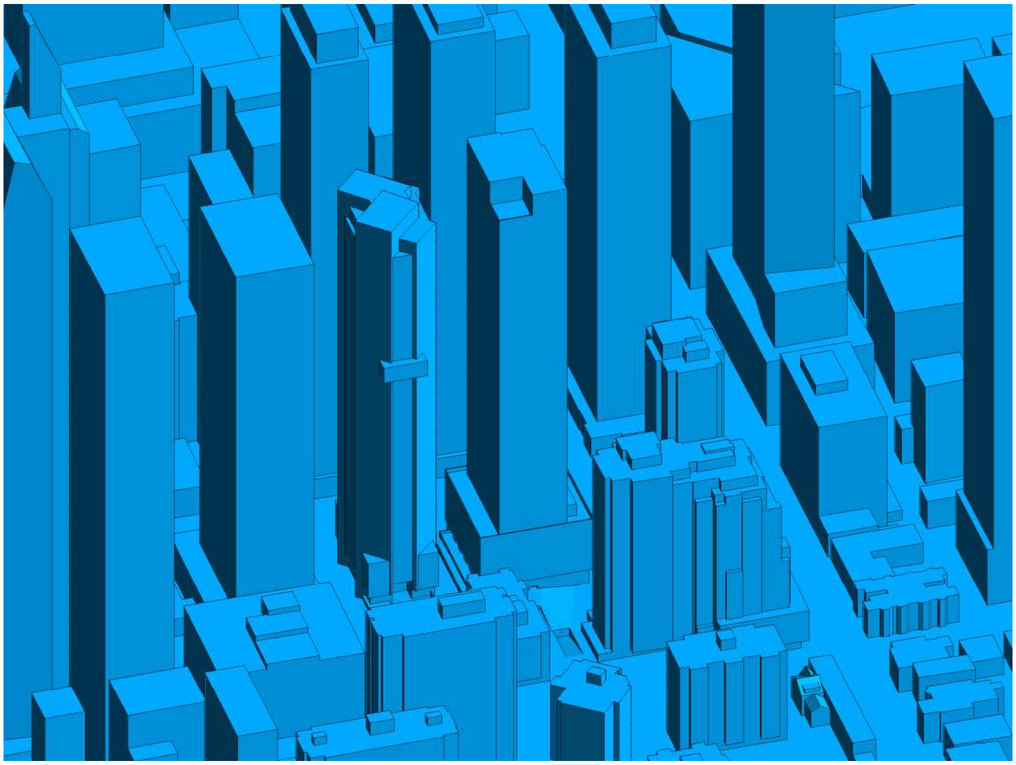


FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, SOUTH PERSPECTIVE

FIGURE 2H: COMPUTATIONAL MODEL, EXISTING MASSING, WEST PERSPECTIVE

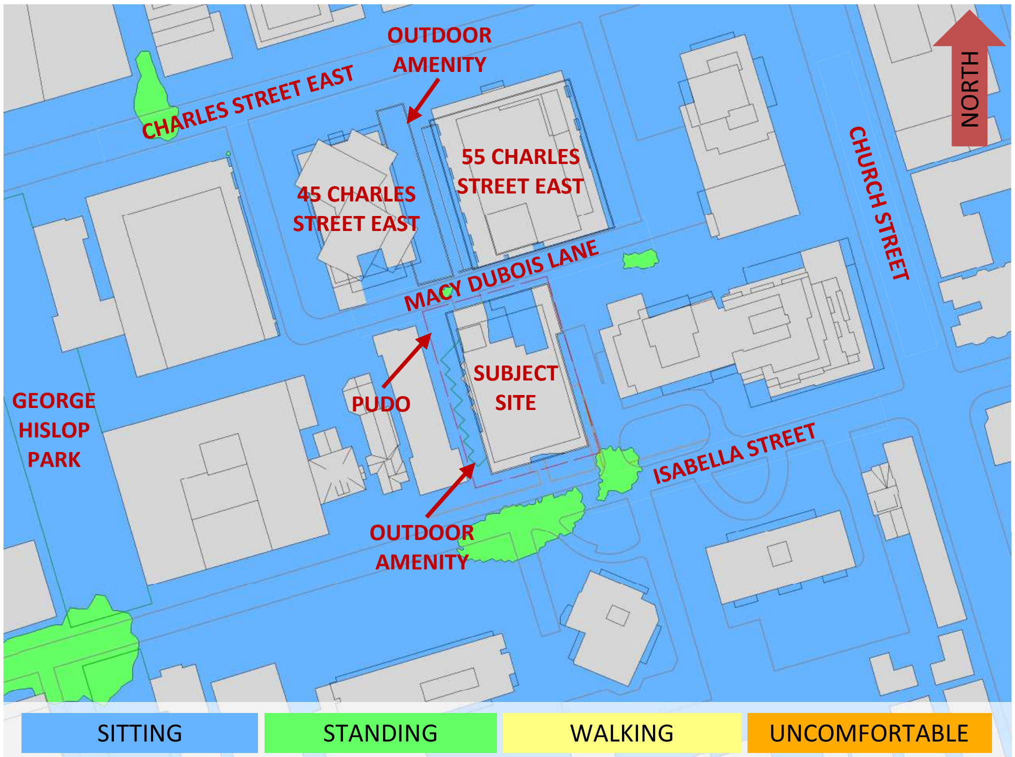


FIGURE 3A: SPRING – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

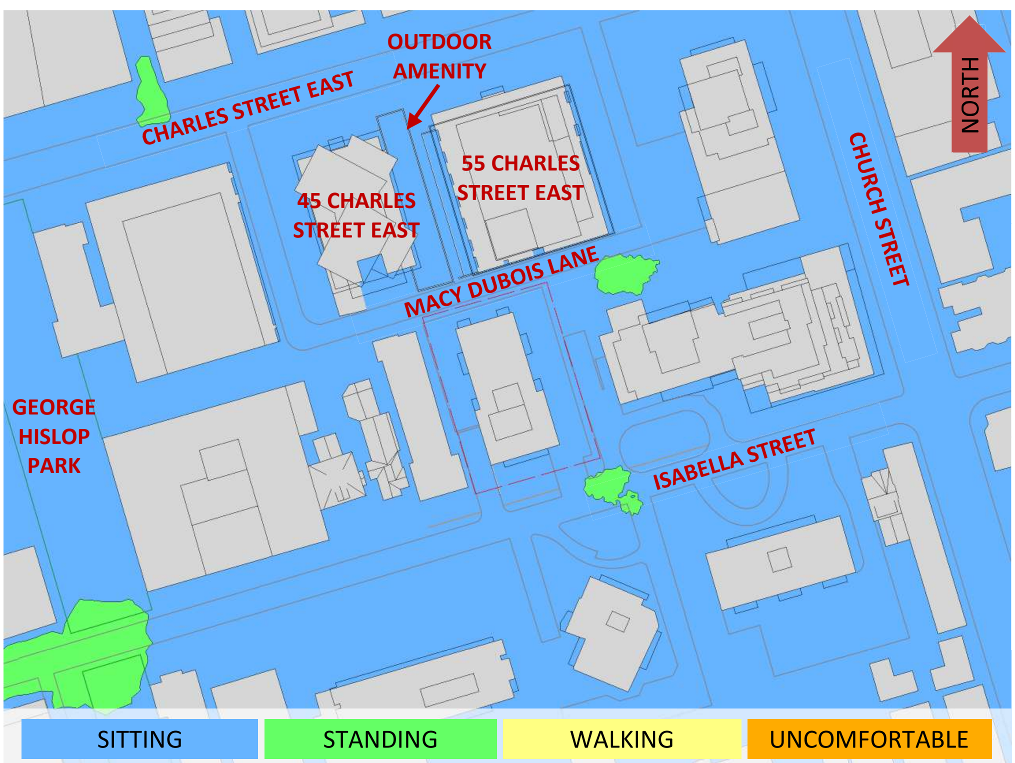


FIGURE 3B: SPRING – EXISTING MASSING – WIND COMFORT, GRADE LEVEL

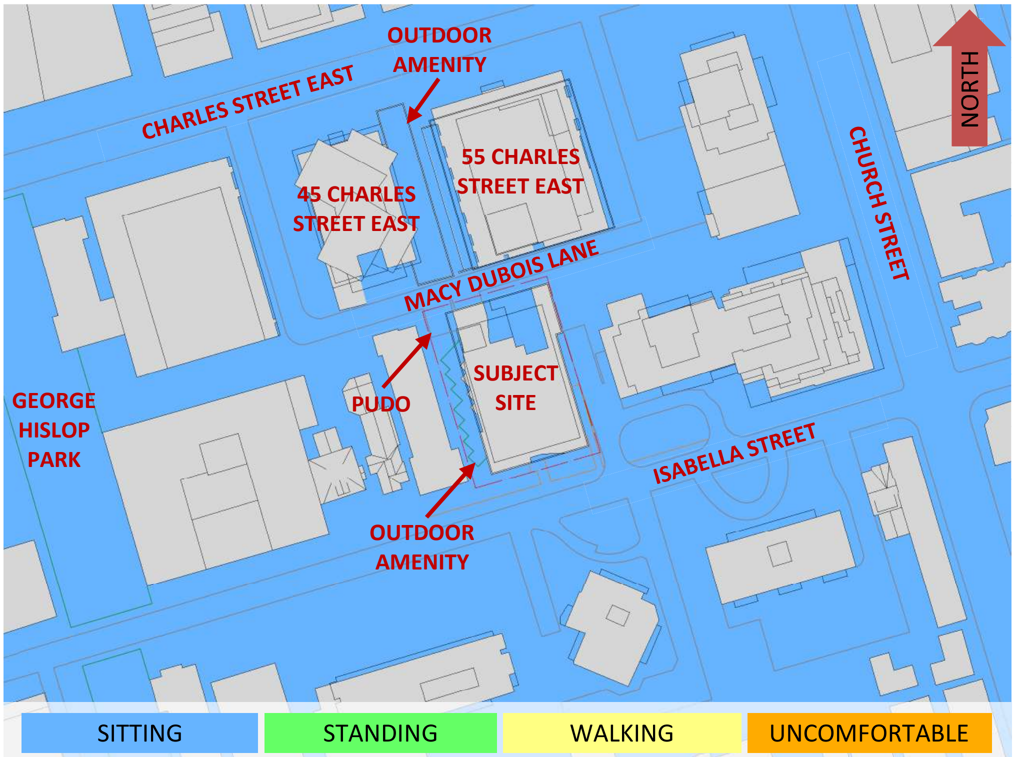


FIGURE 4A: SUMMER – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

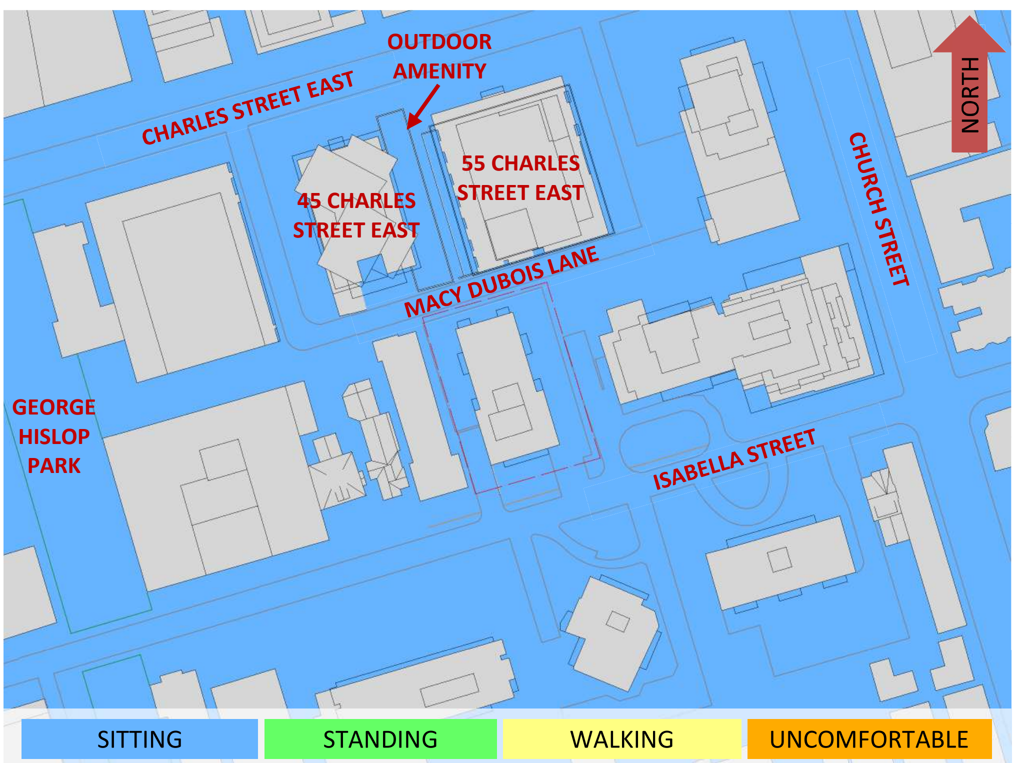


FIGURE 4B: SUMMER – EXISTING MASSING – WIND COMFORT, GRADE LEVEL

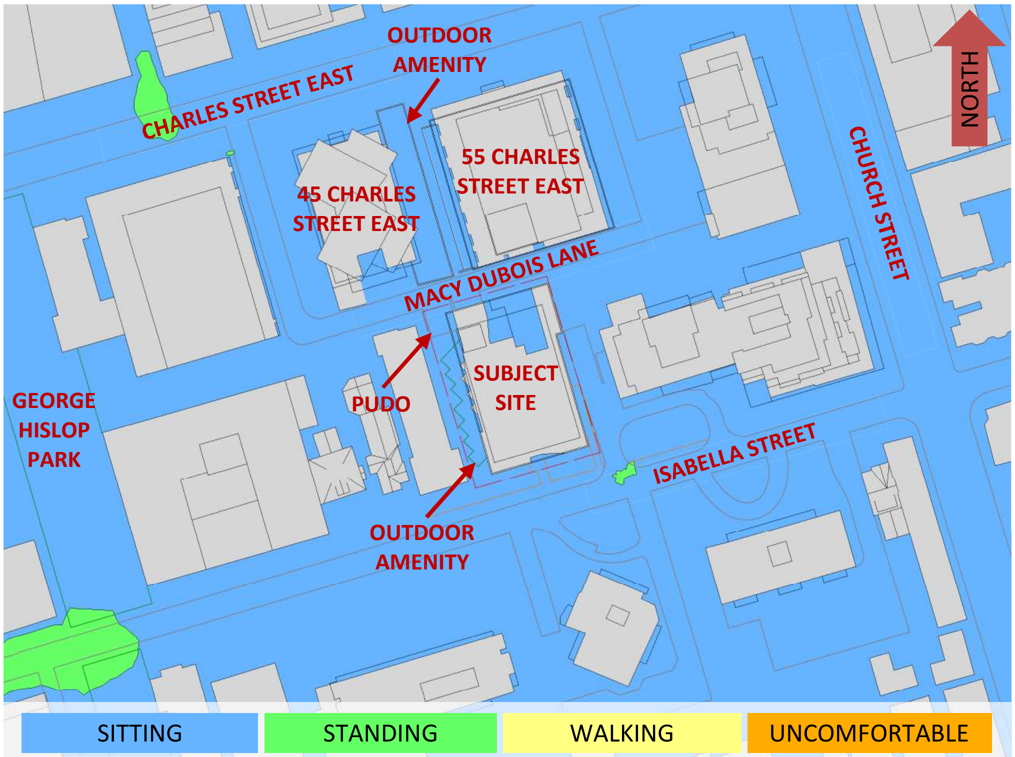


FIGURE 5A: AUTUMN – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

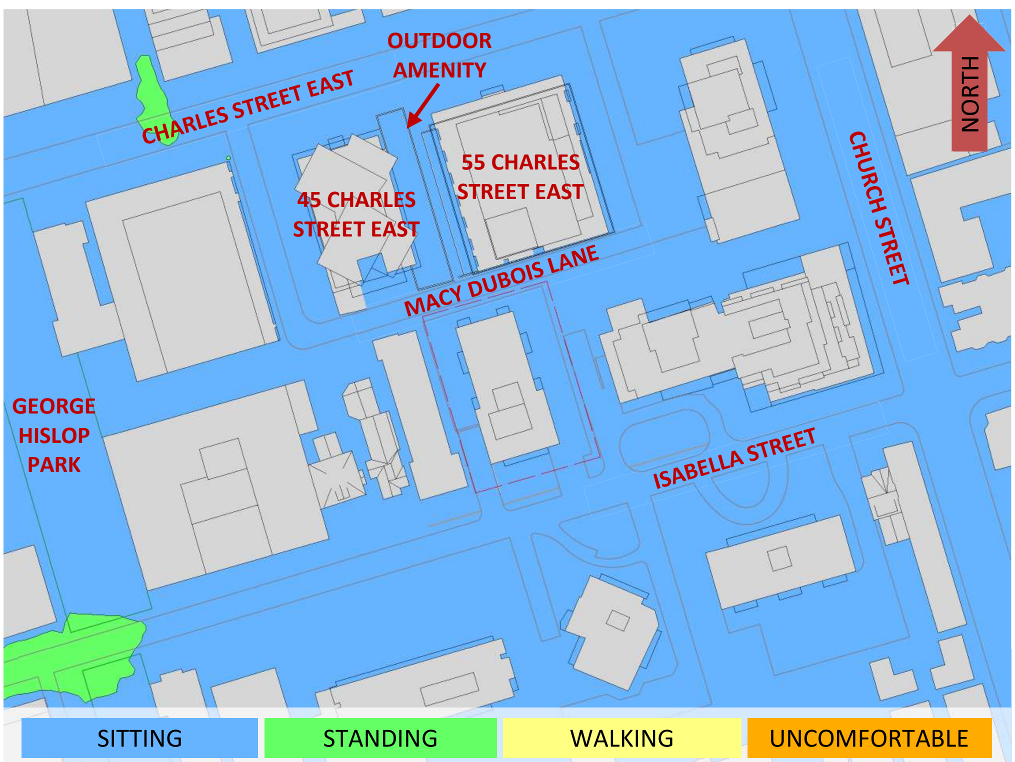


FIGURE 5B: AUTUMN – EXISTING MASSING – WIND COMFORT, GRADE LEVEL

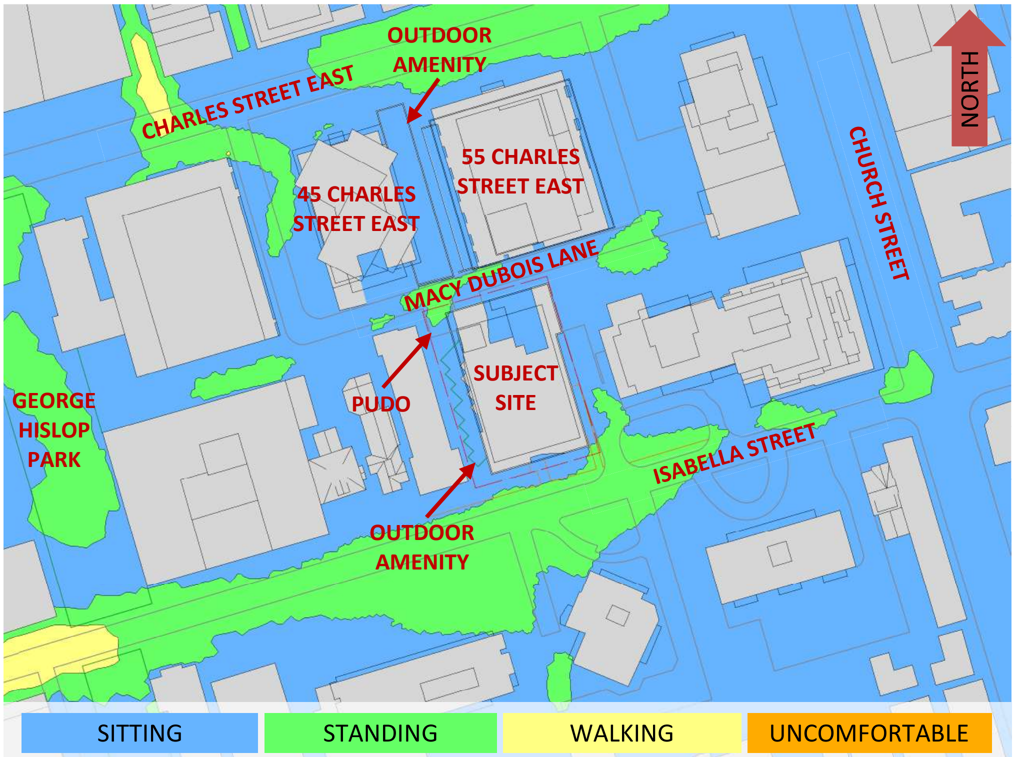


FIGURE 6A: WINTER – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL

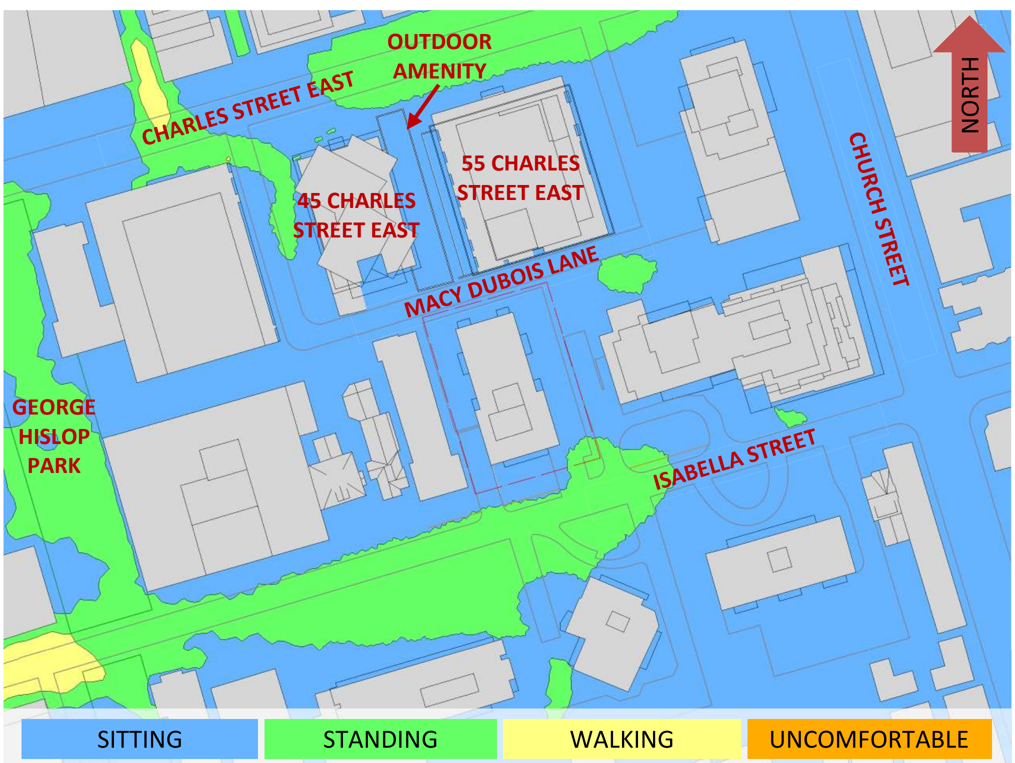


FIGURE 6B: WINTER – EXISTING MASSING – WIND COMFORT, GRADE LEVEL

FIGURE 7A: SPRING – WIND COMFORT, LEVEL 3 COMMON AMENITY TERRACE

FIGURE 7B: SUMMER – WIND COMFORT, LEVEL 3 COMMON AMENITY TERRACE

FIGURE 7C: AUTUMN – WIND COMFORT, LEVEL 3 COMMON AMENITY TERRACE

FIGURE 7D: WINTER – WIND COMFORT, LEVEL 3 COMMON AMENITY TERRACE

FIGURE 8: TYPICAL USE PERIOD, LEVEL 3 COMMON AMENITY TERRACE

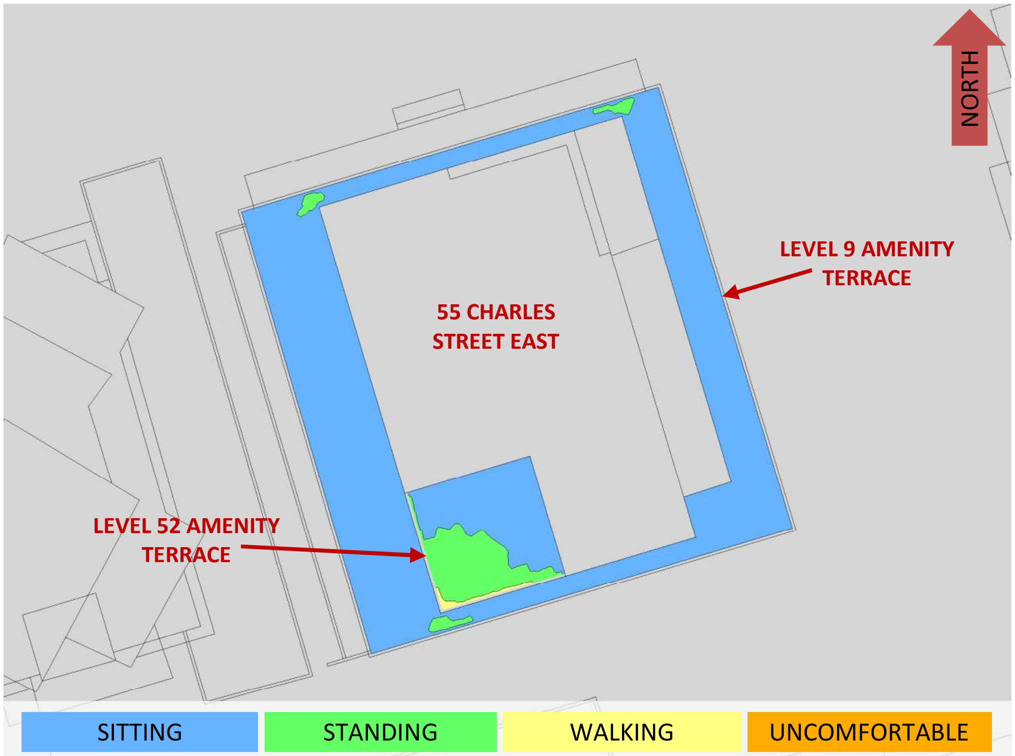


FIGURE 9A: SPRING – WIND COMFORT, ADJACENT AMENITY TERRACES – PROPOSED MASSING

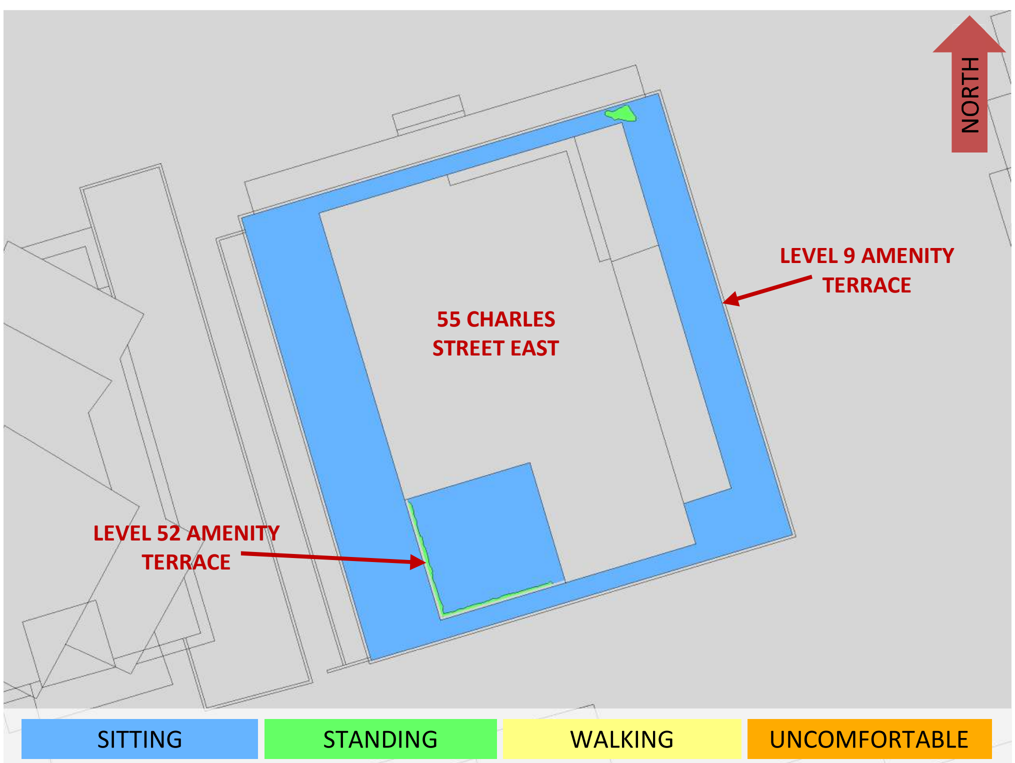


FIGURE 9B: SPRING – WIND COMFORT, ADJACENT AMENITY TERRACES – EXISTING MASSING

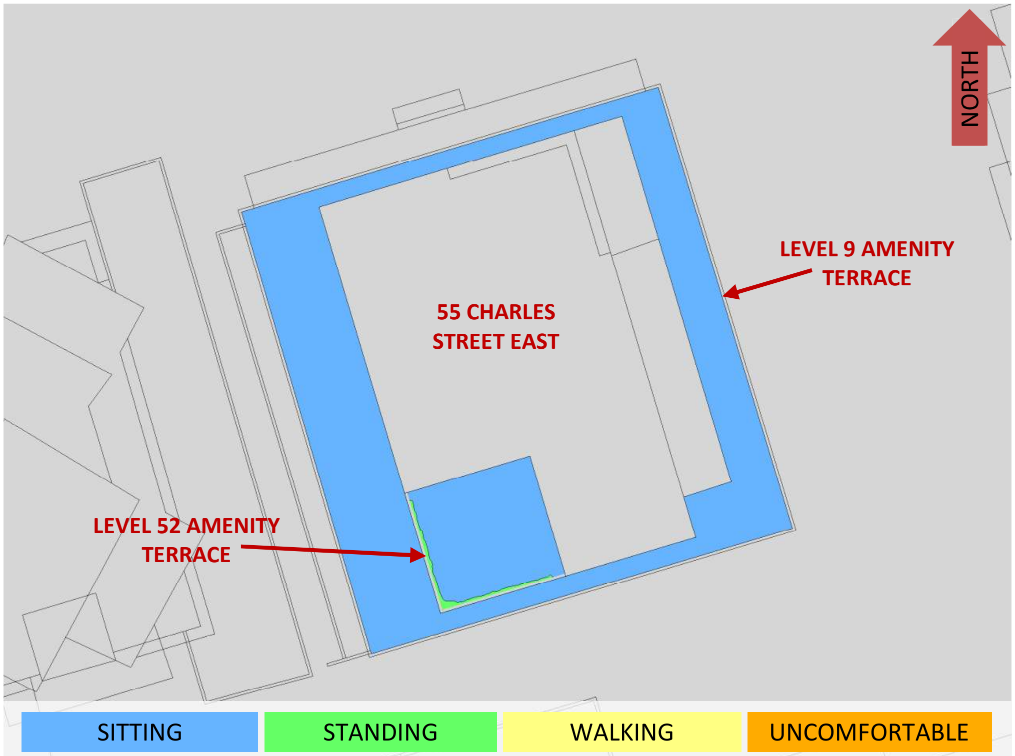


FIGURE 10A: SUMMER – WIND COMFORT, ADJACENT AMENITY TERRACES – PROPOSED MASSING

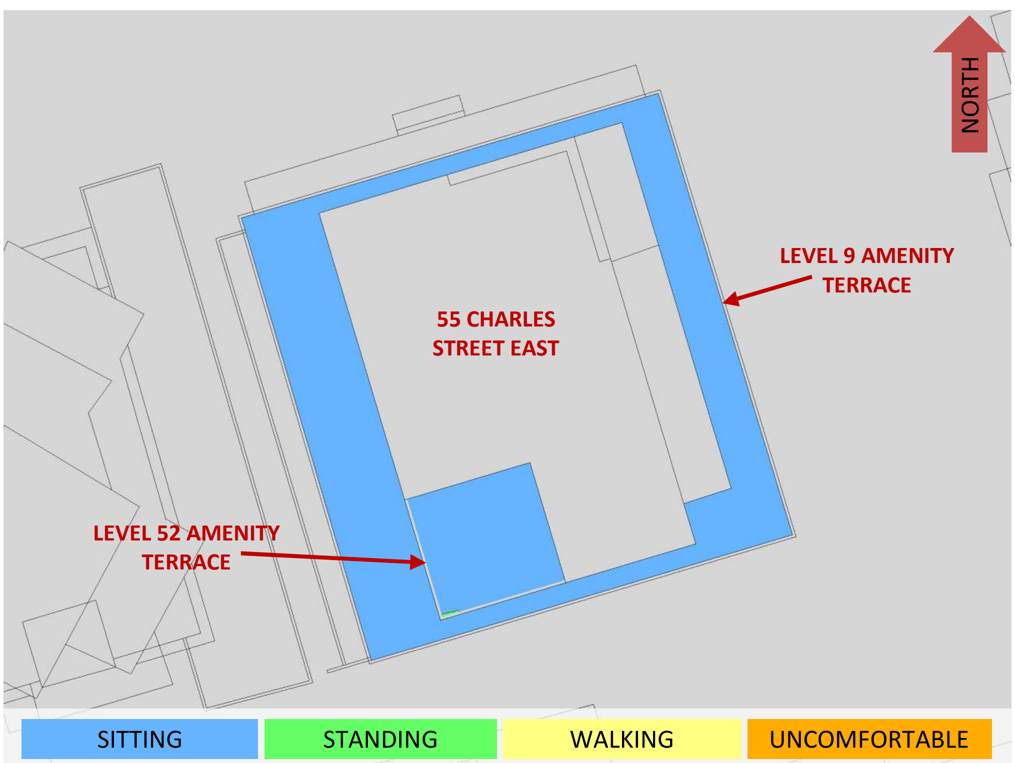


FIGURE 10B: SUMMER – WIND COMFORT, ADJACENT AMENITY TERRACES – EXISTING MASSING

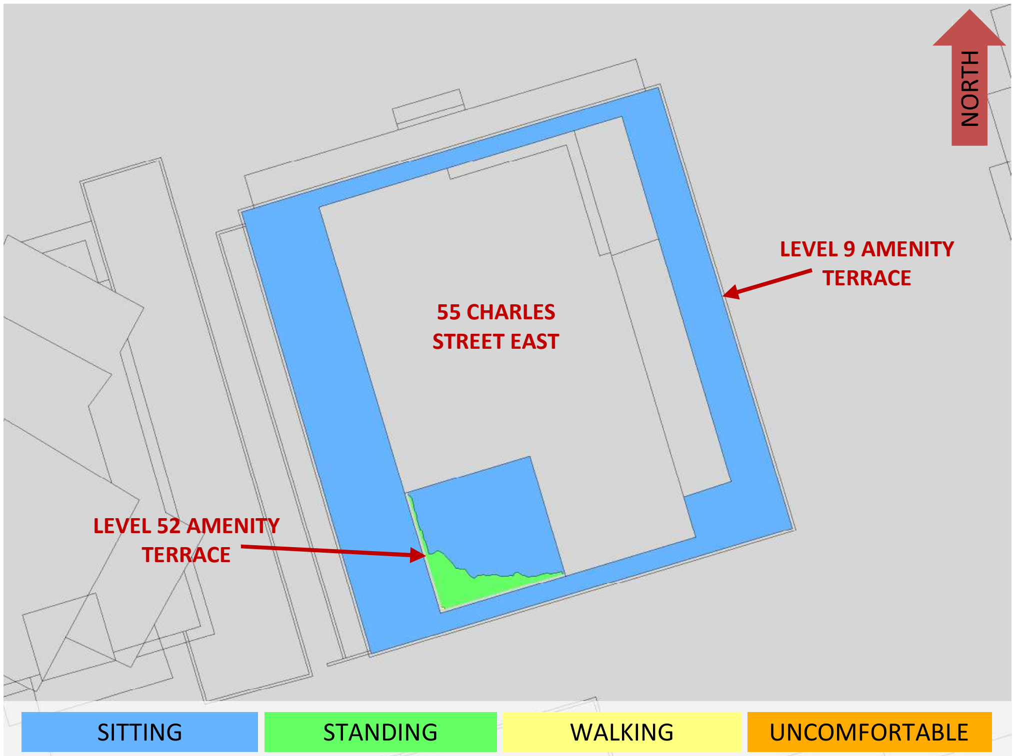


FIGURE 11A: AUTUMN – WIND COMFORT, ADJACENT AMENITY TERRACES – PROPOSED MASSING

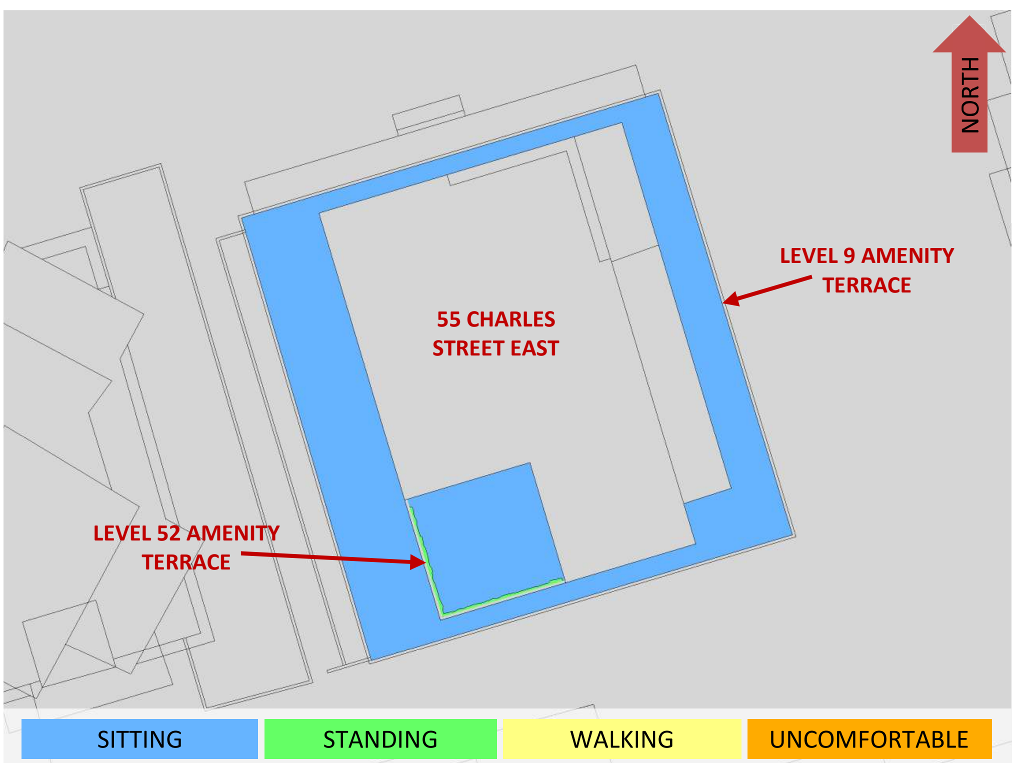


FIGURE 11B: AUTUMN – WIND COMFORT, ADJACENT AMENITY TERRACES – EXISTING MASSING

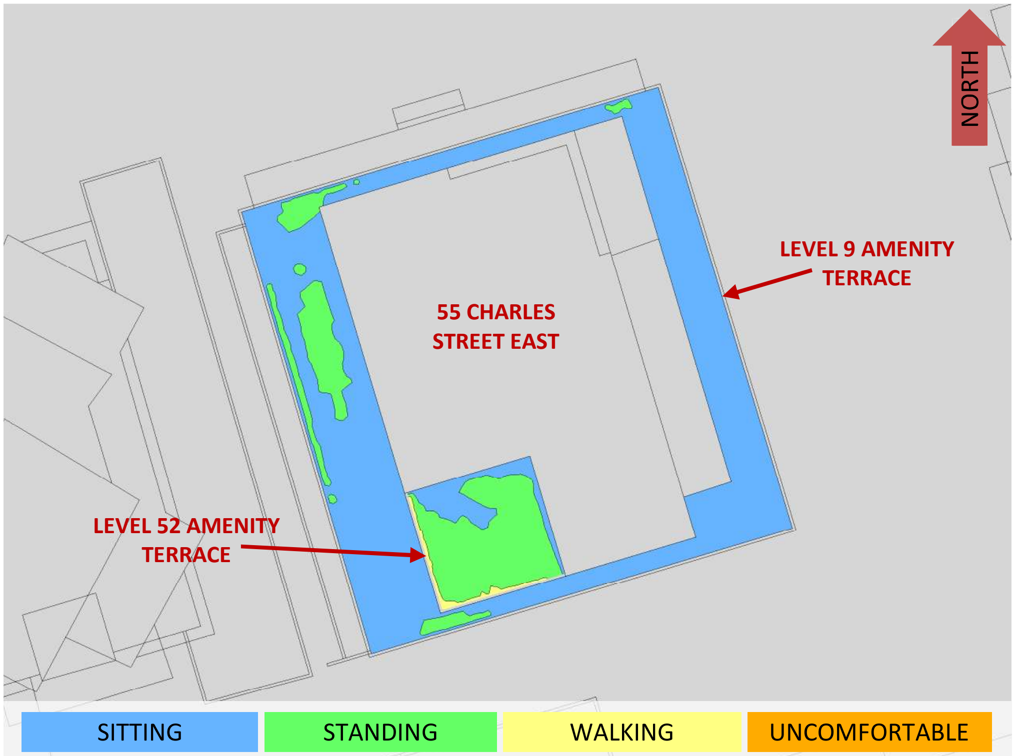


FIGURE 12A: WINTER – WIND COMFORT, ADJACENT AMENITY TERRACES – PROPOSED MASSING

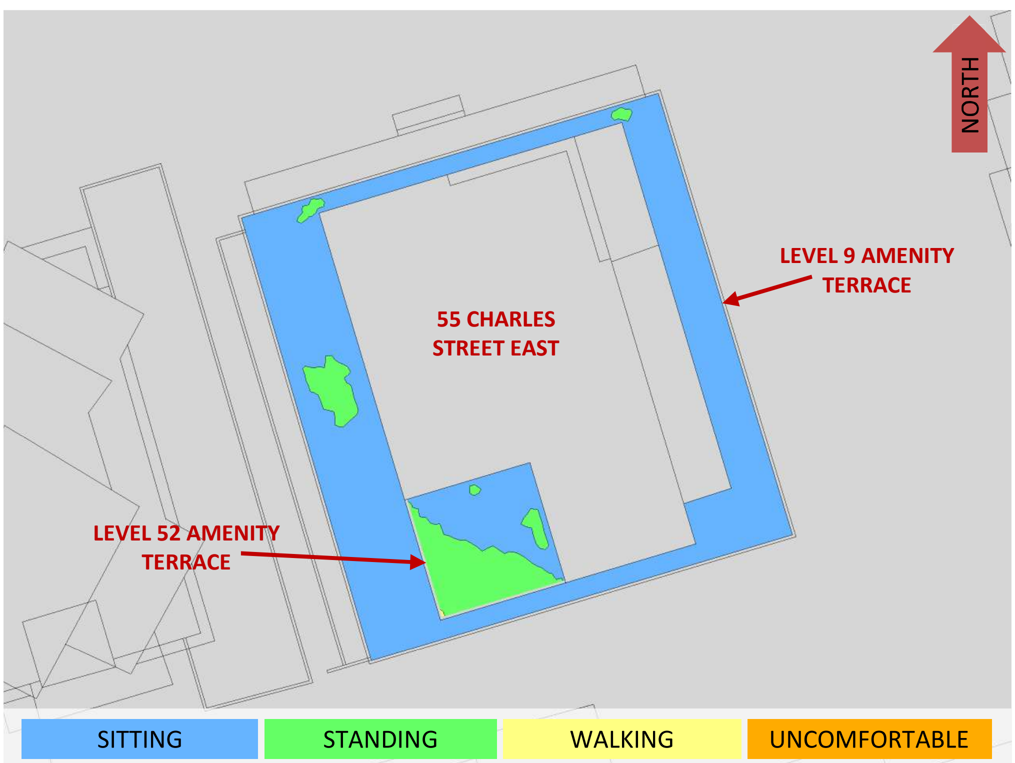


FIGURE 12B: WINTER – WIND COMFORT, ADJACENT AMENITY TERRACES – EXISTING MASSING

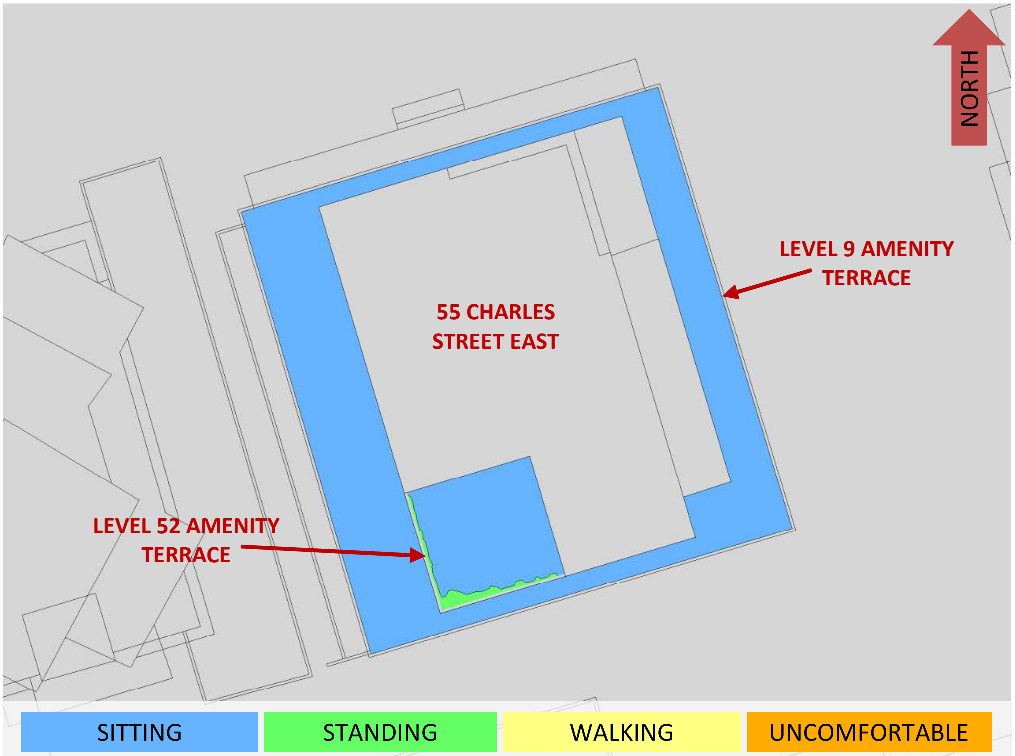


FIGURE 13A: TYPICAL USE PERIOD – ADJACENT AMENITY TERRACES – PROPOSED MASSING

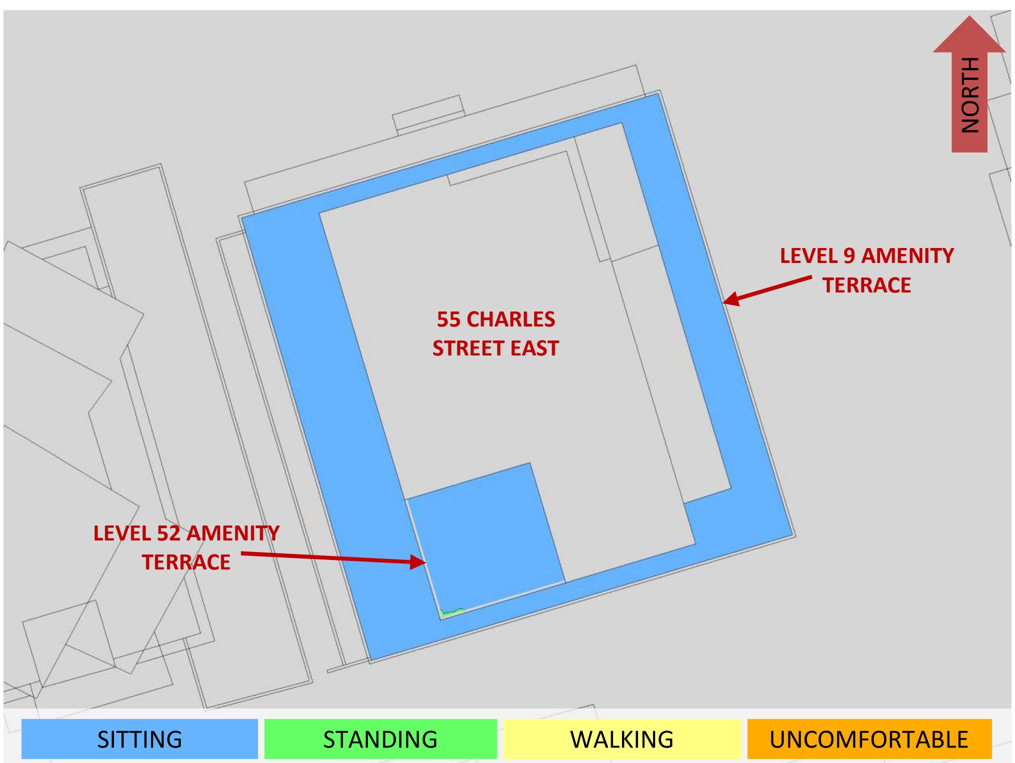
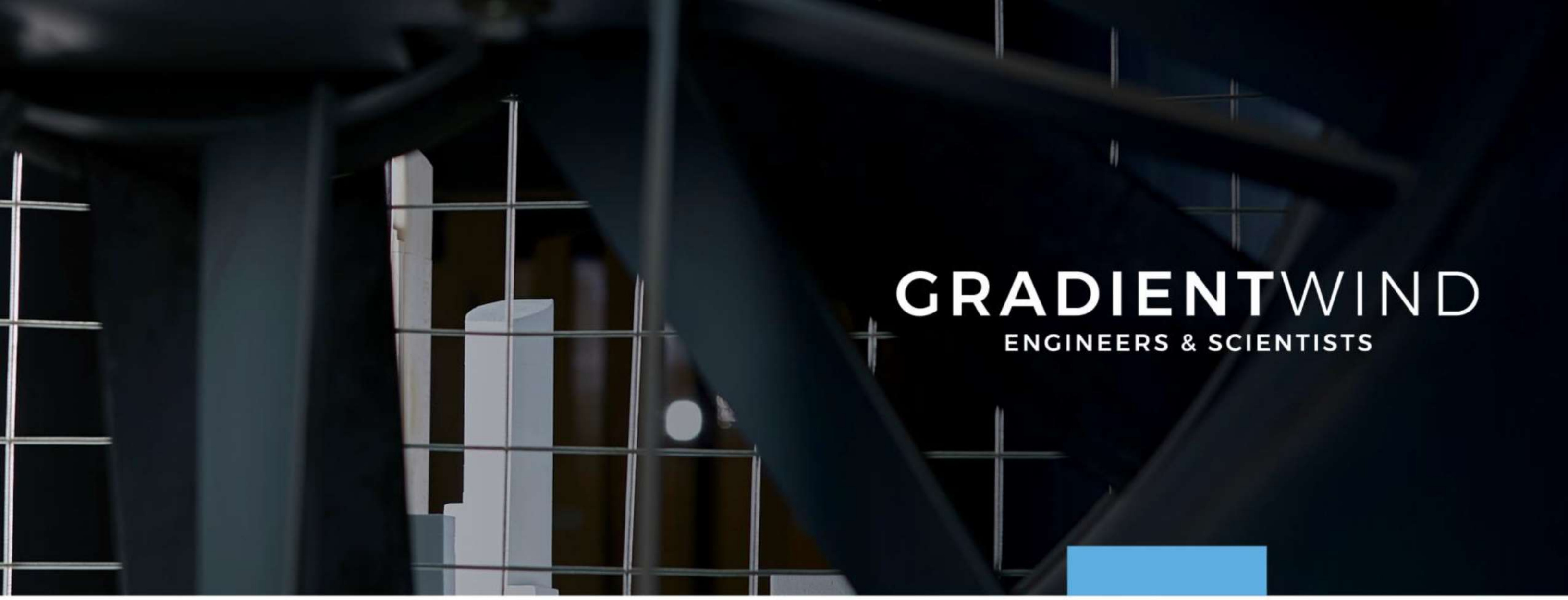
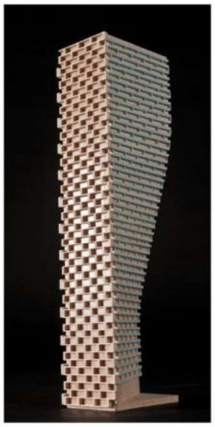


FIGURE 13B: TYPICAL USE PERIOD – ADJACENT AMENITY TERRACES – PROPOSED MASSING





APPENDIX A

SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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

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

where $\boldsymbol{U}$ = mean wind speed, $\boldsymbol{U_g}$ = gradient wind speed, $\boldsymbol{Z}$ = height above ground, $\boldsymbol{Z_g}$ = depth of the boundary layer (gradient height), and 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	0.25
22.5	0.24
45	0.26
67.5	0.27
90	0.28
112.5	0.27
135	0.27
157.5	0.29
180	0.33
202.5	0.31
225	0.28
247.5	0.27
270	0.29
292.5	0.28
315	0.29
337.5	0.27

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].

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

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

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 Engineering Symposium, IWES 2003*, Taiwan, 2003.