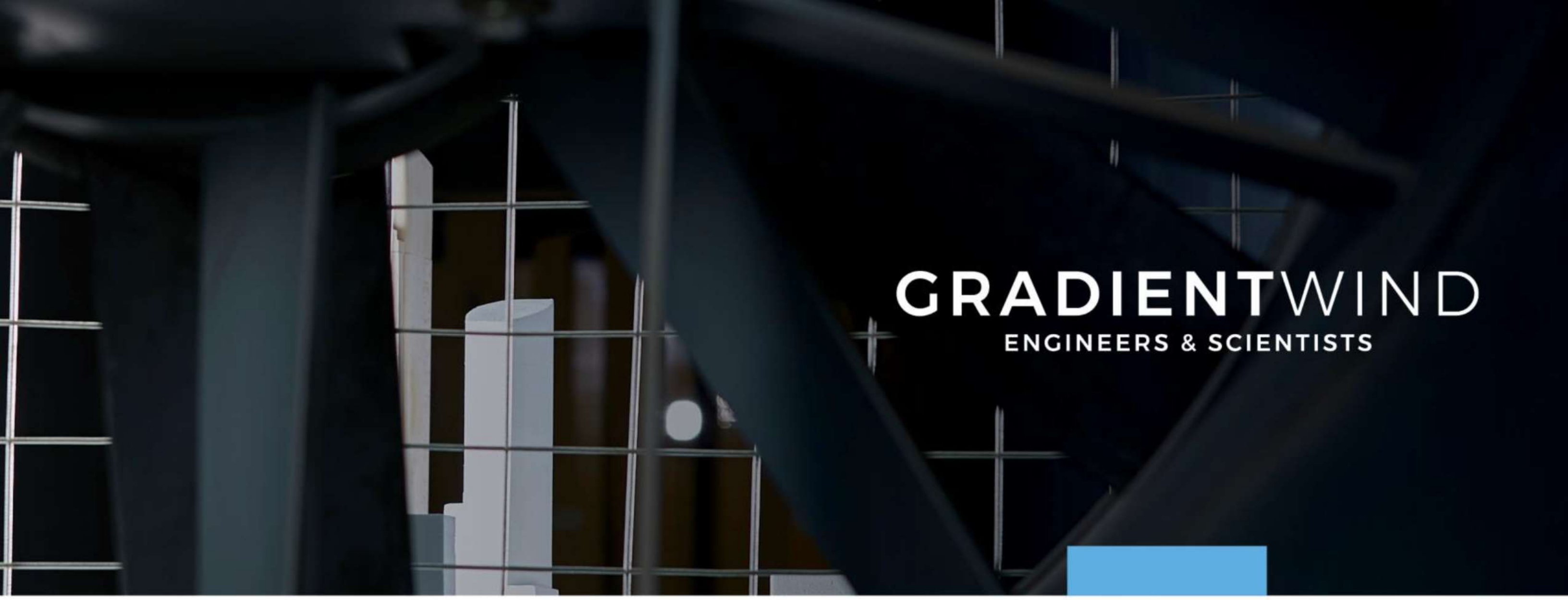
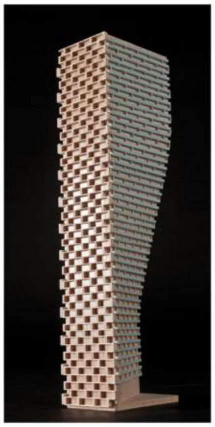


PEDESTRIAN LEVEL WIND STUDY

450 Dufferin Street
Toronto, Ontario

Report: 22-216-PLW



November 3, 2022

PREPARED FOR
HM RK (450 Dufferin) LP
474 Wellington Street West, Suite 200
Toronto, ON M5V 1E3

PREPARED BY
Sunny Kang, B.A.S., Project Coordinator
David Huitema, M.Eng., Junior Wind Scientist
Justin Ferraro, P.Eng., Principal

EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study to satisfy simultaneous Zoning By-law Amendment and Site Plan Control application requirements for the proposed mixed-use residential development located at 450 Dufferin Street in Toronto, Ontario (hereinafter referred to as "subject site" or "proposed development"). Our mandate within this study is to investigate pedestrian wind comfort and safety 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-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 their intended pedestrian uses throughout the year. Specifically, conditions over surrounding sidewalks, laneways, the shared playground serving the public school to the northeast, the loading areas and surface parking serving the neighbouring property to the west, and in the vicinity of building access points, are considered acceptable.

2) Regarding the common amenity terrace serving the proposed development at Level 15, conditions during the typical use period are predicted to be mostly suitable for sitting with standing conditions predicted along the west elevation and at the northeast and southeast corners.

    a. To achieve the sitting comfort class in all areas during the typical use period, we recommend implementing a wind screen around the full perimeter of the terrace, typically glazed and preferably solid (that is, no porosity), extending at least 2 m above the walking surface.

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.

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by HM RK (450 Dufferin) LP to undertake a pedestrian level wind (PLW) study to satisfy simultaneous Zoning By-law Amendment and Site Plan Control application requirements for the proposed mixed-use residential development located at 450 Dufferin Street in Toronto, Ontario (hereinafter referred to as “subject site” or “proposed development”). Our mandate within this study is to investigate pedestrian wind conditions within and surrounding the subject site, and to identify areas where wind conditions may interfere with certain pedestrian activities so that mitigation measures may be considered, where required.

Our work is based on industry standard computer simulations using the computational fluid dynamics (CFD) technique and data analysis procedures, City of Toronto wind comfort and safety criteria, architectural drawings prepared by Superkül in October 2022, surrounding street layouts and existing and approved future building massing information obtained from the City of Toronto, recent satellite imagery, and experience with numerous similar developments in Toronto and elsewhere.

2. TERMS OF REFERENCE

The subject site is located at 450 Dufferin Street in Toronto; situated at the northwest intersection of Dufferin Street and Alma Avenue, bordered by low-rise residential buildings to the north, Dufferin Street to the east, Alma Avenue to the south, and existing low-rise commercial buildings to the west. The proposed development comprises a nominally rectangular 15-storey mixed-use residential building, topped with a mechanical penthouse (MPH) level.

Above two levels of below-grade parking, the ground floor of the proposed development includes a main entrance and bike storage to the south, commercial spaces to the north and east, central elevator core and loading space, and shared building support spaces throughout the remainder of the level. Access to below-grade parking is provided by a ramp at the southwest corner of the proposed development via a laneway from Alma Avenue. The mezzanine level is reserved for commercial use to the north, Levels 2-14 are reserved for residential use, and Level 15 is reserved for indoor amenity. The building steps back from the southwest corner at Level 2, while at Level 5 the tower sets back from the east and north elevations to accommodate private terraces and a green roof. The tower steps back from the north, east, and south elevations to accommodate an outdoor amenity terrace and green roof at Level 15, accompanied by an indoor amenity area to the west.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre (m) radius from the subject site) include a junior and senior public school with a shared playground to the northeast, low-rise residential buildings from the northeast clockwise to the southeast, mid- and high-rise residential buildings to the south, a low-rise commercial building to the southwest, and low-rise residential buildings in the remaining compass directions with two blocks of townhouses to the west-northwest. Notably, the GO Transit – Metrolinx railway extends from the south to the west. The far-field surroundings (defined as the area beyond the near field and within a 2-kilometre (km) radius) are characterized by low-rise massing with isolated mid- and high-rise buildings in all compass directions, with clusters of mid- and high-rise buildings to the southeast, south, and southwest. Notably, Ontario Place is situated approximately 1.9 km to the south-southeast and the open exposure of Lake Ontario extends from the south-southeast clockwise to the west-southwest, approximately 1.5 km to the southwest of the subject site.

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. The existing massing scenario includes the existing massing and future developments that have been approved by the City of Toronto.

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 slightly stronger wind speeds.

4.2 Wind Speed Measurements

The PLW analysis was performed by simulating wind flows and gathering velocity data over a CFD model of the 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

[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

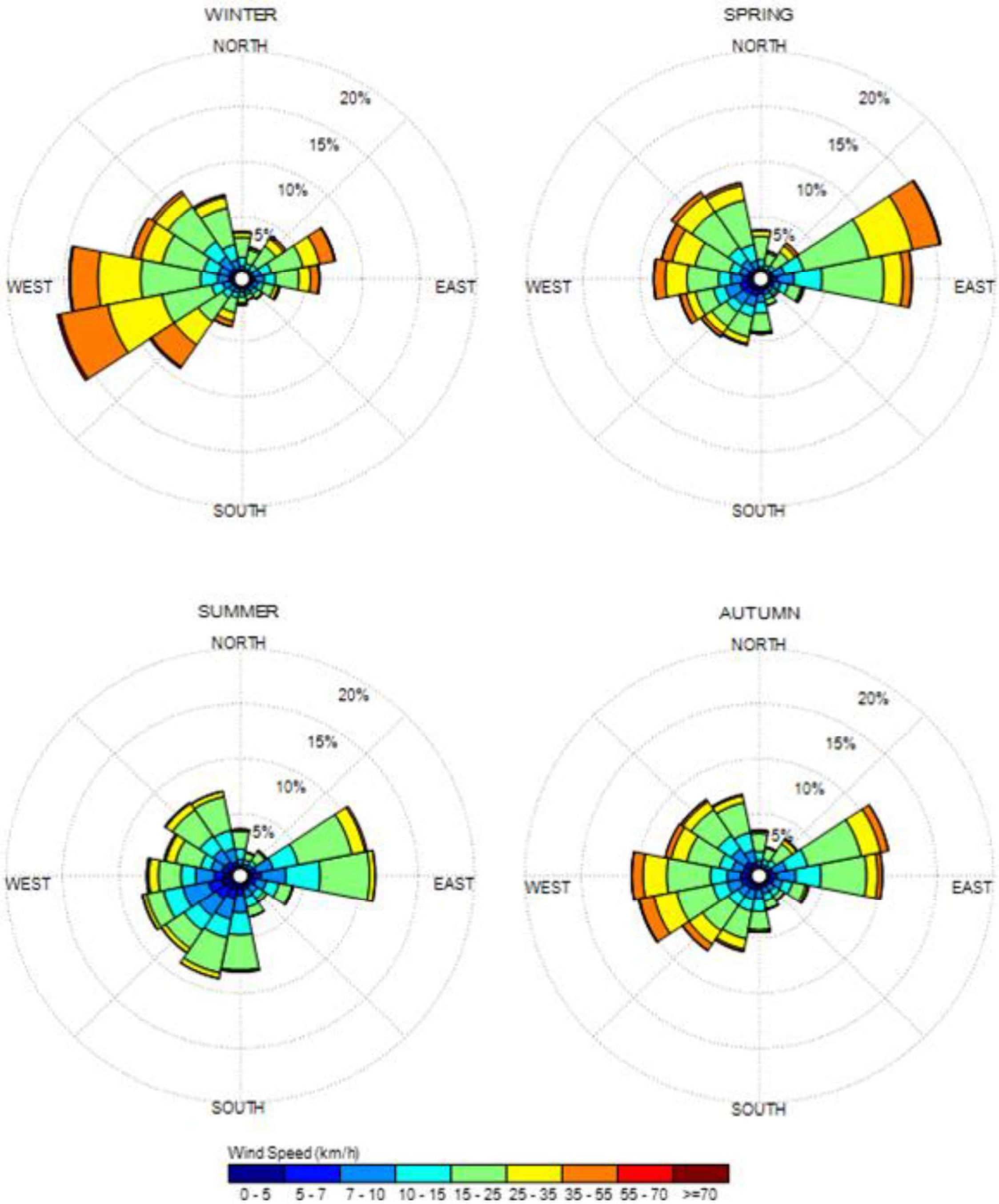
approximately 1.5 m above local grade and the Level 15 common amenity terrace serving the proposed development were referenced to the wind speed at gradient height to generate mean and peak velocity ratios, which were used to calculate full-scale values. Gradient height represents the theoretical depth 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 (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 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 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 (for example, 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 (Typical Use Period)
Café / Patio / Bench / Garden	Sitting (Typical Use Period)
Transit Stop (Without Shelter)	Standing
Transit Stop (With Shelter)	Walking
Public Park / Plaza	Sitting (Typical Use Period)
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 conditions at grade level for the proposed and existing massing scenarios, and by Figures 7A-7D, which illustrate conditions over the common amenity terrace serving the proposed development at Level 15. Conditions are presented as continuous contours of wind comfort 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.

Wind comfort conditions 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 conditions within the noted terrace are predicted to be suitable for sitting during the same period. The details of these conditions are summarized in the following pages for each area of interest.

5.1 Wind Comfort Conditions – Grade Level

Building Access North of Subject Site: Conditions in the vicinity of the building access points along the north elevation of the proposed development are predicted to be suitable for sitting during the summer and autumn, becoming suitable for standing, or better, during the winter and spring. The noted conditions are considered acceptable.

Sidewalks and Building Access Along Dufferin Street: Following the introduction of the proposed development, the public sidewalks along Dufferin Street are predicted to be mostly suitable for sitting during the summer and autumn, becoming suitable for a mix of sitting and standing during the winter and spring. Conditions in the vicinity of all building access points along the east elevation of the proposed development are predicted to be suitable for sitting throughout the year. The noted conditions are considered acceptable.

Conditions over the sidewalks along Dufferin Street with the existing massing 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. While the introduction of the proposed development produces windier conditions in comparison to existing conditions, wind comfort conditions are nevertheless considered acceptable.

Shared Playground Serving Alexander Muir/Gladstone Ave School: Prior to the introduction of the proposed development, conditions over the shared playground serving Alexander Muir/Gladstone Ave Junior and Senior Public School, situated to the northeast of the subject site, are predicted to be suitable for sitting during the typical use period and remain unchanged following the introduction of the proposed development. As such, wind conditions with the proposed development are considered acceptable.

Sidewalks Along Waterloo Avenue and Laneway Southeast of Subject Site: Following the introduction of the proposed development, conditions over the public sidewalks along Waterloo Avenue and the laneway to the 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 sidewalks and laneway with the existing massing are predicted to be suitable for sitting throughout the spring, summer, and autumn, and standing, or better, during the winter. While the introduction of the proposed development produces windier conditions in comparison to existing conditions, wind comfort conditions are nevertheless considered acceptable.

Sidewalks and Building Access Along Alma Avenue: Conditions over the public sidewalks along Alma Avenue prior to the introduction of the proposed development are predicted to be suitable for sitting during the summer, becoming suitable for standing during the spring and autumn, and suitable for a mix of standing and walking during the winter. The noted conditions remain unchanged following the introduction of the proposed development and are considered acceptable.

Owing to the protection of the building façade, conditions in the vicinity of the primary building access point along the south elevation are predicted to be suitable for sitting throughout the year, while conditions in the vicinity of the nearby secondary building access point are predicted to be suitable for sitting during the summer, becoming mostly suitable for standing throughout the remainder of the year. The noted conditions are considered acceptable.

Neighbouring Private Laneway and Loading Areas: Following the introduction of the proposed development, conditions over the private laneway extending from Alma Avenue and the neighbouring loading areas and surface parking serving the existing commercial development situated to the west of the subject site are predicted to be suitable for standing, or better throughout the year. The noted conditions are considered acceptable.

Conditions over the noted areas with the existing massing 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 with an isolated region of walking during the winter. Notably, the introduction of the proposed development is predicted to improve comfort levels over the neighbouring property to the west, in comparison to existing conditions, and wind conditions with the proposed development are considered acceptable.

5.2 Wind Comfort Conditions – Common Amenity Terrace

Level 15 Common Amenity Terrace: Wind comfort conditions over the amenity terrace serving the proposed development at Level 15 are predicted to be suitable for a mix of sitting and standing during the typical use period, as illustrated in Figure 8A. Specifically, conditions are predicted to be suitable for sitting within the majority of the terrace, while standing conditions are predicted at the northeast and southeast corners and along the east elevation.

The areas that are predicted to be suitable for standing, according to the comfort classification in Section 4.4, are also predicted to be suitable for sitting for at least 70% of the time within the majority of the areas and for at least 65% of the time near the northeast and southeast corners during the same period, where the target is 80% to achieve the sitting comfort criterion. To achieve the sitting comfort class in all areas during the typical use period, we recommend implementing a wind screen along the full perimeter of the terrace, typically glazed and preferably solid (that is, no porosity), extending at least 2 m above the walking surface of the terrace.

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.

Regarding primary and secondary building access points, wind conditions predicted in this study are only applicable to pedestrian comfort and safety. As such, the results should not be construed to indicate wind loading on doors and associated hardware.

6. CONCLUSIONS AND RECOMMENDATIONS

A complete summary of the predicted wind 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 of the Toronto wind climate, City of Toronto wind comfort and safety criteria, and experience with numerous similar developments in Toronto and elsewhere, 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 their intended pedestrian uses throughout the year. Specifically, conditions over surrounding sidewalks, laneways, the shared playground serving the public school to the northeast, the loading areas and surface parking serving the neighbouring property to the west, and in the vicinity of building access points, are considered acceptable.

2) Regarding the common amenity terrace serving the proposed development at Level 15, conditions during the typical use period are predicted to be mostly suitable for sitting with standing conditions predicted along the west elevation and at the northeast and southeast corners.

    a. To achieve the sitting comfort class in all areas during the typical use period, we recommend implementing a wind screen around the full perimeter of the terrace, typically glazed and preferably solid, extending at least 2 m above the walking surface.

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,

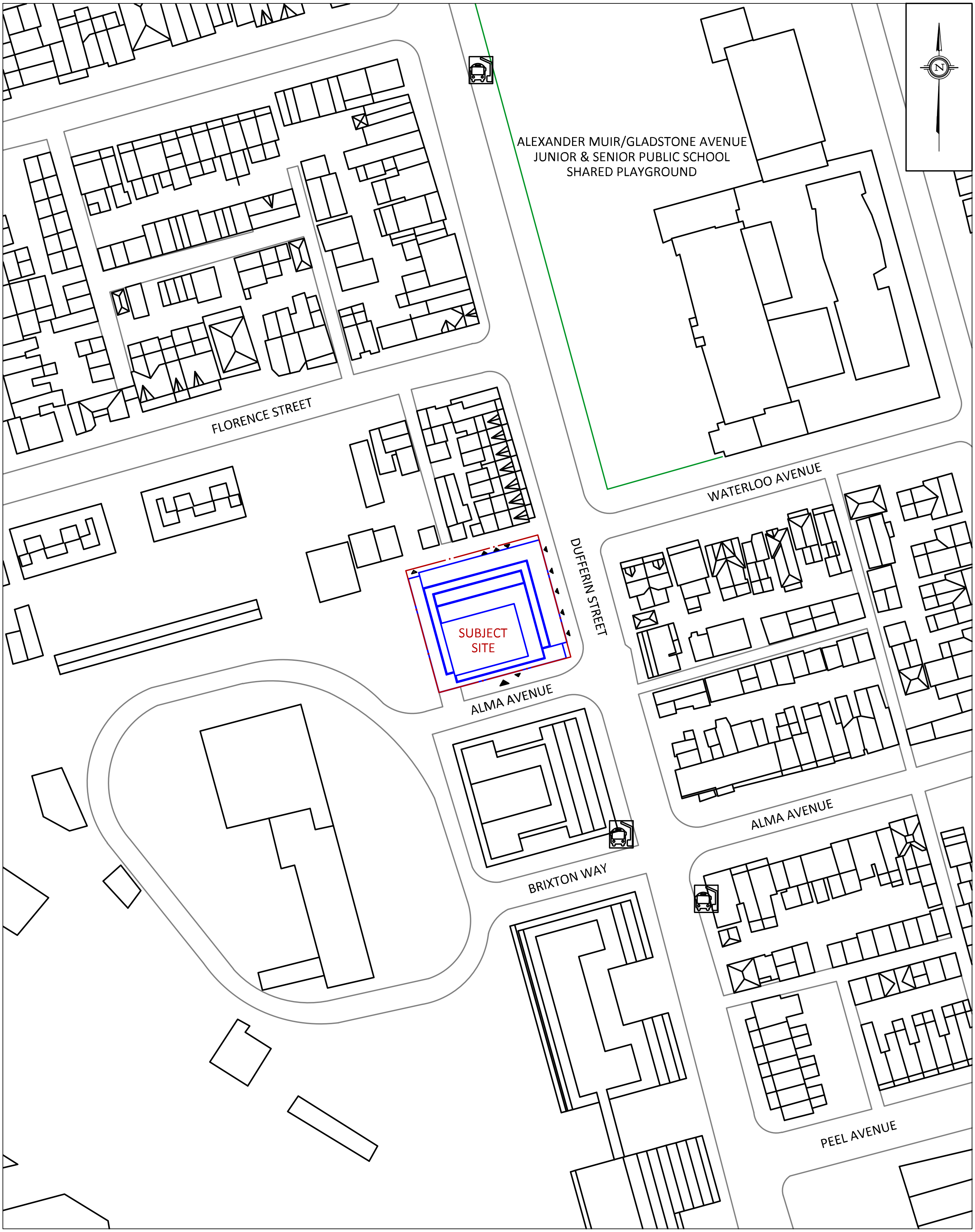
Gradient Wind Engineering Inc.

LICENSED PROFESSIONAL ENGINEER
J. D. FERRARO
100158495
Nov 4, 2022
PROVINCE OF ONTARIO

David Huitema, M.Eng.
Junior Wind Scientist

Justin Ferraro, P.Eng.
Principal

Sunny Kang, B.A.S.
Project Coordinator



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

PROJECT	450 DUFFERIN STREET, TORONTO PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:1500	DRAWING NO.	22-216-PLW-1A
DATE	NOVEMBER 3, 2022	DRAWN BY	S.K.

DESCRIPTION

FIGURE 1A:
PROPOSED SITE PLAN AND SURROUNDING CONTEXT

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PROJECT: 450 DUFFERIN STREET, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1B: EXISTING SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:1500	DRAWING NO.: 22-216-PLW-1B	
DATE: NOVEMBER 3, 2022	DRAWN BY: S.K.	

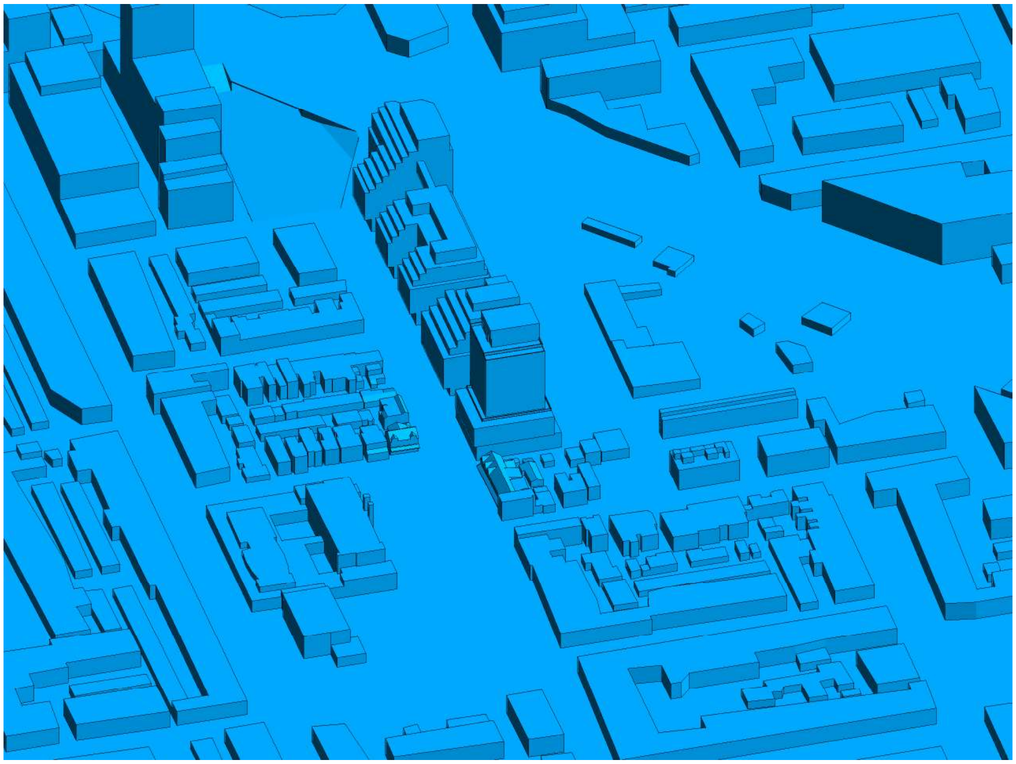


FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTH PERSPECTIVE

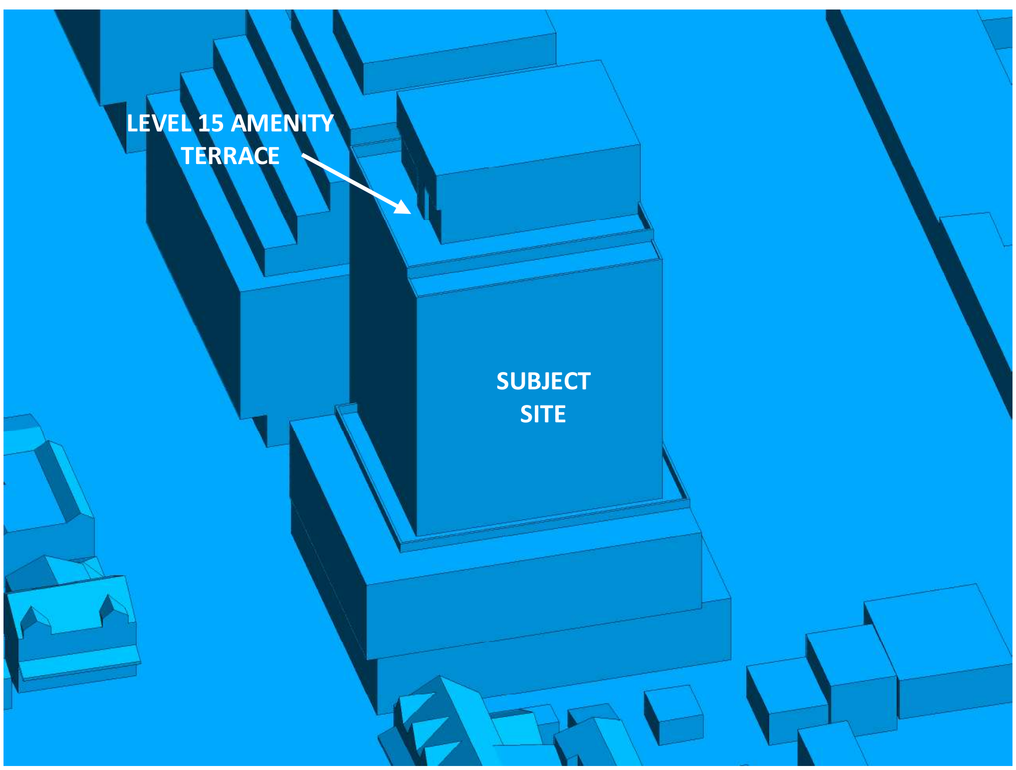


FIGURE 2B: CLOSE-UP VIEW OF FIGURE 2A

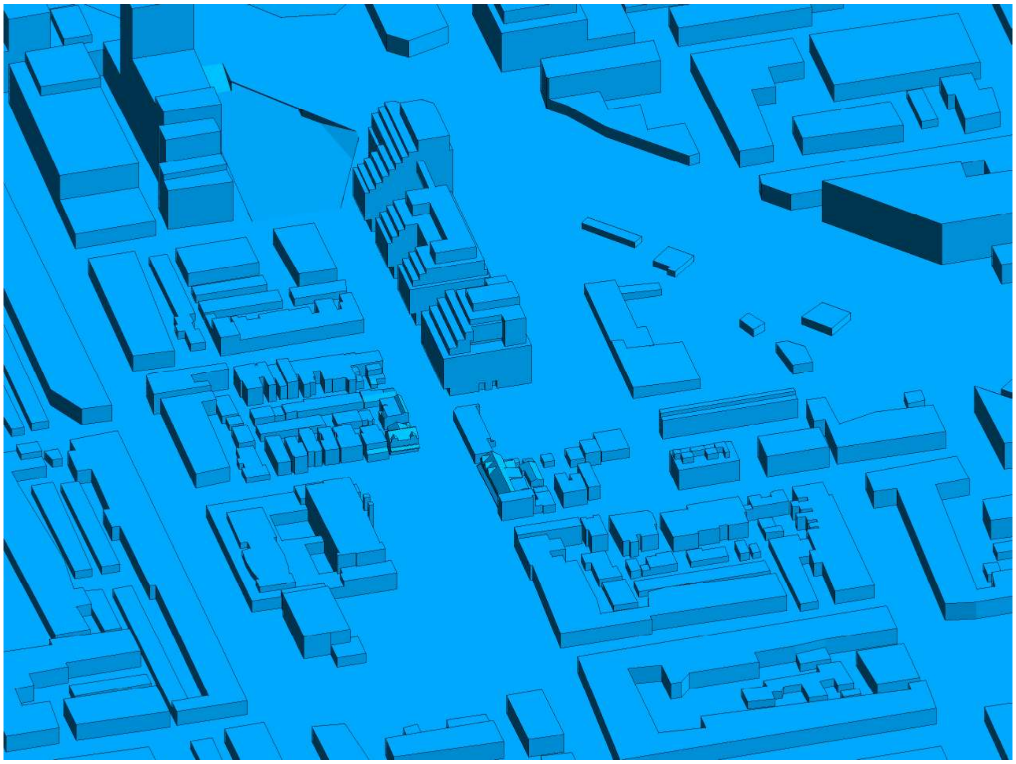


FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTH PERSPECTIVE

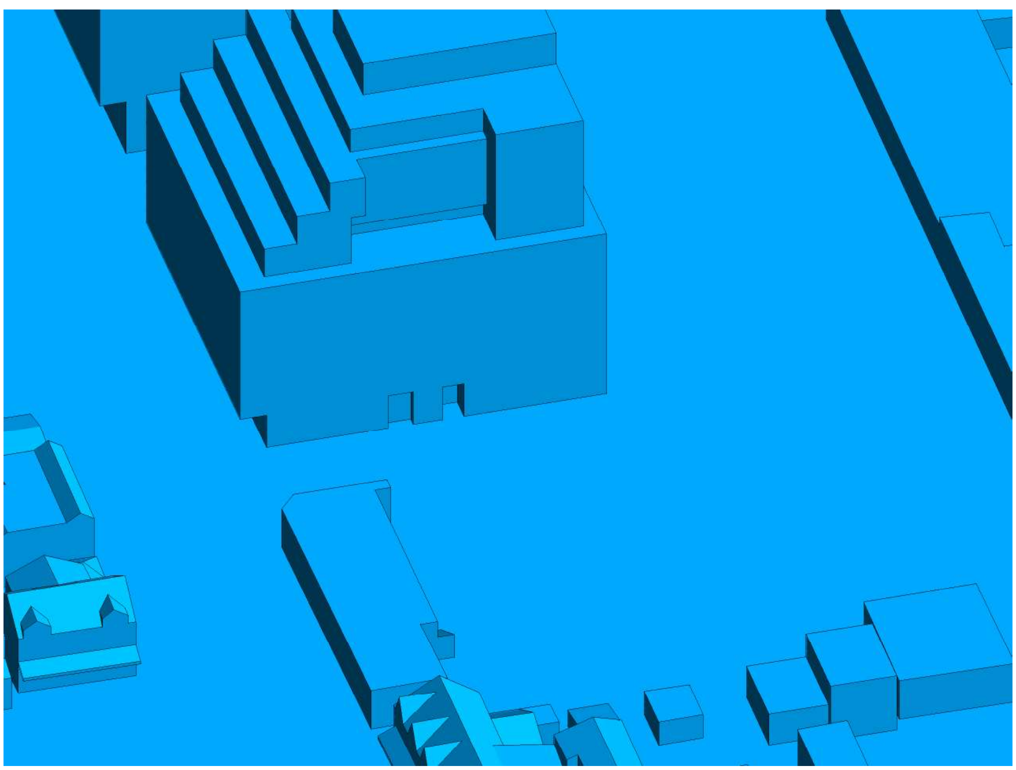


FIGURE 2D: CLOSE-UP VIEW OF FIGURE 2C

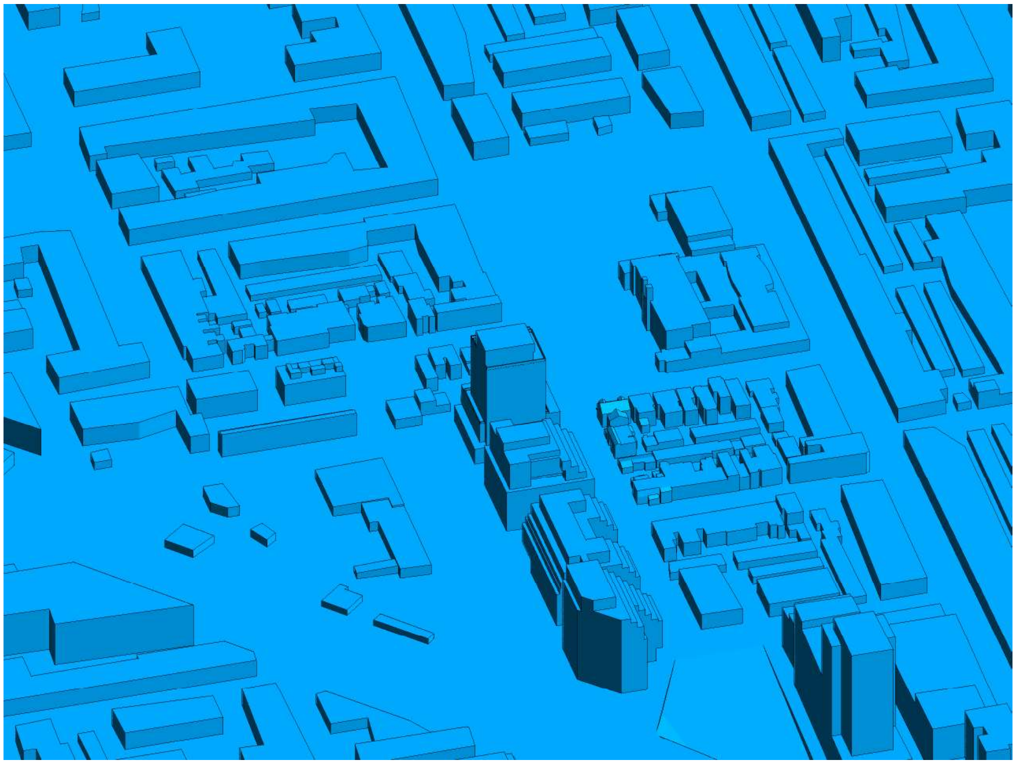


FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTH PERSPECTIVE

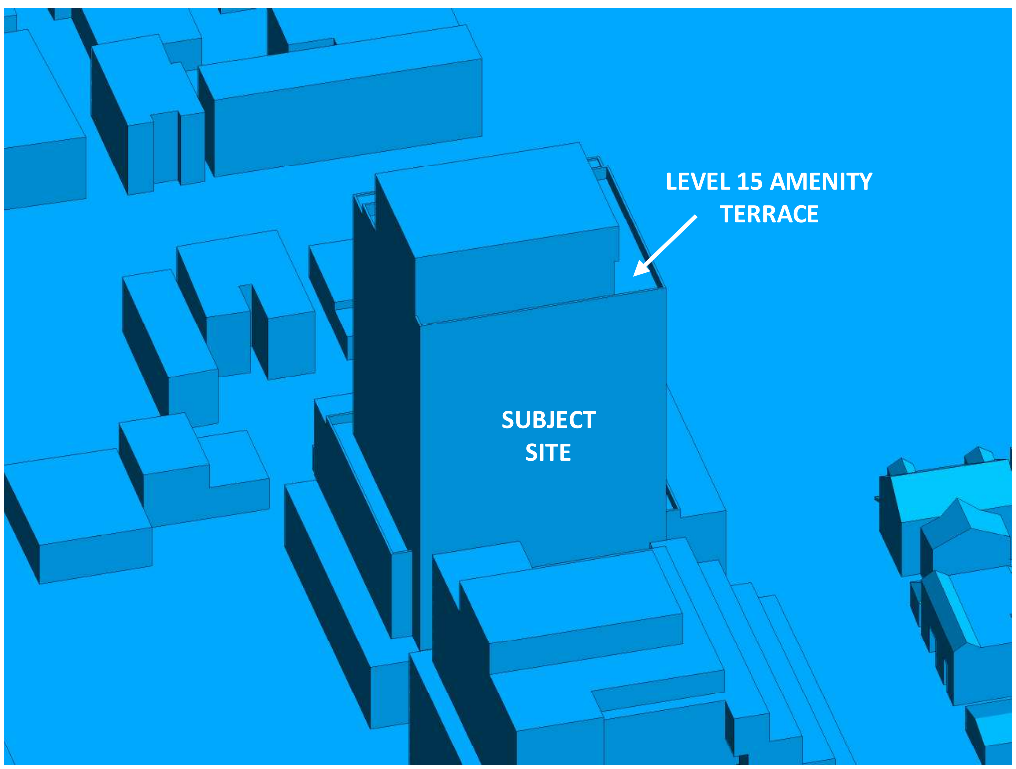


FIGURE 2F: CLOSE-UP VIEW OF FIGURE 2E

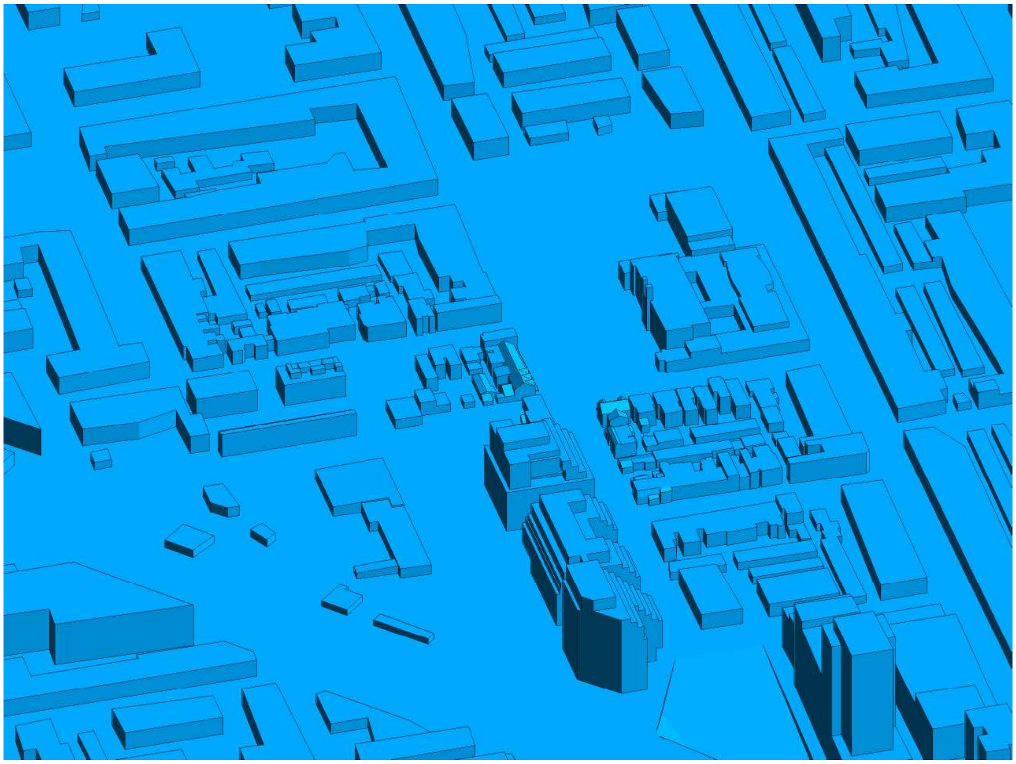


FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, SOUTH PERSPECTIVE

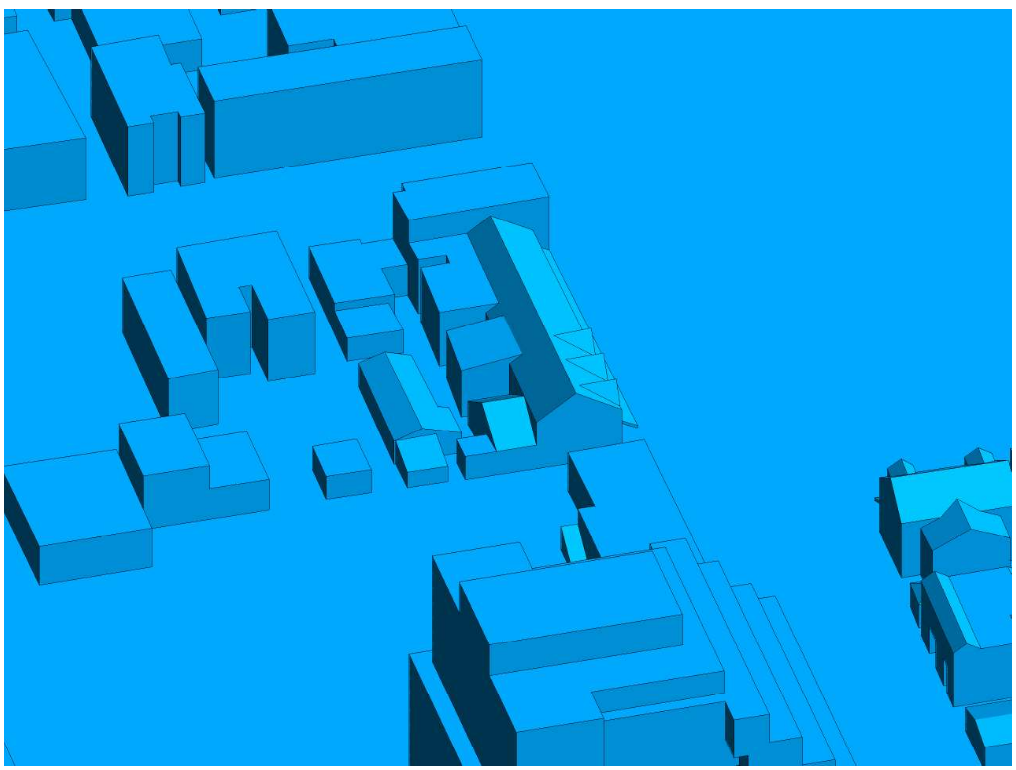


FIGURE 2H: CLOSE-UP VIEW OF FIGURE 2G

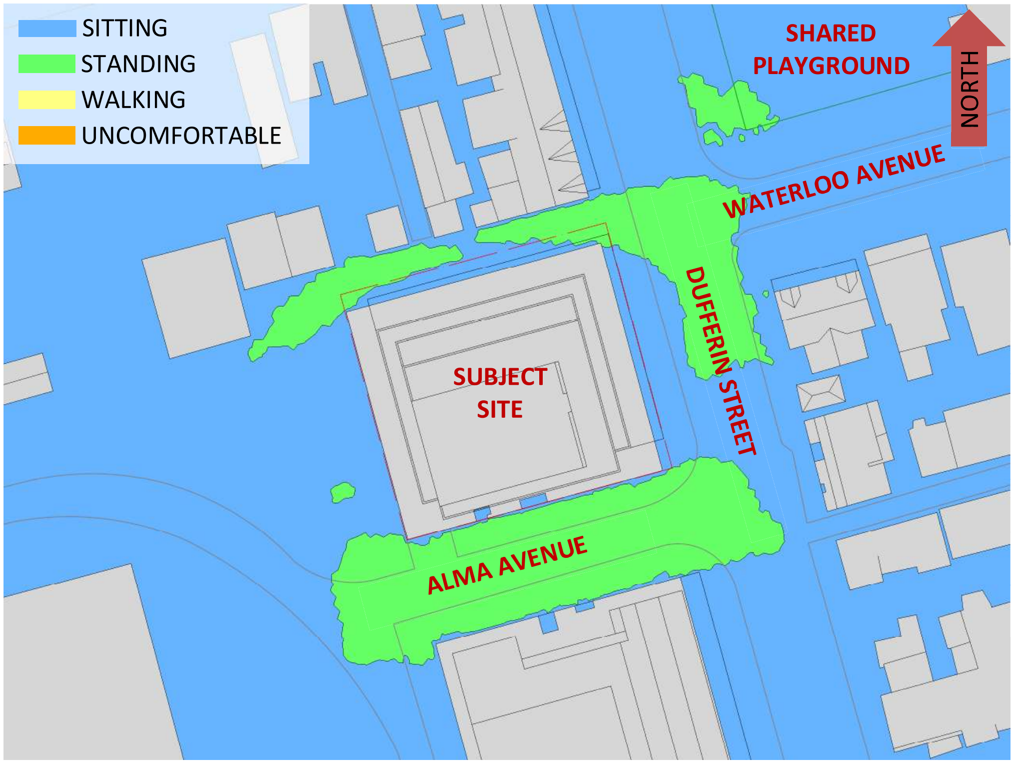


FIGURE 3A: SPRING – PROPOSED – WIND COMFORT, GRADE LEVEL

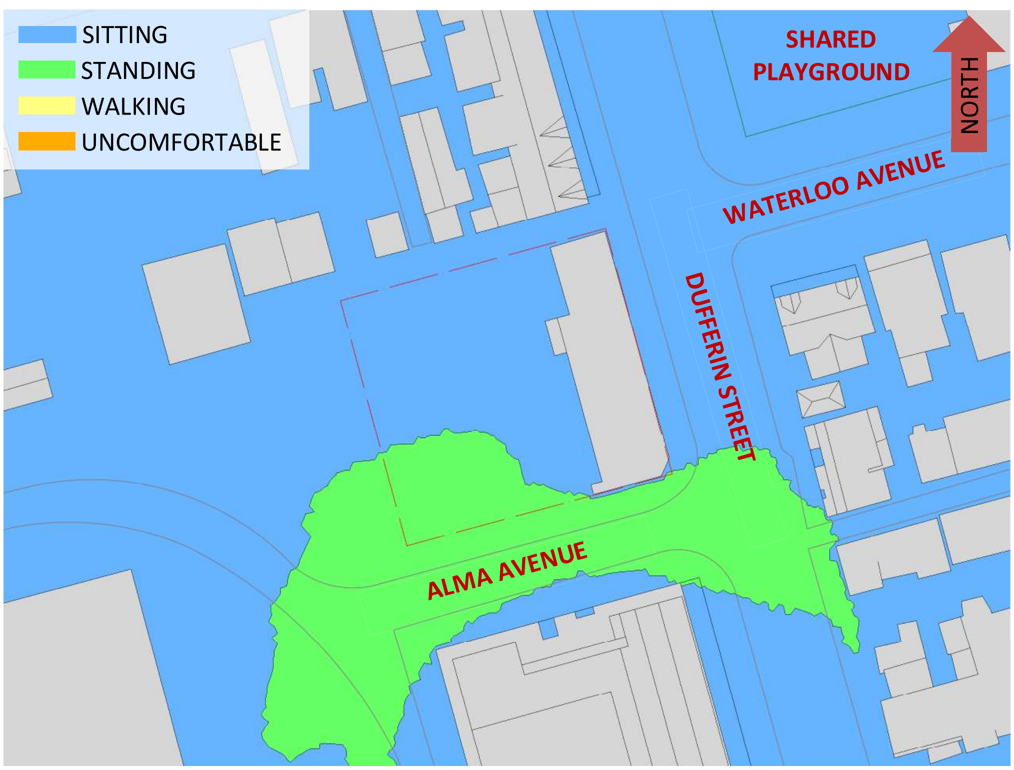


FIGURE 3B: SPRING – EXISTING – WIND COMFORT, GRADE LEVEL

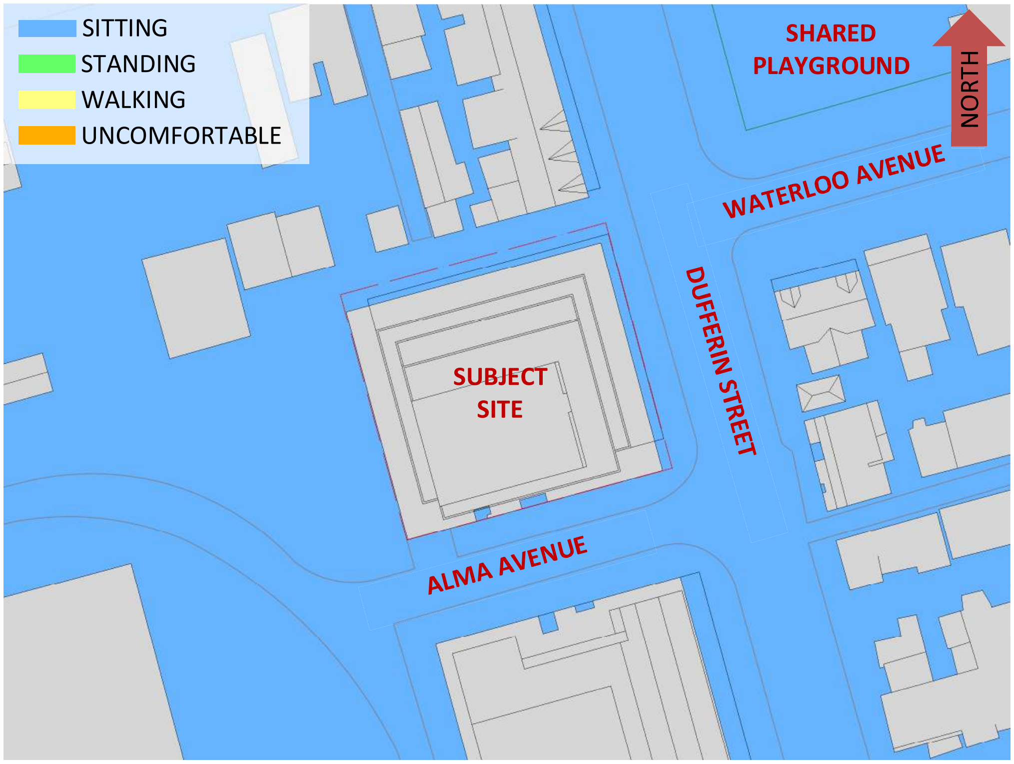


FIGURE 4A: SUMMER – PROPOSED – WIND COMFORT, GRADE LEVEL

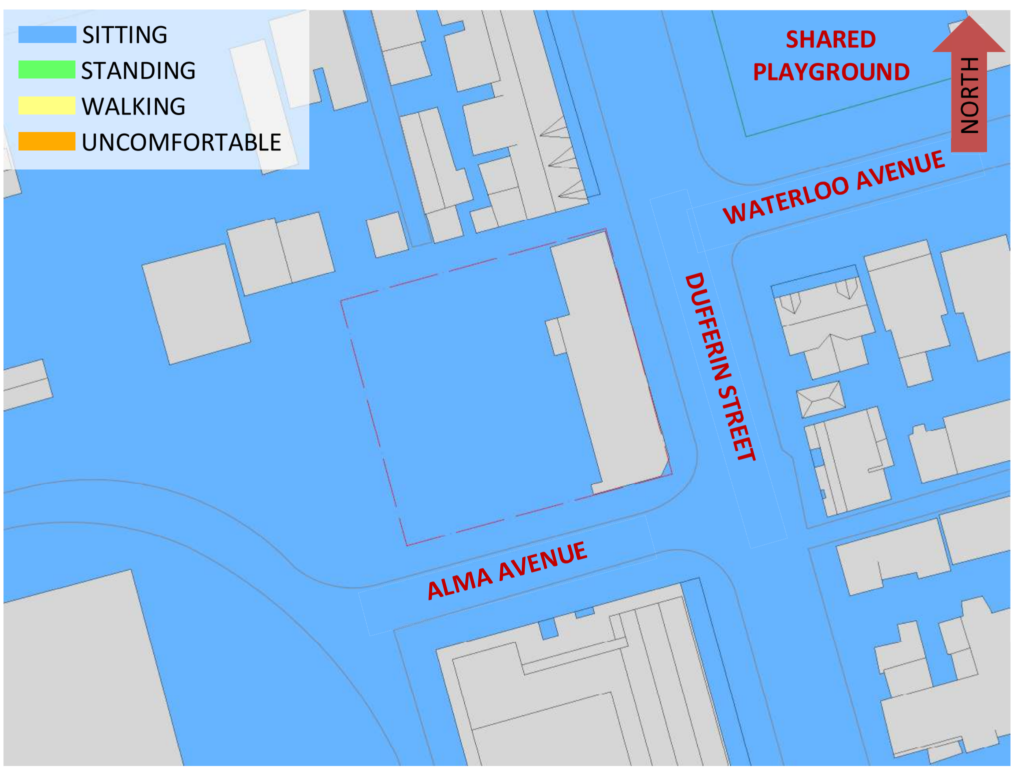


FIGURE 4B: SUMMER – EXISTING – WIND COMFORT, GRADE LEVEL

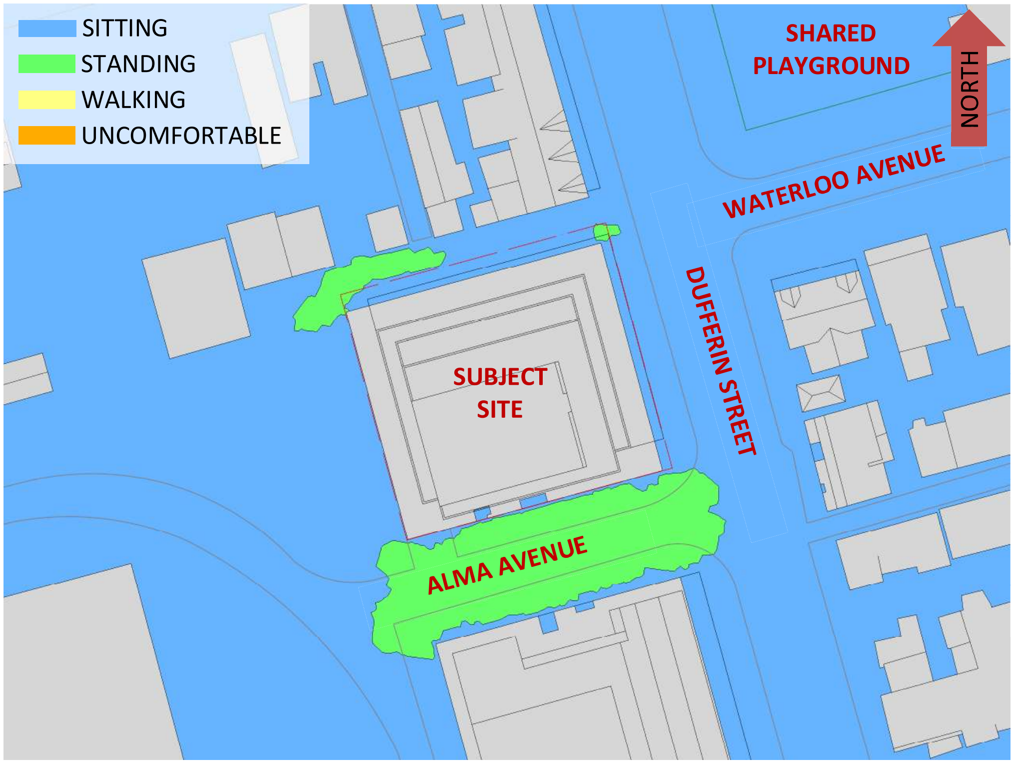


FIGURE 5A: AUTUMN – PROPOSED – WIND COMFORT, GRADE LEVEL

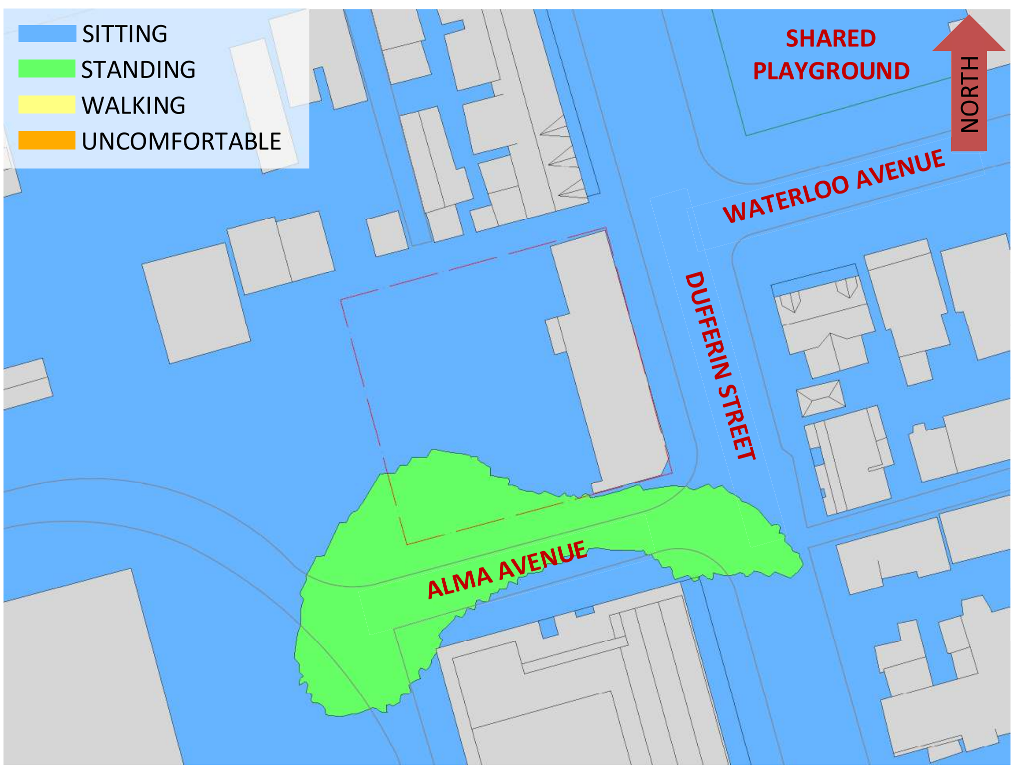


FIGURE 5B: AUTUMN – EXISTING – WIND COMFORT, GRADE LEVEL

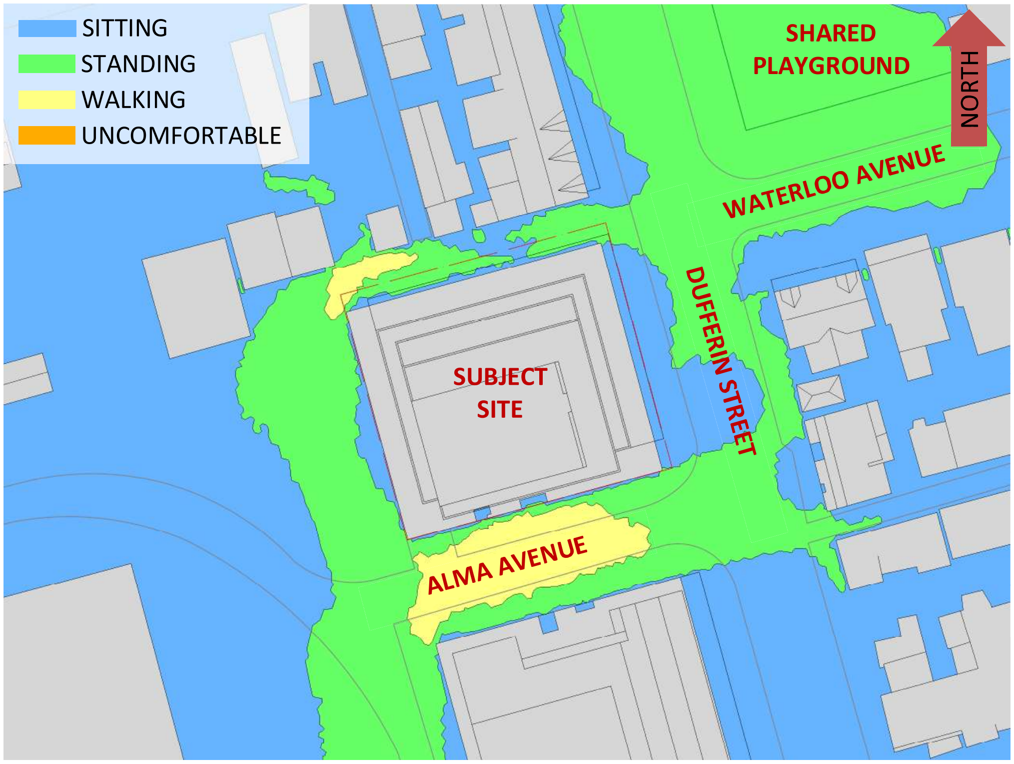


FIGURE 6A: WINTER – PROPOSED – WIND COMFORT, GRADE LEVEL

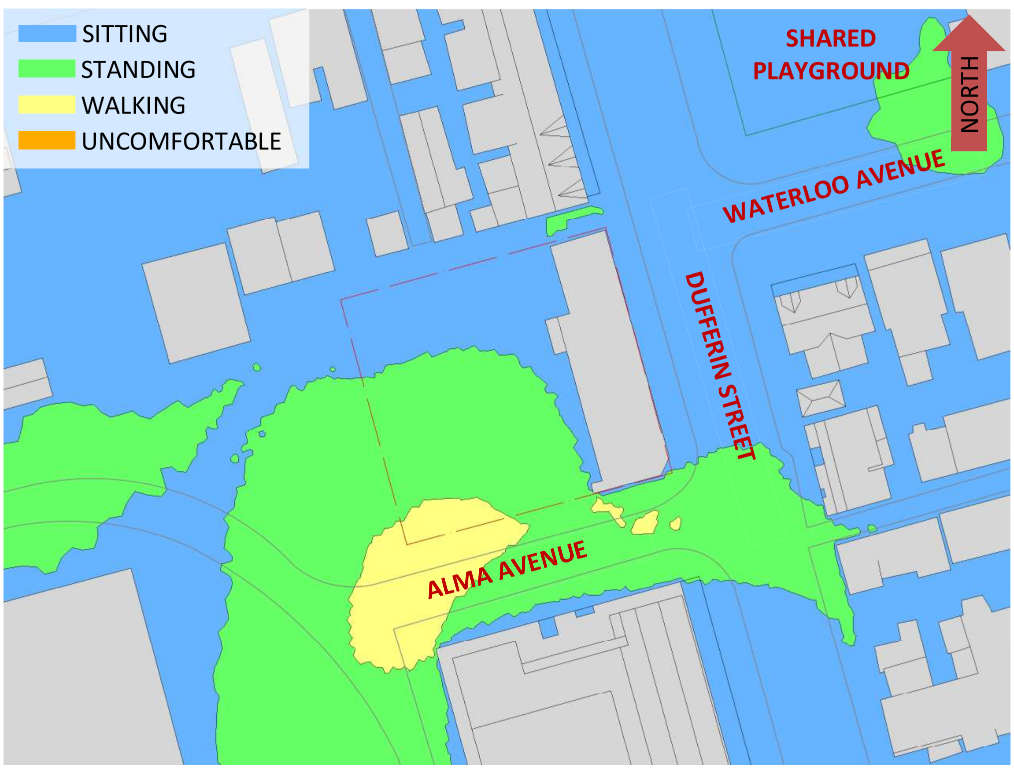


FIGURE 6B: WINTER – EXISTING – WIND COMFORT, GRADE LEVEL

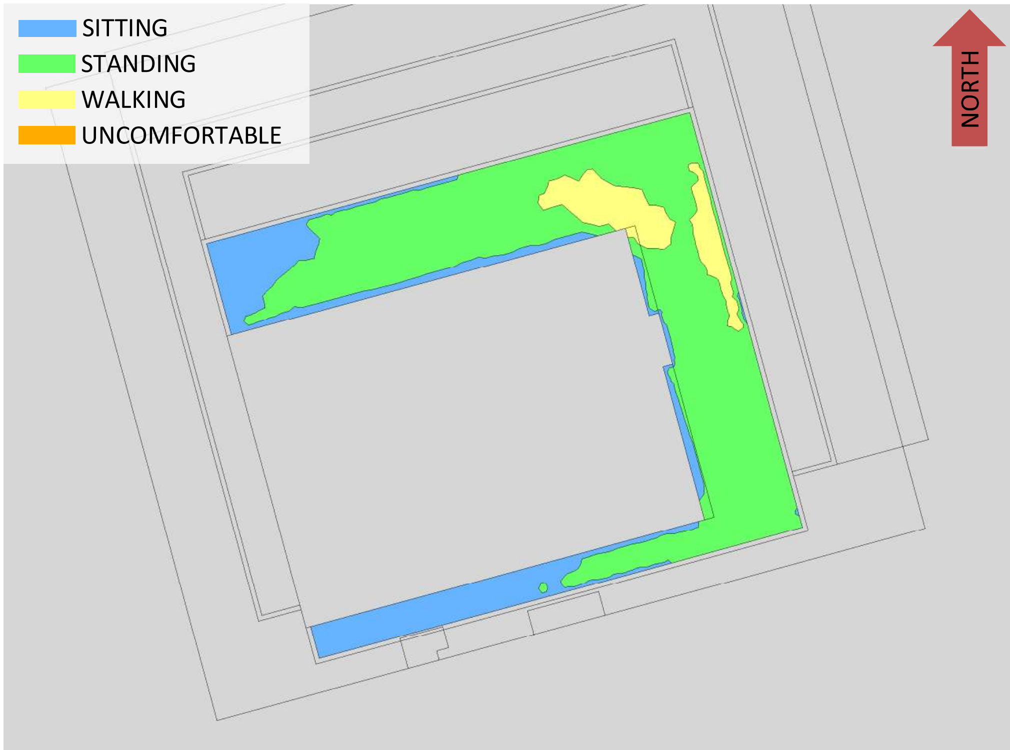


FIGURE 7A: SPRING – WIND COMFORT, LEVEL 15 COMMON AMENITY TERRACE

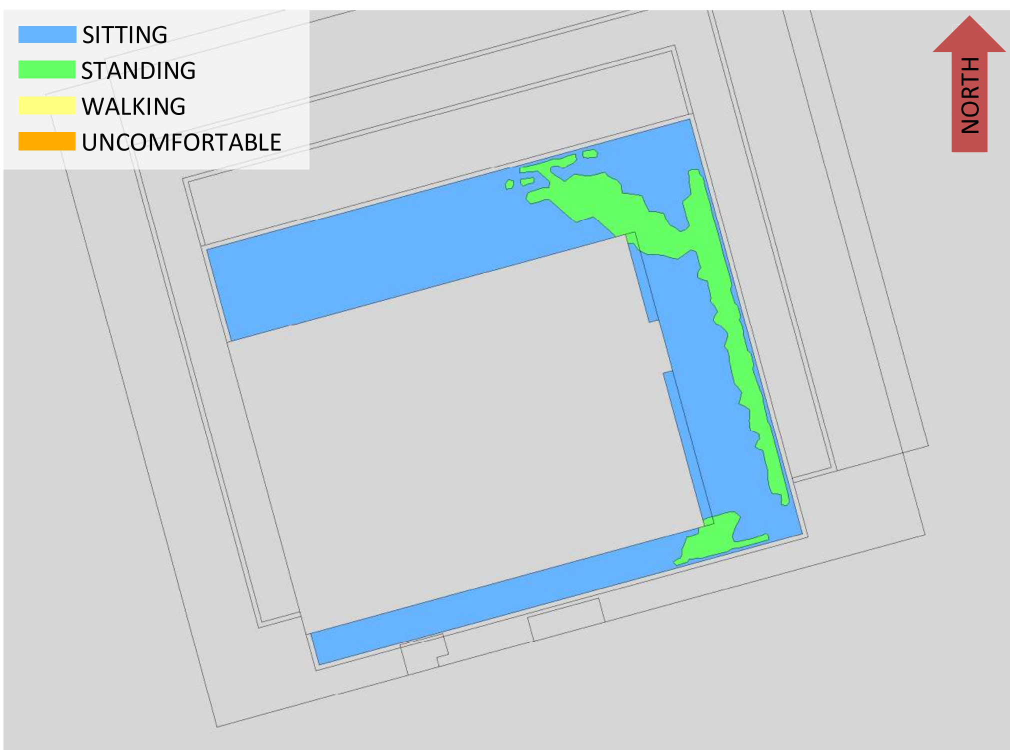


FIGURE 7B: SUMMER – WIND COMFORT, LEVEL 15 COMMON AMENITY TERRACE

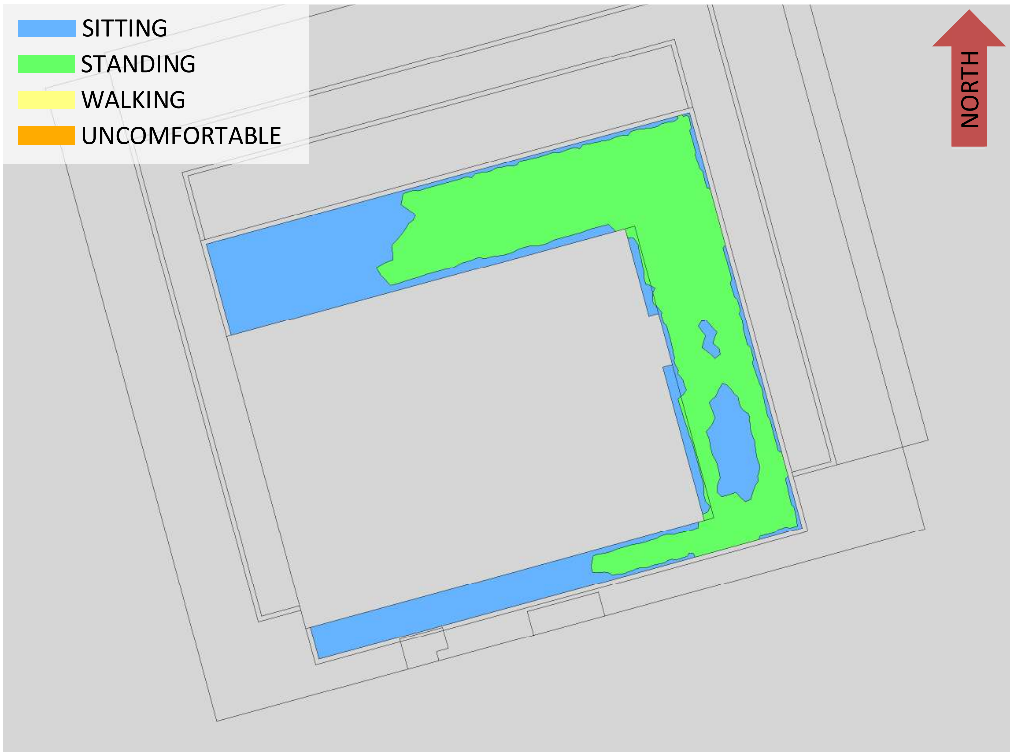


FIGURE 7C: AUTUMN – WIND COMFORT, LEVEL 15 COMMON AMENITY TERRACE

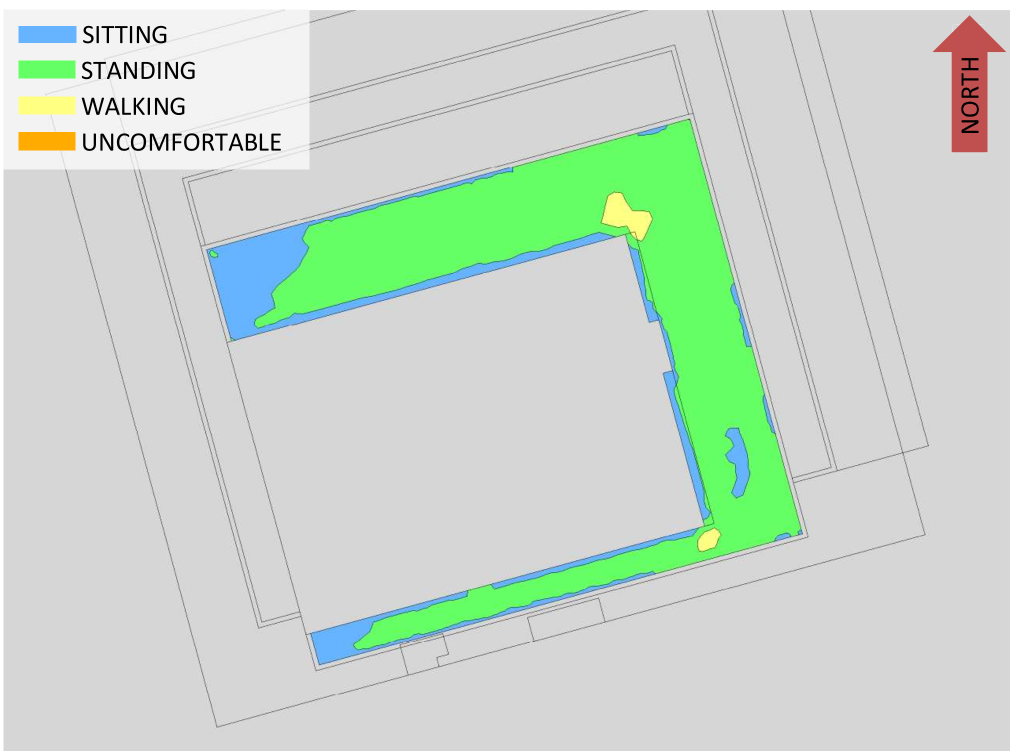


FIGURE 7D: WINTER – WIND COMFORT, LEVEL 15 COMMON AMENITY TERRACE

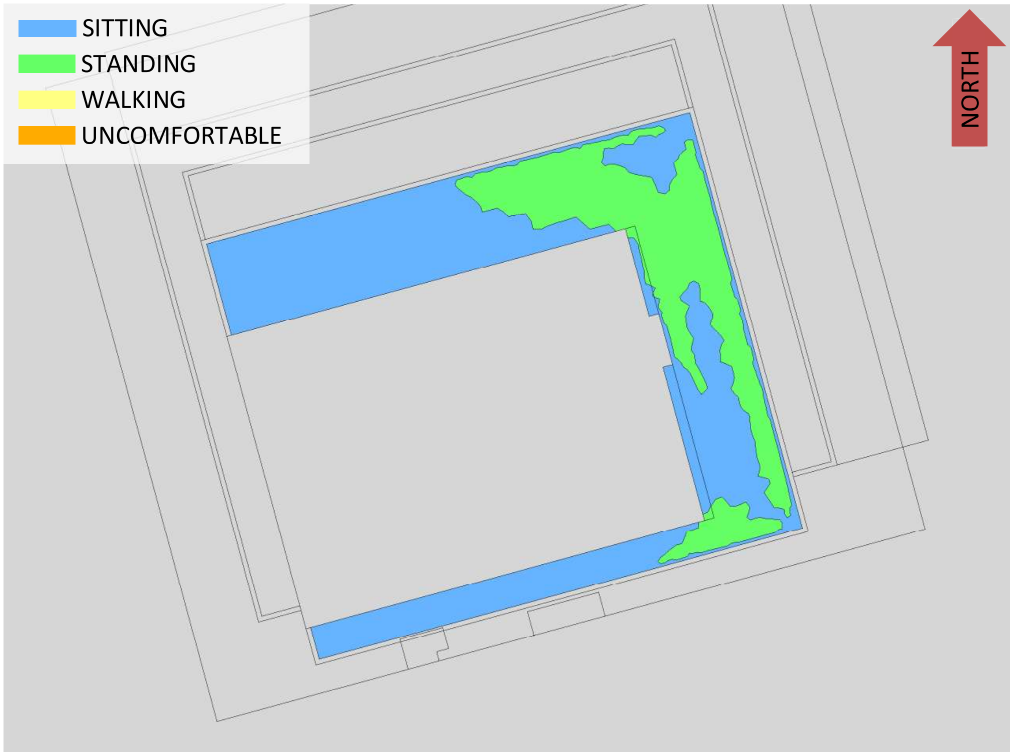


FIGURE 8A: TYPICAL USE PERIOD, LEVEL 15 COMMON AMENITY TERRACE

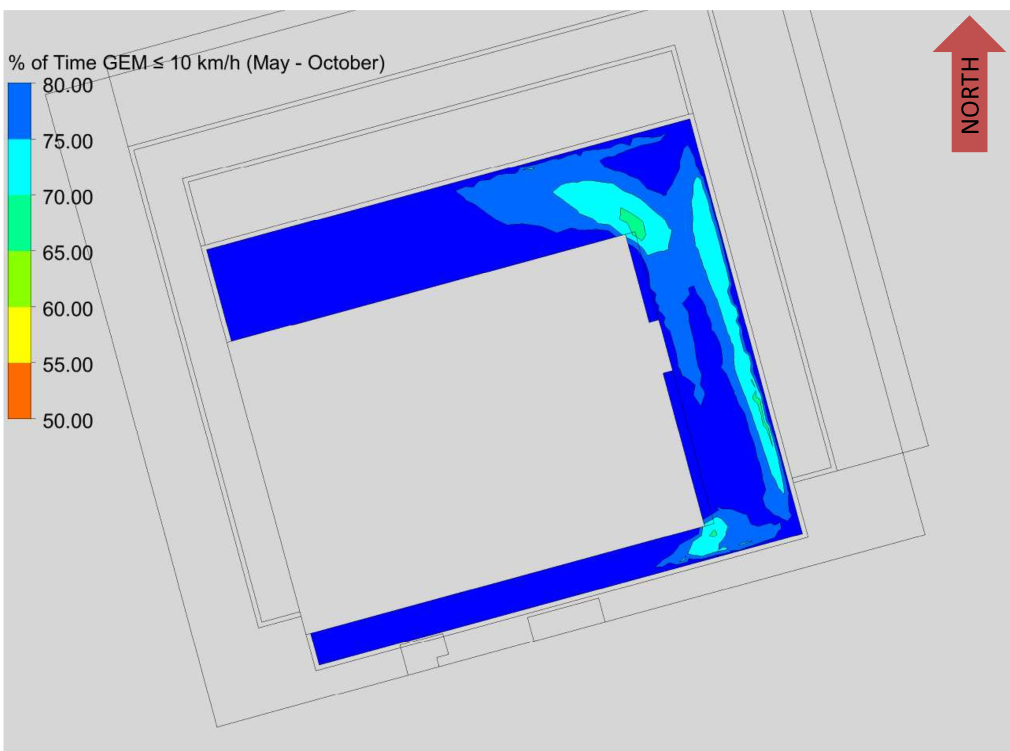
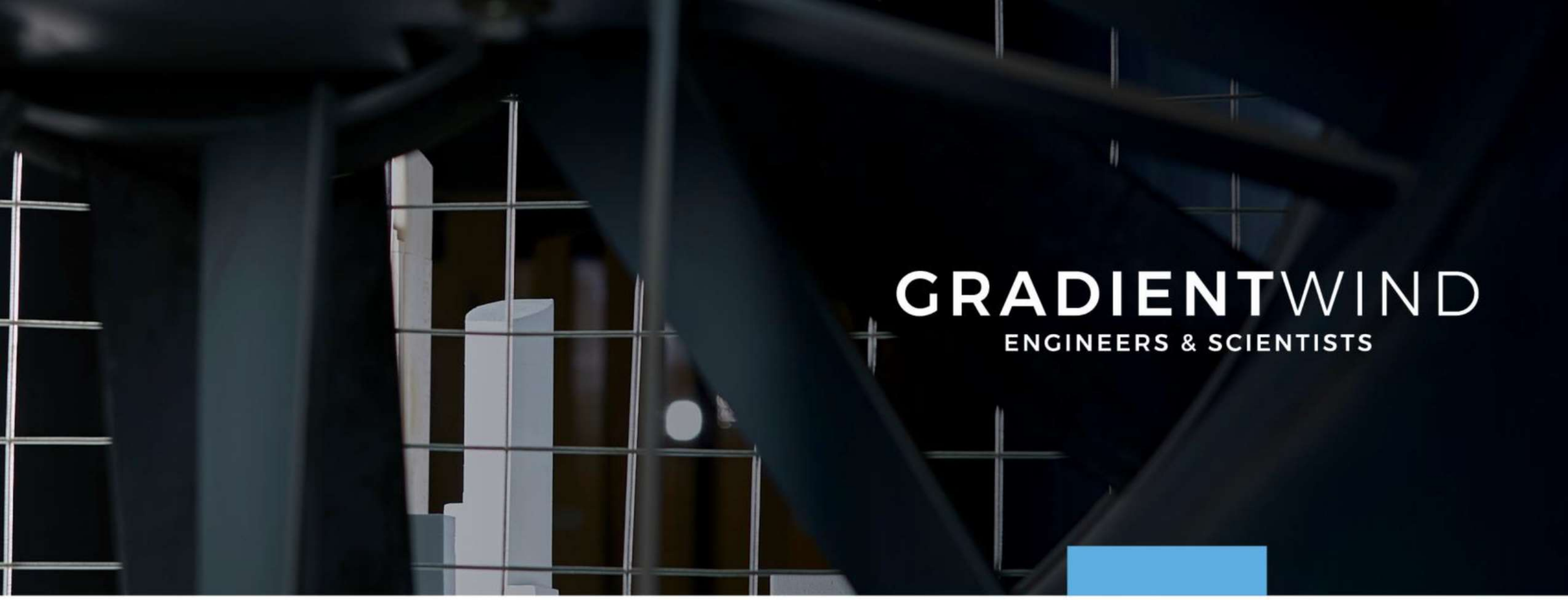
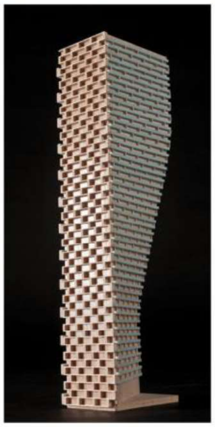


FIGURE 8B: TYPICAL USE PERIOD – % OF TIME SUITABLE FOR SITTING IN FIGURE 8A





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, U = mean wind speed, U_g = gradient wind speed, Z = height above ground, 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 it not captured within the simulation model).

Table 1 presents the values of α used in this study, while Table 2 presents several reference values of α. When the upstream exposure of the far-field surroundings is a mixture of multiple types of terrain, the α values are a weighted average with terrain that is closer to the subject site given greater weight.

TABLE 1: UPSTREAM EXPOSURE (ALPHA VALUE) VS TRUE WIND DIRECTION

Wind Direction (Degrees True)	Alpha Value (α)
0	0.26
22.5	0.26
45	0.27
67.5	0.27
90	0.28
112.5	0.28
135	0.26
157.5	0.24
180	0.24
202.5	0.24
225	0.24
247.5	0.25
270	0.25
292.5	0.26
315	0.26
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, ***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.

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[3] Y. Tamura, H. Kawai, Y. Uematsu, K. Kondo and T. Okhuma, "Revision of AIJ Recommendations for Wind Loads on Buildings," in *The International Wind Engineering Symposium, IWES 2003*, Taiwan, 2003.