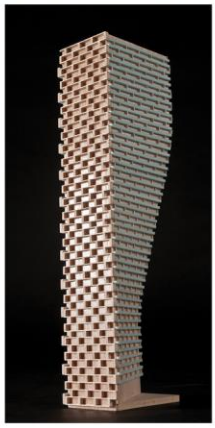
GRADIENTWIND
ENGINEERS & SCIENTISTS

# PEDESTRIAN LEVEL WIND STUDY

5205 King Street
Lincoln, Ontario

Report: 24-125-PLW







November 22, 2024

PREPARED FOR

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# EXECUTIVE SUMMARY

This report describes a pedestrian level wind (PLW) study to satisfy Official Plan Amendment (OPA) and Zoning By-Law (ZBA) application submission requirements for the proposed mixed-use residential development located at 5205 King Steet in Lincoln, 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 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. A complete summary of the predicted wind conditions is provided in Section 5 and illustrated in Figures 3A-5B, and is summarized as follows:

1) The subject site is exposed to the prevailing winds from the southwest compass quadrant, and the existing wind conditions within and surrounding the subject site are predicted to be suitable for a mix of standing and walking during the summer and mostly walking during the winter with uncomfortable conditions to the west.

    a. These conditions are predicted to be generally improved following the introduction of the proposed development. During the winter isolated regions of conditions are predicted to occasionally be considered uncomfortable for walking; these conditions are isolated in location and extent and are primarily located away from pedestrian sensitive areas. Pedestrians are not expected to linger over these areas during the winter months.

    b. Mitigation elements that may be considered by the design team include canopies that wrap around the southeast and southwest corners of Buildings 1 and 2, respectively, extending approximately 3 m in depth from the building façades.

2) Conditions over the surrounding sidewalks, surface parking, drive aisle, walkways, the proposed drop-off areas, loading zones, the outdoor patios serving the Amenity Building, and in the vicinity of building access points, are considered acceptable for the intended pedestrian uses.

3) During the summer, wind conditions over the outdoor amenity area in the northeast corner of the subject site are predicted to be suitable for standing, while conditions over the outdoor patio to the east of Building 2 are predicted to be suitable for mostly sitting with a mix of standing and walking conditions at the south corner of the patio. Depending on programming, the noted conditions may be considered acceptable. Specifically, if the windier areas will not accommodate seating or lounging activities, the noted wind conditions would be considered acceptable. If required by programming, comfort levels may be improved by implementing targeted landscaping elements around sensitive areas such as tall wind screens and coniferous plantings in dense arrangements.

4) Regarding the common amenity terraces serving the proposed development at the rooftop levels, conditions during the summer are predicted to be suitable for mostly standing.

    a. Comfort conditions within the terraces may be extended around sensitive areas by implementing perimeter wind screens, in place of standard height guards, rising to at least 1.8 m above the local walking surface along the perimeter of the terrace in combination with mitigation inboard of the terrace perimeters. This inboard mitigation could take the form of tall wind screens and clusters of dense coniferous plantings located around sensitive areas. The extent of mitigation is dependent on the terrace programming.

    b. Wind conditions over the proposed multi-purpose hard courts atop Building 1 are considered acceptable for an active use amenity area.

5) 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.

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## 1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by UrbanLink Developments (Beamsville) Ltd. to undertake a pedestrian level wind (PLW) study to satisfy Official Plan Amendment (OPA) and Zoning By-Law (ZBA) application submission requirements for the proposed mixed-use residential development located at 5205 King Steet in Lincoln, 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, Niagara Region wind comfort and safety criteria, architectural drawings provided by SRM Architects in October 2024, surrounding street layouts and existing and approved future building massing information obtained from the Town of Lincoln, and recent site imagery.

## 2. TERMS OF REFERENCE

The subject site is located at 5205 King Steet in Beamsville in the Town of Lincoln, situated to the northwest of the intersection of King Street and Lincoln Avenue. The proposed development comprises a 7-storey 'L'-shaped mixed-use residential building (Building 1), a 6-storey rectangular mixed-use residential building (Building 2), and a 2-storey Amenity Building. An exterior amenity area is located at the northeast corner of the subject site at grade.

The proposed development includes one level of underground parking, with access points located at the northwest corner of the subject site and to the north of Building 2. At the P1 Parking level, the 2-storey Amenity Building features a gym with access to the exterior pool located to the north, while its ground floor comprises an indoor amenity and its second level comprises a coworking space. The ground floor of Building 1 includes retail and market space in the south wing fronting King Street, while the north wing is reserved for residential use, with the primary entrance at the inner corner facing the rear of the subject site and an indoor amenity at the outer corner fronting King Street. Building 2 includes retail and restaurant space to the south, an outdoor patio to the east, and residential space to the north. An access driveway provides access from King Street, running between Buildings 1 and 2 to connect to the surface

parking lot and drop-off area located to the north of Building 1. The surface parking lot to the north of Building 2 is accessible from Lincoln Avenue. The remaining floors of Buildings 1 and 2 are reserved for residential use, with outdoor amenities serving the two residential buildings located at their respective rooftop levels.

Regarding wind exposures, the near-field surroundings of the subject site (defined as an area falling within a 200-metre (m) radius of the subject site) are characterized by low-rise residential dwellings from the north clockwise to the south, with a low-rise restaurant with surface parking lot to the south across the intersection of Lincoln Avenue and King Street, and isolated low-rise buildings and green spaces/farm lots in the remaining directions. The far-field surroundings (defined as the area beyond the near field and within a two-kilometre (km) radius) comprise the low-rise massing of Beamsville from the north-northeast clockwise to the south, and fields and green spaces in the remaining directions.

Figure 1A illustrates the subject site and surrounding context, representing the proposed future massing scenario, while Figure 1B illustrates the subject site and surrounding context, representing the existing massing scenario. 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 Lincoln area wind climate, and synthesis of computational data with Niagara Region wind criteria[1]. The following sections describe the analysis procedures, including a discussion of the noted pedestrian wind criteria.

[1] Niagara Region, *Pedestrian Level Wind Study Terms of Reference Guide*, 2022

## 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 the Niagara Falls International Airport in Niagara County, New York. 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 530 m. The process was performed for two context massing scenarios, as noted in Section 2.

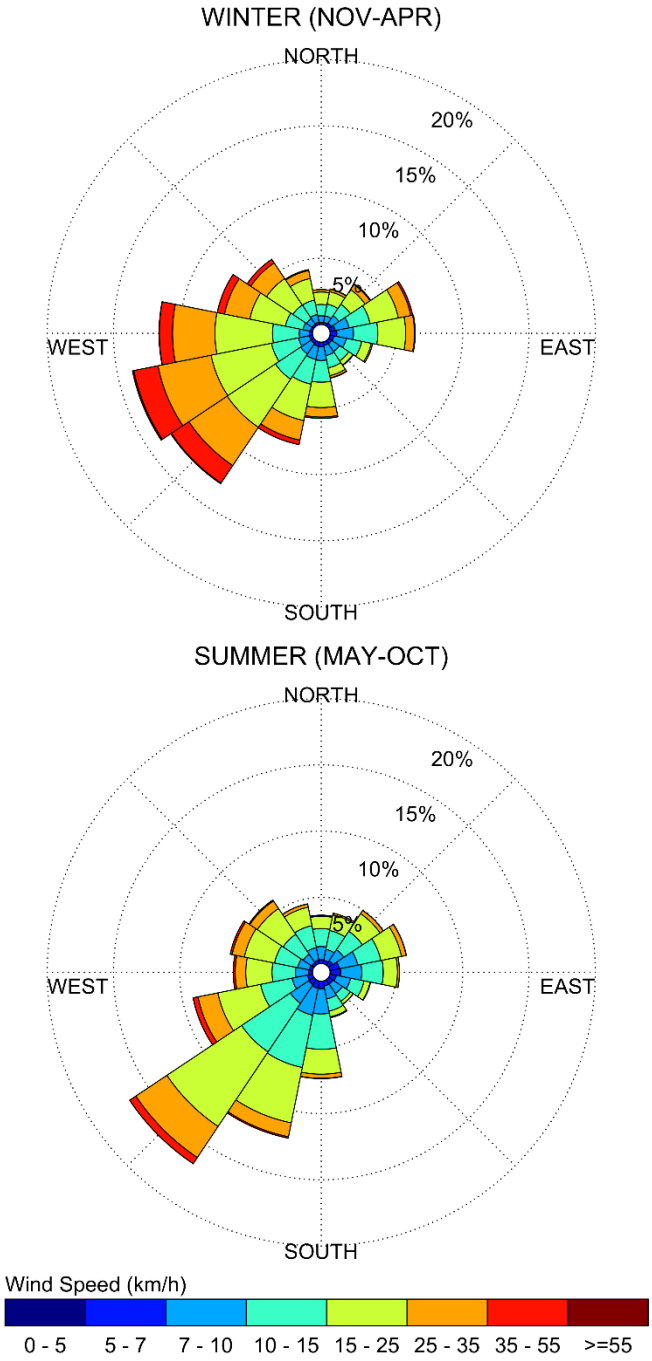
Mean and peak wind speed data obtained over the subject site for each wind direction were interpolated to 36 wind directions at 10° intervals, representing the full compass azimuth. Measured wind speeds approximately 1.5 m above local grade and the rooftop level common amenity terraces serving the proposed 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 Lincoln was developed from approximately 40 years of hourly meteorological wind data recorded at Niagara Falls International Airport. 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 two distinct seasons, as stipulated in the wind criteria. Specifically, the summer season is defined as May though October, and the winter season is defined as November through April, inclusive.

The statistical model of the Niagara Falls 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 Lincoln, the most common winds occur for southwesterly 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
## NIAGARA FALLS INTERNATIONAL AIRPORT, NIAGARA COUNTY, NEW YORK




**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 – Niagara Region

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 Niagara Region 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 Niagara Region 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-4B which illustrate wind conditions at grade level for the proposed and existing massing scenarios. Figures 5A-5B illustrate wind conditions over the common amenity terraces serving both buildings at the rooftop level. Conditions are presented as continuous contours of wind comfort and correspond to the various comfort classes noted 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

The subject site is located in a mixed rural and suburban context with mostly farmland to the southwest, which exposes to the proposed development to the prevailing winds from these directions. Under the existing massing scenario, conditions over the subject site are predicted to be mixed between standing and walking within and surrounding the subject site, becoming suitable for mostly walking during the winter with regions considered uncomfortable for walking to the west.

Following the introduction of the proposed development, the wind conditions at most areas within and surrounding the proposed development are predicted to be improved, particularly to the rear of the subject site as the proposed building massing provides shielding from the direct southwesterly winds. These winds from the southwest clockwise to the west are predicted to downwash towards grade over the southwestern façades of the proposed development and accelerate around the southeast corners of Buildings 1 and 2, around the northwest corner of Building 1, around the southwest corner of Building 2, and between Buildings 1 and 2.

During the winter, isolated regions of conditions that may occasionally be considered uncomfortable for walking are predicted along the drive aisle between Buildings 1 and 2, to the northwest of Building 1, and at the southeast corner of Building 2. Notably, the conditions to the northwest of Building 1 are over the easement for the creek and are not located over accessible pedestrian areas. Furthermore, conditions at the southeast corner of Building 2 are isolated in extent, with the windiest conditions located over the proposed transformer and away from public areas. Over the sidewalk along King Street, conditions are suitable for walking for approximately 78% of the time during the winter, representing a 2% exceedance

of the walking comfort criterion. As the conditions at the southeast corner of Building 2 are limited in extent and the exceedance is considered marginal, the wind conditions at the southeast corner of Building 2 may be considered satisfactory for public sidewalks and walkways.

Between Buildings 1 and 2, the isolated region of conditions that may occasionally be considered uncomfortable for walking is primarily located over the roadway surface and landscaped areas, with limited impact on the proposed pedestrian walkways serving the proposed development. Over the pedestrian walkways, conditions in this area are predicted to be suitable for walking for approximately at least 71% of the time during the winter season, representing a 9% exceedance of the walking threshold. Notably, during the colder months, pedestrians are not expected to linger in these transitional walkway areas. Mitigation elements that may be considered by the design team include canopies that wraparound the southeast and southwest corners of Buildings 1 and 2, respectively, extending approximately 3 m from the building façades to deflect and diffuse the downwash winds.

**Sidewalks along King Street**: Following the introduction of the proposed development, wind comfort conditions over the nearby public sidewalks along King Street are predicted to be mostly suitable for standing, or better, during the summer with isolated areas suitable for walking. During the winter, conditions are predicted to be suitable for walking, or better, with the exception of the isolated windier area at the southeast corner of Building 2, as noted above.

Conditions over the sidewalks along King Street with the existing massing are predicted to be suitable for a mix of standing and walking during the summer, becoming suitable for walking during the winter with uncomfortable wind conditions predicted to the west. Overall, the introduction of the proposed development is predicted to improve pedestrian wind comfort conditions along King Street.

**Sidewalks along Lincoln Avenue**: Following the introduction of the proposed development, wind conditions over the nearby sidewalks along Lincoln Avenue are predicted to be suitable for mostly sitting during the summer with isolated areas that are suitable for standing and walking near the intersection with King Street. During the winter, conditions are predicted to become suitable for standing with an isolated region suitable for walking at King Street. The noted conditions are considered acceptable.

Conditions over the sidewalks along Lincoln Avenue under the existing massing are predicted to be suitable for a mix of sitting and standing during summer, becoming suitable for standing during the winter with walking areas at the intersection with King Street during the winter. Overall, the introduction of the proposed development is predicted to improve pedestrian wind comfort conditions along Lincoln Avenue during the summer, and wind comfort conditions with the proposed development along Lincoln Avenue are nevertheless considered acceptable for sidewalks.

**Outdoor Amenity Area in the Northeast Corner of the Subject Site**: Wind conditions within the outdoor amenity area in the northeast corner of the subject site are predicted to be suitable for standing during the summer, as illustrated in Figure 3A. Over most of the amenity, conditions are predicted to be suitable for sitting for at least 70% of the time during the summer months, where the target is 80% to reach the sitting comfort threshold. Depending on programming, the noted conditions may be considered acceptable. Specifically, if the noted amenity will not accommodate seating or lounging activities, the noted wind conditions would be considered acceptable. If required by programming, comfort levels may be improved with targeted landscaping elements around sensitive areas such as tall wind screens and coniferous plantings in dense arrangements.

**Patio and Pool Area serving the Amenity Building:** During the summer, conditions over the patios and outdoor pool area to the north of the Amenity Building are predicted to be suitable for sitting, which is considered acceptable without mitigation.

**Outdoor Patio to the East of Building 2**: Wind comfort conditions over the outdoor patio to the east of Building 2 are predicted to be suitable for sitting over the majority of the patio, with conditions suitable for a mix of standing and walking at the south corner. Depending on programming, the noted conditions may be considered acceptable. Specifically, if the windier area to the south will not accommodate seating or lounging activities, the noted wind conditions would be considered acceptable.

If required by programming, comfort levels at the south of the patio may be improved with landscaping elements comprising tall wind screens, coniferous plantings in dense arrangements, or a combination thereof that are targeted and located adjacent to designated seating areas to the south, or through the introduction of a wind screen extending from the southeast corner of Building 2 to provide shielding from the winds that navigate and accelerate around the building corner.

**Surface Parking, Walkways, Loading Zone, and Drop-off Area within Subject Site**: Wind conditions over the surface parking, drop-off areas, and loading zones serving the proposed development are predicted to be suitable for standing, or better, throughout the year, which is considered acceptable.

With the exception of the above-noted isolated windier area between Buildings 1 and 2, wind conditions over the walkways serving the proposed development are predicted to be suitable for walking, or better, throughout the year.

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

## 5.2 Wind Comfort Conditions – Rooftop Level Common Amenity Terraces

During the summer, wind conditions within the common amenity terraces serving the proposed development at the rooftop level are predicted to be suitable for standing over most of the terrace areas, as illustrated in Figure 5A.

Sitting conditions may be extended by implementing tall perimeter wind screens, typically glazed and in place of standard height guards, rising to at least 1.8 m above the local walking surface along the perimeter of the terraces in combination with mitigation inboard of the terrace perimeters. This inboard mitigation could take the form of a combination of tall wind screens and clusters of dense coniferous plantings that are targeted adjacent to sensitive areas. The extent of mitigation is dependent on the programming of the terraces. Wind conditions over the proposed multi-purpose hard court at the roof level of Building 1 are considered acceptable for active use, and targeted mitigation elements to improve upon the predicted wind conditions over the area are not required.

## 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 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-5B. Based on computer simulations using the CFD technique, meteorological data analysis of the Lincoln wind climate, Niagara Region wind comfort and safety criteria, and experience with numerous similar developments, the study concludes the following:

1) The subject site is exposed to the prevailing winds from the southwest compass quadrant, and the existing wind conditions within and surrounding the subject site are predicted to be suitable for a mix of standing and walking during the summer and mostly walking during the winter with uncomfortable conditions to the west.

    a. These conditions are predicted to be generally improved following the introduction of the proposed development. During the winter isolated regions of conditions are predicted to occasionally be considered uncomfortable for walking; these conditions are isolated in location and extent and are primarily located away from pedestrian sensitive areas. Pedestrians are not expected to linger over these areas during the winter months.

    b. Mitigation elements that may be considered by the design team include canopies that wrap around the southeast and southwest corners of Buildings 1 and 2, respectively, extending approximately 3 m in depth from the building façades.

2) Conditions over the surrounding sidewalks, surface parking, drive aisle, walkways, the proposed drop-off areas, loading zones, the outdoor patios serving the Amenity Building, and in the vicinity of building access points, are considered acceptable for the intended pedestrian uses.

3) During the summer, wind conditions over the outdoor amenity area in the northeast corner of the subject site are predicted to be suitable for standing, while conditions over the outdoor patio to the east of Building 2 are predicted to be suitable for mostly sitting with a mix of standing and walking conditions at the south corner of the patio. Depending on programming, the noted conditions may be considered acceptable. Specifically, if the windier areas will not accommodate seating or lounging activities, the noted wind conditions would be considered acceptable.

a. If required by programming, comfort levels may be improved by implementing targeted landscaping elements around sensitive areas such as tall wind screens and coniferous plantings in dense arrangements.

4) Regarding the common amenity terraces serving the proposed development at the rooftop levels, conditions during the summer are predicted to be suitable for mostly standing.

   a. Comfort conditions within the terraces may be extended around sensitive areas by implementing perimeter wind screens, in place of standard height guards, rising to at least 1.8 m above the local walking surface along the perimeter of the terrace in combination with mitigation inboard of the terrace perimeters. This inboard mitigation could take the form of tall wind screens and clusters of dense coniferous plantings located around sensitive areas. The extent of mitigation is dependent on the terrace programming.

   b. Wind conditions over the proposed multi-purpose hard courts atop Building 1 are considered acceptable for an active use amenity area.

5) 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,

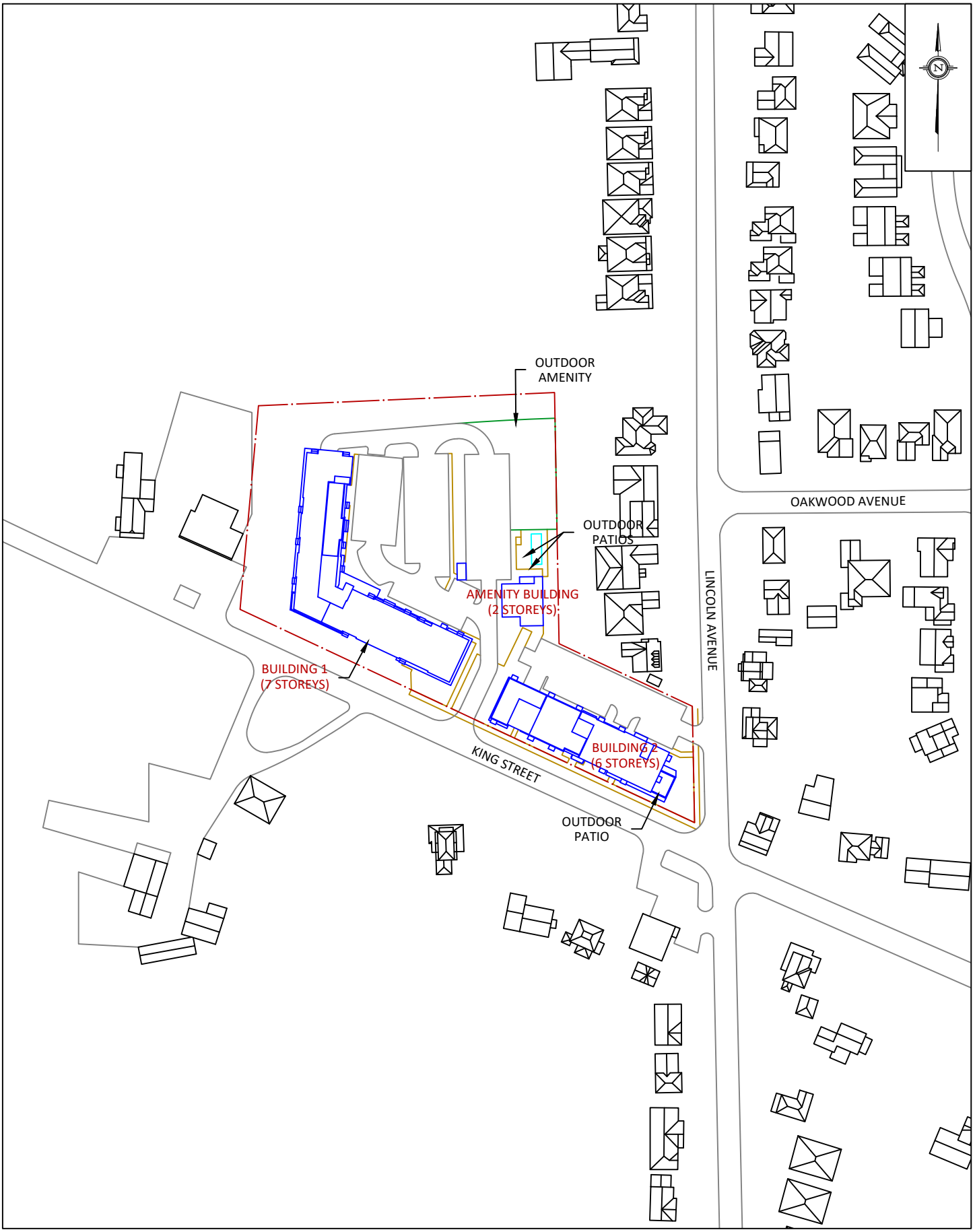
***Gradient Wind Engineering Inc.***



Omar Rioseco, B.Eng.
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CFD Lead Engineer



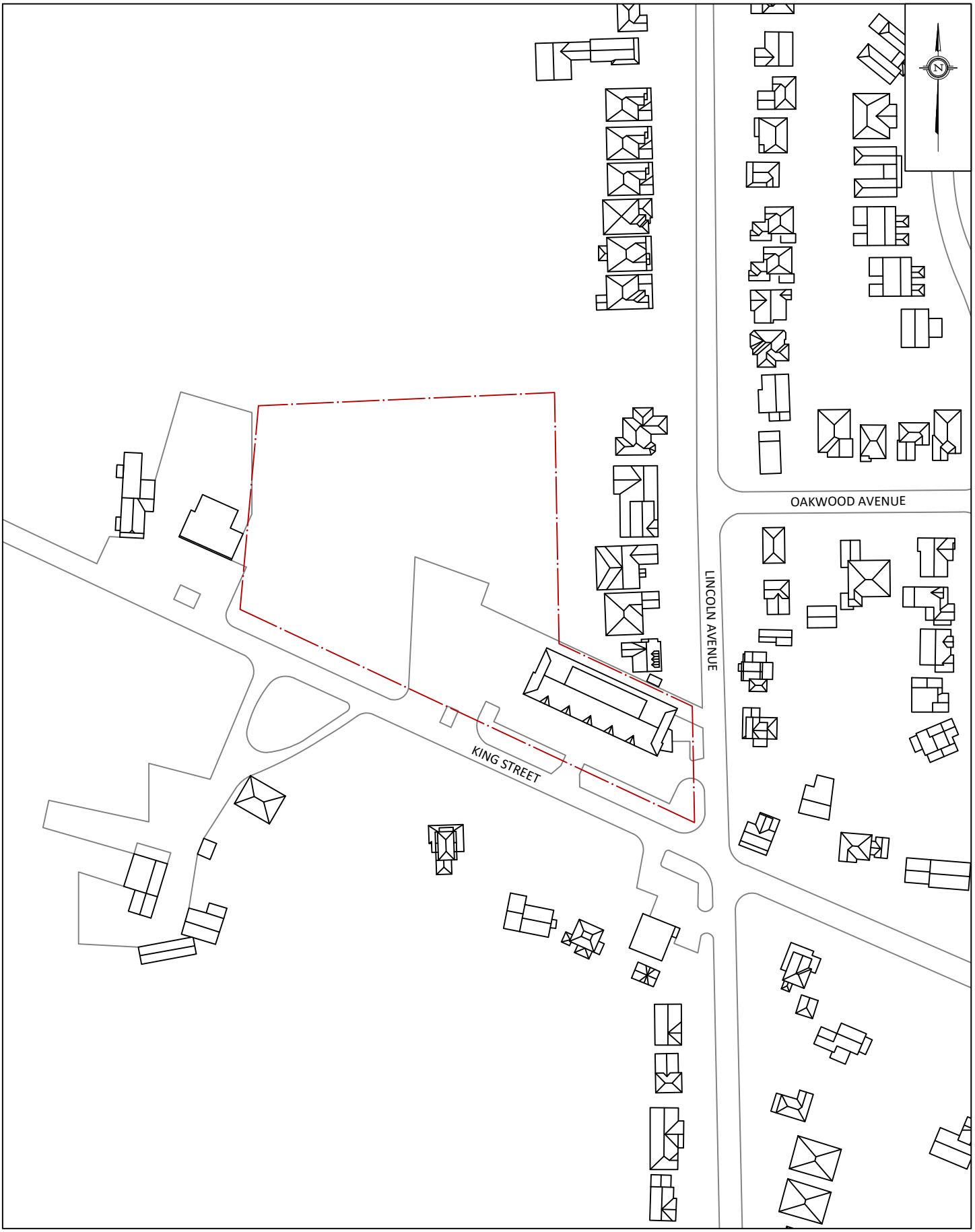

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| | |
|---|---|
| PROJECT | 5205 KING STREET, LINCOLN<br>PEDESTRIAN LEVEL WIND STUDY |
| SCALE | 1:2000 |
| DRAWING NO. | 24-125-PLW-1A |
| DATE | NOVEMBER 15, 2024 |
| DRAWN BY | S.K. |

DESCRIPTION

FIGURE 1A:
PROPOSED SITE PLAN AND SURROUNDING CONTEXT




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|---|---|
| PROJECT | 5205 KING STREET, LINCOLN<br>PEDESTRIAN LEVEL WIND STUDY |
| SCALE | 1:2000 |
| DRAWING NO. | 24-125-PLW-1B |
| DATE | NOVEMBER 15, 2024 |
| DRAWN BY | S.K. |

DESCRIPTION

FIGURE 1B:
EXISTING SITE PLAN AND SURROUNDING CONTEXT

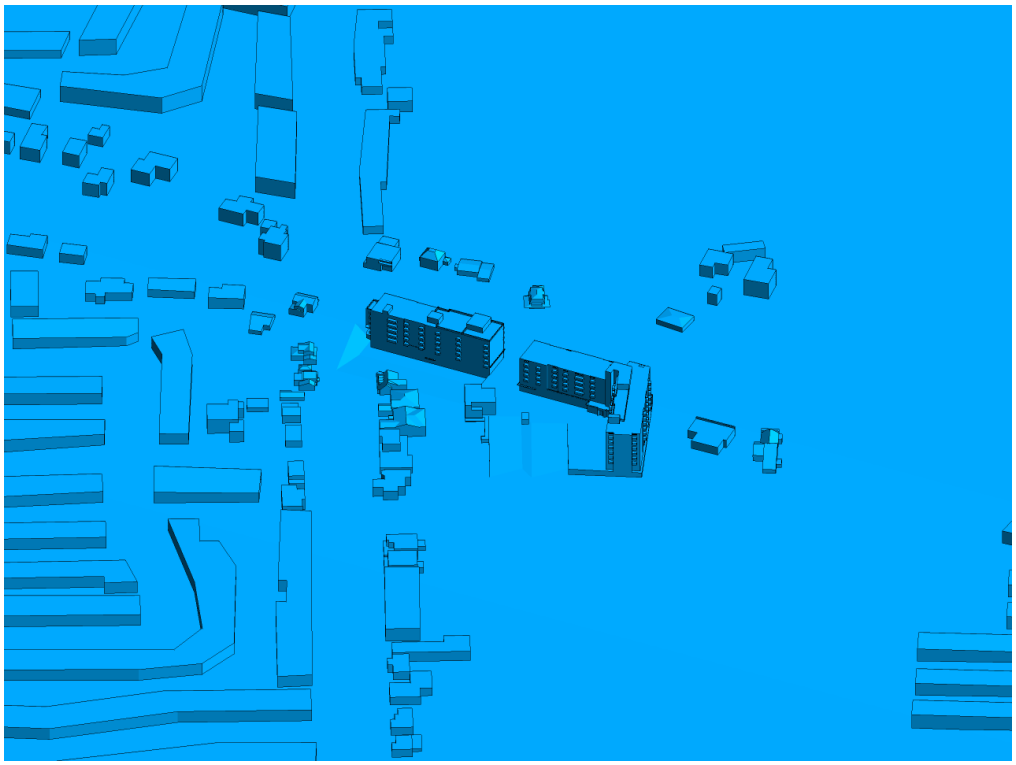


**FIGURE 2A: COMPUTATIONAL MODEL, PROPOSED MASSING, NORTH PERSPECTIVE**

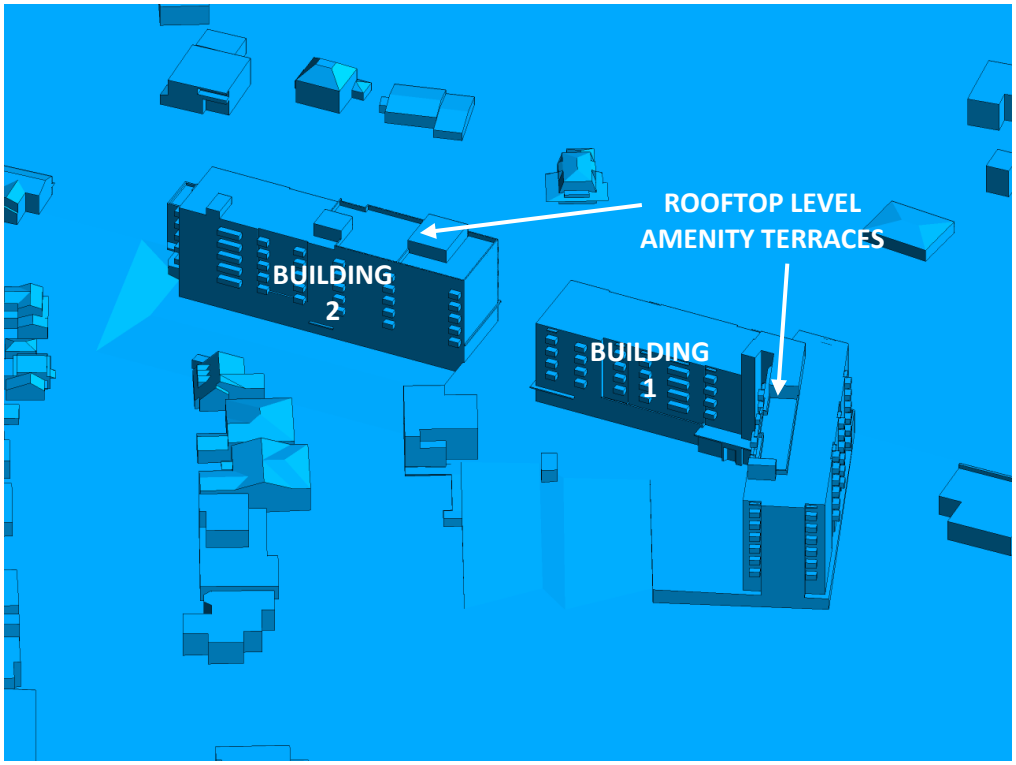



**FIGURE 2B: CLOSE-UP VIEW OF FIGURE 2A**

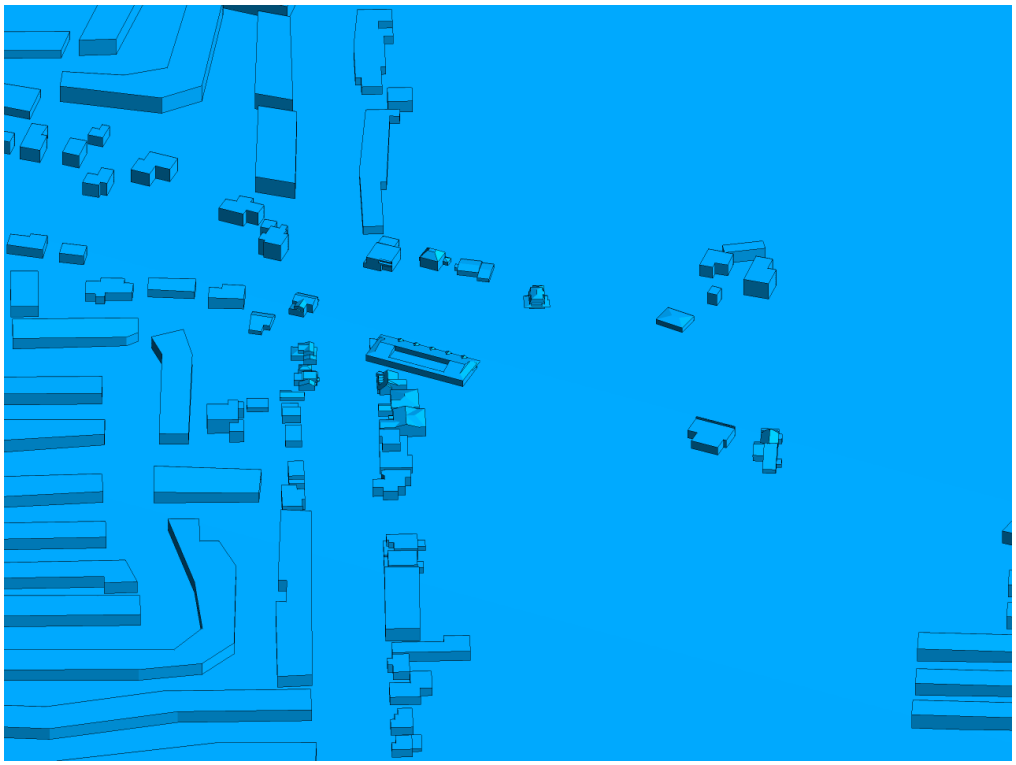


**FIGURE 2C: COMPUTATIONAL MODEL, EXISTING MASSING, NORTH PERSPECTIVE**

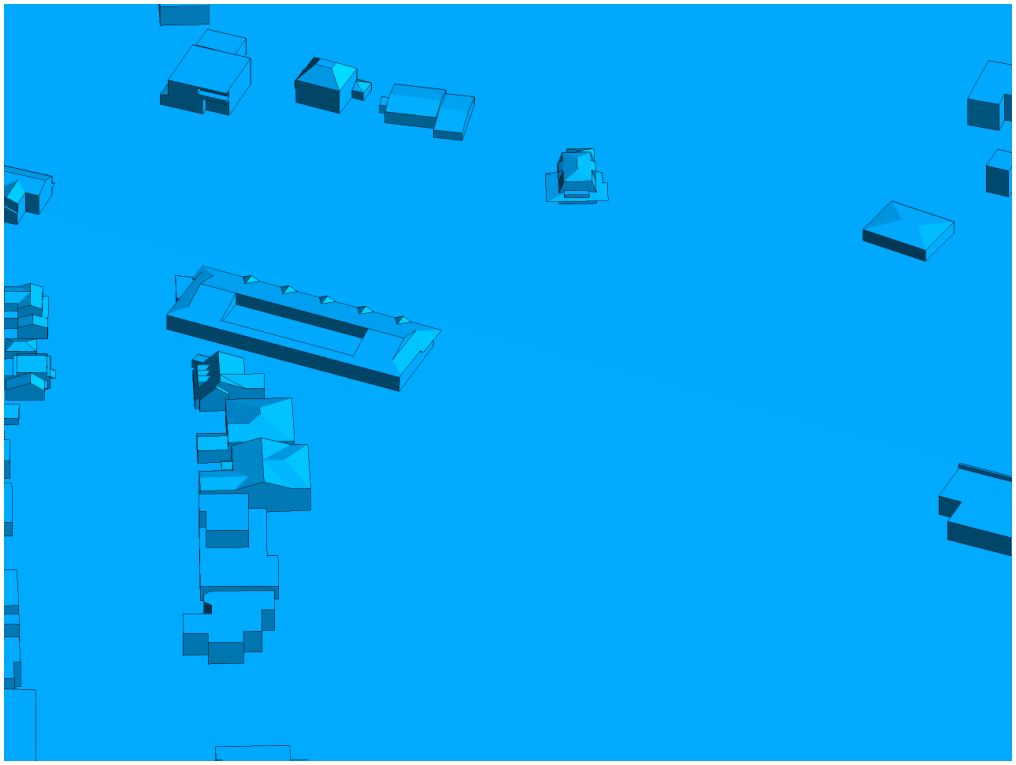


**FIGURE 2D: CLOSE-UP VIEW OF FIGURE 2C**

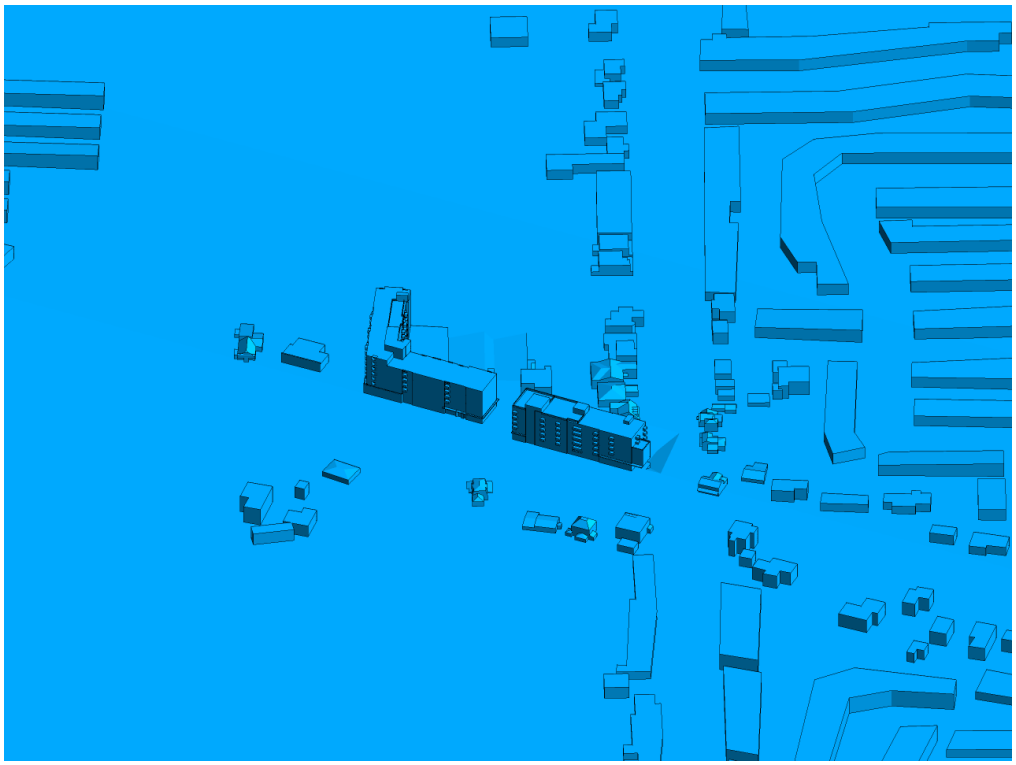


**FIGURE 2E: COMPUTATIONAL MODEL, PROPOSED MASSING, SOUTH PERSPECTIVE**

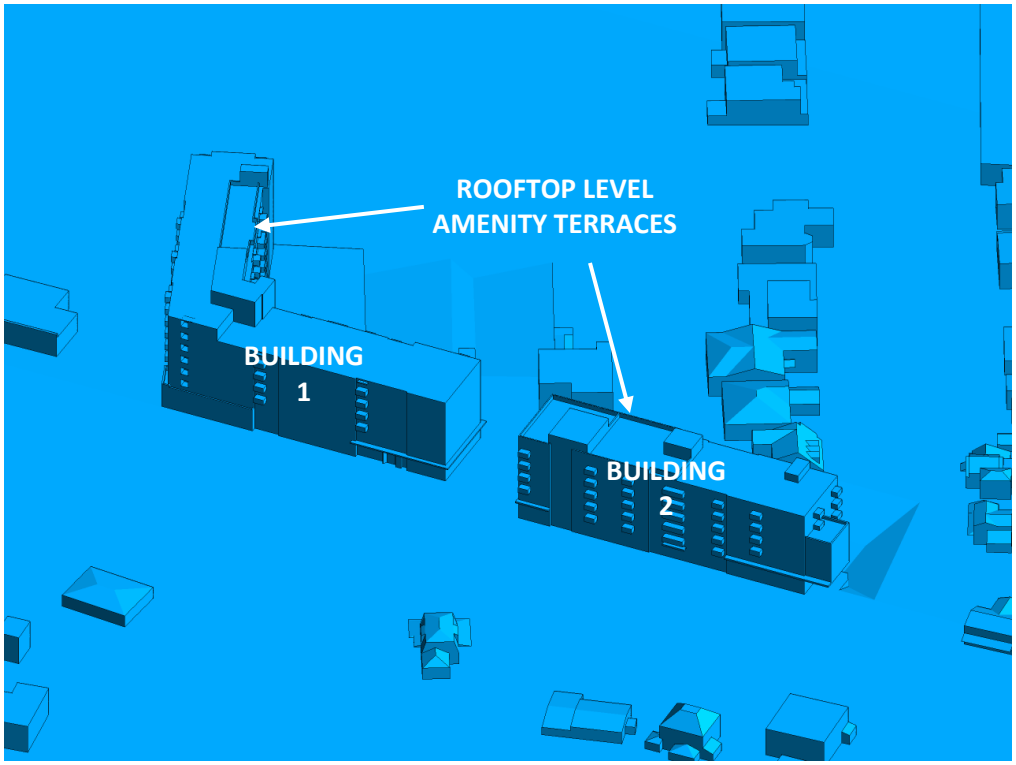



**FIGURE 2F: CLOSE-UP VIEW OF FIGURE 2E**

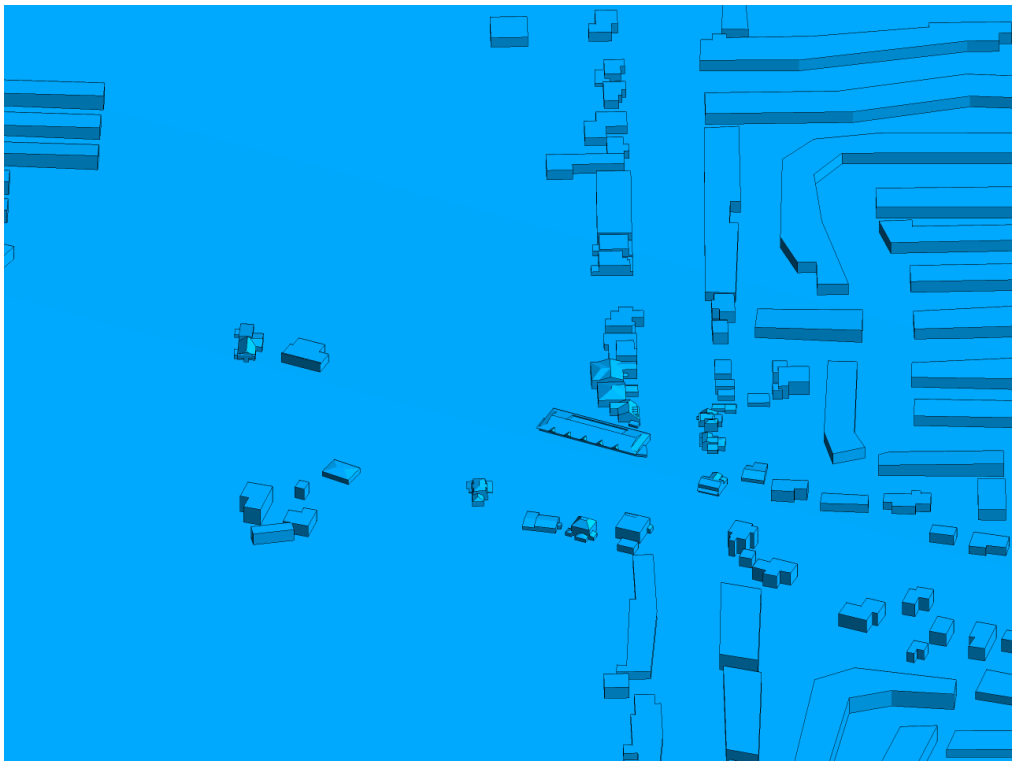


**FIGURE 2G: COMPUTATIONAL MODEL, EXISTING MASSING, SOUTH PERSPECTIVE**

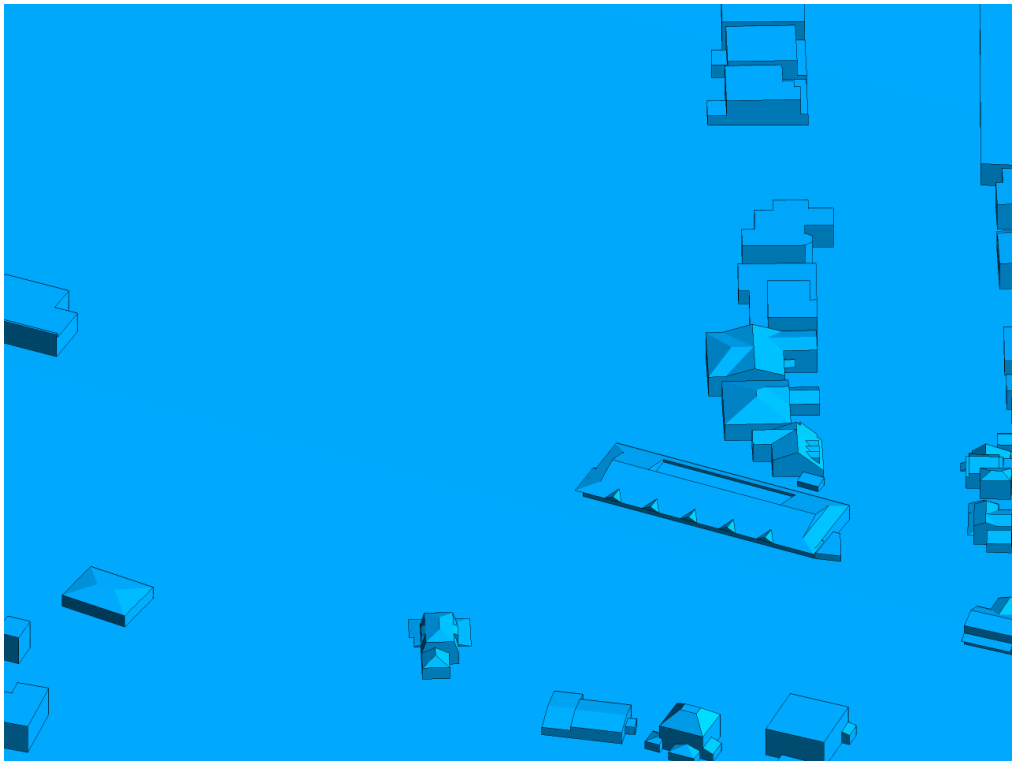


**FIGURE 2H: CLOSE-UP VIEW OF FIGURE 2G**

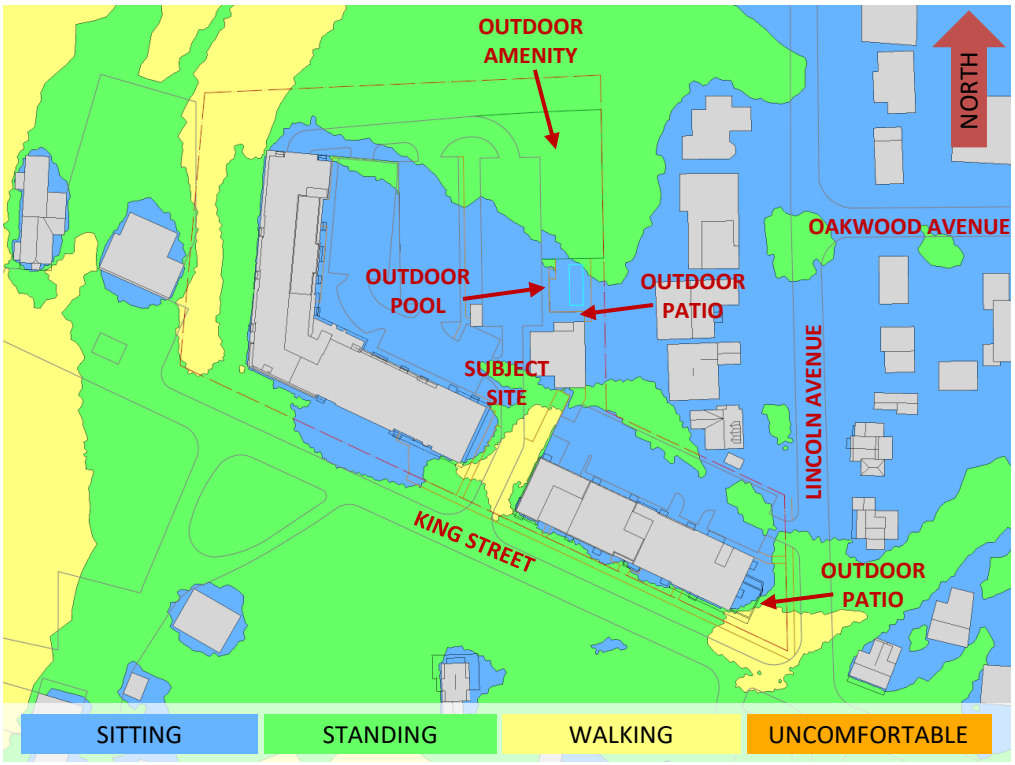



**FIGURE 3A: SUMMER – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL**

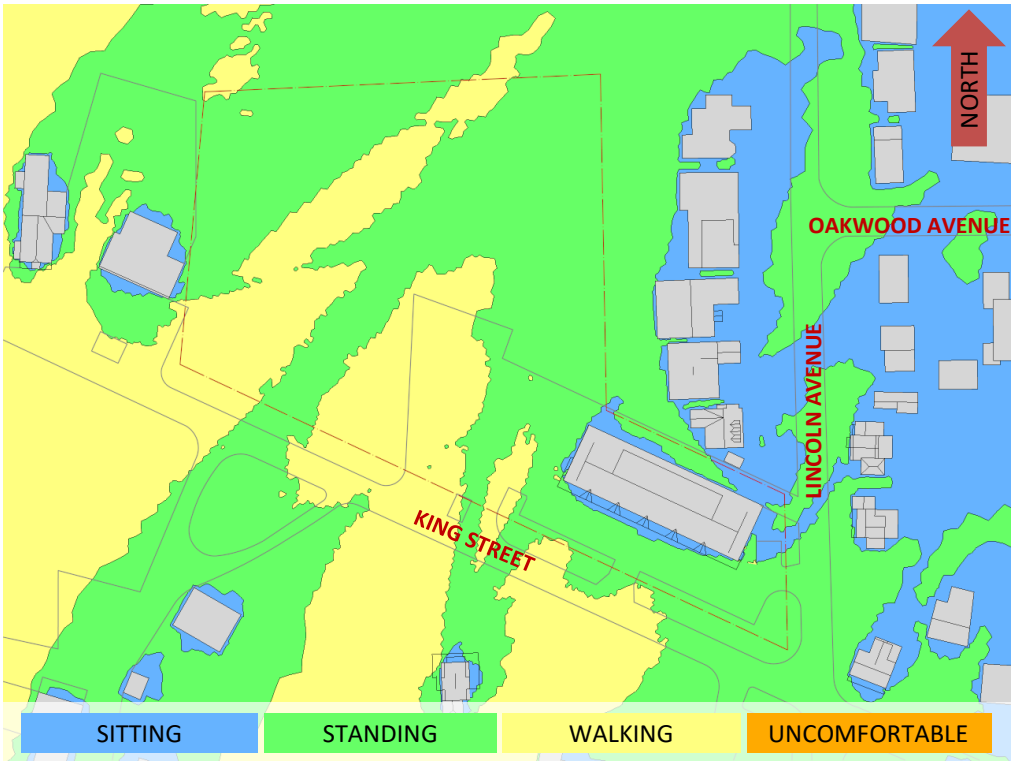



**FIGURE 3B: SUMMER – EXISTING MASSING – WIND COMFORT, GRADE LEVEL**

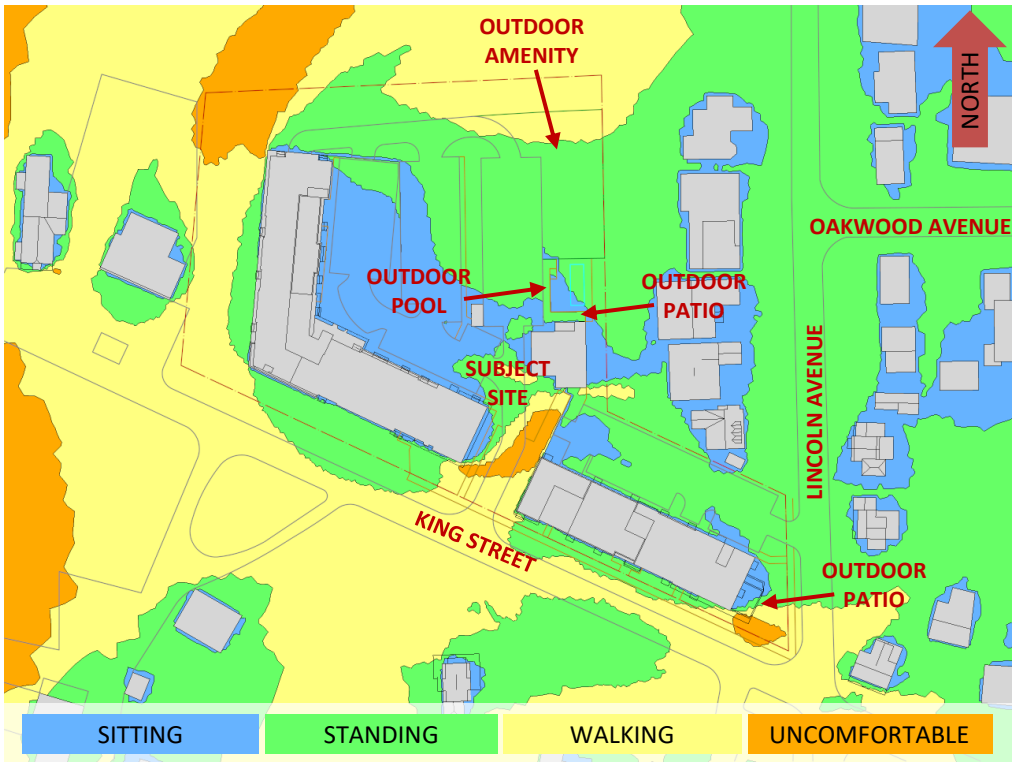



**FIGURE 4A: WINTER – PROPOSED MASSING – WIND COMFORT, GRADE LEVEL**

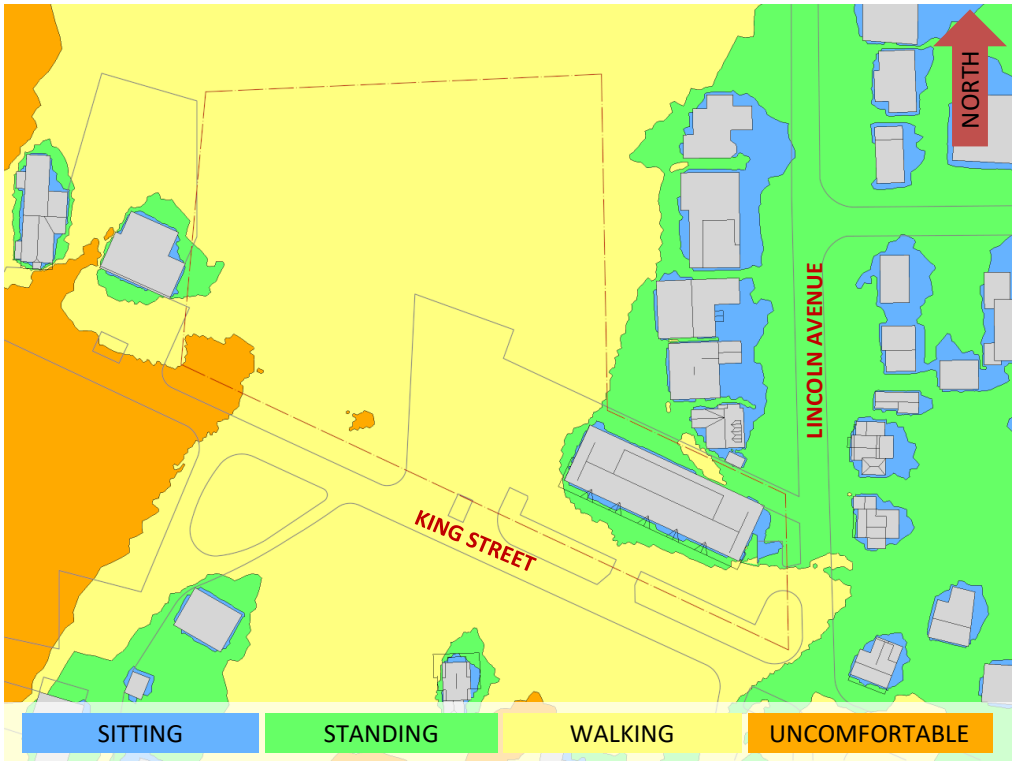



**FIGURE 4B: WINTER – EXISTING MASSING – WIND COMFORT, GRADE LEVEL**

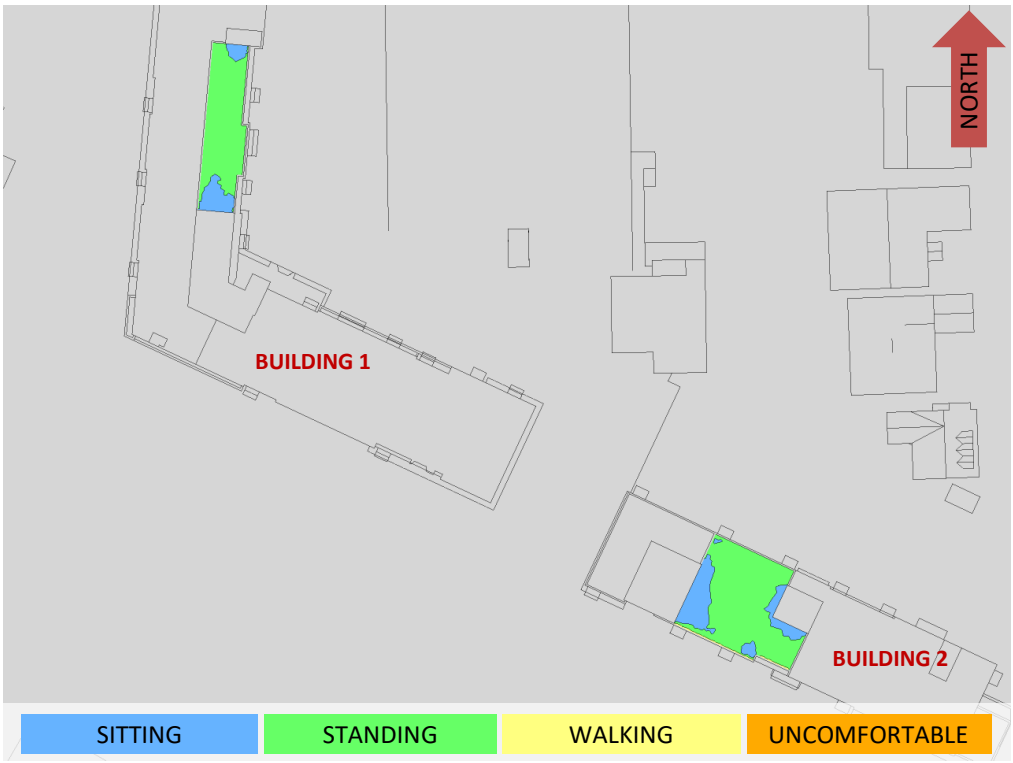



**FIGURE 5A: SUMMER – WIND COMFORT, ROOFTOP LEVEL COMMON AMENITY TERRACES**

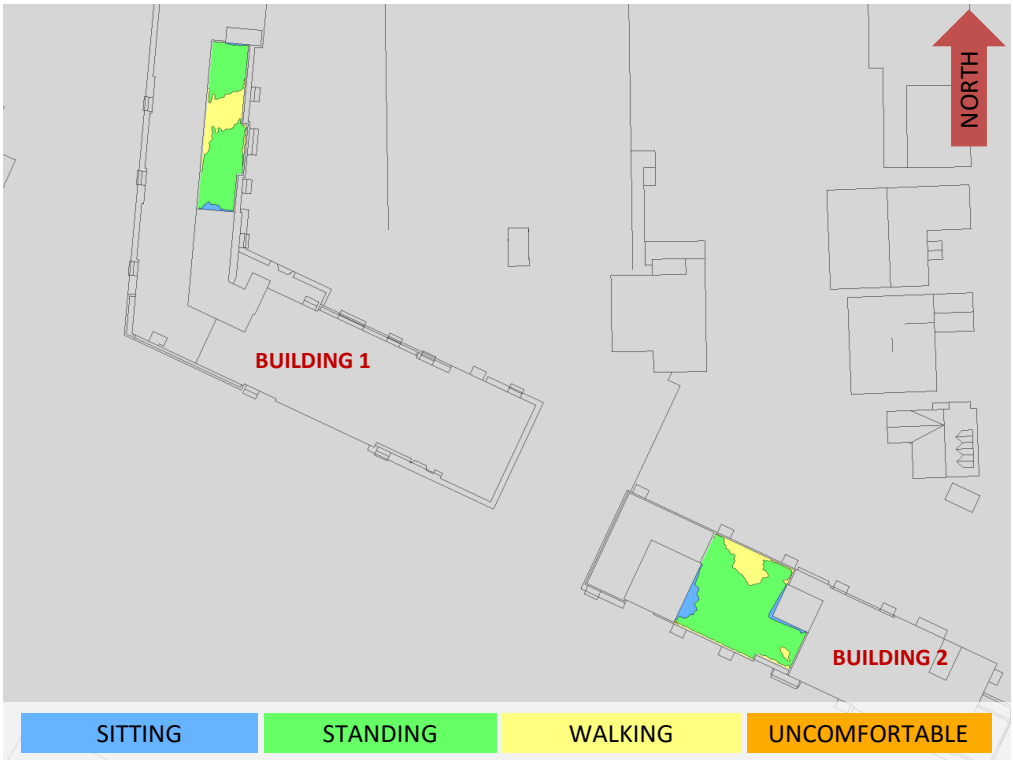



**FIGURE 5B: WINTER – WIND COMFORT, ROOFTOP LEVEL COMMON AMENITY TERRACES**




# APPENDIX A

## SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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## SIMULATION OF THE ATMOSPHERIC BOUNDARY LAYER

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

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

where, $\boldsymbol{U}$ = mean wind speed, $\boldsymbol{U_g}$ = gradient wind speed, $\boldsymbol{Z}$ = height above ground, $\boldsymbol{Z_g}$ = depth of the boundary layer (gradient height), and $\alpha$ 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 35% mean wind speed for Lincoln 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.

$\alpha$ 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 | 0.19 |
| 22.5 | 0.20 |
| 45 | 0.22 |
| 67.5 | 0.22 |
| 90 | 0.22 |
| 112.5 | 0.22 |
| 135 | 0.22 |
| 157.5 | 0.22 |
| 180 | 0.20 |
| 202.5 | 0.19 |
| 225 | 0.19 |
| 247.5 | 0.19 |
| 270 | 0.19 |
| 292.5 | 0.19 |
| 315 | 0.20 |
| 337.5 | 0.19 |

**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].

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

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

where, $I$ = turbulence intensity, $L_t$ = turbulence length scale, $Z$ = height above ground, and $\alpha$ 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.