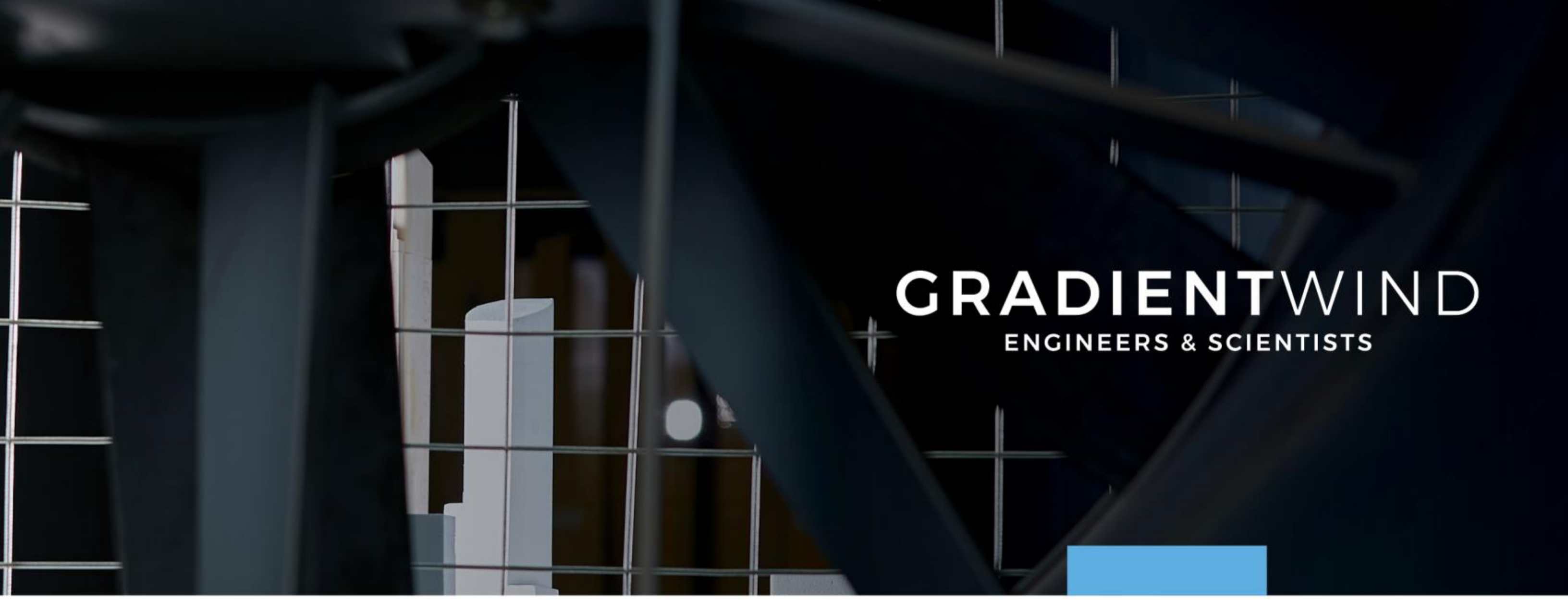
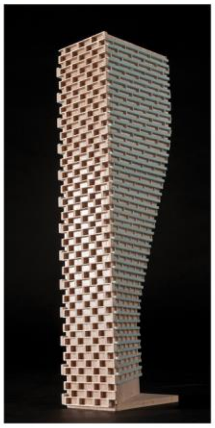
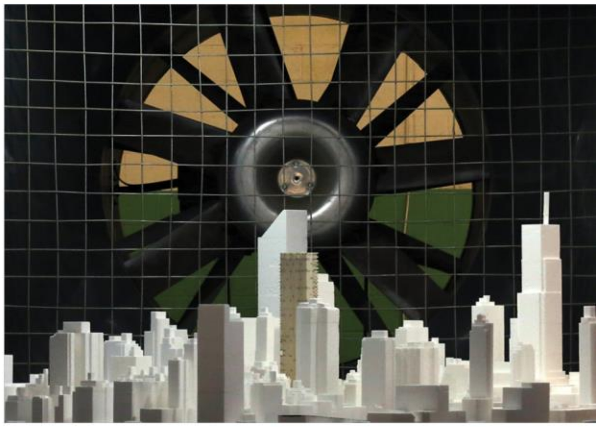


PEDESTRIAN LEVEL WIND STUDY

Yonge & Birch
Toronto, Ontario

REPORT: GW19-200-WTPLW





November 19, 2021

PREPARED FOR
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EXECUTIVE SUMMARY

This report describes a comparative pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 8 Birch Avenue and 1198-1210 Yonge Street in Toronto, Ontario (commonly referred to as “Yonge and Birch”). Two configurations were studied: (i) existing conditions, including all approved, surrounding developments and without the proposed development, and (ii) future conditions with the proposed development in place. The study involves wind tunnel measurements of pedestrian wind speeds using a physical scale model, combined with meteorological data integration, to assess pedestrian comfort at key areas within and surrounding the study site. Grade-level areas investigated include sidewalks, surface parking, laneways, public transit stops, and building access points. Wind comfort is also evaluated over the rooftop outdoor amenity. The results and recommendations derived from these considerations are summarized in the following paragraphs and detailed in the subsequent report.

Our work is based on industry standard wind tunnel testing and data analysis procedures, architectural drawings provided by KPMB Architects in October 2021, surrounding street layouts, as well as existing and approved future building massing information obtained from the City of Toronto, and recent site imagery.

A complete summary of the predicted wind conditions is provided in Section 5.2 of this report and is also illustrated in Figures 2A through 5B, as well as Tables A1 and B1-B3 in the appendices. Based on the wind tunnel test results, meteorological data analysis, and experience with similar developments in the Toronto area, we conclude that the future wind conditions over most grade-level pedestrian wind-sensitive areas within and surrounding the study site will be acceptable for the intended uses on a seasonal basis. To ensure the south elevation retail entrance is comfortable for standing or better throughout the year, mitigation is recommended, as described in Section 5.2. Additionally, the rooftop outdoor amenity will experience wind conditions comfortable for sitting or more sedentary activities throughout the year without the need for mitigation.

A comparison of the existing versus future wind comfort surrounding the study site indicates that the proposed development will generally reduce conditions over nearby sidewalks to the north, east, and south, with conditions generally unchanged elsewhere. Where wind speeds increase, conditions nevertheless remain acceptable for the intended uses.

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience conditions too windy for walking, or that could be considered unsafe.

TABLE OF CONTENTS

1. INTRODUCTION

This report describes a comparative pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 8 Birch Avenue and 1198-1210 Yonge Street in Toronto, Ontario. Two configurations were studied: (i) existing conditions, including all approved, surrounding developments and without the proposed development, and (ii) future conditions with the proposed development in place. The study was performed in accordance with industry standard wind tunnel testing techniques, architectural drawings provided by KPMB Architects in October 2021, surrounding street layouts and existing and approved future building massing information, as well as recent site imagery.

2. TERMS OF REFERENCE

The focus of this comparative pedestrian wind study is the proposed mixed-use, 15-storey development located at 8 Birch Avenue and 1198-1210 Yonge Street in Toronto, Ontario. The study site is situated at the northwest corner of the intersection of Yonge Street and Birch Avenue.

At grade, the study building has an approximately square planform. Covered loading and parking entrances are accessed via Birch Avenue through the west end of the south façade. A residential lobby is centrally located along the east elevation, and retail space occupies the remainder of the east and south elevations. At the mezzanine level, canopies extend over the east and south retail and lobby facades. The floorplate sets back from the west at Level 3, and irregularly from the east above Level 7, accommodating private terraces. At the Mechanical Penthouse (MPH) Level the floorplate sets back from the southwest corner, accommodating an outdoor amenity terrace over the rooftop.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre radius of the site) are characterized by low-rise buildings on the west side of Yonge Street to the north and south, low- and mid-rise buildings to the southeast, and mid-rise buildings to the northeast along Yonge Street, with low-rise beyond. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius) comprise predominantly suburban exposure, transitioning to urban exposure to the south along Yonge Street, and combined with denser clusters of taller buildings to the north near St. Clair Avenue and Davisville Avenue.

Grade-level areas investigated include sidewalks, surface parking, laneways, public transit stops, and building access points. Wind comfort is also evaluated over the rooftop outdoor amenity. Figures 1A and 1B illustrate the study site and surrounding context for the existing and future test scenarios, respectively, and Photographs 1 through 6 depict the wind tunnel model used to conduct the study.

3. OBJECTIVES

The principal objectives of this study are to (i) determine pedestrian level wind comfort and safety conditions at key areas within and surrounding the development site; (ii) identify areas where wind conditions may interfere with the intended uses of outdoor spaces; (iii) recommend suitable mitigation measures, where required; and (iv) evaluate the influence of the proposed development and of surrounding approved future developments, on the existing wind conditions.

4. METHODOLOGY

The approach followed to quantify pedestrian wind conditions over the site is based on wind tunnel measurements of wind speeds at selected locations on a reduced-scale physical model, meteorological analysis of the Toronto area wind climate and synthesis of wind tunnel data with industry-accepted guidelines[1]. The following sections describe the analysis procedures, including a discussion of the pedestrian comfort and safety guidelines.

4.1 Wind Tunnel Context Modelling

A detailed PLW study is performed to determine the influence of local winds at the pedestrian level for a proposed development. The physical model of the proposed development and relevant surroundings, illustrated in Photographs 1 through 6 following the main text, was constructed at a scale of 1:400. The wind tunnel model includes all existing buildings and approved future developments within a full-scale diameter of approximately 840 metres. The general concept and approach to wind tunnel modelling is to provide building and topographic detail in the immediate vicinity of the study site on the surrounding model, and to rely on a length of wind tunnel upwind of the model to develop wind properties consistent with known turbulent intensity profiles that represent the surrounding terrain.

[1] Toronto Development Guide, Pedestrian Level Wind Study Terms of Reference, November 2010

An industry standard practice is to omit trees, vegetation, and other existing and planned landscape elements from the wind tunnel model due to the difficulty of providing accurate seasonal representation of vegetation. The omission of trees and other landscaping elements produces slightly more conservative wind speed values.

4.2 Wind Speed Measurements

The PLW study was performed by testing a total of 36 sensor locations on the scale model in Gradient Wind's wind tunnel. Of these 36 sensors, 35 were located at grade and the remaining sensor was located over the rooftop amenity terrace. Wind speed measurements were performed for each of the 37 sensors for 36 wind directions at 10° intervals. Figures 1A and 1B illustrate a plan of the site and relevant surrounding context for the existing and future test scenarios, respectively, while sensor locations used to investigate wind conditions are illustrated in Figures 2A through 5B.

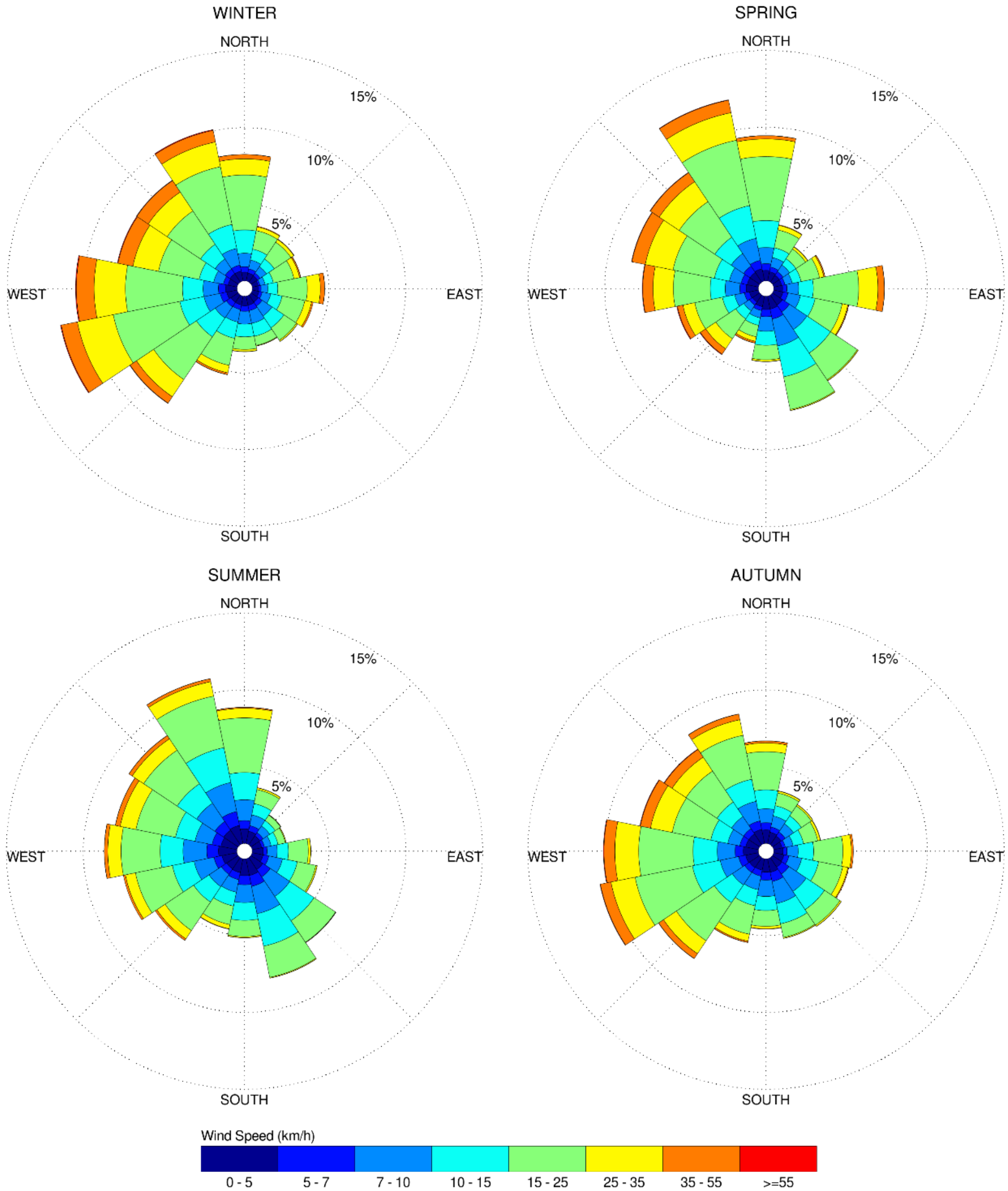
Mean and peak wind speed values for each location and wind direction were calculated from real-time pressure measurements, recorded at a sample rate of 500 samples per second, and taken over a 60-second time period. This period at model-scale corresponds approximately to one hour in full-scale, which matches the time frame of full-scale meteorological observations. Measured mean and gust wind speeds at grade were referenced to the wind speed measured near the ceiling of the wind tunnel to generate mean and peak wind speed ratios. Ceiling height in the wind tunnel represents the depth of the boundary layer of wind flowing over the earth's surface, referred to as the gradient height. Within this boundary layer, mean wind speed increases up to the gradient height and remains constant thereafter. Appendices C and D provide greater detail of the theory behind wind speed measurements. Wind tunnel measurements for this project, conducted in Gradient Wind's wind tunnel facility, meet or exceed guidelines found in the National Building Code of Canada 2015 and of 'Wind Tunnel Studies of Buildings and Structures', ASCE Manual 7 Reports on Engineering Practice No 67.

4.3 Meteorological Data Analysis

A statistical model for winds in Toronto was developed from approximately 40-years of hourly meteorological wind data recorded at Pearson International Airport, and obtained from the local branch of Atmospheric Environment Services of Environment Canada. Wind speed and direction data were analyzed for each month of the year in order to determine the statistically prominent wind directions and corresponding speeds, and to characterize similarities between monthly weather patterns. Based on this portion of the analysis, the four seasons are represented by grouping data from consecutive months based on similarity of weather patterns, and not according to the traditional calendar method.

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 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 concerning pedestrian comfort occur from the southwest clockwise to the north, as well as those from the east. The directional preference and relative magnitude of the wind speed varies somewhat from season to season, with the summer months displaying the calmest winds relative to the remaining seasonal periods.

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES
PEARSON INTERNATIONAL 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 Guidelines

Pedestrian comfort and safety guidelines are based on the mechanical effects of wind without consideration of other meteorological conditions (i.e. temperature, relative humidity). The comfort guidelines assume that pedestrians are appropriately dressed for a specified outdoor activity during any given season. Four pedestrian comfort classes are based on 80% non-exceedance gust wind speed ranges, which include (i) Sitting; (ii) Standing; (iii) Walking; and (iv) Uncomfortable. More specifically, the comfort classes and associated gust wind speed ranges are summarized as follows:

(i) **Sitting** – A wind speed below 16 km/h (i.e. 0 – 16 km/h) would be considered acceptable for sedentary activities, including sitting.

(ii) **Standing** – A wind speed below 22 km/h (i.e. 16 km/h – 22 km/h) is acceptable for activities such as standing or leisurely strolling.

(iii) **Walking** – A wind speed below 30 km/h (i.e. 22 km/h – 30 km/h) is acceptable for walking or more vigorous activities.

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

The pedestrian safety wind speed guideline is based on the approximate threshold that would cause a vulnerable member of the population to fall. A 0.1% exceedance gust wind speed of greater than 90 km/h is classified as dangerous.

The wind speeds associated with the above categories are gust wind speeds. Corresponding mean wind speeds are approximately calculated as gust wind speed minus 1.5 times the root-mean-square (rms) of the wind speed measurements. Gust speeds are used in the guidelines because people tend to be more sensitive to wind gusts than to steady winds for lower wind speed ranges. For strong winds approaching dangerous levels, this effect is less important, because the mean wind can also cause problems for pedestrians. The gust 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.

THE BEAUFORT SCALE

NUMBER	DESCRIPTION	WIND SPEED (KM/H)	DESCRIPTION
2	Light Breeze	4-8	Wind felt on faces
3	Gentle Breeze	8-15	Leaves and small twigs in constant motion; Wind extends light flags
4	Moderate Breeze	15-22	Wind raises dust and loose paper; Small branches are moved
5	Fresh Breeze	22-30	Small trees in leaf begin to sway
6	Strong Breeze	30-40	Large branches in motion; Whistling heard in electrical wires; Umbrellas used with difficulty
7	Moderate Gale	40-50	Whole trees in motion; Inconvenient walking against wind
8	Gale	50-60	Breaks twigs off trees; Generally impedes progress

Experience and research on people's perception of mechanical wind effects has shown that if the wind speed levels are exceeded for more than 20% of the time, the activity level would be judged to be uncomfortable by most people. For instance, if wind speeds of 16 km/h were exceeded for more than 20% of the time most pedestrians would judge that location to be too windy for sitting or more sedentary activities. Similarly, if 30 km/h at a location were exceeded for more than 20% of the time, walking or less vigorous activities would be considered uncomfortable. As most of 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 at tested locations, the assessment of pedestrian comfort involves determining the suitability of the predicted wind conditions for their associated spaces. This step involves comparing the predicted comfort class to the desired comfort class, which is dictated by the location type represented by the sensor (i.e. a sidewalk, building entrance, amenity space, or other). An overview of common pedestrian location types and their desired comfort classes are summarized on the following page.

DESIRED PEDESTRIAN COMFORT CLASSES FOR VARIOUS LOCATION TYPES

Location Types	Desired Comfort Classes
Primary Building Entrance	Standing
Secondary Building Access Point	Walking
Public Sidewalks / Pedestrian Walkways	Walking
Outdoor Amenity Spaces	Sitting / Standing
Cafés / Patios / Benches / Gardens	Sitting / Standing
Plazas	Standing / Walking
Transit Stops	Standing
Public Parks	Sitting / Walking
Garage / Service Entrances	Walking
Vehicular Drop-Off Zones	Walking
Laneways / Loading Zones	Walking

Following the comparison, the location is assigned a descriptor that indicates the suitability of the location for its intended use. The suitability descriptors are summarized as follows:

- **Acceptable**: The predicted wind conditions are suitable for the intended uses of the associated outdoor spaces without the need for mitigation.
- **Acceptable with Mitigation**: The predicted wind conditions are not acceptable for the intended use of a space; however, following the implementation of typical mitigation measures, the wind conditions are expected to satisfy the required comfort guidelines.
- **Mitigation Testing Recommended**: The effectiveness of typical mitigation measures is uncertain, and additional wind tunnel testing is recommended to explore other options and to ensure compliance with the comfort guidelines.
- **Incompatible**: The predicted wind conditions will interfere with the comfortable and/or safe use of a space and cannot be feasibly mitigated to acceptable levels.

5. RESULTS AND DISCUSSION

5.1 Pedestrian Comfort Suitability – Future Conditions

Table A1 in Appendix A provide a summary of seasonal comfort predictions for each sensor location under the future massing scenario considering the study building and all approved surrounding developments. The tables indicate the 80% non-exceedance gust wind speeds and corresponding comfort classifications as defined in Section 4.4. In other words, a gust wind speed threshold of 19.1 for the summer season indicates that 80% of the measured data falls at or below 19.1 km/h during the summer months and conditions are therefore suitable for standing, as the 80% threshold value falls within the exceedance range of 16-22 km/h for standing. The tables include the predicted threshold values for each sensor location during each season, accompanied by the corresponding predicted comfort class (i.e. sitting, standing, walking, etc.).

The most significant findings of the PLW are summarized in the Section 5.2. To assist with understanding and interpretation, predicted conditions for the proposed development are also illustrated in colour-coded format in Figures 2A through 5B. Conditions suitable for sitting are represented by the colour green, while standing is represented by yellow, and walking by blue. Measured mean and gust velocity ratios, which constitutes the raw data upon which the results are based, will be made available upon request.

5.2 Summary of Findings – Future Conditions

Based on the analysis of the measured data, consideration of local climate data, and the suitability descriptors provided in Table A1 in Appendix A, this section summarizes the most significant findings of the PLW study with respect to future conditions, as follows:

1. All public sidewalks within and surrounding the proposed development will experience wind conditions suitable for walking or better during each seasonal period, which is acceptable for the intended uses of the spaces.
2. All laneways and surface parking surrounding the development will be comfortable for standing or better throughout the year, which is acceptable.
3. Most building entrances serving the development will be comfortable for standing or better on a seasonal basis, which is acceptable. A lone exception is at the south elevation retail entrance

(Sensor 31), where conditions exceed the standing criterion during the winter months. To ensure conditions at this entrance are comfortable for standing or better throughout the year, it is recommended to either recess the entrance within the façade, or flank with vertical wind barriers. Alternatively, this entrance could be relocated further to the west, or to the east façade, where conditions are calmer. Such changes to the retail entrance configuration are considered minor and can be made a future date as the design progresses.

4. The public transit stops at Yonge Street and Alcorn Avenue (Sensors 8 & 9) will experience wind conditions suitable for standing or better throughout the year, which is appropriate.

5. The rooftop amenity terrace (Sensor 36) will be comfortable for sitting or more sedentary activities throughout the year, without the need for mitigation.

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience conditions too windy for walking, or that are considered unsafe.

5.3 Pedestrian Comfort Suitability – Existing Versus Future Conditions

To evaluate the influence of the study building on existing wind conditions at and near the study site, an additional pedestrian level wind test was performed for the existing site massing without the study building present. A comparison of wind comfort results for the existing and future configurations is provided in Tables B1 to B3 in Appendix B, which provide a summary of the comparative wind comfort predictions based on summer and winter wind statistics. The future and existing massing scenarios are shown in Photographs 1 through 6 following the main text.

Pedestrian wind comfort resulting from the construction of the study building and future surrounding developments may be described as being *unchanged*, *improved*, or *reduced* as compared to the existing conditions. These designations are not strictly determined by the predicted percentage values, rather by the change to the predicted comfort class.

A review of Tables B1 to B3 indicates that wind comfort will be reduced over sidewalks directly north and south of the site, along Alcorn Avenue and Birch Avenue, respectively, as well as along Yonge Street to the east and south, while remaining generally unchanged elsewhere. Where wind speeds have increased, conditions nevertheless remain acceptable for the intended uses.

6. CONCLUSIONS AND RECOMMENDATIONS

This report summarizes the methodology, results, and recommendations related to a pedestrian level wind study for a proposed mixed-use development located at 8 Birch Avenue and 1198-1210 Yonge Street in Toronto, Ontario. The study was performed in accordance with industry standard wind tunnel testing and data analysis procedures.

A complete summary of the predicted wind conditions is provided in Section 5.2 of this report and is also illustrated in Figures 2A through 5B, as well as Tables A1 and B1-B3 in the appendices. Based on the wind tunnel test results, meteorological data analysis, and experience with similar developments in the Toronto area, we conclude that the future wind conditions over most grade-level pedestrian wind-sensitive areas within and surrounding the study site will be acceptable for the intended uses on a seasonal basis. To ensure the south elevation retail entrance is comfortable for standing or better throughout the year, mitigation is recommended, as described in Section 5.2. Additionally, the rooftop outdoor amenity will experience wind conditions comfortable for sitting or more sedentary activities throughout the year without the need for mitigation.

A comparison of the existing versus future wind comfort surrounding the study site indicates that the proposed development will generally reduce conditions over nearby sidewalks to the north, east, and south, with conditions generally unchanged elsewhere. Where wind speeds increase, conditions nevertheless remain acceptable for the intended uses.

Within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, no areas over the study site were found to experience conditions too windy for walking, or that could be considered unsafe.

This concludes our pedestrian level wind study and report. Please advise the undersigned of any questions or comments.

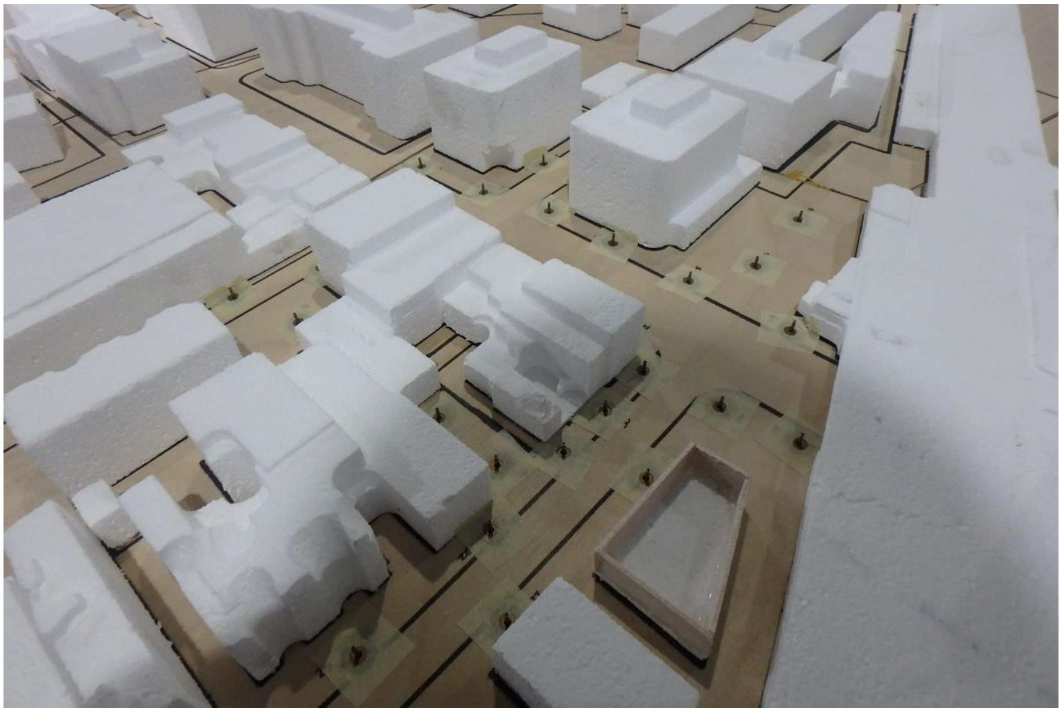
Sincerely,

Gradient Wind Engineering Inc.

Patrick Shorey, B.A.Sc., EIT
Junior Wind Scientist

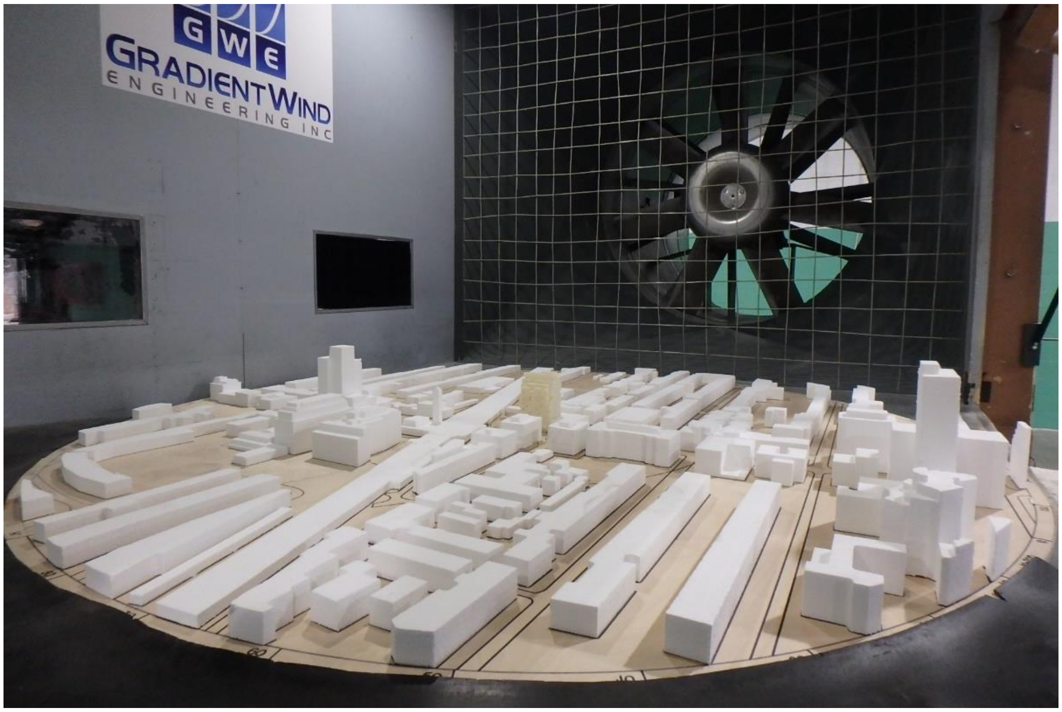
Andrew Sliasas, M.A.Sc., P.Eng.,
Principal

GW19-200-WTPLW

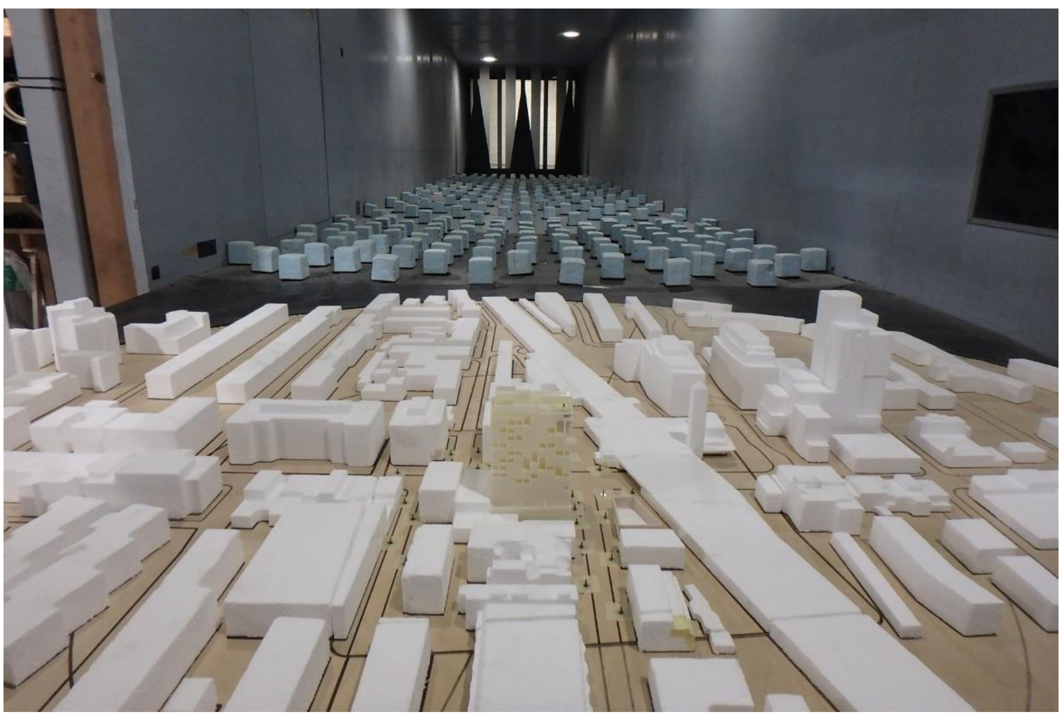


PHOTOGRAPH 1: CLOSE-UP VIEW OF EXISTING CONTEXT MODEL LOOKING NORTHEAST

PHOTOGRAPH 2: CLOSE-UP VIEW OF EXISTING CONTEXT MODEL LOOKING SOUTHWEST



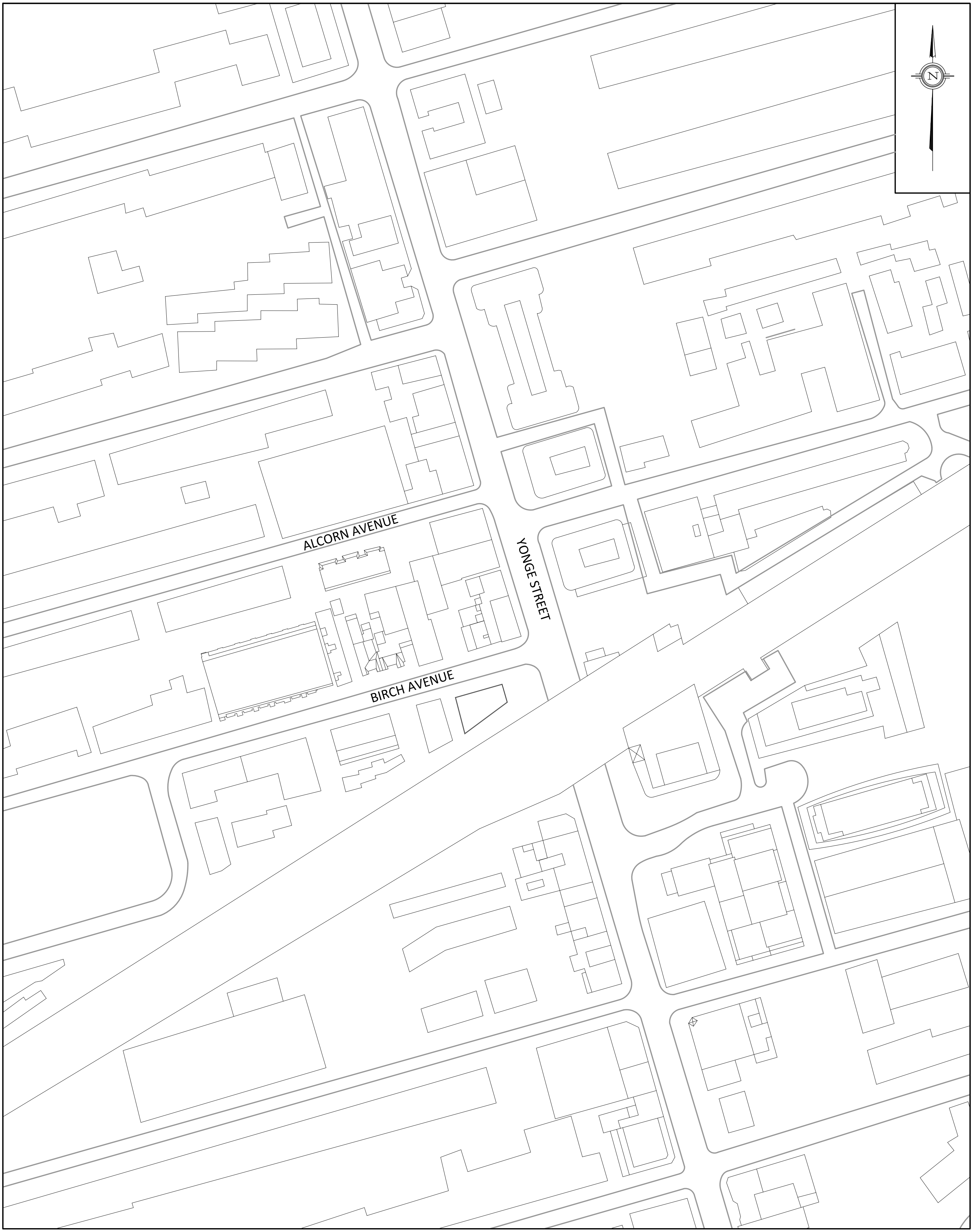
PHOTOGRAPH 3: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING DOWNWIND



PHOTOGRAPH 4: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING UPWIND

PHOTOGRAPH 5: CLOSE-UP VIEW OF STUDY MODEL LOOKING NORTHEAST

PHOTOGRAPH 6: CLOSE-UP VIEW OF STUDY MODEL LOOKING SOUTHWEST



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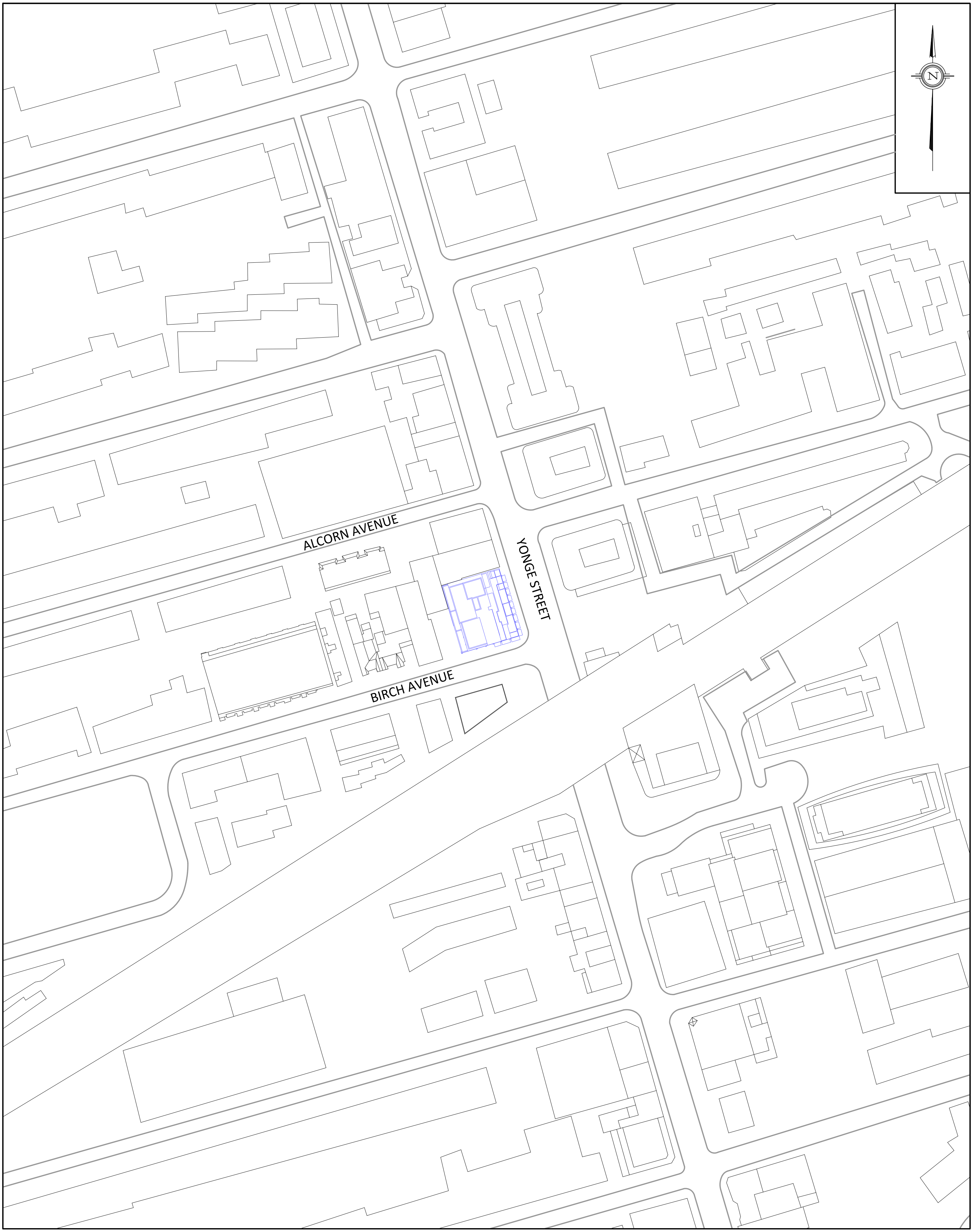
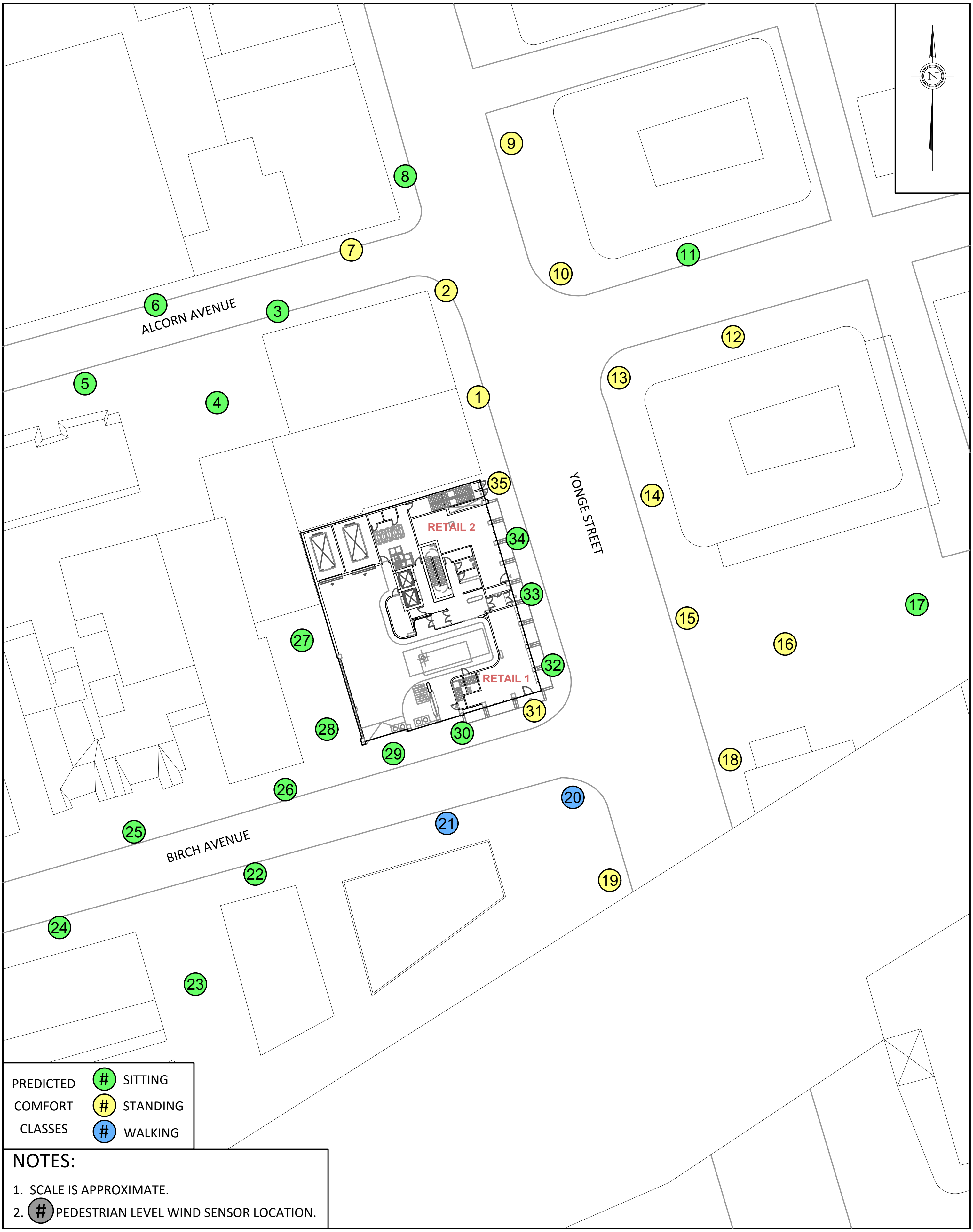
PROJECT	YONGE & BIRCH, TORONTO PEDESTRIAN LEVEL WIND STUDY
SCALE	1:2500 (APPROX.)
DRAWING NO.	GWE19-200-PLW-1A
DATE	NOVEMBER 18, 2021
DRAWN BY	C.E.
DESCRIPTION	FIGURE 1A: SITE PLAN AND SURROUNDING CONTEXT EXISTING TEST SCENARIO



GRADIENTWIND ENGINEERS & SCIENTISTS 127 WALGREEN ROAD, OTTAWA, ON 613 836 0934 • GRADIENTWIND.COM	PROJECT: YONGE & BIRCH, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1B: SITE PLAN AND SURROUNDING CONTEXT FUTURE TEST SCENARIO
	SCALE: 1:2500 (APPROX.)	DRAWING NO. GWE19-200-PLW-1B	
	DATE: NOVEMBER 18, 2021	DRAWN BY: C.E.	



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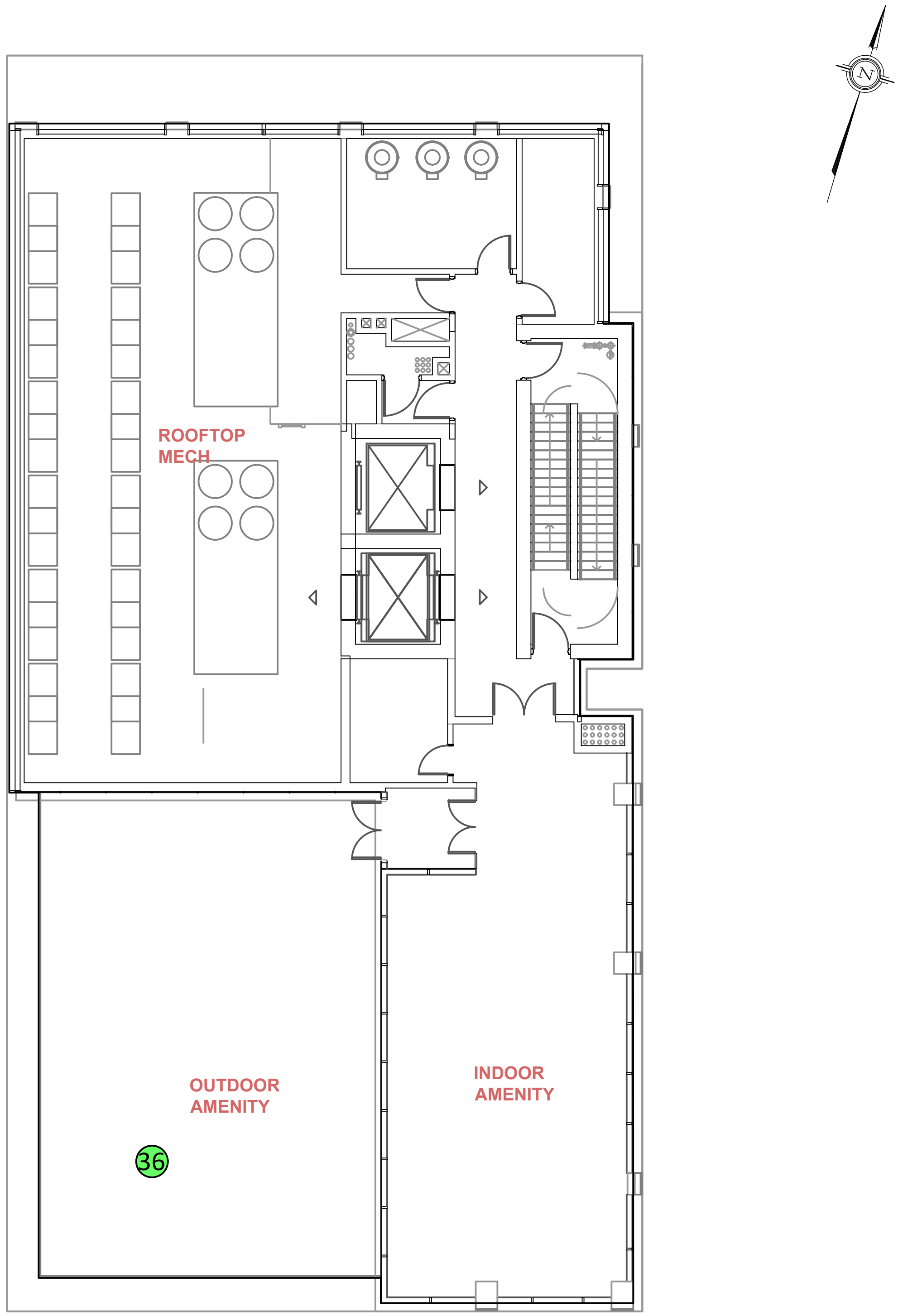
PROJECT	YONGE & BIRCH, TORONTO PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:800 (APPROX.)	DRAWING NO.	GWE19-200-PLW-2A
DATE	NOVEMBER 18, 2021	DRAWN BY	C.E.

DESCRIPTION

FIGURE 2A: SPRING
GROUND FLOOR PLAN
PEDESTRIAN COMFORT PREDICTIONS



PREDICTED COMFORT CLASSES	
#	SITTING
#	STANDING
#	WALKING

NOTES:

1. SCALE IS APPROXIMATE.
2. # PEDESTRIAN LEVEL WIND SENSOR LOCATION.

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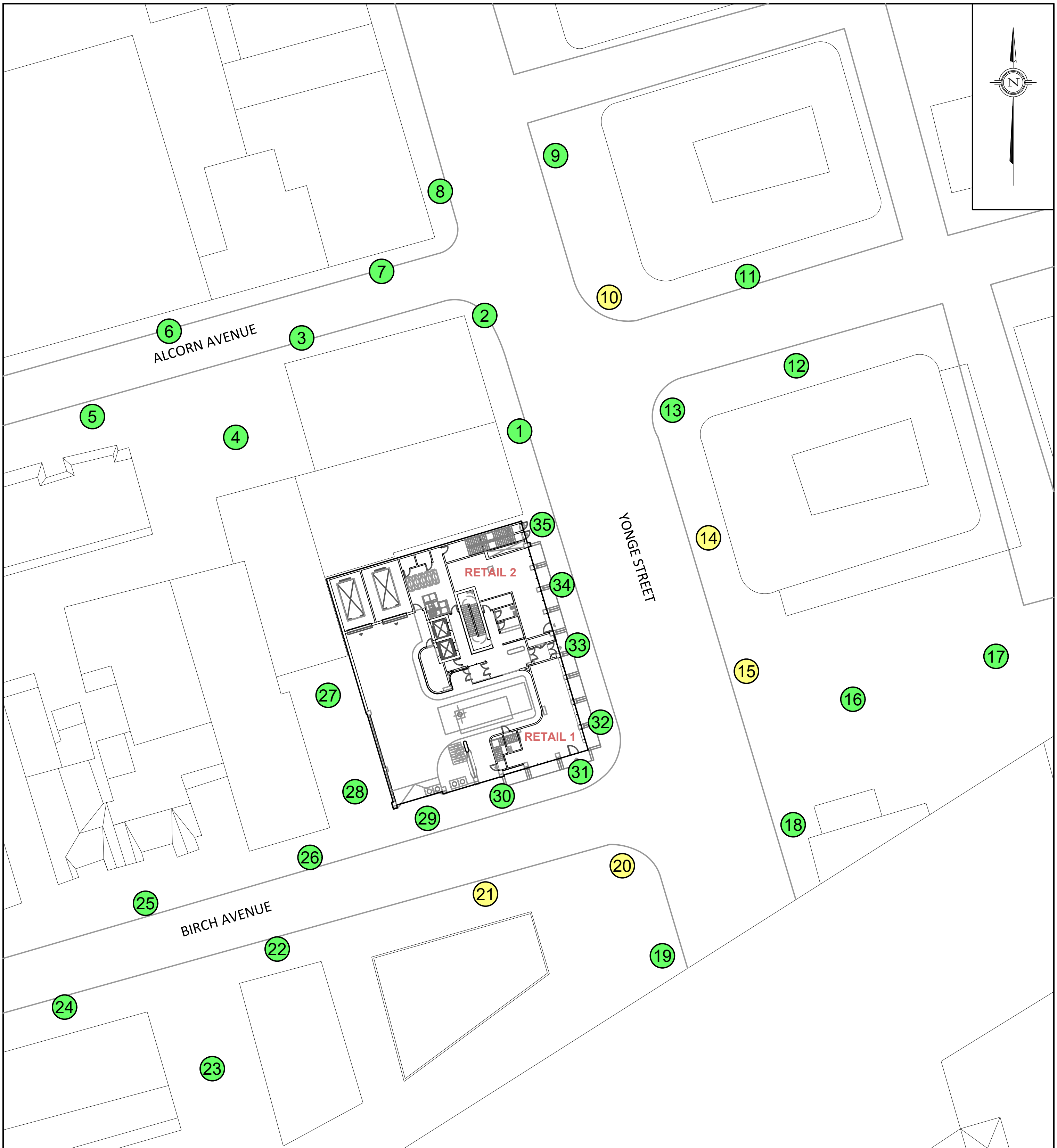
SCALE	1:200 (APPROX.)
DRAWING NO.	GWE19-200-PLW-2B
DATE	NOVEMBER 18, 2021
DRAWN BY	C.E.
DESCRIPTION	FIGURE 2B: SPRING MPH FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS



NOTES:

1. SCALE IS APPROXIMATE.
2. # PEDESTRIAN LEVEL WIND SENSOR LOCATION.

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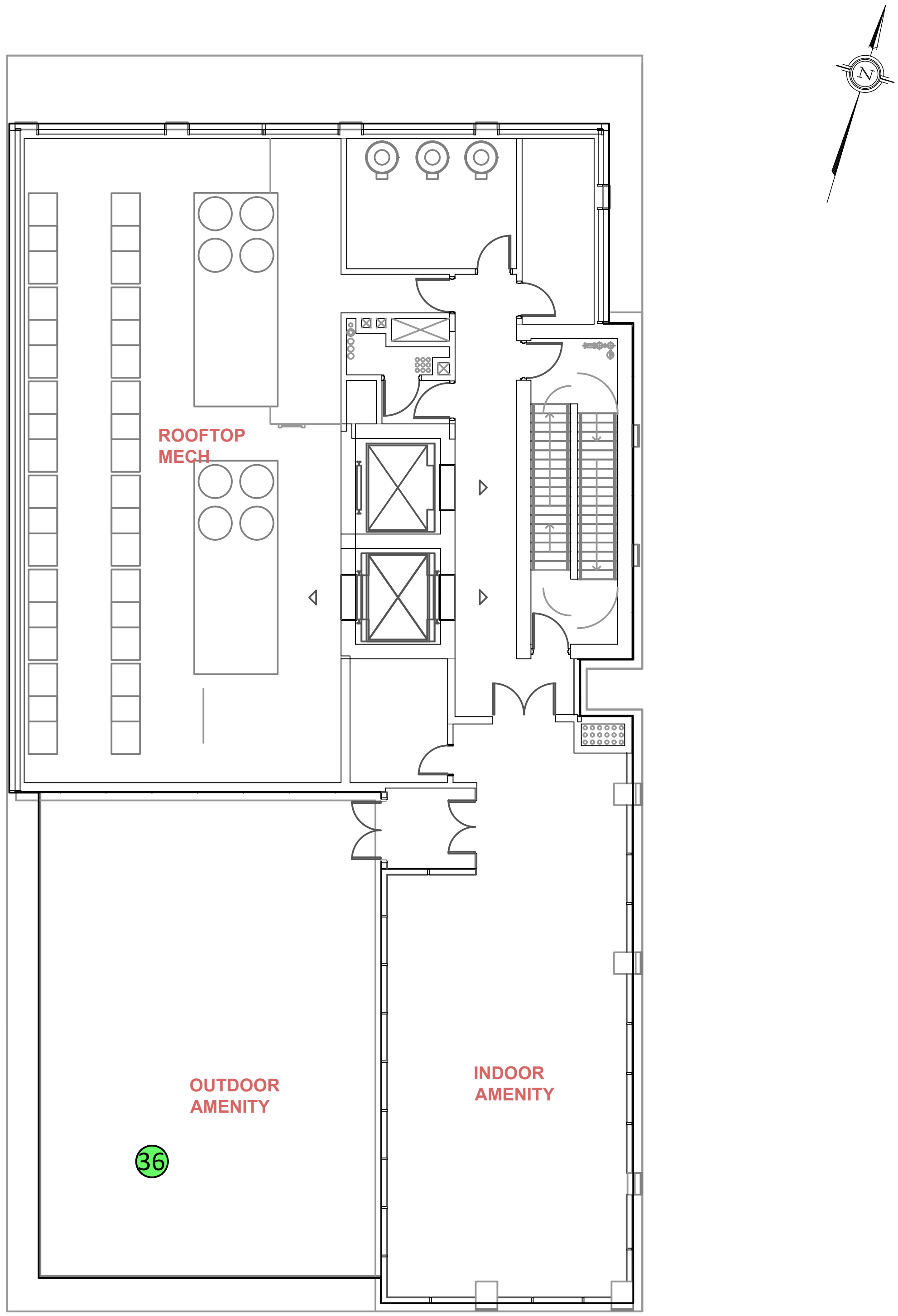
PROJECT	YONGE & BIRCH, TORONTO PEDESTRIAN LEVEL WIND STUDY
SCALE	1:800 (APPROX.)
DRAWING NO.	GWE19-200-PLW-3A
DATE	NOVEMBER 18, 2021
DRAWN BY	C.E.
DESCRIPTION	FIGURE 3A: SUMMER GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS



PREDICTED COMFORT CLASSES
- # SITTING
- # STANDING
- # WALKING

NOTES:

1. SCALE IS APPROXIMATE.
2. # PEDESTRIAN LEVEL WIND SENSOR LOCATION.

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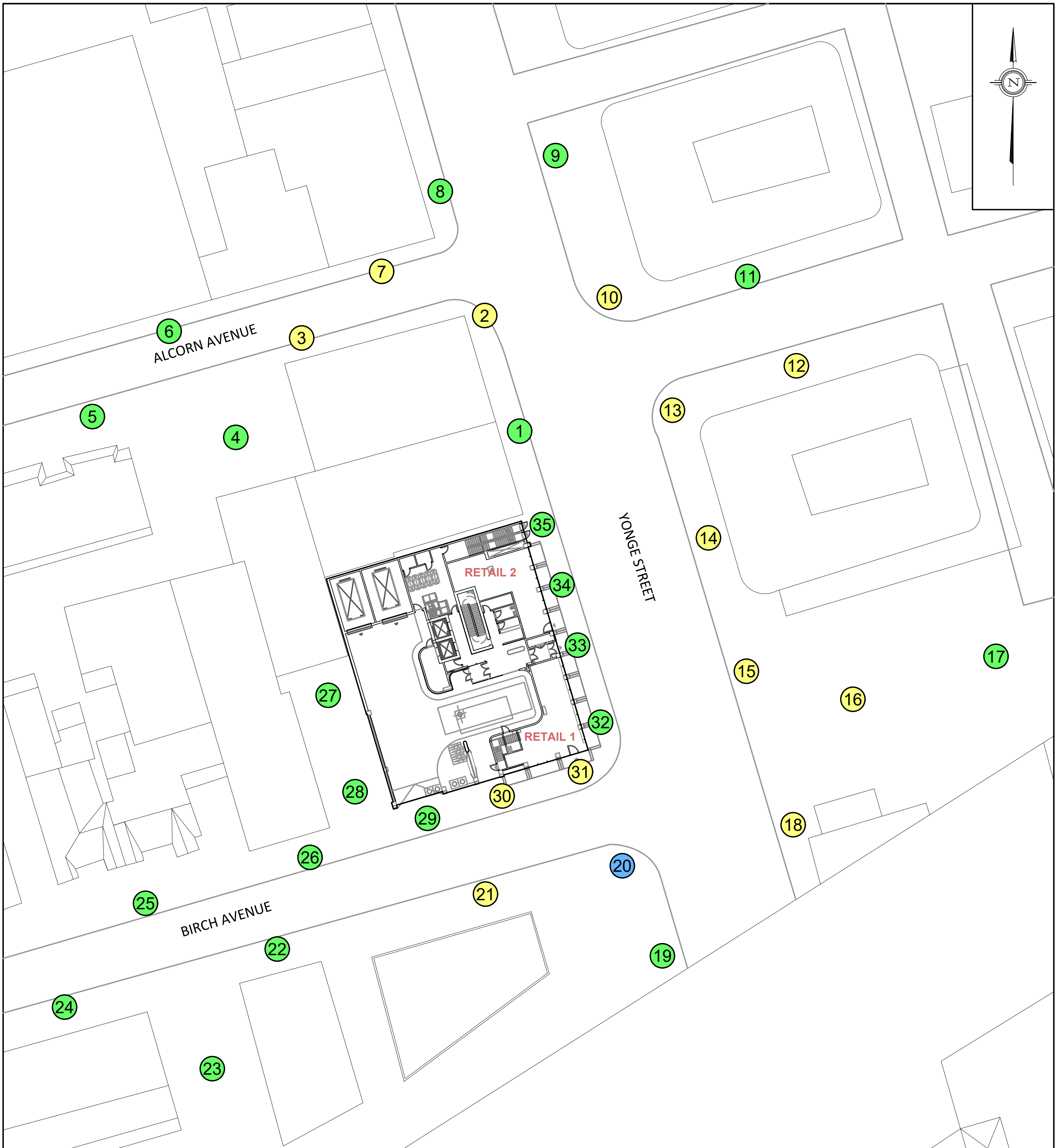
PROJECT	YONGE & BIRCH, TORONTO PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:200 (APPROX.)	DRAWING NO.	GWE19-200-PLW-3B
DATE	NOVEMBER 18, 2021	DRAWN BY	C.E.

DESCRIPTION

FIGURE 3B: SUMMER
MPH FLOOR PLAN
PEDESTRIAN COMFORT PREDICTIONS



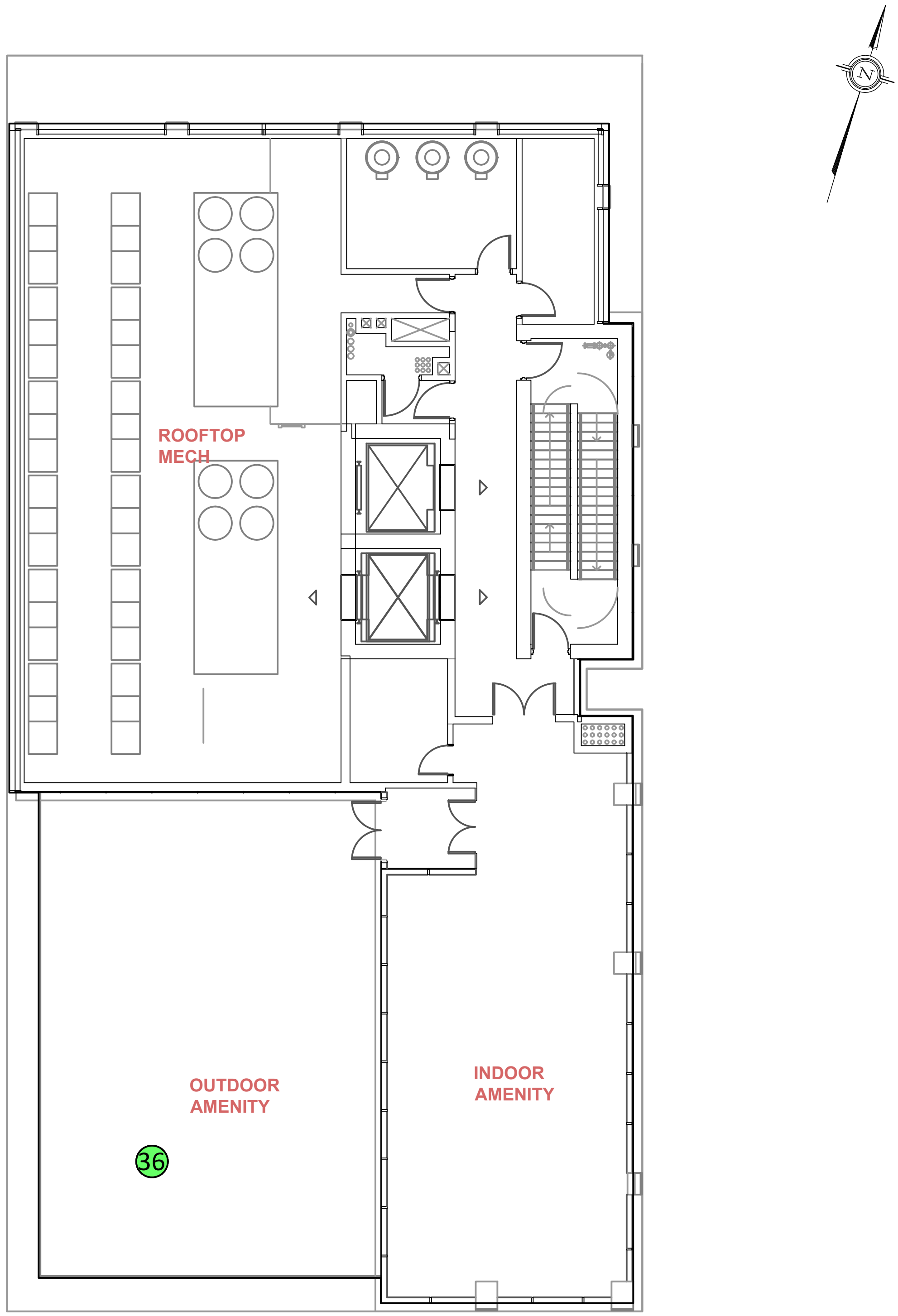
PREDICTED COMFORT CLASSES

- (#) SITTING
- (#) STANDING
- (#) WALKING

NOTES:

1. SCALE IS APPROXIMATE.
2. (#) PEDESTRIAN LEVEL WIND SENSOR LOCATION.

GRADIENTWIND ENGINEERS & SCIENTISTS 127 WALGREEN ROAD, OTTAWA, ON 613 836 0934 • GRADIENTWIND.COM	PROJECT: YONGE & BIRCH, TORONTO PEDESTRIAN LEVEL WIND STUDY SCALE: 1:800 (APPROX.) DRAWING NO.: GWE19-200-PLW-4A DATE: NOVEMBER 18, 2021 DRAWN BY: C.E.	DESCRIPTION: FIGURE 4A: AUTUMN GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS



PREDICTED COMFORT CLASSES	
#	SITTING
#	STANDING
#	WALKING

NOTES:

1. SCALE IS APPROXIMATE.
2. # PEDESTRIAN LEVEL WIND SENSOR LOCATION.

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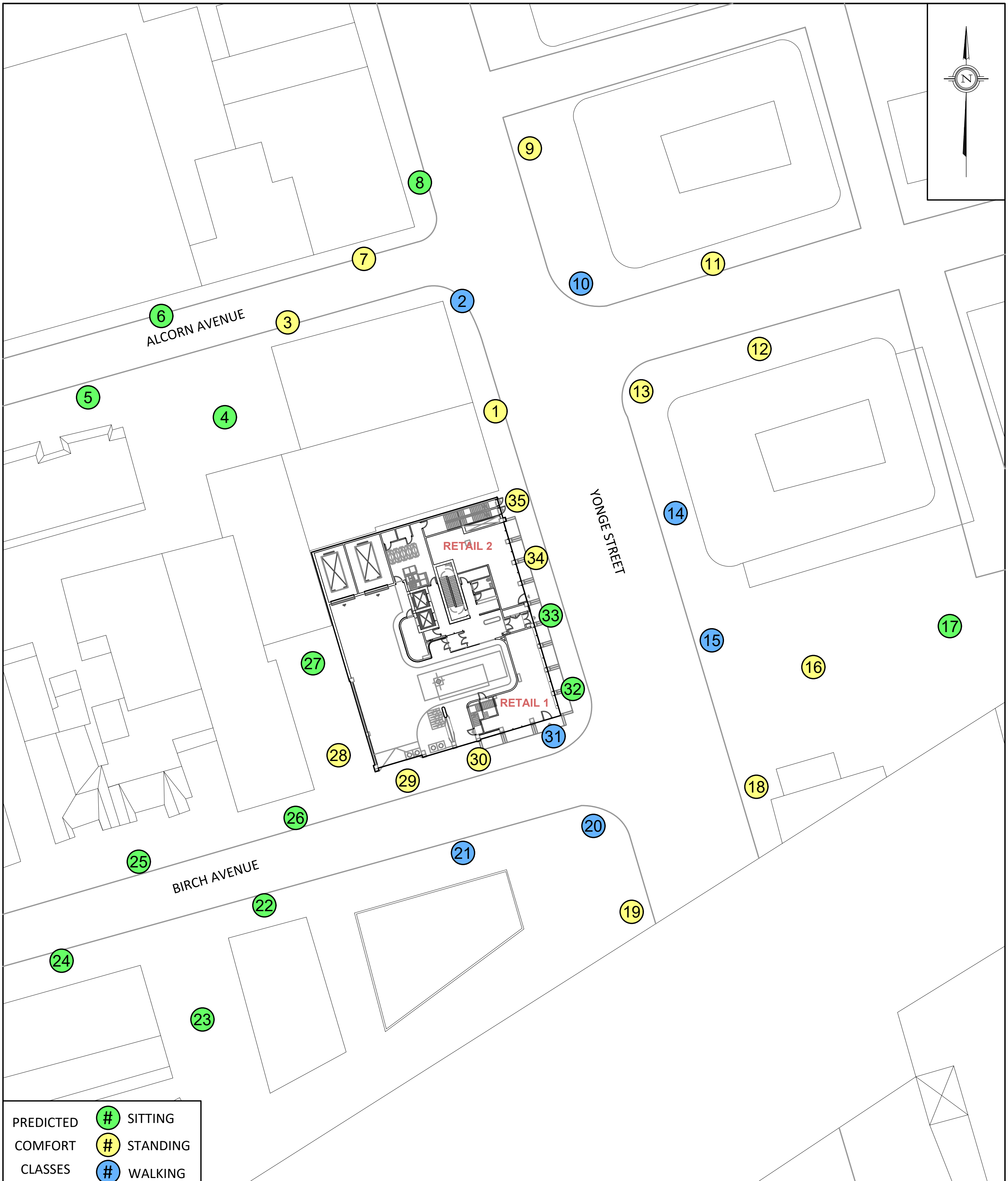
PROJECT	YONGE & BIRCH, TORONTO PEDESTRIAN LEVEL WIND STUDY
SCALE	1:200 (APPROX.)
DRAWING NO.	GWE19-200-PLW-4B
DATE	NOVEMBER 18, 2021
DRAWN BY	C.E.
DESCRIPTION	FIGURE 4B: AUTUMN MPH FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS



NOTES:

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2. # PEDESTRIAN LEVEL WIND SENSOR LOCATION.

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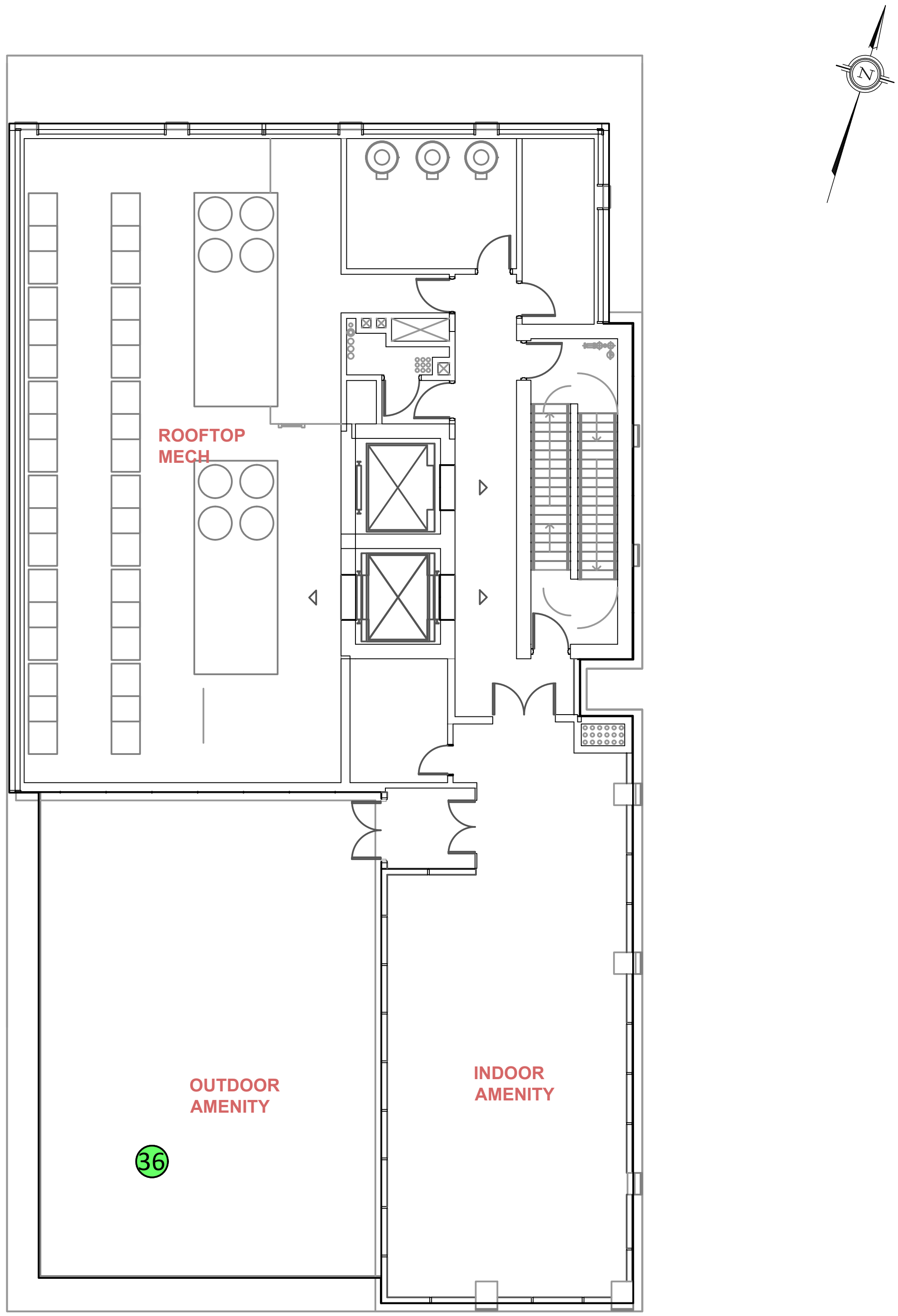
PROJECT		DESCRIPTION
YONGE & BIRCH, TORONTO PEDESTRIAN LEVEL WIND STUDY		FIGURE 5A: WINTER GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:800 (APPROX.)	DRAWING NO.: GWE19-200-PLW-5A	
DATE: NOVEMBER 18, 2021	DRAWN BY: C.E.	



PREDICTED COMFORT CLASSES
- # SITTING
- # STANDING
- # WALKING

NOTES:

1. SCALE IS APPROXIMATE.
2. # PEDESTRIAN LEVEL WIND SENSOR LOCATION.

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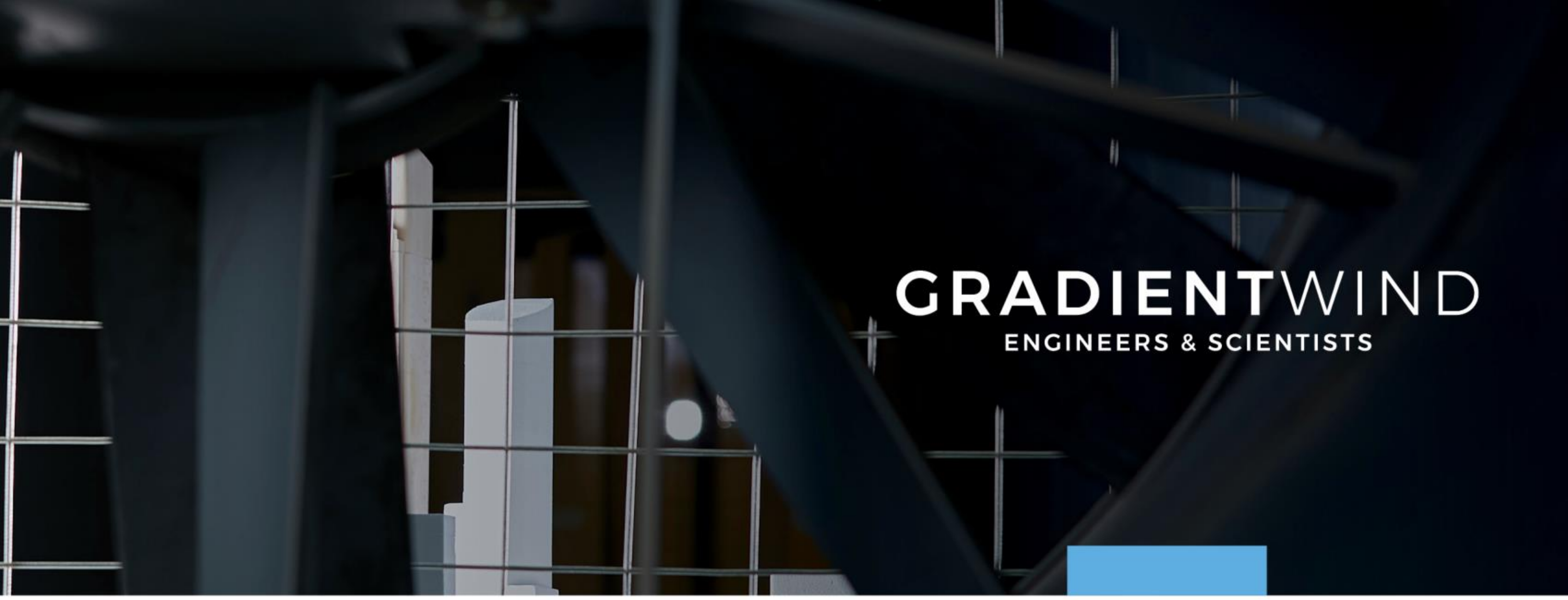
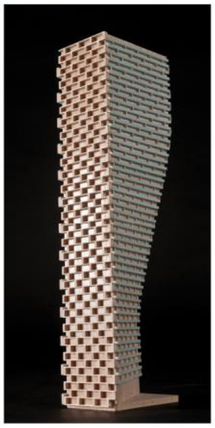
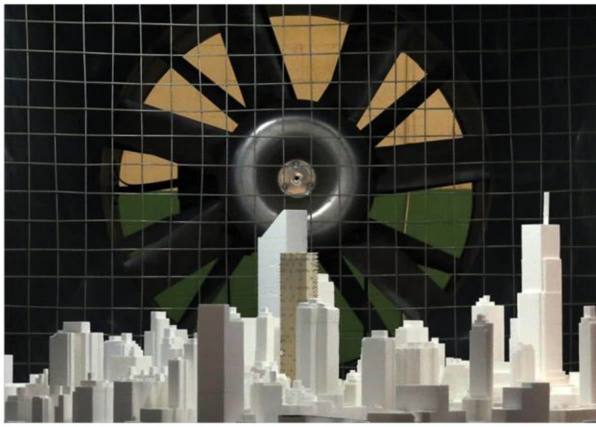
PROJECT	YONGE & BIRCH, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION FIGURE 5B: WINTER MPH FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
SCALE	1:200 (APPROX.)	DRAWING NO. GWE19-200-PLW-5B	
DATE	NOVEMBER 18, 2021	DRAWN BY C.E.	







APPENDIX A

PEDESTRIAN COMFORT SUITABILITY, TABLE A1
(FUTURE CONDITIONS)

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Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-16 km/h = Sitting, 16-22 km/h = Standing, 22-30 km/h = Walking, >30 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE A1: SUMMARY OF PEDESTRIAN COMFORT (FUTURE CONDITIONS)

Sensor	Pedestrian Comfort								Pedestrian Safety	
	Spring		Summer		Autumn		Winter		Annual	
	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Safety Class
1	16.2	Standing	12.4	Sitting	15.4	Sitting	17.6	Standing	46.5	Safe
2	20.8	Standing	16.0	Sitting	20.1	Standing	23.1	Walking	58.8	Safe
3	15.3	Sitting	12.3	Sitting	16.1	Standing	18.4	Standing	51.1	Safe
4	14.2	Sitting	10.8	Sitting	12.9	Sitting	14.9	Sitting	35.4	Safe
5	12.0	Sitting	9.3	Sitting	10.7	Sitting	12.3	Sitting	28.7	Safe
6	11.8	Sitting	9.2	Sitting	11.0	Sitting	12.5	Sitting	28.2	Safe
7	16.7	Standing	13.1	Sitting	16.1	Standing	18.2	Standing	44.5	Safe
8	12.3	Sitting	9.1	Sitting	11.2	Sitting	12.8	Sitting	43.9	Safe
9	16.0	Standing	12.5	Sitting	15.9	Sitting	17.9	Standing	44.8	Safe
10	20.4	Standing	16.1	Standing	20.5	Standing	23.5	Walking	58.7	Safe
11	15.3	Sitting	12.4	Sitting	16.0	Sitting	18.6	Standing	53.6	Safe
12	18.1	Standing	14.3	Sitting	17.1	Standing	19.9	Standing	47.4	Safe
13	18.6	Standing	15.2	Sitting	18.6	Standing	20.8	Standing	50.0	Safe
14	19.5	Standing	16.2	Standing	19.6	Standing	22.0	Walking	54.7	Safe
15	21.9	Standing	17.9	Standing	21.8	Standing	25.4	Walking	65.3	Safe
16	16.6	Standing	13.9	Sitting	17.6	Standing	19.9	Standing	49.8	Safe
17	14.3	Sitting	11.9	Sitting	14.3	Sitting	16.0	Sitting	38.8	Safe
18	16.9	Standing	13.5	Sitting	16.4	Standing	18.8	Standing	46.1	Safe
19	16.6	Standing	13.2	Sitting	15.6	Sitting	18.1	Standing	40.7	Safe
20	22.8	Walking	18.4	Standing	22.3	Walking	25.8	Walking	66.3	Safe
21	22.3	Walking	17.7	Standing	21.0	Standing	24.6	Walking	56.1	Safe
22	14.7	Sitting	11.1	Sitting	13.5	Sitting	15.8	Sitting	39.8	Safe
23	13.3	Sitting	10.5	Sitting	12.9	Sitting	14.4	Sitting	36.9	Safe
24	14.2	Sitting	10.9	Sitting	13.2	Sitting	15.4	Sitting	38.9	Safe
25	12.4	Sitting	9.5	Sitting	11.3	Sitting	13.0	Sitting	31.1	Safe
26	12.4	Sitting	9.6	Sitting	11.1	Sitting	12.5	Sitting	38.4	Safe
27	12.6	Sitting	9.8	Sitting	12.3	Sitting	14.0	Sitting	35.4	Safe
28	15.0	Sitting	12.2	Sitting	14.4	Sitting	16.1	Standing	37.9	Safe
29	14.6	Sitting	11.3	Sitting	14.3	Sitting	16.6	Standing	44.4	Safe
30	15.8	Sitting	12.3	Sitting	16.2	Standing	19.4	Standing	53.0	Safe
31	20.6	Standing	15.9	Sitting	20.2	Standing	23.3	Walking	56.4	Safe
32	15.0	Sitting	11.8	Sitting	13.4	Sitting	15.3	Sitting	35.4	Safe
33	14.7	Sitting	11.5	Sitting	13.4	Sitting	15.7	Sitting	38.1	Safe
34	15.5	Sitting	12.2	Sitting	14.4	Sitting	16.6	Standing	41.1	Safe
35	16.2	Standing	12.9	Sitting	15.4	Sitting	17.6	Standing	42.6	Safe
36	13.3	Sitting	10.4	Sitting	12.0	Sitting	13.9	Sitting	32.2	Safe

APPENDIX B

PEDESTRIAN COMFORT SUITABILITY, TABLES B1-B3
(EXISTING VS FUTURE CONDITIONS)

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Guidelines	
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Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE B1: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

Sensor	Massing Scenario	Summer Pedestrian Comfort			Winter Pedestrian Comfort		
		Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing	Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing
1	Existing	10.5	Sitting	-	14.2	Sitting	-
	Future	12.4	Sitting	Unchanged	17.6	Standing	Reduced
2	Existing	11.3	Sitting	-	15.2	Sitting	-
	Future	16.0	Sitting	Unchanged	23.1	Walking	Reduced
3	Existing	10.1	Sitting	-	13.2	Sitting	-
	Future	12.3	Sitting	Unchanged	18.4	Standing	Reduced
4	Existing	9.2	Sitting	-	12.6	Sitting	-
	Future	10.8	Sitting	Unchanged	14.9	Sitting	Unchanged
5	Existing	9.9	Sitting	-	13.0	Sitting	-
	Future	9.3	Sitting	Unchanged	12.3	Sitting	Unchanged
6	Existing	9.7	Sitting	-	12.8	Sitting	-
	Future	9.2	Sitting	Unchanged	12.5	Sitting	Unchanged
7	Existing	10.8	Sitting	-	14.6	Sitting	-
	Future	13.1	Sitting	Unchanged	18.2	Standing	Reduced
8	Existing	8.7	Sitting	-	12.2	Sitting	-
	Future	9.1	Sitting	Unchanged	12.8	Sitting	Unchanged
9	Existing	12.0	Sitting	-	16.5	Standing	-
	Future	12.5	Sitting	Unchanged	17.9	Standing	Unchanged
10	Existing	13.5	Sitting	-	19.2	Standing	-
	Future	16.1	Standing	Reduced	23.5	Walking	Reduced
11	Existing	13.1	Sitting	-	18.4	Standing	-
	Future	12.4	Sitting	Unchanged	18.6	Standing	Unchanged
12	Existing	14.1	Sitting	-	19.2	Standing	-
	Future	14.3	Sitting	Unchanged	19.9	Standing	Unchanged
13	Existing	13.5	Sitting	-	18.3	Standing	-
	Future	15.2	Sitting	Unchanged	20.8	Standing	Unchanged
14	Existing	10.7	Sitting	-	14.2	Sitting	-
	Future	16.2	Standing	Reduced	22.0	Walking	Reduced
15	Existing	12.2	Sitting	-	17.3	Standing	-
	Future	17.9	Standing	Reduced	25.4	Walking	Reduced

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-16 km/h = Sitting, 16-22 km/h = Standing, 22-30 km/h = Walking, >30 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

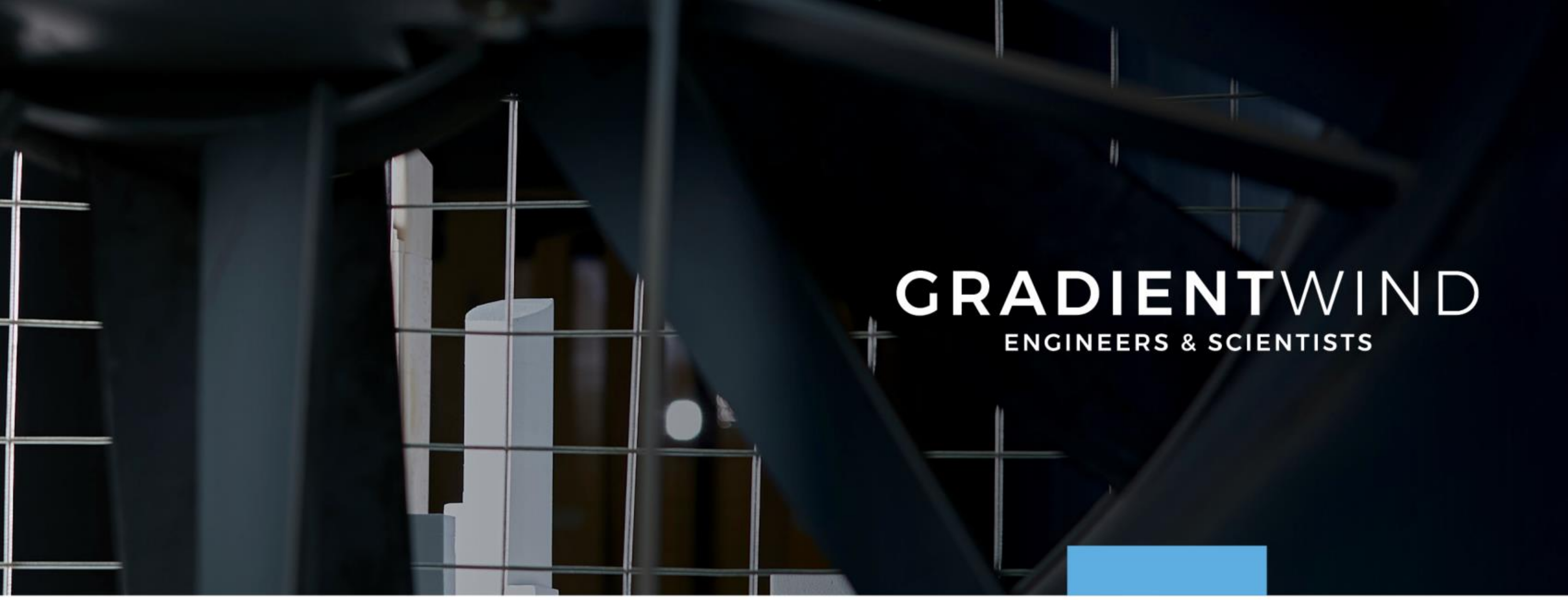
TABLE B2: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

Sensor	Massing Scenario	Summer Pedestrian Comfort			Winter Pedestrian Comfort		
		Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing	Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing
16	Existing	12.8	Sitting	-	17.7	Standing	-
	Future	13.9	Sitting	Unchanged	19.9	Standing	Unchanged
17	Existing	12.0	Sitting	-	16.2	Standing	-
	Future	11.9	Sitting	Unchanged	16.0	Sitting	Improved
18	Existing	10.2	Sitting	-	14.5	Sitting	-
	Future	13.5	Sitting	Unchanged	18.8	Standing	Reduced
19	Existing	11.0	Sitting	-	14.7	Sitting	-
	Future	13.2	Sitting	Unchanged	18.1	Standing	Reduced
20	Existing	10.8	Sitting	-	15.0	Sitting	-
	Future	18.4	Standing	Reduced	25.8	Walking	Reduced
21	Existing	9.5	Sitting	-	12.9	Sitting	-
	Future	17.7	Standing	Reduced	24.6	Walking	Reduced
22	Existing	10.0	Sitting	-	14.0	Sitting	-
	Future	11.1	Sitting	Unchanged	15.8	Sitting	Unchanged
23	Existing	11.4	Sitting	-	15.4	Sitting	-
	Future	10.5	Sitting	Unchanged	14.4	Sitting	Unchanged
24	Existing	11.4	Sitting	-	16.0	Sitting	-
	Future	10.9	Sitting	Unchanged	15.4	Sitting	Unchanged
25	Existing	9.3	Sitting	-	12.3	Sitting	-
	Future	9.5	Sitting	Unchanged	13.0	Sitting	Unchanged
26	Existing	10.5	Sitting	-	14.7	Sitting	-
	Future	9.6	Sitting	Unchanged	12.5	Sitting	Unchanged
27	Existing	7.9	Sitting	-	10.6	Sitting	-
	Future	9.8	Sitting	Unchanged	14.0	Sitting	Unchanged
28	Existing	8.7	Sitting	-	11.3	Sitting	-
	Future	12.2	Sitting	Unchanged	16.1	Standing	Reduced
29	Existing	8.9	Sitting	-	12.0	Sitting	-
	Future	11.3	Sitting	Unchanged	16.6	Standing	Reduced
30	Existing	10.0	Sitting	-	13.7	Sitting	-
	Future	12.3	Sitting	Unchanged	19.4	Standing	Reduced

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-16 km/h = Sitting, 16-22 km/h = Standing, 22-30 km/h = Walking, >30 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE B3: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

Sensor	Massing Scenario	Summer Pedestrian Comfort			Winter Pedestrian Comfort		
		Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing	Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing
31	Existing	10.3	Sitting	-	13.9	Sitting	-
	Future	15.9	Sitting	Unchanged	23.3	Walking	Reduced
32	Existing	8.9	Sitting	-	11.4	Sitting	-
	Future	11.8	Sitting	Unchanged	15.3	Sitting	Unchanged
33	Existing	8.9	Sitting	-	12.0	Sitting	-
	Future	11.5	Sitting	Unchanged	15.7	Sitting	Unchanged
34	Existing	10.3	Sitting	-	14.0	Sitting	-
	Future	12.2	Sitting	Unchanged	16.6	Standing	Reduced
35	Existing	10.5	Sitting	-	14.3	Sitting	-
	Future	12.9	Sitting	Unchanged	17.6	Standing	Reduced



APPENDIX C

WIND TUNNEL SIMULATION OF THE NATURAL WIND

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WIND TUNNEL SIMULATION OF THE NATURAL WIND

Wind flowing over the surface of the earth develops a boundary layer due to the drag produced by surface features such as vegetation and man-made structures. Within this boundary layer, the mean wind speed varies from zero at the surface to the gradient wind speed at the top of the layer. The height of the top of the boundary layer is referred to as the gradient height, above which the velocity remains more-or-less constant for a given synoptic weather system. The mean wind speed is taken to be the average value over one hour. Superimposed on the mean wind speed are fluctuating (or turbulent) components in the longitudinal (i.e. along wind), vertical and lateral directions. Although turbulence varies according to the roughness of the surface, the turbulence level generally increases from nearly zero (smooth flow) at gradient height to maximum values near the ground. While for a calm ocean the maximum could be 20%, the maximum for a very rough surface such as the center of a city could be 100%, or equal to the local mean wind speed. The height of the boundary layer varies in time and over different terrain roughness within the range of 400 metres (m) to 600 m.

Simulating real wind behaviour in a wind tunnel requires simulating the variation of mean wind speed with height, simulating the turbulence intensity, and matching the typical length scales of turbulence. It is the ratio between wind tunnel turbulence length scales and turbulence scales in the atmosphere that determines the geometric scales that models can assume in a wind tunnel. Hence, when a 1:200 scale model is quoted, this implies that the turbulence scales in the wind tunnel and the atmosphere have the same ratios. Some flexibility in this requirement has been shown to produce reasonable wind tunnel predictions compared to full scale. In model scale the mean and turbulence characteristics of the wind are obtained with the use of spires at one end of the tunnel and roughness elements along the floor of the tunnel. The fan is located at the model end and wind is pulled over the spires, roughness elements and model. It has been found that, to a good approximation, the mean wind profile can be represented by a power law relation, shown below, giving height above ground versus wind speed.

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

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.

Figure B1 on the following page plots three velocity profiles for open country, and suburban and urban exposures.

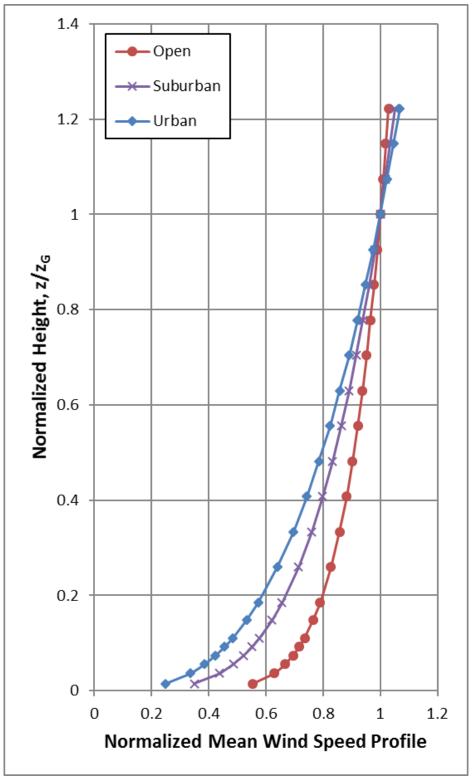
The exponent α varies according to the type of upwind terrain; α ranges from 0.14 for open country to 0.33 for an urban exposure. Figure C2 illustrates the theoretical variation of turbulence for open country, suburban and urban exposures.

The integral length scale of turbulence can be thought of as an average size of gust in the atmosphere. Although it varies with height and ground roughness, it has been found to generally be in the range of 100 m to 200 m in the upper half of the boundary layer. Thus, for a 1:300 scale, the model value should be between 1/3 and 2/3 of a metre. Integral length scales are derived from power spectra, which describe the energy content of wind as a function of frequency. There are several ways of determining integral length scales of turbulence. One way is by comparison of a measured power spectrum in model scale to a non-dimensional theoretical spectrum such as the Davenport spectrum of longitudinal turbulence. Using the Davenport spectrum, which agrees well with full-scale spectra, one can estimate the integral scale by plotting the theoretical spectrum with varying L until it matches as closely as possible the measured spectrum:

$$f \times S(f) = \frac{\dfrac{4(Lf)^2}{U_{10}{}^2}}{\left[1 + \dfrac{4(Lf)^2}{U_{10}{}^2}\right]^{\frac{4}{3}}}$$

Where, f is frequency, S(f) is the spectrum value at frequency f, U10 is the wind speed 10 m above ground level, and L is the characteristic length of turbulence.

Once the wind simulation is correct, the model, constructed to a suitable scale, is installed at the center of the working section of the wind tunnel. Different wind directions are represented by rotating the model to align with the wind tunnel center-line axis.



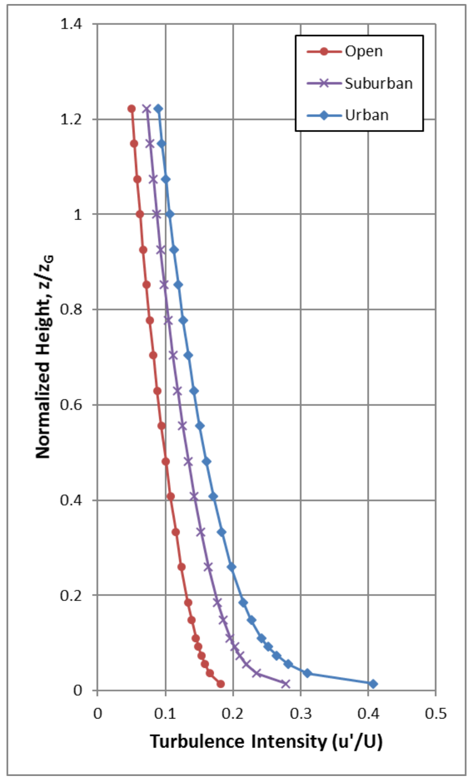


FIGURE C1 (LEFT): MEAN WIND SPEED PROFILES;
FIGURE C2 (RIGHT): TURBULENCE INTENSITY PROFILES

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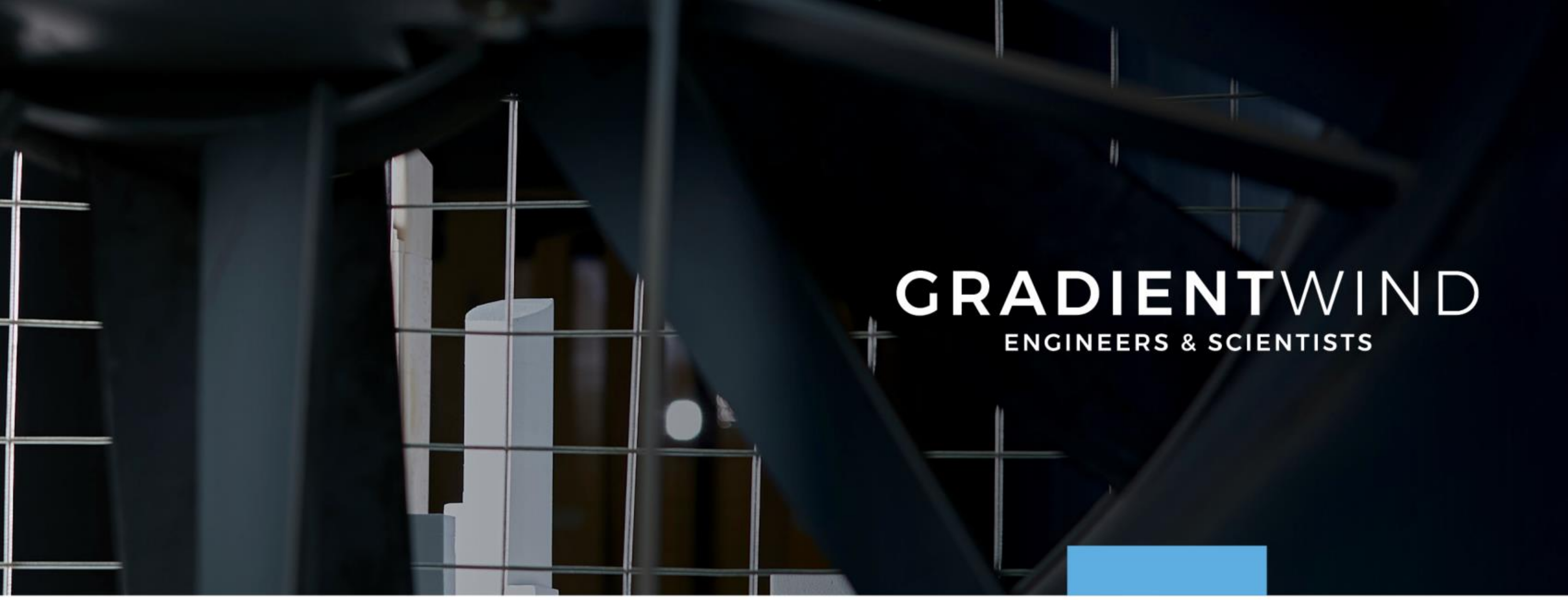

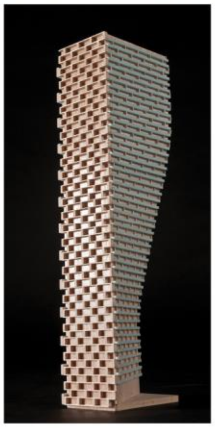

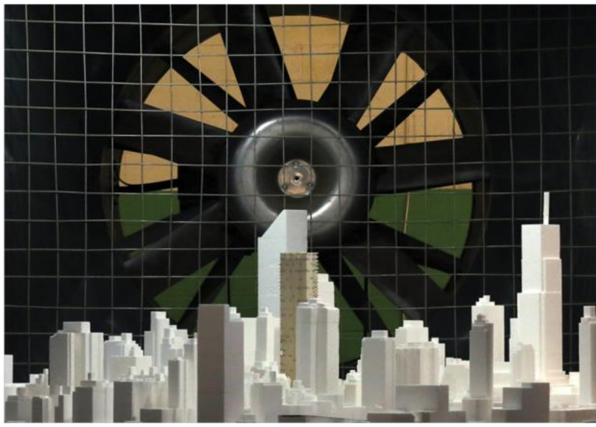

APPENDIX D

PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

Pedestrian level wind studies are performed in a wind tunnel on a physical model of the study buildings at a suitable scale. Instantaneous wind speed measurements are recorded at a model height corresponding to 1.5 m full scale using either a hot wire anemometer or a pressure-based transducer. Measurements are performed at any number of locations on the model and usually for 36 wind directions. For each wind direction, the roughness of the upwind terrain is matched in the wind tunnel to generate the correct mean and turbulent wind profiles approaching the model.

The hot wire anemometer is an instrument consisting of a thin metallic wire conducting an electric current. It is an omni-directional device equally sensitive to wind approaching from any direction in the horizontal plane. By compensating for the cooling effect of wind flowing over the wire, the associated electronics produce an analog voltage signal that can be calibrated against velocity of the air stream. For all measurements, the wire is oriented vertically so as to be sensitive to wind approaching from all directions in a horizontal plane.

The pressure sensor is a small cylindrical device that measures instantaneous pressure differences over a small area. The sensor is connected via tubing to a transducer that translates the pressure to a voltage signal that is recorded by computer. With appropriately designed tubing, the sensor is sensitive to a suitable range of fluctuating velocities.

For a given wind direction and location on the model, a time history of the wind speed is recorded for a period of time equal to one hour in full-scale. The analog signal produced by the hot wire or pressure sensor is digitized at a rate of 400 samples per second. A sample recording for several seconds is illustrated in Figure D1. This data is analyzed to extract the mean, root-mean-square (rms) and the peak of the signal. The peak value, or gust wind speed, is formed by averaging a number of peaks obtained from sub-intervals of the sampling period. The mean and gust speeds are then normalized by the wind tunnel gradient wind speed, which is the speed at the top of the model boundary layer, to obtain mean and gust ratios. At each location, the measurements are repeated for 36 wind directions to produce normalized polar plots, which will be provided upon request.

In order to determine the duration of various wind speeds at full scale for a given measurement location the gust ratios are combined with a statistical (mathematical) model of the wind climate for the project site. This mathematical model is based on hourly wind data obtained from one or more meteorological stations (usually airports) close to the project location. The probability model used to represent the data is the Weibull distribution expressed as:

$$P\left(>U_g\right) = A_\theta \bullet \exp\left[\left(-\frac{U_g}{C_\theta}\right)^{K_\theta}\right]$$

Where,

P (> U_g) is the probability, fraction of time, that the gradient wind speed ***U_g*** is exceeded; ***θ*** is the wind direction measured clockwise from true north, ***A***, ***C***, ***K*** are the Weibull coefficients, (Units: A - dimensionless, C - wind speed units [km/h] for instance, K - dimensionless). ***A_θ*** is the fraction of time wind blows from a 10° sector centered on ***θ***.

Analysis of the hourly wind data recorded for a length of time, on the order of 10 to 30 years, yields the ***A_θ, C_θ*** and ***K_θ*** values. The probability of exceeding a chosen wind speed level, say 20 km/h, at sensor *N* is given by the following expression:

$$P_N(>20) = \Sigma_\theta P\left[\frac{(>20)}{\left(\frac{U_N}{U_g}\right)}\right]$$

$$P_N\,(>20) \;=\; \Sigma_\theta P\,\{>20/(U_N/Ug)\}$$

Where, ***U_N/U_g*** is the gust velocity ratios, where the summation is taken over all 36 wind directions at 10° intervals.

If there are significant seasonal variations in the weather data, as determined by inspection of the $\boldsymbol{C_\theta}$ and $\boldsymbol{K_\theta}$ values, then the analysis is performed separately for two or more times corresponding to the groupings of seasonal wind data. Wind speed levels of interest for predicting pedestrian comfort are based on the comfort guidelines chosen to represent various pedestrian activity levels as discussed in the main text.

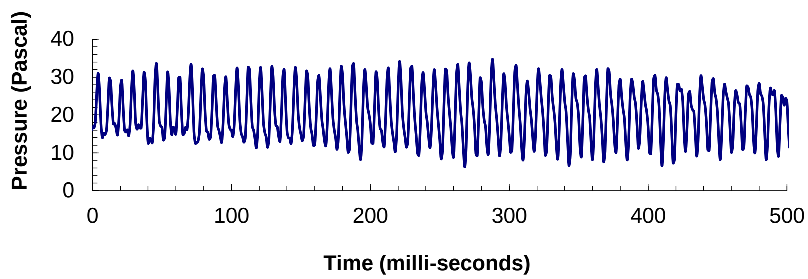

FIGURE D1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR

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