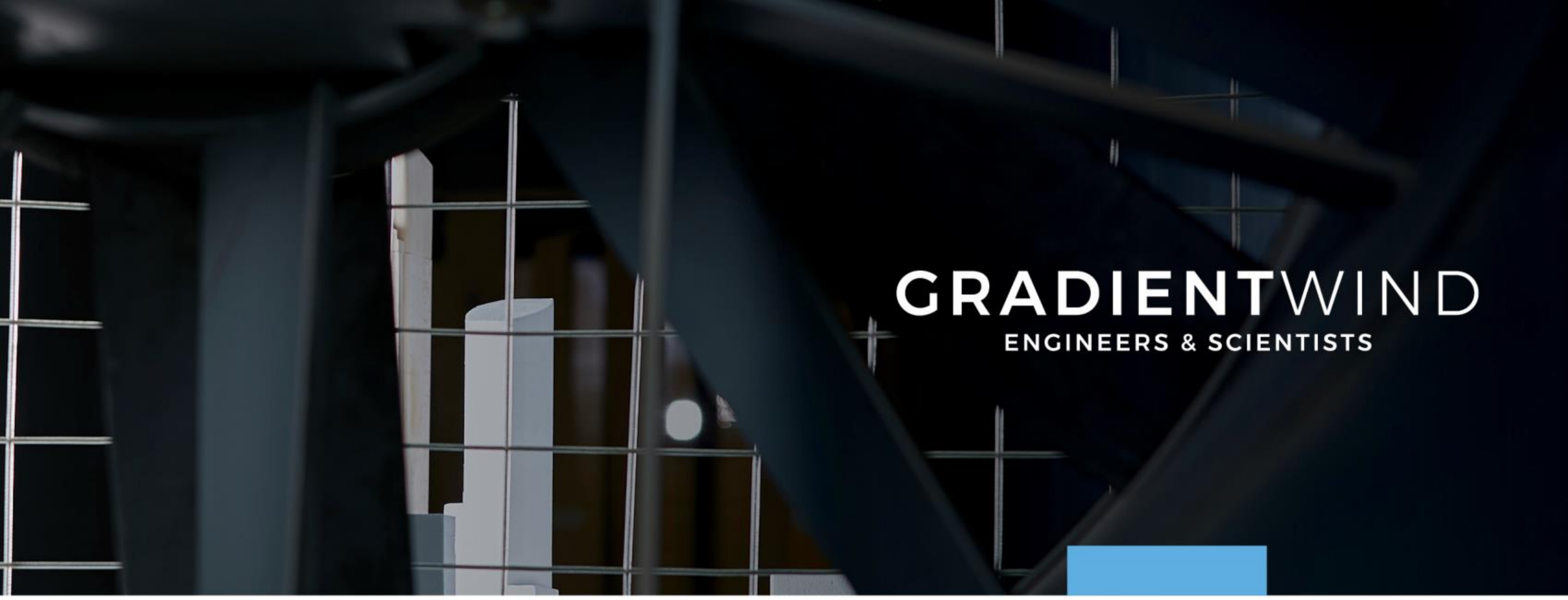
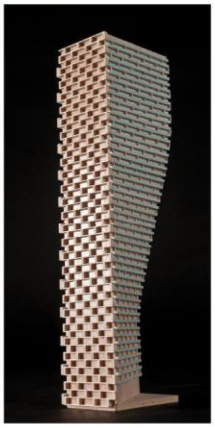
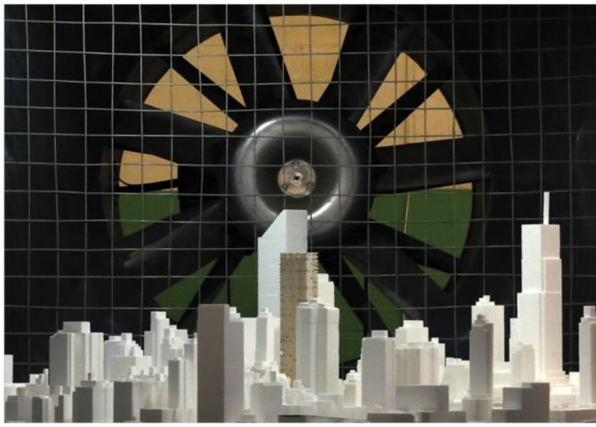


PEDESTRIAN LEVEL WIND STUDY

26 Grenville & 27 Grosvenor
Toronto, Ontario

REPORT: GWE18-106-WTPLW





February 20, 2019

PREPARED FOR
Greenwin Holdings Inc.
19 Lesmill Road
Toronto, Ontario
M3B 2T3

PREPARED BY
Megan Prescott, MESc., Project Manager
Andrew Sliasas, M.A.Sc., P.Eng., Principal

EXECUTIVE SUMMARY

This report describes a pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 26 Grenville Street and 27 Grosvenor Street in Toronto, Ontario. 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, laneways, transit stops, seating areas, and building access points. Wind comfort is also evaluated over the elevated outdoor amenity terraces. 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 prepared by Sweeny &Co Architects provided in November 2018 and updated in January 2019, surrounding street layouts and existing and approved future building massing information, as well as 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-5B, and Tables A1 and A2 in Appendix A. Based on wind tunnel test results, meteorological data analysis of the Toronto wind climate, and experience with similar developments in Toronto, we conclude that wind conditions over all pedestrian sensitive grade-level locations within and surrounding the study site will be acceptable for the intended uses on a seasonal basis.

The outdoor amenity area at the east side of Level 4 will be suitable for sitting during the intended use period of late spring to early autumn without mitigation. If seating is desired near the building corner for the west amenity area serving Level 4, mitigation is recommended in the form of wind barriers as described in Section 5.2.

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

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Greenwin Holdings Inc. to undertake a pedestrian level wind study for a proposed mixed-use development located at 26 Grenville Street and 27 Grosvenor Street in Toronto, Ontario. The study was performed in accordance with the scope of work described in GWE proposal #18-134P, dated May 22, 2018, and is based on industry standard wind tunnel testing techniques, architectural drawings prepared by Sweeny &Co Architects provided in November 2018 and updated in January 2019, 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 detailed pedestrian level wind study is a proposed mixed-use development at 26 Grenville Street and 27 Grosvenor Street in Toronto, Ontario. The study site is located near the centre of a parcel of land bounded by Grosvenor Street to the north, St. Luke Lane to the east, Grenville Street to the south, and Bay Street to the west.

The proposed development comprises two towers connected by a stepped 11-storey podium. The north tower (35 storeys) overlooks Grosvenor Street, while the south tower (50 storeys) overlooks Grenville Street. A double-height driveway intersects the towers at Levels 1 and 2, providing vehicle access from St. Vincent Lane to ground-level loading areas. A ramp accessed from St. Vincent Lane at the southwest corner of the north tower also provides access to three levels of underground parking.

At ground floor, both towers feature retail and a residential lobby, respectively fronting Grosvenor Street and Grenville Street, as well as building support function rooms in the remaining space. A daycare entrance is also located along the north elevation of the north tower. The building planforms are rectangular at grade and diagonally offset from each other, with the north tower having larger frontage. At Level 2, the towers are open to below except for storage areas and two offices. The floorplates of the north and south towers connect at Level 3 where the tower offset overlaps. Level 3 contains a daycare at the northwest corner and a fitness centre in the remaining space. A covered outdoor daycare area is located at the southwest corner of the north tower. At Level 4, the floorplate sets back from the northeast and southwest corners of the south and north towers, respectively, to create separate outdoor amenity areas. Level 4 contains indoor amenity areas adjacent to the outdoor amenity terraces and residential units in the remaining space, while residential units occupy the floors above. The floorplate sets back from all sides at Level 10, and the connective portion of podia between the two towers terminates at Level 12.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre radius of the site) include a moderately dense concentration of low, medium and high-rise developments in all directions. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius), are a continuation of the near field, with increasing density and proportion of high-rise buildings south towards downtown Toronto. The far field transitions to low-rise residential for the remaining directions at greater distances. Queens Park is located approximately 500 metres to the northwest of the study site.

Grade-level areas investigated include sidewalks, laneways, transit stops, seating areas, and building access points. Wind comfort was also evaluated over the elevated outdoor amenity areas. Figure 1 illustrates the study site and surrounding context, and photographs 1 through 4 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; and (iii) recommend suitable mitigation measures, where required.

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.

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

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 4 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.

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 60 sensor locations on the scale model in Gradient Wind's wind tunnel. Of the 60 sensors, 51 were placed at grade level, with the remaining nine on the Level 4 amenity terraces. Wind speed measurements were performed for each of the sensors for 36 wind directions at 10° intervals. Figure 1 illustrates a plan of the site and relevant surrounding context, while sensor locations used to investigate wind conditions are illustrated in Figures 2A through 5B.

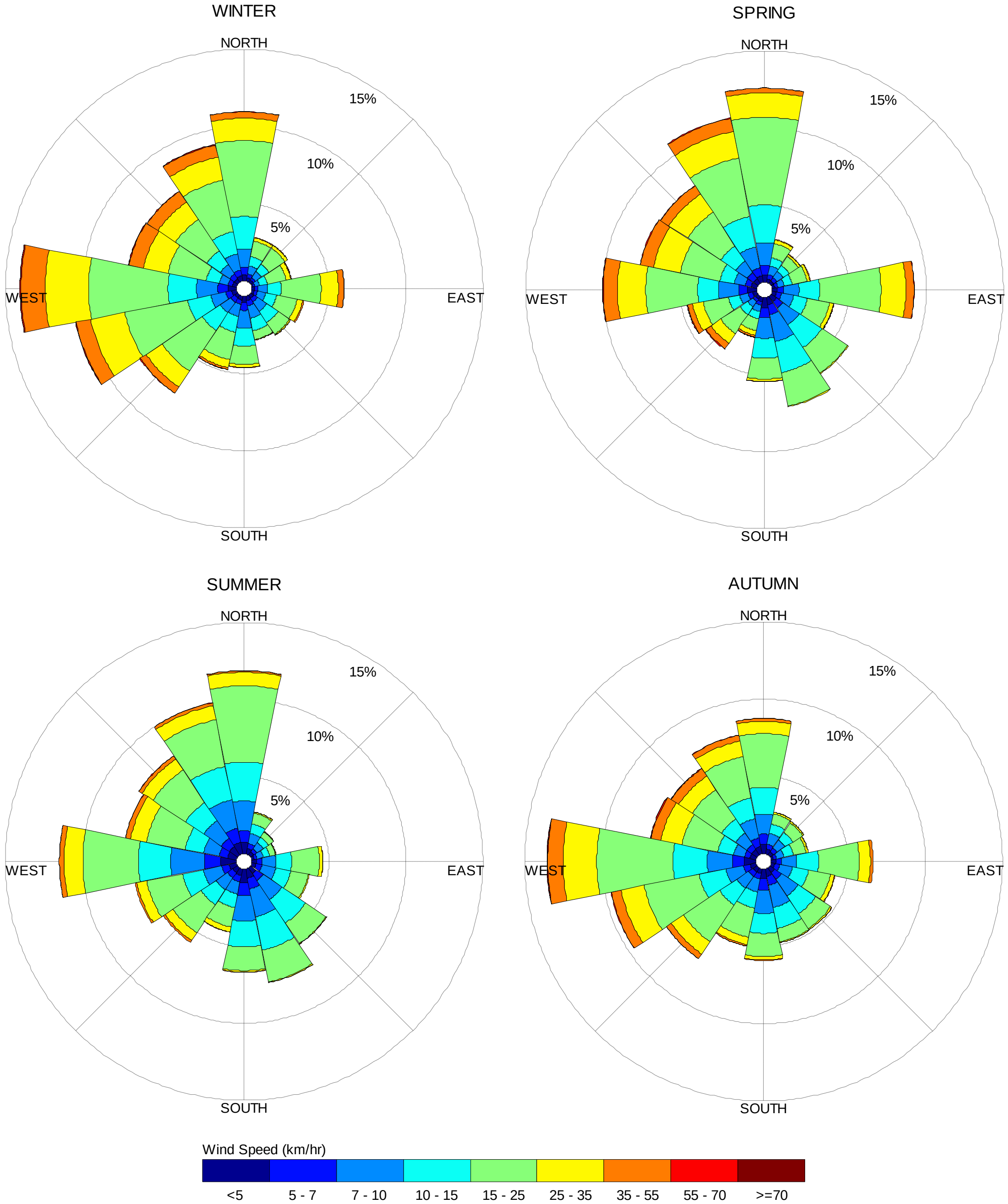
Mean and peak wind speed values for each location and wind direction were calculated from real-time pressure measurements, recorded at a sample rate of 500 samples per second, and taken over a 60-second time period. This period at model-scale corresponds approximately to one hour in full-scale, which 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 B and C 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 2010 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 80% 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

Tables A1 and A2 in Appendix A provide a summary of seasonal comfort predictions for each sensor location. 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.). Sensor locations with a predicted comfort class that is windier than the desired comfort class for that location type are highlighted in red.

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

Based on the analysis of the measured data, consideration of local climate data, and the suitability descriptors provided in Tables A1 and A2 in Appendix A, this section summarizes the most significant findings of the PLW study, as follows:

1. All public sidewalks, laneways and pedestrian walkways within and surrounding the development will experience wind conditions suitable for walking or better throughout the year, with most locations experiencing conditions suitable for sitting or standing. These conditions are acceptable for the intended use.

2. All primary, secondary and service building access points will experience wind conditions suitable for standing or better throughout the year, which is acceptable.

3. The nearby transit stop at the intersection of Grosvenor Street and Bay Street (Sensor 50) will experience wind conditions suitable for standing in the spring, summer and autumn and walking in the fall. This transit stop is equipped with a three-walled vestibule that will allow pedestrians to take cover during limited windy periods. Therefore, these conditions are considered acceptable.

4. The existing seating areas adjacent to the YMCA (Sensors 41 and 42) will be suitable for sitting throughout the year without mitigation, which is acceptable.

5. The covered outdoor daycare space at Level 3 will experience calm wind conditions suitable for sitting throughout the year without mitigation, which is acceptable.

6. The Level 4 amenity area at the east side of the building will experience conditions suitable for sitting from the late spring through the early autumn, which is acceptable. The amenity area at the west side of the building will generally be suitable for sitting during the summer, transitioning to conditions suitable for standing near the building corner (Sensor 53). If seating areas will be provided near the building corner, it is recommended to install a 1.8 metre-tall wind barrier along the full west perimeter of the terrace.

7. 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 wind conditions that are considered unsafe.

6. CONCLUSIONS AND RECOMMENDATIONS

This report summarizes the methodology, results, and recommendations related to a pedestrian level wind study for the proposed mixed-use development located at 26 Grenville Street and 27 Grosvenor Street in Toronto, Ontario. The study was performed in accordance with the scope of work described in GWE proposal #18-134P, dated May 22, 2018, as well as 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-5B, and Tables A1 and A2 in Appendix A. Based on wind tunnel test results, meteorological data analysis of the Toronto wind climate, and experience with similar developments in Toronto, we conclude that wind conditions over all pedestrian sensitive grade-level locations within and surrounding the study site will be acceptable for the intended uses on a seasonal basis.

The outdoor amenity area at the east side of Level 4 will be suitable for sitting during the intended use period of late spring to early autumn without mitigation. If seating is desired near the building corner for the west amenity area serving Level 4, mitigation is recommended in the form of wind barriers as described in Section 5.2.

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,

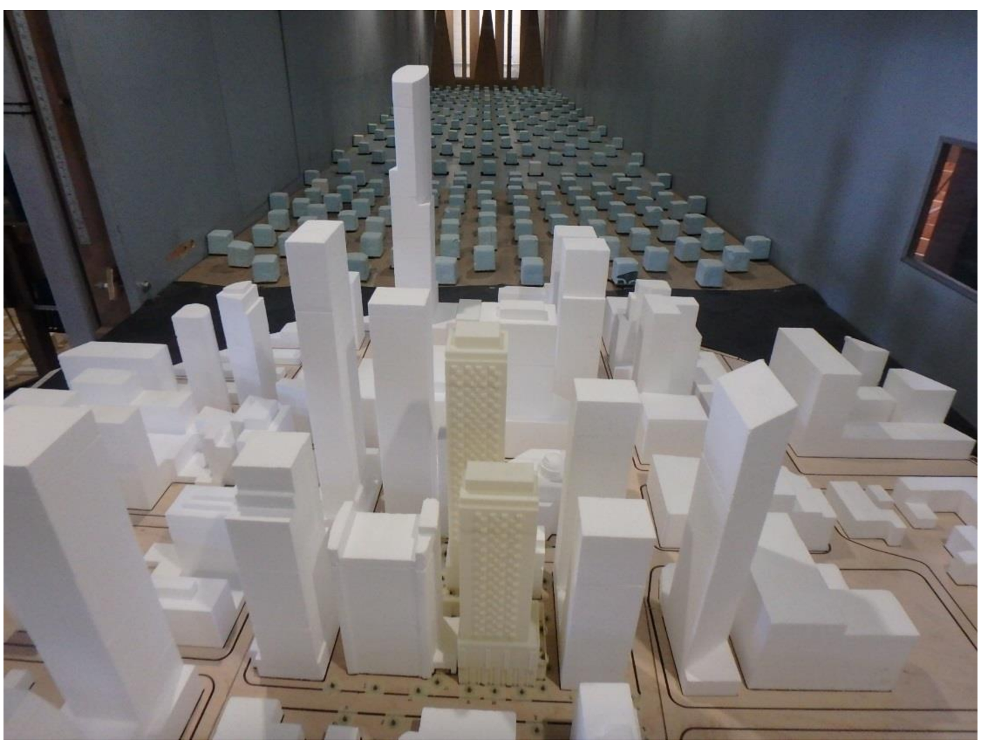
Gradient Wind Engineering Inc.

Megan Prescott, MESc.,
Project Manager

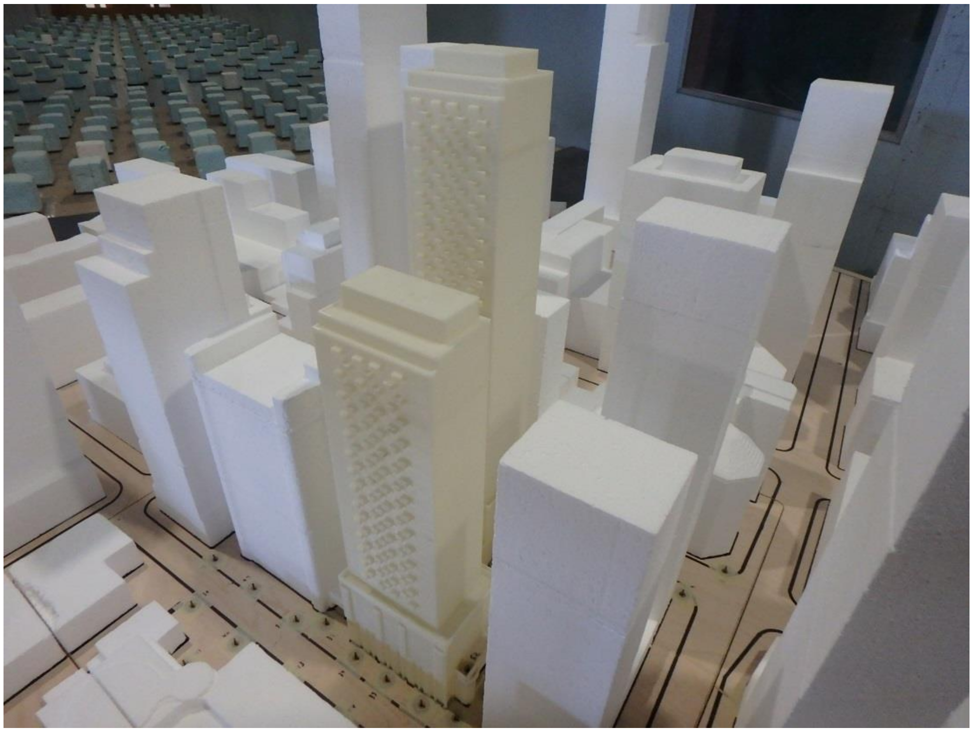
Andrew Sliasas, M.A.Sc., P.Eng.,
Principal

GWE18-106-WTPLW

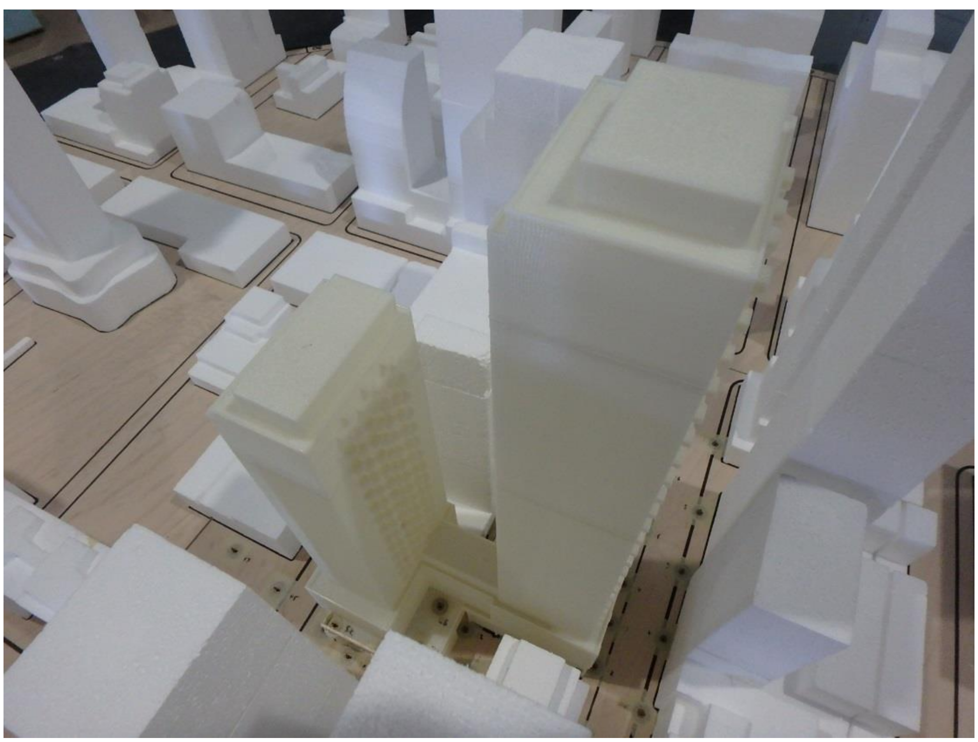
PHOTOGRAPH 1: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING DOWNWIND



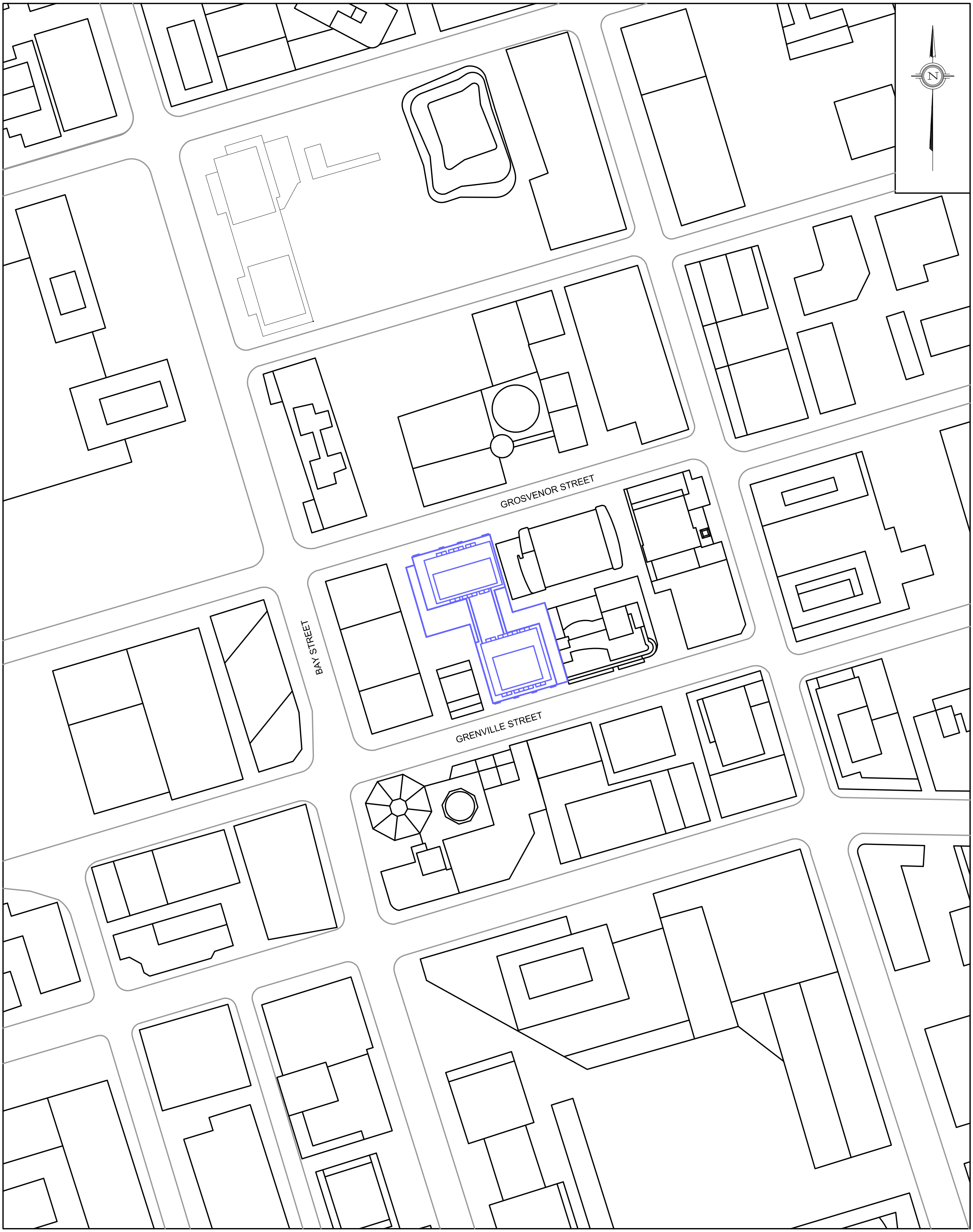
PHOTOGRAPH 2: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING UPWIND



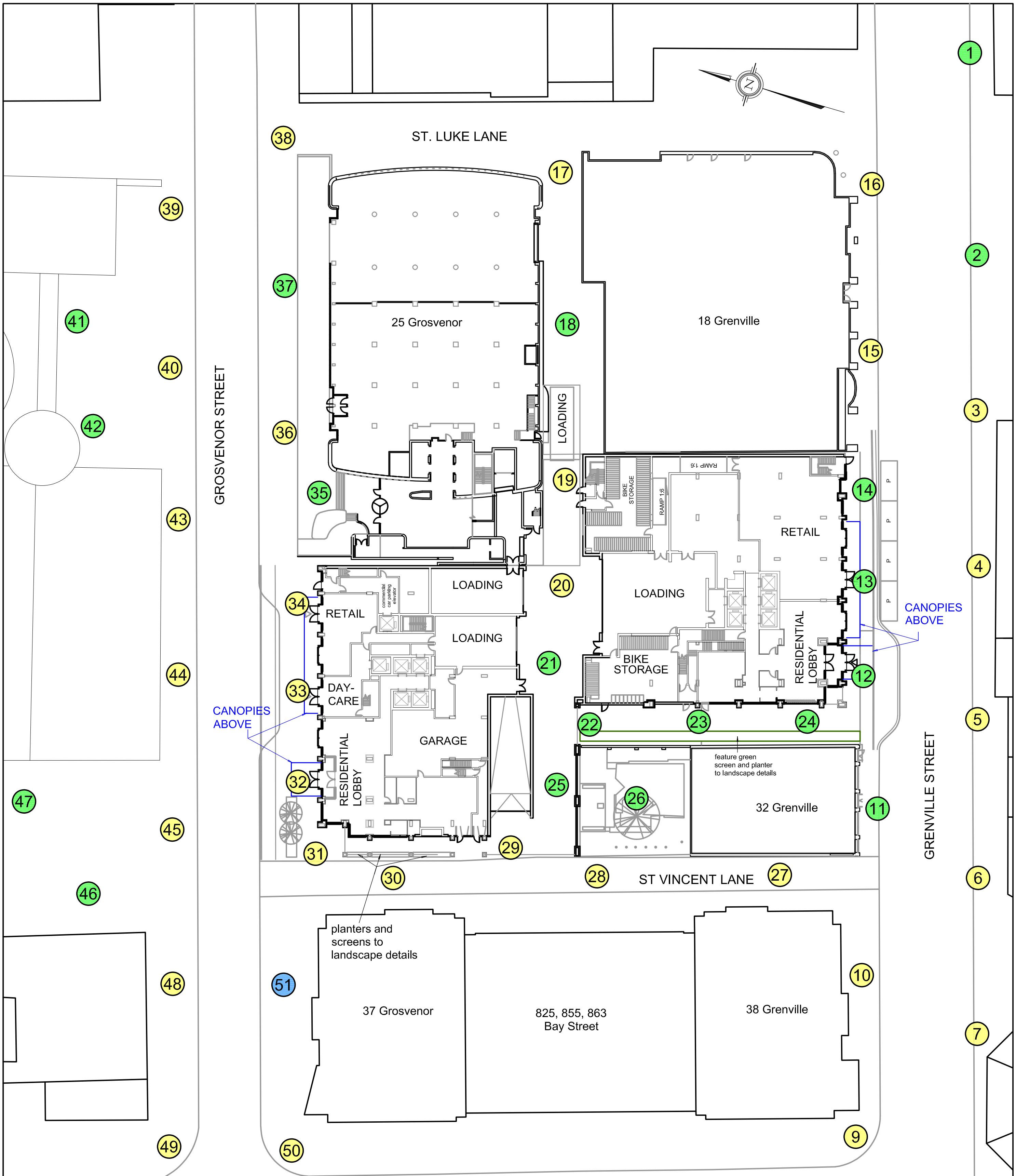
PHOTOGRAPH 3: CLOSE-UP VIEW OF STUDY MODEL LOOKING SOUTHEAST



PHOTOGRAPH 4: CLOSE-UP VIEW OF STUDY MODEL LOOKING NORTHEAST



GRADIENTWIND ENGINEERS & SCIENTISTS 127 WALGREEN ROAD , OTTAWA, ON 613 836 0934 • GRADIENTWIND.COM	PROJECT: 27 GROSVENOR & 26 GRENVILLE, TORONTO PEDESTRIAN LEVEL WIND STUDY	DESCRIPTION: FIGURE 1: SITE PLAN AND SURROUNDING CONTEXT
	SCALE: 1:2500 (APPROX.) / DRAWING NO. GWE18-106-PLW-1	
	DATE: JANUARY 18, 2019 / DRAWN BY S.R.	

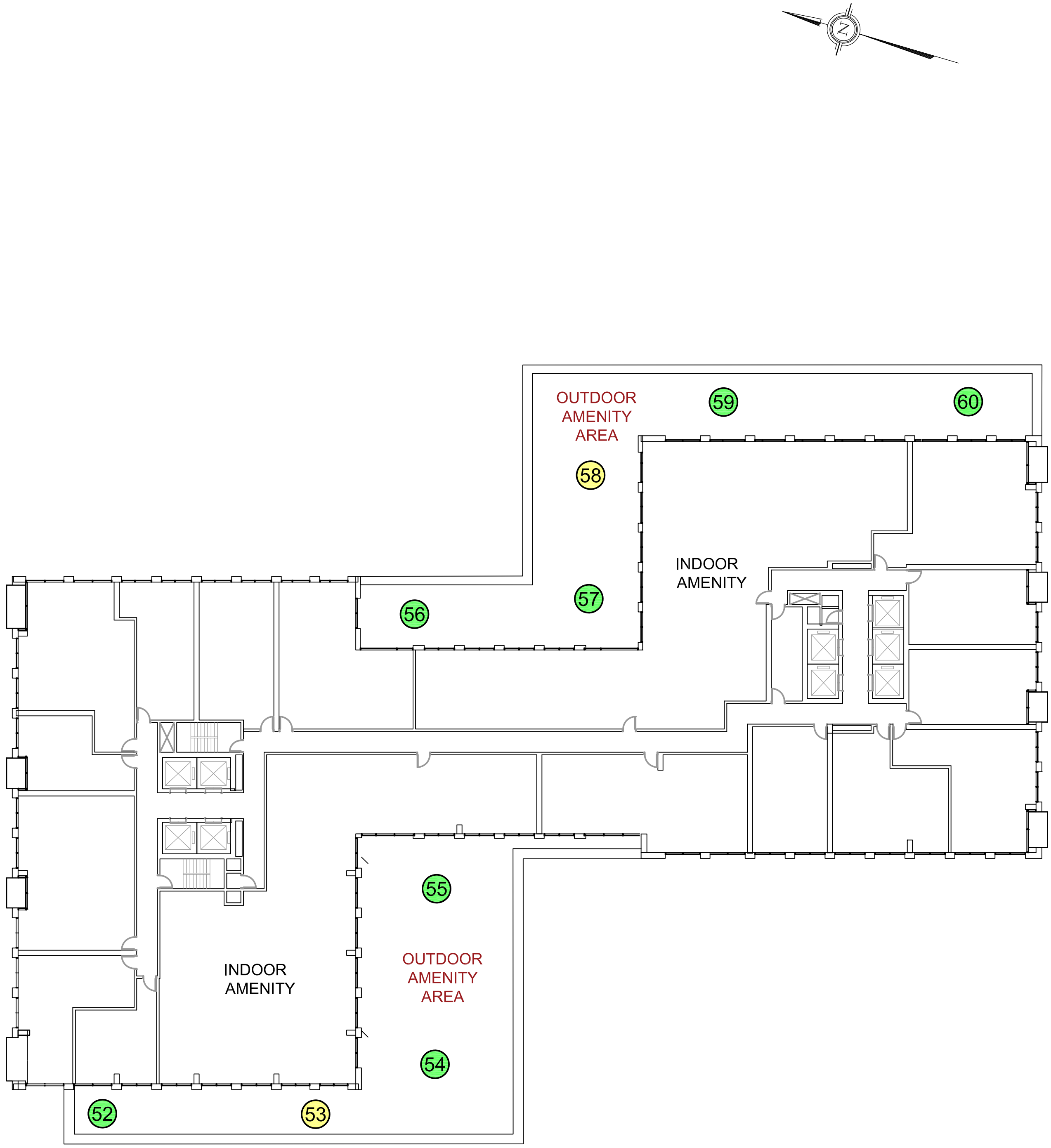


PREDICTED COMFORT CLASSES
- # SITTING
- # STANDING
- # WALKING

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: 27 GROSVENOR & 26 GRENVILLE, TORONTO PEDESTRIAN LEVEL WIND STUDY	DESCRIPTION: FIGURE 2A: SPRING GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
	SCALE: 1:800 (APPROX.) / DRAWING NO.: GWE18-106-PLW-2A	
	DATE: JANUARY 18, 2019 / DRAWN BY: S.R./B.J.	

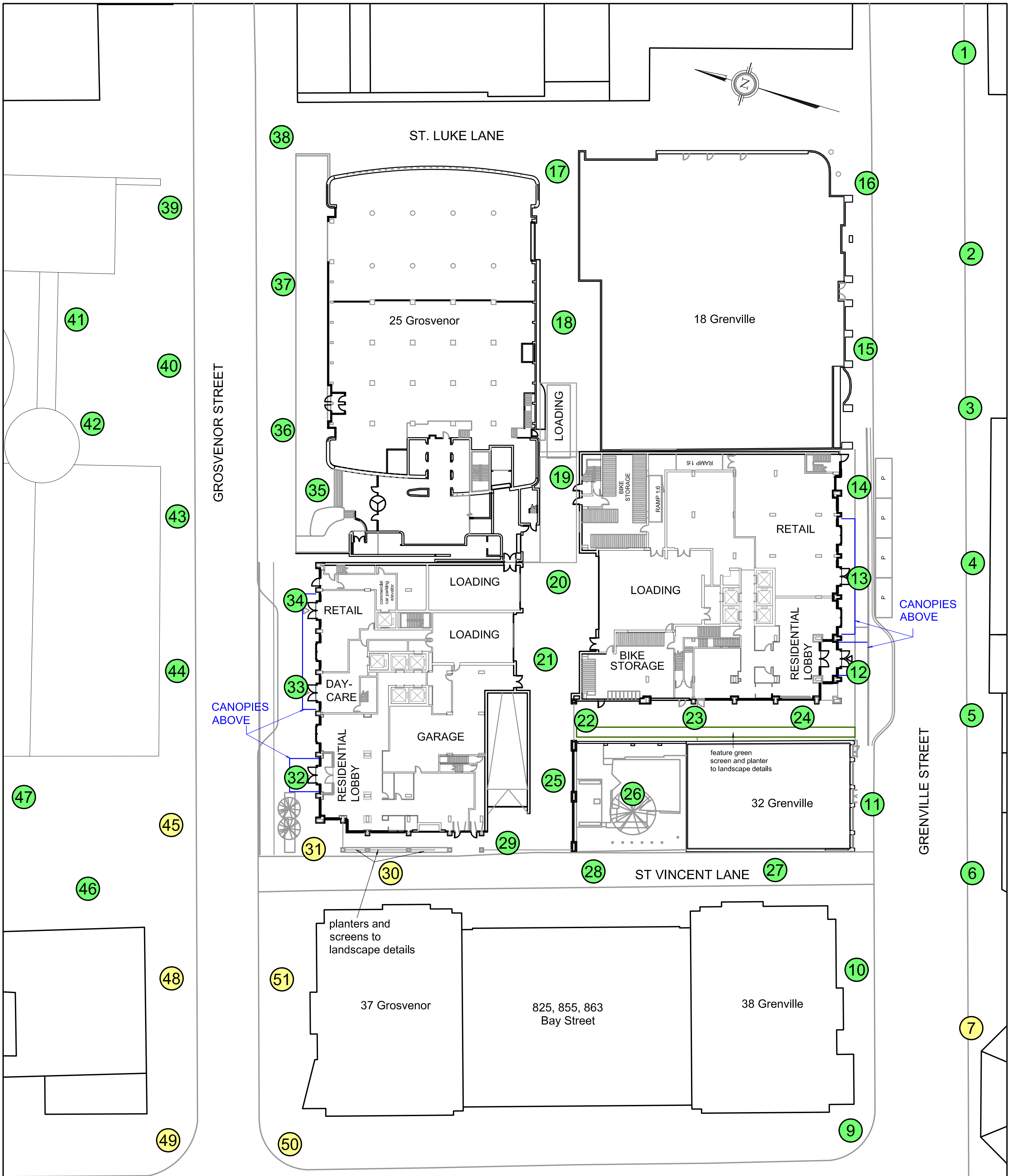


PREDICTED COMFORT CLASSES
- # SITTING
- # STANDING
- # WALKING

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: 27 GROSVENOR & 26 GRENVILLE, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 2B: SPRING LEVEL 4 AMENITY PLAN PEDESTRIAN COMFORT PREDICTIONS
	SCALE: 1:500 (APPROX.)	DRAWING NO.: GWE18-106-PLW-2B	
	DATE: JANUARY 18, 2019	DRAWN BY: S.R./B.J.	



PREDICTED COMFORT CLASSES	
# (green)	SITTING
# (yellow)	STANDING
# (blue)	WALKING

NOTES:

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

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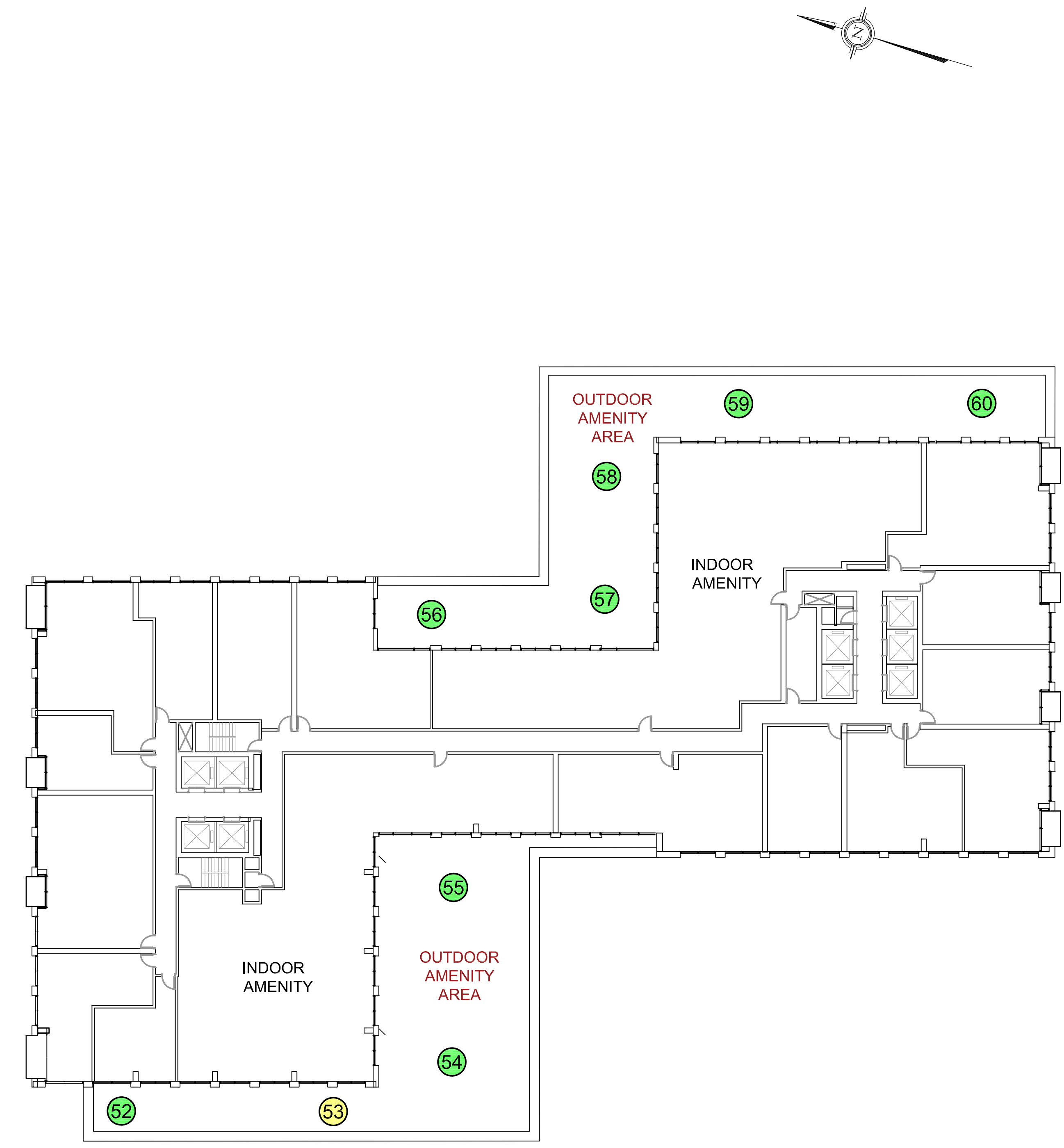
613 836 0934 • GRADIENTWIND.COM

PROJECT	27 GROSVENOR & 26 GRENVILLE, TORONTO PEDESTRIAN LEVEL WIND STUDY
SCALE	1:800 (APPROX.)
DRAWING NO.	GWE18-106-PLW-3A
DATE	JANUARY 18, 2019
DRAWN BY	S.R./B.J.
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.

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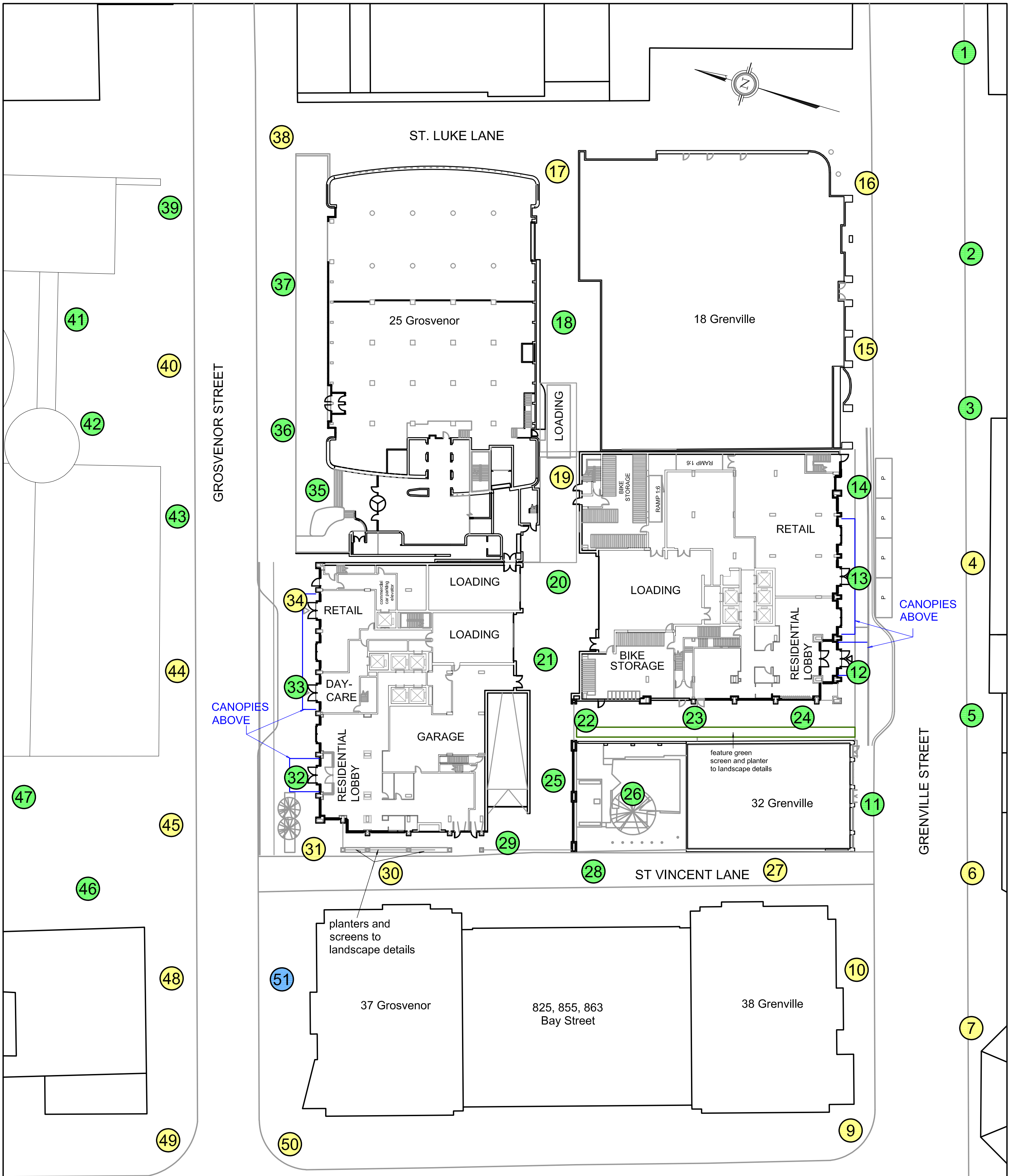
127 WALGREEN ROAD , OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

PROJECT	27 GROSVENOR & 26 GRENVILLE, TORONTO PEDESTRIAN LEVEL WIND STUDY
SCALE	1:500 (APPROX.)
DRAWING NO.	GWE18-106-PLW-3B
DATE	JANUARY 18, 2019
DRAWN BY	S.R./B.J.
DESCRIPTION	FIGURE 3B: SUMMER LEVEL 4 AMENITY 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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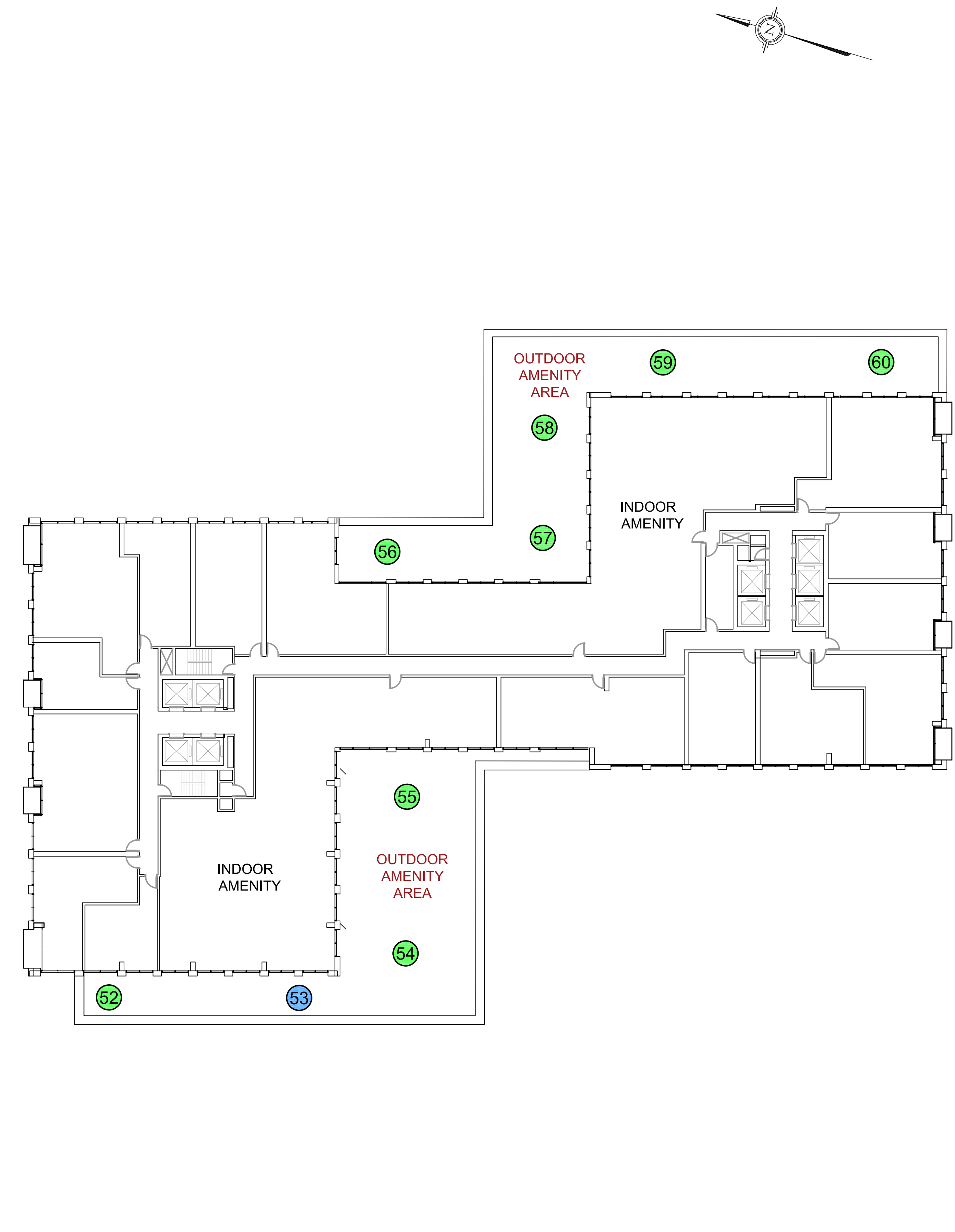
PROJECT	27 GROSVENOR & 26 GRENVILLE, TORONTO PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION FIGURE 4A: AUTUMN GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
SCALE	1:800 (APPROX.)	DRAWING NO. GWE18-106-PLW-4A	
DATE	JANUARY 18, 2019	DRAWN BY S.R./B.J.	



PREDICTED COMFORT CLASSES	
#	SITTING
#	STANDING
#	WALKING

NOTES:

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

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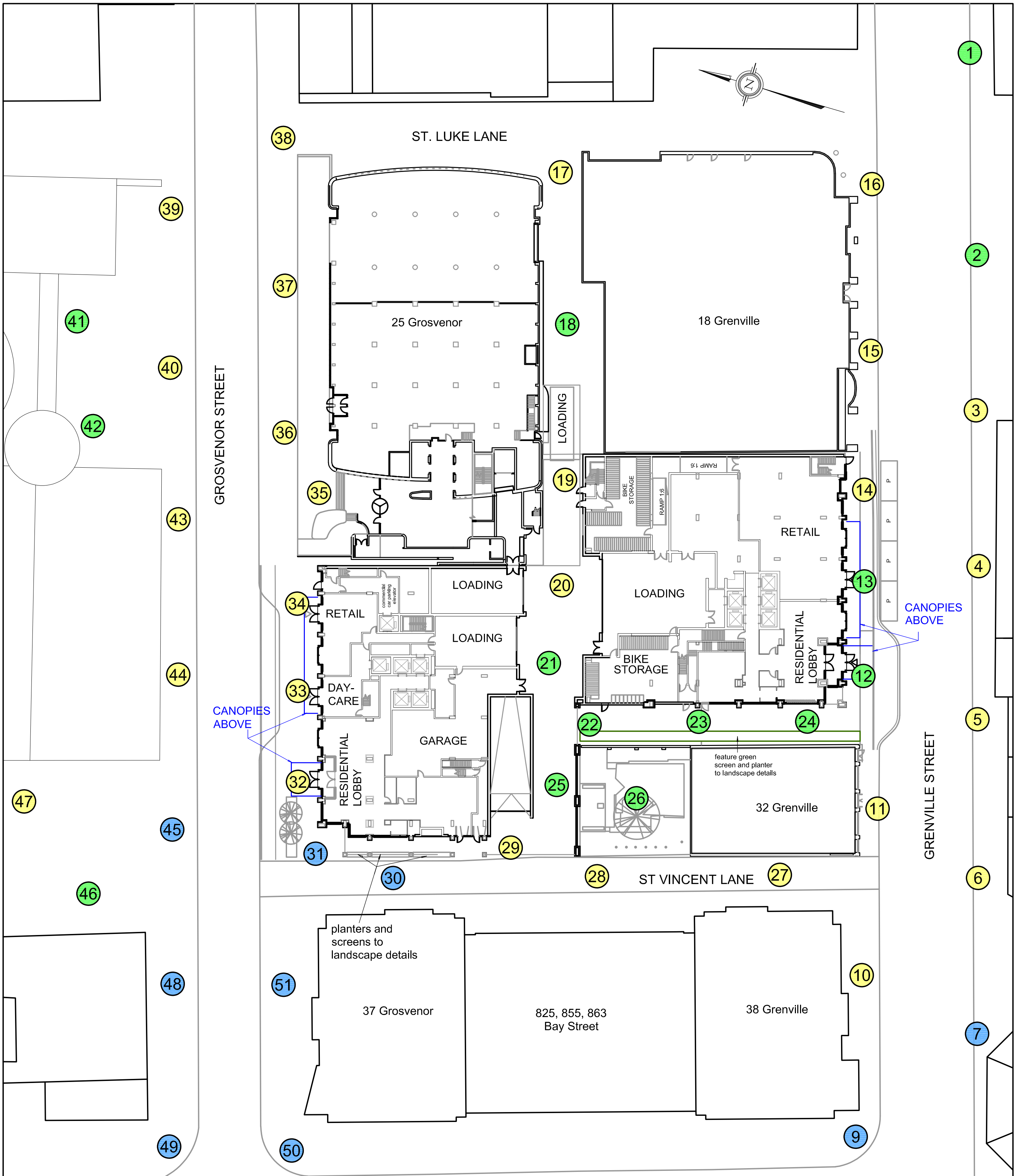
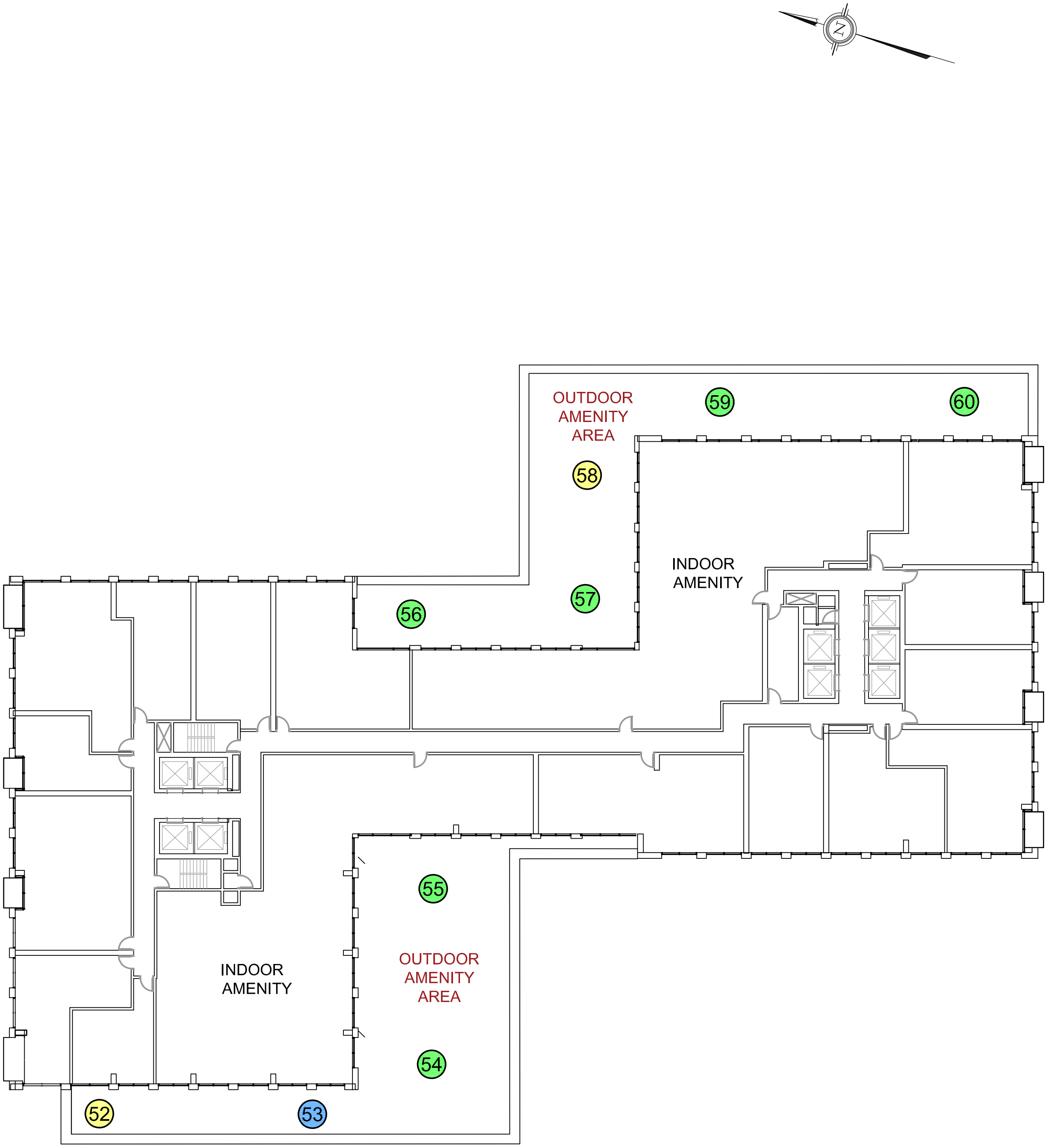
PROJECT	27 GROSVENOR & 26 GRENVILLE, TORONTO PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:500 (APPROX.)	DRAWING NO.	GWE18-106-PLW-4B
DATE	JANUARY 18, 2019	DRAWN BY	S.R./B.J.
DESCRIPTION	FIGURE 4B: AUTUMN LEVEL 4 AMENITY PLAN PEDESTRIAN COMFORT PREDICTIONS		



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: 27 GROSVENOR & 26 GRENVILLE, TORONTO PEDESTRIAN LEVEL WIND STUDY	DESCRIPTION: FIGURE 5A: WINTER GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
	SCALE: 1:800 (APPROX.) — DRAWING NO. GWE18-106-PLW-5A	
	DATE: JANUARY 18, 2019 — DRAWN BY S.R./B.J.	



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

NOTES:

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

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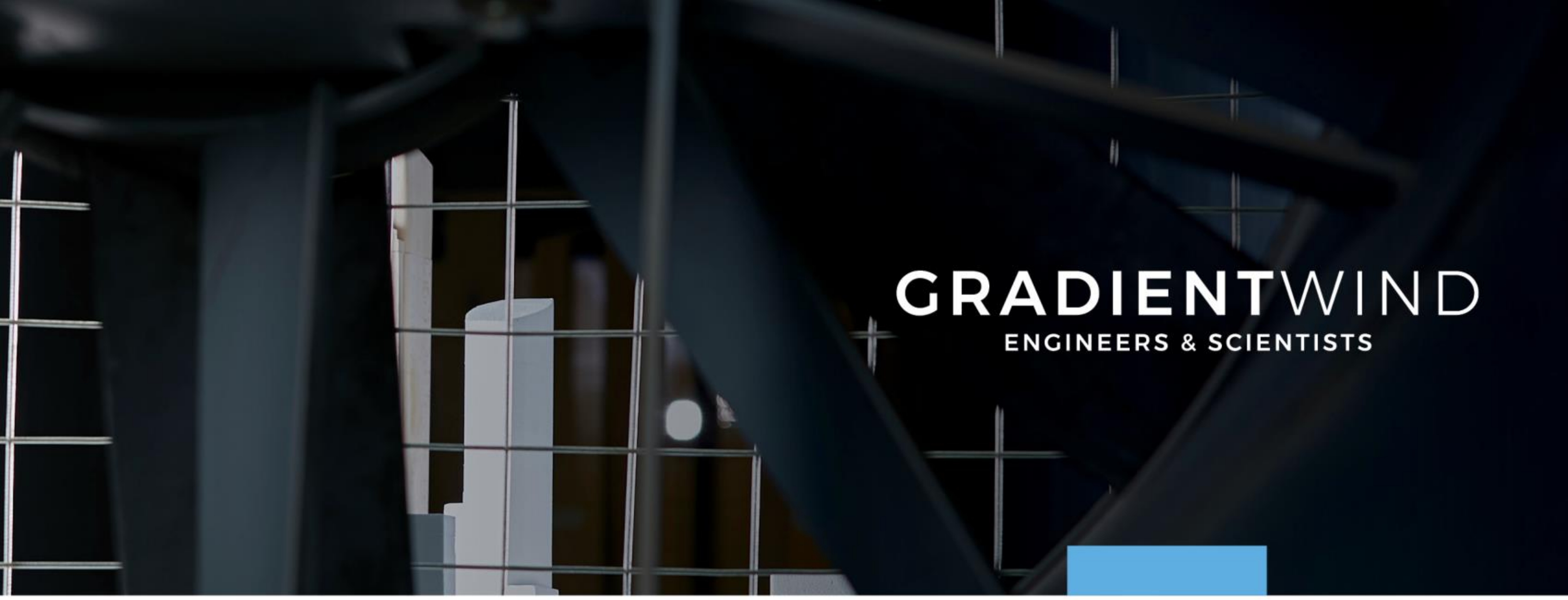
PROJECT	27 GROSVENOR & 26 GRENVILLE, TORONTO PEDESTRIAN LEVEL WIND STUDY		
SCALE	1:500 (APPROX.)	DRAWING NO.	GWE18-106-PLW-5B
DATE	JANUARY 18, 2019	DRAWN BY	S.R./B.J.

DESCRIPTION

FIGURE 5B: WINTER
LEVEL 4 AMENITY PLAN
PEDESTRIAN COMFORT PREDICTIONS



APPENDIX A

PEDESTRIAN COMFORT SUITABILITY, TABLES A1-A2

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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

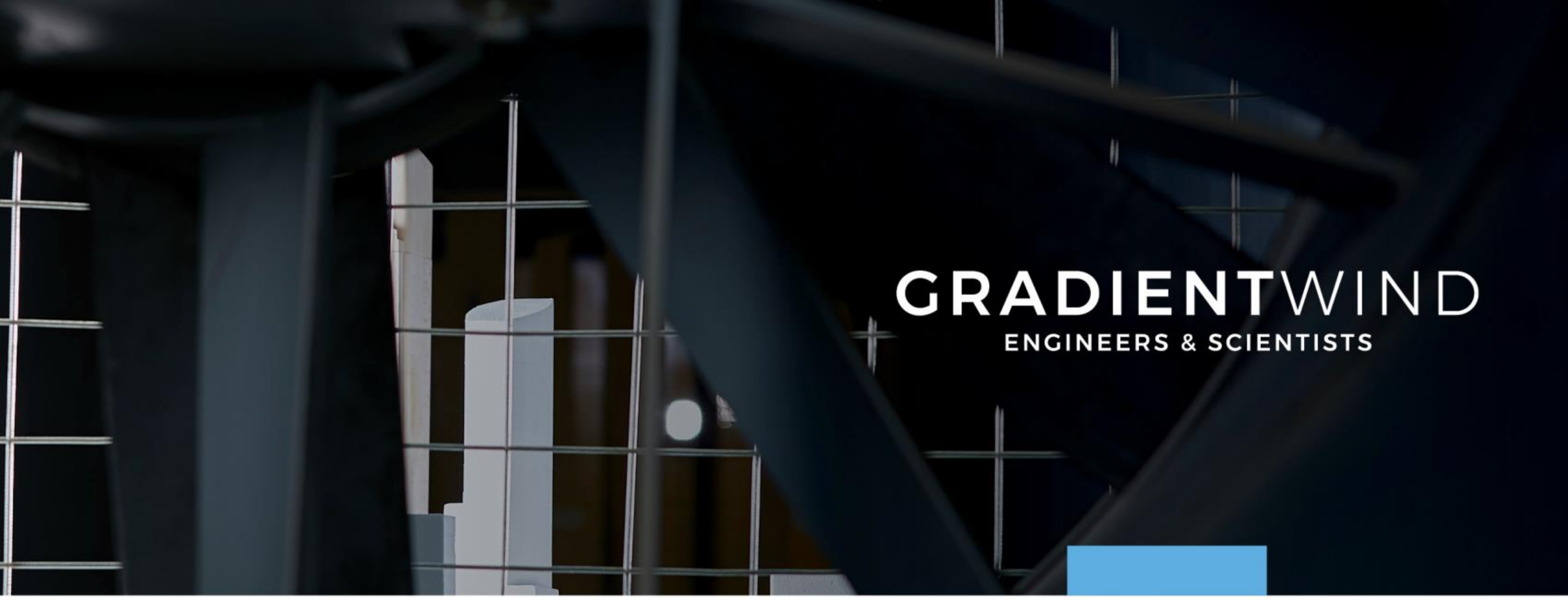
TABLE A1: SUMMARY OF PEDESTRIAN COMFORT

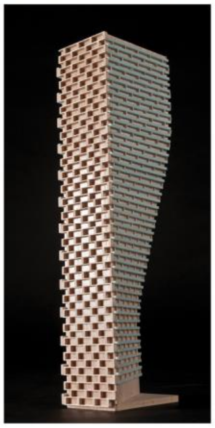
Sensor	Pedestrian Comfort								Pedestrian Safety	
	Spring		Summer		Autumn		Winter		Annual	
	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Safety Class
1	14.4	Sitting	11.1	Sitting	13.8	Sitting	15.7	Sitting	36.9	Safe
2	13.5	Sitting	11.1	Sitting	12.5	Sitting	14.2	Sitting	32.8	Safe
3	16.3	Standing	13.6	Sitting	14.5	Sitting	16.3	Standing	35.6	Safe
4	17.8	Standing	13.9	Sitting	16.5	Standing	18.9	Standing	53.5	Safe
5	16.8	Standing	12.3	Sitting	14.7	Sitting	16.9	Standing	46.7	Safe
6	18.4	Standing	13.7	Sitting	16.7	Standing	19.3	Standing	57.9	Safe
7	21.0	Standing	16.2	Standing	18.8	Standing	22.2	Walking	71.1	Safe
8	17.7	Standing	14.3	Sitting	17.5	Standing	20.2	Standing	53.3	Safe
9	19.0	Standing	14.5	Sitting	18.8	Standing	22.3	Walking	66.4	Safe
10	17.3	Standing	14.0	Sitting	16.5	Standing	19.3	Standing	51.6	Safe
11	15.0	Sitting	11.2	Sitting	14.5	Sitting	16.6	Standing	43.3	Safe
12	13.0	Sitting	10.0	Sitting	12.5	Sitting	14.2	Sitting	43.5	Safe
13	13.7	Sitting	10.9	Sitting	14.2	Sitting	15.9	Sitting	42.9	Safe
14	15.3	Sitting	12.3	Sitting	15.0	Sitting	17.2	Standing	46.3	Safe
15	16.8	Standing	14.0	Sitting	17.0	Standing	19.3	Standing	54.2	Safe
16	18.0	Standing	14.7	Sitting	17.5	Standing	20.1	Standing	49.9	Safe
17	20.0	Standing	15.7	Sitting	18.5	Standing	21.0	Standing	51.1	Safe
18	14.1	Sitting	12.0	Sitting	13.6	Sitting	15.5	Sitting	48.0	Safe
19	19.8	Standing	15.3	Sitting	16.7	Standing	19.6	Standing	47.0	Safe
20	16.2	Standing	12.3	Sitting	14.0	Sitting	16.3	Standing	40.3	Safe
21	12.3	Sitting	9.9	Sitting	12.8	Sitting	14.5	Sitting	44.4	Safe
22	11.6	Sitting	9.2	Sitting	11.4	Sitting	13.1	Sitting	36.0	Safe
23	12.2	Sitting	9.4	Sitting	11.0	Sitting	12.6	Sitting	29.7	Safe
24	12.9	Sitting	10.2	Sitting	13.1	Sitting	15.1	Sitting	39.4	Safe
25	12.3	Sitting	9.5	Sitting	11.7	Sitting	13.2	Sitting	41.7	Safe
26	10.8	Sitting	9.0	Sitting	11.0	Sitting	12.5	Sitting	31.7	Safe
27	17.1	Standing	14.6	Sitting	18.3	Standing	21.0	Standing	58.1	Safe
28	16.1	Standing	12.8	Sitting	14.6	Sitting	17.2	Standing	43.1	Safe
29	16.3	Standing	13.3	Sitting	15.8	Sitting	18.5	Standing	46.5	Safe
30	21.4	Standing	17.2	Standing	20.3	Standing	23.5	Walking	65.3	Safe
31	21.5	Standing	16.8	Standing	19.9	Standing	23.1	Walking	72.4	Safe
32	17.1	Standing	13.5	Sitting	15.8	Sitting	18.3	Standing	46.3	Safe
33	17.5	Standing	13.5	Sitting	15.8	Sitting	18.4	Standing	51.2	Safe
34	18.3	Standing	14.1	Sitting	16.4	Standing	19.3	Standing	54.4	Safe
35	15.6	Sitting	12.1	Sitting	13.9	Sitting	16.4	Standing	44.4	Safe

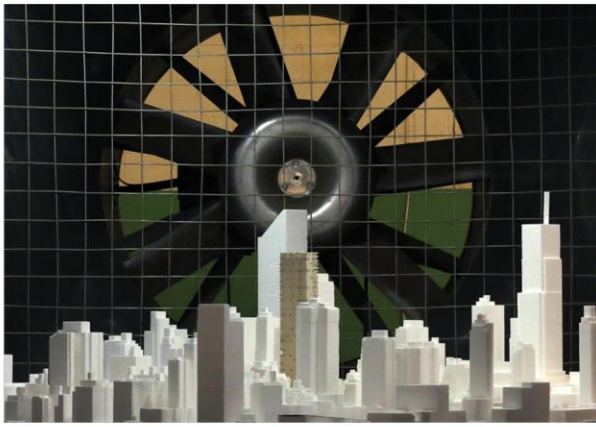
Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-16 km/h = Sitting, 16-22 km/h = Standing, 22-30 km/h =- Walking, >30 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE A2: SUMMARY OF PEDESTRIAN COMFORT

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
36	16.2	Standing	12.8	Sitting	15.0	Sitting	17.5	Standing	50.1	Safe
37	15.8	Sitting	11.6	Sitting	14.3	Sitting	16.4	Standing	50.6	Safe
38	19.5	Standing	15.8	Sitting	18.1	Standing	20.5	Standing	48.9	Safe
39	17.4	Standing	13.3	Sitting	15.4	Sitting	17.4	Standing	47.4	Safe
40	19.2	Standing	15.1	Sitting	17.3	Standing	19.9	Standing	48.5	Safe
41	11.5	Sitting	9.0	Sitting	10.6	Sitting	12.2	Sitting	29.9	Safe
42	10.5	Sitting	8.2	Sitting	9.2	Sitting	10.7	Sitting	24.1	Safe
43	16.1	Standing	13.4	Sitting	16.0	Sitting	18.5	Standing	47.1	Safe
44	17.9	Standing	14.7	Sitting	18.0	Standing	20.4	Standing	51.3	Safe
45	20.2	Standing	16.2	Standing	19.7	Standing	22.7	Walking	54.3	Safe
46	13.0	Sitting	9.7	Sitting	11.9	Sitting	13.3	Sitting	47.8	Safe
47	15.5	Sitting	12.1	Sitting	15.3	Sitting	17.6	Standing	45.2	Safe
48	19.2	Standing	16.4	Standing	20.5	Standing	22.9	Walking	61.4	Safe
49	19.9	Standing	16.4	Standing	21.2	Standing	24.4	Walking	66.2	Safe
50	21.6	Standing	17.2	Standing	20.2	Standing	23.4	Walking	53.2	Safe
51	23.7	Walking	18.9	Standing	23.3	Walking	26.9	Walking	67.9	Safe
52	14.1	Sitting	12.5	Sitting	15.5	Sitting	18.2	Standing	63.3	Safe
53	21.4	Standing	17.8	Standing	22.4	Walking	25.6	Walking	70.0	Safe
54	13.2	Sitting	11.1	Sitting	13.4	Sitting	15.6	Sitting	39.4	Safe
55	8.6	Sitting	7.2	Sitting	8.9	Sitting	10.3	Sitting	29.9	Safe
56	13.0	Sitting	10.0	Sitting	11.0	Sitting	13.1	Sitting	34.6	Safe
57	15.0	Sitting	11.2	Sitting	12.4	Sitting	14.7	Sitting	38.0	Safe
58	19.0	Standing	14.1	Sitting	15.0	Sitting	18.5	Standing	50.7	Safe
59	13.7	Sitting	10.6	Sitting	11.7	Sitting	13.5	Sitting	34.0	Safe
60	11.9	Sitting	9.0	Sitting	10.3	Sitting	11.6	Sitting	38.5	Safe







APPENDIX B

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.

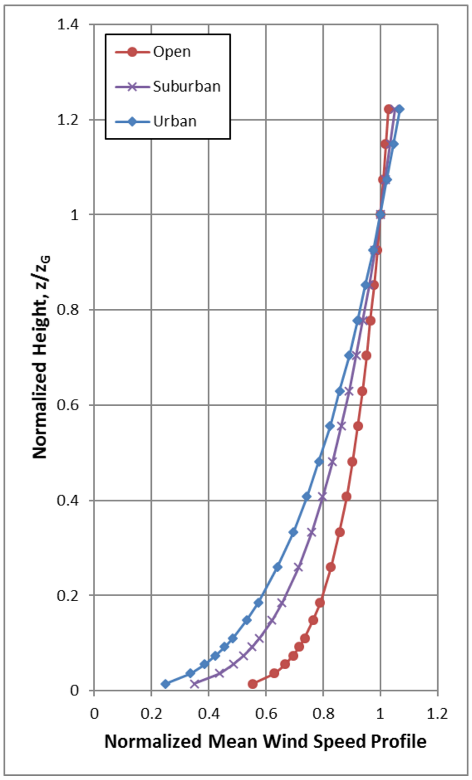
The exponent α varies according to the type of upwind terrain; α ranges from 0.14 for open country to 0.33 for an urban exposure. Figure B2 illustrates the theoretical variation of turbulence for open country, suburban and urban exposures.

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.



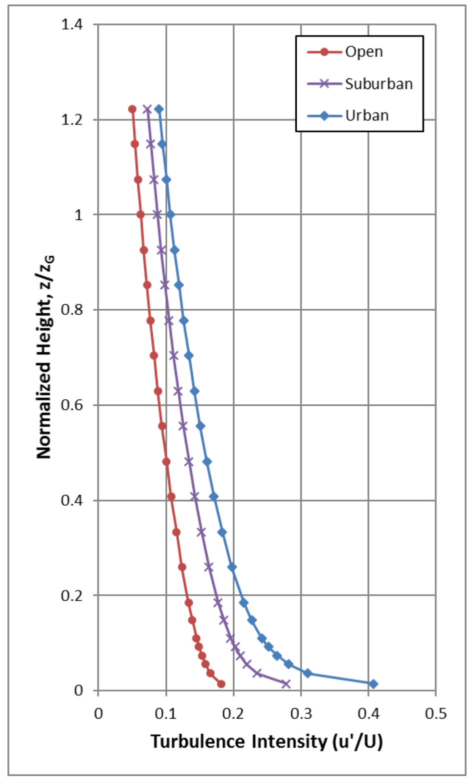


FIGURE B1 (LEFT): MEAN WIND SPEED PROFILES;
FIGURE B2 (RIGHT): TURBULENCE INTENSITY PROFILES

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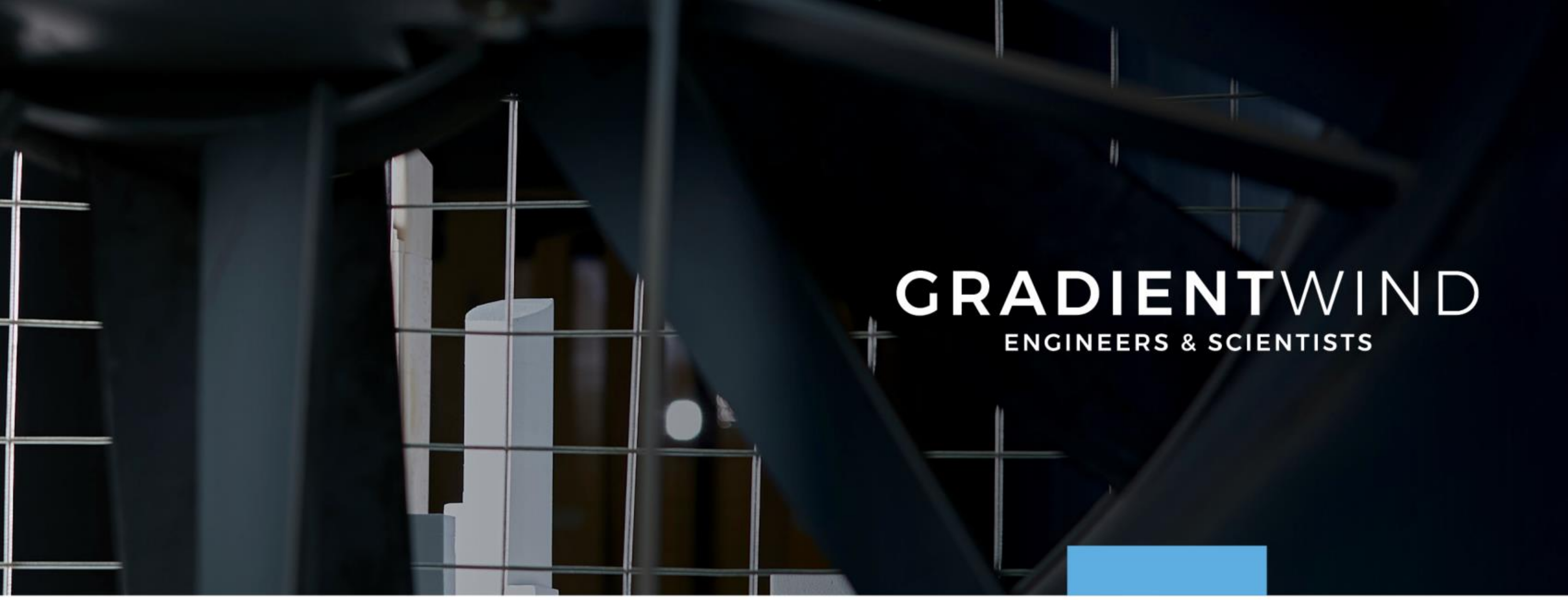

APPENDIX C

PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

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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 B1. 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.

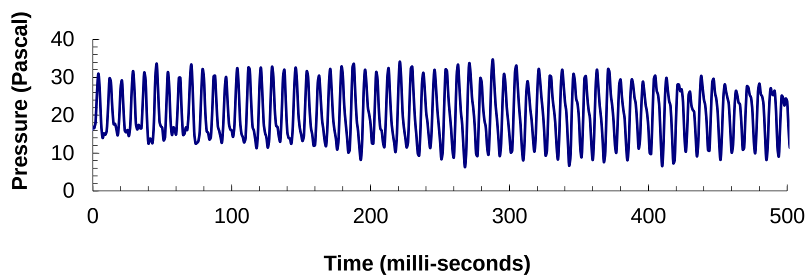

FIGURE C1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR

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