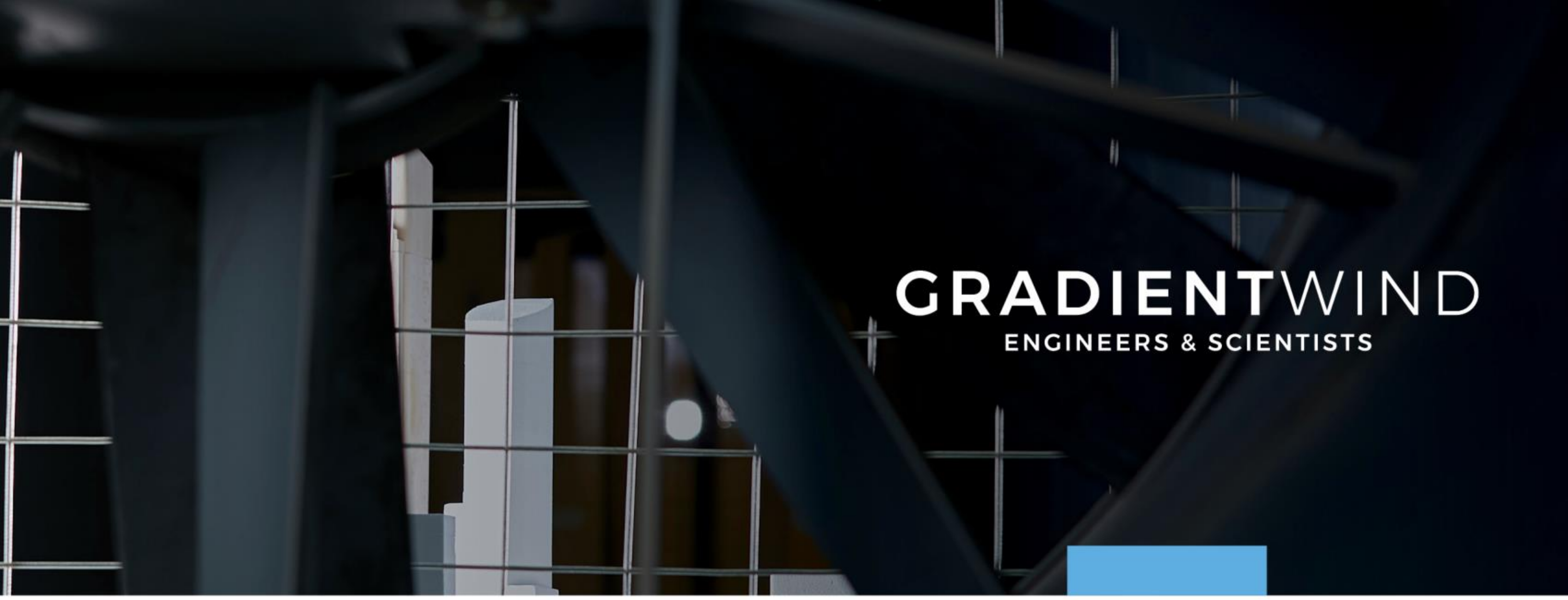
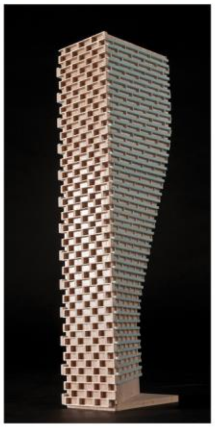
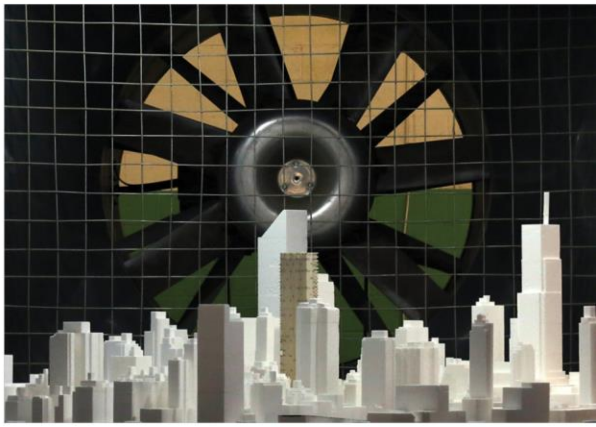


PEDESTRIAN LEVEL WIND STUDY

128 Lakeshore Road East
Mississauga, Ontario

REPORT: GWE21-350-WTPLW





December 9, 2021

PREPARED FOR
BlackTusk Group
800-365 Bay Street
Toronto, ON
M5H 2V1

PREPARED BY
Angelina Gomes, B.Eng., EIT, Junior Wind Scientist
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 128 Lakeshore Road East in Mississauga, 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 pedestrian areas investigated include sidewalks, building access points, parking areas, laneways, green space, plazas, patios, and nearby transit stops. Wind comfort is also evaluated over the rooftop outdoor amenity terrace. To evaluate the influence of the proposed development on the existing wind conditions surrounding the site, two massing configurations were studied: (i) existing conditions without the proposed development, and (ii) conditions with the proposed development in place. 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, City of Mississauga wind criteria, architectural drawings provided by IBI Group in November 2021, surrounding street layouts, as well as existing and approved future building massing information 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-3B, as well as Tables A1-A2 and B1-B3 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in Mississauga, we conclude that conditions over all pedestrian-sensitive areas within and surrounding the development site will be acceptable for the intended pedestrian uses on an annual and seasonal basis.

The rooftop outdoor amenity terrace will be comfortable for sitting or more sedentary activities during the summer, without the need for mitigation.

A comparison of the existing versus future wind comfort surrounding the study site indicates that the proposed development will have a generally neutral influence on grade-level wind conditions, with a few minor exceptions. The laneway directly southwest of the site will experience a slight improvement in pedestrian comfort upon the introduction of the proposed development, while portions of sidewalk along

Ann Street and Lakeshore Road East become somewhat windier. Where wind speeds reduce, 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.

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TABLE OF CONTENTS

1. INTRODUCTION

This report describes a pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 128 Lakeshore Road East in Mississauga, Ontario. The study was performed in accordance with industry standard wind tunnel testing techniques, City of Mississauga wind criteria, architectural drawings provided by IBI Group in November 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 pedestrian wind study is the proposed mixed-use development located at 128 Lakeshore Road East in Mississauga, Ontario. The study site is situated at the east corner of a parcel of land bounded by Helene Street North to the southwest, High Street East to the northwest, Ann Street to the northeast, and Lakeshore Road East to the southeast.

The study building comprises a 10-storey stepped rectangular building with the long axis aligned with Ann Street. Above three levels of below-grade parking, accessed from a covered driveway on the northeast side, the ground floor consists of retail space along the southeast side, and a residential lobby along the northeast side. Levels 2 and above are exclusively residential and at Level 2 the northeast and southwest sides extend to cantilever over the entrances below. Setbacks from all elevations of Level 4, the southeast side of Level 7, and the northwest, northeast, and southeast sides of Level 9 accommodate private terraces. At the mechanical penthouse level, all elevations set back to feature a wraparound outdoor amenity terrace on the building rooftop.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a 200-metre radius of the site) consist of low- and medium-rise buildings in all directions, with Nola Port Credit (15-storeys) directly northwest of the site, Harbourview (20-storeys) to the northeast across Ann Street, and Northshore (22-storeys) further to the northeast on Hurontario Street. The far-field surroundings (defined as the area beyond the near field and within a two-kilometer radius) are characterized as low-rise suburban buildings to the southwest clockwise to the northeast, with isolated medium- and high-rise buildings along Lakeshore Road East and West, and Lake Ontario dominating the northeast clockwise to the southwest.

Grade-level pedestrian areas investigated include sidewalks, building access points, parking areas, laneways, green space, plazas, patios, and nearby transit stops. Wind comfort is also evaluated over the rooftop outdoor amenity terrace. Figures 1A and 1B illustrate the existing and future site plan, respectively, and relevant surrounding context, 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 on the existing wind conditions surrounding the site.

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 Mississauga 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

[1] City of Mississauga Urban Design Terms of Reference, Wind Comfort and Safety Studies, June 2014

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 50 sensor locations on the scale model in Gradient Wind's wind tunnel. Of these 50 sensors, 47 were located at grade and the remaining three sensors were located over the Level 11 amenity terrace. Wind speed measurements were performed for each of the 50 sensors for 36 wind directions at 10° intervals. Figures 1A and 1B illustrate the existing and future site plan, respectively, and relevant surrounding context, while sensor locations used to investigate wind conditions are illustrated in Figures 2A through 3B.

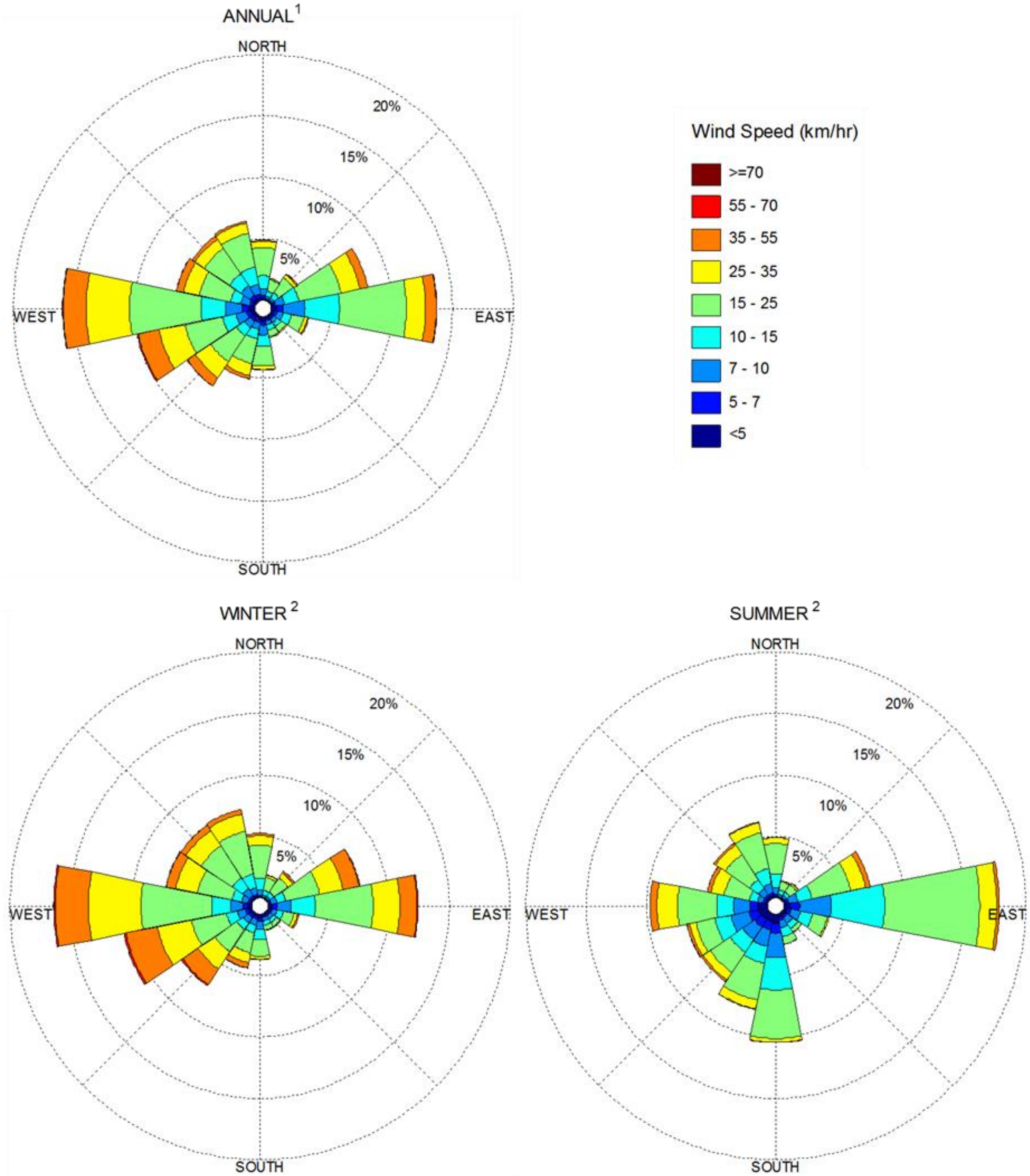
Mean and peak wind speed values for each location and wind direction were calculated from real-time pressure measurements, recorded at a sample rate of 500 samples per second, and taken over a 60-second time period. This period at model-scale corresponds approximately to one hour in full-scale, which 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 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 Mississauga was developed from approximately 35-years of hourly meteorological wind data recorded at Toronto Island Billy Bishop Airport and obtained from Environment and Climate Change Canada. Wind speed and direction data were divided into two distinct seasons, as stipulated in the noted City of Mississauga Urban Design Terms of Reference. More specifically, the summer season is defined as May through October, while the winter season is defined as November through April, inclusive.

The statistical model of the Mississauga area wind climate, which indicates the directional character of local winds on a seasonal basis, is illustrated on the following page. The plots illustrate seasonal distribution of measured wind speeds and directions in kilometers per hour (km/h). Probabilities of occurrence of different wind speeds are represented as stacked polar bars in sixteen azimuth divisions. The radial direction represents the percentage of time for various wind speed ranges per wind direction during the measurement period. The preferred wind speeds and directions can be identified by the longer length of the bars. For Mississauga (south of the Queen Elizabeth Way, or QEW), the most common winds concerning pedestrian comfort during the winter season occur for westerly wind directions, followed by those from the east. The most common winds during the summer season occur for easterly wind directions. The directional preference and relative magnitude of the wind speed varies somewhat from season to season. Also, by convection in microclimate studies, wind direction refers to the wind origin (e.g., a north wind blows from north to south).

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES
TORONTO ISLAND BILLY BISHOP 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. Since both mean and gust wind speeds affect pedestrian comfort, their combined effect is defined in the City of Mississauga Urban Design Terms of Reference[1]. More specifically, the criteria are defined as a Gust Equivalent Mean (GEM) wind speed, which is the greater of the mean wind speed or the gust wind speed divided by 1.85. The wind speed ranges are selected based on 'The Beaufort Scale' (presented on the following page), which describes the effects of forces produced by varying wind speed levels on objects.

Four pedestrian comfort classes and corresponding GEM wind speed ranges are used to assess pedestrian comfort, which include: (i) Sitting; (ii) Standing; (iii) Walking; and (iv) Uncomfortable. More specifically, the comfort classes, wind speed ranges, and limiting criteria are summarized as follows:

(i) **Sitting** – GEM wind speeds below 10 km/h occurring more than 80% of the time would be considered acceptable for sedentary activities, including sitting.

(ii) **Standing** – GEM wind speeds below 15 km/h (i.e. 10-15 km/h) occurring more than 80% of the time are acceptable for activities such as standing, strolling or more vigorous activities.

(iii) **Walking** – GEM wind speeds below 20 km/h (i.e. 15-20 km/h) occurring more than 80% of the time are acceptable for walking or more vigorous activities.

(iv) **Uncomfortable** – Uncomfortable conditions are characterized by predicted values that fall below the 80% criterion for walking. Brisk walking and exercise, such as jogging, would be acceptable for moderate excesses of this criterion.

Gust wind speeds greater than 90 km/h, occurring more than 0.1% of the time on an annual basis, are classified as dangerous. From calculations of stability, it can be shown that gust wind speeds of 90 km/h would be the approximate threshold wind speed that would cause a vulnerable member of the population to fall.

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 GEM wind speeds of 10 km/h were exceeded for more than 20% of the time, most pedestrians would judge that location to be too windy for sitting or more sedentary activities. Similarly, if GEM wind speeds of 20 km/h at a location were exceeded for more than 20% of the time, walking or less vigorous activities would be considered uncomfortable. As 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 across the study site, 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. 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

Tables A1 and A2 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 12.1 for the summer season indicates that 80% of the measured data falls at or below 12.1 km/h during the summer months and conditions are therefore suitable for standing, as the 80% threshold value falls within the exceedance range of 10-15 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 3B. 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 Tables A1-A2 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, laneways, parking areas, and green space within and surrounding the study site 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 primary building access points within the development will be suitable for standing or better throughout the year. For the lobby entrance along Ann Street (Sensor 43), which experiences conditions comfortable for walking during the winter, the doorway has been recessed into the building façade to locally-improve conditions.

All secondary building access points (including stairwell exits and vehicle entrances) will be suitable for standing or better throughout the year, which is appropriate.

3. The nearby plaza and patio southeast of the site across Lakeshore Road East (Sensors 14-16) will be comfortable for sitting throughout each seasonal period, which is acceptable.
4. The nearby transit stops along Lakeshore Road East (Sensors 9 & 12) will be suitable for standing or better throughout the year, which appropriate.
5. The rooftop outdoor amenity (Sensors 48-50) will be comfortable for sitting or more sedentary activities during the summer months, without the need for mitigation.
6. 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.

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 seasonal summary of the comparative wind comfort predictions. 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 speeds at most grade-level areas will remain unchanged upon the introduction of the proposed study building, with improvements along the laneway directly southwest of the site (Sensors 36-38). Although wind speeds marginally increase on portions of sidewalk along Ann Street (Sensor 7), and Lakeshore Road East (Sensors 24, 40, & 41), 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 the proposed mixed-use development located at 128 Lakeshore Road East in Mississauga, 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-3B, as well as Tables A1-A2 and B1-B3 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in Mississauga, we conclude that conditions over all pedestrian-sensitive areas within and surrounding the development site will be acceptable for the intended pedestrian uses on an annual and seasonal basis.

The rooftop outdoor amenity terrace will be comfortable for sitting or more sedentary activities during the summer, without the need for mitigation.

A comparison of the existing versus future wind comfort surrounding the study site indicates that the proposed development will have a generally neutral influence on grade-level wind conditions, with a few minor exceptions. The laneway directly southwest of the site will experience a slight improvement in pedestrian comfort upon the introduction of the proposed development, while portions of sidewalk along Ann Street and Lakeshore Road East become somewhat windier. Where wind speeds reduce, 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.

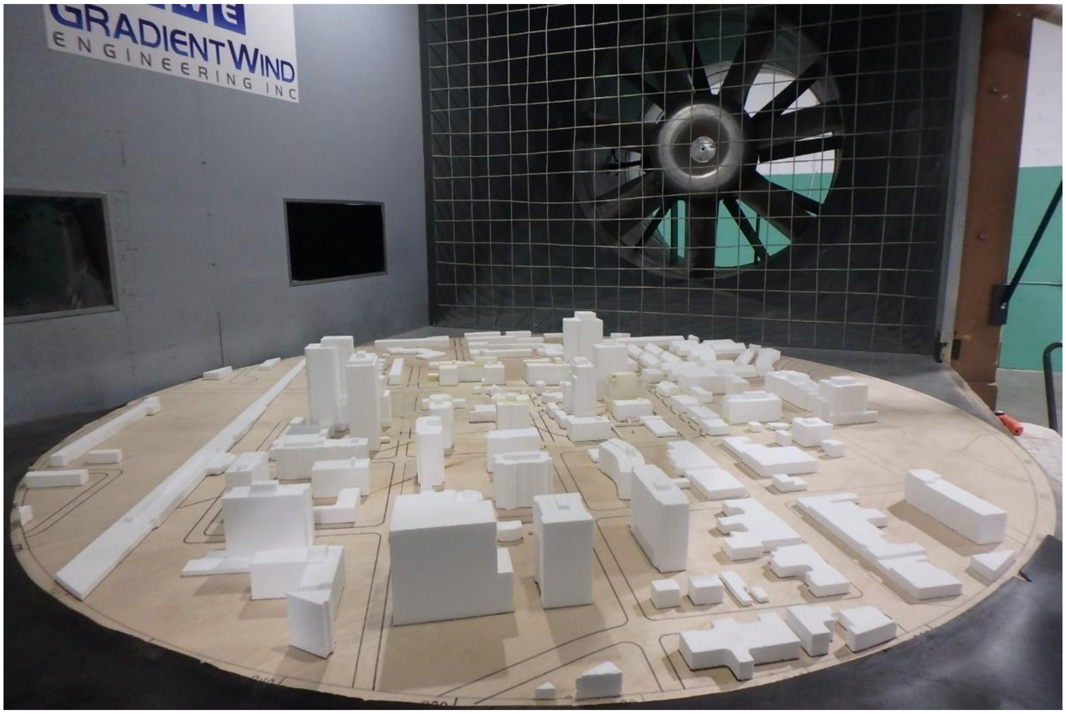
Angelina Gomes, B.Eng., EIT
Junior Wind Scientist

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

GWE21-350-WTPLW

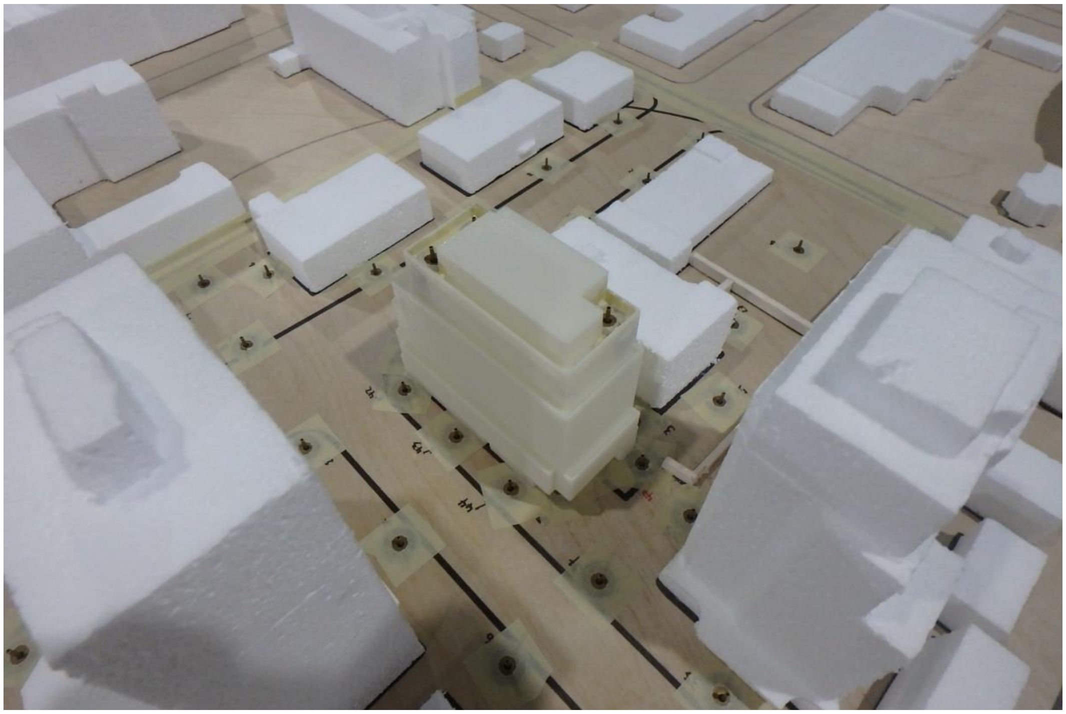
PHOTOGRAPH 1: CLOSE-UP VIEW OF EXISTING CONTEXT MODEL LOOKING SOUTH

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



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 SOUTH

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

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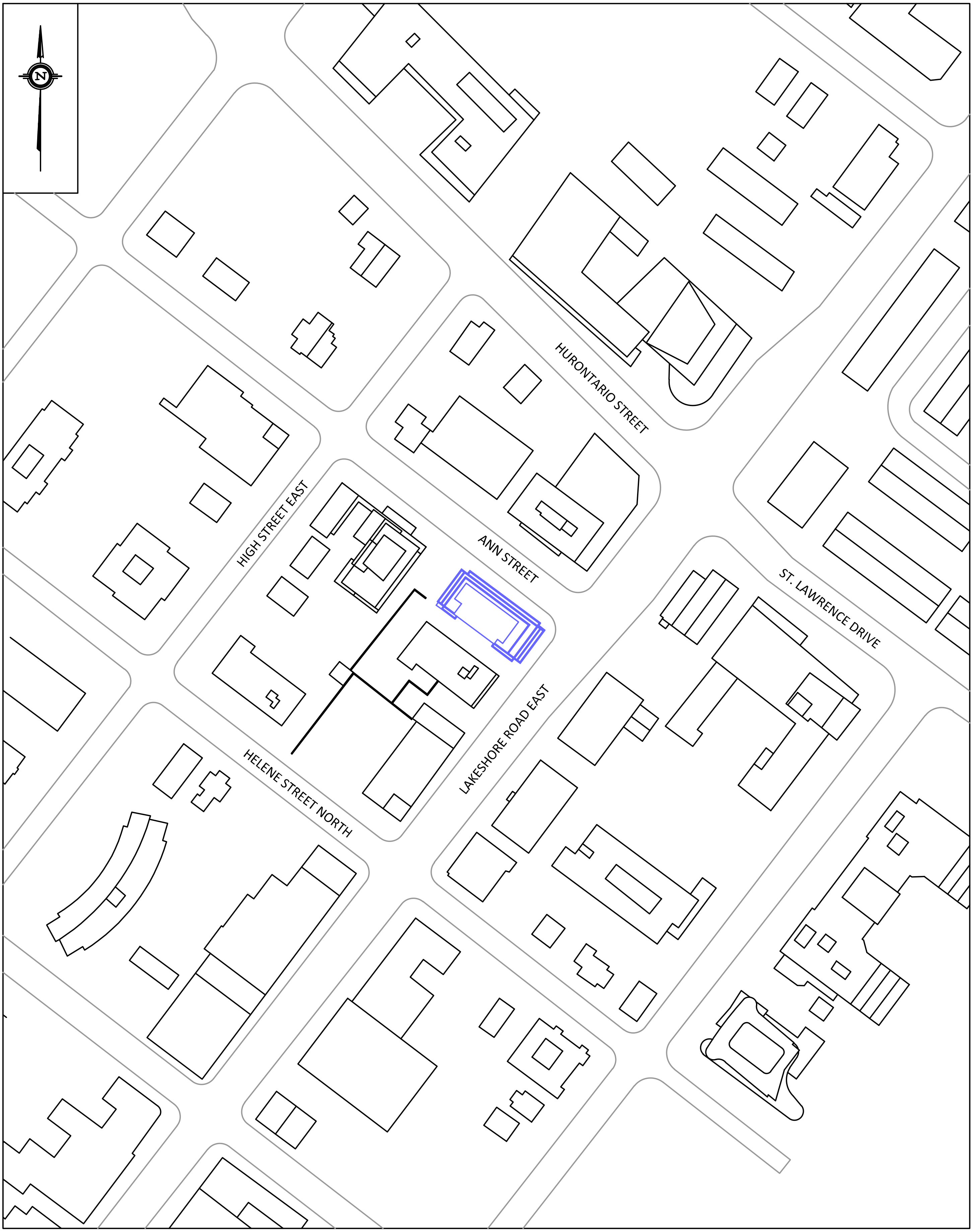
PROJECT		DESCRIPTION
128 LAKESHORE ROAD EAST, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY		FIGURE 1A: EXISTING CONDITIONS SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:2000 (APPROX.)	DRAWING NO.: GWE21-350-PLW-1A	
DATE: NOVEMBER 16, 2021	DRAWN BY: K.A.	



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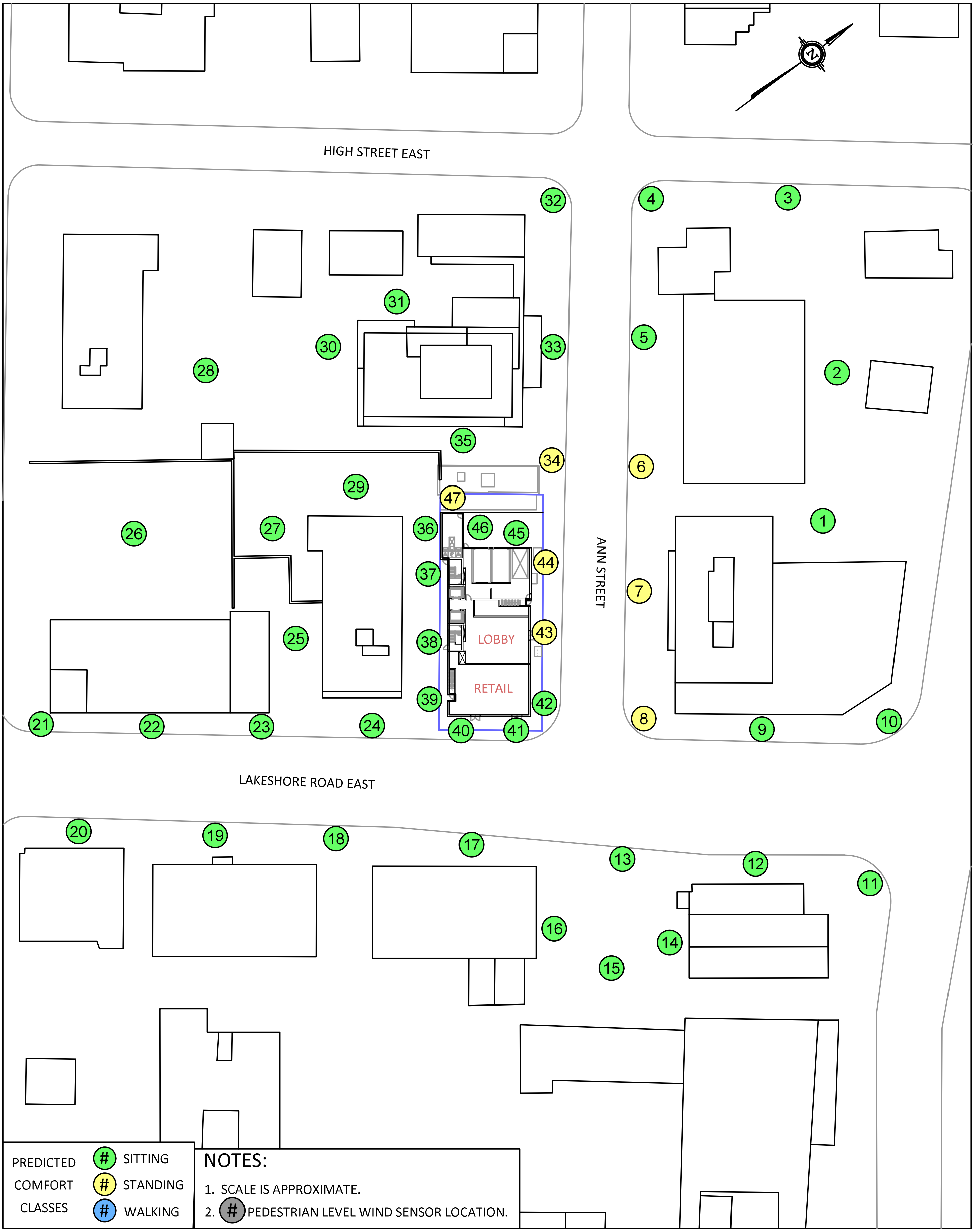
PROJECT: 128 LAKESHORE ROAD EAST, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 1B: FUTURE PROPOSED CONDITIONS SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:2000 (APPROX.)	DRAWING NO.: GWE21-350-PLW-1B	
DATE: NOVEMBER 16, 2021	DRAWN BY: K.A.	



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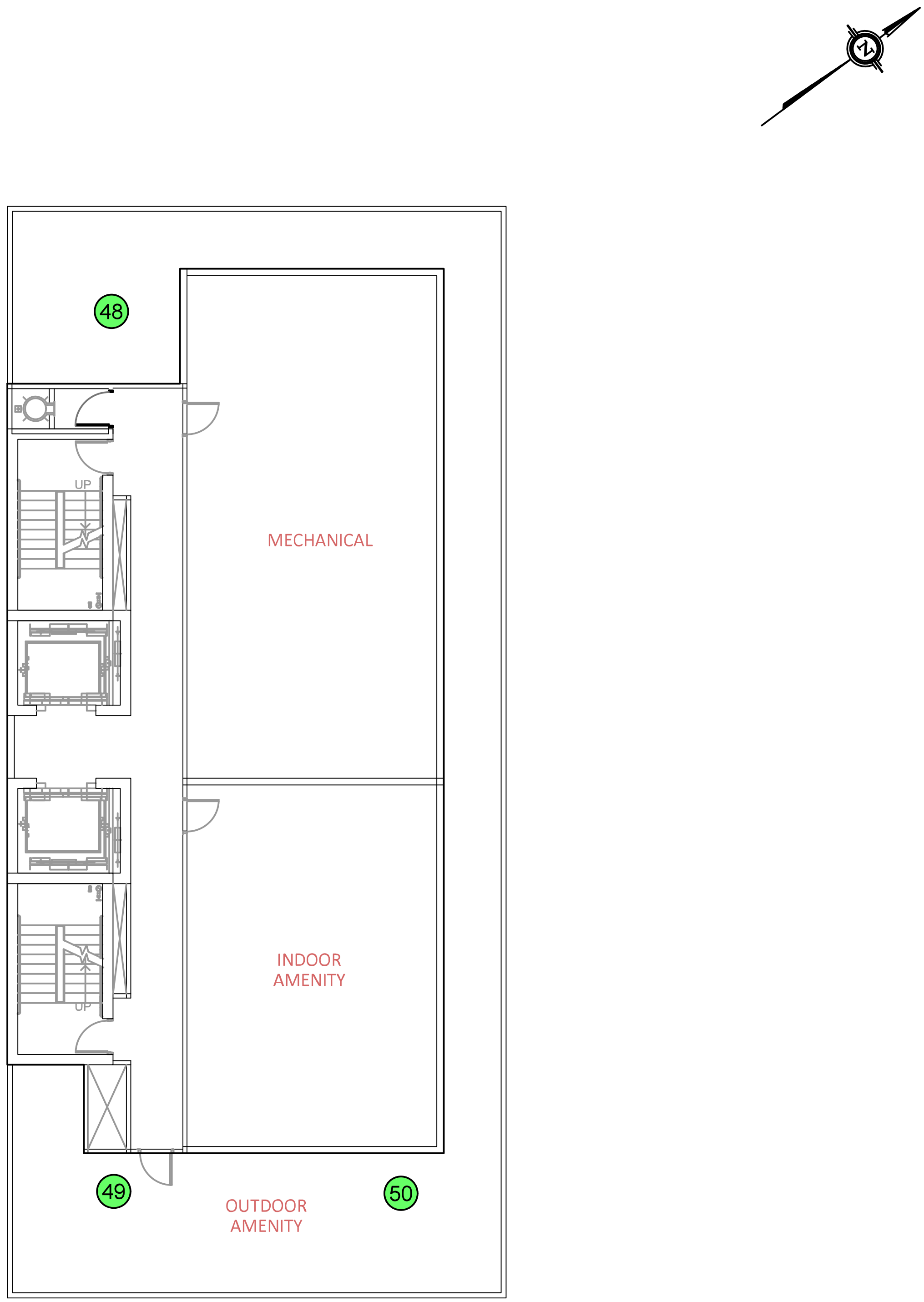
PROJECT: 128 LAKESHORE ROAD EAST, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 2A: SUMMER GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:1000 (APPROX.)	DRAWING NO.: GWE21-350-PLW-2A	
DATE: NOVEMBER 16, 2021	DRAWN BY: K.A.	



PREDICTED COMFORT CLASSES

- # SITTING
- # STANDING
- # WALKING

NOTES:

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

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PROJECT	128 LAKESHORE ROAD EAST, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY
SCALE	1:200 (APPROX.)
DRAWING NO.	GWE21-350-PLW-2B
DATE	NOVEMBER 16, 2021
DRAWN BY	K.A.
DESCRIPTION	FIGURE 2B: SUMMER ROOFTOP OUTDOOR AMENITY PEDESTRIAN COMFORT PREDICTIONS

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

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

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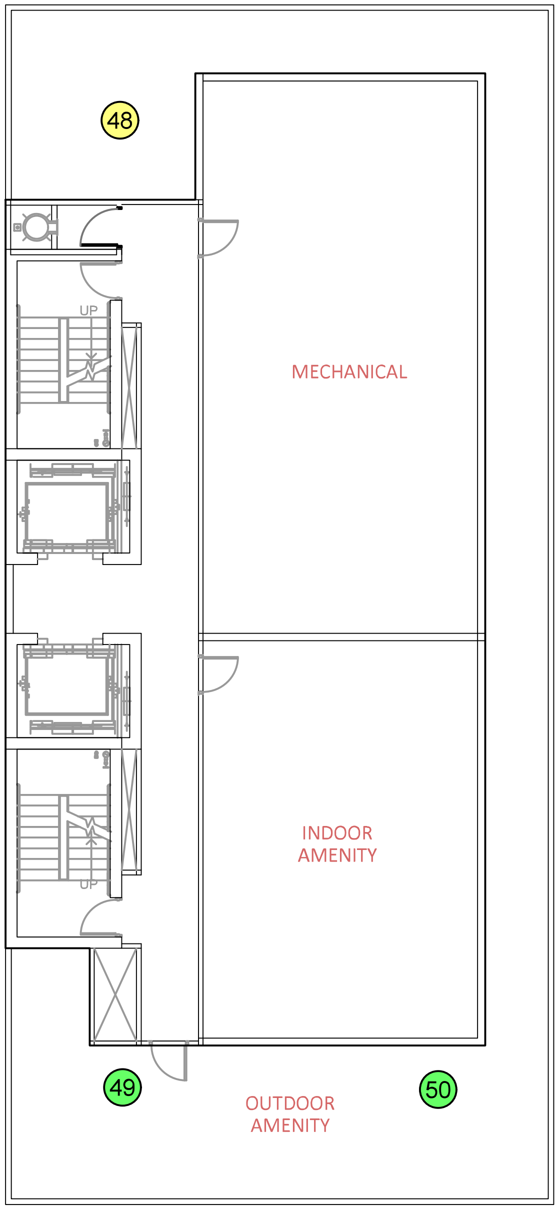
PROJECT: 128 LAKESHORE ROAD EAST, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION: FIGURE 3A: WINTER GROUND FLOOR PLAN PEDESTRIAN COMFORT PREDICTIONS
SCALE: 1:1000 (APPROX.)	DRAWING NO.: GWE21-350-PLW-3A	
DATE: NOVEMBER 16, 2021	DRAWN BY: K.A.	



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

NOTES:

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

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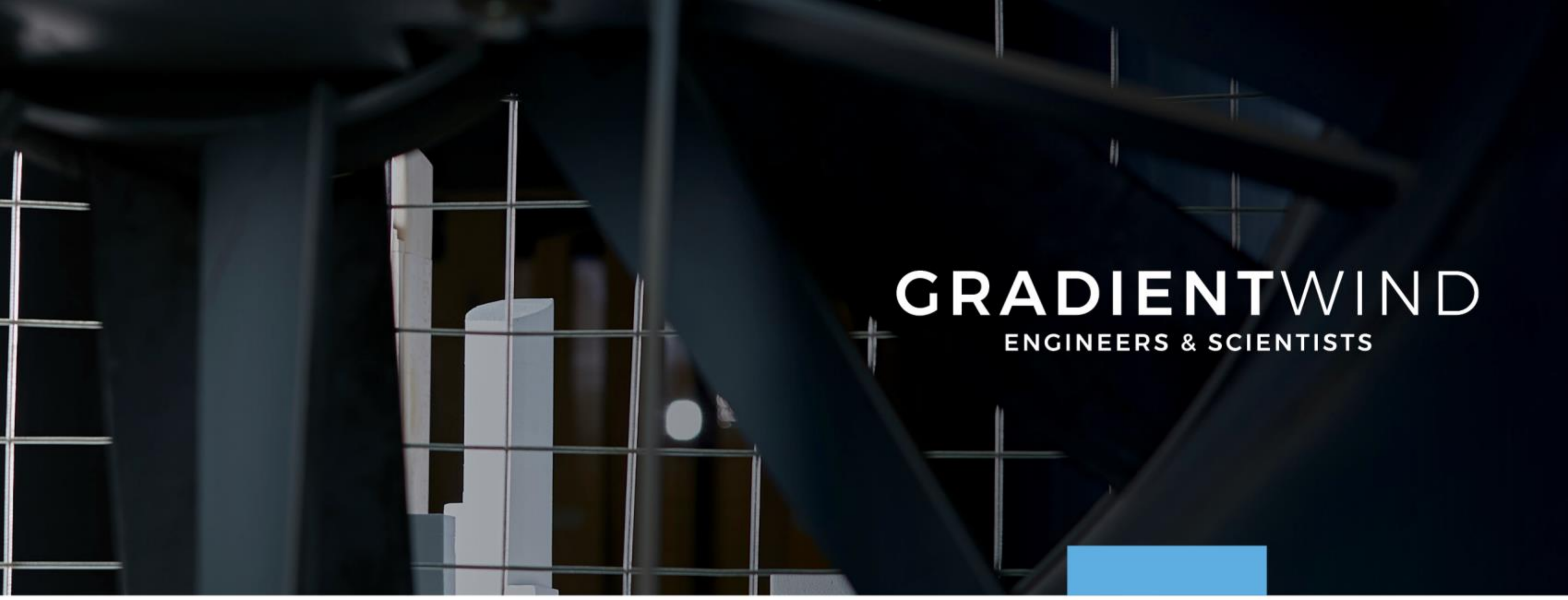
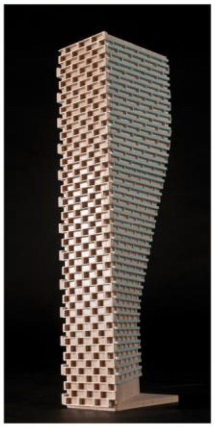
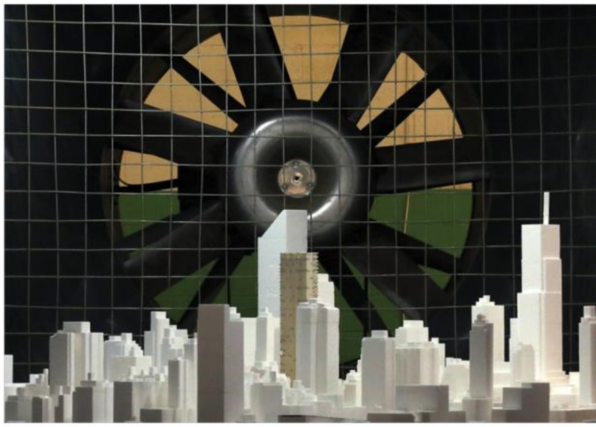
PROJECT	128 LAKESHORE ROAD EAST, MISSISSAUGA PEDESTRIAN LEVEL WIND STUDY	
SCALE	1:200 (APPROX.)	DRAWING NO. GWE21-350-PLW-3B
DATE	NOVEMBER 16, 2021	DRAWN BY K.A.

DESCRIPTION

FIGURE 3B: WINTER
ROOFTOP OUTDOOR AMENITY
PEDESTRIAN COMFORT PREDICTIONS







APPENDIX A

PEDESTRIAN COMFORT SUITABILITY, TABLES A1-A2
(FUTURE CONDITIONS)

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Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

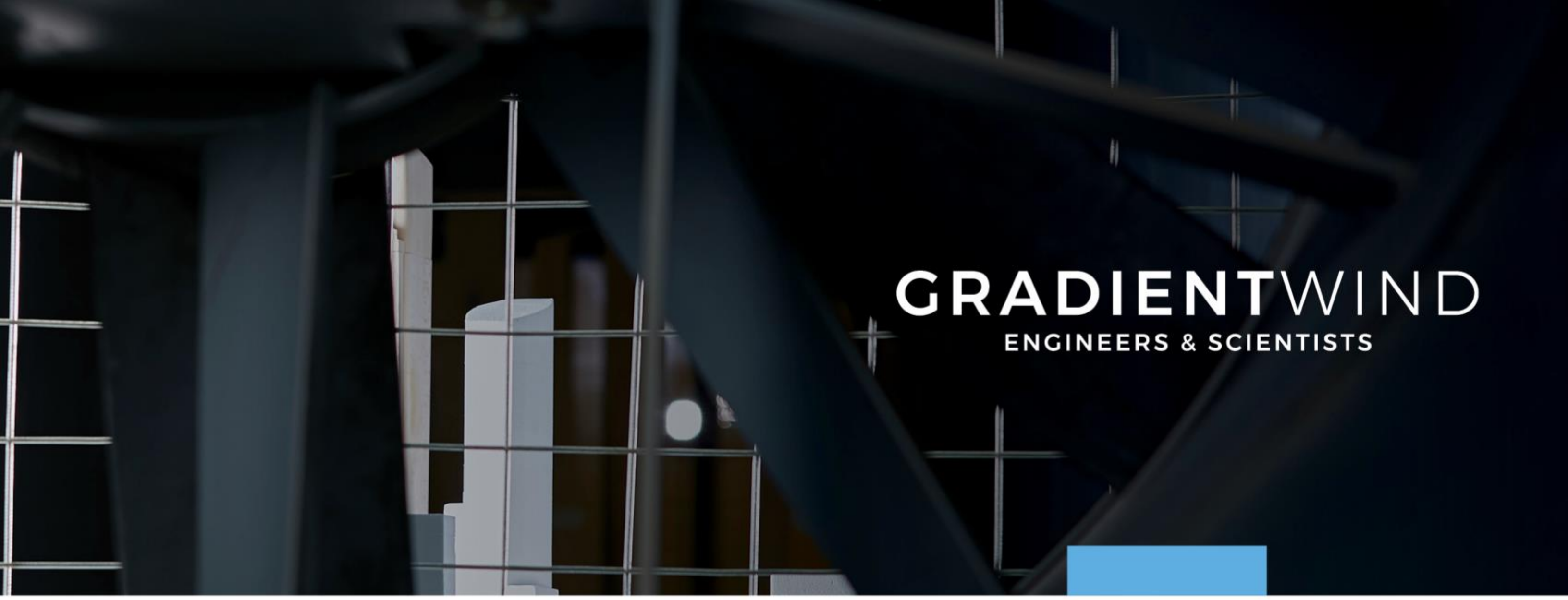
TABLE A1: SUMMARY OF PEDESTRIAN COMFORT (FUTURE CONDITIONS)

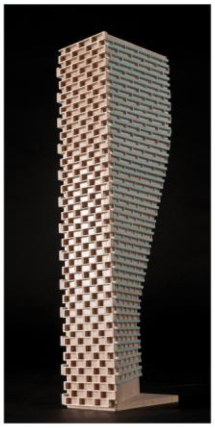
Sensor	Pedestrian Comfort				Pedestrian Safety	
	Summer		Winter		Annual	
	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Safety Class
1	8.4	Sitting	12.7	Standing	47.2	Safe
2	8.9	Sitting	12.7	Standing	63.9	Safe
3	7.3	Sitting	11.3	Standing	39.2	Safe
4	7.3	Sitting	11.6	Standing	43.1	Safe
5	8.6	Sitting	12.6	Standing	46.0	Safe
6	10.2	Standing	12.9	Standing	49.0	Safe
7	12.9	Standing	18.1	Walking	65.2	Safe
8	10.6	Standing	15.7	Walking	54.9	Safe
9	7.6	Sitting	11.1	Standing	44.4	Safe
10	8.4	Sitting	11.8	Standing	42.3	Safe
11	8.6	Sitting	13.2	Standing	46.6	Safe
12	8.1	Sitting	12.0	Standing	44.0	Safe
13	8.2	Sitting	12.3	Standing	42.0	Safe
14	5.7	Sitting	8.8	Sitting	33.5	Safe
15	5.9	Sitting	9.4	Sitting	39.5	Safe
16	6.3	Sitting	9.3	Sitting	36.8	Safe
17	9.2	Sitting	13.6	Standing	55.3	Safe
18	8.8	Sitting	13.4	Standing	42.5	Safe
19	8.6	Sitting	12.6	Standing	44.7	Safe
20	6.1	Sitting	9.7	Sitting	35.7	Safe
21	8.0	Sitting	10.9	Standing	44.0	Safe
22	6.3	Sitting	8.7	Sitting	35.6	Safe
23	7.3	Sitting	9.9	Sitting	50.5	Safe
24	7.6	Sitting	10.6	Standing	40.4	Safe
25	6.3	Sitting	8.5	Sitting	35.2	Safe
26	6.5	Sitting	9.5	Sitting	37.7	Safe
27	7.4	Sitting	11.8	Standing	46.7	Safe
28	8.2	Sitting	12.0	Standing	44.1	Safe
29	8.3	Sitting	13.1	Standing	55.3	Safe
30	8.3	Sitting	12.6	Standing	60.9	Safe
31	9.2	Sitting	11.3	Standing	53.5	Safe
32	7.2	Sitting	10.9	Standing	39.5	Safe
33	8.2	Sitting	11.1	Standing	43.5	Safe
34	12.0	Standing	16.7	Walking	54.5	Safe
35	9.1	Sitting	14.5	Standing	55.0	Safe

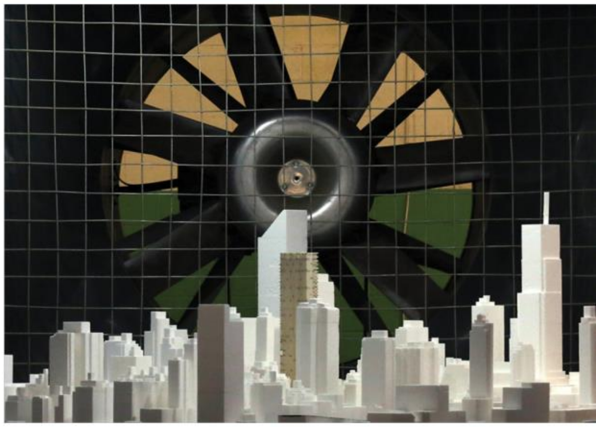
Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** 0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

TABLE A2: SUMMARY OF PEDESTRIAN COMFORT (FUTURE CONDITONS)

Sensor	Pedestrian Comfort				Pedestrian Safety	
	Summer		Winter		Annual	
	Wind Speed	Comfort Class	Wind Speed	Comfort Class	Wind Speed	Safety Class
36	6.9	Sitting	10.0	Sitting	41.6	Safe
37	6.5	Sitting	9.3	Sitting	45.7	Safe
38	7.4	Sitting	9.9	Sitting	53.8	Safe
39	7.8	Sitting	12.0	Standing	54.6	Safe
40	7.7	Sitting	10.3	Standing	46.8	Safe
41	6.6	Sitting	10.5	Standing	51.2	Safe
42	9.6	Sitting	14.3	Standing	50.3	Safe
43	12.2	Standing	16.8	Walking	56.6	Safe
44	12.8	Standing	19.2	Walking	66.7	Safe
45	6.4	Sitting	10.0	Sitting	42.5	Safe
46	6.5	Sitting	10.1	Standing	49.1	Safe
47	11.4	Standing	19.7	Walking	68.2	Safe
48	6.6	Sitting	11.4	Standing	46.0	Safe
49	7.6	Sitting	9.4	Sitting	57.6	Safe
50	7.6	Sitting	10.0	Sitting	40.6	Safe







APPENDIX B

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

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Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** (0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 km/h = Walking, >20 km/h = Uncomfortable
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	9.4	Sitting	-	13.7	Standing	-
	Future	8.4	Sitting	Unchanged	12.7	Standing	Unchanged
2	Existing	9.4	Sitting	-	12.9	Standing	-
	Future	8.9	Sitting	Unchanged	12.7	Standing	Unchanged
3	Existing	8.3	Sitting	-	13.0	Standing	-
	Future	7.3	Sitting	Unchanged	11.3	Standing	Unchanged
4	Existing	7.5	Sitting	-	11.5	Standing	-
	Future	7.3	Sitting	Unchanged	11.6	Standing	Unchanged
5	Existing	9.6	Sitting	-	13.6	Standing	-
	Future	8.6	Sitting	Unchanged	12.6	Standing	Unchanged
6	Existing	10.9	Standing	-	14.8	Standing	-
	Future	10.2	Standing	Unchanged	12.9	Standing	Unchanged
7	Existing	10.3	Standing	-	14.6	Standing	-
	Future	12.9	Standing	Unchanged	18.1	Walking	Reduced
8	Existing	11.5	Standing	-	15.9	Walking	-
	Future	10.6	Standing	Unchanged	15.7	Walking	Unchanged
9	Existing	8.2	Sitting	-	11.6	Standing	-
	Future	7.6	Sitting	Unchanged	11.1	Standing	Unchanged
10	Existing	8.9	Sitting	-	11.6	Standing	-
	Future	8.4	Sitting	Unchanged	11.8	Standing	Unchanged
11	Existing	9.1	Sitting	-	14.0	Standing	-
	Future	8.6	Sitting	Unchanged	13.2	Standing	Unchanged
12	Existing	9.6	Sitting	-	13.9	Standing	-
	Future	8.1	Sitting	Unchanged	12.0	Standing	Unchanged
13	Existing	8.7	Sitting	-	13.3	Standing	-
	Future	8.2	Sitting	Unchanged	12.3	Standing	Unchanged
14	Existing	5.6	Sitting	-	9.0	Sitting	-
	Future	5.7	Sitting	Unchanged	8.8	Sitting	Unchanged
15	Existing	5.9	Sitting	-	9.7	Sitting	-
	Future	5.9	Sitting	Unchanged	9.4	Sitting	Unchanged

Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** (0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

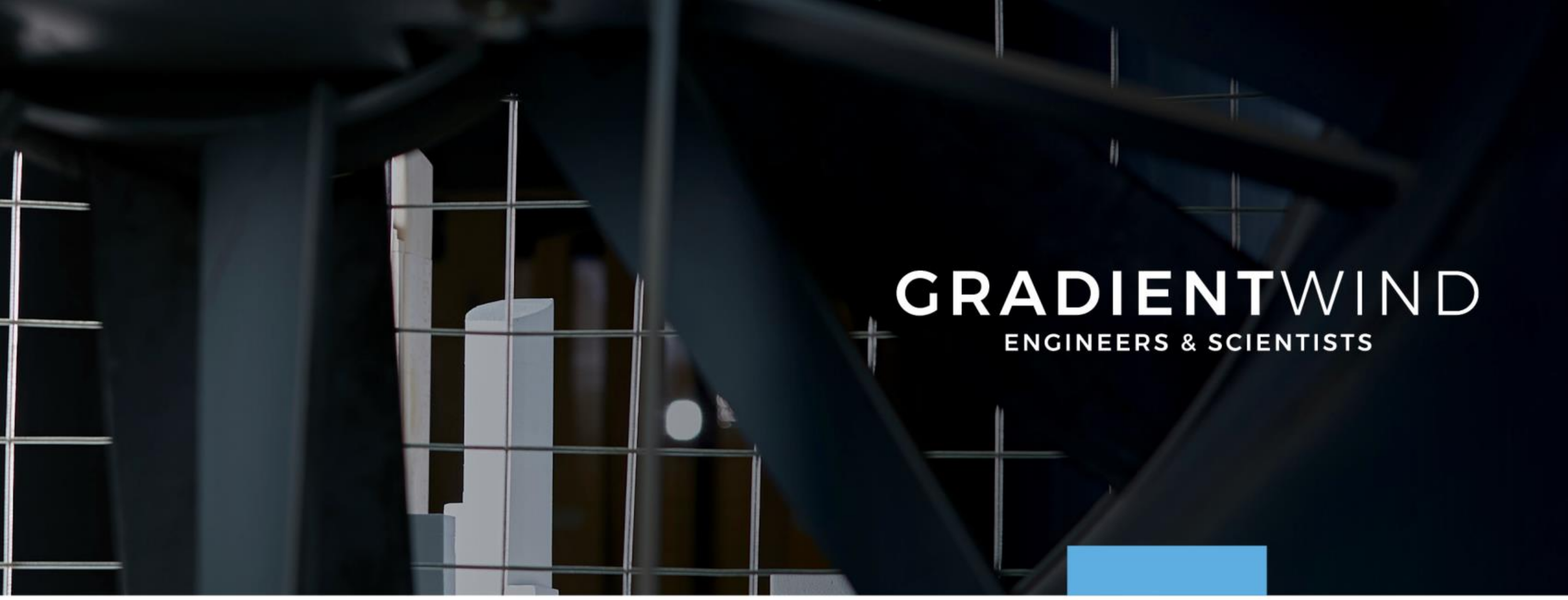
TABLE B2: COMPARATIVE SUMMARY OF PEDESTRIAN COMFORT

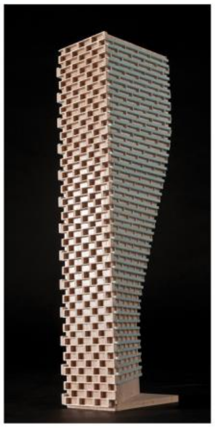
Sensor	Massing Scenario	Summer Pedestrian Comfort			Winter Pedestrian Comfort		
		Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing	Wind Speed (km/h) 80% data ≤	Predicted Comfort Class	Future Comfort Class Compared to Existing
16	Existing	5.4	Sitting	-	8.3	Sitting	-
	Future	6.3	Sitting	Unchanged	9.3	Sitting	Unchanged
17	Existing	7.1	Sitting	-	11.0	Standing	-
	Future	9.2	Sitting	Unchanged	13.6	Standing	Unchanged
18	Existing	8.2	Sitting	-	12.8	Standing	-
	Future	8.8	Sitting	Unchanged	13.4	Standing	Unchanged
19	Existing	8.7	Sitting	-	13.2	Standing	-
	Future	8.6	Sitting	Unchanged	12.6	Standing	Unchanged
20	Existing	6.0	Sitting	-	9.7	Sitting	-
	Future	6.1	Sitting	Unchanged	9.7	Sitting	Unchanged
21	Existing	7.5	Sitting	-	10.6	Standing	-
	Future	8.0	Sitting	Unchanged	10.9	Standing	Unchanged
22	Existing	6.3	Sitting	-	8.6	Sitting	-
	Future	6.3	Sitting	Unchanged	8.7	Sitting	Unchanged
23	Existing	6.3	Sitting	-	9.0	Sitting	-
	Future	7.3	Sitting	Unchanged	9.9	Sitting	Unchanged
24	Existing	7.0	Sitting	-	10.0	Sitting	-
	Future	7.6	Sitting	Unchanged	10.6	Standing	Reduced
25	Existing	6.3	Sitting	-	8.6	Sitting	-
	Future	6.3	Sitting	Unchanged	8.5	Sitting	Unchanged
26	Existing	6.9	Sitting	-	10.0	Sitting	-
	Future	6.5	Sitting	Unchanged	9.5	Sitting	Unchanged
27	Existing	6.3	Sitting	-	10.0	Standing	-
	Future	7.4	Sitting	Unchanged	11.8	Standing	Unchanged
28	Existing	9.0	Sitting	-	12.6	Standing	-
	Future	8.2	Sitting	Unchanged	12.0	Standing	Unchanged
29	Existing	8.6	Sitting	-	12.0	Standing	-
	Future	8.3	Sitting	Unchanged	13.1	Standing	Unchanged
30	Existing	9.3	Sitting	-	13.6	Standing	-
	Future	8.3	Sitting	Unchanged	12.6	Standing	Unchanged

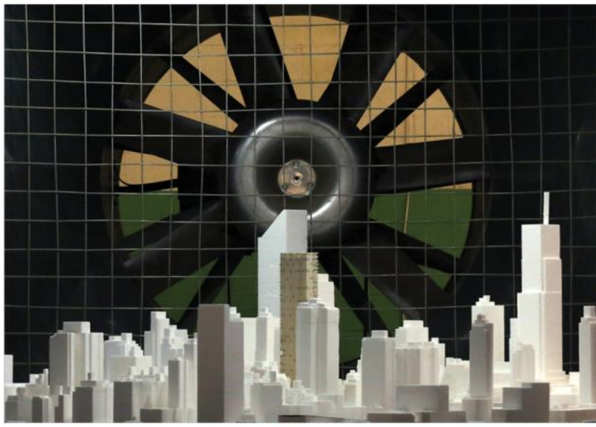
Guidelines	
Pedestrian Comfort	**20% exceedance wind speed** (0-10 km/h = Sitting, 10-15 km/h = Standing, 15-20 km/h = Walking, >20 km/h = Uncomfortable
Pedestrian Safety	**0.1% exceedance wind speed** 0-90 km/h = Safe

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	9.2	Sitting	-	11.4	Standing	-
	Future	9.2	Sitting	Unchanged	11.3	Standing	Unchanged
32	Existing	7.5	Sitting	-	10.8	Standing	-
	Future	7.2	Sitting	Unchanged	10.9	Standing	Unchanged
33	Existing	8.4	Sitting	-	11.5	Standing	-
	Future	8.2	Sitting	Unchanged	11.1	Standing	Unchanged
34	Existing	13.7	Standing	-	17.9	Walking	-
	Future	12.0	Standing	Unchanged	16.7	Walking	Unchanged
35	Existing	7.0	Sitting	-	11.3	Standing	-
	Future	9.1	Sitting	Unchanged	14.5	Standing	Unchanged
36	Existing	9.0	Sitting	-	15.0	Standing	-
	Future	6.9	Sitting	Unchanged	10.0	Sitting	Improved
37	Existing	9.7	Sitting	-	14.4	Standing	-
	Future	6.5	Sitting	Unchanged	9.3	Sitting	Improved
38	Existing	9.1	Sitting	-	12.9	Standing	-
	Future	7.4	Sitting	Unchanged	9.9	Sitting	Improved
39	Existing	8.0	Sitting	-	12.4	Standing	-
	Future	7.8	Sitting	Unchanged	12.0	Standing	Unchanged
40	Existing	6.5	Sitting	-	9.5	Sitting	-
	Future	7.7	Sitting	Unchanged	10.3	Standing	Reduced
41	Existing	6.5	Sitting	-	9.7	Sitting	-
	Future	6.6	Sitting	Unchanged	10.5	Standing	Reduced
42	Existing	8.6	Sitting	-	12.2	Standing	-
	Future	9.6	Sitting	Unchanged	14.3	Standing	Unchanged
43	Existing	11.9	Standing	-	16.3	Walking	-
	Future	12.2	Standing	Unchanged	16.8	Walking	Unchanged
44	Existing	12.6	Standing	-	16.9	Walking	-
	Future	12.8	Standing	Unchanged	19.2	Walking	Unchanged
45	Existing	8.8	Sitting	-	12.7	Standing	-
	Future	6.4	Sitting	Unchanged	10.0	Sitting	Improved







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.

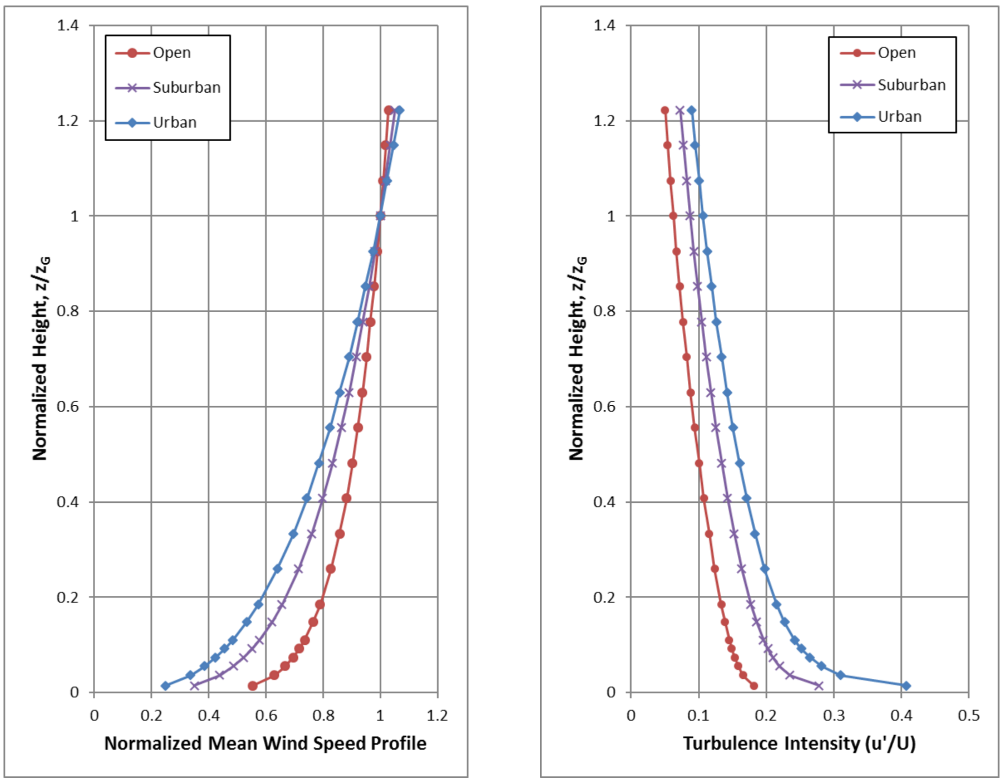

FIGURE C1 (LEFT): MEAN WIND SPEED PROFILES;
FIGURE C2 (RIGHT): TURBULENCE INTENSITY PROFILES

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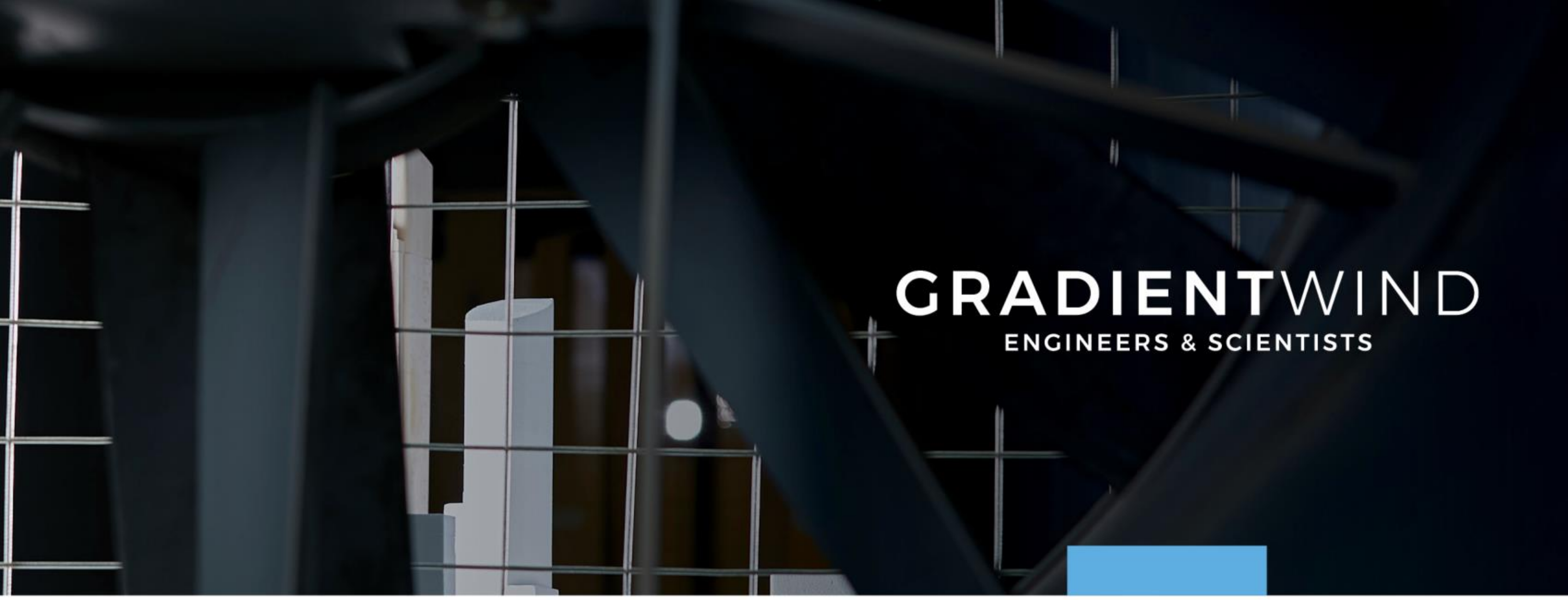

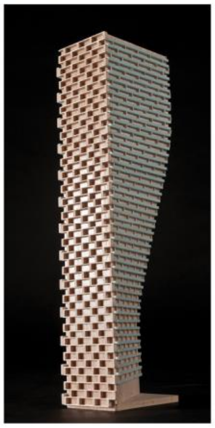

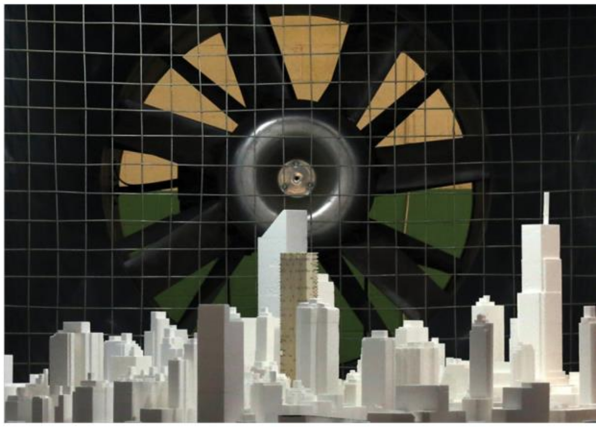

APPENDIX D

PEDESTRIAN LEVEL WIND MEASUREMENT METHODOLOGY

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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 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 C_θ and K_θ 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.

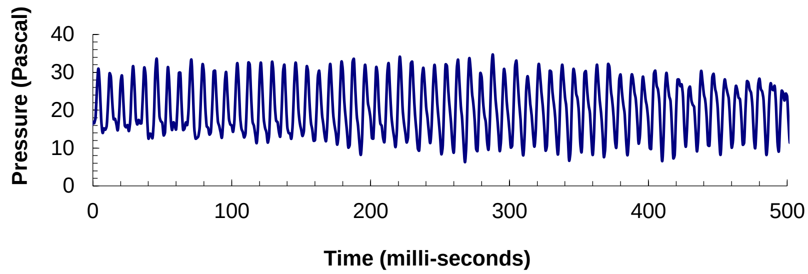

FIGURE D1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR

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