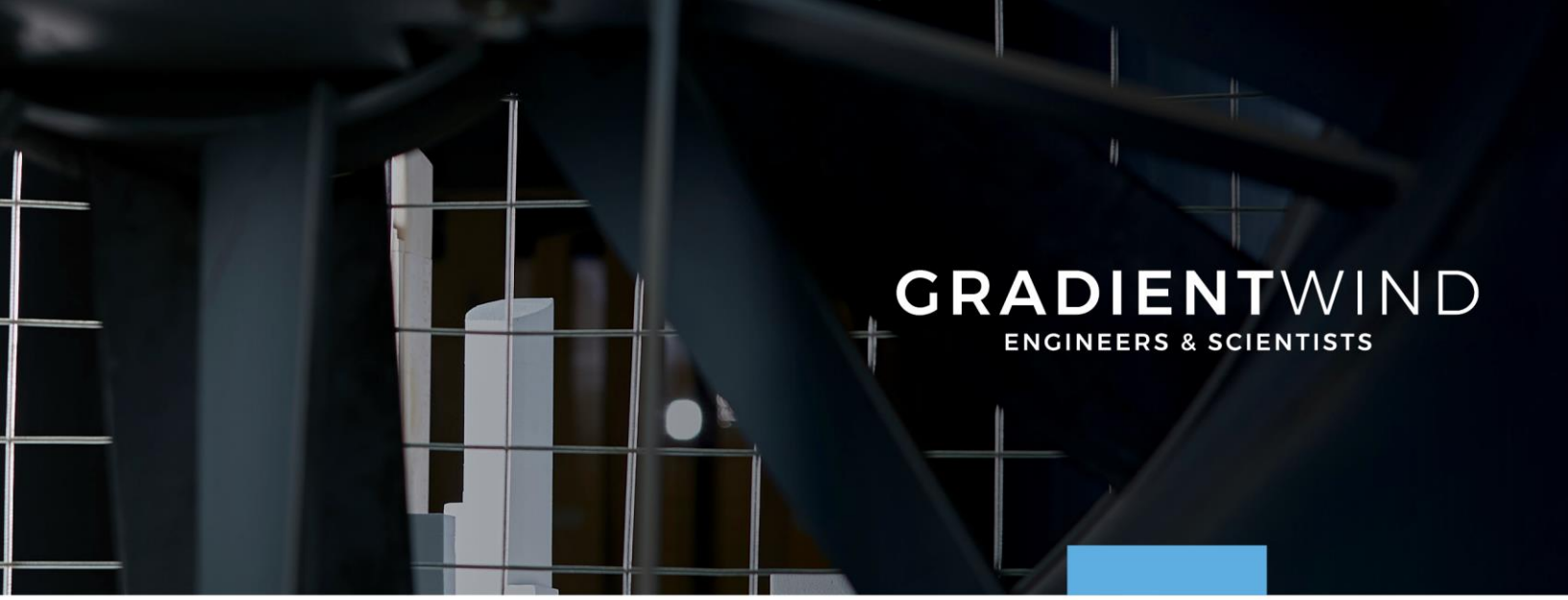
Appendix D: Pedestrian-Level Wind Study

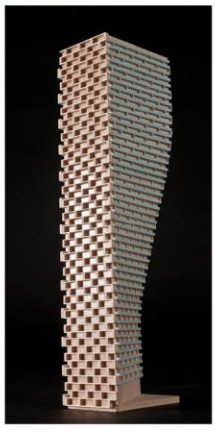


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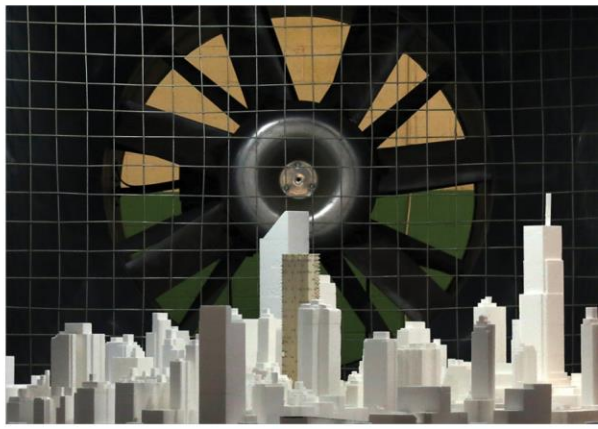
PEDESTRIAN LEVEL WIND STUDY

40 & 56 Quay Street
Brooklyn, New York

REPORT: GW24-215-WTPLW-R1







March 17, 2025

PREPARED FOR

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EXECUTIVE SUMMARY

This report describes a pedestrian level wind study undertaken to assess wind conditions for a proposed mixed-use development located at 40 & 56 Quay Street in Brooklyn, New York. The study involves wind tunnel measurements of pedestrian wind speeds using a physical scale model, combined with meteorological data integration, to assess pedestrian safety at key areas within and surrounding the study site. Grade-level areas investigated include sidewalks, parking areas, laneways, walkways, landscaped spaces, and building access points. The results and recommendations derived from these considerations are summarized in the following paragraphs and detailed in the subsequent report.

Our work is based on industry standard wind tunnel testing and data analysis procedures, architectural drawings provided by FXCollaborative Architects LLP in February 2025, surrounding street layouts and existing and approved future building massing information, as well as recent site imagery.

A complete summary of the predicted wind safety conditions is provided in Section 5 of this report, and is also illustrated in Figure 2, and Tables A1-A3 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in New York, we conclude that future wind conditions within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, over all grade-level pedestrian sensitive areas within and surrounding the study site will not exceed the annual safety criterion.

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1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained to undertake a pedestrian level wind study for a proposed mixed-use development located at 40 & 56 Quay Street in Brooklyn, New York. The study was performed in accordance with industry standard wind tunnel testing techniques, architectural drawings provided by FXCollaborative Architects LLP, in February 2025, 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 40 & 56 Quay Street, a proposed mixed-use development in Brooklyn, New York. The study site is situated at the southwest corner of the intersection of Franklin Street and Quay Street.

The development comprises approximately 56- and 41-storey towers on a shared 12-storey podium (Building 1) to the west and an approximately 21-storey building to the east (Building 2). The podiums are longitudinally aligned with Quay Street, with a proposed publicly accessible open space separating the buildings. A 4-storey museum is planned west of Building 1. At grade, Building 1 comprises retail spaces to the northwest and east, a central residential lobby fronting Quay Street, a large lounge/coworking space along the south elevation, and a ramp to underground parking to the northwest, accessible from Quay Street. At Level 2, the floorplate sets back from the south elevation, accommodating outdoor/indoor amenities, with a commercial facility along the north elevation. The floorplate sets back from the north elevation to meet the base of the towers at Level 3 and features a residential terrace. At Level 13, the floorplates set back centrally to the towers' floorplates, accommodating a central outdoor amenity with adjacent indoor amenities and residential spaces elsewhere. Above, the floorplates rise to their respective full height, where a mechanical penthouse, as well as indoor and outdoor amenities for the west tower, complete Building 1.

To the east, Building 2 comprises a central residential lobby to the north fronting Quay Street, retail spaces to the east and west and at the southwest corner, and a mechanical room to the south. At Level 2, the floorplate sets back from the south to form an approximate 'U'-shape planform. As the building rises, it

features setbacks on the east side at Levels 13, 19, and 22, with a mechanical penthouse completing the building.

Regarding wind exposures, the near-field surroundings of the development (defined as an area falling within a radius of 600 feet (') from the subject site) are characterized primarily by the open exposure of Bushwick Inlet in the southwest quadrant, a mix of low- and mid-rise buildings to the east, and high-rise buildings to the north-northwest. In particular, 15 West Street (29-storeys) is under construction to the north across Quay Street, and 60 Wharf Drive (40-storeys) is to the further northwest, as well as several other largely approved developments. The far-field surroundings (defined as the area beyond the near-field and within a radius of 7,000'), are characterized primarily by a mix of low and mid-rise buildings in all directions, with high-rise buildings to the north, northwest and southwest along the East River, which flows north-south approximately 800 feet west of the site.

Grade-level areas investigated include sidewalks, parking areas, laneways, walkways, landscaped spaces, and building access points. 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 safety at key areas within and surrounding the development site; (ii) recommend suitable mitigation measures, where/if required.

4. METHODOLOGY

The approach followed to quantify pedestrian wind safety 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 Brooklyn area wind climate, and synthesis of wind tunnel data with industry-accepted guidelines. The following sections describe the analysis procedures, including a discussion of the pedestrian 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 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 2,800'. 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 78 grade level sensor locations on the scale model in Gradient Wind's wind tunnel. Wind speed measurements were performed for each of the 78 sensors for 36 wind directions at 10° intervals at a height of 5' above grade or elevated surfaces. Figure 1 illustrates a plan of the site and relevant surrounding context, while sensor locations used to investigate wind conditions are illustrated in Figure 2.

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 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 gust wind speeds at grade were referenced to the wind speed measured near the ceiling of the wind tunnel to generate 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

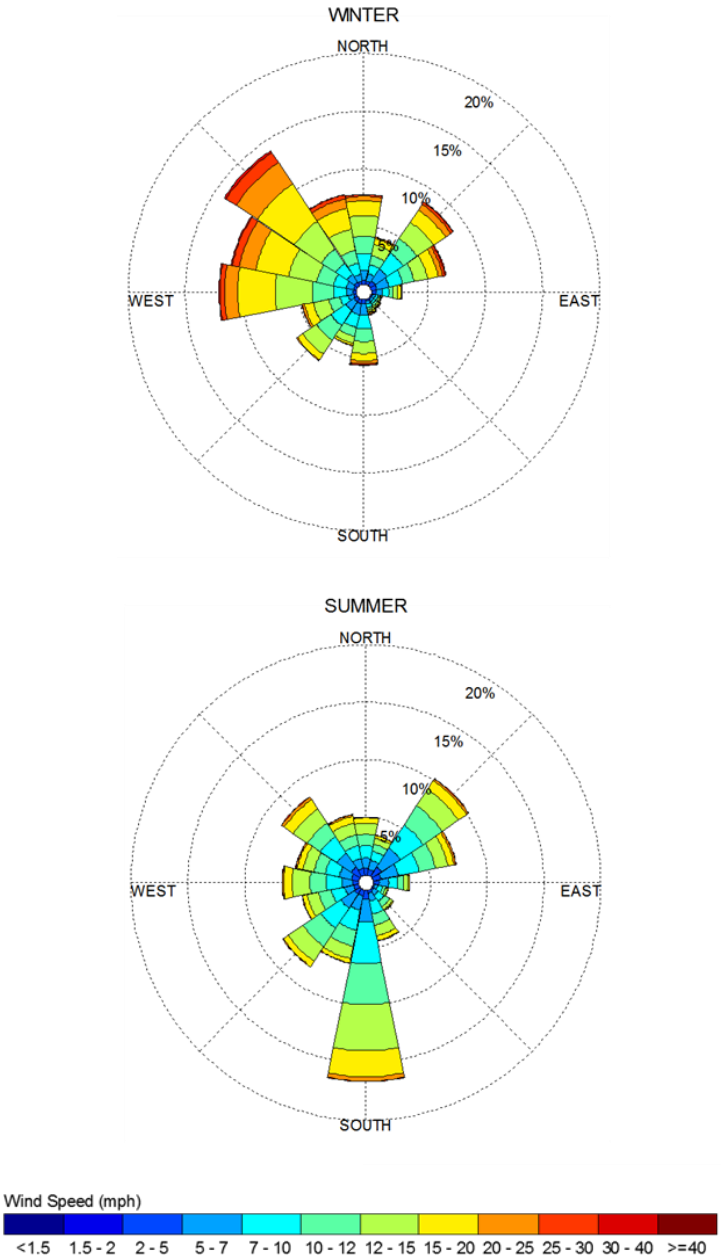
Gradient Wind's wind tunnel facility, meet or exceed guidelines found in 'Wind Tunnel Studies of Buildings and Structures', ASCE Manual 7 Reports on Engineering Practice No 67.

4.3 Meteorological Data Analysis

A statistical model for winds in Brooklyn was developed from approximately 40-years of hourly meteorological wind data recorded at LaGuardia International Airport in New York. 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 Brooklyn 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 miles per hour (mph). 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 Brooklyn, the most common winds occur for northwest, northeast, and south directions. 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 winter.

SEASONAL DISTRIBUTION OF WINDS FOR VARIOUS PROBABILITIES
LAGUARDIA INTERNATIONAL AIRPORT, NEW YORK, NEW YORK



Notes:

1. Radial distances indicate percentage of time of wind events.
2. Wind speeds are mean hourly in mph, measured at 33’ above the ground.

4.4 Pedestrian Safety Guidelines

Pedestrian safety guidelines are based on the mechanical effects of wind without consideration of other meteorological conditions (i.e. temperature, relative humidity). The pedestrian safety wind speed guideline is also 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 56 mph is classified as dangerous.

5. RESULTS AND DISCUSSION

Tables A1-A3 in Appendix A provide a summary of seasonal safety predictions for each sensor location. To assist with understanding and interpretation, predicted conditions for the proposed development are also illustrated in colour-coded format in Figure 2. For locations where the wind safety criterion is exceeded, the sensor is highlighted in red.

1. Future wind conditions within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, over all grade-level pedestrian sensitive areas (sidewalks, parking areas, laneways, walkways, landscaped spaces, amenity areas, and building access points) within and surrounding the study site will not exceed the annual safety criterion, which is acceptable.

6. CONCLUSIONS AND RECOMMENDATIONS

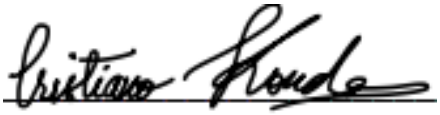
This report summarizes the methodology, results, and recommendations related to a pedestrian level wind study for the proposed mixed-use development located at 40 & 56 Quay Street in Brooklyn, New York. The study was performed in accordance with industry standard wind tunnel testing and data analysis procedures.

A complete summary of the predicted wind safety conditions is provided in Section 5 of this report, and is also illustrated in Figure 2, and Tables A1-A3 in the appendices. Based on wind tunnel test results, meteorological data analysis, and experience with similar developments in New York, we conclude that future wind conditions within the context of typical weather patterns, which exclude anomalous localized storm events such as tornadoes and downbursts, over all grade-level pedestrian sensitive areas within and surrounding the study site will not exceed the annual safety criterion.

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

Sincerely,

Gradient Wind Engineering Inc.



Cristiano Kondo, MESc.,
Junior Wind Scientist

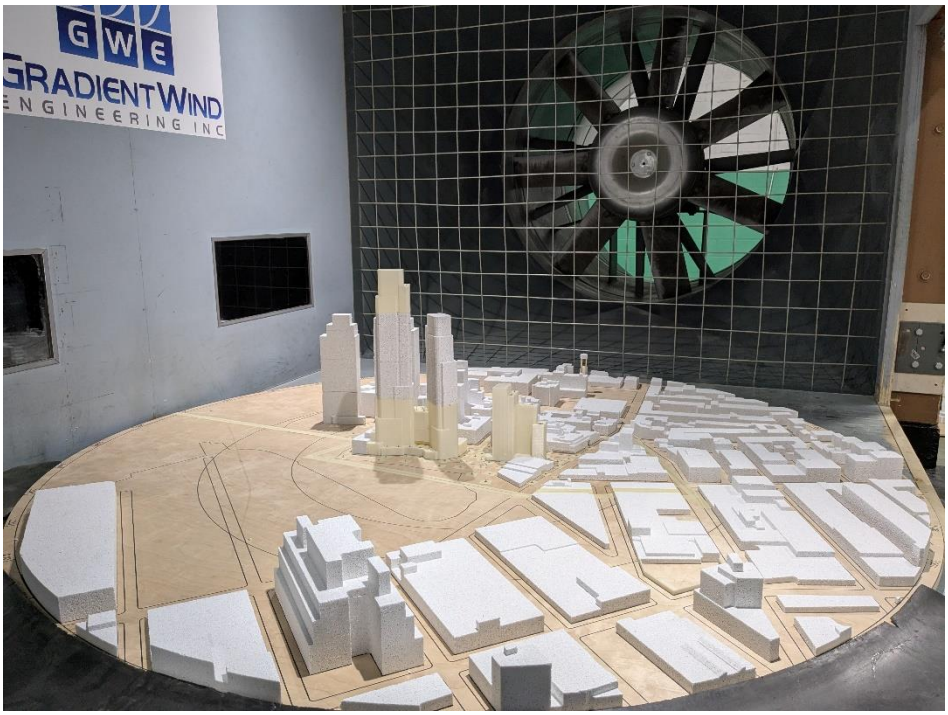


Nick Petersen, P.Eng.,
Wind Engineer

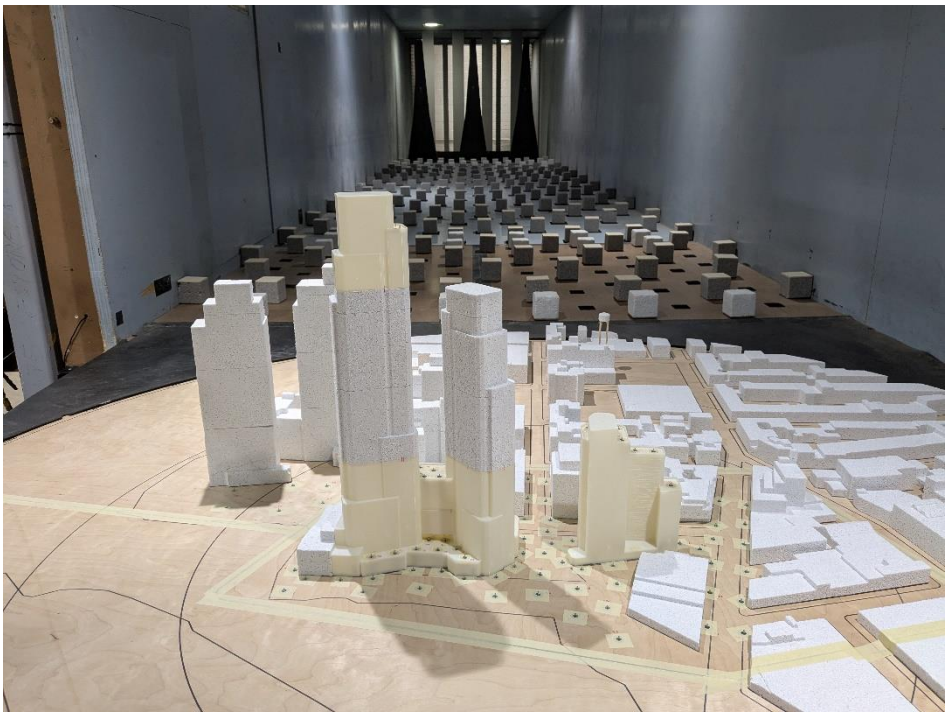


Angelina Gomes, B.Eng., EIT,
Wind Scientist

GW24-215-WTPLW-R1-DRAFT



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



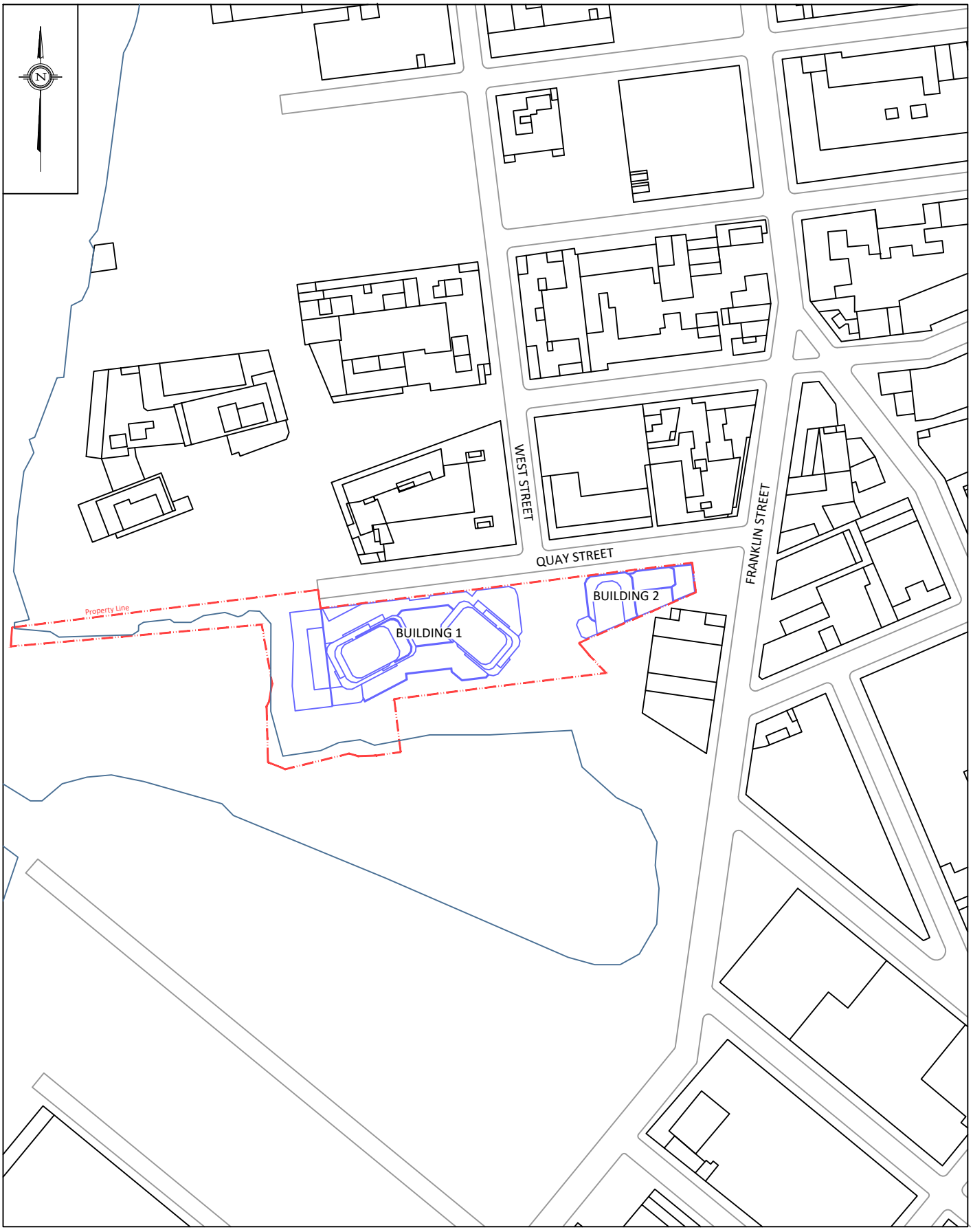
PHOTOGRAPH 2: STUDY MODEL INSIDE THE GWE WIND TUNNEL LOOKING UPWIND



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



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

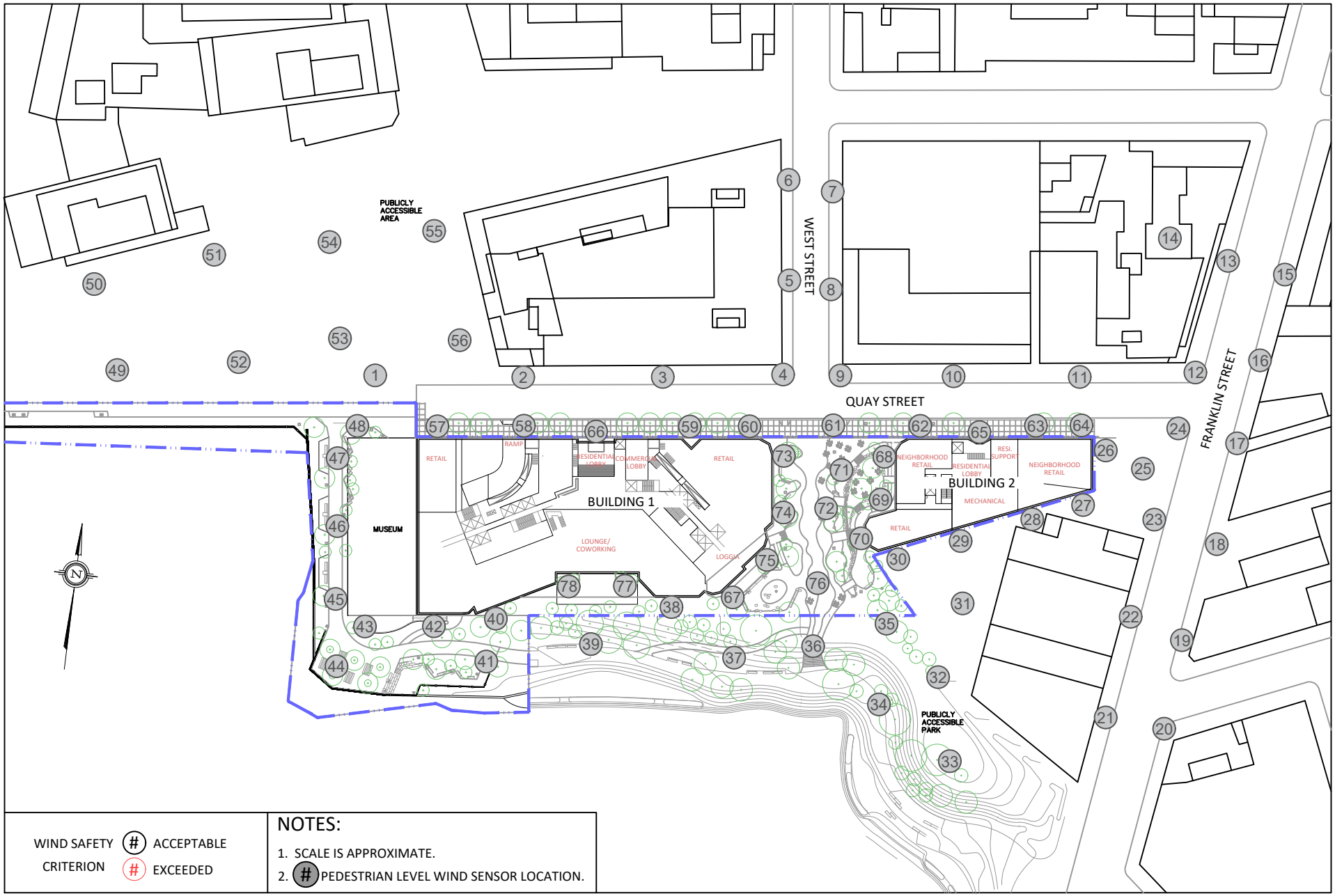


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PROJECT	40 & 56 QUAY STREET, BROOKLYN, NY PEDESTRIAN LEVEL WIND STUDY		DESCRIPTION
SCALE	1:2500 (APPROX.)	DRAWING NO.	GW24-215-PLW-1
DATE	MARCH 17, 2025	DRAWN BY	K.A.

FIGURE 1:
PROPOSED DEVELOPMENT SITE
AND SURROUNDING CONTEXT



WIND SAFETY CRITERION
(#) ACCEPTABLE
(#) EXCEEDED

NOTES:

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

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SCALE	1:1400 (APPROX.)
DRAWING NO.	GW24-215-PLW-2
DATE	MARCH 17, 2025
DRAWN BY	K.A.

DESCRIPTION

FIGURE 2
PROPOSED GRADE LEVEL PLW SENSOR LAYOUT
PEDESTRIAN SAFETY PREDICTIONS



APPENDIX A

PEDESTRIAN SAFETY SUITABILITY
TABLES A1-A3

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Guidelines	
Pedestrian Safety	**0.1% exceedance wind speed** 0-56 mph = Safe

TABLE A1: SUMMARY OF PEDESTRIAN COMFORT (PROPOSED SCENARIO)

Sensor	Pedestrian Safety	
	Annual	
	Wind Speed	Safety Class
1	34.8	Safe
2	34.3	Safe
3	36.5	Safe
4	25.6	Safe
5	31.5	Safe
6	27.4	Safe
7	29.1	Safe
8	29.0	Safe
9	33.9	Safe
10	42.1	Safe
11	36.3	Safe
12	30.5	Safe
13	22.9	Safe
14	15.9	Safe
15	27.0	Safe
16	32.1	Safe
17	27.6	Safe
18	21.9	Safe
19	20.2	Safe
20	26.6	Safe
21	20.9	Safe
22	17.8	Safe
23	26.3	Safe
24	29.2	Safe
25	30.5	Safe
26	33.5	Safe
27	30.5	Safe
28	26.2	Safe
29	21.9	Safe
30	29.7	Safe
31	25.2	Safe
32	22.0	Safe
33	26.5	Safe
34	27.3	Safe
35	28.0	Safe

Guidelines	
Pedestrian Safety	**0.1% exceedance wind speed** 0-56 mph = Safe

TABLE A2: SUMMARY OF PEDESTRIAN COMFORT (PROPOSED SCENARIO)

Sensor	Pedestrian Safety	
	Annual	
	Wind Speed	Safety Class
36	33.3	Safe
37	36.9	Safe
38	33.9	Safe
39	37.0	Safe
40	32.7	Safe
41	32.0	Safe
42	29.9	Safe
43	31.2	Safe
44	38.4	Safe
45	33.4	Safe
46	28.7	Safe
47	30.9	Safe
48	38.3	Safe
49	42.3	Safe
50	33.3	Safe
51	40.4	Safe
52	37.4	Safe
53	35.2	Safe
54	35.3	Safe
55	43.1	Safe
56	28.7	Safe
57	32.5	Safe
58	32.5	Safe
59	29.3	Safe
60	26.9	Safe
61	35.0	Safe
62	33.4	Safe
63	26.5	Safe
64	32.6	Safe
65	24.7	Safe
66	31.3	Safe
67	44.7	Safe
68	36.7	Safe
69	26.9	Safe
70	34.1	Safe

Guidelines	
Pedestrian Safety	**0.1% exceedance wind speed** 0-56 mph = Safe

TABLE A3: SUMMARY OF PEDESTRIAN COMFORT (PROPOSED SCENARIO)

Sensor	Pedestrian Safety	
	Annual	
	Wind Speed	Safety Class
71	37.2	Safe
72	38.7	Safe
73	37.9	Safe
74	39.1	Safe
75	43.3	Safe
76	34.7	Safe
77	24.4	Safe
78	21.9	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; ***U*** = mean wind speed, U_g = gradient wind speed, ***Z*** = height above ground, Z_g = depth of the boundary layer (gradient height) and α is the power law exponent.

Figure C1 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:

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

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.

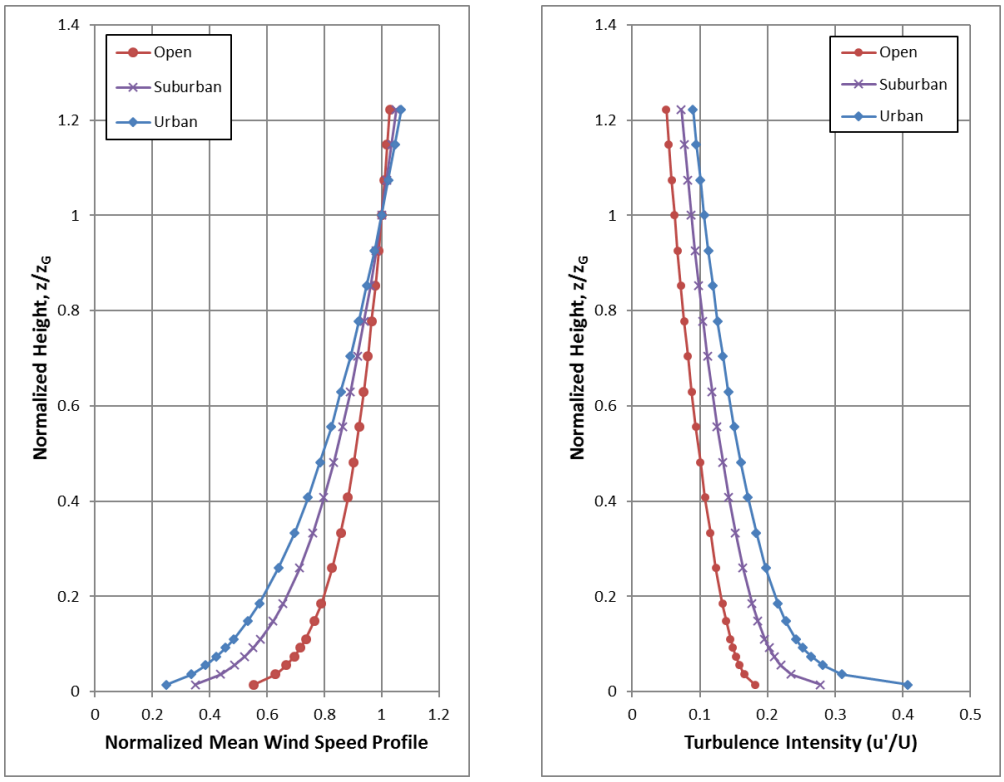


FIGURE C1 (LEFT): MEAN WIND SPEED PROFILES;
FIGURE C2 (RIGHT): TURBULENCE INTENSITY PROFILES

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APPENDIX 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 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) = Σ_θ 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.

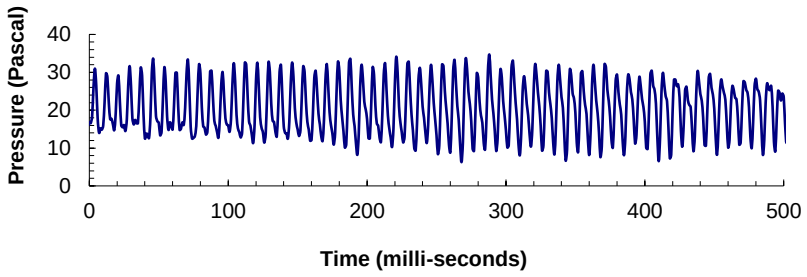


FIGURE D1: TIME VERSUS VELOCITY TRACE FOR A TYPICAL WIND SENSOR

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