BRAMPTON

PEDESTRIAN LEVEL WIND STUDY GUIDELINES AND TERMS OF REFERENCE

Prepared by:

City of Brampton, Urban Design – Planning & Development

In collaboration with:

RWDI

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LIST OF ACRONYMS

OPA	Official Plan Amendment
ZBA	Zoning Bylaw Amendment
SPA	Site Plan Application
CFD	Computational Fluid Dynamics
WT	Wind Tunnel

1 INTRODUCTION

1.1 Description

Pedestrian Level Wind Study ('Wind Study') is a technical report that provides a visual model and written evaluation to determine the wind impact of a proposed development, informs and directs the development design to be wind responsive, and ensures that wind conditions on and around the proposed development are acceptable throughout the year.

The Terms of Reference provides technical guidance for standardization of Wind Study methodologies, triggers, application process, wind comfort and safety criteria, reporting requirements, and wind control mitigation strategies.

1.2 Objectives

Wind is a crucial parameter that defines human comfort. The mechanical force of wind on a person can impact common daily activities in varying levels. Typically, the higher the wind speed, the greater the wind force on a person; the more active a person is in an instance, the greater the wind speed one can tolerate.

Tall buildings can have major impacts on the wind conditions in their surrounding context especially when they are considerably taller than surrounding buildings. Tall buildings tend to intercept the stronger winds that exist at high elevations and redirect them downwards towards the ground level. Winds around the base of such buildings can be accelerated up to several times the values that existed prior to the tall buildings, thus creating uncomfortable and sometimes unsafe conditions for pedestrians. It is important to consider the potential impacts of a proposed development on the local microclimate early in the planning and design process as this allows sufficient time to consider appropriate wind control and mitigation strategies, including significant changes to site and building designs. The objective is to maintain comfortable and safe pedestrian level wind conditions that are appropriate for the time of year and the intended use of pedestrian areas.

2 REQUIRMENTS

2.1 Who Can Conduct a Wind Study?

A wind study must be prepared by a qualified microclimate professional and should be signed, stamped, and sealed by a Professional Engineer. Where a wind study is prepared by a company which do not have extensive experience in pedestrian level wind evaluation, an independent peer review may be required at the expense of the applicant.

2.2 Types of Pedestrian Level Wind Studies

The City of Brampton accepts two types of wind studies:

1. **Computational Fluid Dynamics (CFD) Study:** A digital model tested with a software.
2. **Wind Tunnel (WT) Study:** A scale physical model tested in a wind tunnel.

Methodology and specifications for each study type are provided in **Appendix A.**

2.3 Triggers for a Wind Study

Properties or circumstances of a project, such as the height, site area and number of buildings that, through precedents, are known to be causative factors for noticeable wind impacts around the project are referred to as "triggers". In addition, proximity to parks, ravines, and other open spaces is also considered as a trigger that will influence the wind study type. If the project meets the conditions specified under the list of triggers below, then a wind assessment would be requested using the specified study types.

Low Trigger: CFD Study is required

- A development proposal with a building height that is between 25 m and 50 m, inclusive.

High Triggers: WT Study is required

- A development proposal with a building height that is greater than 50 m.
- A development proposal with 2 or more buildings that are 25 m in height or taller.
- A development proposal with a site area of 3 hectares or more, and a building that is 25 m in height or taller.
- A development proposal with a building(s) that is 25 m in height or taller, and located adjacent to parks and ravines, schools, playgrounds and outdoor recreational spaces, and other areas deemed pedestrian sensitive at the discretion of the City of Brampton.

Note, a WT study may be required for lower building heights depending on consultant's recommendation.

3 APPLICATION PROCESS

Requirements for the application process for the two Trigger Levels (described in Section 2.3) and the types of study required are detailed herein and summarized in Table 1.

3.1 General Guidelines

- Prior to submission of a planning application (OPA/ZBA/SPA), applicant shall consult with the City Planning and attend a pre-consultation meeting to agree upon the most appropriate approach for the wind study based on the triggers described in Section 2.3.
- The applicant is strongly encouraged to provide a graphical representation of the proposed wind-measurement locations to the City Planning for review and documentation purposes prior to conducting a Wind Study. The scope of the Wind Study should cover all key pedestrian areas according to the guidelines described in Section 4.5.
- The applicant may be asked to submit documentation of the test scenarios for review by the City's Planner and Urban Designer prior to any wind study to confirm the appropriateness of the physical context being modelled for the wind study.
- If the wind study shows that the proposed development is predicted to produce wind conditions that are considered unacceptable, the City's Planner and Urban Designer shall be consulted to discuss potential strategies going forward.
- For high-rise pre-construction projects that have been completed before the issuance of the Pedestrian Level Wind Studies Terms of Reference, a wind study may be required (at any stage) for a planning application approval purpose, at the discretion of the City. The City may request a Wind Study at: Official Plan Amendment, Secondary and Community Plan, District Plan, Subdivision Application, Consent Application, Zone Change Application, Condominium Application, Site Plan Control, Consent to Sever, or Minor Variance. If a request is not made at an earlier stage in the development process, this does not preclude the City from requesting the Wind Study at a later stage.

3.2 Pre-Application Consultation

A preliminary CFD study is encouraged to be completed for developments that meet the criteria for High Trigger prior to the Pre-Application Consultation stage. The CFD study report should demonstrates the wind impact of the proposed massing and a description of design changes that will be adopted to achieve acceptable wind conditions on and around the project as the project moves forward. This information is encouraged to be provided at the Pre-Application Consultation stage to explore the following at early stages of the development design in order to:

- Increase the possibility of improving the existing wind conditions.
- Assess the potential impact of wind conditions created by the development on the surroundings.
- Identify early design changes strictly relating to the massing, orientation and positioning of the development that can minimize its wind impact.

Although a CFD study is recommended at Pre-Application Consultation stage for developments that meet the criteria for High Trigger, a WT study will be required for the submission of a planning application (OPA/ZBA/SPA).

3.3 Official Plan and/or Zoning By-Law Amendment (OPA/ZBA)

The OPA/ZBA submission to the City should include a wind study report that shows satisfactory wind conditions on and around the project. CFD wind study will be required for developments that meet the criteria for Low Trigger, while WT study will be required for developments that meet the criteria for High Trigger. If needed, or requested by the City, wind control measures should be implemented, and their effectiveness should be demonstrated through additional studies.

3.4 Confirmation of Proper Implementation

Prior to Site Plan Approval (SPA) for any Building Permit clearance, the following clause shall be included on the Site Plan and all relevant drawings:

"The Microclimate Specialist shall confirm to the satisfaction of Planning, Building & Economic Development Department that the 'as constructed' buildings and wind mitigation measures are following the recommendations of the Pedestrian Wind Comfort and Safety Studies."

Prior to the final site works inspection by City staff, the City may request that the Microclimate Specialist shall issue a letter confirming that the wind mitigation measures have been installed in accordance with the recommendations of the Wind Study.

3.5 Site Plan Application (SPA)

For an SPA, a wind study will be required if significant design changes have been made since the previous submission to evaluate the project's performance and ensure it continues to satisfy the recommended wind criteria. The consultant's professional opinion regarding the changes is to be presented in writing to inform this decision. The City, at their discretion, may ask for additional studies.

Examples of significant design changes are described in **Appendix B.1**. The design submitted should incorporate all recommendations from previous submissions.

TABLE 1: APPLICATION PROCESS AND WIND STUDY TYPE

The methodology and specifications for each study type is described in **Appendix A**.

	Trigger Level	
Process	**Low**	**High**
OPA/ZBA/SPA Pre-Application (Encouraged)	N/A	CFD Study
OPA/ZBA Application (Required)	CFD Study	WT Study
SPA Application (Required)	• If the project went through an OPA and/or ZBA process, and there have been significant changes (**Appendix B.1**), wind impacts of the new design should be confirmed using the same type of wind study conducted for the final OPA/ZBA submission. • If the project went through an OPA/ZBA process, and there have been no significant changes (as described in **Appendix B.1**), an additional wind study is not required upon the confirmation of wind consultant.	

4 TECHNICAL REQUIRMENTS FOR WIND STUDIES

4.1 Meteorological Data Collection

Long-term wind data recorded in major airports are often used in the prediction of pedestrian wind conditions. For the City of Brampton, wind data from Pearson International Airport should be used.

- A minimum of 30 years of hourly wind data should be used.
- The Data is to be presented and used on two-seasons basis defined as follows:
  - Summer: May – October
  - Winter: November – April
- Appropriate hours of pedestrian usage for a typical project (e.g., between 6:00 and 23:00) should be considered for wind comfort, while data for 24 hours should be used to assess wind safety.

4.2 Design Criteria

The predicted wind speeds and frequencies should be compared to the following wind comfort and safety criteria shown below in **Table 2**. Wind comfort may be affected by both mean and gust speeds and their combined effect should be quantified as a Gust Equivalent Mean (GEM), while only gust speeds are to be considered in the wind safety criterion.

The assessment will consider the predicted comfort level and the intended pedestrian usage. If the proposed development produces pedestrian comfort conditions that prove to be less than desirable based on the intended use (as per the definitions in **Table 2**), the developer shall propose mitigation strategies and/or investigate alternatives to the proposed design with the help of microclimate consultant. The consultant will confirm if the wind mitigations recommended will address the undesirable conditions and provide commentary in the final report. If the proposed development results in unsafe gust speeds (Table 2), a revised Wind Study incorporating mitigation measures, which will help to eliminate the safety concern, is needed.

TABLE 2: WIND CRITERIA FOR PEDESTRIAN COMFORT AND SAFETY			
COMFORT CATEGORY	GEM SPEED (km/h)	DESCRIPTION	AREA OF APPLICATION
Sitting	$\leq$ 10	Light breezes desired for outdoor seating areas where one can read a paper without having it blown away.	Park benches, restaurant seating, balconies, amenity terraces, etc. intended for relaxed, and usually seated activities.
Standing	$\leq$ 15	Gentle breezes suitable for passive pedestrian activities where a breeze may be tolerated	Main entrances, bus-stops and other outdoor areas where seated activities can be avoided.
Walking	$\leq$ 20	Relatively high speeds that can be tolerated during intentional walking, running and other active movements.	Sidewalks, parking lots, alleyways and areas where pedestrian activity is primarily for walking.
Uncomfortable	> 20	Strong winds, considered a nuisance for most activities.	May be accepted in areas not intended for pedestrian access

NOTES:

1) The required seasonal compliance is 80% of the time for the Sitting, Standing and Walking categories. The Uncomfortable categorization is applicable if the criteria for Walking are not met.
2) Gust Equivalent Mean (GEM) speed = maximum of either mean speed or gust speed/1.85.
3) The gust speed can be measured directly from wind tunnel or estimated as mean speed + (3 x RMS speed).
4) Comfort calculations are applied to each season and based on wind events recorded between 6:00 and 23:00 daily.

SAFETY CRITERION	GUST SPEED (km/h)	DESCRIPTION	AREA OF APPLICATION
Exceeded	> 90	Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is required.	Not acceptable in any area of interest

NOTES:

5) Wind safety assessment is based on an annual exceedance of 9 hours or 0.1% of the time for 24 hours a day

4.3 Project and Proximity Model

For both CFD and WT Studies, the following items should be considered:

- The model should be constructed to include all massing and architectural features on the project that would influence wind flow around it. Typically dimensions less than 1 m do not have a notable impact on wind related to pedestrian comfort.
- The surrounding context (proximity model) within a minimum radius of approximately 350 m from the center of the proposed development site should be modelled. Tall buildings outside of this zone that could have an influence on wind conditions within the project site – based on the expert opinion of the Consultant – should be included.
- Structures and natural features beyond the modelled surroundings shall be represented physically and/or numerically, as appropriate for the study type.
- Landscaping features should not be considered for wind studies, unless, through discussions with the City, such features are to be included for wind mitigation.

For WT Studies, model scale of 1:400 to 1:300 have proven to be effective at representing relevant architectural details on the project and surrounding context. A scale outside the range may be used provided the reason for the choice of scale and why the recommended scales would not be appropriate is included in the Wind Study Report. Note that the model scale chosen for optimal data quality could vary, depending on the test equipment and instrumentation use. For CFD studies, models are typically at 1:1 scale.

4.4 Context and Massing Scenarios

The most objective way to assess the impact of a proposed development on wind conditions around it is to compare it to existing conditions. If the project is expected to result in less than acceptable wind conditions, then further assessments should be conducted to evaluate a wind mitigation plan that can be implemented in the final design of the Project. In some parts of the City, it may be prudent to consider a Future Scenario. The following scenarios typically need to be considered for every project:

- **Existing Scenario:** Existing site and all existing surrounding buildings, significant topographic features, developments under construction and projects that were approved for construction in the preceding 5 years.
- **Proposed Scenario:** Proposed project in place of existing site within its context.
- **Future Scenario, if warranted:** Proposed project within its context and buildings that are part of a future development identified by the City and deemed by the wind consultant to have a potential impact on winds at the subject site.

- **Mitigation Scenario(s), if warranted**: Undesirable wind conditions should be mitigated primarily with changes to the building siting and massing. Where mitigation is required to achieve acceptable wind comfort and safety conditions, mitigation measures should be implemented to the Proposed Scenario in order to demonstrate the benefits of the mitigation strategies.
  The acceptable mitigation methods are described in Appendix B.2.
- **Phasing Scenario(s), if applicable:** Where the site construction is phased, there is a need to assess interim design phases, as that may create adverse conditions before subsequent buildings are added to the site. The City may ask for different site Scenarios.

4.5 Areas of Interest

The scope of the assessment should cover all key pedestrian areas on and within one block of the Project in all directions. Key pedestrian areas where wind conditions should be assessed include, but are not limited to:

- Perimeter of the Project
- Major entrances of the proposed building
- Major entrances of neighbouring buildings
- Communal on-site amenity areas
- Publicly accessible above-grade areas
- Sidewalks adjacent to the proposed building
- Transit stops adjacent to the proposed building
- Parking lots adjacent to the proposed building
- Public parks or recreational areas adjacent to the proposed building
- Privately Owned Public Spaces (POPS) adjacent to the proposed building
- Community centers adjacent to the proposed building
- School or universities adjacent to the proposed building

The City may ask for additional areas of interest for the wind assessment.

4.6 Report

Where a wind study is to be completed, provide a report that include:

- Type of application, application number, municipal address and the company who has prepared the analysis.
- Objectives of the study and brief description of the project (at minimum describe height and location, including a location map).
- Description and images of the study and proximity models.
- Description of the source and period of meteorological data used, including a graphical representation displaying the prevailing wind directions.
- Wind criteria for pedestrian comfort and safety.
- Results and Discussion
    - Wind speeds must be presented in km/h.
    - Results should correspond to pedestrian level (i.e., approximately 1.5 m above the concerned level).
    - **For CFD study,** graphical presentation of simulation results representing comfort categories for two seasons is required, along with an indication of any areas where the safety criterion is estimated to be exceeded.
    - **For WT Study,** results shall be presented in both tabular and graphical forms for all the test scenarios, with seasonal comfort data and annual safety data.
    - The report text shall include interpretation of the results for each scenario as it relates to the Design Criteria, discussions about causative flow mechanisms and recommendations for mitigation of adverse or undesirable wind conditions.
    - Where conditions are predicted to be unacceptable for the intended pedestrian usage, design alternatives and wind control strategies should be recommended to improve the wind conditions to acceptable levels, or appropriate adjustments to pedestrian usage should be suggested in consultation with City staff.
    - The report text shall provide directions about next steps, and/or if a revised study, incorporating mitigation measures, is required.

4.7 Peer Review

If the City is not satisfied with the level of experience demonstrated by the consultant or wishes to verify the results of a study, a peer review of the wind study may be required by the City at any stage of the application. The cost of the peer review is to be borne by the applicant.

APPENDIX A:

METHODOLOGY AND SPECIFICATIONS OF WIND STUDIES

Wind assessments can be done through Computational Fluid Dynamics (CFD) modelling, and physical scale modelling in wind tunnels. The following is a description and technical requirements of the different methodologies.

A.1 Computational Fluid Dynamics (CFD) Study

CFD is a numerical technique that can be used for simulating wind flows in complex environments. For urban wind modelling, CFD techniques are used to generate a virtual wind tunnel where flows around the study building, site and its surroundings are simulated in full scale. The computational domain that covers the site and its surroundings is divided into millions of small cells where calculations are performed, yielding a prediction of wind conditions across the entire study domain. CFD excels as a tool for urban wind modelling, presenting early design advice, resolving complex flow physics, and helping diagnose problematic wind conditions. It is useful for the qualitative assessment of complex buildings and contexts and provides a visual representation of the potential wind conditions which makes it easy to judge or compare designs and site scenarios.

CFD is not suited to predicting wind patterns for safety-based design issues on buildings. It struggles to accurately predict flow separation, turbulent eddies (circular movement of air) and gusts (brief but strong rush of wind) within the urban environment. It is these types of flow behaviour that can cause pedestrian discomfort and safety concerns.

Requirements for a CFD Study

- A minimum of 16 wind directions at equal intervals shall be simulated.
- The CFD simulation shall appropriately represent the atmospheric boundary layer for winds approaching the computational model.
- The processing of results should consider the probability of all wind directions simulated using meteorological data as described in Section 4.1.
- The results shall be presented for all areas of interest in the form of wind speed contours at a horizontal plane approximately 1.5 m above local grade or concerned levels.
- The results for seasonal comfort should be based on the Design Criteria (Section 4.2). Compliance with the annual safety criterion may be assessed using experience-based methods and areas where the criterion is assessed to be exceeded should be indicated in the wind study report.

A.2 Wind Tunnel (WT) Study

Wind tunnel testing is the established tool used for modelling wind flow around buildings and structures in order to quantify and assess wind conditions, among other types of assessments. A scale model of the study area and surroundings are placed in a wind tunnel, instrumented appropriately for wind speed measurements, and subjected to wind flows physically simulated to represent winds approaching the actual site. In general, such modelling provides a good, quantified representation of both mean and gust effects and the transient behaviour of wind. It is a complex tool and requires experience and expertise to produce useful information and to interpret data, and therefore are accessible only through consultants and universities that specialize in wind engineering.

Requirements for a WT Study

- 36 wind directions at equal intervals shall be tested.
- The wind simulation facility must be capable of simulating the earth's atmospheric boundary layer and appropriate profiles for each of the wind directions tested.
- Wind speed sensors used to measure local wind speeds shall be omni-directional and represent the horizontal wind speed at a full-scale height of approximately 1.5 m above local grade or concerned levels.
- Sensors should be capable of measuring mean wind speed and wind speed fluctuations with time, including peak gusts of three to ten second duration. Peak gusts can be directly measured from wind tunnel testing or estimated by "Mean + 3*RMS" wind speeds.
- Sampling time in the wind tunnel shall represent a minimum of one hour of full-scale time.
- The model scale should be selected to allow representation of sufficient architectural detail on the proposed development while including the surrounding context within approximately 400 m of the center of the proposed development site (typically scales of 1:300 or 1:400 have proven to be effective). Structures and natural features beyond the modelled surroundings shall be appropriately represented in the wind tunnel upwind of the scale model.
- Sensor locations should capture all areas of interest as described in Section 4.5.
- Sensors shall be placed at least every 10 m along a street frontage of the study buildings and at all locations where pedestrians will travel or gather. A typical development project would require a minimum of 50 sensor locations on and around the proposed development to provide adequate coverage.
- The analysis should consider the probability of all wind directions tested using meteorological data obtained in accordance with the description in Section 4.1.
- The results shall be presented in both tabular and graphical forms for all the test scenarios, with seasonal comfort data and annual safety data based on the Design Criteria (Section 4.2).

APPENDIX B:

SIGNIFICANT DESIGN CHANGES AND WIND CONTROL MITIGATION STRATEGIES

B.1 Significant Design Changes

The significance of a design change with respect to its impact on wind conditions must be evaluated by the Consultant and through discussions with the City between the OPA/ZBA and SPA submissions, as the criteria will vary for each project.

Some criteria are considered significant include, but are not limited to changes:

- in the number of buildings on the site or in the surroundings
- in the orientation/location of a building on the site
- in the setback of a building (or part of a building) from a public sidewalk and open spaces
- in the height of a building
- in the offset distance of a tower from podium edges
- in canopies and small-scale architectural features
- in the shape of the building massing

These criteria will be evaluated by the Consultant and City staff as wind impacts depend on a combination of on-site massing, off-site massing, geographic and meteorological factors.

B.2 Wind Control Mitigation Strategies

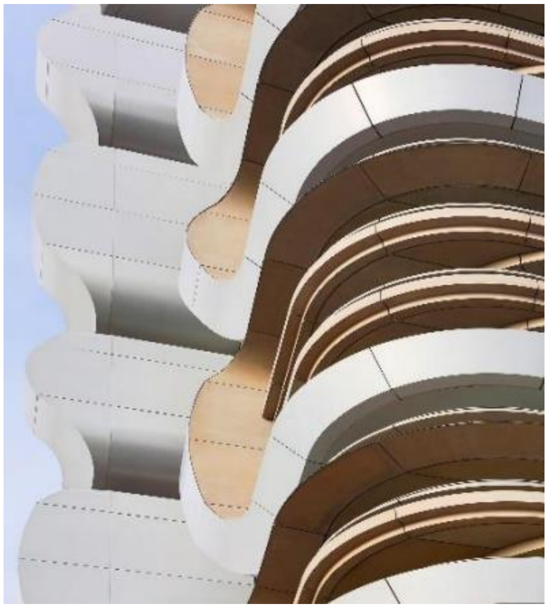
In areas where wind conditions are considered to be unacceptable for the intended pedestrian use, or unsafe (as defined in Section 4.2) and will be accessible to pedestrians, wind control mitigation strategies shall be developed and/or tested to demonstrate their efficacy. In more extreme cases the developer in consultation with the microclimate specialist, may need to investigate and prepare design alternatives that can achieve more acceptable wind conditions.

Wind Control Mitigation Strategies may include the following:

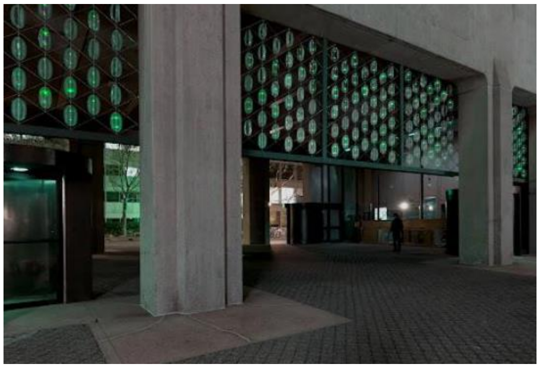
- **Building Form** – Strategic reshaping of the building can allow wind flow around it to be either more streamlined (chamfered or rounded corners) or diffused at corners (stepped or re-entrant corners). This approach is considered a large-scale solution that would lower the potential for severe wind impact at grade and has a large area of influence. These adjustments can be assisted by tower setbacks, tower separation, podiums, colonnades/arcades, corner articulations, entrances are away from corners, balconies or terraces, winter gardens, stepped or transitioned building (see examples below for reference).




- **Architectural Details –** Features such as facade articulations, canopies, covered walkways and recessed entrances are effective solutions for localized wind mitigation. Recessed walls create areas that will be protected from ambient wind activity. Recessed entrances and covered walkways provide a protected area for pedestrians at the base of tall towers that are prone to downwash impacts (see examples below for reference).



- **Smaller-scale measures** – Features such as wind screens, trellises, public art and other localized features can be considered at an advanced design stage for area-specific wind speed reductions and refinements. The impact of these features is typically limited to a small area around them. Wind screens may be placed on both sides of entrances, on sidewalks and in parks and other open spaces to create localized low wind areas. It is recommended that wind screens be at least 2 m tall and approximately 20-30% open/porous for good wind control efficacy (see examples below for reference).



- **Trees and landscaping elements** – The impact of trees and landscaping elements are also typically limited to a small area around them. Coniferous and marcescent species, are commonly used to improve wind conditions to appropriate levels, all year round. Deciduous landscaping is most effective during the summer months. These landscaping elements cannot replace architectural features or other built elements, as soft landscaping may not sufficiently mitigate wind impacts during all seasons. Trees and landscaping can only be applied to supplement existing mitigation measures.