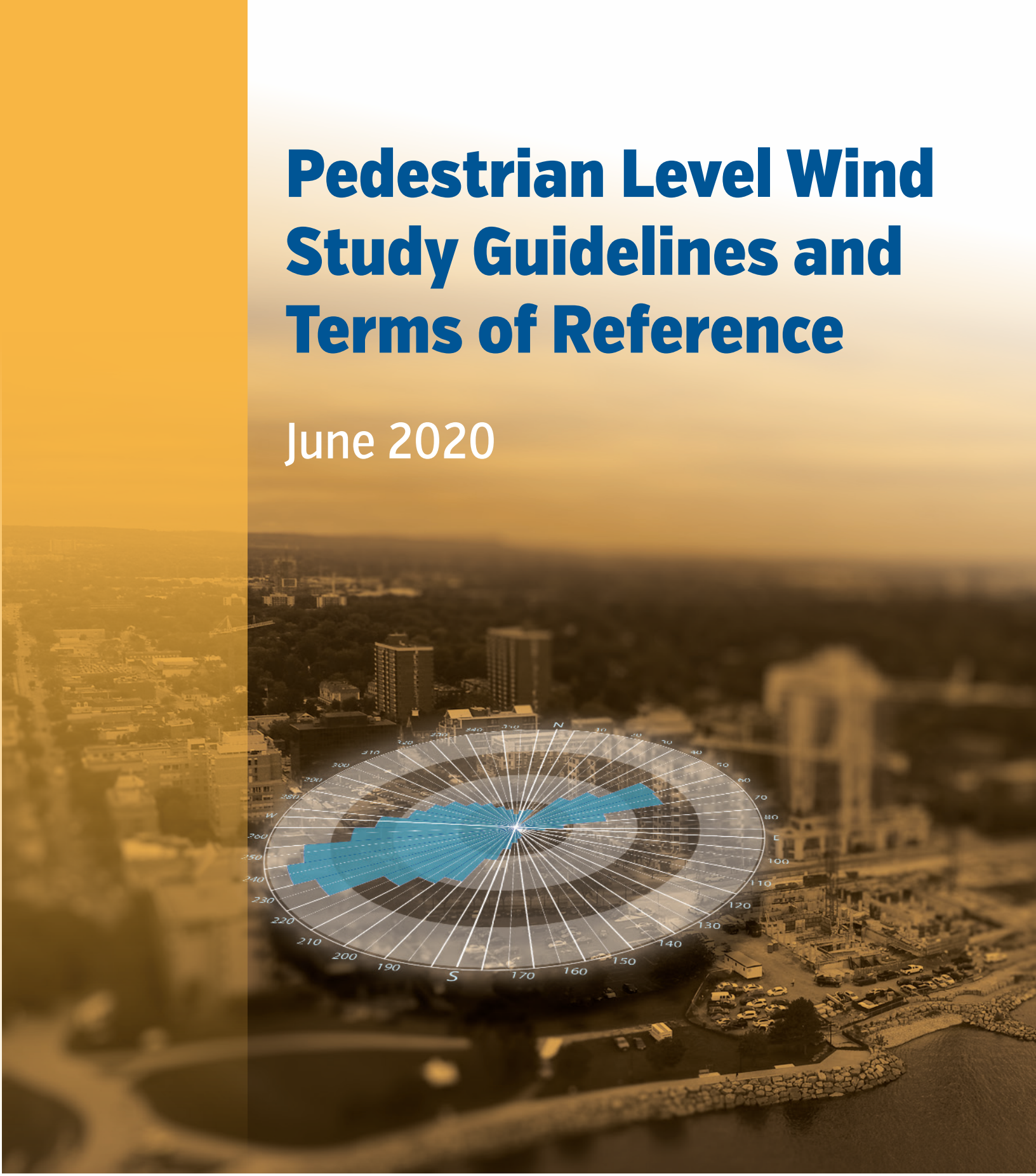
Pedestrian Level Wind Study Guidelines and Terms of Reference

June 2020



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CITY OF Burlington

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1.0 Introduction

1.1 Purpose

A Pedestrian Level Wind Study ('Wind Study') is conducted to predict and assess the wind impacts of proposed buildings and site designs on surrounding public and private spaces in addition to on-site wind conditions. The objective is to ensure pedestrian comfort and safety is maintained as Burlington continues to grow and develop. Acceptable pedestrian level wind conditions are assessed by season and the intended use for the areas being studied. Acceptable pedestrian level wind conditions do not exceed the recommended maximum for a particular activity, such as sitting, standing, leisurely or fast walking.

Taller buildings can introduce wind conditions that impact their surrounding context especially when the building is considerably taller than surrounding buildings. Consideration of potential impacts on the local micro-climate should be determined early in the planning and design process, allowing for sufficient time to consider appropriate wind control and mitigation strategies, that may include changes to site and building designs.

1.2 How to Use the Guidelines

This document should be used by the development community to inform development proposals within the City of Burlington. It should be read in its entirety when designing buildings that meet the thresholds set out in Section 2.0.

This document sets expectations for high quality design outcomes but does not anticipate every design scenario. It is not the intention of this document to limit creativity. When it can be demonstrated that an alternative achieves the intent of the guidelines, the alternative solution may be permitted.

This document is a tool for City Staff to be used in the review and evaluation of development applications. When additional advice is appropriate, the City may consider peer review by an independent third party.

Terms defined

Find a definition for underlined terms in the Glossary included on page 17.

1.3 Who can conduct a Wind Study?

A Wind Study shall be prepared by a qualified microclimate professional. If a Wind Study is prepared by an individual or company that does not have extensive experience in pedestrian level wind evaluation, an independent peer review may be required at the expense of the applicant.

1.4 When is a Wind Study required?

A Wind Study may be required as part of proposals for the following development applications:

- Official Plan Amendment;
- Zoning By-law Amendment; and
- Site Plan Approval;

  A Wind Study will typically only be required through the Site Plan Approval process:

  - where significant changes are made to the building design since the previous Wind Study was completed during the Zoning By-law Amendment process; or,
  - on sites where a contemporary planning application has not been completed (e.g. where a site contains legacy zoning);

The requirement for a Wind Study will be identified at the Formal Pre-consultation stage of a development application.

2.0 Triggers for a Wind Study

2.1 Building Height

- A Qualitative Wind Assessment ('Qualitative Assessment') is required as a minimum for development proposals with building heights of 5- to 11-storeys; however, a Quantitative Wind Assessment ('Wind Tunnel Test') may be required at the discretion of City staff based on building exposure, size, sensitivity, and other factors.
- A Wind Tunnel Test is required for development proposals with building heights of 12-storeys or more.

2.2 Number of Buildings

- A Wind Tunnel Test is required for development proposals with two or more buildings 5-storeys in height or more.

2.3 Site Location

- Development proposals with building heights of 5-storeys or more that are located between Queen Elizabeth Way and the Lake Ontario shoreline require a Wind Tunnel Test due to wind conditions present in proximity to the lake.
- A Wind Tunnel Test is required for development proposals with building heights of 5-storeys or more when a proposed building is located within a distance equal to the height of the tallest proposed building from a low-rise residential neighbourhood area.

2.4 Site Area (Size)

- A Wind Tunnel Test is required for development proposals with a site area of 3 hectares or more, and a building that is 5-storeys in height or more.

Table 2.1: Triggers for a Wind Study

Potential Triggers	Qualitative Assessment	Quantitative Wind Assessment*
Building Height	5- to 11-storeys	12-storeys
No. of Buildings	1	2 or more > 5-storeys in height
Site Location		Between QEW and Lake Ontario; or, Where the building height-to-separation distance ratio is less than 1:1 from low-rise area.
Site Area (Size)		≥ 3 ha

*A Wind Tunnel Test is triggered if any of the following attributes are present

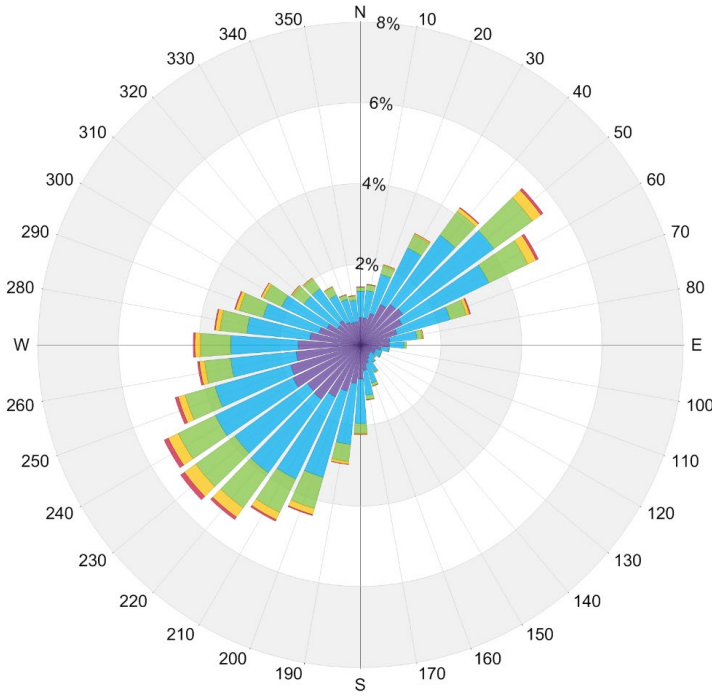
3.0 Methodology

3.1 Wind Data Collection

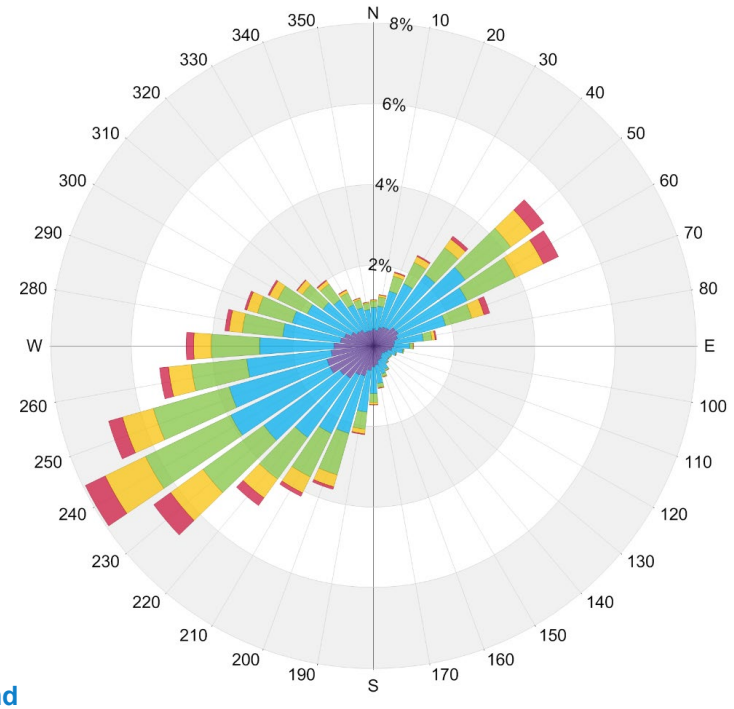
A minimum of approximately 30 years of hourly wind data from the John C. Munro Hamilton International Airport should be used along with data from other nearby weather stations, in order to confirm wind directionality and speeds. Wind data should be presented on a two-season basis as follows:

- Summer: May through October; and
- Winter: November through April.

Appropriate hours of pedestrian use for a typical project (i.e. between 06:00 and 23:00) should be considered for wind comfort, while data across a 24-hour period should be used to assess wind safety.



Summer
(May - October)



Winter
(November - April)

Wind Speed (km/h)	Probability (%) Summer	Winter
Calm	3.9	2.4
1-10	33.8	21.8
11-20	43.1	39.5
21-30	15.4	23.6
31-40	3.0	9.1
>40	0.8	3.6

Figure 3.1 - Hamilton International Airport 1990-2019) Wind Rose Diagram (Directional Distribution (%) of Winds (Blowing From)
Image credit: RWDI

3.2 Qualitative Assessment

Qualitative Assessment relies on the observation and interpretation of wind conditions from a qualified professional. It may be conducted as either a Desktop Assessment, or by using Computational Fluid Dynamics (CFD).

a. Desktop Assessment

Description

- A Desktop Assessment predicts and estimates wind speeds at critical locations surrounding a proposed development. Desktop Assessments rely on a qualified microclimate professional's expertise and analysis of the local built form and climate context in order to make a judgment on wind conditions. Desktop Assessments are most suitable for buildings with lower heights, or in areas where the proposed buildings are similar in height and scale to the surrounding context.

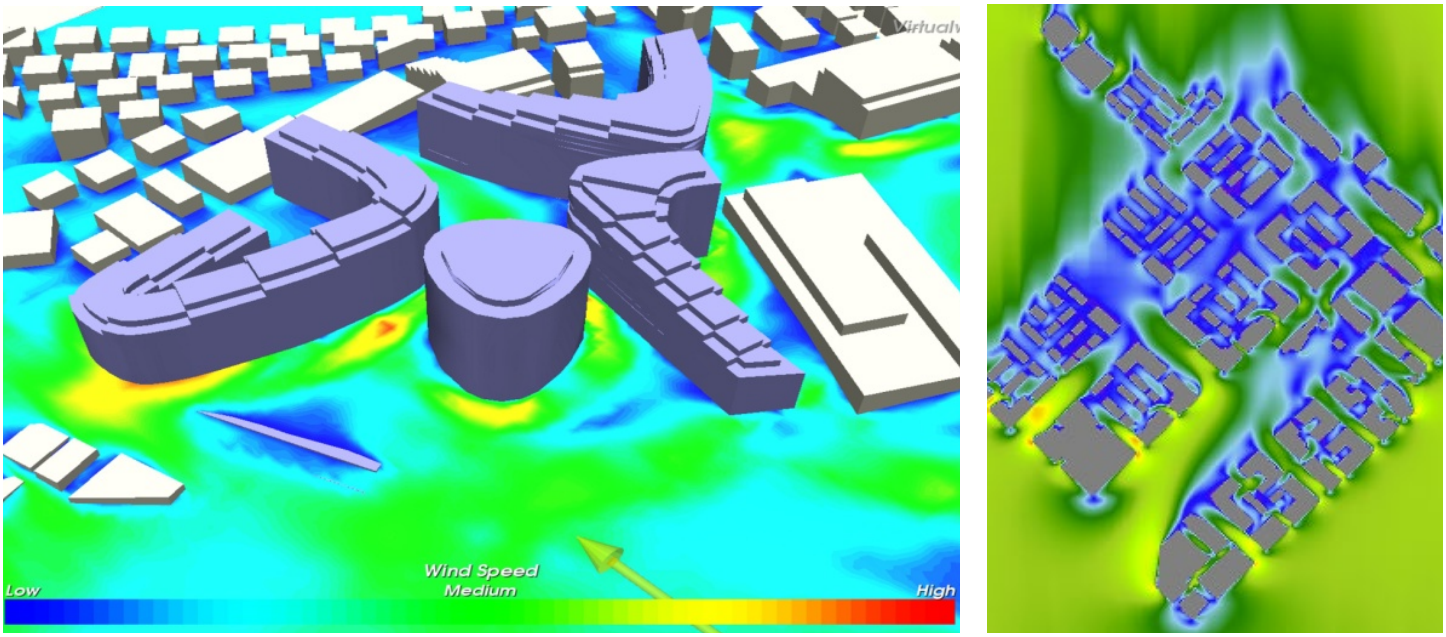


Figure 3.2 - Perspective and plan view of Computational Fluid Dynamics Analysis
Image credit: RWDI

Requirements

- Assessment should be based on the standard wind comfort criteria described in Table 4.1 Pedestrian Wind Comfort Criteria (see Table 4.1 on page 10).
- Where wind conditions are unacceptable for the intended use, mitigation methods to improve the wind comfort to acceptable levels must be modeled and tested.

b. Computational Fluid Dynamics (CFD)

Description

- CFD analysis allows qualified microclimate professionals to use computer simulation modelling to visualize the wind flow patterns around a proposed building. CFD does not adequately simulate gusts.

Requirements

- CFD simulations should appropriately represent the atmospheric boundary layer for winds interacting with the computational model.
- Wind speeds presented should include horizontal planes at pedestrian level (i.e. 1.5 metres above local grade), as well as specific vertical slices that indicate flow conditions in critical areas identified in collaboration with City staff. Critical areas may include common outdoor amenity areas.
- Wind data input should include all wind directions available for the area to account for the probability of occurrence of wind at critical pedestrian locations from all directions and times of year.
- CFD studies should test a minimum of six wind directions. At least four prevailing directions and two additional directions, at a minimum, should be included.
- Where the proposed building form or orientation may lead to undesirable or increased wind activity, additional wind directions may be required by City staff.
- The potential wind comfort and safety categories should be assessed for both the summer and winter seasons for all areas of interest in the vicinity of the proposal and described by a qualified microclimate professional in a technical report. If wind conditions are predicted to exceed the acceptable comfort criteria for the proposed function of any particular area, design alternatives and wind mitigation measures must be modeled and tested in the CFD simulation and described in the final report.

3.3 Quantitative Assessment (Wind Tunnel Test)

Wind Tunnel Tests utilize a physical scale model in a specialized boundary-layer wind tunnel facility to predict and assess the potential wind conditions at specific locations at the pedestrian level between buildings. Quantitative Assessment methods are the most accurate means of accessing potential wind conditions.

a. Wind Tunnel Test

Description

- Wind Tunnel Testing is conducted in a boundary-layer wind tunnel and presents a number of advantages over Qualitative Assessments. Wind Tunnel Testing enables rapid testing of 36 directions of wind and the ability to test for gusts.

Requirements

- Tests must use 36 wind directions in 10-degree increments to capture all possible predicted wind directions in 360 degrees.



Figure 3.3 - Building model in a wind tunnel facility
Image credit: RWDI

- 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 speeds shall be presented in km/h.
- 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 metres above local grade. These sensors must be capable of measuring mean wind speed and wind speed fluctuations with time, including peak gusts of three to ten second duration. 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 350 metres of the centre 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.
- Sensors shall be placed apart a maximum of the equivalent of 10 metres in full scale along a street frontage of the study buildings and at all locations where pedestrians will travel or gather, including but not limited to common outdoor amenity areas. A minimum sensor coverage area of 1 times the building height or 1 street block (whichever is determined to be more appropriate in consultation with City staff) should be used.
- Prior to conducting the test, sensor locations must be identified and submitted to City staff in the form of a scaled Sensor Location Plan identifying all proposed sensor locations and associated uses. If the plan is not approved, staff will work with the applicant to revise the Sensor Location Plan until staff are satisfied that adequate coverage is provided.
- The final results shall be presented in both tabular and graphic forms for all the test configurations, with seasonal comfort data and annual safety data.
- The potential wind comfort and safety categories should be assessed for all areas of interest in the vicinity of the proposal and described by a qualified microclimate professional in a technical report. If wind conditions are predicted to exceed the acceptable comfort criteria for the proposed function of any particular area, design alternatives and wind mitigation measures must be tested and described in the final report.

4.0 Wind Impact Criteria

4.1 Introduction

To evaluate wind impacts, the public realm context surrounding a proposed development is evaluated based on various intended uses in outdoor spaces within the boundaries of, and in proximity to the proposed development.

4.2 Wind Comfort and Safety Criteria

Categories and measurements for wind impact are defined through the Pedestrian Wind Comfort Criteria (Table 4.1) and Pedestrian Wind Safety Criteria (Table 4.2).

Each comfort category contains a Gust Equivalent Mean (GEM) wind speed. GEM should be evaluated as a comparison between the existing wind condition and the wind condition resulting from the proposed development. The existing condition is studied to establish a baseline for comparison. A criterion is met if the predicted wind speeds and frequencies occur at least four out of five days below the respective threshold.

Gust winds are used exclusively when considering wind safety. These are generally rare events that may impact pedestrian safety.

Descriptions used in the Pedestrian Wind Comfort Criteria are to be applied to specific locations on and around a proposed development site, based on the intended use of each space. To account for differences in prevailing wind conditions by season, data should be presented based on tests conducted for both the summer and winter season.

Sitting: The Sitting comfort criteria is the most stringent and is appropriate for dedicated seating areas including cafes, patios, and outdoor restaurants. It may also apply to areas for sitting located in outdoor amenity areas.

Standing: The Standing comfort criteria applies to areas where pedestrians will tend to stand and linger for short periods. This includes main building entrances, bus stops, plazas, and some areas of parks. It is also applicable to outdoor amenity areas other than seating locations.

Leisurely Walking: The Leisurely Walking comfort criteria applies to areas where lower-speed walking or strolling is intended. This includes retail streets and streets with high levels of activity between interior and exterior areas. It also includes areas that encourage congregation and movement such as parks.

Fast Walking: The Fast Walking comfort criteria applies to areas through which pedestrians and other users walk and travel at medium to high speeds.

Uncomfortable: The Uncomfortable comfort criteria indicates where pedestrian activities are inappropriate under the present wind conditions. Wind mitigation measures to attenuate wind speeds to an acceptable level are required.

Table 4.1: Pedestrian Wind Comfort Criteria		
Wind Comfort Category	**GEM Speed (km/h)**	**Description**
Sitting	≤ 10	Calm or light breezes • Appropriate for dedicated seating areas such as cafes, patios, and outdoor amenity areas
Standing	≤ 14	Gentle breezes • Appropriate for main building entrances, bus stops, and other places where pedestrians may linger
Leisurely Walking	≤ 17	Moderate winds • Appropriate for shopping and strolling along retail streets and parks
Fast Walking	≤ 20	Relative higher speed winds • Appropriate for areas where pedestrians are walking, running, or cycling without lingering
Uncomfortable	> 20	Strong winds • Inappropriate due to nuisance for all pedestrian activities • Wind mitigation measures required
Notes: (1) GEM is defined as the maximum mean wind speed or gust speed divided by 1.85 (whichever is larger). Gust speed can be directly measured in a wind tunnel or represented by mean wind speed + 3 x RMS (Root Mean Square) wind speed. (2) GEM speeds listed above are based on a seasonal exceedance of 20% of the time between 06:00 and 23:00. The criterion has been met if the wind speeds occur at least four out of five days.		

Table 4.2: Pedestrian Wind Safety Criteria		
Safety Criterion	**Gust Speed (km/h)**	**Description**
Exceeded	> 90	• Excessive gust speeds • Adverse effect on pedestrian's balance and footing • Wind mitigation is required
Notes: (1) Based on an annual exceedance of 9 hours or 0.1% of the time for 24 hours a day. (2) Gust speed can be directly measured in a wind tunnel or represented by mean wind speed + 3 x RMS wind speed.		

5.0 Mitigation Measures

5.1 Introduction

Where wind conditions are considered unacceptable for the intended pedestrian use or unsafe, wind control mitigation strategies must be developed and tested. Test results must demonstrate that the resultant conditions meet the wind comfort category intended for the proposed function of an area, and/or the safety criterion.

The most effective wind control measures involve adjustments to the building and site design early in the design process. This may include:

- Building massing adjustments or alternative designs that are more responsive to the local wind climate;
- Incorporating podiums, tower setbacks, notches and/or colonnades;
- Strategic implementation of canopies, wind screens, façade elements, landscaping, planters, public art and/or other features that prove to be effective for mitigating problematic wind conditions; and
- Modifications to the proposed function of an area.

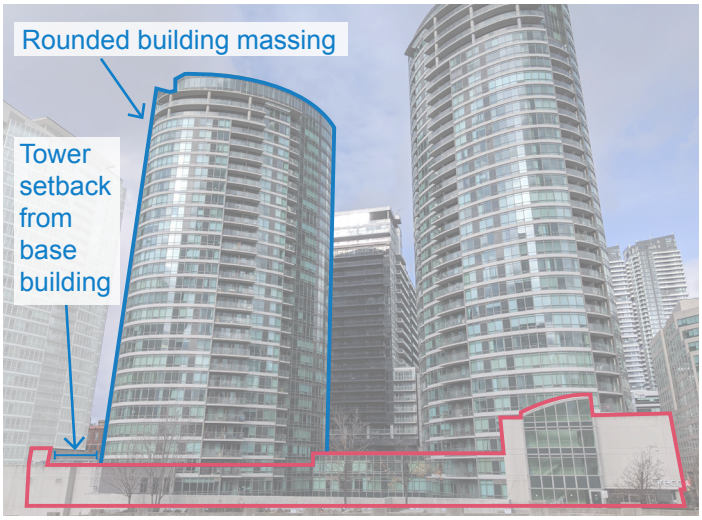


Figure 5.1 - A rounded tall tower on a base building element
Image credit: Brook McIlroy

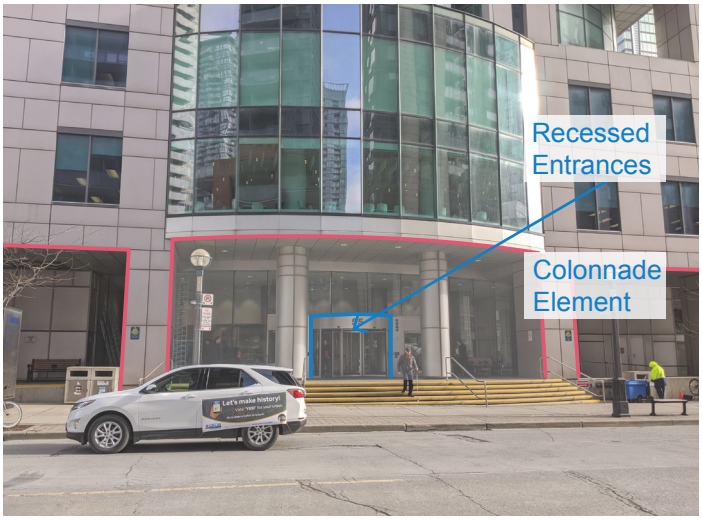


Figure 5.2 - A recessed entrance area with adjacent colonnade areas
Image credit: Brook McIlroy

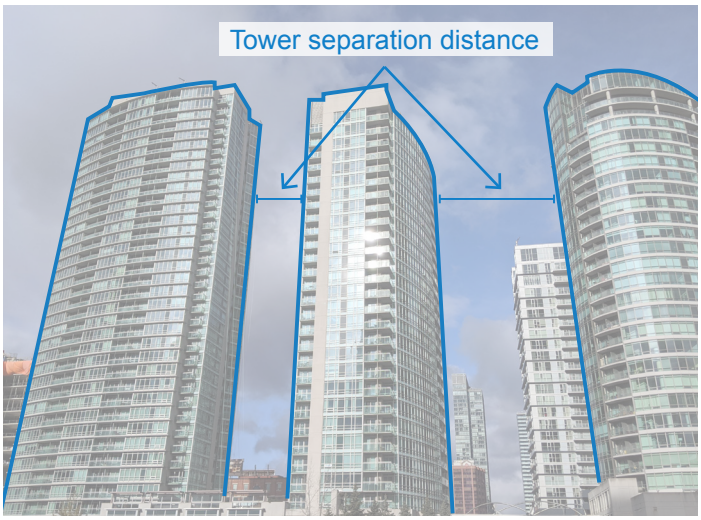


Figure 5.3 - Adequate tower separation distance
Image credit: Brook McIlroy

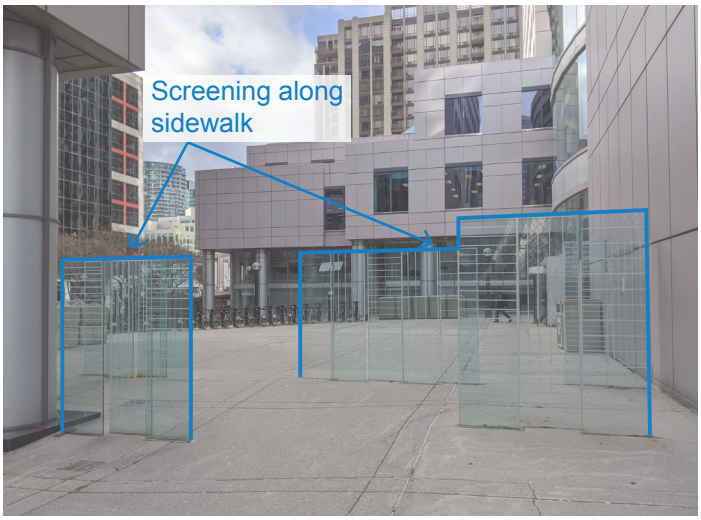


Figure 5.4 - Vertical screening between two building elements at grade
Image credit: Brook McIlroy

5.2 Design Strategies for Wind Mitigation

a. Building Design Measures

- Tower Setback from Base Building/Podium (Figure 5.1): Downward wind flow will be disbursed at the base building/podium to improve wind conditions at the pedestrian level.
- Massing Modifications (Figure 5.1): Increased step-backs and curved building elements can be introduced to reduce downward wind flows and funneling.
- Screening, Canopies, and Colonnades (Figure 5.2): Screening and canopies can be applied to pedestrian oriented areas to deflect winds.
- Recessed Entrances (Figure 5.2): Recessed entrances provide a sheltered area for pedestrian congregation.

b. Site Design Measures

- Tower Separation (Figure 5.3): Additional separation and modifications to building orientation and design may reduce wind acceleration between buildings.
- Screening Along Sidewalk (Figure 5.4): Vertical screening can be implemented along sidewalks to deflect winds.
- Trees and Landscaping: Some landscaping elements, especially coniferous and marcescent tree species, can be planted to improve wind conditions. These 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**.

6.0 Submission Format

A technical report shall be prepared upon the completion of a Wind Study. In General, the report should address the following items set out in Sections 6.1 - 6.4, inclusive:

Submissions shall be completed to the satisfaction of the Community Planning Department.

6.1 Physical Context

a. Building and Site Information

- What is the height of the proposed development?
    - Provide respective building heights (in metres) that include and exclude the mechanical penthouse.
    - Provide the total number of storeys.
- Where is it located?
    - Provide the municipal address.
- Are there existing structures to remain?
    - Describe the existing structures on the site and state if they will remain.
- Identify any key pedestrian areas on the site (to be approved by City staff). Key areas may include, but are not limited to:
    - Major building entrances;
    - Sidewalks (adjacent to the proposed building;
    - Parking lots (adjacent to the proposed building;
    - Public amenity spaces (e.g. parks, plazas, courtyards, trails, public pools, restaurant patios, common outdoor amenity areas etc); and
    - Transit Stops.

b. Surroundings

- Describe the topography of the area;
    - Describe the topography of the surrounding context within a 350 metre radius from the centre of the site.
- Is the surrounding area developed or undergoing development?
    - Provide a summary of existing and planned built form context within a 350 metre radius from the centre of the site.
- What are the heights of surrounding buildings or developments (existing or planned)?
    - Describe the heights of surrounding buildings or developments within a 350 metre radius from the centre of the site.
- Identify any key pedestrian areas in the surrounding area:
    - Describe and identify key pedestrian areas on and surrounding the site within a 350 metre radius from the centre of the site.

6.2 Study Approach

a. Type of Study

- Describe the type of qualitative or quantitative study being conducted, per Sections 3.2 and 3.3.
- Present the meteorological data and criteria used in the assessment of wind conditions:
    - Describe where the meteorological data was collected, and where the data was obtained; and
    - Include wind rose diagrams, by season, which express wind speeds.

b. Configurations – Describe which are being used in the analysis

- Existing: Includes all existing buildings, significant topographic features, and all developments currently approved or under construction within a 350 metre radius from the centre of the site. This provides a snapshot of the context as it exists today.
- Proposed: Includes all components of the Existing Condition within a 350 metre radius from the centre of the site, plus the proposed development.
- Future (if applicable): Add any proposed buildings as identified by the City of Burlington.
- Mitigation (if required to bring wind conditions within levels defined in Tables 4.1 and 4.2): Includes all components of the Existing Condition within a 350 metre radius from the centre of the site, plus the proposed development with wind mitigation measures applied.

6.3 Test Results

- Present study results graphically and discuss wind conditions on and around the development. Graphical standards pertaining to identification of key pedestrian areas and sensor locations are included in **Appendix A**. Conditions in existing and proposed configurations for summer and winter seasons must be described. Submissions must be generated in full colour.
- Provide statement to indicate frequency that comfort and/or safety wind conditions are expected to be exceeded.
- Where wind comfort and/or safety conditions are exceeded, provide details of any mitigation strategies to bring wind conditions to appropriate levels, along with the results of testing of the mitigation measures as defined in Section 6.4 below.

6.4 Mitigation Strategies

- • Where mitigation measures are proposed, additional testing must be completed and presented to ensure mitigation measures result in wind conditions that are adequate for the intended use. Subsequent testing may be requested at the discretion of City staff.

Glossary

Colonnade: A row of evenly spaced columns supporting a roof,
arches or an entablature.

Computational Fluid Dynamics (CFD): CFD is the use of computer simulation modelling to visualize the wind flow patterns around a proposed building.

Desktop Assessment: Desktop Assessments rely on a qualified microclimate professional's expertise and analysis of the local built form and climate context in order to make a judgment on wind conditions.

Exceedance: Beyond that which is allowed or stipulated by a set limit.

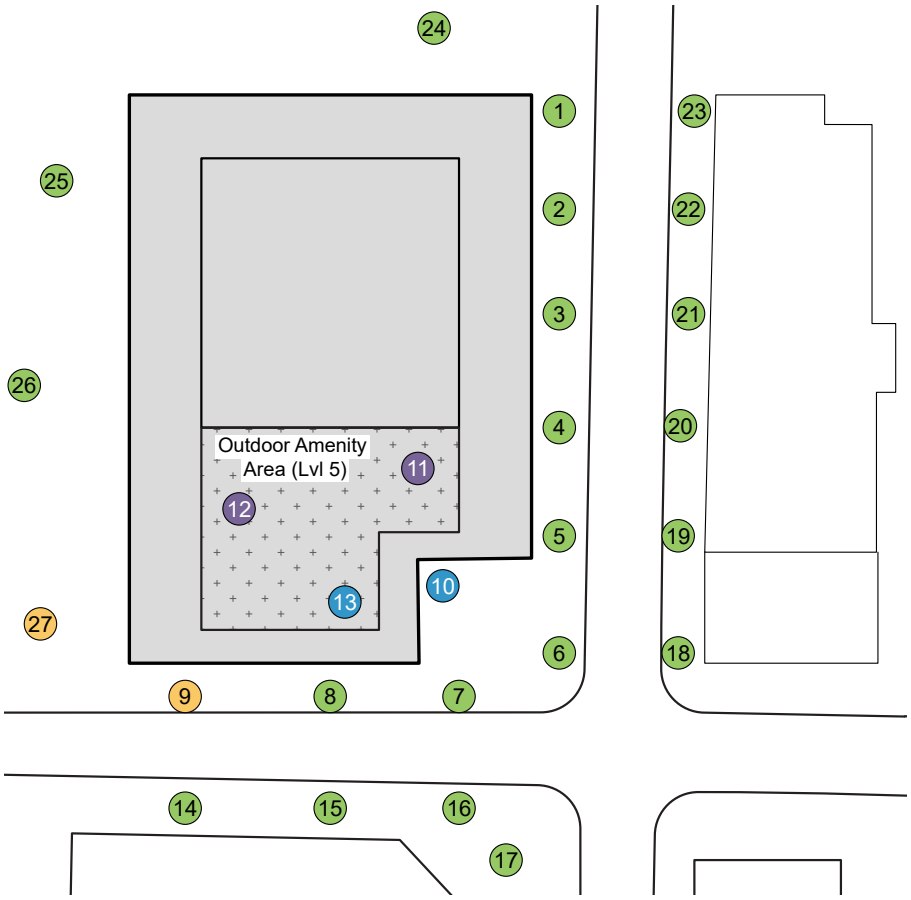
Marcescent Tree Species: Plants with leaves that wither, but remain
attached to the stem without falling off.

Qualitative Assessment: Includes Desktop Assessment and Computational Fluid Dynamics.

Wind Tunnel Test: Wind Tunnel Tests utilize a physical scale model in a specialized boundary-layer wind tunnel facility to predict and assess the potential wind conditions at specific locations at the pedestrian level between buildings.

Appendix A: Graphical Standards

Example Wind Tunnel Test Sensor Location Plan and Predicted Pedestrian Wind Comfort Criteria



Predicted Comfort Classes

- # Sitting
- # Standing
- # Leisurely Walking
- # Fast Walking
- # Uncomfortable

Notes

1. Example diagram not to scale
2. (#) Pedestrian level wind sensor location
3. Diagram may be divided by levels (eg. Grade, Amenity Floors, etc)

Colour Key For Reference

#	Sitting	R: 120 G:100 B:150
#	Standing	R: 50 G:150 B:200
#	Leisurely Walking	R:150 G:200 B:100
#	Fast Walking	R:250 G:200 B:100
#	Uncomfortable	R:200 G:100 B:100

Project Name and Address

Example Wind Tunnel Test Sensor Location Description

1	Sidewalk	11	Outdoor amenity area (Lvl 5)	21	Sidewalk
2	Sidewalk	12	Outdoor amenity area (Lvl 5)	22	Sidewalk
3	Sidewalk	13	Outdoor amenity area (Lvl 5)	23	Sidewalk
4	Sidewalk	14	Sidewalk	24	Surface parking
5	Sidewalk	15	Sidewalk	25	Surface parking
6	Sidewalk	16	Transit Stop	26	Surface parking
7	Transit Stop	17	Entrance (adjacent building)	27	Surface parking
8	Sidewalk	18	Sidewalk		
9	Sidewalk	19	Sidewalk		
10	Major building entrance	20	Sidewalk		

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