TOWN OF GRIMSBY

Terms of Reference

Wind Study

Materials prepared by: Urban Design and Landscape Architecture Planning and Development Services, Niagara Region, in collaboration with RWDI.

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DESCRIPTION

Pedestrian Level Wind Study (hereafter called 'Wind Study') is a technical report that provides a model and written description that is to deliver consistent and fulsome wind analysis as a result of a development proposal. The Wind Study will determine the wind impact of a development, inform and direct the development design to be wind-responsive, and ensure that wind conditions on and around the development are adequate at various times of the year. This document provides Terms of Reference for Wind Studies required as part of the planning applications of development proposals for the Town of Grimsby.

Wind is a crucial parameter that defines human comfort. The mechanical force of wind on people can impact daily common 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. The Pedestrian Level Wind Study – Terms of Reference deals with the wind effects on people and how conducive it is to pedestrian use of outdoor areas.

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RATIONALE

These standards are intended to reduce undesirable wind activity, and to create comfortable spaces that align with outdoor pedestrian usage throughout the year.

Properties or circumstances of a project, such as the scale, shape, height, location, density of surroundings, proximity to important areas, etc. that, through precedents, are known to be causative factors for noticeable wind impacts around the project are referred to as "triggers". If the project meets the specifications under the following triggers, then a wind assessment would be required for the project.

Note: Wind assessments are required for habitable buildings, and do not apply to structures such as farm buildings, communication towers, etc.

Height Triggers

Low Trigger: A Qualitative Wind Assessment may be required for any proposal for a building that is four or more storeys, where the Official Plan directs for a wind study to be submitted, or where it has been requested by Town Staff for the purposes of a complete application.

High Trigger: A Quantitative Wind Assessment may be required for a development that is at least 12 storeys.

Additional Triggers

A Quantitative Wind Assessment (High Trigger) is required for a proposed development if it is at least 23m or 7 storeys and is:

- Located within 2.5km of Lake Ontario due to increased exposure to lake-effect winds.
- Comprised of two or more buildings as multiple buildings in close proximity, as this typically results in higher wind activity.

REQUIREMENTS

Qualified Persons

A Wind Study must be prepared by a qualified microclimate professional. The studies are to be signed and sealed by a Professional Engineer. 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.

Types of Wind Studies

Depending on the trigger level, the Town of Grimsby accepts two types of wind studies:

1. **Qualitative Wind Study:** A desktop assessment using computational fluid dynamics (CFD).
2. **Quantitative Wind Study**: A scale model study using a boundary-layer wind tunnel.

Requirements for the application process for the two Trigger Levels and the types of study required are described in Table 1 below.

Table 1: Application Process and Wind Study Type		
The methodology and specification for each study type are described in the Appendix.		
Trigger Level	**Low**	**High**
OPA/ ZBA Application	Qualitative Assessment (i.e., Desktop assessment using computational fluid dynamics, CFD)	Quantitative Assessment (i.e., Wind tunnel study)
SPA Application	• If the project did not go through an OPA/ZBA process or it went through an OPA/ZBA process, but there have been significant changes (i.e. revisions to built form, height, and/or massing), 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, an additional wind study is not required upon the confirmation of wind consultant. • The type of wind study required is at the discretion of the Town of Grimsby.	

Technical Requirements

The following is a summary of the technical requirements for a Wind Study. Detailed information is provided in the Appendix.

- The use of long-term wind data can be obtained from Niagara Falls International Airport, Niagara Falls, New York, and John C. Munro International Airport, Hamilton, Ontario.
- The Wind Study should use the pedestrian wind criteria to evaluate wind comfort and safety as outlined in this document (Table 2 in Appendix).
- To determine the wind impact associated with a new development, the predicted wind conditions should be related back to the Existing Scenario. Note that the Existing Scenario should include both existing buildings as well as approved planning applications for new buildings surrounding the property. Additional Scenarios may be evaluated as required.
- Based on the Trigger Level, a Qualitative Assessment using computational fluid dynamics or a Quantitative Assessment using a boundary-layer wind tunnel should be pursued. The specific requirements for each study type are outlined in the Appendix.
- Potential wind mitigation solutions and/or recommendations for revised building massing should be detailed in the Wind Study.

APPLICATION PROCESS

Communication with the Town

- Prior to applying, the Applicant is strongly recommended to consult with the Town and attend a pre-consultation meeting where the requirements can be scoped based upon the triggers described in this document.
- Prior to applying, wind measurement locations or influence areas should be discussed and confirmed with the Town. General guidelines for areas of interest are described in the Appendix.

- To confirm the accuracy of the scale model for the wind tunnel study, the Applicant may be asked to submit test scenarios for review by the Town, prior to any wind testing or simulation.
- If the wind study indicates that the proposed development is predicted to produce wind conditions that are considered unsafe or unacceptable, the Town shall be consulted to discuss potential wind mitigation strategies going forward.

Official Plan and Zoning By-law Amendment (OPA/ZBA)

The Town may require the submission of a wind study report that shows satisfactory wind conditions on and around the project where it has been identified through the Official Plan or though a pre-consultation meeting. If needed, wind control measures should be implemented, and their effectiveness demonstrated through additional studies.

Site Plan Control Application (SPA)

A wind study may be required if significant design changes have been made since the previous submission to evaluate the project's performance, or where it has been identified as a requirement through a pre-consultation meeting to ensure the proposal can satisfy the recommended wind criteria. The consultant's professional opinion regarding the changes is to be presented in writing to inform this decision. The Town, at their discretion, may ask for additional studies.

Examples of significant design changes are described in the Appendix (Section A.6.2). The design submitted should incorporate all recommendations from previous submissions.

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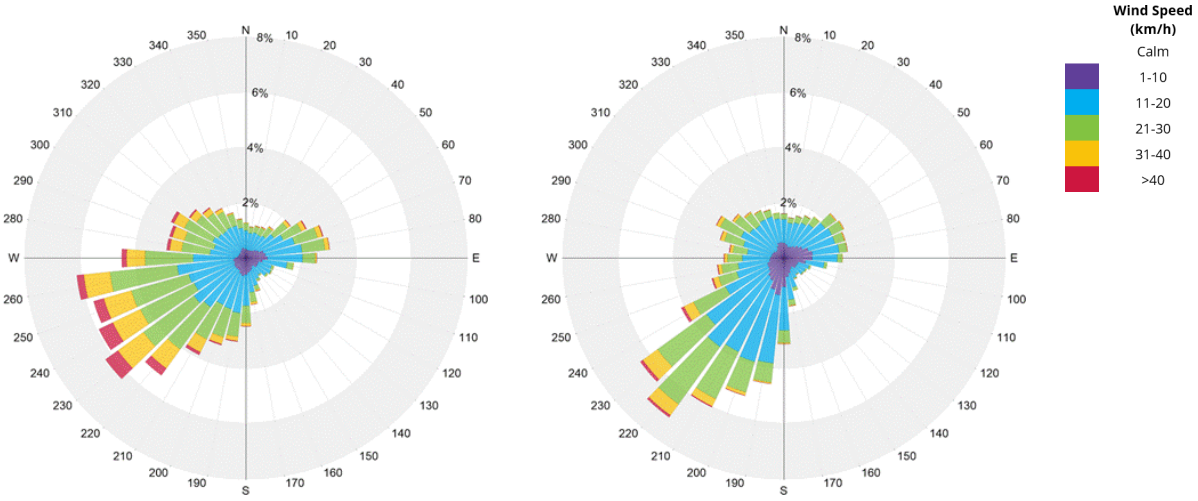
APPENDIX

APPENDIX: METHODOLOGY AND SPECIFICATIONS

A.1 Meteorological Data

Long-term wind data recorded in major airports are often used in the prediction of pedestrian wind conditions. In the Niagara Region, wind climate is affected by the adjacent Lake Ontario and Lake Erie, and wind data obtained from Niagara Falls International Airport, Niagara Falls, New York can be used to conduct pedestrian wind studies.

Wind data should be presented on a two-season basis: Summer (defined as May through October) and Winter (defined as November through April). Appropriate hours of pedestrian usage for a typical project (i.e. between 06:00 and 23:00) should be used for wind comfort, while data for 24-hours should be used to assess pedestrian wind safety. The wind roses obtained from Niagara Falls International Airport are provided in Image 1 for both seasons.



Summer (May to October) **Winter (November to April)**

Image 1: Above, Directional Distribution of Winds Approaching Niagara Falls International Airport (1991 to 2020)

A.2 Wind Criteria for Pedestrian Comfort and Safety

The public realm, streetscapes and public/private outdoor open spaces related to the existing and proposed buildings are to be comfortable for their intended use. Table 2 describes the minimum criteria for specific locations. The criteria deal with comfort and safety of pedestrians:

Comfort: Commonly experienced wind speeds have been categorized into ranges based on the activity level of a person that the winds would be conducive to. Lower wind speeds are desirable for passive activities and active pedestrians would be tolerant of higher wind speeds.

Safety: It is important to assess wind conditions in the pedestrian realm from a safety perspective, as strong wind gusts can deter safe pedestrian use of outdoor spaces. Wind speeds associated with wind gusts are infrequent but deserve special attention due to their potential impact on pedestrian safety.

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Table 2: Wind Criteria for Pedestrian Comfort and Safety				
Comfort	**GEM Speed (km/h)**	**Minimum Occurrence (% of Time)**	**Description**	**Area of Application**
Sitting	≤ 10	80	Light breezes desired for outdoor seating areas where one can read a paper without having it blown away.	Park benches, restaurant and café seating, balconies, amenity terraces, children's areas, etc. intended for relaxed, and usually seated activities.
Standing	≤ 15	80	Gentle breezes suitable for passive pedestrian activities where a breeze may be tolerated.	Main entrances, bus-stops, dog areas, and other outdoor areas where seated activities are not expected.
Walking	≤ 20	80	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	20	Strong winds, considered a nuisance for most activities.	Not acceptable in areas with pedestrian access
Notes: 1) Gust Equivalent Mean (GEM) speed = maximum of either mean speed or gust speed/1.85. The gust speed can be measured directly from wind tunnel or estimated as mean speed + (3 x RMS speed). 2) Comfort calculations are to be based on wind events recorded between 6:00 and 23:00 daily				
Safety Criterion	**Gust Speed (km/h)**	**Minimum Occurrence Annual**	**Description**	**Area of Application**
Exceeded	> 90	0.1% (9 hours in a year)	Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required.	Not acceptable in any area of interest
Notes: 3) Safety calculations are to be based on wind events recorded for 24 hours a day				

A.3 Configurations

A Wind Study report should present the following scenarios:

- **Existing Scenario**: Existing site and all existing surrounding buildings, significant topographical features, developments under construction and projects that were approved for construction in the last 5 years.
- **Proposed Scenario**: Proposed project in place of existing site.
- **Mitigation Scenario(s), if warranted**: Undesirable wind conditions can be mitigated through various measures ranging from building massing changes to landscaping elements. Where mitigation is required to achieve acceptable pedestrian wind comfort levels, mitigation measures should be implemented in the Proposed configuration scenario to demonstrate the benefits of the mitigation strategies.
- **Phasing Scenario(s), if applicable**: Where the site construction is phased, there is a need to assess interim scenarios, as well as scenarios that may create adverse conditions before subsequent buildings are added to the site. The Town may ask for the study of different site scenarios.

A.4 Areas of Interest

Wind studies will focus on the public realm and shared open space(s) on the site and adjacent to the site including:

- Sidewalks (public and private) adjacent to the development, building entrances and building perimeters on the site and adjacent to the site,
- Privately Owned Public Spaces (POPS) on site and on adjacent sites,
- Public parks, recreational areas, school yards, ravines, and other recreational areas on or adjacent to the site,
- Above-grade pedestrian locations, including outdoor shared amenity space, roof terraces, for the building and adjacent to the site, and
- Town staff may ask for additional areas of interest for the wind assessment.

A.5 Specifications for Wind Studies

A.5.1 Qualitative Assessment

As outlined in Table 1, a Qualitative Assessment may be conducted as a Desktop Assessment using computational fluid dynamics (CFD).

A Desktop Assessment is based on CFD simulations of the existing and proposed configurations, together with the wind consultant’s experience and professional judgement. Example CFD simulation results are shown in Image 2.



Image 2: Example computational fluid dynamics simulation results.

Requirements for a Desktop Assessment:

- A prediction of wind speeds at critical locations around a proposed development, while acknowledging the primary wind directions and frequencies of strong wind events.
- The use of the standard wind comfort and safety criteria and the meteorological data outlined in this document.
- Where wind conditions are considered unacceptable for the intended pedestrian usage, mitigation concepts and recommendations should be presented to improve wind conditions.

CFD is a numerical modelling technique for simulating wind flow in complex environments. For wind modelling, CFD techniques are used to generate a virtual wind tunnel where flows around the site, surroundings and the study building are simulated at full scale. The computational domain that covers the site and surroundings is divided into millions of small cells where calculations are performed, allowing for results to be presented in high spatial resolution. There are no limitations to the number of points of measurement and results can be obtained from any data point in the computational domain even after the simulation is over. CFD allows for the “mapping” of wind conditions across the entire study-domain.

CFD excels as a tool for wind modelling for providing 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). It is these types of flow behaviours that can cause pedestrian discomfort and safety concerns.

Requirements for a CFD Study:

- Software
    - The CFD software used should follow the COST 732 Best Practice Guideline for CFD Simulations.
    - The CFD simulation should appropriately represent the atmospheric boundary layer for winds approaching the project.
    - The user or the Consultant should be confident with the results produced and ensure that it is technically correct.
- A minimum of sixteen (16) wind directions at equal intervals, as follows, shall be simulated.
- Analysis and Results
    - Wind speeds shall be presented in km/h.
    - Assessment should be done for all areas of interest.
    - The processing of results should consider the probability of all wind directions simulated using meteorological data as described in the Appendix.
    - 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 grade or the concerned level.
    - The results for seasonal comfort should be based on the wind comfort and safety criteria. Compliance with the annual safety criterion may be assessed numerically or using experience-based methods and areas where the criterion is assessed to be exceeded should be indicated graphically.

A.5.2 Qualitative Assessment

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 (Image 3). In general, such modelling provides a quantified representation of both mean and gust effects and the transient behavior 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.

- The wind simulation facility must be capable of simulating the earth's atmospheric boundary layer and appropriate wind speed and turbulence profiles for each of the wind directions tested.
- Wind Speed Measurement
    - 36 wind directions at equal intervals shall be tested
    - Sensors shall be omni-directional and shall measure the magnitude of horizontal wind speeds.
    - The measurements should represent the wind speed at a full-scale height of approximately 1.5 m above local grade.
    - Sensors and instrumentation 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 and sampling frequency a minimum of 1 Hz in full scale.
- Sensor Placement

  - Sensors shall be placed at a full-scale interval of approximately 10 m along street frontages of the project buildings and at all locations where pedestrians will gather. The interval may be increased farther away from the project site.
  - Locations to capture all areas of interest as described in Section A.4. Generally, it should include entrances to the project building(s) and major entrances to buildings across the street from the project in all directions, sidewalks, seating areas, bus stops, plazas, etc.
  - A typical development project would require a minimum of 50 sensor locations on and around the proposed development to provide adequate coverage.
- Analysis and Results
  - Wind speeds shall be presented in km/h.
  - The analysis should consider the probability of all wind directions tested using meteorological data.
  - The results shall be presented in both tabular and graphic forms for all the test scenarios, with seasonal comfort data and annual safety data.
  - The table of results must include wind speed and associated wind speed category at each measurement location.



Image 3: Example study model in a boundary-layer wind tunnel.

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A.6 Wind Responsive Design Guidelines

A.6.1 Basic Flow Patterns

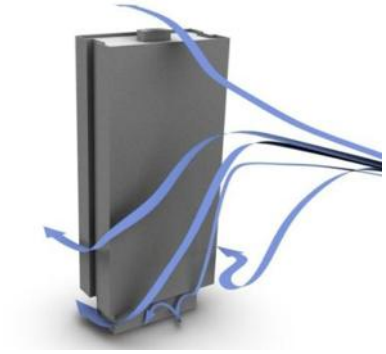
Wind speed increases with elevation; wind typically flows unobstructed and at high speeds over areas of uniform height (built structures or natural terrain). Short buildings typically do no deflect winds to a level that would result in adverse wind impacts. Wind, when obstructed by a structure such as a building, will find the path of least resistance to continue its motion, in the process, creating zones of high-wind activity around the building. The following is an overview of some of the common wind flow mechanisms seen in the built environment. One or a combination of such mechanisms could result in undesirable wind activity in the pedestrian realm, depending on the local climate, building form and its exposure to winds and the surrounding terrain.

Consider a tall building with the broad façade facing a strong wind stream. When the stream is intercepted by the building, some of the flow moves upward and over the building, but much of the stream is redirected downward (Downwashing) and around the lower portion of the building.

The flow attaches to the building, and then separates at the edges creating high wind activity at the corners (Corner Acceleration). This effect could be intensified if a short building is located upwind, because of the air pressure differential between the top and bottom of the building. The area between the buildings could be very windy as a result. However, strategic master planning uses this arrangement to an advantage as locating shorter buildings upwind of taller ones reduces the exposure of the taller and more impactful buildings to wind, thereby reducing the potential for adverse wind impacts.

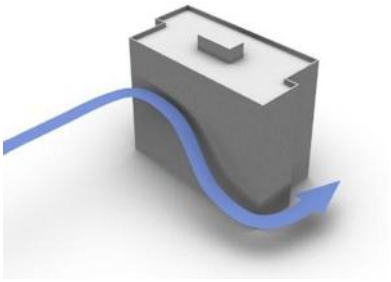
When gaps between buildings, that are narrow relative to the building heights, are aligned with the prevailing winds, wind accelerates in the gaps because of what's commonly called Venturi effect. A similar acceleration is also common under bridges and in underpasses as the air is forced to go through a narrow passage.

Typically, wind interacts with multiple buildings and the resulting flow is much more complex. Depending on the wind-rearrangement caused by building groups (or a single building on its own), the causative flow mechanisms involved and design flexibility, the choice between "spot-treatments" and measures that have a large-scale impact becomes critical.



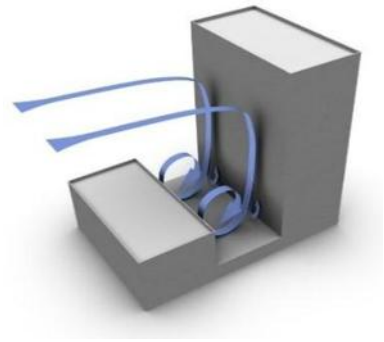
Downwashing Flows

Tall buildings tend to intercept the stronger winds at higher elevations and redirect them to the ground level. This is often the main cause for wind accelerations around large buildings at the pedestrian level.



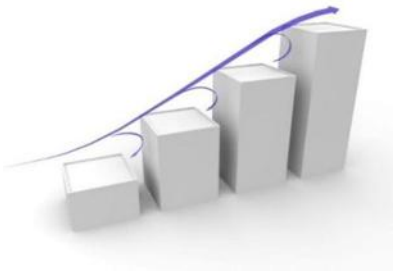
Corner Acceleration

When winds approach at an oblique angle to a tall façade and are deflected down, a localized increase in the wind activity or corner acceleration can be expected around the exposed building corners at pedestrian level.



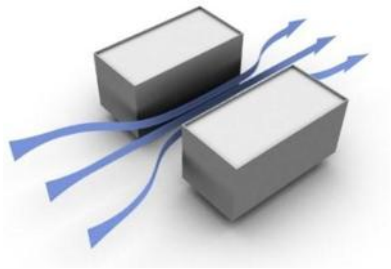
Short Building Upwind of Tall Building

Shorter adjacent buildings have the potential to capture and accelerate downwashed winds.



Short Buildings Upwind Reduce Wind-Exposure of Downwind Buildings

Potential wind impacts would be moderated by stepped massing of the building as its location adjacent to shorter buildings or lower roofs of the neighbouring buildings disrupting downwash.



Venturi/Channelling Effect

When two buildings are situated side by side, wind flow tends to accelerate through the space between the buildings due to channelling effect caused by the narrow gap.

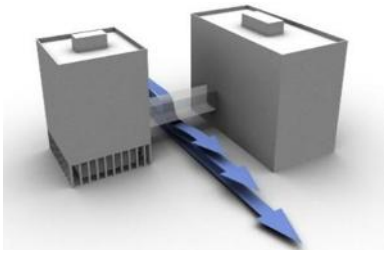


Image 4: Examples of common wind flows