Toronto Under the Gardiner

Local Identity - Enviromental quality

Content

How to read this chapter

The following pages intend to provide an overview of the environmental context around the Gardiner to support the following design phases which will identify specific areas of intervention.

Being the areas under the Gardiner extremely diverse, the intent of this chapter is only to provide a general understanding of the environmental context (climate, visual and acoustical comfort, water management...). More detailed analysis must follow up, based on the specific identity of each area of intervention.

After a description of the climate (historical and future projected data) and of the resulting outdoor comfort, we gather they main local comfort parameters we will have to work on to enhance the user experience under the Gardiner.

The chapter ends with typical environmental simulations, which must be performed again during the next design phases, when precise areas of interventions and design goals will be set.

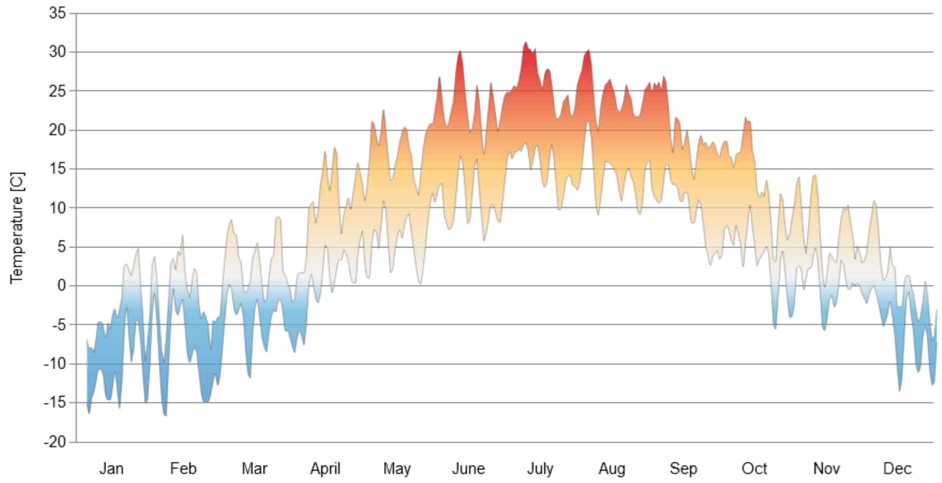
1. Climate Analysis

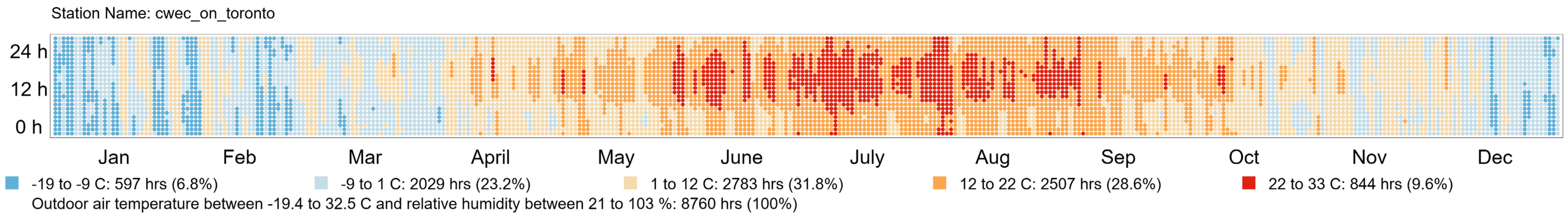
This paragraph describes they key facts of the climate in Toronto, based on the historical data collected from the Pearson International airport.

The historical data has been then projected with an assumed average future scenario with 3°C up to 4°C increase in temperatures compared to pre-industrial levels (which does not comply with the Paris agreement, but that is better than a businesses as usual scenario).

Toronto Climate (hystorical data)
Temperature

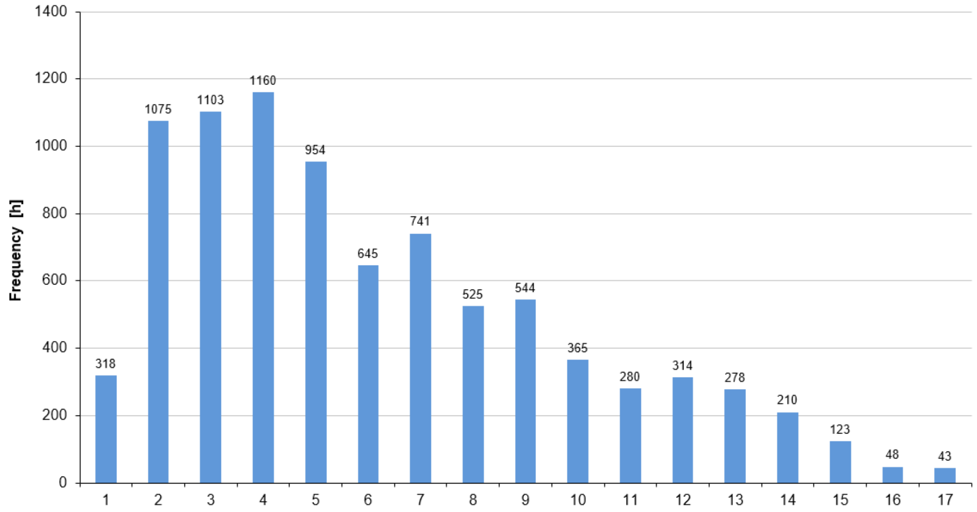
The temperatures range between an absolute minimum of -19.4°C and an absolute maximum of 32.5°C.
The annual temperature profile of Toronto shows approximately 4 months with ambient temperatures below 0°C.
30% of the year temperatures are below 0°C.
1.4% of the year temperature are above 28°C.

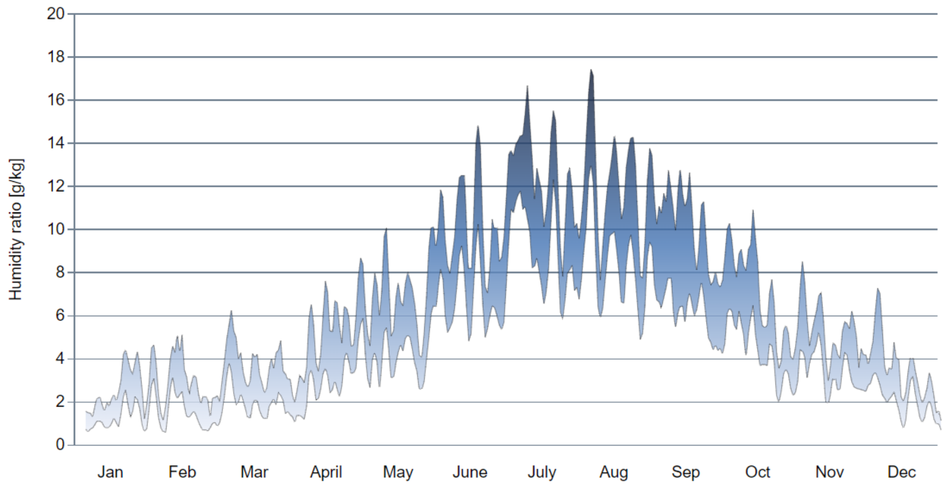




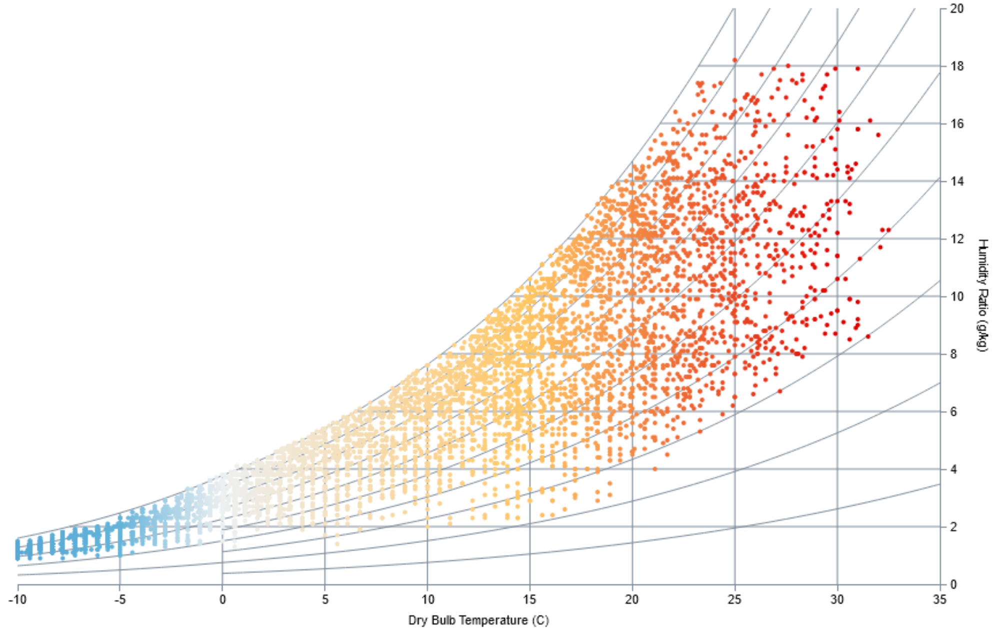
Toronto Climate (hystorical data)
Humidity

7.6% of the year the humidity ratio is >12 g/kg and 1.2% for >15 g/kg.
Usually, humidity ratios higher than 12 g/kg are considered too humid in absence of air movement or breeze. Humidity ratios higher than 15 g/kg are considered too humid also in precence of air movement or breeze.



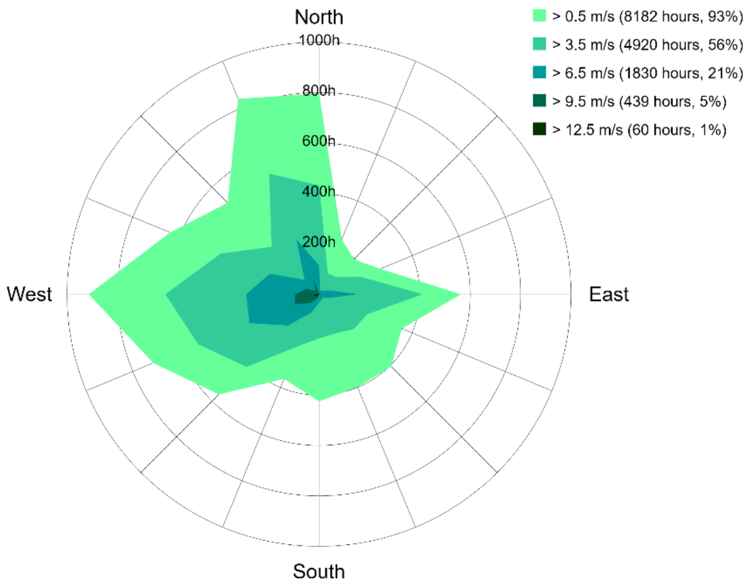


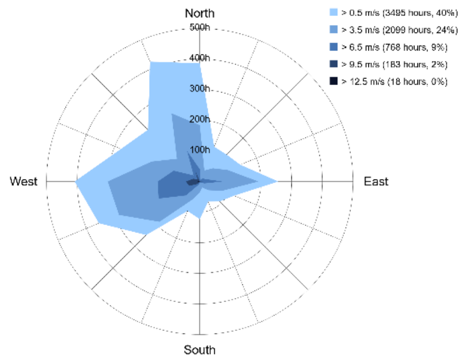
Station name: cwec_on_toronto
Period of min-max average: 3 days
Yearly humidity ratio [g/kg] profile
5425 Hours in bounds (out of 8760) between 0.4 and 18.2 g/kg
Turn: 0 degrees



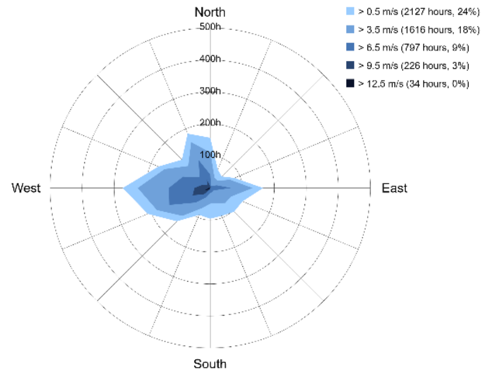
Toronto Climate (hystorical data)
Wind

Cold winds (with air temperatures under 13°C) come mainly from the west, as well as some low velocity winds from the north and east. Velocities are mostly between 0.5 and 6.5 m/s.
Warm winds (with air temperatures over 13°C) come mainly from the southeast and north, with occasional but daytime high-velocity warm winds from the southwest. Velocities are mostly less than 3.5 m/s.

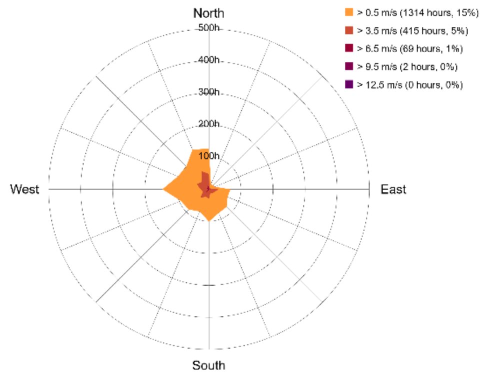




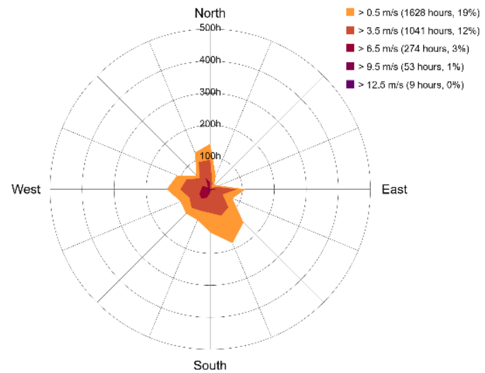
Winter Day



Winter Night



Summer Day



Summer Night

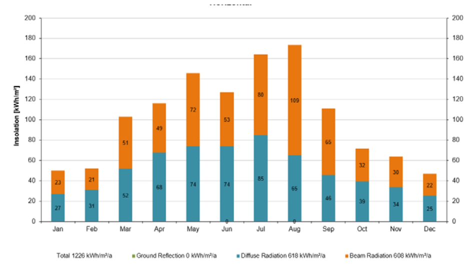
Toronto Climate (hystorical data)
Solar Radiation

Different orientations receive different amounts of energy annually due to different incident angles against the surface. For example, one square meter of an horizontal surface receives a total amount of solar energy equal to 1226 kWh/year.

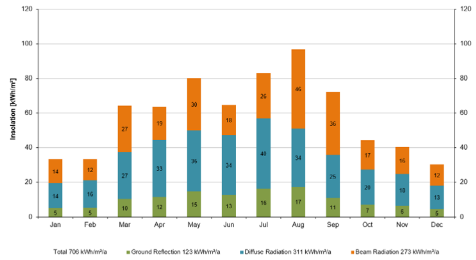
The amounts of solar radiation for different orientations suggest that solar applications (such as solar thermal or photovoltaic panels) are possible in all orientations except north.
The panels can be placed horizontally (in order to reduce self-shading effects and maximize the receiver areas) as well as vertically (e.g. to the eastern or western planes).

A high percentage of diffuse radiation (around 50% of the annual irradiation) is a result of cloud cover. Climates with an high cloud cover percentage call for photovoltaic technologies able to capture the diffuse part of radiation, in order to maximize their efficiency.

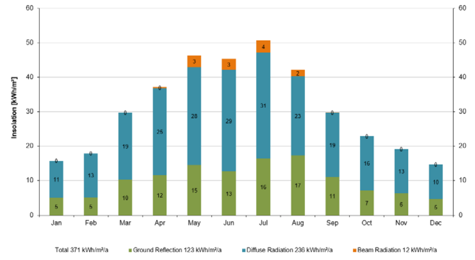
Horizontal



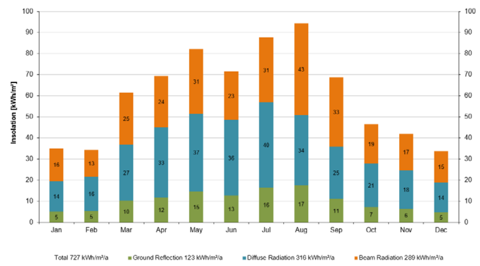
East



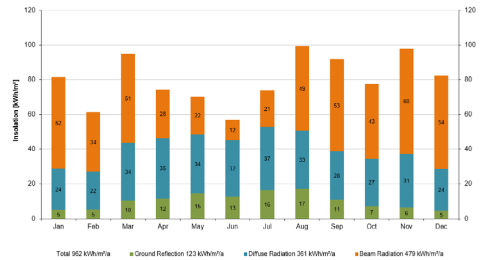
North



West



South

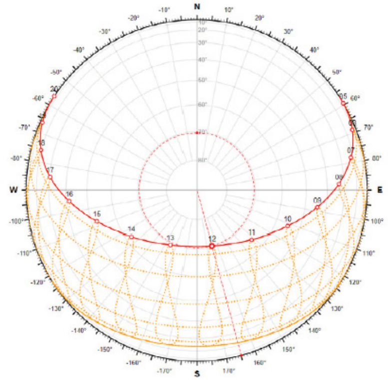


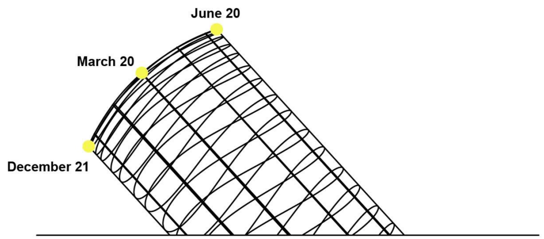
Toronto Climate (hystorical data)
Sun Position and Cloud Coverage

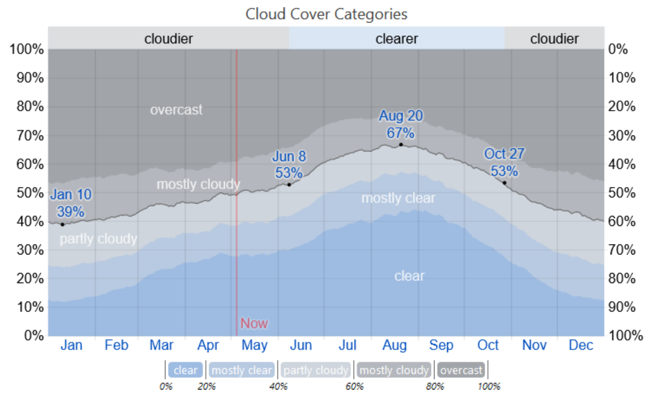
Understanding site sun angles is essential to maximize solar exposure within cities by considering the ratios between the height of the buildings and its corresponding street width.

Afternoon horizontal sun angles:
23° in December
42° in March and September
64° in June.

Cloud coverage in the summer months are around 40% which helps contribute to lowering solar radiation levels. The winters experience around 55% cloud coverage which limits beneficial solar gain.





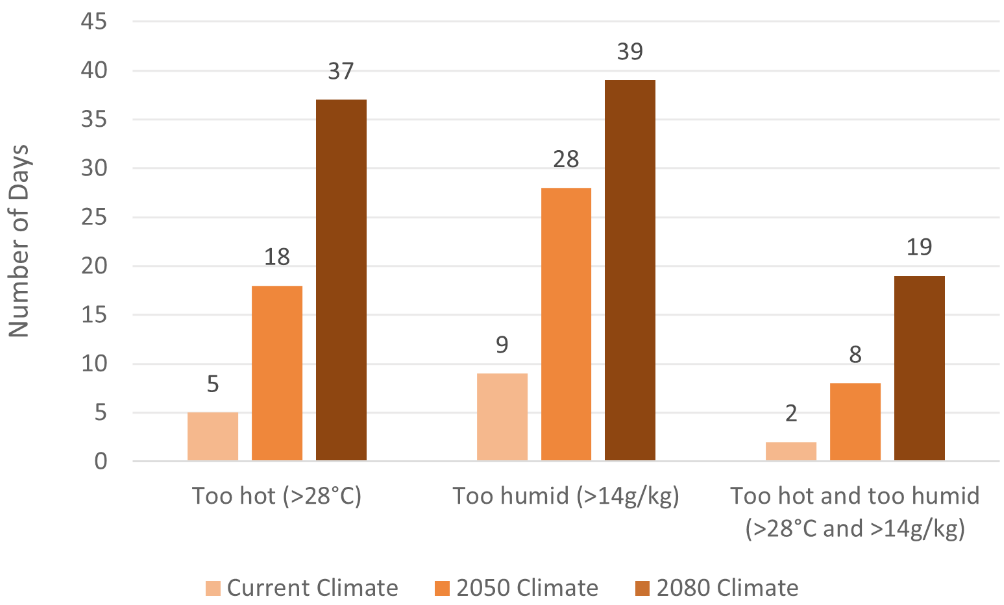


Future Climate

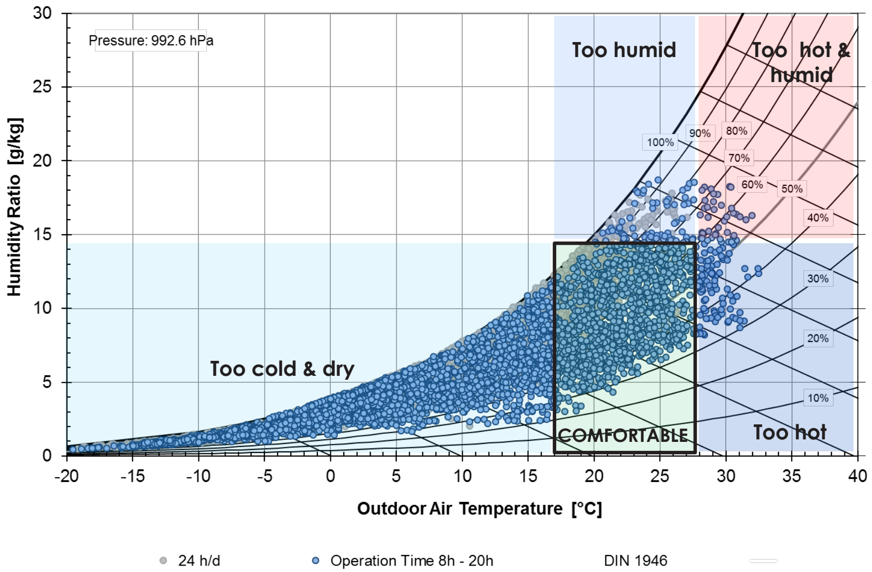
Expected changes in weather patterns and extreme weather events projected by climate change scenarios for the City of Toronto are here summarized.

Key predictions for Toronto's future climate include:

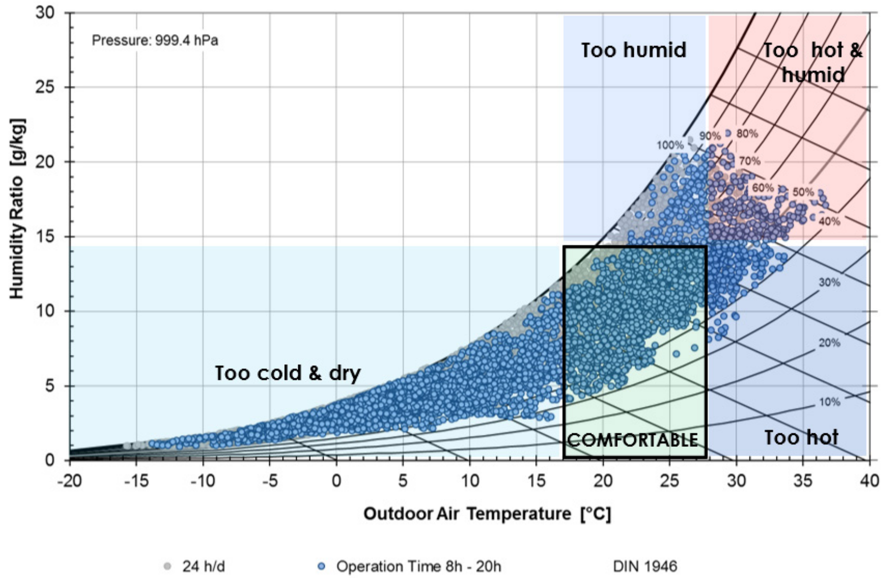
• An increase in projected average summer temperatures by 3.8 °C
• An increase in extreme daily minimum temperatures by 13 °C
• An increase in the number of days above 20 °C from 133 to 160
• An increase in the number of days above 0 °C by 16%
• An increase in the number of "heat waves" (i.e. events with more than 3 consecutive days of temperatures greater than 32°C) from an average of 0.57 occurrences per year to 5 occurrences per year
• An increase in the number of days requiring air conditioning from 10 to180
• A decrease in the number days requiring extra heating from 440 to 60
• Slightly more precipitation overall, with the highest increases expected forthe months of July (+80%) and August (+50%)
• A smaller number of storm events, but an increase in the amount of precipitation in these events



Future Climate (comparison)



CURRENT CLIMATE - HYSTORICAL DATA



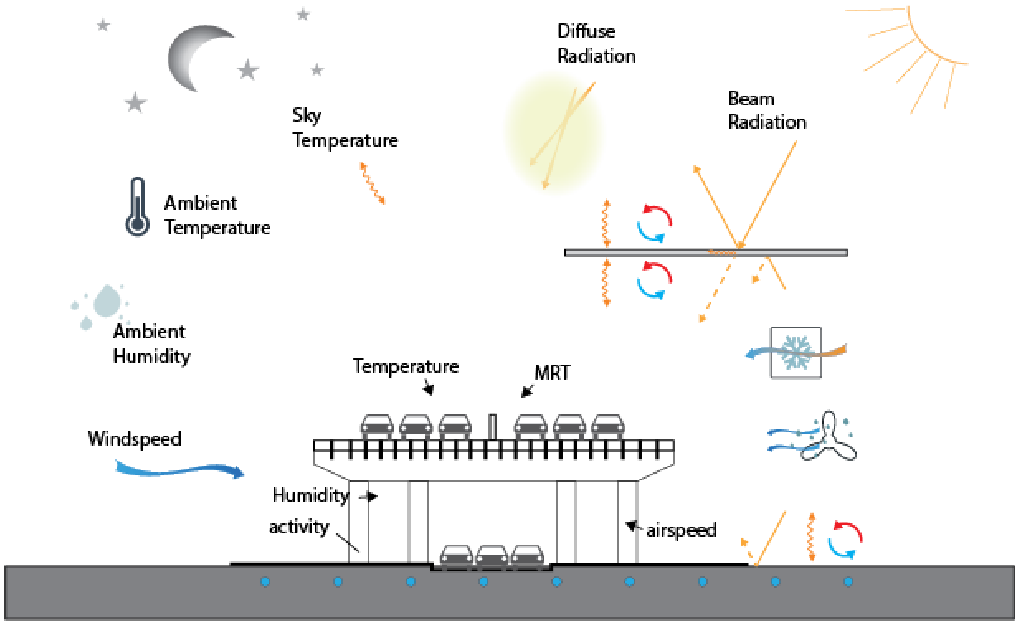
FUTURE CLIMATE - 2100 PROJECTION

2. Outdoor Comfort

This paragraph describes how, with an holistic understanding of it, outdoor comfort can be manipulated in order to enhance the outdoor comfort under and/or around the Gardiner.
The strategies presented are purely conceptual, and must be translated into actual design solutions during the next design phases.

Parameters defining outdoor comfort under the Gardiner

Outdoor comfort depends on many parameters. Solar radiation (direct and diffuse) and wind direction are the main drivers together with air temperature and humidity.
The environment surrounding the users (such us buildings, plazas/streets, trees...) reflects back solar radiation in the form of long-wave radiation which also plays an important role in defining outdoor comfort, especially in very dense cities where thermal mass heats up during daytime while still emitting long-wave radiation overnight (the main drivers of the heat island effect). A deep understanding of these parameters allows for the design of comfortable urban spaces where outdoor activities can be maximized all year around.



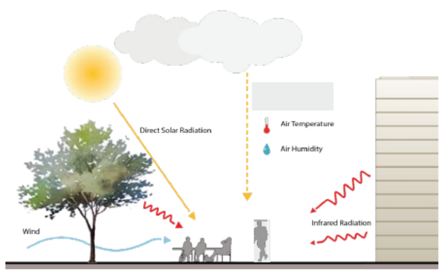
Key success Metric - UTCI

Universal Thermal Climate Index (UTCI) equivalent temperature is the basic metric used for evaluating outdoor comfort. The UTCI of an actual thermal condition is the air temperature that would cause the same dynamic physiological response.

The UTCI
- Applies to all climates and seasons.
- Scales the clothing factor according to the outside temperature.
- Shows a temperature scale as an index, which refers to the heat / cold stress perception of humans
- Vegetation and water can impact the infrared radiation and alter the Equivalent Temperature

Each UTCI range is calculated to a specific time period. In winter, the appropriate target is the 'comfortable' and, when necessary, the 'slight cold stress' or 'lightly cold' ranges are also acceptable. Also in summer, it is acceptable in peak conditions to feel 'slightly hot' or 'hot', but only for a few hours.

Outdoor Comfort Parameters:



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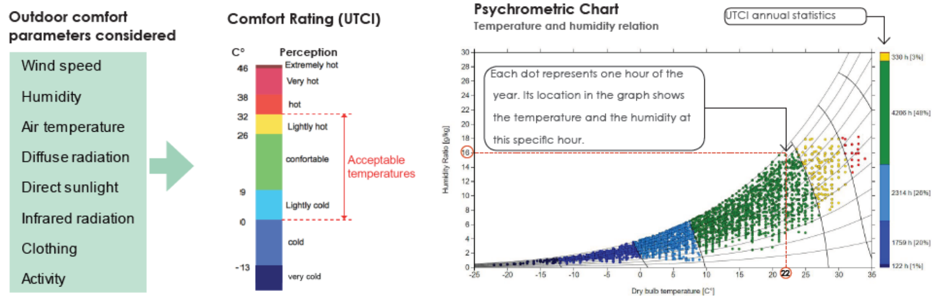
Comfort Visualizations Explanation



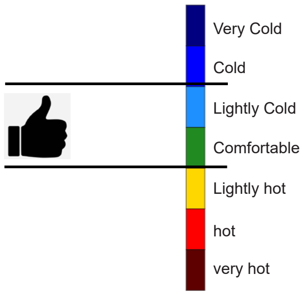
Winter Season in Toronto

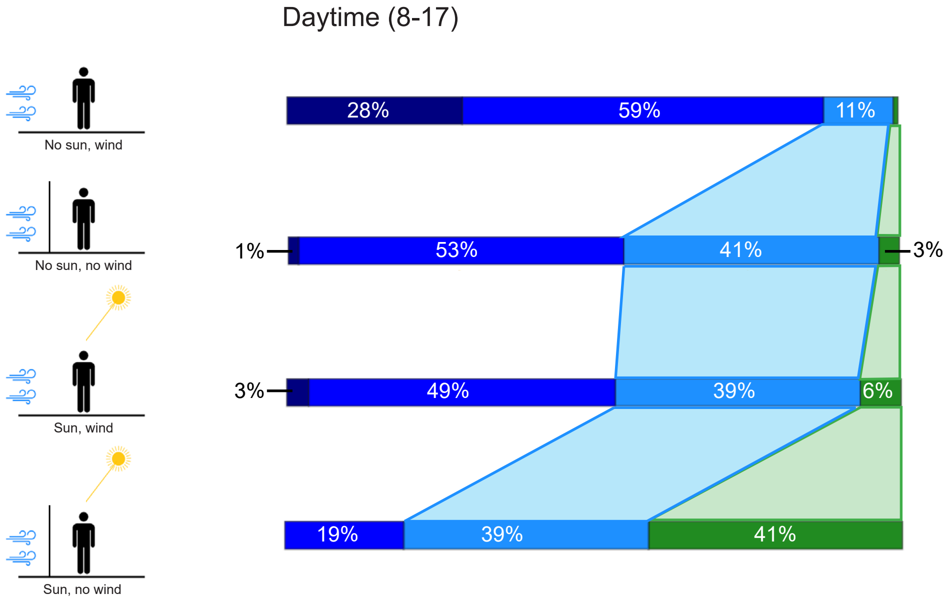
Winter comfort is highly dependent on wind and sun exposure. While wind can have a positive impact in peak summer conditions, it negatively influences thermal comfort for the entire winter.

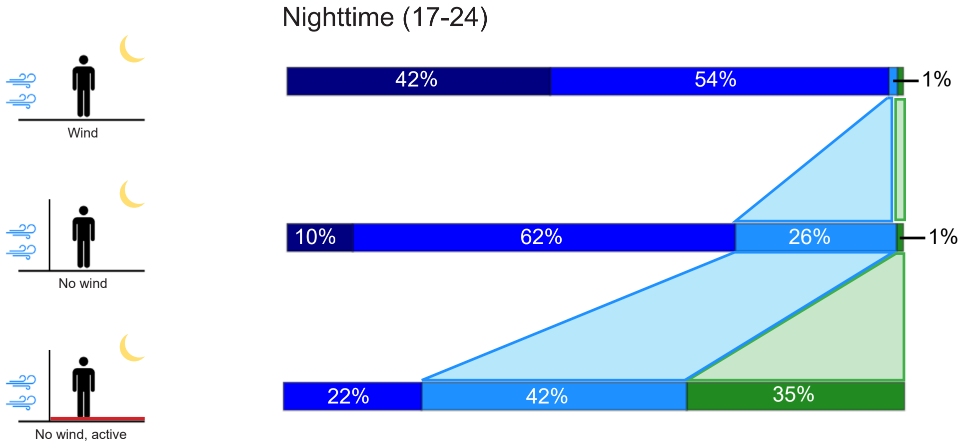
The main strategy for comfort in a winter city is to expose an area to the sun while protecting it from the wind, in such conditions, it is possible to have reasonably comfortable (comfortable + lightly cold) outdoor activities for almost 80% of the year, without the use of additional specific solutions.

Winter evenings in wind-protected areas also require active solutions (such us heated benches or radiant floors), for those spaces where outdoor activities are desired.

The impact of sun, wind and active heating on UTCI is shown to the right.







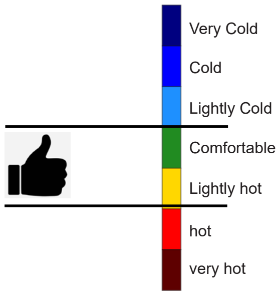
Summer Season in Toronto

Summer comfort is highly influenced by sun exposure. The first step is therefore to provide protection from the sun. This protection must be firstly achieved through building massing, with naturally shaded spaces maximized according to the buildings' geometries.

Considerable improvement of the outdoor comfort is given already when shade is provided. In such a situation, it is reasonable to consider comfortable outdoor activities for almost 100% of this period without the use of additional specific solutions.

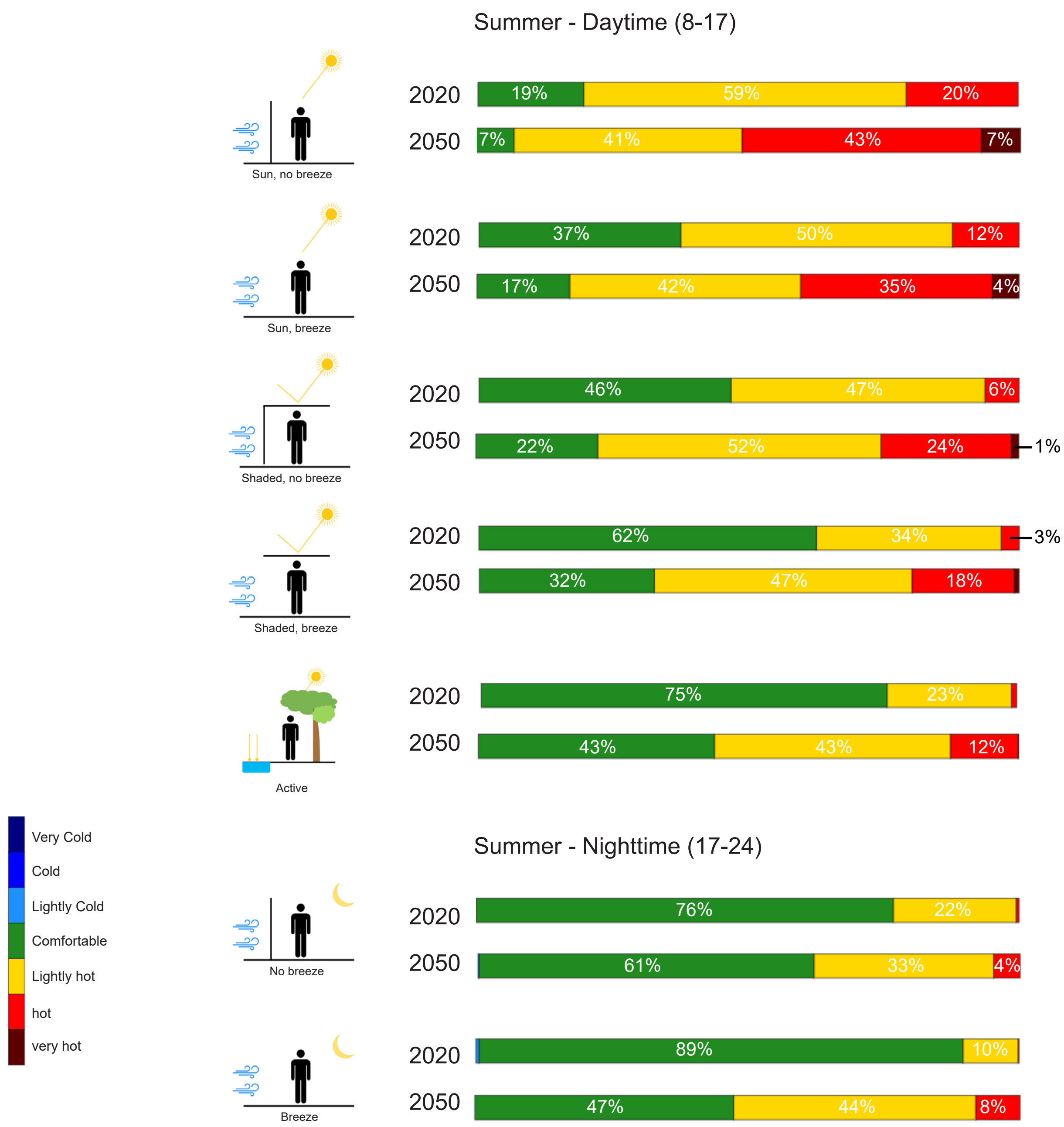
Wind penetration increases outdoor comfort only in high density areas (often warmer due to heat island effects). On the contrary, it may be counter-productive in open fields when air temperatures tent to be lower.

The impact of sun, shading, breeze and active cooling on UTCI is shown to the right.



Cliamte Adaptation: what about oudoor comfort in the future?

Outdoor comfort is greatly threatened by the effects of climate change with worsened extreme events and heat waves. Strong heat stress is a considerable risk and will become more recurrent at higher latitudes such as Toronto. Heat illness due to heat stroke and heat exhaustion create the risk of an elevated number of deaths in summer months.



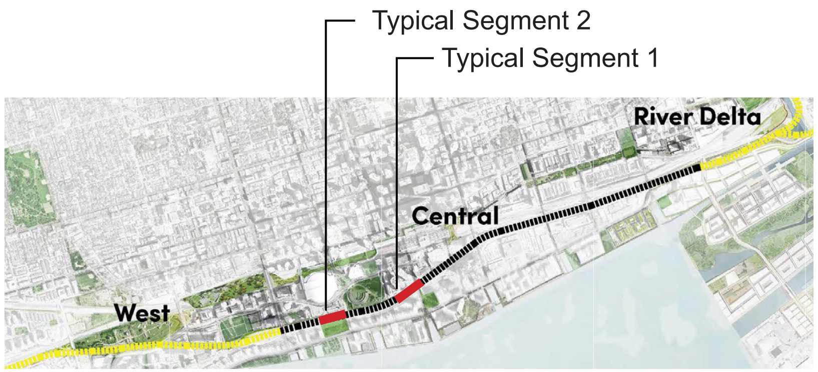
3. Local Comfort Parameters

This paragraph intends to describe other parameters to control the environmental quality under the Gardiner beyond thermal comfort, as investigated in the previous paragraph.
Typical sections are presented in order to conceptually visualize how all these parameters interact one with another.

What are the key parameters which can help defining the user experience under the Gardiner?

In an urban environment, especially under the Gardiner, outdoor thermal comfort is not the only success metric. There are other as important parameters, such as visual comfort, acoustic comfort and rain protection.

As it runs through the whole city of Toronto, the Gardiner's context can significantly vary. For this reason, we zoomed into typical sections to show the major parameters which will have to be considered to enhance the current user experience under the Gardiner. Some of the parameters listed on the right are present in more than one location.

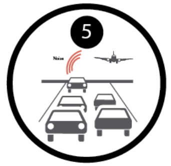


Urban Heat Island Effect

URBAN HEAT ISLAND EFFECT
The urban heat island effect is created by the absorption of solar energy by materials with low albedo commonly used within the urban environment (such us black asphalt or dark concrete). These materials heat up during the day and often are not able to cool down during the night.

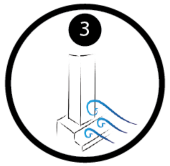
Solar Access

SOLAR ACCESS
Passive solar radiation and natural daylight received on-site, closely related with season and time of the day.



Acoustic Comfort

ACOUSTIC COMFORT
Acoustical pollution caused by traffic and surrounding materials with low absorption.



Wind Comfort

WIND
Wind behavior caused by regional wind pattern and local urban topography.

Air Quality

AIR QUALITY
Air pollution caused by traffic and building sites.

Visual Comfort

VISUAL COMFORT
Illuminance and luminance on different surfaces, which can lead to glare or high contrasts.

Water Management

WATER MANAGEMENT
Rainwater management from the Gardiner to the underground.

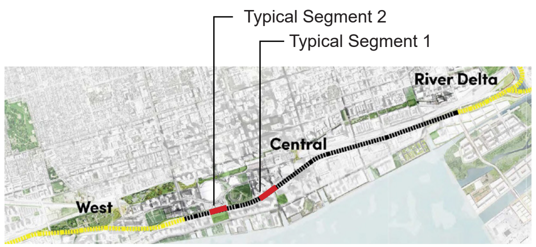
Typical Segment 1: Segments in high-density areas (winter)

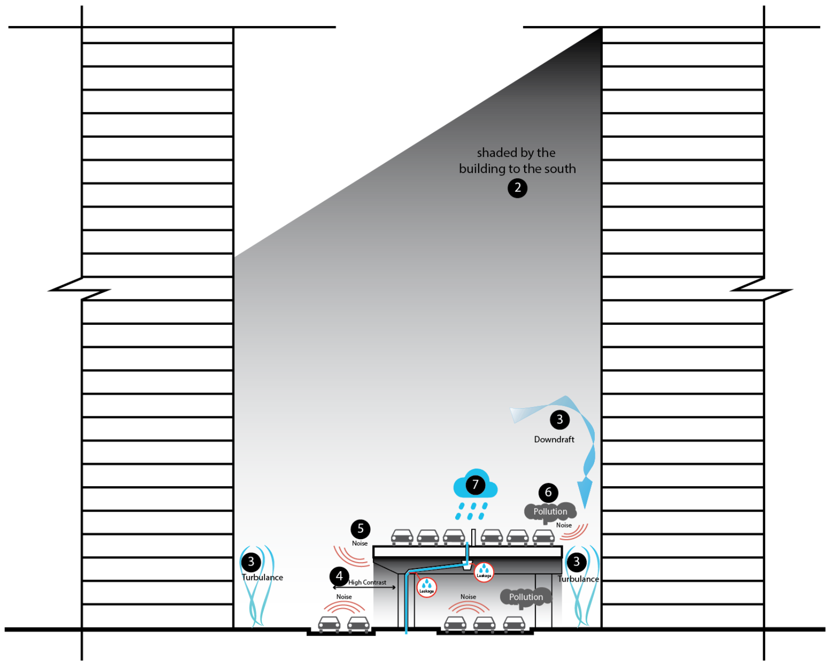
For the parts running through a dense urban area surrounded by high-rise buildings, wind comfort is crucial in winter. There are three major potential issues to consider:

1 - Cold west-prevailing winds channeled under and/or along the Gardiner;
2 - Turbulent and accelerated winds at the pedestrian level near the corner of the tall buildings;
3 - Downdrafts caused by the tall buildings with a direct negative impact on the pedestrian thermal comfort.

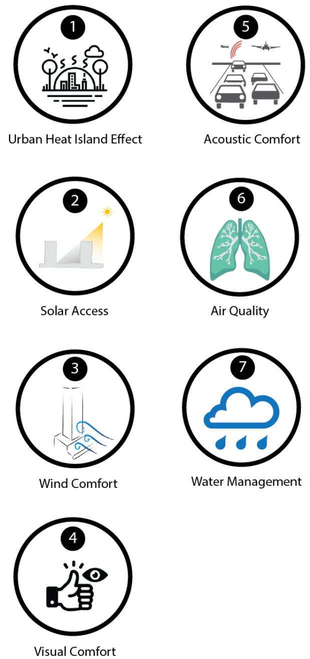
Besides wind, solar access is also strongly impacted by potential tall buildings, especially the ones to the east, south and west of the Gardiner. Depending on the roughness of the facade of the buildings, the noise pollutions generated by the cars above/below the Gardiner will be reflected within the canyon, hence, worsen the acoustical comfort of the area.

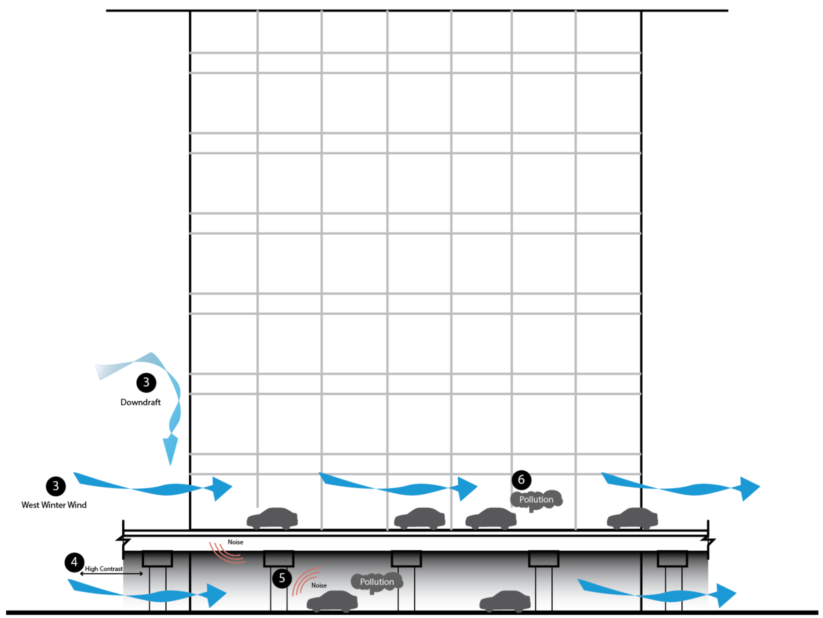
This typical segment of the Gardiner shows a flat concrete soffit which can be used to maximize light penetration.





Section Across the Gardiner

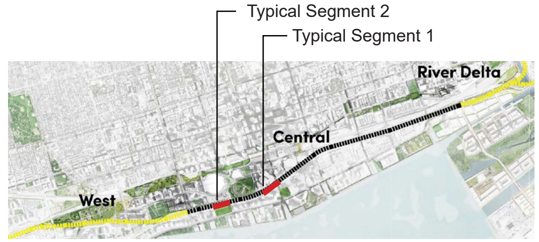


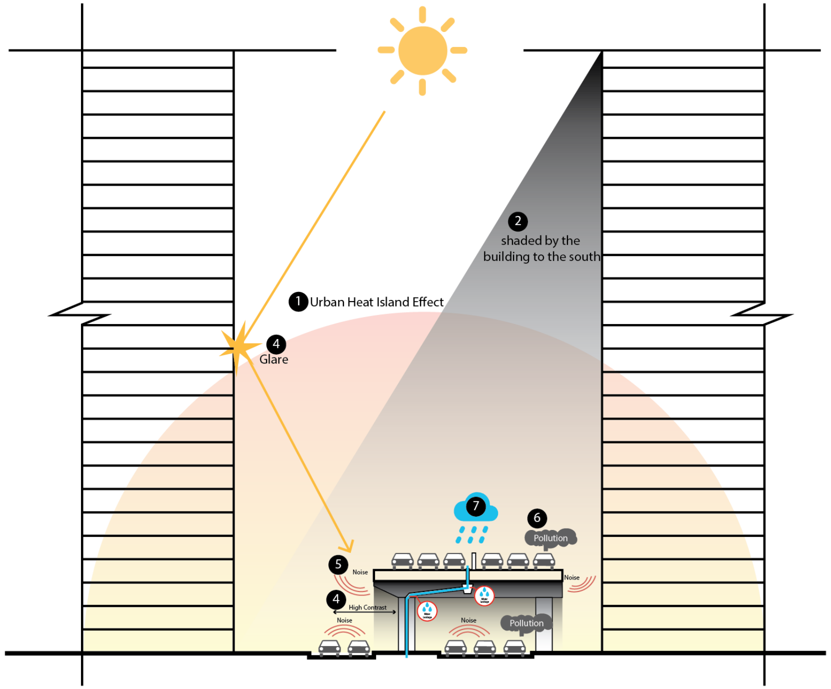


Section Along the Gardiner

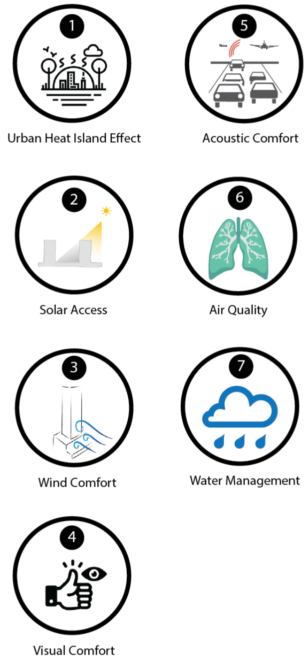
Typical Segment 1: Segments in high-density areas (summer)

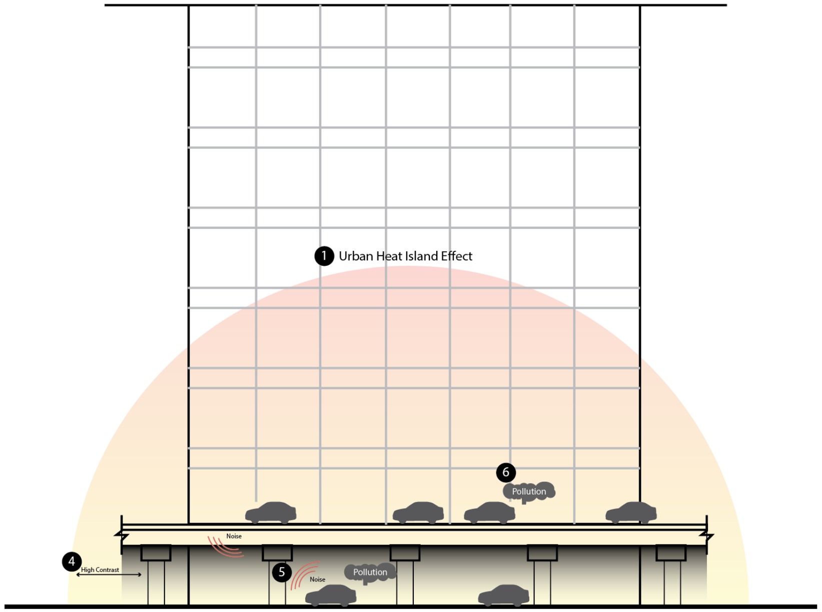
In summer, the major challenge in dense urban areas is heat island effects. High-density areas have more thermal mass and less view to the sky than low-density ones. The combination of these two factors trap the heat accumulated during the day to the day after.
Especially if the buildings around are fully glazed, direct light will be re-directed within the canyon, inducing glare and spots of thermal discomfort. Glare will jepradize the safety of the drivers and the visual comfort of the pedestrians and/or users of the spaces under the Gardiner.





Section Across the Gardiner

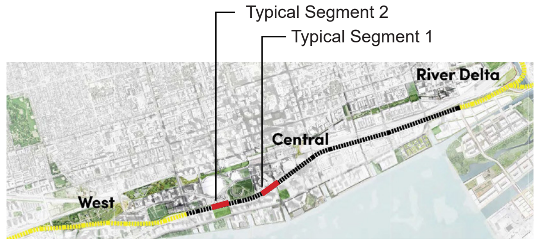


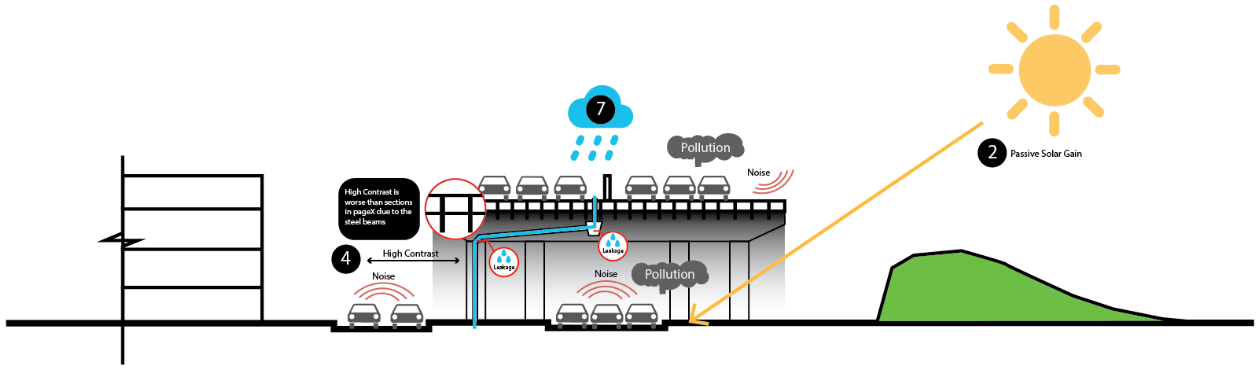


Section Along the Gardiner

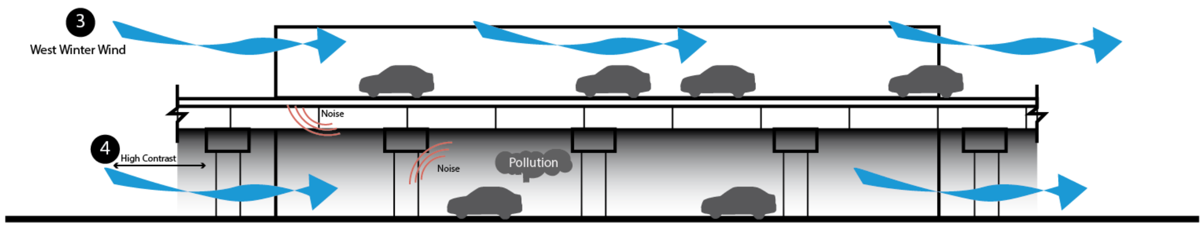
Typical Segment 2: Segments in low-density areas (winter)

The segments of the Garidner passing through low-density areas are more subject to winds running parallel to the Gardiner, which will need to be controlled in order to extend as much as possible the use of the outdoors spaces. Depending on the surroundings, these areas can benefit of the low sun-angles to create sun exposed and wind protected enviroments, particularly usefull during the coldest months.





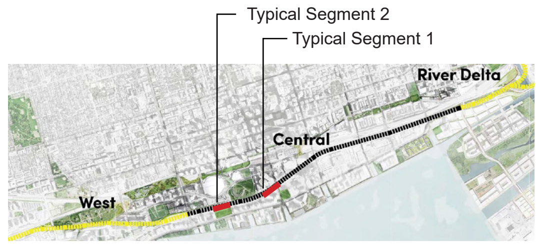
Section Across the Gardiner

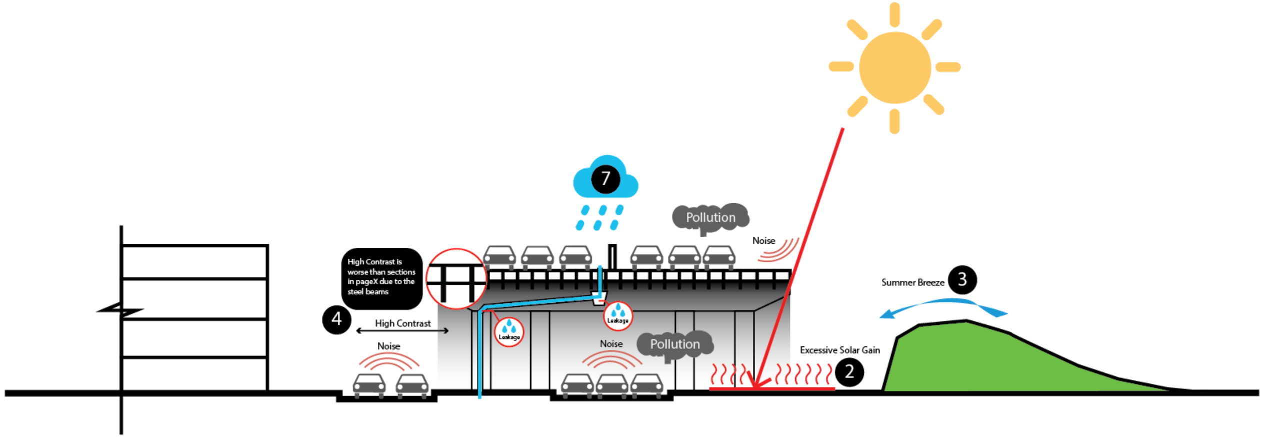


Section Along the Gardiner

Typical Segment 2: Segments in low-density areas (summer)

The segments of the Garidner passing through low-density areas are more exposed to solar radiation, which is not beneficial in summer. The deck of the Gardiner will probably be warmer than the one in high-density areas, hence, will start radiating (long-wave) onto the pedestrians and/or users of the areas below it. On the other hand, this higher solar exposure make these kind of segments eligible for solar applications such us photo-voltaic panels, which can also be used in a form of canopies to provide additional shading.





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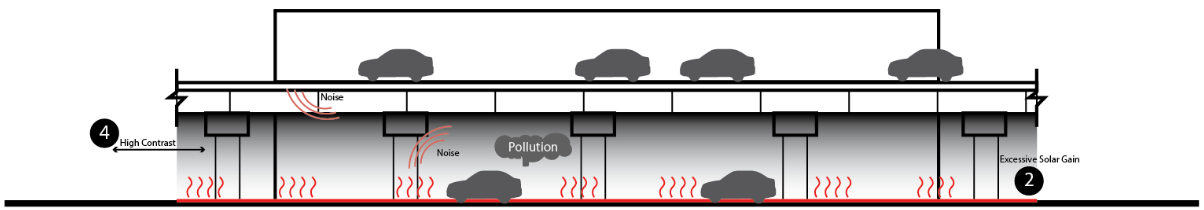


Section Along the Gardiner

4. Preliminary Environmental Simulations

This final paragraph shows some preliminary environmental simulations in 2 typical sections.
The intent is to draw some first conclusions and also to show the methodology which will be used to propose specific design solutions during the next design phases.

Three studies have been performed:

- contrast: the higher the difference in between the candela/sqm emitted by different surfaces, the higher the contrast. The higher the contrast, the more the spaces under the Gardiner will be perceived as dark, even is they have enough natural daylight penetration;

- radiation: the surrounding plays an essential role in defining sun exposed an shaded areas. A radiation map allows to detect these areas, in order to drive the urban design for the different seasons;

- wind behavior: currently we believe there is not need for CFD (computational fluid dynamic) simulations. We defined some potential wind behavior based on our experience and academic role of thumbs. However, being wind control a very important topic, CFD simulations might be necessary in the next phases to inform the design of the outdoor areas.

Visual Comfort - Contrast

Visual comfort is the combination of many factors:

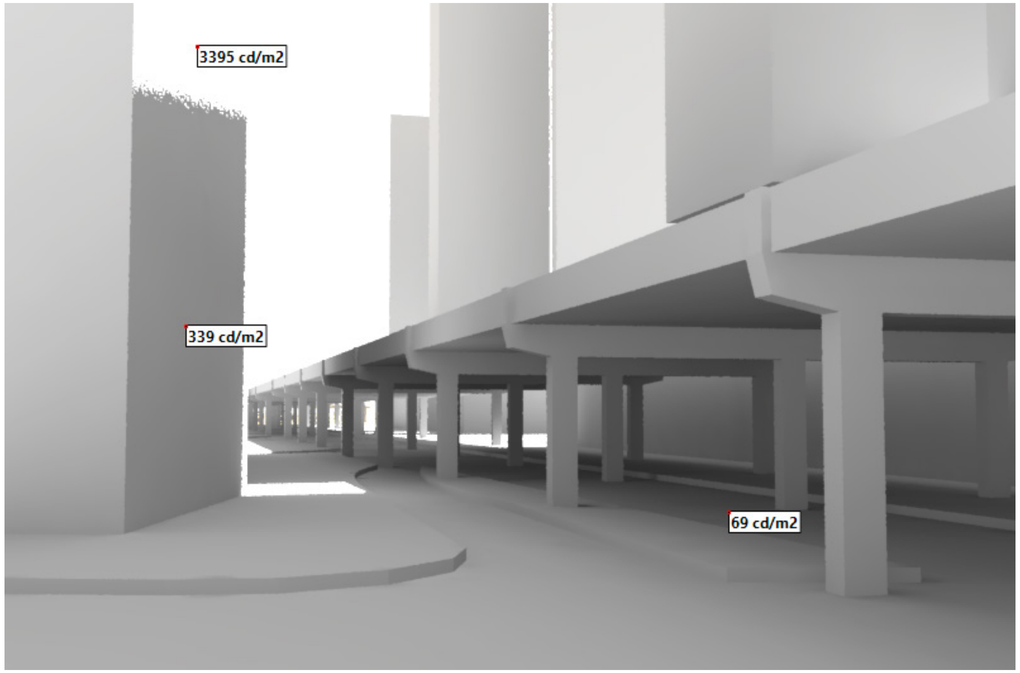
- Glare-free natural daylight penetration: natural daylight has a recognized impact on our circadian cycle, massively impacting our mood, concentration, motivation etc. Glare strongly depends on the contrast in between two different surfaces: the contrast created by two surfaces with different luminance levels is perceived by the human eyes as glare, hence, discomfort. The latter, can induce to lack of concentration or reduce the ability of performing certain tasks, such as driving.

- Urban land marks offering a clear sense of orientation to the visitors

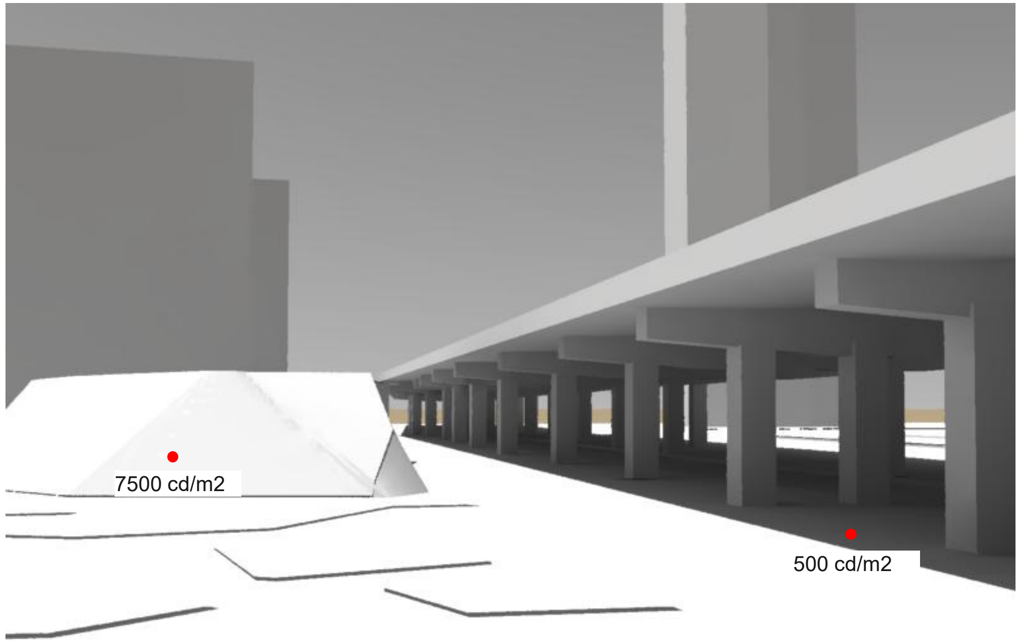
-Sufficient and homogeneous artificial illumination during nighttime.

Visual comfort must be provide with an urban design which reflects a reasonable balance between the factors above mentioned. For the Gardiner, one challenge is the high potential contrast between surfaces. The figures to the right show that the higher the difference in luminance between surfaces, the higher the contrast. This means that the space with the lower luminance is perceived as dark, even if it is not.

Especially for low density areas with high solar illumination (e.g. typical condition 2), contrast must be controlled in order not to let the areas under the Gardiner being perceived as darker as they actually are.



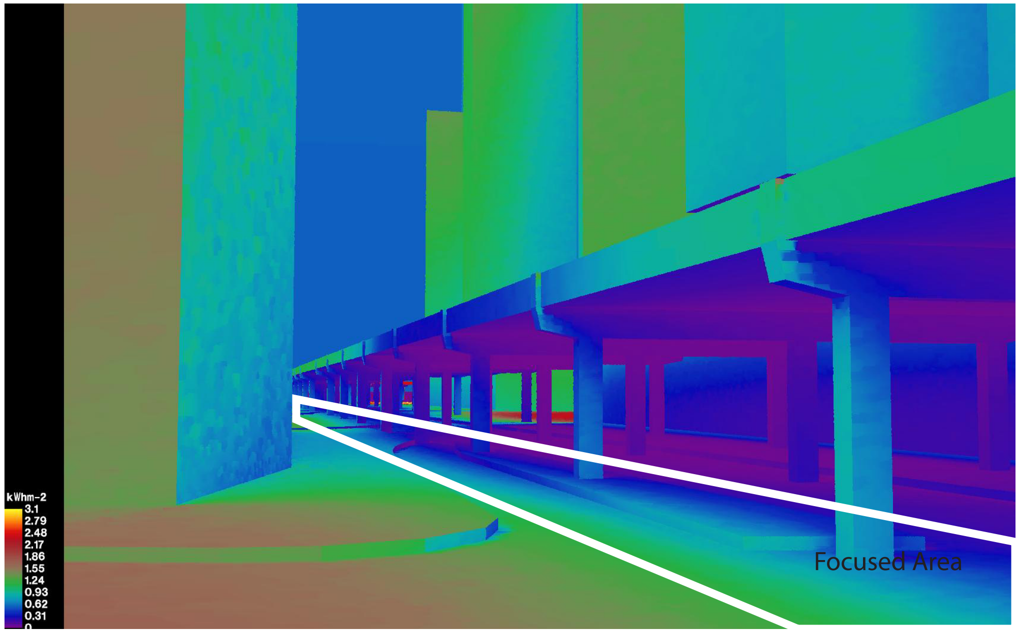
Typical condition 1: high density



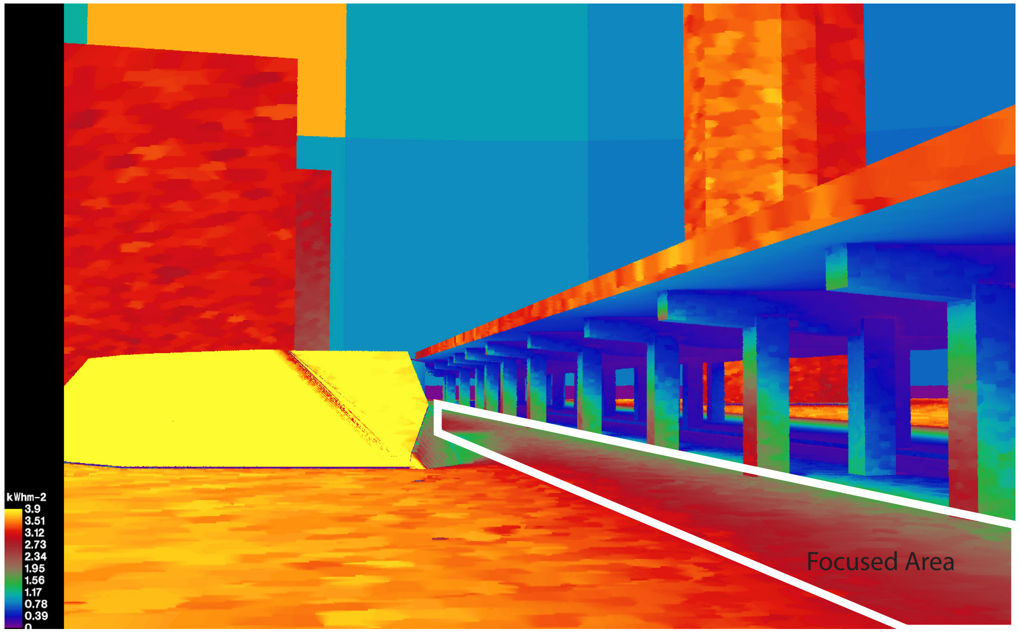
Typical condition 2: low density (higher risk for contrast)

Solar radiation - Sun exposure / Sun protection

Figures on the right shows the average solar radiation received on the two segments during 1 typical day in spring. The lower the density the more the solar radiation. For this reason, low-density areas are potentially more comfortable in winter than the high-density ones. The opposite instead for the warm seasons.



Typical condition 1: high density

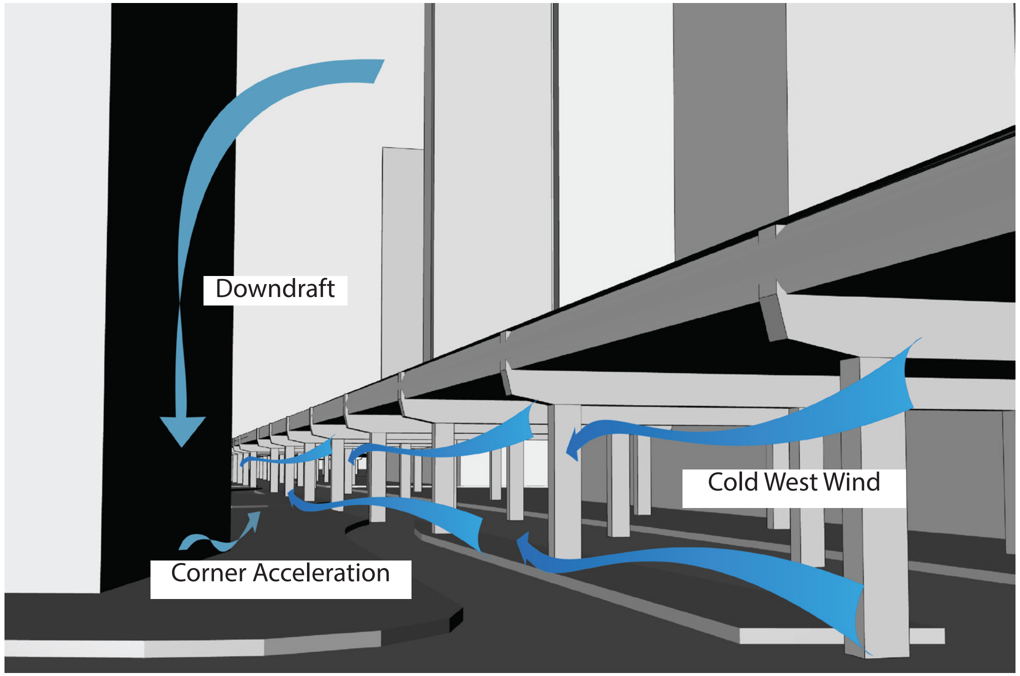


Typical condition 2: low density

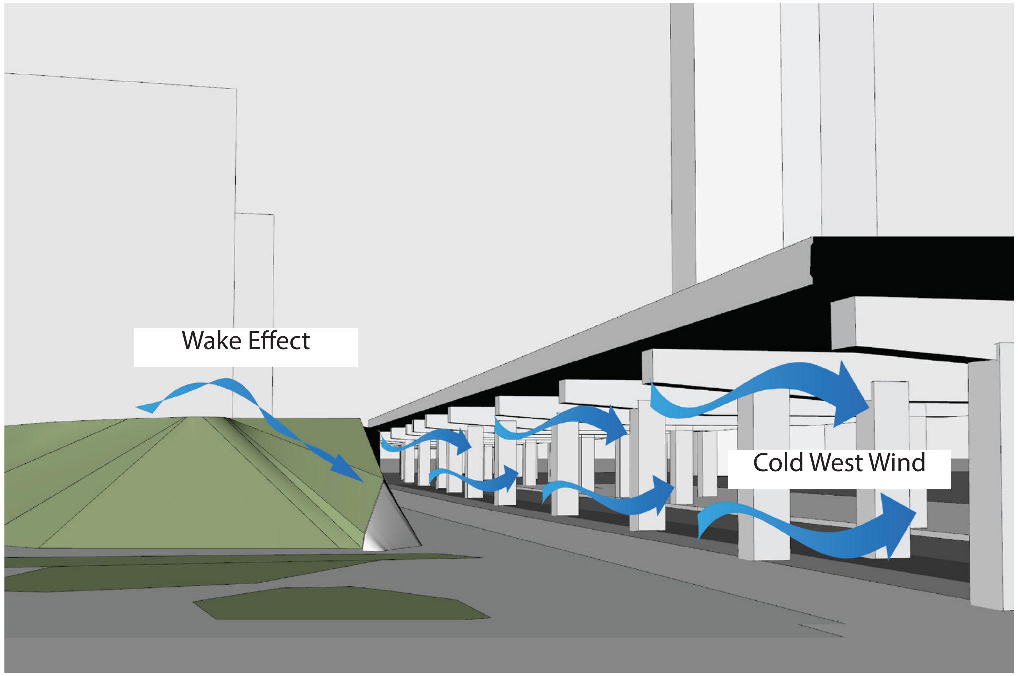
Wind behaviour - Downdrafts

The figures to the right show some schematic wind patterns for high-density and low-density areas. The higher the density of the area the more the risk of downdraft and comer acceleration caused by the tall buildings. The lower the density of the area, the more prominent the prevailing wind direction (west) channeled along the Gardiner.

In the next phases of design, CFD (computational fluid dynamic) studies are recommended to design the spaces in order to reduce the wind in winter, and maximize the wind in summer, especially for the areas subject to heat island effects.



Typical condition 1: high density



Typical condition 2: low density