Appendix C to EICS-02-22

TECHNICAL REPORT

City of Burlington

Climate Resilient Burlington
Climate Change Vulnerability & Risk Assessment

DECEMBER 2021

In partnership with:

A Carbon Neutral Company

EXECUTIVE SUMMARY

1 CONTEXT

In April 2019, Burlington's City Council passed a motion to declare a climate emergency, joining a club of over 500 local governments across Canada. Through the declaration, the City of Burlington (the "City") deepened its commitment: to reduce emissions of greenhouse gases which will contribute to the collective goal of limiting future global temperature increases; to protect the local economy, environment and community from current and future climate-related impacts; and to apply a climate lens to its plans, programs and projects.

The City has shown leadership when it comes to reducing greenhouse gas emissions—committing to net zero emissions from City operations by 2040 and net zero community emissions by 2050. The overall goal of this project is to develop the City's first comprehensive climate adaptation plan—"Climate Resilient Burlington (CRB): A Plan for Adapting to Warmer, Wetter and Wilder Weather"—to enhance the resilience of both City operations and the broader community to risks presented by climate change and to take advantage of any opportunities that may arise, building upon actions already taken. As an input to the development process, this technical report presents the climate change vulnerability and risk assessment (VRA), which provides the foundations for formulating strategies to tackle material risks and opportunities.

2 APPROACH

The approach to the VRA is based on the Intergovernmental Panel on Climate Change's latest conceptualization of climate risk and can be viewed as a risk assessment with an embedded vulnerability assessment component. It is consistent with the recently published International Standards Organization (ISO) guidelines for climate vulnerability and risk assessments (ISO 14091) and adaptation planning for local governments and communities (ISO 14092), and entails five activities:

These activities are largely informed by a bottom-up, participatory approach that recognizes the skills and experiences of City staff and a range of community stakeholders, who are engaged throughout in the co-production of outcomes at each stage. This approach builds momentum for successful adaptation planning and implementation by including all key stakeholders in all aspects of the development process.

The scope of the assessment is defined along the following dimensions: 1. **Boundaries** - reflecting what the City can control and influence, the assessment is largely confined to direct climate-related impacts within the City's boundaries, with the exception of impacts on Lake Ontario with consequences for Burlington. Within these boundaries, a comprehensive (or community-wide) approach is adopted, that considers impacts to private property, the local economy, the health and lifestyle of residents, social equity, and natural capital, as well as impacts to public assets, infrastructure and services. 2. **Climate impacts -** both slow-onset (chronic) stresses and sudden-onset (acute) discrete events are considered. 3. **Timeframe -** the assessment considers impacts arising from projected climate changes out to the 2060s (the 30-year time period encompassing 2051-2080). 4. **Climate scenario -** to ensure no risks are missed future climate projections are based on the most conservative of global "no climate policy" scenarios, RCP 8.5.

In total, twenty-seven climate impact statements for an individual event of defined intensity were ultimately developed that identify "who" or "what" in Burlington will be impacted, the specific way they will be impacted and the associated consequences, as well as linking the impacts to changes in one or more climatic drivers. Twenty-four of these impact statements have largely negative consequences (the "hazards" in orange) and three have largely positive consequences (the "opportunities" in green):

Drought	Cooling demand	Low water levels (creeks)	Shifting ecoregions
Freezing rain	Air quality	Grass fires	Late spring frost
Heavy snow	Extreme heat	Forest fires	Creek flooding
High winds	Freeze-thaw cycles	Heating demand	Longer growing season
Vector-borne diseases	Stormwater flooding	Water demand	Increased active transportation
Invasive species & pests	Wet conditions	Winter recreation	Increased summer recreation season
High water levels (Lake Ontario)	Water quality (algal bloom) (Lake Ontario)	Mismatched timing of plant & animal lifecycles	

The sensitivity and coping capacity of Burlington with respect to each climate impact statement was assessed over the course of four virtual "vulnerability" workshops with City staff and the community stakeholders in September 2021. At the workshops, participants discussed the impact statements and rated both the sensitivity and coping capacity of Burlington on a 1 (low) to 5 (high) interval, using pre-defined scoring scales provided by the project team. Following the workshop, the project team used the information elicited from participants to generate a measure of Burlington's level of vulnerability relating to each statement.

The level of consequences for Burlington associated with each climate impact statement was assessed at two virtual "risk" workshops in September 2021. In addition to reviewing and discussing the results of the vulnerability assessment, participants rated the consequences of each hazard and opportunity—assuming it occurs—on a 1 (low) to 5 (high) interval using a scale provided by the project team. Participants considered consequences for public health and safety, the natural environment, social functioning, economic vitality and City services. Prior to the workshops, the project team assessed the annual probability of each climate hazard or opportunity occurring at a defined intensity level in the recent past and in the 2060s and mapped these estimates onto a predefined 1 (rare) to 5 (almost certain) scoring scale. Participants were given the opportunity to discuss and refine the likelihood estimates. After the workshop, the project team generated an overall measure of risk or expected benefit for Burlington, arising from each climate hazard and climate opportunity, respectively—computed as follows:

Vulnerability score [1-5] x Likelihood score [1-5] x Consequence score [1-5] =Risk or benefit [1-125]

Risk and expected benefit levels were calculated for each climate impact statement, as well as for individual consequences. This information is used to establish priorities for the adaptation planning phase of the project.

3 RESULTS OF VULNERABILITY AND RISK ASSESSMENTS

The level of risk assigned to each climate hazard and climate opportunity affecting Burlington in the near future (2051-2080) is shown in **Figure E-1**. It is evident from the left-hand-side of the figure that Burlington is most vulnerable to the following climate hazards (with vulnerability scores of four or higher): high water levels in Lake Ontario; high winds; mismatched timing of plant and animal lifecycles; air quality; shifting ecoregions; stormwater flooding; invasive species and pests; and freezing rain. Regarding the climate opportunities, Burlington was assessed to have the greatest propensity to benefit from increased active transportation, followed by a longer growing season, and then an increase in the summer recreation season.

Looking at the right-hand-side of **Figure E-1**, high winds were assessed to represent the highest level of risk for Burlington in the near future, primarily because of the City's relatively high vulnerability to this hazard and its high likelihood of occurring at the defined intensity level. The next highest level of risk is associated with shifting ecoregions, followed by freezing rain, wet conditions, and water quality (algal bloom) issues with beaches on Lake Ontario. All of these climate hazards also have a high likelihood of occurring at the defined intensity level. The assessed likelihood score in combination with a medium to high vulnerability score and a medium to high consequence score is why these hazards are emerging as top priority risks. The climate hazards representing the lowest level of risk for Burlington are grass fires and forest fires. In the former case, this is primarily due to Burlington's low vulnerability to grass fires and low anticipated consequences should a fire occur. In the latter case, this is largely because the likelihood of a forest fire occurring at the defined intensity level is medium, and Burlington's vulnerability to forest fires is relatively low.

Regarding the three climate opportunities, increased active transport is assessed as providing the largest expected benefits for Burlington, primarily because of Burlington's higher propensity to seize these benefits compared with the other two opportunities.

4 PRIORITIES FOR ADAPTATION PLANNING

Setting priorities for adaptation planning is typically pre-determined based on a combination of the estimated risk rating and the City's 'risk appetite'. Risk appetite refers to both: (a) the amount of risk the City is willing to tolerate; and (b) the type and nature of the risk the City believes it is most vulnerable to. In the absence of a pre-determined risk appetite for the City, the following rules were adopted:

Table E-1. Adaptation Planning Priority Rules

Adaptation Priority	Risk Score	Adaptation Planning
Extreme	Greater or equal to 90^{th} percentile [>= 77]	Individual consequences taken forward to adaptation planning phase of project
High	80^{th} to 90^{th} percentile [69 to <77]	
Medium	60^{th} to 80^{th} percentile [51 to <69]	
Low	Less than 60^{th} percentile [<51], except if consequence score is greater or equal to 4	Not considered in adaptation planning phase

In total, 38 individual consequences arising from climate hazards are being taken forward to the adaptation planning phase of the project (see **Figure E-2**). All the consequences associated with the three climate opportunities considered were assessed as "low priorities" for adaptation planning (i.e., with overall expected benefit scores less than 51).

Hazards

Vulnerabiltiy	Score	Consequence	Score	Likelihood	Score	Risk	Score	Rank
High water levels (Lake Ontario)	4.2	Extreme heat	5.0	Wet conditions	5.0	High winds	81.7	1
High winds	4.1	High water levels (Lake Ontario)	4.4	Water quality	5.0	Shifting ecoregion	79.4	2
Mismatched timing of plant and animal lifecycles	4.1	Stormwater flooding	4.4	Grass fire	5.0	Freezing rain	79.3	3
Air quality	4.1	Invasive species and pests	4.2	Freezing rain	5.0	Wet conditions	79.0	4
Shifting ecoregion	4.1	Water quality	4.1	High winds	5.0	Water quality	77.8	5
Stormwater flooding	4.1	Air quality	4.1	Heavy snow	5.0	Heavy snow	71.8	6
Invasive species and pests	4.0	Cooling demand	4.1	Vector-borne disease	5.0	Vector-borne disease	70.0	7
Freezing rain	4.0	Heavy snow	4.1	Loss of winter recreation	5.0	Extreme heat	69.7	8
Wet conditions	3.9	Wet conditions	4.0	Shifting ecoregion	5.0	Cooling demand	67.6	9
Low water levels	3.8	Creek flooding	4.0	Late spring frost	5.0	Freeze-thaw cycles	59.3	10
Water quality	3.8	Freezing rain	4.0	Increase water demand	5.0	Late spring frost	58.3	11
Creek flooding	3.6	High winds	3.9	Freeze-thaw cycles	5.0	High water levels (Lake Ontario)	55.4	12
Late spring frost	3.5	Shifting ecoregion	3.9	Cooling demand	5.0	Stormwater flooding	53.1	13
Increase water demand	3.5	Low water levels	3.8	Heating demand	5.0	Mismatched timing of plant and animal lifecycles	52.8	14
Heavy snow	3.5	Freeze-thaw cycles	3.7	Extreme heat	4.0	Air quality	50.5	15
Vector-borne disease	3.5	Drought	3.4	Mismatched timing of plant and animal lifecycles	4.0	Invasive species and pests	50.3	16
Drought	3.5	Late spring frost	3.3	Drought	3.0	Increase water demand	48.7	17
Extreme heat	3.5	Heating demand	3.3	Stormwater flooding	3.0	Heating demand	37.3	18
Cooling demand	3.3	Mismatched timing of plant and animal lifecycles	3.2	High water levels (Lake Ontario)	3.0	Drought	35.3	19
Freeze-thaw cycles	3.2	Forest fire	3.2	Forest fire	3.0	Loss of winter recreation	31.5	20
Loss of winter recreation	2.5	Increase water demand	2.8	Air quality	3.0	Creek flooding	28.8	21
Heating demand	2.3	Vector-borne disease	4.0	Invasive species and pests	3.0	Low water levels	28.6	22
Grass fire	2.2	Loss of winter recreation	2.5	Creek flooding	2.0	Grass fire	25.6	23
Forest fire	2.2	Grass fire	2.3	Low water levels	2.0	Forest fire	21.0	24

Highest risk → Lowest risk

Opportunities

Vulnerabiltiy	Score	Consequence	Score	Likelihood	Score	Risk	Score	Rank
Increased active transportation	3.3	Increased summer recreation season	3.5	Increased active transportation	4.0	Increased active transportation	45.5	1
Longer growing season	2.7	Increased active transportation	3.5	Increased summer recreation season	4.0	Increased summer recreation season	35.3	2
Increased summer recreation season	2.5	Longer growing season	3.3	Longer growing season	4.0	Longer growing season	35.2	3

Note: the risk score for a particular climate hazard or opportunity may differ from the product of the scores for the three determinants of risk (vulnerability x likelihood x consequence) due to rounding.

Figure E-1 Level of Risk Assessed for Climate Hazards and Opportunities Affecting Burlington in the Near Future (2051-2080)

Consequences (climate hazard)	Consequence Score	Risk Score	Adaptation priority
Power outages (High winds)	3.9	81.7	Extreme
Shifting ecoregions, resulting in fewer native plant and animal species and more invasive species (Shifting ecoregion)	3.9	79.4	
Road traffice accidents and transportation delays, including active transportation (Freezing rain)	4.0	79.3	
Basement flooding (Wet conditions)	4.0	79.0	
Damage to trees / tree branches (High winds)	3.8	78.6	
Power outages (Freezing rain)	4.0	78.5	
Damage to trees and shrubs (Freezing rain)	3.9	78.3	
Restricted access to, closure of beach- and water-based recreation activities (Water quality)	4.1	77.8	
Property damage (High winds)	3.7	76.8	High
Flooding of agricultural fields (Wet conditions)	3.7	73.2	
Road traffic accidents and transportation delays, including active transportation (Heavy snow)	4.1	71.8	
Injuries fram falls on iced surface (Freezing rain)	3.6	71.0	
Damage to parks and sport fields (Wet conditions)	3.6	70.9	
Increased salt use and sanding (Freezing rain)	3.5	70.0	
Negative health outcomes (Vector-borne disease)	4.0	70.0	
Negative health outcomes (Extreme heat)	5.0	69.7	
Increased stress on aquatic habitat (Water quality)	3.7	69.6	
Maintenance and operational costs (Heavy snow)	3.9	68.2	Medium
Increased investment expenditures and annual operating and maintenance expenses (Cooling demand)	4.1	67.6	
Property damage (Freezing rain)	3.3	65.0	
Power outages (Cooling demand)	3.9	65.0	
Urban heat island effects (Cooling demand)	3.9	64.1	
Greenhouse gas emission and emissions of criteria air contaminants (Cooling demand)	3.9	64.1	
Damage to buildings and facilities (High winds)	3.1	63.1	
Impacts to municipal water treatment (Water quality)	3.3	63.0	
Increased risk of illness from mold growth (Wet conditions)	3.2	62.5	
Damage to, and decreased service life of, building and infrastructure (Freeze-thaw cycles)	3.7	59.3	
Early emergency of flowering crops, which are then susceptible to damage from late frost (Late spring frost)	3.3	58.3	
Soil erosion (High winds)	2.8	57.7	
Erosion of beaches and shoreline habitat (High water levels (Lake Ontario))	4.4	55.4	
Basement flooding (Stormwater flooding)	4.4	53.1	
Decreased reproduction and survival (Mismatched timing of plant and animal lifecycles)	3.2	52.8	
Delays and/or cancellations of outdoor events and activities (High winds)	2.5	51.2	
Negative health outcomes (Air quality)	4.1	50.5	High consequences
Invasive species and pests (Invasive species and pests)	4.2	50.3	High consequences
Damage to lakeshore active transport and pathway network (High water levels (Lake Ontario))	4.0	49.9	High consequences
Flooding of roads along shoreline (High water levels (Lake Ontario))	4.0	49.9	High consequences
Damage and erosion to creek banks (Creek flooding)	4.0	28.8	High consequences

Figure E-2 Recommended Priorities for the Adaptation Action Planning Phase of the Project

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LIST OF ABBREVIATIONS

BARC	Building Adaptive and Resilient Communities
CRB	Climate Resilient Burlington
GCoM	Global Covenant of Mayors for Climate and Energy
CRF	Common Reporting Framework (of GCoM Canada)
GHG	Greenhouse gas(es)
ICLEI	Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization
PCP	Partners for Climate Protection
RCP	Representative Concentration Pathway
VRA	Climate Change Vulnerability and Risk Assessment

1 INTRODUCTION

On Tuesday, April 23rd, 2019, Burlington's City Council passed a motion to declare a climate emergency, joining a club of over 500 local governments across Canada. Through the declaration, the City of Burlington (the "City") deepened its commitment: to reduce emissions of greenhouse (heat-trapping) gases which will contribute to the collective goal of limiting future global temperature increases; to protect the local economy, environment and community from climate-related impacts the City is already experiencing such as the ice storm in December 2013, the flood in August 2014, high water levels in Lake Ontario in 2017 and 2019, and more frequent heat waves and damaging windstorms, as well as unavoidable impacts of future climate change; and to apply a climate lens to its plans, programs and projects.

In December 2019, the City joined the Global Covenant of Mayors for Climate and Energy (GCoM), a leading international climate program. This alliance of global cities and local governments shares a common vision for an inclusive, just, low emission and climate resilient society, achieved through voluntary action to reduce greenhouse emissions and to adapt to climate change. The City was one of 25 Canadian municipalities selected to join GCoM's "Showcase Cities" pilot program. The pilot brought together and leveraged the existing Federation of Canadian Municipality's Partners for Climate Protection (PCP) and ICLEI (Local Governments for Sustainability) Canada's Building Adaptive and Resilient Communities (BARC) programs with GCoM to test how the three programs can complement each other and provide the necessary framework and support to advance more ambitious climate action planning, reporting and implementation. All three programs have reporting requirements to demonstrate the completion of set tasks: for example, the submission of a climate vulnerability and risk assessment or the setting of climate adaptation goals and targets.

The City has shown leadership when it comes to reducing greenhouse gas emissions; in 2016, City Council approved Burlington's 2015-2040 Strategic Plan committing to net zero emissions from City operations by 2040 and in April 2020 it committed to net zero community emissions by 2050 through the Climate Action Plan. The overall goal of this project is to develop the City's first comprehensive climate adaptation plan—"Climate Resilient Burlington (CRB): A Plan for Adapting to Warmer, Wetter and Wilder Weather"—to enhance the resilience of both City operations and the broader community to risks presented by climate change and to take advantage of any opportunities that may arise, building upon actions already taken. Specifically, the project is to complete Milestones 1 (Initiate), 2 (Research) and 3 (Plan) of the BARC program and simultaneously comply with the reporting requirements of the GCoM and Canada's Common Reporting Framework (CRF) for the three adaptation badges ("assessment", "goal" and "plan").

This report presents the climate change vulnerability and risk assessment (VRA). This is a technical report with an intended audience of internal stakeholders to the City and external community stakeholders as identified by the City. This report was not prepared as a public facing document. It fulfills the requirements of Milestone 2 (Research) of BARC and Badge 1 (Assessment) of the GCoM and Canada's CRF. The report is structured as follows:

- Section 2 defines the scope of the VRA.
- Section 3 includes a description of the methodology.
- Section 4 provides the results of the separate vulnerability assessment and risk assessment.
- Section 5 identifies priorities for the adaptation planning phase of the project.
- Appendix A identifies the list of attendees at the risk and vulnerability workshops.
- Appendix B provides the climate impact statements developed and assessed during this phase of the project.
- Appendix C lists the estimated risk levels by individual consequences listed in the impact statements.

2 SCOPE OF THE ASSESSMENT

It is important to be clear about what is covered by the vulnerability and risk assessment (VRA) and consequently, what is excluded. The scope of the VRA is defined along four dimensions:

Geographical Boundaries (or Spatial Scope)

There are multiple options used in vulnerability and risk assessments that consider the spatial scope. For practical reasons—in terms of what the City can control and influence—the assessment is largely confined to climate-related hazards that have direct impacts within the City's boundaries. Within these boundaries, a comprehensive (or 'community-wide') approach is adopted, that considers impacts to private property, the local economy, the health and lifestyle of residents, social equity, and natural capital, as well as impacts to public infrastructure, assets and services. Four notable exceptions to the spatial boundaries of the assessment include the direct impacts of climate change on (1) water levels in Lake Ontario, (2) water quality (algal bloom) in Lake Ontario, and (3) damage and disruption to drinking water supplied from outside the City limits, and (4) damage and disruption to electricity supplied from outside the City limits.

Broad Types of Climate-Related Impacts

In terms of climate-related hazards, both slow-onset (chronic) stresses and sudden-onset (acute) discrete events are within scope. The latter tend to be short duration events, that typically last minutes, hours, days, or weeks. These will generally occur irrespective of climate change—though their frequency, intensity, or distribution may alter because of climate change. Examples include windstorms, heavy snowfall events, freezing rain events, wildfire, and temperature extremes. Slow-onset stresses, in contrast, are caused entirely by climate change, with impacts unfolding gradually, building up over longer time frames—decades or more. Examples of slow-onset impacts include warming trends in air and surface water temperatures and ecosystem shifts.

Future Climate Scenarios

Projections of future climate change are available for a range of greenhouse gas emissions, concentrations, and radiative forcing scenarios—or Representative Concentrations Pathways (RCPs). When assessing climate-related risks it is prudent to consider the greatest plausible change scenario relative to the present, which in practice means working with projected changes for the Burlington under the RCP 8.5 scenario, i.e., the most conservative of global "no climate policy" scenarios (see the text box). The primary justification for using RCP 8.5 is that it means no risks are missed during the VRA. Uncertainties relating to whether the future unfolds along RCP 8.5 or along a different, lower emission RCP, are managed during the adaptation planning phase.

RCP 8.5

The magnitude and rate of change in the climate over the remainder of this century is uncertain and will largely depend on global efforts to reduce emissions of greenhouse gases and to protect and enhance carbon sinks. This uncertainty is captured using different emission scenarios, known as Representative Concentration Pathways (or "RCPs"). Each RCP is based on different levels of "radiative forcing" by the end of the century. Radiative forcing is a measure of how much energy inflows from the sun and outflows back out into space are out of balance because of different factors, including concentrations of greenhouse gases in the atmosphere. RCP 8.5 (indicating an end-of-century increase in radiative forcing of 8.5 watts per metre squared relative to pre-industrial times) is a high baseline emission scenario associated with higher levels of global warming. The mean annual temperature for the Burlington region, for example, is projected to average +12.8°C in the near future (2051-2080), an increase of 4.2°C from its average value over the baseline period (1976-2005).

Time Horizon

The assessment considers impacts arising from projected climate and associated environmental changes out to the 2060s (the 30-year time period encompassing 2051-2080).

3 METHODOLOGY

3.1 Risk Based Climate Vulnerability Assessment

Our approach to the VRA is based on the Intergovernmental Panel on Climate Change's latest conceptualization of climate risk and can be viewed as a risk assessment with an embedded vulnerability assessment component, which we refer to as a "risk-based climate vulnerability assessment". It is also consistent with the recently published International Standards Organization (ISO) guidelines; 14091 [Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment] and 14092 [Adaptation to Climate Change—Requirements and guidance on adaptation planning for local governments and communities]. The methodology, which is depicted in **Figure 3-1**, thus reflects current best practice. Outcomes from the application of the methodology also satisfy the Milestone 1-2 requirements of the BARC framework and provide the information needed for Badge 1 of the GCoM Canada's CRF.

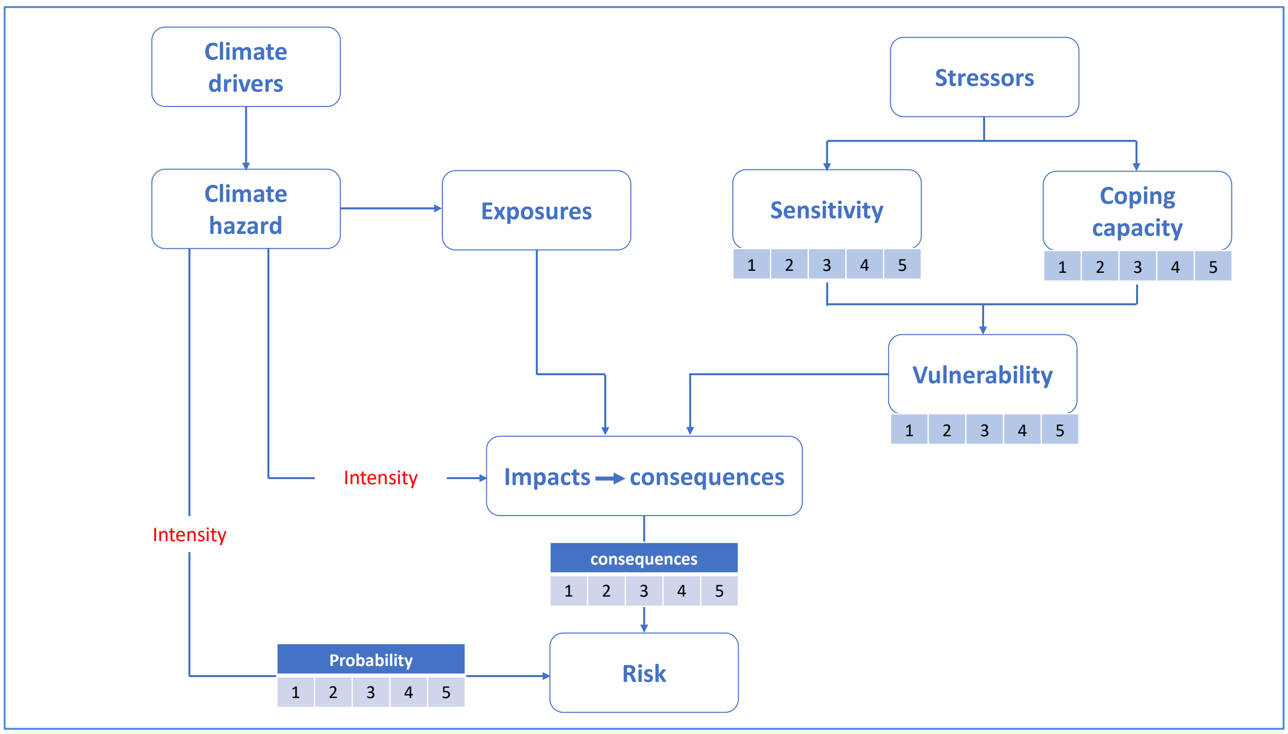


Figure 3-1 Risk-Based Climate Vulnerability Assessment

As evident from **Figure 3-1**, our risk-based climate vulnerability assessment comprises several elements—indicated by the boxes in the figure. The arrows show the links between these elements and the flow of information. Some key concepts or terms for the VRA include:

- A **hazard** is a potential source of harm.
- A **climate hazard** - like urban flooding - is a special type of hazard that is (at least partially) caused by **climatic drivers.** Climate change may also give rise to beneficial opportunities, like a longer growing season.
- **Climate drivers** - like a high intensity, short duration rainfall event - are climate variables or indices that influence the hazard or opportunity.

- **Exposure** refers to who and what in Burlington are potentially affected by the hazard or opportunity. For a hazard, this describes the presence of people, assets, natural systems, and economic, social, and cultural resources in specific places within Burlington that could be adversely affected.
- **Sensitivity** considers different population groups, assets, etc. that will exhibit varying degrees of susceptibility to be harmed by any given hazard, or to benefit from an opportunity.
- **Coping capacity** refers to Burlington's means of coping with the impacts and consequences of the climate hazard or being able to take advantage of an opportunity that arises. With our approach to the VRA, we define coping capacity as the ability of people, organizations, systems, etc. to successfully adjust, accommodate, and - for hazards, recover from the anticipated impacts of a hazard in the short-term - using existing institutional capacity, and financial, human and social capital (see the text box).
- **Vulnerability** is derived from the interplay of sensitivity, coping capacity and existing non-climate stresses or pressures.

Coping Capacity vs Adaptive Capacity

Coping capacity takes a short-to-medium term view on the capacity of people, institutions, organizations, and systems to address, manage, and overcome occurring adverse conditions using currently available resources. In contrast, adaptive capacity takes a medium-to-long-term perspective. It can be viewed as the 'room to move' for adaptation—i.e., the scope to increase coping capacity, reduce sensitivity and exposure to climate-related hazards, and reduce the influence of non-climate stressors. It is therefore important to consider adaptive capacity of Burlington when assessing the feasibility of adaptation options and for adaptation planning. However, coping capacity is a better suited concept for assessing climate-related risks.

Non-climate '**stressors**' can have an important effect on vulnerability to specific climate hazards. Examples of such stressors include population growth or changes to land-use; a growing percentage of impervious surfaces in a defined area will generally increase the likelihood of flooding events and thus the risk to all exposed assets and services, natural systems, etc. sensitive to flooding.

The interplay of the climate hazard (or opportunity) and the exposed objects will give rise to a range of potential biophysical **impacts** and **consequences** of interest—including, for example, in the context of a hazard: damage or loss of buildings, contents and inventories, equipment and vehicles, and other forms of property; injuries, illnesses or the need for primary or secondary care; or interruption to regular living arrangements requiring individuals and families to temporarily evacuate or permanently relocate. As shown in **Figure 3-1**, the vulnerability of exposed objects to a given climate hazard will influence the magnitude or severity of these impacts and consequences. The magnitude of impacts and consequences also depends on the intensity level of the climate hazard. Take, for example, a tornado; an EF 3 tornado will cause significantly more damage than an EF 0. Likewise, a 110 km per hour wind gust will cause more damage than a 70 km per hour gust. This also applies to climate opportunities.

For an individual climate hazard, the elements described above combine to define the risk that hazard represents for Burlington, where risk is essentially a measure of the expected consequences of the hazard, incorporating the likelihood of it occurring at a defined intensity level. It is this measure of climate-related risk that informs priorities for the adaptation planning phase of the project. While the estimated level of risk associated with a climate hazard informs priority setting, other elements of the methodology outlined in **Figure 3-1** provide crucial information for adaptation planning. Besides being an important input to the assessment of consequences and overall levels of risk, understanding Burlington's vulnerability to priority hazards is important when it comes to formulating the adaptation plan. Similarly, for an individual climate opportunity, the same elements combine to define the expected benefit that opportunity represents for Burlington, where the expected benefit is a measure of the expected beneficial consequences arising from the opportunity, incorporating the likelihood of it occurring at a defined intensity level.

Adaptation actions, in general, seek to do three things: one, reduce (increase) the exposure of people, assets, systems, etc. to climate hazards (opportunities); two, reduce (increase) their sensitivity to the hazard (opportunity) should they be exposed; and three, increase the coping capacity of those affected and the City more generally. It is therefore crucial to have some understanding of those sensitivities, as well as key gaps in coping capacity, when it comes to formulating adaptation strategies.

3.2 Participatory Approach to Assessment

Regarding implementation of the methodology, a bottom-up, participatory approach was adopted that recognizes the skills and experiences of City staff and a range of external stakeholders (the 'community-group') and uses them in the co-production of the VRA. This approach builds momentum for successful adaptation planning and implementation by including all key stakeholders in all stages of the development process. Indeed, stakeholders provided input throughout the process to:

- Prioritize the highest climate-related vulnerabilities and risks for Burlington.
- Align initiatives to coordinate resources.
- Identify opportunities to address multiple risks from individual initiatives.
- Elevate initiatives to provide multiple (co-)benefits.
- Collaborate across departments, stakeholders, and jurisdictions.

Prior to the start of this project, the City had already established internal (staff) and external (community) stakeholder groups who, among other things, had provided input on a provisional set of climate impact statements (discussed in **Section 3.3** below). Additional stakeholders were identified to supplement the skills and knowledge available for the VRA.

To inform the VRA, stakeholders participated in a series of virtual workshops using the Microsoft TEAMs communications platform and MURAL; these workshops are described in **Section 3.4** (vulnerability assessment) and **Section 3.5** (risk assessment) below. Appendix A provides a list of staff and community stakeholders involved in the VRA workshops.

3.3 Climate Impact Statements

The starting point for the VRA is a set of impact statements that characterise the cause-and-effect relationship, or impact chain, between climate hazards of concern and the consequences of these hazards for the system being assessed. The main elements of an impact statement are shown as blue shaded boxes in **Figure 3-2**. A robust statement should identify the "someone" or "something" that will be impacted, the specific way they will be impacted and the associated consequences, as well as linking the impacts to changes in an individual climate hazard and one or more climatic drivers. The statement should also include information on the intensity of the climate hazard.

It is crucial to have a single hazard of defined intensity, since that will influence the magnitude of impacts, the likelihood of the hazard, and the sensitivity and coping capacity of exposed people, assets, systems, etc. While many climate-related hazards have multiple intensity levels - like tornados, wind speeds, or flood events - it is not practically feasible to assess the full distribution of event intensities for all hazards. It is necessary to define one intensity or threshold level for each hazard of concern, which will be 'scored' during the vulnerability and risk assessments.

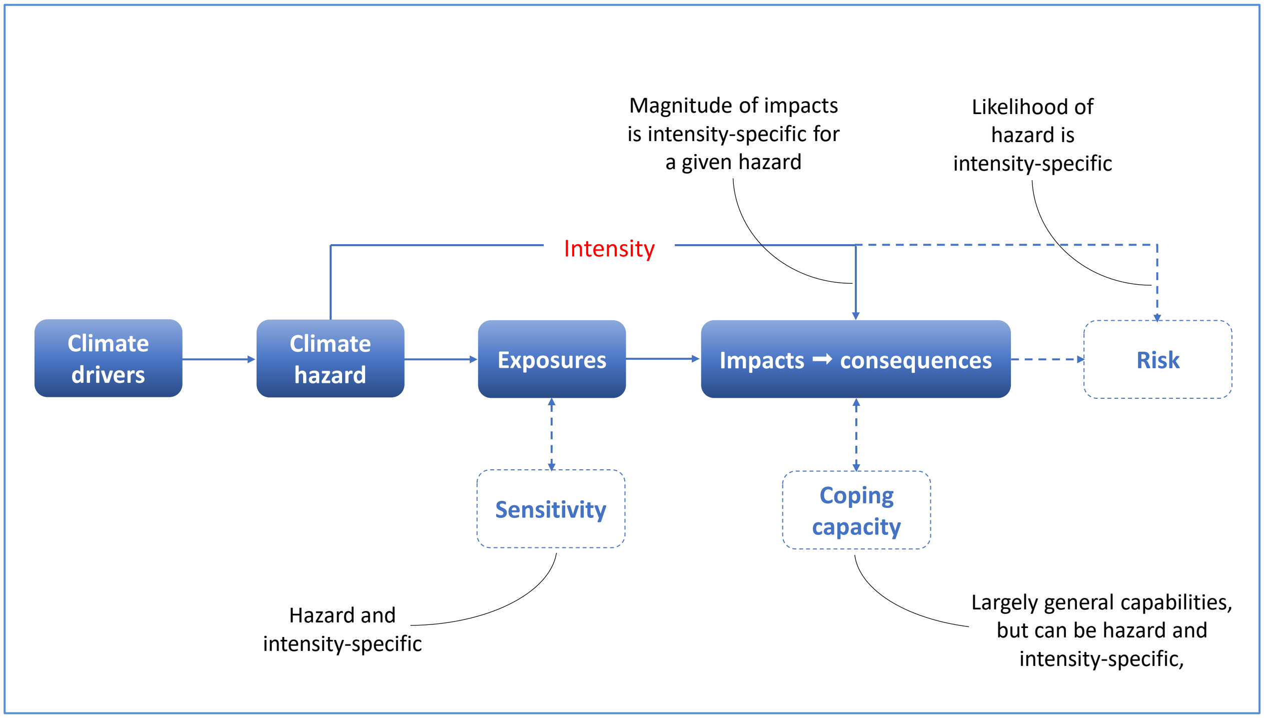


Figure 3-2 Structure and Elements of an Impact Statement (or Impact Chain) for a Climate Hazard[1]

Prior to the start of this project, an initial list of over 70 impact statements were developed via surveys and meetings with City staff and the community stakeholder groups. These impact statements were organized by exposure themes—the 'who' and 'what' is affected, like City operations, the natural environment, etc. Moreover, the statements for each exposure theme–like the natural environment—had a mix of climate drivers. That is, each impact statement was not specific to a single defined climate hazard or opportunity.

The provisional set of impact statements thus needed to be re-framed to fit with our proposed risk-based climate vulnerability approach. Specifically, the impact statements needed to be re-worded without losing any of the original content, so they were specific to an individual climate hazard or opportunity with a defined intensity level. This re-framing was necessary to facilitate scoring sensitivity, coping capacity, consequences, and likelihood with stakeholders at the vulnerability and risk assessment workshops.

The re-framing of the impact statements initially resulted in 22 climate hazards with primarily negative consequences (the "threats") and three climate opportunities, with largely positive consequences, as shown in **Table 3-1**. As part of the re-framing of the original statements by the project team, we also further developed the anticipated consequences and the 'who' and 'what' that could be affected (see **Figure 3-3**). Streamlined versions of the more detailed statements served as the starting point for the vulnerability assessment (again, see **Figure 3-3**).

Through the course of the vulnerability and risk assessments, the impact statements belonging to this updated set of 25 climate hazards and opportunities have been modified based on input from City staff and the community

[1] The impact statement (or chain) for a climate opportunity is similarly structured.

stakeholders. The finalized impact statements are provided in **Appendix B**, along with summary results from both assessments.

Table 3-1 Re-Framed List of Climate Hazards and Opportunities for Vulnerability Assessment

• Drought	• Cooling demand	• Low water levels (creeks)	• Shifting ecoregions
• Wildfire	• Air quality	• High water levels (Lake)	• Timing of spring frost
• Freezing rain	• Extreme heat	• Water quality (algal bloom) (all water bodies)	• Mismatched timing of plant & animal lifecycles
• Heavy snow	• Freeze-thaw cycles	• Heating demand	• Growing season
• High wind speeds & wind gusts	• Urban flooding	• Water demand	• Active transportation
• Vector-borne diseases	• Creek flooding	• Winter recreation	• Shoulder season
• Invasive species & pests			

Note: 'Hazards' are shaded orange and 'opportunities' are shaded green.

Original Climate Statements from City

Sector

Agriculture	Increasing summer temperature and changes in precipitation patterns leading to more heat and water stress on agricultural production resulting in reduced crop yield and more frequent crop failures. *Impact or Consequence*
	More extreme heat and cold events leading to animals (domestic and livestock) left in spaces that are not weather appropriate resulting in increased risk of morbidity and mortality.
	Increased heavy rainfall events leading to increased flooding resulting in decreased access to fields and delayed seeding or harvesting.
	Increased heavy rainfall events leading to loss of top-soil due to runoff and crop destruction impacting carbon sequestration.
	More variable and extreme weather (early spring followed by frost) will lead to early emergence of flowering crops resulting in heavy crop losses (fruit trees).

Re-framing and elaboration of original impact statements by project team

Re-framing and Elaboration of Impact Statements by Climate Hazard or Opportunity

Climate Hazard

Extreme Heat

Climate Driver(s):	• [Increased] mean maximum summer temperature; • [Increased] very hot and extremely hot days; • [Increased] heat waves; • [Increased] hot season; • [Increased] tropical nights

Impacts and consequences arising from extreme heat:	Affected systems and sectors:	Consequences for:
Range of minor to severe acute clinical outcomes (e.g., heat rash, heat cramps, heat syncope, exhaustion, heat stroke), which can result in hospitalization and premature death, resulting in direct costs (arising from the consumption of medical services), indirect costs (arising from foregone leisure opportunities or lost production due to ill-health), and welfare losses to the value individuals attribute to the emotional distress, pain, and suffering that they, family and friends experience as a result of ill-health or loss of life	Public health; Emergency services	Public heath & safety; Public administration
Risk of building mechanical systems failure as summer (July) design standards are exceeded, resulting in repair and replacement expenditures, as well as potential for disruption to goods and service provision	Residential buildings; ICI buildings; City operations	Economic vitality; Public administration
Decline in use of outdoor recreation facilities and sports fields, as well as active transportation, leading to reduced wellbeing	Recreation	Community & lifestyle
Reduction in willing of workers to supply labour and in labour productivity in high-risk sectors (those with largely outdoor occupations), resulting in lower economic output	Commercial; Industrial	Economic vitality
Increased heat stress for animals and livestock, causing distress, metabolic disruptions and immune suppression causing infections, and potential mortality, as well as productivity losses in livestock	Agriculture; Wildlife *Sector*	Environment & sustainability; Economic vitality
Increase demand for **space cooling** *Impact or Consequence*	See cooling demand	See cooling demand
Increase in risk of **wildfires**	See wildfires	See wildfires
Increased **water demand**	See water demand	See water demand
Increased **drought**	See drought	See drought

Streamlining of impact statements for use at the vulnerability assessment workshops

Streamlined Impact Statements by Climate Hazard or Opportunity

Climate Hazard

Extreme Heat

Climate driver(s)	• Mean maximum summer temperature [Increase] • Very hot and extremely hot days [Increase] • Heat waves [Increase] • Hot season [Increase] • Tropical nights [Increase]
Definition / intensity threshold (provisional)	A heat wave (three consecutive days of temperatures above +30°C)
Data source for definition	Climate Atlas of Canada
Potential impacts on Burlington *if hazard occurs*	• Illness health and, in rare cases, premature loss of life • Risk of building mechanical systems failure • Decline in use of outdoor recreation facilities and sports fields • Reduction in willingness of workers to supply labour and in loss of labour productivity • Increased heat stress for animals and livestock *Impact or Consequence*

Figure 3-3 Process of Re-Framing Impact Statements as Inputs to the Vulnerability Assessment

3.4 Vulnerability Assessment

The vulnerability assessment was performed over the course of four virtual workshops; two workshops with City staff and two workshops with community stakeholders. Each workshop was two and a half hours in length. Halton Region and Conservation Halton were included in the City staff stakeholder group due to the direct alignment and knowledge of critical City infrastructure. All stakeholders were in the same workshops for the risk assessment.

Two separate workshops were held with each group of stakeholders on September 13th, 2021. At these workshops, participants were invited to address the following questions:

- Does the draft impact statement definition and proposed intensity/threshold level make sense to you?
- Do you have an alternative suggestion for how the climate hazard or opportunity could be defined for Burlington (e.g., is there a specific threshold or intensity level at which the event becomes a concern)?
- Are you aware of any data sources relevant to the climate hazard or opportunity, other than those listed?
- Who or what in Burlington would be more affected, positively, or negatively?
- Are there any major gaps in the impact statements or critical revisions needed?

To help stakeholders with the fourth question, they were provided with the following examples of who (people) and what (assets, natural systems, and economic, cultural, and social resources) could be affected from exposure to the climate hazard or opportunity being assessed:

- Residential property
- Commercial / public buildings & facilities
- Transportation infrastructure / services
- Natural habitat / ecosystem services
- Drainage infrastructure
- Utilities – water supply & sanitation
- Utilities – energy
- Emergency services
- City / Regional operations
- Agriculture sector
- Manufacturing sector
- Recreation & cultural services
- Service sectors – e.g., retail
- Outdoor workforce
- Public health
- Elderly population
- Infants and children
- Low-income individuals and families
- Individuals with chronic illnesses
- Marginalized / underserved groups

For each climate hazard and opportunity, the project team proposed a provisional threshold or intensity level that defined the climate event, drawing from past experience in Burlington, the literature, and assessments for other jurisdictions performed by the project team. For example, the threshold or intensity level for several hazards—like high winds and heavy snow—were defined by Environment Canada's criteria for issuing public weather alerts.

Following these first two workshops, the impact statements were updated to capture feedback from participants to the questions asked. On September 15th, 2021, a further two separate workshops were held with each group of stakeholders. The purpose of these workshops was to develop an overall "sensitivity" score and "coping capacity" score for each climate hazard and opportunity, as defined on the impact statement.
These scores are then combined to derive a measure of hazard- and opportunity-specific vulnerability—expressed on a 1-5 scale: low through medium through high.

Estimated levels of vulnerability inform the scoring of consequence levels at the risk assessment workshops (described in **Section 3.5**). The 'heat map' in Figure 3-4 shows conceptually how the scores are combined to determine levels of vulnerability. The first thing to note here, is that a score of five for sensitivity, indicates high levels of susceptibility to impacts from exposure. For a hazard, that is clearly a bad outcome. The more sensitive an individual is to poor air quality, for example, the more severe the consequences they will experience from exposure, all else being equal.

When it comes to the risk assessment, it is also the case that a score of five for anticipated consequences indicates extreme consequences—i.e., the worst outcome. Furthermore, a score of five for likelihood indicates that a hazard is almost certain to occur. Again, this is the worst outcome for a hazard. So, for consistency across the methodology it is necessary for a value of five to be the worst outcome across all core elements. But a score of five for coping capacity is the best outcome, indicating high levels of coping capacity. As a result, following the second vulnerability workshops, the project team inverted the elicited scores for coping capacity—as shown on the left of the heat map in **Figure 3-4** and in effect, created a measure of the "lack of coping capacity", where five is now the worst outcome.

As shown on the heat map, combinations of low sensitivity and a low lack of coping capacity define lows levels of vulnerability, and combinations of high levels of both elements define high levels of vulnerability. It is climate hazards and opportunities that fall in this latter group that will be of priority concerned for stakeholders.

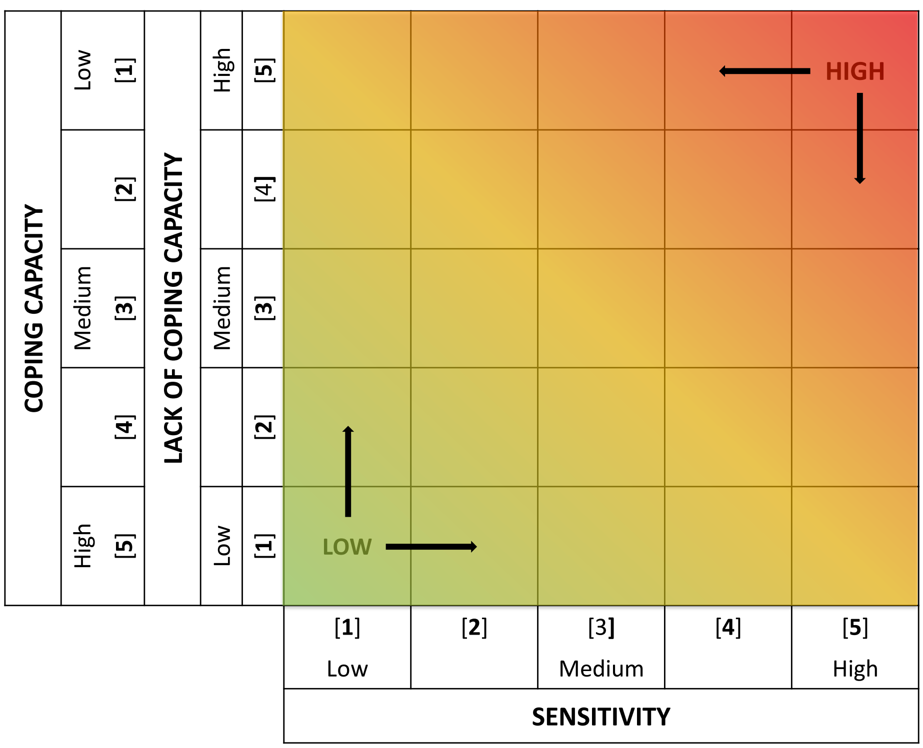


Figure 3-4 Vulnerability Heat Map Concept

3.4.1 Scoring "Sensitivity"

To satisfy the requirements of Milestone 2 of the BARC framework, it is necessary to use a semi-quantitative approach to both the vulnerability and risk assessments. This involves assigning categorical (very rare to almost certain) or numerical values (1 to 5) to the following factors: sensitivity, coping capacity, consequences, and likelihood. And ultimately to climate risk. To facilitate numerical scoring at the workshops, scoring rubrics were prepared by the project team in advance of the workshops for each of these components.

The 1 (low) to 5 (high) scoring rubrics for sensitivity are provided in **Table 3-2** for hazards and **Table 3-3** for opportunities. For the purpose of the workshop, the following working definition was adopted: **sensitivity indicates the degree to which people, assets, natural systems, or economic, cultural, or social resources might be affected by the climate hazard (opportunity) to which they are exposed**. For each climate hazard and opportunity, and corresponding impact statement, workshop participants were invited to answer the question in the header of each table, scoring their responses from 1 (low) to 5 (high).

Table 3-2 Rubric for Scoring Sensitivity to Hazards

Sensitivity Levels		If the climate hazard occurred in Burlington today at the defined intensity, the exposed assets, systems, resources, or individuals would:
High	[5]	Be *enormously* affected – functionality would be enormously limited / impaired or lost
Medium-high	[4]	Be *majorly* affected – functionality would be majorly limited / impaired
Medium	[3]	Be *moderately* affected – functionality would be moderately limited / impaired
Medium-low	[2]	Be *minorly* affected – functionality would be somewhat limited / impaired
Low	[1]	Be *minimally* affected – functionality would be inappreciably limited / impaired

Table 3-3 Rubric for Scoring Sensitivity To Opportunities

Sensitivity Levels		If the climate opportunity occurred in Burlington today at the defined intensity, the exposed assets, systems, resources, or individuals would:
High	[5]	Be *enormously* affected – functionality would be enormously enhanced / improved
Medium-high	[4]	Be *majorly* affected – functionality would be majorly enhanced / improved
Medium	[3]	Be *moderately* affected – functionality would be moderately enhanced / improved
Medium-low	[2]	Be *minorly* affected – functionality would be somewhat enhanced / improved
Low	[1]	Be *minimally* affected – functionality would be inappreciably enhanced / improved

There are many factors that will influence the sensitivity of an exposed object to a climate hazard or opportunity. To assist participants with scoring sensitivity at the workshop, they were provided with the following examples which are relevant to climate hazards and opportunities being assessed:

- Economic (employment, output) dependence on high-risk sectors
- Prevalence of chronic respiratory and cardiovascular disease
- Prevalence of food insecurity
- Proportion of workforce in 'high-risk' sectors (largely outdoor occupations)
- Presence of endangered, threatened, and special concern animals and plants
- Proportion of elderly, infants and children in the population
- Perceived mental health of residents
- Prevalence of energy poverty
- Economic (employment, output) diversity
- Condition, age and energy efficiency of the building stock
- Proximity of trees to buildings and infrastructure
- Percentage of population living in high-rise apartment blocks
- Proportion of the electricity network underground
- Prevalence of on-street parking
- Proportion of land area in populated areas that is vegetated
- Proportion of workforce community > 15 minutes commute
- Participation rates in water- and beach-based recreation
- Perceived neighbourhood safety from traffic and crime

For example, the proportion of electricity wires underground will reduce its sensitivity to high winds and freezing rain. The proportion of the workforce in outdoor occupations is going to increase the sensitivity of productivity to heat exposures and poor air quality. The prevalence of energy poverty in the community will make the population more sensitive to increased cooling demand and spikes in energy prices. The condition and age of the building stock will influence its sensitivity to high winds, heavy snow events, and extreme heat. The proportion of the populated land area that is vegetated will influence sensitivity to urban heat island effects and stormwater flooding. And the sensitivity of active transportation use will be influenced by perceptions about neighbourhood safety from traffic and crime.

3.4.2 Scoring "Coping Capacity"

The 1 (low) to 5 (high) scoring rubrics for coping capacity are provided in **Table 3-4** for hazards and **Table 3-5** for opportunities. For the purpose of the workshop, the following working definition was adopted for a climate hazard: **coping capacity indicates the extent to which people, both public sector and private sector organizations, and natural systems exposed to a climate hazard, can successfully adjust, accommodate, and recover from the anticipated impacts in the short-term using existing institutional arrangements, and financial, human and social capital.**

Two key points should be noted regarding this definition. First, by successful we mean full resumption of business-as-usual and in the short-term, certainly not a year or more down the road. And by existing arrangements and capitals, we mean within existing operating budgets and in the absence of new actions to enhance the adaptative capacity of Burlington—such as building knowledge and awareness in the community, enhancing social cohesion and connectedness, increasing access to health care, strengthening emergency preparedness, enhancing monitoring or surveillance programs, etc.

Table 3-4 Rubric for Scoring Coping Capacity for Hazards

Coping Capacity Levels		Using existing institutional arrangements, and financial, human and social capital, to what extent can Burlington successfully accommodate, adjust to and recover from the anticipated impacts and consequences of the climate hazard:
High	[5]	City is fully able to accommodate or adjust to anticipated consequences and certain to return to previous levels of functionality
Medium-high	[4]	City is mostly able to accommodate or adjust to anticipated impacts and very likely to achieve previous levels of functionality
Medium	[3]	City is moderately able to adjust, accommodate, and recover from the anticipated impacts and likely to achieve previous levels of functionality
Medium-low	[2]	City is somewhat able to accommodate or adjust to anticipated impacts and unlikely to achieve previous levels of functionality
Low	[1]	City is neither able to accommodate or adjust to anticipated consequences nor return to previous levels of functionality

Table 3-5 Rubric for Scoring Coping Capacity for Opportunities

Coping Capacity Levels		Using existing institutional arrangements, and financial, human and social capital, to what extent can Burlington successfully adjust to, and take advantage of, the anticipated benefits presented by the climate opportunity:
High	[5]	City is fully able to adjust to and take advantage of opportunity
Medium-high	[4]	City is mostly able to adjust to and take advantage of opportunity
Medium	[3]	City is moderately able to adjust to and take advantage of opportunity
Medium-low	[2]	City is somewhat able to adjust to and take advantage of opportunity
Low	[1]	City is marginally able to adjust to and take advantage of opportunity

For each climate hazard and opportunity, and corresponding impact statement, workshop participants were invited to answer the question in the header of **Table 3-4** and **Table 3-5**, scoring their responses from 1 (low) to 5 (high). Like sensitivity, there are many factors that will influence the coping capacity of people, organizations, and natural systems in Burlington to climate hazards or opportunities. Participants were provided with the following example determinants of coping capacity to assist with assigning scores to each hazard and opportunity:

- Levels of educational attainment
- Disposable income of affected individuals and families
- Accessibility of healthcare services
- Income poverty and inequality
- Demographic dependency ratio
- Prevalence of Business Continuity and Disaster Plans in business sectors
- Efficacy of affected utilities
- Vector- and disease surveillance programs
- Preparedness of emergency services
- Prevalence of discrimination
- City operating budgets
- Pests and invasive species monitoring programs
- Proportion of elderly living alone
- Air quality alerts (and access to alerts)
- Penetration of appropriate insurance
- Trust in institutions and others
- Prevalence of crime
- Proportion of population that are “new-comers”

In contrast to sensitivity, however, many indicators of coping capacity are generally applicable, and not specific to hazards or opportunities For example, levels of crime and discrimination in the community, higher proportions of new-comers, trust in institutions and other members of the community, and inequalities, are all determinants of social cohesion and connectedness; higher levels of which increase our capacity to cope with any adverse event. Likewise, higher levels of education and disposable income are associated with higher levels of coping capacity.

The results of the vulnerability assessment are presented in **Section 4**.

3.5 Risk Assessment

The risk assessment was performed over the course of two virtual workshops with both City staff and the community stakeholders together; each workshop was two and a half hours in length. The first workshop was held on September 28th, 2021, during which participants reviewed the results of the vulnerability assessment and began the process of scoring the consequences of each climate hazard and opportunity on a 1 (low) to 5 (high) scale. The scoring of consequences was completed at a second workshop held on September 29th, 2021.

Prior to the risk assessment workshops, the project team updated the impact statements for each climate hazard and opportunity to include the results of the vulnerability assessment as well as address feedback received from participants. The feedback primarily concerned the definition of climate hazards and opportunities, as well as the assumed threshold or level of intensity.

In addition, “urban flooding” was split into “stormwater flooding” and “wet conditions” to differentiate between short-duration and long-duration events that had a wider spatial impact. “Wildfire” was also split between a “grass fire” which the City currently experiences and a “forest fire” which could happen in forested areas as the climate changes. Furthermore, “water quality (algal blooms)” was limited to beaches on Lake Ontario, as opposed to applying to all water bodies. This increased the number of climate hazards to 24. And in total, 27 climate hazards and opportunities were considered during the risk assessment.

The revised hazard and opportunity definitions and thresholds / intensity levels used for the risk assessment workshops are listed in **Table 3-6**. As well as updating the impact statements, the project team developed rubrics for scoring the consequences of the climate hazards and opportunities (see **Section 3.5.2**) and the likelihood of those consequences occurring (see **Section 3.5.1**).

Table 3-6 Summary of Climate Hazard and Opportunity Definitions and Thresholds / Intensity Levels

Hazards	Event Intensity / Threshold
High winds	Sustained winds of 70 km/h or more; and/or gusts to 90 km/h or more
Shifting ecoregion	Northward shift of ecoregion climate envelopes
Freezing rain	A freezing rain event
Wet conditions	73mm of precipitation in a 5-day period (the projected wettest 5-day period in the 2060's)
Water quality (algal bloom)	An algal bloom at Burlington public beaches
Heavy snow	15 cm or more of snow fall within 12 hours or less
Extreme heat	7 heat waves (three consecutive days of temperatures above +30°C) in a year
Cooling demand	A summer with Cooling Degree Days greater than or equal to 797 [the projected mean value for the 2060s]
Freeze-thaw cycles	45 freeze-thaw cycles in a year [the projected mean value for the 2060s]
Late spring frost	A late spring frost [April 3 is the projected date of last spring frost in the 2060s]
High water levels	A water level on Lake Ontario of 75.92 metres (the 2019 high water level)
Stormwater flooding	Rainfall intensity of 145 mm per hour over a 10-minute period [1:100 year event]
Mismatched timing of plant and animal lifecycles	Mismatch of climate conditions and/or photo-period for animals and plants, such as migratory birds
Air quality	Air Quality Health Index (AQHI) of 7 or higher (High or very high health risk)
Invasive species and pests	Outbreak of a new invasive species affecting 10% of the City's urban tree canopy, native vegetation and gardens
Increased water demand	5% increase in summer water demand [associated with a projected increase in Mean Maximum Summer Temperature of 4.6°C]
Vector-borne disease	54 cases of Lyme disease per 100,000 [the projected mean value for the 2080's]
Heating demand	A winter with greater than or equal to 2680 Heating Degree Days [the projected mean value for the 2060s]
Drought	Extreme drought conditions ("D3" according to the Canadian Drought Monitor, a 20–25-year event)
Loss of winter recreation	A mild winter, with greater than or equal to 27 Mild Winter Days
Creek flooding	Creek flooding event defined as the 1:100 year 24-hour rainfall event [5.15 mm per hour]
Low water levels	Extreme low water conditions that threaten aquatic habitat and hydrological function
Grass fire	An uncontrolled grass fire within City limits, of more than 1 acre in size
Forest fire	An unplanned fire - including unauthorized human-caused fires – occurring on forest lands

Opportunities	Event Intensity / Threshold
Longer growing season	A frost-free season of 228 days [the projected mean value for the 2060s]
Increased summer recreation	A frost-free season of 228 days [the projected mean value for the 2060s]
Increased active transportation	A frost-free season of 228 days [the projected mean value for the 2060s]

3.5.1 Scoring Likelihood

The 1 (rare) to 5 (almost certain) scoring rubric for the likelihood of a climate hazard or opportunity occurring at the defined threshold or intensity level is provided in **Table 3-7**. Prior to the workshop the project team assessed the annual probability of the climate hazard or opportunity occurring in the baseline period and in the near future (i.e., the 2051-2080 period, referred to as the 2060s) using one of four different methods:

- **Indicator projection**: Data readily available from the Climate Atlas of Canada, at the threshold level of concern.
- **Analysis of frequency distributions**: The frequency distributions for the primary climate variable were downloaded from the Climate Atlas of Canada and used to estimate the probability of the projected value occurring in any given year, over average, in both periods of interests.
- **Research from other assessments or studies**: Where relevant climate projections were not available from the Climate Atlas of Canada, research and data from other assessments and published studies were used to estimate the future likelihood of occurrence.
- **Professional judgement**: In cases where none of the above approaches could be used, the professional judgement of City staff and the community stakeholder team was used to estimate likelihoods.

The estimated values were then translated into 1 (low) to 5 (high) scores using the likelihood scoring rubric in **Table 3-7.**

Table 3-7 Rubric for Scoring the Likelihood of Climate Hazards or Opportunities Occurring

Score	Description	Discrete Event	Ongoing Stress
1	**Rare**	Event is expected to happen less than once every 100 years (Annual probability < 1% in the 2060s)	Impact is almost certain not to occur between now and the 2060s (<5% probability)
2	**Unlikely**	Event is expected to happen about once every 51-100 years (1 - 2% annual probability in the 2060s)	Impact is not anticipated to occur between now and the 2060s (5-29% probability)
3	**Possible**	Event is expected to happen about once every 11-50 years (2 - 10% annual probability in the 2060s)	Impact is as likely as not to occur between now and the 2060s (30-49% probability)
4	**Likely**	Event is expected to happen about once every 3-10 years (10 - 50% annual probability in the 2060s)	Impact is expected to occur between now and the 2060s; it would be surprising if it did not occur (50-90% probability)
5	**Almost certain**	Event is expected to happen once every two years or more frequently (Annual probability > 50% in the 2060s)	Impact is almost certain to occur between now and the 2060s (91-100% probability)

3.5.2 Scoring Consequences

Consequences were assessed based on five categories important to City objectives, which are described in **Table 3-8**:

- Public Health & Safety.
- Economic Vitality.
- Natural Environment.
- Social Functioning.
- City Services.

The 1 (low) to 5 (high) scoring rubrics for the consequences of hazards and opportunities are provided in, **Table 3-9** and **Table 3-10**, respectively. The scoring rubrics are designed to allow workshop participants to assess the range of consequences anticipated to result from each climate hazard and opportunity across the five categories.

Within each theme a few considerations will influence the score assigned a consequence. For example, if scoring the consequences of a climate hazard for public health & safety in Burlington, a participant should consider the anticipated number of fatalities, injuries, diseases & hospitalizations, and psychological impacts.

At the workshops, prior to scoring consequences, participants were invited one last time to expand upon the list of potential consequences of each climate hazard and opportunity for Burlington. When scoring consequences, participants were instructed to take account of existing and firm forthcoming measures that would reduce expected negative impacts (e.g., by reducing exposure or sensitivity, or by increasing coping capacity, or any combination thereof) or increase expected positive impacts. Also, participants were instructed to assess the consequence for Burlington today, and not to try and envision what the City might look like in the 2060s. In effect, they were instructed to overlay the climate of the 2060s on the Burlington of today.

Following the risk assessment workshops, the likelihood and consequences scores for each hazard and opportunity are combined with the results of the vulnerability assessment to derive an overall measure of risk for Burlington. These risk scores are used to rank-order the climate hazards and opportunities, and to generate a heat map, or risk rating matrix, for the City. The results of the risk assessment are presented in **Section 4.**

Table 3-8 Definition of Consequences Categories

Category	Considerations	Description
Public health & safety	Fatalities	Premature deaths attributable to a climate hazard
	Injuries, disease & hospitalizations	Injuries, illnesses or the need for primary or secondary care attributable to a climate hazard
	Psychological impacts	Impacts to the mental health and emotional wellbeing of individuals attributable directly or indirectly to a climate hazard
Social functioning	Social cohesion	Changes to community supports and networks, community reciprocity, and trust and relationships between members of the community
	Displacement	Interruption to regular living arrangements attributable to a climate hazard, requiring individuals and families to temporarily evacuate or permanently relocate
	Cultural resources	Impacts to objects, sites, practices, or resources of cultural or historical importance due to a climate hazard
Economic vitality	Property damage	Damage or loss of buildings, contents and inventories, equipment and vehicles, and other forms of property, due to a climate hazard
	Infrastructure damage	Damage or loss of (transport, water & sanitation, drainage, energy, waste management, etc.) infrastructure due to a climate hazard, with associated interruption or loss of services
	Economic productivity	Disruption or loss of ability of individuals, businesses and government to produce, consume and trade goods and services, and to generate income and support livelihoods
	Equity	Changes to existing disparities, inequalities and deprivation across the community attributable to a climate hazard affecting vulnerable, marginalized and underserved population groups
Natural environment	Natural environment	Consequences of a climate hazard for land, water, air, plants and animals, and the provision of ecosystem services
City services	Operations	Impacts to the City's ability to all deliver services without interruption or workarounds due to a climate hazard
	Financial impacts	Financial burden of the climate hazard for the City's capital and operating budgets
	Reputation	Changes to the public's perception of the City (council and staff) attributable to the impacts of a climate hazard

Table 3-9 Rubric for Scoring Consequences of Climate Hazards

	Very Low [1]	Low [2]	Medium [3]	High [4]	Very High [5]
Public health & safety	No directly related loss of life No directly related injuries, illnesses, diseases or need to access healthcare services Minimal short-term reaction of fear or anxiety, or disruption to daily life	⟷	No directly related deaths 5-10 people injured or experiencing illness, some requiring hospital treatment Widespread moderate, temporary feelings of fear and anxiety	⟷	5 or more directly related deaths 100 or more people injured, many seriously, or experiencing illness, many requiring hospital treatment Widespread and severe disturbance resulting in chronic psychological effects, like PTSD
Natural environment	Minimal or no environmental disruption or damage Affected resources recovering full functionality within days	⟷	Isolated but reversible damage to wildlife, habitat and ecosystems, or short-term disruption to environmental amenities Full restoration of function possible, but could take months	⟷	Widespread and irreversible damage to wildlife, habitat and ecosystems, or long-term damage, disruption to environmental amenities Full restoration of function is not possible, or could take decades
Social functioning	Minimal disruption to daily life Minimal or no change in community cohesion and trust in others No self-evacuations Minimal or no impact on cultural resources, recovering full functionality within days	⟷	Week-long disruption to daily life Moderate erosion of community cohesion and trust in others Small areas of the City (1 block) seeing temporary self-evacuations Moderate damage to cultural resources, with full recovery taking months	⟷	Months long disruption to daily life (e.g., inability to access schools, recreation) Severe, widespread erosion of community cohesion and trust in others Large areas of some neighbourhoods requiring temporary evacuations, with some permanent displacement High damage to cultural resources, full recovery may not be possible or could take years

[continued] Rubric for Scoring Consequences of Climate Hazards

	Very Low [1]	Low [2]	Medium [3]	High [4]	Very High [5]
Economic vitality	Potential direct and indirect economic losses of less than $50,000 Minimal or no disruption to economic sectors, jobs and livelihoods Minimal or no impact to infrastructure services Negligible impact on existing disparities, inequalities, or deprivation	⟺	Potential direct and indirect economic losses of $0.5M Week-long disruption to an important economic sector and associated jobs & livelihoods Week-long disruption to infrastructure services Moderate, temporary exacerbation of existing disparities, inequalities, or deprivation	⟺	Potential direct and indirect economic losses of $50M or more Long-term disruption or loss of an important economic sector and associated job & livelihood losses Months long disruption to infrastructure services Significant, prolonged exacerbation of existing disparities, inequalities, or deprivation
City services	Little or no expected additional costs to City Minimal or no impact on operations and delivery of services Public reaction is minimal-little or no erosion of trust in City (council & staff)	⟺	Added costs amount to 50% of contingency / extreme weather reserve ($2.5M) Operations and services temporarily interrupted for weeks before backlog is cleared Public reaction is moderate -negative view of City (council & staff) is held by several community groups or a neighbourhood	⟺	Added cost far exceeds contingency and extreme weather reserves (>$10M) Operations and services severely interrupted – additional resources required to clear backlog, taking months Public reaction is significant -negative view of City (council & staff) is widespread, spanning the majority of population

Table 3-10 Rubric for Scoring Consequences of Climate Opportunities

Very Low [score = 1]	Low [score = 2]	Medium [score = 3]	High [score = 4]	Very High [score = 5]
Minimal or no increase in jobs and economic activity, benefiting a few businesses	⟷	Direct and indirect economic gains of $0.5M, and/or modest increases in employment opportunities in a sector of the local economy	⟷	Direct and indirect economic gains of $50M, and/or large increases in employment opportunities in key sectors of the local economy, or the creation of a new sector
Minimal improvement to the lifestyle, and/o physical and emotional well-being of some residents	⟷	Modest improvements to the lifestyle, and/or physical and emotional well-being of specific population groups (e.g., outdoor recreationalists) in Burlington	⟷	Noteworthy improvements to the lifestyle, and/or physical and emotional well-being of the majority of residents in Burlington
Existing disparities, inequalities and deprivation across the community is unchanged	⟷	Moderate reduction in existing disparities, inequalities and deprivation for some marginalized groups	⟷	Large reductions in existing disparities, inequalities and deprivation for majority of marginalized groups
Minimal or no improvement in the City's annual operating surplus (revenues less expenses)	⟷	Modest improvement in the City's annual operating surplus (revenues less expenses)	⟷	Significant improvement in the City's annual operating surplus (revenues less expenses)

4 RESULTS FROM THE VULNERABILITY AND RISK ASSESSMENTS

In total, 24 climate-related hazards with largely negative consequences ("threats") and three climate-related opportunities with largely positive consequences were assessed through the climate change vulnerability and risk assessment process (VRA). The results are presented below. Detailed summary tables for each climate hazard and opportunity (and their corresponding impact statement) are provided in Appendix B.

4.1 Vulnerability to Climate Hazards

Scoring for sensitivity and lack of coping capacity was determined for each climate hazard and opportunity based on the arithmetic average score elicited from all City staff and community stakeholder participants at the vulnerability workshops. Vulnerability was then assessed for each climate hazard and opportunity by taking the average of sensitivity and lack of coping capacity. See **Figure 4-1** at the end of this section for scoring results.

Sensitivity Results

Table 4-1 provides a summary of sensitivity results. Climate hazards with the following sensitivity scores are interpreted as:

- Score: 4.0 to 5.0 means "functionality would be majorly to enormously **limited/impaired** or **lost** if hazard occurred".
- Score: 3.0 to <4.0 means "functionality would be moderately to majorly **limited/impaired** or **lost** if hazard occurred".
- Score: <3.0 means "functionality would be minorly to moderately **limited/impaired** or **lost** if hazard occurred".

Climate opportunities with the following sensitivity scores are interpreted as:

- Score: 4.0 to 5.0 means "functionality would be majorly to enormously **enhanced/improved** if opportunity occurred".
- Score: 3.0 to <4.0 means "functionality would be moderately to majorly **enhanced/improved** if opportunity occurred".
- Score: <3.0 means "functionality would be minorly to moderately **enhanced/improved** if opportunity occurred".

Table 4-1 Interpretation of Sensitivity Results

Majorly to Enormously Sensitive	Moderately to Majorly Sensitive	Minorly to Moderately Sensitive
High winds	Shifting ecoregions	Heating demand
Invasive species and pests	Heavy snow	Grass fire
Air quality	Creek flooding	Forest fire
High water levels (Lake Ontario)	Low water levels	Loss of winter recreation
Stormwater flooding	Water quality (algal bloom)	*Longer growing season*
Extreme heat	Increased water demand	
Freezing rain	Cooling demand	
Mismatched timing of plant and animal lifecycles	Late spring frost	
Wet conditions	Vector-borne disease	
	Drought	
	Freeze-thaw cycles	
	Increased active transportation	
	Increased summer recreation season	

Note: Italicized text refers to *climate opportunities* and normal text refers to climate hazards.

Lack of Coping Capacity Results

Results from the assessment of (lack of) coping capacity are summarized in **Table 4-2**. Climate hazards with the following (lack of) coping capacity scores are interpreted as:

- Score: 4.0 to 5.0 means "City is unable to somewhat able to **accommodate or adjust** to anticipated impacts and will not return to, or is unlikely to return to, previous levels of functionality".
- Score: 3.0 to <4.0 means "City is somewhat to moderately able to **accommodate or adjust** to anticipated impacts and is unlikely to likely to return to previous levels of functionality".
- Score: <3.0 means "City is moderately to mostly able to **accommodate or adjust** to anticipated impacts and is likely to very likely to return to previous levels of functionality".

Climate opportunities with the following (lack of) coping capacity scores are interpreted as:

- Score: 4.0 to 5.0 means "City is unable to somewhat able to **adjust to and take advantage** of opportunity".
- Score: 3.0 to <4.0 means "City is somewhat to moderately able to **adjust to and take advantage** of opportunity".
- Score: <3.0 means "City of moderately to mostly able to **adjust to and take advantage** of opportunity".

Table 4-2 Interpretation of Lack of Coping Capacity Results

Unable or Somewhat Able to Accommodate/Adjust	Somewhat to Moderately Able to Accommodate/Adjust	Moderately to Mostly Able to Accommodate/Adjust
Shifting ecoregions	Wet conditions	Cooling demand
Mismatched timing of plant and animal lifecycles	High winds	Loss of winter recreation
High water levels (Lake Ontario)	Stormwater flooding	Extreme heat
	Low water levels	Heating demand
	Air quality	Grass fire
	Water quality (algal bloom)	Forest fire
	Freezing rain	*Longer growing season*
	Invasive species and pests	*Increased summer recreation season*
	Drought	
	Creek flooding	
	Vector-borne disease	
	Late spring frost	
	Increased water demand	
	Heavy snow	
	Freeze-thaw cycles	
	Increased active transportation	

Note: Italicized text refers to *climate opportunities* and normal text refers to climate hazards.

Vulnerability Results

Vulnerability assessment scores are shown in **Figure 4-1** alongside scores for sensitivity and lack of coping capacity. The results of the vulnerability assessment are also presented in the form of a 'heat map' in **Figure 4-2**, which plots each climate hazard and opportunity in a Cartesian plane based on its mean sensitivity (x-axis) and mean lack of coping capacity score (y-axis). Consistent with the results in **Figure 4-1**, those climate hazards and opportunities to which Burlington was assessed to be most vulnerable are located towards the upper right-hand corner of the heat map.

It is evident from the heat map that Burlington is still moderately vulnerable to heating demand, and grass and forest fires in absolute terms, even if these climate hazards are of least concern in relative terms. Regarding the climate opportunities, Burlington was assessed to have the greatest propensity to benefit from increased active transportation, followed by a longer growing season, and then an increase in the summer recreation season.

Sensitivity

Highest sensitivity → Lowest sensitivity

High winds	4.3
Invasive species and pests	4.3
Air quality	4.3
High water levels (Lake Ontario)	4.3
Stormwater flooding	4.2
Extreme heat	4.2
Freezing rain	4.1
Mismatched timing of plant and animal lifecycles	4.0
Wet conditions	4.0
Shifting ecoregion	3.9
Heavy snow	3.8
Creek flooding	3.7
Low water levels	3.7
Water quality	3.7
Increase water demand	3.6
Cooling demand	3.6
Late spring frost	3.5
Vector-borne disease	3.5
Drought	3.4
Freeze-thaw cycles	3.4
Increased active transportation	3.1
Increased summer recreation season	3.0
Longer growing season	2.8
Heating demand	2.4
Grass fire	2.3
Forest fire	2.3
Loss of winter recreation	2.2

Lack of coping capacity

Highest lack of coping capacity → Lowest lack of coping capacity

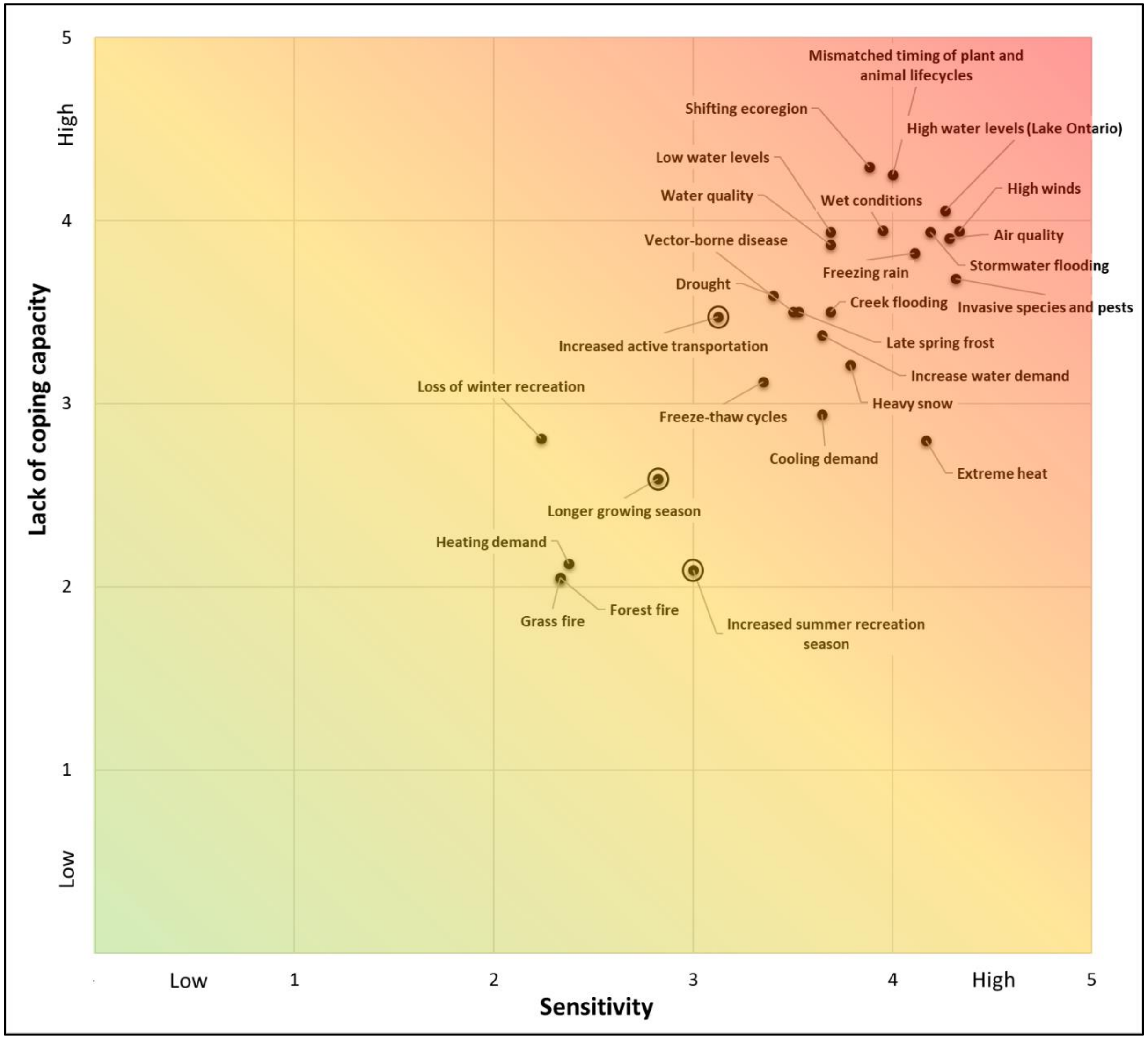
Shifting ecoregion	4.3
Mismatched timing of plant and animal lifecycles	4.3
High water levels (Lake Ontario)	4.1
Wet conditions	3.9
High winds	3.9
Stormwater flooding	3.9
Low water levels	3.9
Air quality	3.9
Water quality	3.9
Freezing rain	3.8
Invasive species and pests	3.7
Drought	3.6
Creek flooding	3.5
Vector-borne disease	3.5
Late spring frost	3.5
Increased active transportation	3.5
Increase water demand	3.4
Heavy snow	3.2
Freeze-thaw cycles	3.1
Cooling demand	2.9
Loss of winter recreation	2.8
Extreme heat	2.8
Longer growing season	2.6
Heating demand	2.1
Increased summer recreation season	2.1
Grass fire	2.1
Forest fire	2.1

Vulnerability

Highest vulnerability → Lowest vulnerability

High water levels (Lake Ontario)	4.2
High winds	4.1
Mismatched timing of plant and animal lifecycles	4.1
Air quality	4.1
Shifting ecoregion	4.1
Stormwater flooding	4.1
Invasive species and pests	4.0
Freezing rain	4.0
Wet conditions	3.9
Low water levels	3.8
Water quality	3.8
Creek flooding	3.6
Late spring frost	3.5
Increase water demand	3.5
Heavy snow	3.5
Vector-borne disease	3.5
Drought	3.5
Extreme heat	3.5
Increased active transportation	3.3
Cooling demand	3.3
Freeze-thaw cycles	3.2
Longer growing season	2.7
Increased summer recreation season	2.5
Loss of winter recreation	2.5
Heating demand	2.3
Grass fire	2.2
Forest fire	2.2

Figure 4-1 Vulnerability of Burlington to Climate Hazards



Notes: The circled solid dots in the matrix indicate climate opportunities.

Figure 4-2 Vulnerability Heat Map for Burlington

The City is most **vulnerable** to the following climate hazards (with vulnerability scores of four or higher):

High water levels in Lake Ontario

High winds

Mismatching timing of plant & animal lifecycles

Air quality

Shifting ecoregions

Stormwater flooding

Invasive species and pests

Freezing rain

4.2 Severity of Consequences

For each climate hazard and opportunity, participants at the risk assessment workshops scored the severity level of each consequence listed in the impact statement individually. Regarding drought, for example, the following listed consequences were scored individually:

- Reduced crop / forage yields and productivity.
- Damage to trails, parks, playing fields.
- Increased tree mortality.
- Increased blowing dust.
- Increased stress on aquatic and terrestrial.

The mean score for each listed consequence was then estimated across all participants who provided a score for that consequence (1 Low to 5 High). For the purpose of the risk assessment, the overall consequence score assigned to each climate hazard and opportunity is the maximum mean score across all listed consequences for that hazard or opportunity. This is in keeping with the precautionary principle and the principle behind the use of greatest plausible change (i.e., working with RCP 8.5). For example, the mean score across all workshop participants for each drought consequence is shown below:

- 2.8: reduced crop / forage yields and productivity).
- 3.1: damage to trails, parks, playing fields.
- 3.4: increased tree mortality.
- 2.1: increased blowing dust.
- 3.4: Increased stress on aquatic and terrestrial.

Hence, drought is assigned a consequence score of 3.4, the maximum score across all consequences.

The results of the consequence assessment are shown in **Figure 4-3**. The most severe consequences for Burlington are assessed to arise from extreme heat events, and specifically, heat stress to residents. This is followed by high water levels on Lake Ontario (with erosion of beaches and shoreline habitat the highest ranked consequence), then stormwater flooding (with basement flooding the highest ranked consequence). The least severe consequences for Burlington are assessed to arise from grass fires, followed by loss of winter recreation and increased water demand.

Regarding the climate opportunities, the largest benefits are assessed to result from both increased summer recreation (with an extended tourism season the highest ranked benefit) and increased active transportation (with increased physical activity and associated health outcomes the highest ranked benefit). Though, for both of these opportunities, the difference in assessed benefits with respect to a longer growing season is negligible.

4.3 Likelihood of Climate Hazards

The results of the likelihood assessment for each climate hazard and opportunity are summarised in **Table 4-3**. In total, 14 hazards are estimated as “almost certain” to occur in the near future (i.e., the likelihood score = 5) at the defined threshold or intensity level. Only two hazards are unlikely to occur over this period based on the defined threshold: creek flooding (current 1:100 year return period or 1% probability event will increase to a 1.8% probability in the 2060s) and low water levels. All three “opportunities” are likely to occur in the near future.

Table 4-3 Likelihood of Climate Hazards and Opportunities Occurring at the Defined Threshold of Intensity Level

Hazards	Recent Past		Near future (2060s)		Data source/notes
	Annual probability	Likelihood score	Annual probability	Likelihood score	
1. High winds		5		5	Environment and Climate Change Canada. 0.6 events per year (2012-2019)
2. Shifting ecoregion				5	Professional judgement
3. Freezing rain		5		5	Environment and Climate Change Canada. 1.9 events per year (2013-2019)
4. Wet conditions	40%	4	56%	5	Climate Atlas of Canada. Estimate of annual exceedance probability
5. Water quality (algal bloom)		5		5	Professional judgement [2 algal blooms (blue-green algae) in the past 5 years]
6. Heavy snow		5		5	Environment and Climate Change Canada. 1.3 events per year (2014-2019)
7. Extreme heat	1%-2%	2	41%	4	Climate Atlas of Canada. Estimate of annual exceedance probability
8. Cooling demand	<1%	1	58%	5	Climate Atlas of Canada. Estimate of annual exceedance probability
9. Freeze-thaw cycles	98%	5	68%	5	Climate Atlas of Canada. Estimate of annual exceedance probability
10. Late spring frost	95%	5	60%	5	Climate Atlas of Canada. Estimate of annual exceedance probability
11. High water levels (Lake Ontario)	1%	1		3	Department of Fisheries and Oceans; W.F. Baird & Associates Report
12. Stormwater flooding	1%	1	2.4%	3	Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change
13. Mismatched timing of plant and animal lifecycles				4	Professional judgement
14. Air quality		3		3	Burlington AQHI. 1 event between 2015 and 2020
15. Invasive species and pests				3	Professional judgement
16. Increased water demand	1%-2%	2	72%	5	Climate Atlas of Canada. Estimate of annual exceedance probability
17. Vector-borne disease	0%	1	51%	5	Boyd et al (2020) Costing Climate Change Impacts on Human Health Across Canada; Climate Atlas of Canada (estimate of annual exceedance probability)
18. Heating demand	100%	5	57%	5	Climate Atlas of Canada. Estimate of annual exceedance probability

Hazards	Recent Past		Near future (2060s)		Data source/notes
	Annual probability	Likelihood score	Annual probability	Likelihood score	
19. Drought				3	Canadian Drought Monitor (20-25 year event)
20. Loss of winter recreation	100%	5	55%	5	Climate Atlas of Canada. Estimate of annual exceedance probability
21. Creek flooding	1%	1	1.8%	2	Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change - HAMILTON RBG
22. Low water levels		2		2	Professional judgement
23. Grass fire		5		5	Burlington Fire Department (estimated 1-2 per year historically)
24. Forest fire		3		3	Professional judgement
Opportunities					
1. Longer growing season	1%-2%	2	45%	4	Climate Atlas of Canada. Estimate of annual exceedance probability
2. Increased summer recreation season	1%-2%	2	45%	4	Climate Atlas of Canada. Estimate of annual exceedance probability
3. Increased active transportation	1%-2%	2	45%	4	Climate Atlas of Canada. Estimate of annual exceedance probability

4.4 Level of Risk

The outcomes of the vulnerability, likelihood and consequence assessments are pulled together to assign an overall level of risk to each climate hazard and opportunity. Specifically, the level of risk assigned a climate hazard or opportunity is given by:

Vulnerability score [1-5] x Likelihood score [1-5] x Consequence score [1-5] =Risk [1-125]

The level of risk assigned to each climate hazard and opportunity affecting Burlington in the near future (2051-2080) is shown in **Figure 4-3**. The results of the risk assessment are also presented in the form of a 'heat map' in **Figure 4-4**, which plots each climate hazard and opportunity in a Cartesian plane based on its likelihood score (x-axis) and maximum mean consequence score (y-axis). Consistent with the results in **Figure 4-3**, those climate hazards and opportunities to which Burlington was assessed to be most at risk (or benefit most, for opportunities) are located towards the upper right-hand corner of the heat map. The estimated risk levels for individually defined consequences are provided in Appendix B.

High winds were assessed to represent the highest level of risk for Burlington in the near future, primarily because of the City's relative high vulnerability to this hazard and its high likelihood (a score of 5 out of 5) of occurring at the defined intensity level. The next highest level of risk is associated with shifting ecoregions, followed by freezing rain, wet conditions, and water quality (algal bloom) issues. All of these climate hazards also have a high likelihood of occurring at the defined intensity level. The assessed likelihood score in combination with a medium to high vulnerability score and a medium to high consequence score is why these hazards are emerging as top priority risks.

Across these top five rated risks, only wet conditions and water quality (algal bloom) issues have several common climate drivers—specifically, relating to precipitation extremes (indicated by the blue Xs in the orange shaded cells in **Figure 4-5**): heavy precipitation days, short duration, high intensity rainfall, maximum 1-day precipitation, and maximum 5-day precipitation.

The climate hazards representing the lowest level of risk for Burlington are grass fires and forest fires. In the former case, this is primarily due to Burlington's low vulnerability to grass fires and low anticipated consequences should a fire occur. In the latter case, this is largely because the likelihood of a forest fire occurring at the defined intensity level is medium, and Burlington's vulnerability to forest fires is relatively low.

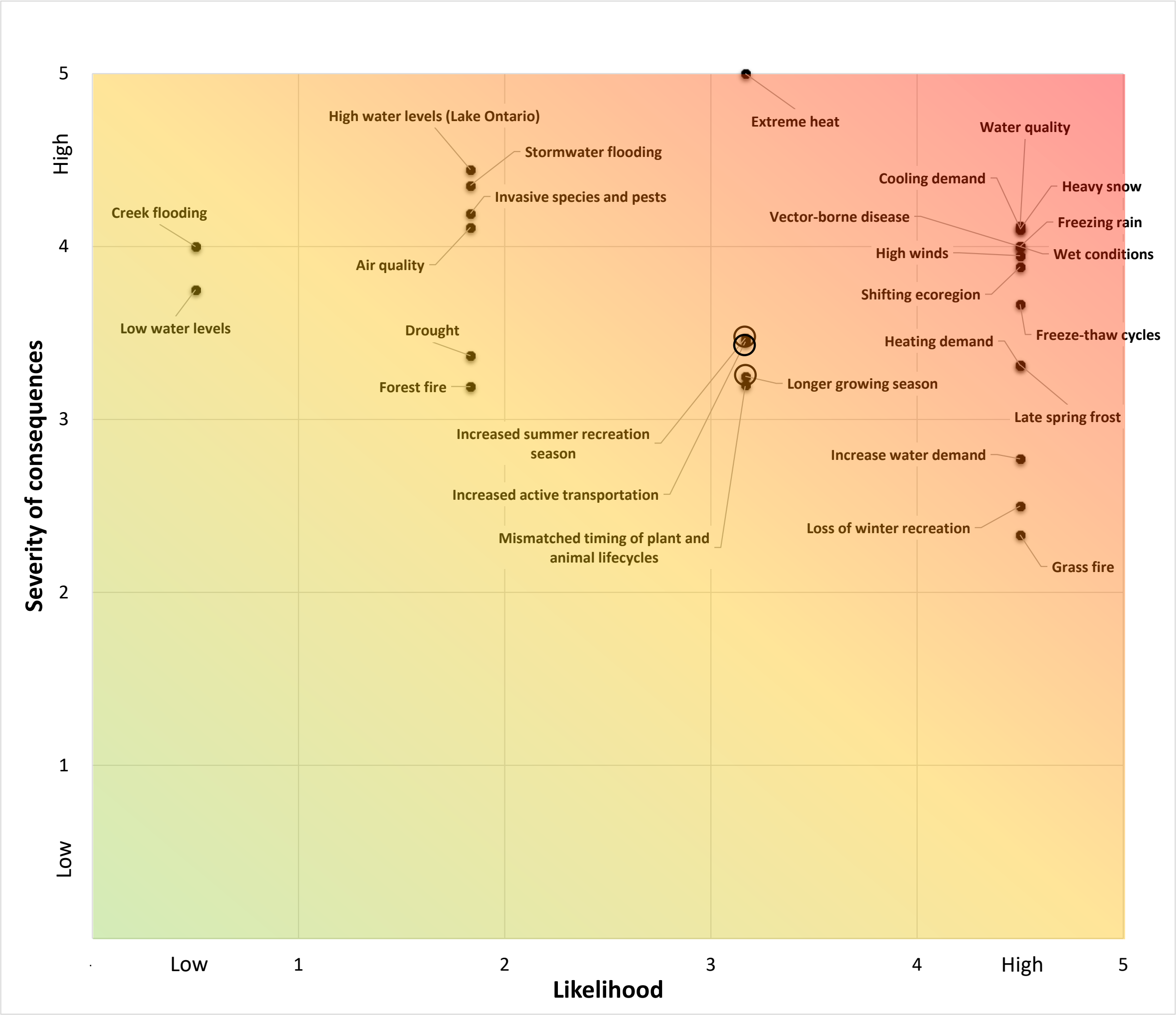
Regarding the three climate opportunities, increased active transport is assessed as providing the largest expected benefits for Burlington, primarily because of Burlington's higher propensity to seize these benefits vis-à-vis the other two opportunities.

	Vulnerabiltiy		Consequence		Likelihood		Risk		
Hazards	High water levels (Lake Ontario)	4.2	Extreme heat	5.0	Wet conditions	5.0	High winds	81.7	1
	High winds	4.1	High water levels (Lake Ontario)	4.4	Water quality	5.0	Shifting ecoregion	79.4	2
	Mismatched timing of plant and animal lifecycles	4.1	Stormwater flooding	4.4	Grass fire	5.0	Freezing rain	79.3	3
	Air quality	4.1	Invasive species and pests	4.2	Freezing rain	5.0	Wet conditions	79.0	4
	Shifting ecoregion	4.1	Water quality	4.1	High winds	5.0	Water quality	77.8	5
	Stormwater flooding	4.1	Air quality	4.1	Heavy snow	5.0	Heavy snow	71.8	6
	Invasive species and pests	4.0	Cooling demand	4.1	Vector-borne disease	5.0	Vector-borne disease	70.0	7
	Freezing rain	4.0	Heavy snow	4.1	Loss of winter recreation	5.0	Extreme heat	69.7	8
	Wet conditions	3.9	Wet conditions	4.0	Shifting ecoregion	5.0	Cooling demand	67.6	9
	Low water levels	3.8	Creek flooding	4.0	Late spring frost	5.0	Freeze-thaw cycles	59.3	10
	Water quality	3.8	Freezing rain	4.0	Increase water demand	5.0	Late spring frost	58.3	11
	Creek flooding	3.6	High winds	3.9	Freeze-thaw cycles	5.0	High water levels (Lake Ontario)	55.4	12
	Late spring frost	3.5	Shifting ecoregion	3.9	Cooling demand	5.0	Stormwater flooding	53.1	13
	Increase water demand	3.5	Low water levels	3.8	Heating demand	5.0	Mismatched timing of plant and animal lifecycles	52.8	14
	Heavy snow	3.5	Freeze-thaw cycles	3.7	Extreme heat	4.0	Air quality	50.5	15
	Vector-borne disease	3.5	Drought	3.4	Mismatched timing of plant and animal lifecycles	4.0	Invasive species and pests	50.3	16
	Drought	3.5	Late spring frost	3.3	Drought	3.0	Increase water demand	48.7	17
	Extreme heat	3.5	Heating demand	3.3	Stormwater flooding	3.0	Heating demand	37.3	18
	Cooling demand	3.3	Mismatched timing of plant and animal lifecycles	3.2	High water levels (Lake Ontario)	3.0	Drought	35.3	19
	Freeze-thaw cycles	3.2	Forest fire	3.2	Forest fire	3.0	Loss of winter recreation	31.5	20
	Loss of winter recreation	2.5	Increase water demand	2.8	Air quality	3.0	Creek flooding	28.8	21
	Heating demand	2.3	Vector-borne disease	4.0	Invasive species and pests	3.0	Low water levels	28.6	22
	Grass fire	2.2	Loss of winter recreation	2.5	Creek flooding	2.0	Grass fire	25.6	23
	Forest fire	2.2	Grass fire	2.3	Low water levels	2.0	Forest fire	21.0	24
Opportunities	Increased active transportation	3.3	Increased summer recreation season	3.5	Increased active transportation	4.0	Increased active transportation	45.5	1
	Longer growing season	2.7	Increased active transportation	3.5	Increased summer recreation season	4.0	Increased summer recreation season	35.3	2
	Increased summer recreation season	2.5	Longer growing season	3.3	Longer growing season	4.0	Longer growing season	35.2	3

Highest risk → Lowest risk

Note: the risk score for a particular climate hazard or opportunity may differ from the product of the scores for the three determinants of risk (vulnerability x likelihood x consequence) due to rounding.

Figure 4-3 Level of Risk Assessed for Climate Hazards Affecting Burlington in the Near Future (2051-2080)



Notes: The circled solid dots in the matrix indicate climate opportunities. For ease of presentation, the likelihood scores have been re-scaled to fit between the grid lines as opposed to sitting on the grid lines. For example, all climate hazards assessed a likelihood score of 5 are shown between 4 and 5 in the heat map; this avoids placing hazards on the secondary y-axis.

Figure 4-4 Climate Risk Heat Map for Burlington

		High winds		Shifting ecoregions				Freezing rain		Wet conditions				Water quality									
		Wind gusts	Wind pressures	Mean annual temperature	Mean annual precipitation	Growing Degree Days (+5°C)	Seasonality	Freezing precipitation	Freezing Degree Days	Heavy precipitation days	Short duration, high intensity rainfall	Max 1-day precipitation	Max 5-day precipitation	Heat waves	Heavy precipitation days	Hot season	Max 1-day precipitation	Max 5-day precipitation	Mean maximum summer temperature	Mean summer precipitation	Short duration, high intensity rainfall	Snow loads	Very hot and extremely hot days
High winds	Wind gusts																						
	Wind pressures																						
Shifting ecoregions	Mean annual temperature																						
	Mean annual precipitation																						
	Growing Degree Days (+5°C)																						
	Seasonality																						
Freezing rain	Freezing precipitation																						
	Freezing Degree Days																						
Wet conditions	Heavy precipitation days														X								
	Short duration, high intensity rainfall																				X		
	Max 1-day precipitation																X						
	Max 5-day precipitation																	X					
Water quality	Heat waves																						
	Heavy precipitation days									X													
	Hot season																						
	Max 1-day precipitation											X											
	Max 5-day precipitation												X										
	Mean maximum summer temperature																						
	Mean summer precipitation																						
	Short duration, high intensity rainfall										X												
	Snow loads																						
	Very hot and extremely hot days																						

Figure 4-5 Common Climate Drivers Between Top Five Risks

5 PRIORITIES FOR ACTION PLANNING

Now that a list of climate hazards and opportunities have been generated and assessed, they need to be prioritised to decide which are taken forward to the adaptation planning phase. Priorities are typically pre-determined based on a combination of the estimated risk rating (and its sub-components) and the City's 'risk appetite'. Risk appetite refers to both: (a) the amount of risk the City is willing to tolerate; and (b) the type and nature of the risk the City believes it is most vulnerable to. Regarding (b) for example, Burlington may accept some level of financial risk to operations but is unwilling to tolerate risks to the health and safety of residents. In effect, it is not the absolute value of an assessed risk which is important; rather, it is whether or not the risk is regarded as tolerable by Burlington, or how far the risk is away from tolerability, which is important. The less acceptable the risk, the higher the priority which should be given to addressing it.

When evaluating climate opportunities, the concept of risk appetite embraces consideration of how much the City is prepared to actively put at risk to seize the expected benefits of the opportunity.

Risk appetite is therefore expressed as a set of boundaries providing clear guidance on which climate hazards and opportunities to take forward to action planning based on the results of the vulnerability and risk assessments.

In the absence of a pre-determined risk appetite for the City, the following rules are adopted as summarized in **Table 5-1**.

Table 5-1 Adaptation Planning Priority Rules

Priority	Risk Score	Adaptation Planning
Extreme	Greater or equal to 90th percentile [>= 77]	Considered in adaptation planning process
High	80th to 90th percentile [69 to <77]	
Medium	60th to 80th percentile [51 to <69]	
Low	Less than 60th percentile [<51], except if consequence score is greater or equal to 4	Not considered in adaptation planning process

Figure 5-1 divides the climate hazards and opportunities) into extreme, high, medium, and low priorities for the adaptation action planning phase of the project, based on the overall assessed risk score. Each climate hazard contains a mix of low to high priority consequences—as each consequence was scored individually.

The following five additional consequences are prioritized for adaptation planning since they have a consequence score greater or equal to 4, although a risk score less than the 60th percentile:

- Negative health outcomes [Air quality].
- Invasive species and pests [Invasive species and pests].
- Damage to lakeshore active transport and pathway network [High water levels (Lake Ontario)].
- Flooding of roads along shoreline [High water levels (Lake Ontario)].
- Damage and erosion to creek banks [Creek flooding].

In total, 38 individual consequences are being taken forward. All the consequences associated with the climate "opportunities" considered were assessed as low priorities (i.e., with overall risk scores less than 51). See **Appendix C** for further details on the scoring of all defined consequences.

Climate hazards	Likelihood Score	Vulnerability Score	Consequences Score	Risk Score	Adaptation priority
High winds	5.0	4.1	3.9	81.7	EXTREME
Shifting ecoregion	5.0	4.1	3.9	79.4	
Freezing rain	5.0	4.0	4.0	79.3	
Wet conditions	5.0	3.9	4.0	79.0	
Water quality	5.0	3.8	4.1	77.8	
Heavy snow	5.0	3.5	4.1	71.8	HIGH
Vector-borne disease	5.0	3.5	4.0	70.0	
Extreme heat	4.0	3.5	5.0	69.7	
Cooling demand	5.0	3.3	4.1	67.6	MEDIUM
Freeze-thaw cycles	5.0	3.2	3.7	59.3	
Late spring frost	5.0	3.5	3.3	58.3	
High water levels (Lake Ontario)	3.0	4.2	4.4	55.4	
Stormwater flooding	3.0	4.1	4.4	53.1	
Mismatched timing of plant and animal lifecycles	4.0	4.1	3.2	52.8	
Air quality	3.0	4.1	4.1	50.5	LOW
Invasive species and pests	3.0	4.0	4.2	50.3	
Increase water demand	5.0	3.5	2.8	48.7	
Heating demand	5.0	2.3	3.3	37.3	
Drought	3.0	3.5	3.4	35.3	
Loss of winter recreation	5.0	2.5	2.5	31.5	
Creek flooding	2.0	3.6	4.0	28.8	
Low water levels	2.0	3.8	3.8	28.6	
Grass fire	5.0	2.2	2.3	25.6	
Forest fire	3.0	2.2	3.2	21.0	
Climate opportunities	**Likelihood** Score	**Vulnerability** Score	**Consequences** Score	**Benefit** Score	**Adaptation priority**
Increased active transportation	4.0	3.3	3.5	45.5	LOW
Increased summer recreation season	4.0	2.5	3.5	35.3	
Longer growing season	4.0	2.7	3.3	35.2	

Note: The risk score for a particular climate hazard or opportunity may differ from the product of the scores for the three determinants of risk (vulnerability x likelihood x consequence) due to rounding.

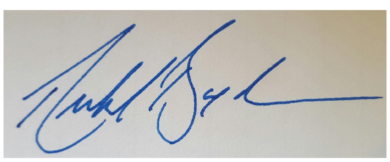
Figure 5-1 Recommended Priorities for the Adaptation Action Planning Phase of the Project

CLOSURE

This report was prepared for the City of Burlington to assess the vulnerability and risks of climate hazards to the community of Burlington. The results inform the priorities to take forward to adaptation planning.

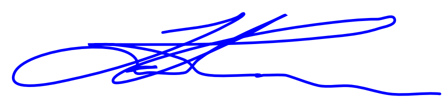
The services provided by Associated Engineering (Ont.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (Ont.) Ltd.



Richard Boyd, Ph.D.
All One Sky Foundation
Vulnerability and Risk Analyst

Jeff Zukiwsky, MRM, RPP
All One Sky Foundation
Climate Resilience Planner



Twyla Kowalczyk, M.Sc., P.Eng.
Associated Engineering
Project Manager

TK/da

APPENDIX A - VULNERABILITY AND RISK WORKSHOP ATTENDANCE TABLE

Table A-1 City Staff Stakeholder List

Department	Name	Workshop #			
		1A	1B	2A	2B
Building and Bylaw	Jackie Murphy	●	●		●
City Manager's Office	Jeff Crowder			●	●
Community Planning	Alison Enns	●			
Community Planning	Laura Ross		●	●	●
Community Planning (staff liaison on behalf of Burlington Agricultural and Rural Affairs Advisory Committee)	Kelly Cook				●
Conservation Halton, Planning and Watershed Management (external agency)	Chitra Gowda	●	●	●	●
Conservation Halton, Planning and Watershed Management (external agency)	Kim Barrett	●	●	●	●
Corporate Legal Services	Cecilia Essien	●			
Engineering Services	Ingrid Vanderbrug	●	●	●	●
Engineering Services	Amy Daca	●	●	●	●
Engineering Services	Umar Malik	●	●	●	●
Environment, Infrastructure and Community Services (EICS)	Ken Pirhonen		●		
EICS	Paul Swioklo	●	●	●	●
EICS	Fleur Storace-Hogan	●	●	●	●
EICS	Lynn Robichaud	●	●		●
Finance	Ellen Chen	●	●		
Fire	Amber Rushton				●
Halton Region, CAO's office (external agency)	Samantha Thompson	●	●	●	●
Human Resources	Matt Girodat		●	●	●
Recreation, Community and Culture	Denise Beard		●	●	●
Roads, Parks and Forestry	Matt Koevoets			●	
Roads, Parks and Forestry	Steve Robinson	●	●		●
Roads, Parks and Forestry	Kyle McLoughlin			●	
Roads, Parks and Forestry	Nadia Blackburn	●			
Transportation	Kaylan Edgcumbe	●			
Transportation	Nicholas Pongetti		●	●	●

Halton Region used a one-window approach where one member from the CAO's office attended workshops, consulted with staff from different departments, then submitted comments on behalf of the Region.

Table A-2 Community Stakeholder List

Association	Name	Workshop #			
		1A	1B	2A	2B
BurlingtonGreen Environmental Association	Marwa Selim	●	●	●	●
Burlington Hydro Inc.	Christine Hallas	●		●	●
BOMA (Building Owners and Managers Association) Canada	Bala Gnanam	●	●		●
Centre for Climate Change Management at Mohawk College	Emily Vis		●	●	
Centre for Climate Change Management at Mohawk College	Kate Flynn	●			
Community Development Halton	Mike Nixon	●	●		
Enbridge Gas	David Dyer	●	●	●	●
Halton Environmental Network	Stephanie Bush		●		●
Ministry of Transportation	Kyle Perdue	●	●	●	●
Royal Botanical Gardens	Chris McAnally	●	●	●	●
Sustainability Leadership	Rafiq Dhanji	●	●	●	
United Way Halton and Hamilton	Vivien Underdown	●	●	●	●
West End Home Builders' Association	Michelle Diplock	●		●	●
West End Home Builders' Association	Tom Hilditch		●		

The following organizations agreed to participate in the CRB project, but were unable to attend these workshops:
- Burlington Agricultural and Rural Affairs Advisory Committee.
- Burlington Economic Development.
- Burlington Sustainable Development Advisory Committee.
- Halton Catholic District School Board.

The following organizations were invited, but were unable to participate in the CRB project due to staff capacity:
- Halton District School Board.
- Metrolinx.

Invited, but no response received:
- 407-ETR

APPENDIX B - SUMMARY OF CLIMATE IMPACT STATEMENTS AND VULNERABILITY AND RISK ASSESSMENT RESULTS

Hazards

High Winds

Climate driver(s)		• Hourly and daily wind gusts [Increase] • Hourly wind pressures [Increase]		
Definition / threshold		Sustained winds of 70 km/h or more; and/or gusts to 90 km/h or more		
Vulnerability		Sensitivity [4.3] = **High**	Lack of Coping Capacity [3.9] = **Med-High**	Vulnerability [4.1] = **High**
Likelihood	**Historic**	**[5]** Annual probability > 50% historically [0.6 events per year from 2012-2019]		
	Future	**[5]** Annual probability > 50% in the 2060s		

Consequences	**Consequence score**	**Risk score**
Power outages from tree branches breaking and damaging electricity infrastructure, disruption to services (water supply, etc.)	3.9	**81.7**
Damage to trees / tree branches resulting in loss of ecosystem services, and increased clean-up costs	3.8	**78.6**
Property damage (buildings, cars, etc.), from tree branches breaking, requiring clean-up, repair and replacement expenditures	3.7	**76.8**
Damage to buildings and facilities directly from high winds, resulting in repair and replacement expenditures	3.1	**63.1**
Soil erosion, resulting in loss of ecosystem services	2.8	**57.7**
Delays and/or cancellations of outdoor events and activities	2.5	**51.2**
Road traffic accidents and transportation delays, including active transportation due to hazardous conditions	2.4	**49.4**
Injuries and potential fatalities from blowing debris	2.2	**45.0**

Shifting Ecoregion

Climate driver(s)		• Mean annual temperature [Increase] • Mean annual precipitation [Increase] • Growing Degree Days (+5°C) [Increase] • Seasonality [Decrease]		
Definition / threshold		Northward shift of ecoregion climate envelopes		
Vulnerability		Sensitivity [3.9] = **Med-High**	Lack of Coping Capacity [4.3] = **High**	Vulnerability [4.1] = **High**
Likelihood	**Historic**			
	Future	**[5]** 91-100% probability in the 2060s (single event)		
Consequences			**Consequence score**	**Risk score**
Shifting ecoregions, resulting in fewer native plant and animal species and more invasive species, leading to impairment or loss of ecosystem services, including biodiversity and habitat services			3.9	**79.4**

Freezing Rain

Climate driver(s)		• Freezing precipitation [Decrease] • Freezing Degree Days [Decrease]		
Definition / threshold		A freezing rain event		
Vulnerability		Sensitivity [4.1] = **High**	Lack of Coping Capacity [3.8] = **Med-High**	Vulnerability [4.0] = **Med-High**
Likelihood	**Historic**	**[5]** Annual probability historically [1.9 events per year from 2013-2019]		
	Future	**[5]** Annual probability > 50% in the 2060s		
Consequences			**Consequence score**	**Risk score**
Road traffic accidents and transportation delays, including active transportation due to hazardous conditions			4.0	**79.3**
Power outages from tree branches breaking and damaging electricity infrastructure, expenditure on repairs and replacement, and disruption to services (power supply, water supply, etc.)			4.0	**78.5**
Damage to trees and shrubs resulting in loss of ecosystem services, and increased clean-up costs			3.9	**78.3**
Injuries from falls on iced surfaces (e.g., sidewalks), in particular for elderly citizens			3.6	**71.0**
Increased salt use and sanding, resulting in increased maintenance and operational costs			3.5	**70.0**
Property damage (buildings, cars, etc.), from tree branches breaking, requiring clean-up, repair and replacement expenditures			3.3	**65.0**

Wet Conditions

Climate driver(s)		• Intense rainfall [Increase] • Heavy precipitation days [Increase] • Max 1-day and 5-day precipitation [Increase]		
Definition / threshold		73mm of precipitation in a 5-day period (the projected wettest 5-day period in the 2060's)		
Vulnerability		Sensitivity [4.0] = **Med-High**	Sensitivity [3.9] = **Med-High**	Sensitivity [3.9] = **Med-High**
Likelihood	**Historic**	**[4]** 40% annual probability historically		
	Future	**[5]** 56% annual probability in the 2060s [an increase of 15% from the historic value]		

Consequences	**Consequence score**	**Risk score**
Basement flooding (sewer backups, foundation infiltration, basement windows, etc.) resulting in exposure to pathogens and associated illness, as well as clean-up and restoration expenditures	4.0	**79.0**
Flooding of agricultural fields, resulting in delayed seeding or harvesting, leading to reduced productivity	3.7	**73.2**
Damage to parks and sports fields, resulting in temporary loss of use, and increased maintenance expenditures	3.6	**70.9**
Increased risk of illness from mold growth if properties not adequately restored during recovery	3.2	**62.5**

Water Quality (Algal Bloom)

Climate driver(s)		• Drought [Expected increase] • Extreme heat [More] • Stormwater flooding [Increase] • Creek flooding [Increase] • Low water levels		
Definition / threshold		An algal bloom at Burlington public beaches		
Vulnerability		Sensitivity [3.7] = **Med-High**	Lack of Coping Capacity [3.9] = **Med-High**	Vulnerability [3.8] = **Med-High**
Likelihood	**Historic**	**[5]** Annual probability > 50% historically		
	Future	**[5]** Annual probability > 50% in the 2060s		

Consequences	**Consequence score**	**Risk score**
Restricted access to, closure of beach- and water-based recreation activities	4.1	**77.8**
Increased stress on aquatic habitat, resulting in impairment or loss of ecosystem services	3.7	**69.6**
Impacts to municipal water treatment processes, and potential contamination and human health risks	3.3	**63.0**

Heavy Snow

Climate driver(s)		• Snow loads [Decrease] • Moisture from open winter surface on Great Lakes [Expected increase]		
Definition / threshold		15 cm or more of snow fall within 12 hours or less		
Vulnerability		Sensitivity [3.8] = **Med-High**	Lack of Coping Capacity [3.2] = **Med-High**	Vulnerability [3.5] = **Med-High**
Likelihood	**Historic**	**[5]** Annual probability > 50% historically [1.3 events per year from 2014-2019]		
	Future	**[5]** Annual probability > 50% in the 2060s		

Consequences	**Consequence score**	**Risk score**
Road traffic accidents and transportation delays, including active transportation due to hazardous conditions	4.1	**71.8**
Maintenance and operational costs from salt use, sanding and snow removal	3.9	**68.2**
Damage to trees / tree branches resulting in loss of ecosystem services, and increased clean-up costs	2.8	**48.1**
Health risks, particularly for vulnerable populations (elderly) from shovelling	2.6	**45.7**
Property damage (buildings, cars, etc.), from tree branches breaking, requiring clean-up, repair and replacement expenditures	2.5	**42.9**
Power outages from tree branches breaking and damaging electricity infrastructure, disruption to services (water supply, etc.)	2.5	**42.9**

Vector-Borne Diseases

Climate driver(s)		• Mean annual temperature [Increase] • Mean minimum winter temperature [Increase] • Total annual precipitation [Increase]		
Definition / threshold		54 cases of Lyme disease per 100,000 [the projected mean value for the 2080's]		
Vulnerability		Sensitivity [3.5] = **Med-High**	Lack of Coping Capacity [3.5] = **Med-High**	Vulnerability [3.5] = **Med-High**
Likelihood	**Historic**	**[1]** 0% annual probability historically		
	Future	**[5]** 51% annual probability in the 2060s		

Consequences	**Consequence score**	**Risk score**
Negative health outcomes which can result in hospitalization and occasionally death, resulting in direct costs, indirect costs, and welfare losses	4.0	70.0

Extreme Heat

<table>
<tr><td colspan="2">Climate driver(s)</td><td colspan="4">Mean maximum summer temperature [Increase]
Very hot and extremely hot days [Increase]
Heat waves [Increase]
Hot season [Increase]
Tropical nights [Increase]</td></tr>
<tr><td colspan="2">Definition / threshold</td><td colspan="4">7 heat waves (three consecutive days of temperatures above +30°C) in a year</td></tr>
<tr><td colspan="2">Vulnerability</td><td>Sensitivity [4.2] = High</td><td colspan="2">Lack of Coping Capacity [2.8] = Medium</td><td>Vulnerability [3.5] = Med-High</td></tr>
<tr><td rowspan="2">Likelihood</td><td>Historic</td><td colspan="4">[2] >1% annual probability historically [About 2 heat waves per year]</td></tr>
<tr><td>Future</td><td colspan="4">[4] 41% annual probability in the 2060s</td></tr>
<tr><td colspan="4">Consequences</td><td>Consequence score</td><td>Risk score</td></tr>
<tr><td colspan="4">Negative health outcomes which can result in hospitalization and premature death, resulting in direct costs, indirect costs, and welfare losses</td><td>5.0</td><td>69.7</td></tr>
<tr><td colspan="4">Increased heat stress for animals and livestock, causing distress, potential mortality, and productivity losses</td><td>3.1</td><td>43.8</td></tr>
<tr><td colspan="4">Impacts to building mechanical systems resulting in repair and replacement expenditures, and potential for disruption to goods and service provision</td><td>3.1</td><td>43.7</td></tr>
<tr><td colspan="4">Reduction in labour supply and labour productivity in high-risk sectors, resulting in lower economic output</td><td>3.1</td><td>43.3</td></tr>
<tr><td colspan="4">Decline in use of outdoor recreation facilities and sports fields, as well as active transportation, leading to reduced well-being</td><td>3.0</td><td>41.8</td></tr>
<tr><td colspan="4">Temporary closure of buildings (e.g., schools) without air conditioning, disrupting services and daily life”</td><td>2.6</td><td>36.5</td></tr>
</table>

Cooling Demand

Climate driver(s)		• Cooling Degree Days [Increase] • Mean summer temperature [Increase] • Extreme heat [More]		
Definition / threshold		A summer with Cooling Degree Days greater than or equal to 797 [the projected 2060's value]		
Vulnerability		Sensitivity [3.6] = **Med-High**	Lack of Coping Capacity [2.9] = **Medium**	Vulnerability [3.3] = **Med-High**
Likelihood	**Historic**	**[1]** <1% annual probability historically		
	Future	**[5]** 58% annual probability in the 2060s		

Consequences	**Consequence score**	**Risk score**
Increased investment expenditures and annual operating and maintenance expenses for space cooling	4.1	**67.6**
Power outages from increased peak demand for electricity and risk of power outages and disruption to services (power supply, water supply, ICT) with cascading disruption for other services (transport), economic activity and daily life	3.9	**65.0**
Greenhouse gas emissions and emissions of criteria air contaminants, depending on energy mix used to generate the electricity for air conditioning	3.9	**64.1**
Increase released heat to the atmosphere, increasing outside ambient air temperatures and **urban heat island effects**	3.9	**64.1**

*In 2020 93% of electricity in Ontario was from zero-carbon emitting sources.

Freeze-Thaw Cycles

Climate driver(s)		• Freeze-thaw cycles [Decrease]		
Definition / threshold		45 freeze-thaw cycles in a year [the projected mean value for the 2060s]		
Vulnerability		Sensitivity [3.4] = **Med-High**	Lack of Coping Capacity [3.1] = **Med-High**	Vulnerability [3.2] = **Med-High**
Likelihood	**Historic**	**[5]** 98% annual probability historically		
	Future	**[5]** 65% annual probability in the 2060s		

Consequences	**Consequence score**	**Risk score**
Damage to, and decreased service life of, buildings and infrastructure (foundations, walls, roofs, roads, sidewalks, parking lots, recreation facilities, pipes, culverts, etc.), resulting in disruption of services and increased repair and replacement expenditures	3.7	**59.3**

Late Spring Frost

Climate driver(s)		• Date of last spring frost [Earlier] • Variability date of last spring frost [Increase] • Mean spring temperature [Increase]		
Definition / threshold		A late spring frost [April 3 is the projected date of last spring frost in the 2060s]		
Vulnerability		Sensitivity [3.5] = **High**	Lack of Coping Capacity [3.5] = **Med-High**	Vulnerability [3.5] = **Med-High**
Likelihood	**Historic**	**[5]** 95% annual probability historically		
	Future	**[5]** 60% annual probability in the 2060s		
Consequences			**Consequence score**	**Risk score**
Warmer springs will lead to **early emergence of flowering crops, which are then susceptible to damage from late frosts** (associated with increased variability in the date of the last frost, even though the mean date is becoming earlier in the year), leading to output and financial losses for farmers and growers			3.3	**58.3**

High Water Levels in Lake Ontario

Climate driver(s)		• Mean annual precipitation [Increase] • Mean spring precipitation [Increase] • Mean winter precipitation [Increase] • Urban flooding [More] • Creek flooding [More]		
Definition / threshold		A water level on Lake Ontario of 75.92 metres (the 2019 high water level)		
Vulnerability		Sensitivity [4.3] = **High**	Lack of Coping Capacity [4.1] = **High**	Vulnerability [4.2] = **High**
Likelihood	**Historic**	**[1]** Annual probability < 1% historically [1:100-year event]		
	Future	**[3]** 2 - 10% annual probability in the 2060s		
Consequences			**Consequence score**	**Risk score**
Erosion of beaches and shoreline habitat, resulting in impairment or loss of ecosystem services, including recreation			4.4	**55.4**
Damage to lakeshore active transport and pathway network, resulting in expenditure on repairs and replacement, and closures and disruption to use			4.0	**49.9**
Flooding of roads along shoreline, leading to disruption of transport services, and expenditures on clean-up and repairs			4.0	**49.9**
Damage to lakeshore infrastructure, buildings and facilities, resulting in expenditure on repairs and replacement, closures and disruption to provision of goods & services, and evacuations			3.2	**39.5**

Stormwater Flooding

Climate driver(s)		• Intense rainfall [Increase] • Heavy precipitation days [Increase] • Max 1-day and 5-day precipitation [Increase]		
Definition / threshold		Rainfall intensity of 145 mm per hour over a 10-minute period [1:100 year]		
Vulnerability		Sensitivity [4.2] = High	Lack of Coping Capacity [3.9] = **Med-High**	Vulnerability [4.1] = **High**
Likelihood	**Historic**	**[1]** <1% annual probability historically [1:100 year]		
	Future	**[3]** 2 - 10% annual probability in the 2060s [1:42 year]		

Consequences	**Consequence score**	**Risk score**
Basement flooding (sewer backups, foundation infiltration, basement windows, etc.) resulting in exposure to pathogens and associated illness, as well as clean-up and restoration expenditures	4.4	**53.1**
Flooding of roads and parking lots, leading to disruption of transport services	3.7	**45.4**
Damage to buildings and facilities resulting in expenditure on repairs and replacement, closures and disruption to provision of public and private sector goods & services	3.4	**41.6**
Flooding of electricity infrastructure resulting in power outages, and expenditure on repairs and replacement, and disruption to services	3.2	**39.4**
Increased risk of illness from mold growth if properties not adequately restored during recovery	3.0	**36.6**

Mismatched Timing of Plant and Animal Lifecycles

Climate driver(s)		• Mean spring temperature [Increase] • Variability in mean spring temperature (Increase]		
Definition / threshold		Mismatch of climate conditions and/or photo-period for animals and plans, such as migratory birds		
Vulnerability		Sensitivity [4.0] = **Med-High**	Lack of Coping Capacity [4.3] = **High**	Vulnerability [4.1] = **High**
Likelihood	**Historic**			
	Future	**[4]** 50-90% probability in the 2060s (single event)		

Consequences	**Consequence score**	**Risk score**
Mismatched timing of plant and animal lifecycles (in conjunction with a stable photoperiod) (e.g., emergence of flowers and leaves, hibernating salamanders, returning migrant birds, reproductive cycles, etc.), resulting in **decreased reproduction and survival**, with cascading consequences for ecosystem services	3.2	**52.8**

Air Quality

Climate driver(s)		• Mean maximum summer temperature [Increase] • Extreme heat [More] • Grass fires [More]		
Definition / threshold		Air Quality Health Index (AQHI) of 7 or higher. High or very high health risk		
Vulnerability		Sensitivity [4.3] = **High**	Lack of Coping Capacity [3.9] = **Med-High**	Vulnerability [4.1] = **High**
Likelihood	**Historic**	**[3]** 2 - 10% annual probability in the 2060s [1 event between 2015 and 2020]		
	Future	**[3]** 2 - 10% annual probability in the 2060s		
Consequences			**Consequence score**	**Risk score**
Negative health outcomes which can result in hospitalization and premature death, resulting in direct costs, indirect costs, and welfare losses			4.1	**50.5**

Invasive Species and Pests

Climate driver(s)		• Mean minimum winter temperature [Increase] • Winter days [Decrease] • Growing season length [Increase] • Mean total spring precipitation [Increase] • Ice days [Fewer]		
Definition / threshold		Outbreak of a new invasive species affecting 10% of the City's urban tree canopy, native vegetation and gardens		
Vulnerability		Sensitivity [4.3] = **High**	Lack of Coping Capacity [3.7] = **Med-High**	Vulnerability [4.0] = **Med-High**
Likelihood	**Historic**			
	Future	**[3]** 30-49% probability in the 2060s (single event)		
Consequences			**Consequence score**	**Risk score**
Outbreak of a new invasive species resulting in damage or loss of native vegetation, gardens and urban tree canopy, requiring additional maintenance, repair and replacement expenditures			2.5	**31.5**

Increased Water Demand

Climate driver(s)		• Mean maximum summer temperature [Increase] • Drought [Expected increase] • Extreme heat [More]			
Definition / threshold		5% increase in summer water demand [associated with a projected increase in Mean Maximum Summer Temperature of 4.6°C]			
Vulnerability		Sensitivity [3.6] = **Med-High**	Lack of Coping Capacity [3.4] = **Med-High**	Vulnerability [3.5] = **Med-High**	
Likelihood	**Historic**	**[2]** >1% annual probability historically			
	Future	**[5]** 72% annual probability in the 2060s			
Consequences				**Consequence score**	**Risk score**
Increased outdoor water use for irrigation, pools, splash pads, fountains, etc., as well as fighting wildfires				2.8	**48.7**
Increased indoor domestic water demand, increasing pressure on the water treatment and distribution system and leading to increased costs				2.3	**40.4**

Heating Demand

Climate driver(s)		• Heating Degree Days [Decrease] • Mean winter temperature [Increase]			
Definition / threshold		A winter with greater than or equal to 2680 Heating Degree Days [the projected mean value for the 2060s]			
Vulnerability		Sensitivity [2.4] = **Medium**	Lack of Coping Capacity [2.1] = **Medium**	Vulnerability [2.3] = **Medium**	
Likelihood	**Historic**	**[5]** 100% annual probability historically			
	Future	**[5]** 57% annual probability in the 2060s			
Consequences				**Consequence score**	**Risk score**
Greenhouse gas emissions and emissions of criteria air contaminants, which will depend on the energy mix used to heat buildings and to generate electricity				3.3	**37.3**
Operation of space heating technologies, resulting in **annual operating and maintenance expenses**				3.2	**35.7**

Drought

<table>
<tr><td colspan="2">Climate driver(s)</td><td colspan="4">Mean summer precipitation [No change]
Mean summer temperature [Increase]
Extreme heat [More]</td></tr>
<tr><td colspan="2">Definition / threshold</td><td colspan="4">Extreme drought conditions [“D3” according to the Canadian Drought Monitor, a 20–25-year event]</td></tr>
<tr><td colspan="2">Vulnerability</td><td>Sensitivity [3.4] = Med-High</td><td>Lack of Coping Capacity [3.6] = Med-High</td><td colspan="2">Vulnerability [3.5] = Med-High</td></tr>
<tr><td rowspan="2">Likelihood</td><td>Historic</td><td colspan="4">[3] 2 - 10% annual probability in the 2060s</td></tr>
<tr><td>Future</td><td colspan="4">[3] 2 - 10% annual probability in the 2060s</td></tr>
<tr><td colspan="4">Consequences</td><td>Consequence score</td><td>Risk score</td></tr>
<tr><td colspan="4">Increased tree mortality resulting in loss of ecosystem services and increased replacement costs</td><td>3.4</td><td>35.3</td></tr>
<tr><td colspan="4">Increased stress on aquatic and terrestrial habitat, resulting in impairment or loss of ecosystem services</td><td>3.4</td><td>35.2</td></tr>
<tr><td colspan="4">Damage to trails, parks, playing fields leading to a loss of recreation amenity and increased repair and maintenance costs</td><td>3.1</td><td>32.0</td></tr>
<tr><td colspan="4">Reduced crop / forage yields and productivity, reducing farm incomes and agricultural GDP, and impacting local food prices and security</td><td>2.8</td><td>29.2</td></tr>
<tr><td colspan="4">Increased blowing dust, leading to higher operational costs for City (cleaning)</td><td>2.1</td><td>22.1</td></tr>
</table>

Loss of Winter Recreation

<table>
<tr><td colspan="2">Climate driver(s)</td><td colspan="4">Mild winter days (-5°C) [Decrease]
Freezing Degree Days [Decrease]
Frost-free season [Increase]</td></tr>
<tr><td colspan="2">Definition / threshold</td><td colspan="4">A mild winter, with greater than or equal to 27 Mild Winter Days [the projected mean value for the 2060s]</td></tr>
<tr><td colspan="2">Vulnerability</td><td>Sensitivity [2.2] = Medium</td><td>Lack of Coping Capacity [2.8] = Medium</td><td colspan="2">Vulnerability [2.5] = Medium</td></tr>
<tr><td rowspan="2">Likelihood</td><td>Historic</td><td colspan="4">[5] 100% annual probability historically</td></tr>
<tr><td>Future</td><td colspan="4">[5] 55% annual probability in the 2060s</td></tr>
<tr><td colspan="4">Consequences</td><td>Consequence score</td><td>Risk score</td></tr>
<tr><td colspan="4">Reduced outdoor winter recreation opportunities (ice skating, tobogganing, etc.), leading to a loss of recreation amenity (participation and quality of experience)</td><td>2.5</td><td>31.5</td></tr>
</table>

Creek Flooding

Climate driver(s)		• Intense rainfall [Increase] • Heavy precipitation days [Increase] • Max 1-day and 5-day precipitation [Increase]		
Definition / threshold		Creek flooding event defined as the 1:100 year 24-hour rainfall event [5.15 mm per hour]		
Vulnerability		Sensitivity [3.7] = **Med-High**	Lack of Coping Capacity [3.5] = **Medium**	Vulnerability [3.6] = **Med-High**
Likelihood	**Historic**	**[1]** <1% Annual probability in the 2060s [1:100 year]		
	Future	**[2]** 1 - 2% annual probability in the 2060s [1:55 year]		
Consequences			**Consequence score**	**Risk score**
Damage and erosion to creek banks, resulting in loss of habitat and ecosystem services			4.0	**28.8**
Basement flooding (sewer backups, foundation infiltration, basement windows, etc.) resulting in exposure to pathogens and associated illness, as well as clean-up and restoration expenditures			3.7	**26.6**
Flooding of roads, leading to disruption of transport services			3.1	**22.3**
Damage to homes and buildings, resulting in expenditure on repairs and replacement, and potential evacuations			2.9	**21.1**
Increased risk of illness from mold growth if properties not adequately restored during recovery			2.6	**18.5**

Low Water Levels in Creeks and Streams

Climate driver(s)		• Snow loads [Decrease] • Mean summer precipitation [No change] • Drought [Expected increase]		
Definition / threshold		Extreme low water conditions that threaten aquatic habitat and hydrological function		
Vulnerability		Sensitivity [3.7] = **Med-High**	Lack of Coping Capacity [3.9] = **Med-High**	Vulnerability [3.8] = **Med-High**
Likelihood	**Historic**	**[2]** >1% annual probability historically		
	Future	**[2]** >1% annual probability historically		
Consequences			**Consequence score**	**Risk score**
Increased water stress for aquatic plants and animals, resulting in disturbance to provision of ecosystem services			3.8	**28.6**
Reductions in water availability and drinking water supply, with activation of Conservation Authority's Low Water Response Plan			2.7	**20.3**

Grass Fire

Climate driver(s)		• Mean summer precipitation [No change] • Extreme heat [More] • Drought [Expected increase]			
Definition / threshold		An uncontrolled grass, brush of scrub fire within City limits, of more than 1 acre in size			
Vulnerability		Sensitivity [2.3] = **Med**	Lack of Coping Capacity [2.1] = **Med**	Vulnerability [2.2] = **Med**	
Likelihood	**Historic**	**[5]** Annual probability > 50% historically			
	Future	**[5]** Annual probability > 50% in the 2060s			
Consequences				**Consequence score**	**Risk score**
Damage to terrestrial habitat, resulting in impairment or loss of ecosystem services, including increasing carbon emissions				2.3	**25.6**
Transportation delays and disruptions due to smoke and reduced visibility, disrupting economic activity				1.9	**20.5**

Forest Fire

Climate driver(s)		• Mean summer precipitation [No change] • Extreme heat [More] • Drought [Expected increase]			
Definition / threshold		An unplanned fire - including unauthorized human-caused fires - occurring on forest lands			
Vulnerability		Sensitivity [2.3] = **Med**	Lack of Coping Capacity [2.1] = **Med**	Vulnerability [2.2] = **Med**	
Likelihood	**Historic**	**[1]** Annual probability < 1% historically			
	Future	**[3]** 30-49% probability in the 2060s			
Consequences				**Consequence score**	**Risk score**
Tree mortality resulting in loss of ecosystem services and increased replacement costs				3.2	**21.0**
Damage to terrestrial habitat, resulting in impairment or loss of ecosystem services, including increasing carbon emissions				2.9	**19.1**
Damage to (nature or built) sites of cultural or spiritual heritage, resulting in expenditure on repairs and replacement				2.4	**15.9**
Damage to infrastructure resulting in expenditure on repairs and replacement, and disruption to services (power supply, water supply, ICT)				2.3	**14.9**
Damage to buildings resulting in expenditure on repairs and replacement, evacuations and the need for temporary accommodation				2.1	**13.7**
Transportation delays and disruptions due to smoke and reduced visibility, disrupting economic activity				2.0	**12.9**

Opportunities

Increased Active Transportation

Climate driver(s)		• Mean annual and mean seasonal temperature [Increase] • Length of frost-free season [Increase] • Freezing Degree Days [Decrease] • Inclement weather, limiting factor [Increase]			
Definition / threshold		A frost-free season of 228 days [the projected mean value for the 2060's]			
Vulnerability		Sensitivity [3.1] = **Med-High**	Lack of Coping Capacity [3.5] = **Med-High**	Vulnerability [3.3] = **Med-High**	
Likelihood	**Historic**	**[2]** >1% annual probability historically.			
	Future	**[4]** 45% annual probability in the 2060s			
Consequences				**Consequence score**	**Risk score**
Increased physical activity and associated beneficial physical and mental health outcomes for participants				3.5	**45.5**
Increased use of active transportation networks, reducing vehicles use, congestion, noise, air pollution, and GHG emissions				3.0	**39.6**

Increased Summer Recreation Season

Climate driver(s)		• Mean spring temperature [Increase] • Mean fall temperature [Increase] • Length of frost-free season [Increase] • Heat waves and inclement weather, limiting factors [Increase]			
Definition / threshold		A frost-free season of 228 days [the projected mean value for the 2060's]			
Vulnerability		Sensitivity [3.0] = **Medium**	Lack of Coping Capacity [2.1] = **Medium**	Vulnerability [2.5] = **Medium**	
Likelihood	**Historic**	**[2]** >1% annual probability historically			
	Future	**[4]** 45% annual probability in the 2060s			
Consequences				**Consequence score**	**Risk score**
Extended summer tourism season with benefits for restaurants, hotels, etc.				3.5	**35.3**
Increased time to host outdoor festivals and events				3.4	**34.7**
Extended season for, and increased participation in outdoor recreation activities (pools, golf courses, parks, green spaces, etc.)				3.2	**32.9**

Longer Growing Season

<table>
<tr><td colspan="2">Climate driver(s)</td><td colspan="4">Length of frost-free season [Increase]
Date of last spring frost [Earlier]
Date of first fall frost [Later]
Mean spring temperature [Increase]
Mean fall temperature [Increase]
Mean spring precipitation, limiting factor [Increase]</td></tr>
<tr><td colspan="2">Definition / threshold</td><td colspan="4">A frost-free season of 228 days [the projected mean value for the 2060’s]</td></tr>
<tr><td colspan="2">Vulnerability</td><td>Sensitivity [2.8] = Medium</td><td>Lack of Coping Capacity [2.6] = Medium</td><td colspan="2">Vulnerability [2.7] = Medium</td></tr>
<tr><td rowspan="2">Likelihood</td><td>Historic</td><td colspan="4">[2] >1% annual probability historically</td></tr>
<tr><td>Future</td><td colspan="4">[4] 45% annual probability in the 2060s</td></tr>
<tr><td colspan="4">Consequences</td><td>Consequence score</td><td>Risk score</td></tr>
<tr><td colspan="4">Trees, plants and crops have a longer window to grow and mature, increasing productivity of crops on farms and home / community gardens</td><td>3.3</td><td>35.2</td></tr>
</table>

APPENDIX C - ESTIMATED RISK LEVELS BY INDIVIDUAL CONSEQUENCES

Consequences (climate hazard)	Likelihood	Vulnerability		Consequence		Risk		Adaptation priority
	Score	Score	Rank	Score	Rank	Score	Rank	
Power outages (High winds)	5.0	4.1	5	3.9	16	81.7	1	Extreme
Shifting ecoregions, resulting in fewer native plant and animal species and more invasive species (Shifting ecoregion)	5.0	4.1	15	3.9	22	79.4	2	
Road traffice accidents and transportation delays, including active transportation (Freezing rain)	5.0	4.0	22	4.0	9	79.3	3	
Basement flooding (Wet conditions)	5.0	3.9	28	4.0	9	79.0	4	
Damage to trees / tree branches (High winds)	5.0	4.1	5	3.8	23	78.6	5	
Power outages (Freezing rain)	5.0	4.0	22	4.0	15	78.5	6	
Damage to trees and shrubs (Freezing rain)	5.0	4.0	22	3.9	16	78.3	7	
Restricted access to, closure of beach- and water-based recreation activities (Water quality)	5.0	3.8	34	4.1	5	77.8	8	
Property damage (High winds)	5.0	4.1	5	3.7	26	76.8	9	High
Flooding of agricultural fields (Wet conditions)	5.0	3.9	28	3.7	27	73.2	10	
Road traffic accidents and transportation delays, including active transportation (Heavy snow)	5.0	3.5	45	4.1	8	71.8	11	
Injuries fram falls on iced surface (Freezing rain)	5.0	4.0	22	3.6	32	71.0	12	
Damage to parks and sport fields (Wet conditions)	5.0	3.9	28	3.6	31	70.9	13	
Increased salt use and sanding (Freezing rain)	5.0	4.0	22	3.5	33	70.0	14	
Negative health outcomes (Vector-borne disease)	5.0	3.5	45	4.0	9	70.0	15	
Negative health outcomes (Extreme heat)	4.0	3.5	57	5.0	1	69.7	16	
Increased stress on aquatic habitat (Water quality)	5.0	3.8	34	3.7	29	69.6	17	
Maintenance and operational costs (Heavy snow)	5.0	3.5	45	3.9	19	68.2	18	Medium
Increased investment expenditures and annual operating and maintenance expenses (Cooling demand)	5.0	3.3	63	4.1	7	67.6	19	
Property damage (Freezing rain)	5.0	4.0	22	3.3	40	65.0	20	
Power outages (Cooling demand)	5.0	3.3	63	3.9	16	65.0	21	
Urban heat island effects (Cooling demand)	5.0	3.3	63	3.9	19	64.1	22	
Greenhouse gas emission and emissions of criteria air contaminants (Cooling demand)	5.0	3.3	63	3.9	21	64.1	23	
Damage to buildings and facilities (High winds)	5.0	4.1	5	3.1	52	63.1	24	
Impacts to municipal water treatment (Water quality)	5.0	3.8	34	3.3	37	63.0	25	
Increased risk of illness from mold growth (Wet conditions)	5.0	3.9	28	3.2	45	62.5	26	
Damage to, and decreased service life of, building and infrastructure (Freeze-thaw cycles)	5.0	3.2	67	3.7	30	59.3	27	
Early emergency of flowering crops, which are then susceptible to damage from late frost (Late spring frost)	5.0	3.5	42	3.3	38	58.3	28	
Soil erosion (High winds)	5.0	4.1	5	2.8	57	57.7	29	
Erosion of beaches and shoreline habitat (High water levels (Lake Ontario))	3.0	4.2	1	4.4	2	55.4	30	
Basement flooding (Stormwater flooding)	3.0	4.1	16	4.4	3	53.1	31	
Decreased reproduction and survival (Mismatched timing of plant and animal lifecycles)	4.0	4.1	13	3.2	42	52.8	32	
Delays and/or cancellations of outdoor events and activities (High winds)	5.0	4.1	5	2.5	66	51.2	33	

Consequences (climate hazard)	Likelihood	Vulnerability		Consequence		Risk		Adaptation priority
	Score	Score	Rank	Score	Rank	Score	Rank	
Invasive species and pests (Invasive species and pests)	3.0	4.0	21	4.2	4	50.3	35	**High consequences**
Damage to lakeshore active transport and pathway network (High water levels (Lake Ontario))	3.0	4.2	1	4.0	9	49.9	36	**High consequences**
Flooding of roads along shoreline (High water levels (Lake Ontario))	3.0	4.2	1	4.0	9	49.9	36	**High consequences**
Road traffic accidents and transportation delays, including active transportation (High winds)	5.0	4.1	5	2.4	70	49.4	38	**Low**
Increased outdoor water use (Increase water demand)	5.0	3.5	43	2.8	59	48.7	39	
Damage to trees / tree branches (Heavy snow)	5.0	3.5	45	2.8	60	48.1	40	
Health risks, particularly for vulnerable popylations (elderly) (Heavy snow)	5.0	3.5	45	2.6	63	45.7	41	
Flooding of roads and parking lots (Stormwater flooding)	3.0	4.1	16	3.7	25	45.4	42	
Injuries and potential fatalities (High winds)	5.0	4.1	5	2.2	74	45.0	43	
Increased heat stress for animals and livestock (Extreme heat)	4.0	3.5	57	3.1	47	43.8	44	
Impacts to building mechanical systems (Extreme heat)	4.0	3.5	57	3.1	48	43.7	45	
Reduction in labour supply and labour (Extreme heat)	4.0	3.5	57	3.1	49	43.3	46	
Property damage (Heavy snow)	5.0	3.5	45	2.5	67	42.9	47	
Power outages (Heavy snow)	5.0	3.5	45	2.5	67	42.9	47	
Decline in use of outdoor recreation (Extreme heat)	4.0	3.5	57	3.0	53	41.8	49	
Damage to buildings and facilities (Stormwater flooding)	3.0	4.1	16	3.4	34	41.6	50	
Increased indoor domentic water demand (Increase water demand)	5.0	3.5	43	2.3	72	40.4	51	
Damage to lakeshore infrastructure, buildings and facilities (High water levels (Lake Ontario))	3.0	4.2	1	3.2	45	39.5	52	
Flooding of electrical infrastructure (Stormwater flooding)	3.0	4.1	16	3.2	41	39.4	53	
Greenhouse gas emission and emissions of criteria air contaminants (Heating demand)	5.0	2.3	69	3.3	39	37.3	54	
Increased risk of illness from mold growth (Stormwater flooding)	3.0	4.1	16	3.0	53	36.6	55	
Temporary closure of buildings (Extreme heat)	4.0	3.5	57	2.6	62	36.5	56	
Annual operating and maintenance expenses (Heating demand)	5.0	2.3	69	3.2	44	35.7	57	
Increased tree mortality (Drought)	3.0	3.5	52	3.4	35	35.3	58	
Increased stress on aquatic and terrestrial (Drought)	3.0	3.5	52	3.4	36	35.2	59	
Damage to trails, parks, playing fields (Drought)	3.0	3.5	52	3.1	51	32.0	60	
Reduced outdoor winter recreation opportunities (Loss of winter recreation)	5.0	2.5	68	2.5	65	31.5	61	
Reduced crop / forage yields and productivity (Drought)	3.0	3.5	52	2.8	58	29.2	62	
Damage and erosion to creek banks (Creek flooding)	2.0	3.6	37	4.0	9	28.8	63	**High consequences**

Consequences (climate hazard)	Likelihood	Vulnerability		Consequence		Risk		Adaptation priority
	Score	Score	Rank	Score	Rank	Score	Rank	
Increased water sress for aquatic plants and animals (Low water levels)	2.0	3.8	32	3.8	24	28.6	64	Low
Basement flooding (Creek flooding)	2.0	3.6	37	3.7	28	26.6	65	
Damage to terrestrial habitat (Grass fire)	5.0	2.2	71	2.3	71	25.6	66	
Flooding of roads (Creek flooding)	2.0	3.6	37	3.1	49	22.3	67	
Increased blowing dust (Drought)	3.0	3.5	52	2.1	75	22.1	68	
Damage to homes and buildings (Creek flooding)	2.0	3.6	37	2.9	55	21.2	69	
Tree mortality resulting in loss of ecosystem services (Forest fire)	3.0	2.2	71	3.2	43	21.0	70	
Transportation delays and disruptions (Grass fire)	5.0	2.2	71	1.9	78	20.5	71	
Reductions in water availability and drinking water supply (Low water levels)	2.0	3.8	32	2.7	61	20.3	72	
Damage to terrestrial habitat (Forest fire)	3.0	2.2	71	2.9	56	19.1	73	
Increased risk of illness from mold growth (Creek flooding)	2.0	3.6	37	2.6	64	18.5	74	
Damage to (natural and built) sites of cultural or spiritual heritage (Forest fire)	3.0	2.2	71	2.4	69	15.9	75	
Damage to infrastructure (Forest fire)	3.0	2.2	71	2.3	73	14.9	76	
Damage to buildings (Forest fire)	3.0	2.2	71	2.1	76	13.7	77	
Transportation delays and disruptions (Forest fire)	3.0	2.2	71	2.0	77	12.9	78	

Consequences (climate opportunity)	Likelihood	Vulnerability		Consequence		Benefit		Adaptation priorities
	Score	Score	Rank	Score	Rank	Score	Rank	
Increased physical activity and assocciated beneficial physical and mental health outcomes (Increased active transportation)	4.0	3.3	1.0	3.5	2.0	45.5	1.0	Low
Increased use of active transportaiton networks (Increased active transportation)	4.0	3.3	1.0	3.0	6.0	39.6	2.0	
Extended summer tourism season (Increased summer recreation season)	4.0	2.5	4.0	3.5	1.0	35.3	3.0	
Increased productivity of crops (Longer growing season)	4.0	2.7	3.0	3.3	4.0	35.2	4.0	
Increased time to host outdoor festivals and events (Increased summer recreation season)	4.0	2.5	4.0	3.4	3.0	34.7	5.0	
Extended season for, and incresaed participation in outdoor recreation activities (Increased summer recreation season)	4.0	2.5	4.0	3.2	5.0	32.9	6.0	

Note: the risk score for a particular climate hazard or opportunity may differ from the product of the scores for the three determinants of risk (vulnerability x likelihood x consequence) due to rounding.