Matrix Solutions Inc.
A Montrose Environmental Company

CONSERVATION HALTON WATERSHED CLIMATE CHANGE VULNERABILITY AND RISK ASSESSMENT

FINAL REPORT

Prepared for:
CONSERVATION HALTON

Prepared by:
MATRIX SOLUTIONS INC., A MONTROSE ENVIRONMENTAL COMPANY

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Mississauga, Ontario

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CONSERVATION HALTON TERRITORIAL ACKNOWLEDGEMENTS

We are reminded that Conservation Halton's watersheds are situated on treaty land that is steeped in rich Indigenous history and home to many First Nations and Métis people today. We have a responsibility for the stewardship of the land on which we live and work.

We acknowledge the Mississaugas of the Credit First Nation and Six Nations of the Grand River of the Anishinaabeg, Ongweh'onweh, and Hyron-wendat (Wyandot) Peoples of whose traditional territory we are situated.

ACKNOWLEDGEMENTS

The Project Team would like to acknowledge the contributions of all those who participated in the development of Conservation Halton's Climate Change Vulnerability and Risk Assessment. Extensive engagement with internal and external stakeholders was critical to the project's success, resulting in meaningful dialogue about climate change impacts through Conservation Halton and collaboration on adaptation action recommendations.

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- Glenn Farmer, Manager (Flood Forecasting and Operations)
- Ilona Feldmann, Resource Planning Coordinator
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- Martin Keller, Senior Manager (Watershed Planning and Source Protection)
- Barbara Veale, Senior Director (Watershed Management and Climate Change)

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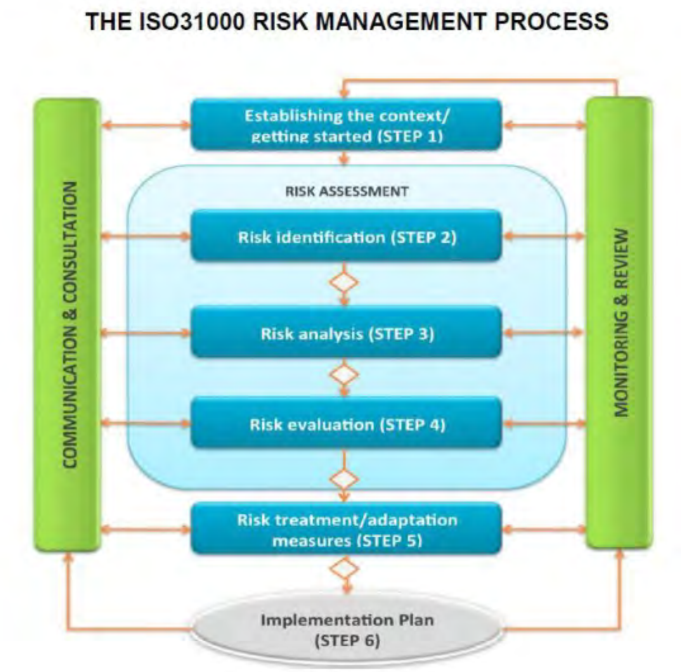
EXECUTIVE SUMMARY

Conservation Halton serves the local community by offering essential services designed to tackle and alleviate environmental challenges, especially those intensified by climate change. These challenges, like threats to human health, property, and the well-being of terrestrial and aquatic ecosystems, are on the rise. Conservation Halton provides programs to enhance the resilience of the watershed's ecosystem. This, in turn, safeguards local communities from the adverse effects of increasingly unpredictable, warmer, and wetter weather patterns associated with climate change. Through this process it has become clear that the natural resources at the watershed level provide critical services to the residents of these watersheds and need to be maintained, protected, and expanded.

This Climate Change Vulnerability and Risk Assessment, developed in collaboration with Conservation Halton, aims to evaluate the potential future climate risks to the natural resources in their watersheds. The goal is to identify where vulnerability and risk is highest to natural resources and recommend additional actions that can be taken to boost adaptive capacity and resilience. These actions will assist Conservation Halton in maintaining and protecting their jurisdiction's natural resources and the associated services that these resources provide in a changing climate. Natural resources, like forests and wetlands, act as a protective shield against climate change impacts, such as flooding, affecting residents across the watershed. By prioritizing actions that enhance the ability of these resources and employing environmental science Conservation Halton can fortify the resilience of watershed ecosystems. This is in alignment with Conservation Halton's Strategic Plan Momentum (Conservation Halton, 2024), and aims to reduce the negative effects of climate change on local communities.

Methodology

The risk assessment methodology is based on the International Organization for Standardization (ISO) 31000 risk framework (see below). This process involved continuous engagement with Conservation Halton staff. The risk management process was focused on natural resources, where the Climate Change Vulnerability and Risk Assessment offers a unique and comprehensive approach for evaluating climate risks and developing adaptation measures for these resources, which is something not frequently done on a watershed scale.



Source: https://www.iso.org/obp/ui/#iso:std:iso:31000:ed-2:v1:en

The recommendations from this assessment build on existing programs and services implemented or planned by Conservation Halton. The assessment pinpoints areas where climate hazards and impacts on natural resources may affect Conservation Halton's ability to deliver services.

Communication and collaboration with stakeholders were central to the assessment process. Internal stakeholders, including those within Conservation Halton, and external stakeholders, particularly local municipalities within Conservation Halton's jurisdiction, were actively involved. The organization's in-depth understanding of its natural resources, watersheds, programming, operations, and services played a pivotal role in crafting the Climate Change Vulnerability and Risk Assessment. This internal knowledge provided valuable insights utilized throughout the assessment. It was key to understand where there has been historical experience with vulnerability in the current climate, and how existing and planned programs may enhance adaptive capacity of Conservation Halton.

A strategic review of legislative requirements and previous reports was conducted to better understand the context around climate change and adaptation within Conservation Halton’s jurisdiction. This involved considering national and provincial climate change guidelines, as well as reviewing previous work by Conservation Halton in assessing the vulnerabilities of the watersheds and the inventories of natural resources. In Ontario, Conservation Halton operates under the Conservation Authorities Act, which has as its purpose "to provide for the organization and delivery of programs and services that further the conservation, restoration, development and management of natural resources in watersheds in Ontario." Section 21 of the Act sets out the range of programs and services that conservation authorities can provide. Specific programs and services that a conservation authority must provide includes the consideration of climate change as set out in O. Reg. 686/21. In addition, the legislation allows for a delivery of additional programs and services provided that agreements between the conservation authority and their participating municipalities for their delivery are in place. This enables conservation authorities and their municipal partners to be responsive to natural resource issues and management needs unique to their watershed.

Conservation Halton is currently developing a Watershed-based Resource Management Strategy as required by legislation. The purpose of this initiative is to ensure compliance with the legislation, identify those issues and risks that limit the effectiveness of programs and services, and identify actions and associated costs to address the issues and mitigate risks.

Natural Resources

The selection of key natural resources for this assessment was collaboratively developed during an early workshop with Conservation Halton's staff. These resources hold substantial importance and provide various benefits across Conservation Halton's watersheds. The significant natural resources considered in the assessment include:

- forests
- groundwater
- Lakeshore
- meadow
- pond/lake
- stream
- wetland – swamp
- wetland – marsh
- vernal pools

Climate Hazards

As part of the strategic context review, Matrix identified climate hazards that played a crucial role in shaping the risk assessment stage. To understand how each potential hazard might change in the future due to climate conditions, Matrix considered the historical record and utilized best practice climate change projections under a high emissions scenario. This involved selecting specific climate variables or parameters that best capture the conditions and drawing information from nationally recognized climate data portals and published material. Matrix assessed how these variables are likely to change in the mid-term (30 years) and long-term (60 years) future.

While there were subtle differences in historical records and future projections across Conservation Halton's watersheds (e.g., above and below the Niagara Escarpment), there was an overall high level of uniformity in the changes in future climate conditions and the likelihood of occurrence between data portals and previous studies for most parameters. The following climate hazards are the ones that best quantified the impact on natural resources in Conservation Halton's watersheds:

- dry conditions
- rainfall/riverine flooding
- heat stress
- seasonal changes
- snowpack reduction
- wind

Of these hazards, snowpack reduction and seasonal changes were the only climate parameters to have a higher likelihood of occurrence scoring value in the 2080s in comparison to the 2050s, whereas for the others the projected change was similar for both future time periods.

Consequences of Climate Change

Matrix used the likelihood scores along with the consequence scores to determine the level of risk Conservation Halton faces regarding future climate conditions that could adversely impact natural resources, ecosystems, and the services dependent on them. The vulnerability and risk assessment process allowed Matrix to leverage existing knowledge and evidence concerning future climate projections and the natural functions of the watershed and helped identify and prioritize climate risks. During the risk identification step, Matrix pinpointed where climate hazards could potentially impact natural resources. Out of the 54 potential combinations of climate hazards and natural resource types, Conservation Halton staff confirmed that only one case had no interactions, while 53 cases exhibited interactions.

Consequences arise when there is an interaction between a climate hazard and a natural resource that causes a measurable shift in the natural resource's condition and performance and the level of services that they provide. The consequences were placed into seven categories used in calculating the risk rating:

- human health and property
- terrestrial ecology
- aquatic ecology
- water quality
- erosion and sedimentation
- flooding
- Conservation Halton services

These categories helped assess the magnitude, extent, or duration of consequences, providing a comprehensive framework for evaluating the overall risk associated with climate hazards and their impacts on natural resources.

Climate Change Impacts

The Project Team collaborated with subject matter experts from Conservation Halton to gather insights and assign values to consequences for interactions between natural resources and climate hazards under each of the seven categories identified. This step was crucial in harnessing the diversity of expertise across watershed managers and technical experts in assessing the potential impacts of climate change on these natural resources. Once consensus was reached on consequence scores, the next step was calculating risk scores.

The watershed level assessment considered factors like land use and vulnerable areas defined by Conservation Halton and by mapping natural resource location onto the watershed. This qualitative analysis aimed to discuss risks across the watersheds, identifying areas that might be more vulnerable than others. This comprehensive approach ensured a thorough understanding of the potential impact of climate hazards on natural resources throughout Conservation Halton's watersheds.

After assessing vulnerability and risk at the watershed level, Matrix evaluated adaptive capacity by examining programs and services already provided by Conservation Halton that enhance the resilience of the watersheds. The adaptive capacity measures are linked to the following areas:

- Conservation Halton’s programs and services
- flood forecasting and warning
- flood and erosion control
- drought/low water program
- management of Conservation Authority-owned land
- Drinking Water Source Protection
- surface and groundwater monitoring programs
- ecological monitoring programs
- regulating the impacts of development and activities in hazard areas
- watershed strategies

Findings

The risk assessment findings show how natural resources may be affected by different climate hazards. In consultation with Conservation Halton staff, it was decided to focus on interactions that had a "high" (15+) or "very high" (20+) risk rating. The analysis revealed 38 interactions for 2050 climate projections and 41 interactions for 2080 projections. The only change between 2050 and 2080 was that some risks, like snowpack reduction and seasonal changes, became more likely, and received higher risk ratings. Heat stress, rainfall, and seasonal changes were the top three climate hazards associated with high, and very high-risk ratings. This information helped prioritize where to focus efforts in managing climate-related risks.

Recommendations

This section provides the recommendations emerging from this risk assessment, supported by input from subject matter experts across diverse fields from Conservation Halton and Matrix. Most of these recommendations are not standalone initiatives but represent the continuation of ongoing efforts and commitments already made by Conservation Halton. Examples of ongoing and relevant programs include the 2020 *Strategic Forest Management Plan* and the 2023 report *Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds*.

The recommendations considered the adaptive capacity measures and existing studies by Conservation Halton that also propose recommendations for the watersheds. The discussion includes suggestions on how Conservation Halton can enhance existing programs and studies to contribute to the development of a Watershed-based Resource Management Strategy.

General Recommendations

These initial general recommendations are provided to give overarching guidance to assist in building Conservation Halton's adaptive capacity to a changing climate. More detailed recommendations follow.

- Review all monitoring programs to integrate climate change considerations by evaluating monitoring network density, data collection methods, measurement parameters, and monitoring protocols. Identify key indicators and assess spatial and temporal scales for aligning with projected climate change impacts. Enhance monitoring efforts with emerging technologies and data sharing mechanisms to inform adaptive strategies and sustainable management practices.

- Renew Watershed Plans for each of Conservation Halton's watersheds to encompass scenarios integrating climate change projections, land use changes, and natural resource scenarios reflecting climate change impacts. These plans will anticipate hydrological shifts and ecological impacts within the watershed. Integrate land use and natural resource scenarios to assess potential stressors and inform adaptive management strategies for sustainable watershed management amidst evolving environmental conditions.

- Model hydrologic impacts of climate change on a watershed scale. Utilize climate projections and hydrological models to simulate changes in rainfall intensity, duration, and frequency over time. Incorporate Intensity-Duration-Frequency (IDF) curve shifts into planning and risk assessment frameworks to enhance resilience against extreme weather events and mitigate potential flood risks associated with climate variability.

- Continue to coordinate with municipal partners to share climate change data and develop collaborative strategies. Create a hub for climate change data and watershed-scale assessments to facilitate information sharing and decision making among stakeholders. Ensure accessibility and compatibility of data formats to allow for analysis and integration into municipal planning processes. Foster informed actions and resilience-building efforts across interconnected communities and watersheds.

Flooding

1. **Operations:**

   - Consider how climate change impacts flood risk and may necessitate changes in the operation of water control infrastructure.

   - Continue updating Conservation Halton's flood forecasting and warning system to reflect any changes in seasonality or rainfall patterns that may emerge from climate change.

   - Consider reviewing the operational requirements for water control infrastructure to meet the seasonal, recreational, and flood mitigation needs while considering the potential of low water levels due to climate change.

2. **Monitoring**:

   - Continue to monitor ice jams as seasonal changes and snowpack reduction exacerbate risks, reducing spring freshet, increasing runoff volumes, and elevating the likelihood of ice jams, erosion, and flooding.

   - Expand weather station network to provide coverage over a greater area of the jurisdiction to capture high-intensity, short duration, and localized storm events to enable timely responses to flood threats. This will increase the data for flood forecasting and warning, as well as hydrologic model calibration.

3. **Manage**: Maintain and expand natural areas (forest, wetland, etc.) to help maintain the hydrologic conditions in the watersheds. The water retention services of these areas help mitigate current flood risk and will be critical in providing adaptive capacity to intensive rainfall events under future climate conditions.

4. **Modelling:** Regularly update regulatory flood hazard mapping around ponds and streams to reflect the changes due to climate change.

   - Continue updating regulatory flood hazard mapping around streams to reflect the potential changes due to climate change. Consider implementing flood risk mapping to support municipal emergency preparedness. This will reduce risks to human health and property, with increased flooding potential impacting emergency services and property damage.

- Use future climate scenarios, natural resource scenarios and hydrologic and hydraulic models to identify potential flood risk zones. This would identify possible water depth and velocity in flooded areas. This information can be used for emergency preparedness and risk management.

- Use hydrologic modelling to measure the potential impacts and help inform possible mitigation measures of climate change on wetlands. This would include reviewing ecologic impacts to wetlands and the ability of wetlands to mitigate flooding through vegetation changes and potential degradation.

Erosion and Sedimentation

1. **Monitoring**:

   - Monitor the rate of shoreline erosion. Study the potential for an increase in shoreline erosion from intensified storm surges and wave action, compromising shoreline integrity. Investigate strategies to mitigate shoreline erosion.

   - Monitor stream and valley slope stability to provide important information for flood and erosion control to allow for the development of effective strategies to manage the impacts of increased bankfull erosion flow events.

   - Undertake regular recurring watercourse erosion surveys and mitigate situations that introduce or aggravate the erosion hazard and associated impacts on infrastructure and valley ecology along accessible creek reaches.

Groundwater

1. **Monitoring:** Continue monitoring groundwater quantity through the Provincial Groundwater Monitoring Program and expanded locations at selected wetlands.

2. **Groundwater Discharge:** Utilize, and where needed, enhance existing groundwater models to better understand the interactions between surface and groundwater and assess and map out important groundwater discharge reaches throughout the watersheds. Validate modelling with surface water monitoring and aquatic information.

Water Quality

1. **Planning**: Continue to incorporate groundwater quality and quantity planning in the development of the Watershed Plans for the watersheds within Conservation Halton's jurisdiction.

2. **Surface Water Monitoring**: Identify gaps in the surface water quality monitoring network and expand the monitoring network with a goal of identifying and possibly mitigating trends resulting from climate change. Assess the monitoring network for its ability to capture water quality trends. Continue monitoring surface water for the temperature impacts associated with reduced groundwater flow or the impacts of higher temperature groundwater. Continue monitoring water temperatures, water levels, erosion and pollutant loading in ponds/lakes for any negative impacts on biodiversity due to climate change.

3. **Wetlands Monitoring and Improvement:** Expand wetland monitoring, preservation, and improvement programs to mitigate against water quality impacts. Monitor outfall of swamps that have historic records of water quality monitoring for the measurement of any reduction in water quality due to the impacts of climate change on the ability of swamps to provide the service of water quality improvement. Preserve and enhance natural wetlands to maintain the water quality improvements provided by these ecosystems, wherever possible. Increase wetland habitat to increase the water quality benefits and mitigate potential impacts from climate change on existing wetlands and possibly improve the water quality by a greater degree.

Aquatic Ecology

1. **Monitoring:** Continue and adjust, if needed, various monitoring programs being executed within the watersheds and implement a process to identify climate change impacts through these programs. Specific monitoring programs include:

   - Continue and adjust, if needed, the aquatic monitoring system that includes regular assessments of stream levels, rainfall patterns, water temperature, erosion dynamics, and water quality to assess aquatic biodiversity for changes due to climate change.

   - Continue and adjust, if needed, monitoring for impacts of climate change causing a reduction in fish spawning habitats due to the degraded quality of aquatic ecosystems in marshes.

2. **Restoration**: Implement the recommendations in the *Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds* report to "Develop species-specific monitoring and restoration strategies for target species at risk and climate-vulnerable species on Conservation Halton lands." Implement this recommendation for species impacted by the climate change effects on aquatic habitat including vernal pools.

3. **Modelling:** Undertake modelling of future climate scenarios to better understand and predict the impacts of climate change on the thermal dynamics of streams. Identify the risk of specific streams no longer being refugia for cold-water species. This will allow for identification of reaches where targeted restoration efforts would be beneficial to maintain a cold-water status under future climatic conditions.

Terrestrial Ecology

Forests

Recommendations for forests are particularly relevant for the large tracts of forest located above the Niagara Escarpment in northern Bronte Creek and the northwestern areas of Sixteen Mile Creek. These represent the largest areas of forest cover in Conservation Halton's jurisdiction.

1. **Monitoring**: Continue monitoring forest health using the Long-term Environmental Monitoring Program (LEMP) and other monitoring initiatives, including invasive species

2. **Wetland Monitoring:** Continue and adjust, if needed, Conservation Halton's LEMP to monitor vernal pool, swamp, and marsh habitats particularly for early spring breeding amphibians due to changes in snowpack and seasonality.

3. **Habitat Corridors:** Model the impact of climate change on wildlife corridors and migration patterns by integrating species-specific habitat suitability models, climate projections, and landscape connectivity analyses. Incorporate future climate scenarios to assess potential shifts in habitat ranges and corridor effectiveness.

4. **Build Resiliency**: Continue with existing programs designed to build resilient forests within the watersheds:

    - Implement the recommendations outlined in the 2020 *Strategic Forest Management Plan* to build forest resiliency against climate change. This will be accomplished through building the forest's resilience using effective management practices and by incorporating mitigation and adaptation strategies.

    - Implement recommendations from the *Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds* report, focusing on enhancing forest resilience in particular Recommendation 5: "Develop a Seed Strategy for Conservation Halton's tree planting program to ensure that planting stock is adapted to future climate conditions."

5. **Expand Forests:** Expand forested areas through strategic land acquisition, when possible, to mitigate any forest losses due to climate change or even expand forested area to improve habitat connectivity and provide high quality contiguous habitat.

6. **Protect Against Fire**: Prepare for the onset of forest fire conditions due to heat stress and precipitation changes on Conservation Halton owned lands.

Biodiversity Loss

1. **Monitoring**: Maintain ongoing wildlife habitat monitoring in the LEMP and other monitoring initiatives.

2. **Implement the recommendations in the Conservation Halton study**: *Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds,* 2023 report, pertaining to terrestrial biodiversity loss and climate change.

3. **Develop Invasive Species Strategy**: Develop an Invasive Species strategy and cooperate with other levels of government to coordinate efforts on detection, protection against, and destruction of invasive species.

Conservation Halton Services

1. **Adapt services:**

   - Assess potential alterations to visitor experiences, considering the potential impact on park revenue due to the lack of forest cover or degraded natural areas.

   - Prepare for potential impacts on Conservation Halton's services, including beach closures, infrastructure maintenance, reduction in availability of snow for skiing, and visitor experiences, due to heat stress, wind, and seasonal changes.

2. **Safety:**

   - Continue to implement signage and safety programs warning users of Conservation Halton's trails and natural areas to inform of ticks and the potential for Lyme disease.

   - Consider addressing the potential of safety concerns on lakeside authority property due to the potential for increased risk of tripping and falling due to precipitation, waves, and wind, impacting human health and safety.

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APPENDICES

1 INTRODUCTION

Conservation Halton has initiated a Watershed Climate Change Vulnerability and Risk Assessment project as a first step in developing a Watershed Climate Resiliency Strategy for the watersheds in their jurisdiction. The goal of the Watershed Climate Resiliency Strategy is to identify actions that will improve the adaptive capacity and resiliency of the watersheds to cope with and adapt to the impacts of warmer, wetter, and wilder weather. The Watershed Climate Resiliency Strategy will support the Watershed-based Resource Management Strategy.

This Climate Change Vulnerability and Risk Assessment is one of the first steps as part of this process and will ultimately provide strategic recommendations for managing natural resources throughout the watershed to enhance their resilience against the impacts of climate change. There are two overarching responses to climate change: mitigation and adaptation measures. Mitigation measures refer to actions that reduce the greenhouse gas emissions that cause climate change, and adaptation measures refer to actions that manage and reduce the risk of climate change impacts. This assessment will focus on recommending adaptation measures applicable to Conservation Halton and their natural resources.

By identifying where natural resources and ecosystems are most at risk to climate change, the findings in this report will feed into the Watershed Climate Resiliency Strategy and ultimately the Watershed-based Resource Management Strategy, and thereby help Conservation Halton evaluate resource issues and risks within their jurisdiction in support of their programs and services as required by the Province of Ontario by the end of 2024. The relationship between this Climate Change Vulnerability and Risk Assessment and the Watershed Climate Resiliency Strategy is illustrated in Figure 1.

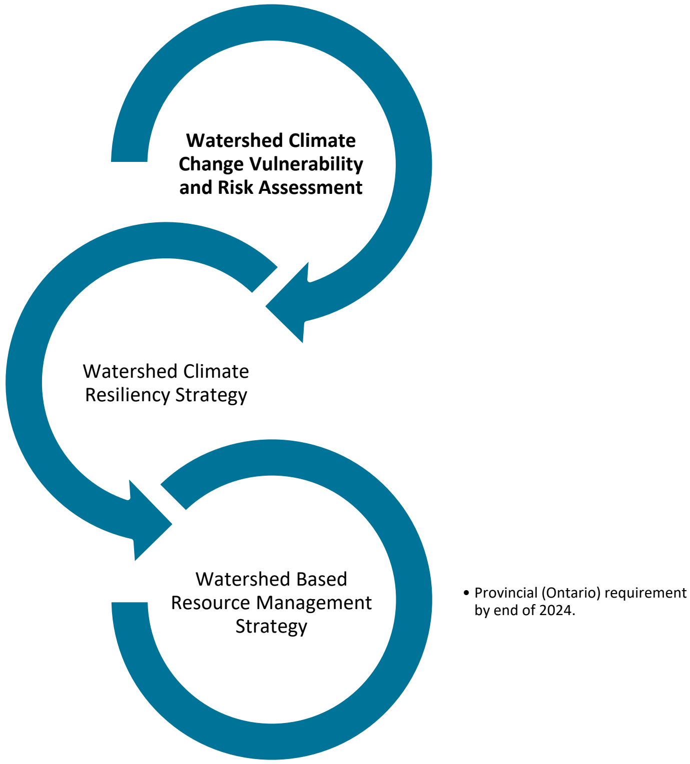


Figure 1 Flow Chart of Conservation Halton's Climate Change Assessment Process

The recommended actions in this Climate Change Vulnerability and Risk Assessment represent a strategic and evidence-based response to projected future climate risks to the natural resources within Conservation Halton watershed and the services that they provide.

1.1 Values and Priorities of Conservation Halton

As part of the Momentum Strategic Plan, Conservation Halton identified their values and priorities to set their overall goals and guide their business decisions through to 2024. A significant portion of the Strategic Plan is to protect their communities and ecosystems from the impacts of climate change, through which they identified specific values and priorities that are harmonious with the purpose of this Climate Change Vulnerability and Risk Assessment. The values and priorities applicable to this assessment are outlined in Table 1 below.

Table 1 Applicable Conservation Halton Strategic Plan Values and Priorities

Values	Priorities
Sustainability We consider the environmental impact of everything we do and always keep future generations in mind when making decisions.	**Natural Hazards and Water** Protect people, property, drinking water sources and natural resources to support development that is in balance with the environment.
Resilience We are positive and proud of our ability to quickly and effectively respond to change.	**Science, Conservation, and Restoration** Use environmental science, collaborative research, and collective data to protect the integrity and strengthen the resilience of our ecosystems. • Undertake and implement watershed plans to identify and prioritize actions that enhance sustainability. • Identify and promote climate change approaches for watershed resiliency and lead by example.

As part of the Watershed-based Resource Management Strategy, guiding principles and objectives for the delivery of Conservation Halton's programs and services are being developed. These statements will align with the legislative requirements, the Momentum Strategic Plan and agreements made between Conservation Halton and its participating municipalities.

1.2 Objective and Scope: Climate Change Vulnerability and Risk Assessment

The objective of the Climate Change Vulnerability and Risk Assessment is to identify the degree to which the key natural resources within Conservation Halton's watersheds are affected by the variability and extremes of the current and projected future climate change. The findings of the assessment will provide a framework and inform priorities and management actions that will form part of the Watershed Climate Resiliency Strategy and inform the provincially required Watershed-based Resource Management Strategy.

1.3 Project Methodology

The overall project methodology is summarized in the flow chart in Figure 2 and outlines the different project stages, beginning with the establishment of a work plan and culminating in the completion of the Climate Change Vulnerability and Risk Assessment, along with guidance to implement the recommendations.

The methodology consists of risk assessment techniques applied through a climate lens and evaluated through the natural resources. The methodology is based on the International Organization for Standardization (ISO) 31000 risk framework, which includes risk assessment and implementation and risk management, involves ongoing engagement with Conservation Halton staff, and applies continuous monitoring and review in its development. By framing the risk management process on natural resources, the Climate Change Vulnerability and Risk Assessment provides a holistic and broad perspective to the evaluation of risk and the development of adaptation measures.

Based on a review of the selected background documents, there is a wide range in climate-related consequences that Conservation Halton and local municipalities have identified. Although more work remains for Conservation Halton to fully integrate climate change considerations into their planning processes, the Climate Change Vulnerability and Risk Assessment should provide an initial and solid foundation for Conservation Halton to make meaningful progress toward becoming more climate resilient and developing their Watershed-based Resource Management Strategy.

The recommendations of this Climate Change Vulnerability and Risk Assessment build upon areas and actions that Conservation Halton is already addressing with regard to extreme weather conditions, and even climate change, through existing and planned measures, although much of these are being delivered on an individual basis rather than in a coordinated and evidence-based fashion. The Climate Change Vulnerability and Risk Assessment highlights where the risks of climate hazards may become more significant for natural resources performance and Conservation Halton's ability to deliver services. As such, the results of the risk assessment should help identify where the level of effort and time/effort investment is best allocated.

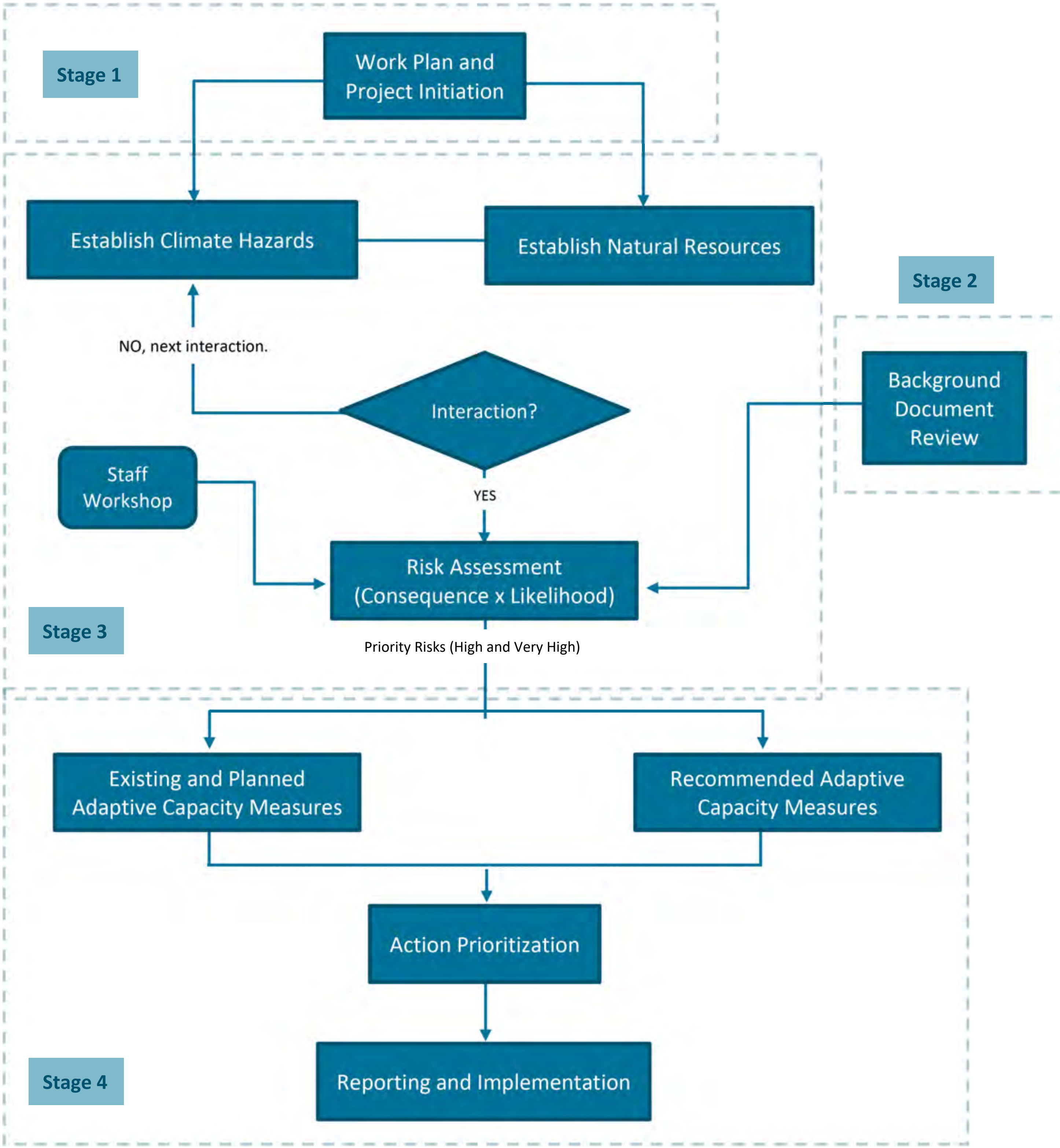


Figure 2 Project Methodology

1.3.1 Project Geographical Limits

Generally, the geographic scope of the Climate Change Vulnerability and Risk Assessment is bound by Conservation Halton's watersheds boundaries, while recognizing the impact of climate change beyond these boundaries. For example, there are communities upstream of the watershed that may impact the adaptation measures implements within Conservation Halton's jurisdiction further downstream. However, improved climate resiliency within the watershed boundary will likely have a positive impact on all communities upstream and adjacent to the watershed.

Figure 3 shows the geographical limits of Conservation Halton's watersheds (Conservation Halton, 2018).

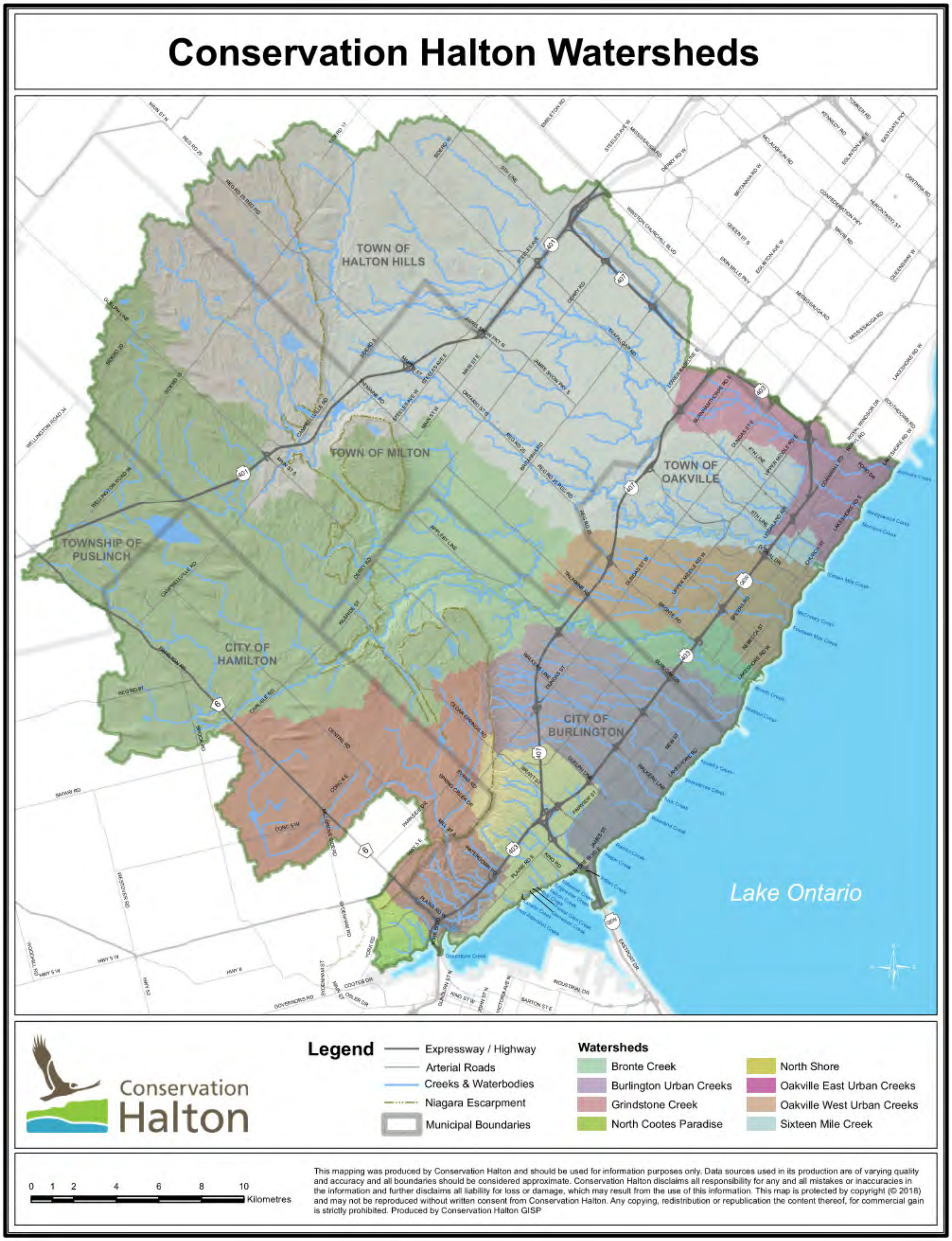


Figure 3 Conservation Halton's Watershed Boundaries

1.3.2 Watershed-based Approach to Climate Change Vulnerability and Risk Assessment

This Climate Change Vulnerability and Risk Assessment develops risk rating scores for each natural resource group, which have been mapped on the watersheds that make up Conservation Halton's jurisdiction. The risk assessment results will be used at the watershed-wide level to determine vulnerable areas, the consequences of climate change on natural resources, and inform what areas throughout the watershed would benefit from implementing adaptive capacity measures. The watershed level analysis is primarily qualitative, informed based on an extensive background review of Conservation Halton's documentation and various workshops and engagement sessions with Conservation Halton staff.

The risk assessment process has established an understanding of the vulnerable natural resources throughout the watershed based on composition of natural areas and land use allocation. This step of the study involved the calculation of land areas within each watershed and relied heavily on existing watershed studies, spatial data, and input and collaboration with Conservation Halton.

The vulnerability of a watershed to climate change is influenced by a combination of natural and human-related factors. Watersheds are complex systems that are particularly sensitive to changes in climate, as they play a crucial role in regulating water flow, supporting biodiversity, and providing ecosystem services. The following key factors affect the vulnerability of a watershed to climate change and will be considered in the watershed-wide analysis:

- **Hydrological characteristics:** The hydrological characteristics of a watershed including its size, shape, topography, and land use will play a significant role in its vulnerability. Watersheds with large permeable areas and intricate drainage patterns may be more resilient to changes in precipitation and runoff than simpler watersheds. Watersheds with permeable soils (e.g., sands, gravels) and natural ground cover will absorb excess moisture and be more resilient to increased precipitation.

- **Land use:** Watersheds with large areas of natural lands will be more resilient than urbanized watersheds or even watersheds with agricultural land use, primarily due to impervious services and human interaction. Combinations of increased temperature and sediment loading will lead to more water quality impacts.

- **Ecosystem health and biodiversity:** The health and diversity of natural ecosystems within the watershed can influence its resilience to climate change impacts. Healthy wetlands, forests, and other natural habitats can regulate water flow, store carbon, and provide habitat for various species, contributing to the overall ecosystem stability. The percentage of land cover will be used as an approximate measure of resiliency. Less contiguous natural areas (fragmented landscapes) can be more vulnerable to climate change. As an example, small wetland complexes may be more vulnerable to increased evapotranspiration and consequential decrease in surface area coverage extent as compared to larger wetland complexes. Larger areas are more likely to provide higher quality habitat.

Assessing the vulnerability of a watershed to climate change requires considering all these factors and understanding their interactions and feedbacks. Implementing integrated water resources management practices, conserving natural habitats, and promoting sustainable land use are essential strategies to enhance the resilience of watersheds to climate change impacts.

With a completed evaluation of the risks and vulnerabilities on a watershed basis, the Project Team considered the role of existing adaptive capacity measures that are in place to maintain the resilience of the natural features within each watershed. Based on this existing inventory, this report provides recommendations on adaptation measures or plans to be implemented elsewhere. These are high level recommendations, relying on more careful consideration and next steps modelling on a local level.

1.4 Project Engagement

1.4.1 Engagement and Communications Objectives

This Climate Change Vulnerability and Risk Assessment is an important project for Conservation Halton, its residents, businesses, and their partners. Ongoing engagement with stakeholders (both internal and external) was critical to the project's success, resulting in meaningful dialogue about climate change impacts and adaptation opportunities, and a more collaborative implementation process of adaptation measures. A Communication Plan was prepared to establish effective communication channels throughout the assessment and was circulated to and approved by Conservation Halton. The Communication Plan (August 29, 2023) is provided in Appendix A.

Conservation Halton's knowledge of their own natural resources, watershed, programming, operations, and services was the single most important factor in developing the Climate Change Vulnerability and Risk Assessment. As such, significant staff engagement was conducted throughout the project to leverage this knowledge for the risk assessment and development of adaptation actions.

The engagement objectives of the project included:

- involving and collaborating with internal stakeholders in all aspects of the development of the Climate Change Vulnerability and Risk Assessment, resulting in:
    - confirming the objective and purpose of the Climate Change Vulnerability and Risk Assessment
    - identifying climate hazard interactions with Conservation Halton's watersheds natural resources
    - establishing consequence categories and definitions
    - establishing and reviewing the risk assessment scores
    - prioritizing risk scores
    - identifying current and potential adaptation actions

- building support for the Climate Change Vulnerability and Risk Assessment, ensuring sustainable implementation across Conservation Halton's watersheds by aligning with strategic planning documents and business objectives
- consulting with members of local municipalities and providing avenues for feedback at specific points in the process

The communications objectives of the project included:

- establishing a baseline understanding of climate adaptation, the watershed's changing climate, and the risks posed by climate change
- ensuring that key internal stakeholders are aware of the project, its goals, progress, and timelines
- providing an overall summary of the knowledge supplied from strategic context sources
- keeping members of local municipalities informed about the Climate Change Vulnerability and Risk Assessment and its development progress

1.4.2 Engagement Audiences

This Climate Change Vulnerability and Risk Assessment is a highly collaborative initiative, and as such, internal engagement efforts were a major piece in developing the assessment. There were three staff project groups who contributed to the success of the project, and were defined as the Core Project Team, subject matter experts, and the Steering Committee. Local municipalities and organizations within the jurisdiction of Conservation Halton's watersheds were also consulted and informed of the project progress.

Local Municipalities and Organizations (External): Responsible for providing input from a municipal perspective during specific phases of the study.

- City of Burlington
- Town of Halton Hills
- City of Hamilton
- Town of Milton
- City of Mississauga
- Town of Oakville
- Township of Puslinch
- Regional Municipality of Halton
- Wellington County
- Regional Municipality of Peel
- Hamilton Naturalists' Club
- Royal Botanical Gardens

1.4.3 Level of Engagement

The engagement groups were consulted for different purposes, and all served different roles. The engagement levels for each stakeholder group are outlined in Table 2. Engagement and influence increase as you move from left to right on the table.

Table 2 Level of Engagement of Internal and External Stakeholders

Consult (Gather Information)	Involve (Discuss)	Collaborate (Work Together)
• Local Municipalities • Local Organizations	• Core Project Team • Subject Matter Experts	• Core Project Team • Subject Matter Experts • Steering Committee

Sharing information (informing) takes place across all levels of engagement.

1.4.4 Equity, Diversity, Inclusion, and Reconciliation

Acknowledging Equity, Diversity, Inclusion, and Reconciliation through the Climate Change Vulnerability and Risk Assessment is important because climate change disproportionately impacts vulnerable populations, such as seniors, racialized communities, and low-income residents. By acknowledging and addressing inequalities, where possible, in the development and implementation of adaptation actions, the Climate Change Vulnerability and Risk Assessment can help reduce the impact of climate change on vulnerable populations and ensure that the benefits of the adaptation actions are distributed fairly.

The Climate Change Vulnerability and Risk Assessment is an opportunity for Conservation Halton take meaningful actions that advance reconciliation and deepen their relationship with Indigenous communities. It is important for Conservation Halton to acknowledge that Indigenous peoples are uniquely vulnerable to the impacts of climate change due to their connections to the natural world (McGregor 2019).

1.5 Project Team Meetings and Workshops

1.5.1 Staff Working Group Meetings and Workshops

Throughout the project, Staff Working Group members participated in meetings and small group workshops. The Staff Working Group contributed to a number of key elements in developing the Climate Change Vulnerability and Risk Assessment, including setting the objective and purpose, identifying the key natural resources and consequence categories, assessing climate hazard interaction with their department's/division's and developing and reviewing risk assessment scores.

Fourteen (14) Conservation Halton staff members were part of the Staff Working Group and participated in meetings and/or workshops during the project, contributing to building support for the project and ownership of the actions. The Staff Working Group engagement sessions advanced the objectives of establishing a baseline understanding among Conservation Halton staff about climate adaptation, Conservation Halton's watersheds changing climate and climate risks, and awareness of the project's objective and purpose, progress, and timelines.

Biweekly meetings were held throughout the project's life cycle, along with two workshops: the Natural Resource Workshop and Risk Assessment Workshop. In the Natural Resource Workshop, the Core Project Team and subject matter experts established a list of natural resources and climate-related consequence categories, which were further refined. The Risk Assessment Workshop involved subject matter experts providing their input on risk scores and reviewing the risk assessment process.

1.5.1.1 Senior Leadership Team Engagement Session

On November 28, 2023, Conservation Halton included this Climate Change Vulnerability and Risk Assessment as part of their Senior Leadership Team Engagement Session. In this session, the Senior Leadership Team at Conservation Halton was informed of the project purpose, progress, and desired outcome. It was important to have support and engagement of the Senior Leadership Team to ensure decision makers within Conservation Halton were well informed of the project and how it will impact Conservation Halton's watersheds. The Senior Leadership Team expressed interest in the outcomes of the Climate Change Vulnerability and Risk Assessment, with particular interest in establishing justification for climate-related adaptation programs and services that may be implemented as a result of the project.

1.5.1.2 External Engagement Sessions

Conservation Halton invited the local municipalities and organizations to share information about the development of the Climate Change Vulnerability and Risk Assessment and to answer questions about the project and climate adaptation efforts.

Participants expressed their understanding that weather is becoming more extreme and that adaptation measures are necessary for communities to be resilient and provided specific input on natural resource issues in their local jurisdictions. They expressed enthusiasm and appreciation that Conservation Halton is developing the Climate Change Risk and Vulnerability Assessment and stressed the importance of viewing the impacts of climate change on a watershed scale and the importance of monitoring and modelling trends.

1.6 Municipal Engagement Survey

Municipalities and stakeholders within the jurisdiction of the Conservation Halton watershed were consulted for their input with respect to climate risk for their individual municipal natural heritage systems. The municipalities and stakeholders engaged in this survey are listed in Section 2.2 – Engagement Audiences, and the survey responses are summarized in Appendix B.

1.7 Strategic Context Review

1.7.1 Climate Change and Adaptation

Climate is the weather we experience averaged over an extended period of time, and the term climate change refers to long-term shifts in our climate, including temperature, precipitation, and weather patterns. Throughout the history of the earth, there have been shifts in our climate due to natural causes such as variations in the solar cycle; however, since the 1800s our climate has been changing more rapidly due to human activities (e.g., the burning of fossil fuels, methane emissions from livestock and landfills, land use changes, and deforestation) that generate greenhouse gases (IPCC 2022). These greenhouse Gases trap the heat radiating from the earth and prevent it from escaping into space, which raises the temperatures in our atmosphere. The earth's mean temperature today is about 1.1°C warmer than in the late 1800s, and the last decade (2011-2020) was the warmest on record (WMO 2022).

With the increases in temperature, we are experiencing rising sea levels, loss of snowpack and ice (thinning glaciers, thawing permafrost), more extreme heat, less extreme cold, longer growing seasons, shorter snow and ice cover seasons, earlier spring peak streamflow, and shifting precipitation patterns (Warren and Lulham 2021). This has led to other environmental impacts, including increased incidences of poor air quality (e.g., from ground level ozone, particulate matter); short-duration, high-intensity rainfall events; windstorms; more frequent and prolonged periods of drought; wildfires and urban interface fires; increased coastal erosion; storm surge flooding; decreased water quality; increased spread of invasive species and decrease in biodiversity; and the increased spread of vector-borne diseases (Warren and Lulham 2021).

The earth's climate is a dynamic system, with changes in one area affecting and influencing other areas. There is an interdependence of climate, ecosystems and biodiversity, and human societies that play out across continents, nations, and at the regional level. Physical infrastructure has been identified as the highest area of risk to extreme weather events and climate change risk facing Canada along with coastal communities, northern communities, human health and wellness, ecosystems, and fisheries (CCA 2019). Urban areas are a particular concern because more people live in cities than in rural areas (55% globally, 80% in Canada), and many of the natural surfaces (e.g., forests, fields) have been replaced by impervious surfaces, which exacerbate flood risk and also absorb and reradiate heat. Further, increased population density in urban areas often results in greater consequences due to climate change impacts on grey and green infrastructure and the services that they provide, which in turn impacts individuals, communities, and economies (Brown et al. 2021).

There are two overarching responses to climate change: mitigation and adaptation measures. Mitigation measures refer to actions that reduce the greenhouse gas emissions that cause climate change, such as switching to clean energy from fossil fuels and using less energy by being more energy efficient. Adaptation measures refer to actions that manage and reduce the risk of climate change impacts, such as infrastructure upgrades, flood protection, disaster management, and business continuity planning. There are also initiatives that co-benefit both mitigation and adaptation, such as planting trees (e.g., to increase the urban tree canopy, sequester carbon, help reduce flood risk, and reduce the effects of the urban heat island), water conservation efforts (e.g., which reduces the amount of water use, water treatment requirements, and amount of energy used in treatment and distribution), and more intensive land use (e.g., reducing energy use, and providing residents with more resilient transportation options; Figure 4). The findings in this project are focused on adaptation measures geared towards the watershed's natural resources.

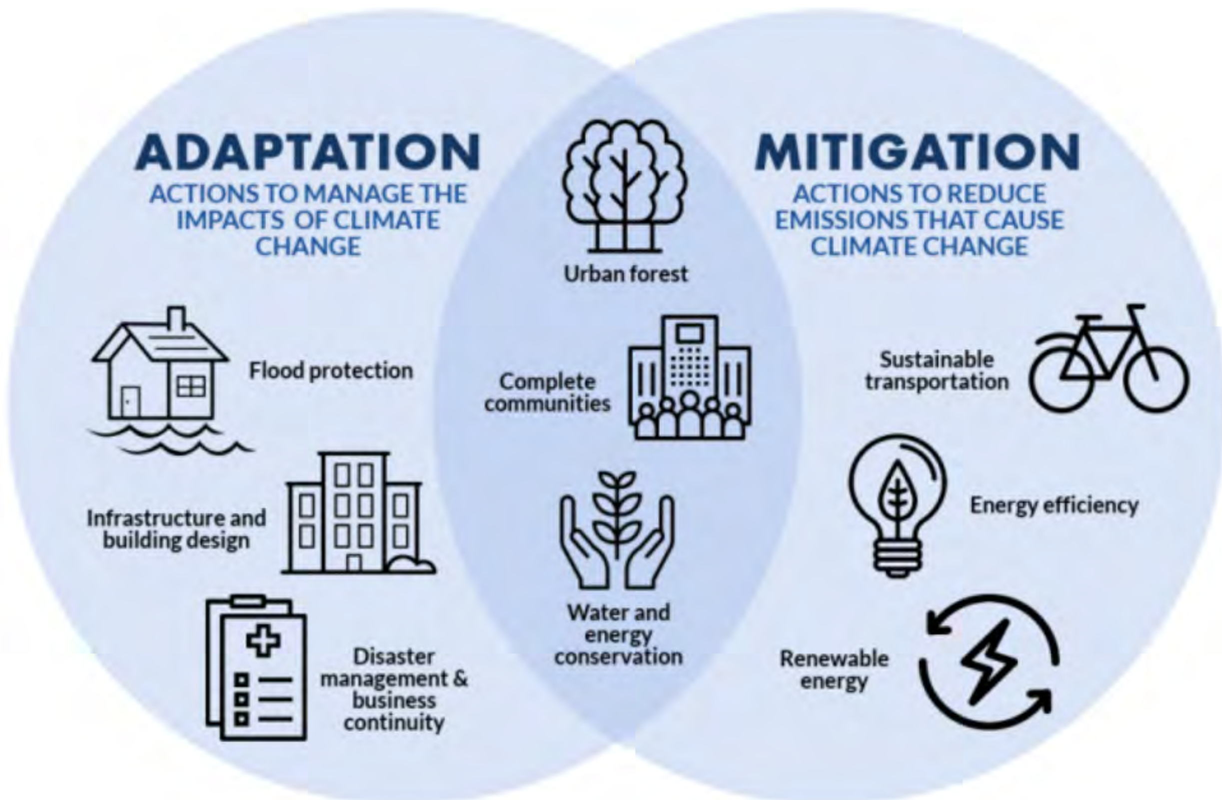


Figure 4 Mitigation versus Adaptation (from The Corporation of the City of Waterloo 2019)

The need to act is also shaped by recent experience with extreme weather events and their impacts on infrastructure asset performance and disruptions in service delivery and growing concern about how vulnerability and risk to acute and chronic changes in climate will increase in the future.

Adaptation builds resilience and reduces risk related to current and future climate change impacts, and adaptive capacity refers to the ability of economic and social systems, institutions, and ecosystems to adjust to impacts, to capitalize upon opportunities, and to minimize consequences. Generally, social and economic systems in Canada, including municipalities and conservation authorities across Ontario, have a relatively high level of adaptive capacity but the damage inflicted by extreme weather events is a reminder that vulnerability and risk continues to be a concern.

1.7.2 Climate Change Strategies, Assessments and Guidance: National and Provincial Level

In recent years there has been a wide-range of climate change strategies, assessments, data, actions, and guidance that has been produced by the federal and provincial governments. Since the Pan-Canadian Framework on Clean Growth and Climate Change was adopted in 2016, which focused on growing Canada's economy and building resilience to climate change, the federal government's activities have greatly influence municipalities. This includes supporting national climate change vulnerability assessments at the sectoral and regional scale; developing climate data portals (e.g., through the Canadian Centre of Climate Services); committing over $180 billion in funding over 12 years for new infrastructure funding through multiple programs; establishing requirements for the application of a "Climate Lens" to new federally-funded infrastructure projects that account for mitigation and adaptation; and updating standards and building codes, including guidance on using climate data to inform design standards for buildings and infrastructure.

In December 2020, the Government of Canada committed to develop a National Adaptation Strategy (Government of Canada 2022a) with provincial, territorial, and municipal governments; Indigenous Peoples; and other key partners. As part of a strengthened climate plan "A Healthy Environment and a Healthy Economy," the strategy aims to establish a shared vision for climate resilience in Canada. This includes the identification of key priorities for increased collaboration and the establishment of a framework for measuring progress at the national level. The National Adaptation Strategy was released in December 2022 in conjunction with the "Government of Canada Adaptation Action Plan" (Government of Canada 2022b), which is intended to be an implementation document for the strategy. The National Adaptation Strategy outlines a shared path to a more climate resilient Canada that addresses five key systems: (i) disaster resilience; (ii) health and well-being; (iii) nature and biodiversity; (iv) infrastructure; and (v) economy and workers. The action plan outlines 84 actions to advance adaptation throughout the five National Adaptation Strategy systems and address both immediate and future climate risks to Canada. In the case of nature and biodiversity, the goal of the National Adaptation Strategy is that biodiversity loss will have been halted and reversed and nature has fully recovered, allowing for natural and human adaptation where ecosystems and communities are thriving together in a changing climate, and with human systems existing in close connection with natural systems.

Conservation Halton strives to be a leader in climate change adaptation at the watershed level, a strategy that requires collaboration with the local municipalities throughout the watershed. As such, many of the key overarching messages around climate change and adaptation for municipalities as highlighted in "Canada in a Changing Climate: National Issues Report" (Brown et al. 2021) are applicable to Conservation Halton and the process to develop and implement the Watershed-based Resource Management Strategy. These key takeaways are outlined as follows:

- Enhancing green spaces helps cities and towns adapt to climate change. Green infrastructure, such as parks, wetlands, and green roofs, in Canada's cities and towns increases the quality of life for residents and improves climate resilience.

- Working together yields the most successful outcomes. Effective adaptation approaches to climate change consider diverse perspectives and priorities. Local governments are increasingly playing a strong role in driving meaningful collaboration with different groups when it comes to designing, planning, and implementing adaptation in their communities.

- Indigenous peoples in cities and towns are often affected in unique ways by climate change. Strengthening collaboration with Indigenous peoples will require increased capacity and additional research.

- Implementation of adaptation initiatives by cities and towns is not keeping pace with the risks posed by current weather extremes and future climate changes. However, examples of implementation are becoming more common, and the barriers to action are being reduced.

- Monitoring and evaluation of adaptation is an important and often overlooked step. Monitoring and evaluation methods are required to track adaptation progress and measure whether adaptation efforts are resulting in their desired outcomes.

In regard to Ontario, five of the seven key messages outlined in “Canada in a Changing Climate: Regional Perspective Report - Ontario” (Douglas and Pearson 2022) are relevant to Conservation Halton and the Watershed-based Resource Management Strategy:

- Nature-based approaches help address climate change impacts on biodiversity and ecosystem services, which are magnified through the cumulative effects of climate change, habitat loss, urbanization, pollution, and other threats.

- Adaptive management is key for addressing impacts in the Great Lakes Basin, where the combined effects of climate change, land use changes, and other stressors have negative impacts. Despite mechanisms to address complex governance challenges, adaptation across the Great Lakes Basin remains relatively fragmented; however, many communities have embraced adaptive management practices in light of uncertainties in future changes in climate.

- Adaptation improves forest health, carbon storage, and biodiversity, noting that changes in drought, pests, fire, and wind regimes are of particular concern given the resulting cumulative impacts.

- Existing human health inequities will be worsened by climate change, and local assessments of climate change vulnerability that include consideration of health equity will provide a foundation for stronger and more widespread adaptation action.

- Progress on adaptation planning and implementation remains limited in Ontario, where the primary focus is still placed on the assessment of risk and vulnerability. Although there are examples of implementation, there is little evidence of adaptation being mainstreamed into decision making broadly. Further, in most jurisdictions, systems for monitoring and evaluating adaptation action and effectiveness remain inadequate.

In Ontario, Conservation Halton operates under the Conservation Authorities Act, which has as its purpose "to provide for the organization and delivery of programs and services that further the conservation, restoration, development and management of natural resources in watersheds in Ontario." Section 21 of the Act sets out the range of programs and services that conservation authorities can provide. Specific programs and services that a conservation authority must provide includes the consideration of climate change as set out in O. Reg. 686/21. In addition, the legislation allows for a delivery of additional programs and services provided that agreements between the conservation authority and their participating municipalities for their delivery are in place. This enables conservation authorities and their municipal partners to be responsive to natural resource issues and management needs unique to their watershed.

“Preserving and Protecting our Environment for Future Generations: A Made-in-Ontario Environment Plan” (MECP, 2018) expressed a commitment to help prepare families and communities for the costs and impacts of climate change and to protect the natural environment, communities, business, and municipalities. In terms of municipalities, their main focus has been on planning and asset management, specifically “A Place to Grow: Growth Plan for the Greater Golden Horseshoe” (Government of Ontario, 2020), the “Provincial Policy Statement, 2020” (Ministry of Municipal Housing and Affairs, 2020), and O. Reg. 588/17 Asset Management Planning for Municipal Infrastructure. In August 2020, the Ontario Ministry of the Environment, Conservation and Parks announced that they were commissioning the province’s first ever multisector climate change impact assessment. The study is intended to be based upon the best science and information to understand where and how climate change is likely to affect communities, critical infrastructure, economies, and the natural environment, while helping to strengthen the province’s resilience to the impacts of climate change. There is no public indication that this assessment will lead to an updated provincial adaptation plan, with actions that support resiliency and adaptive capacity, other than those noted above.

1.7.3 Climate Risk Assessment Methods

There is a growing literature regarding climate risk assessment methods which served as useful resources when informing the methodology applied to developing the Climate Change Vulnerability and Risk Assessment. This includes ISO 31000 for risk management, the ISO 1409X series of climate adaptation standards, ICLEI BARC and their worksheets, and the Public Infrastructure Engineering Vulnerability Committee (PIEVC) family of vulnerability protocols. The “PIEVC High Level Screening Guide” is particularly noteworthy as it has become the de facto climate risk assessment method to support applications for federal funding of new infrastructure through the climate lens requirements. In addition to assessing climate vulnerability, risk and resilience of natural resources, its application can also be applied to:

- asset management, capital and master planning
- infrastructure operations and management evaluation and review

- asset portfolio assessment and evaluation
- municipal climate vulnerability and risk assessment (O'Driscoll et al. 2022)

Of particular note is the likelihood framework, that is based on a "middle-baseline" scoring method, which assigns changes in the probabilities of occurrence to climate hazards relative to a historical period. This framework is more relatable to decision makers than conventional likelihood scales adopted through the original PIEVC Protocol, the Intergovernmental Panel on Climate Change (IPCC), Climate Lens, and many ICLEI BARC climate risk assessments.

1.7.4 Issues and Vulnerabilities in Conservation Halton's Watersheds

The following is a summary of the watershed-wide issues that are currently faced by Conservation Halton's ecosystems and resources. Through the review, the key watershed-scale natural resource issues outlined by Conservation Halton's documentation (Request for Public Input – Resource Issues in Conservation Halton's Watersheds Draft Report, Conservation Halton September 2023) are summarized below. It is important to note that the findings in the Draft Report (Conservation Halton, September 2023) are preliminary and subject to modification based on public feedback

Riverine Flooding: The flooding that occurs in river and creek channels, and adjacent areas during periods of high water flow. Characterized by the overflow of water from the river onto the surrounding land, riverine flooding may cause damage to infrastructure and property, slope failure, bank and overland erosion, degraded water quality and degraded/loss of natural features.

Drought: Typically results from a period of persistent, drier conditions with less than normal precipitation and high temperatures. Drought may occur when there is a water shortage, which may be due to loss and fragmentation of forests and wetlands, increased use of surface and groundwater and climate change.

Valley Erosion: Excessive loss of soil due to natural creek processes which may result in bank slumping, scouring, undercutting, slope failure, degraded water quality and accumulation of contaminated sediment. Valley erosion occurs after periodic increases in peak creek flow, changes in channel form, unstable steep slopes, loss of riparian vegetation, increased sediment load levels, ice jams, and soil type.

Surface and Groundwater Quality – Chloride: Chloride is released through natural processes such as bedrock weathering and precipitation, however, significant increases have been observed in surface water over the last 50 years (Conservation Halton, Resource Issues Draft Report). Factors that increase chloride concentrations can include use of road and water softening salts, stormwater management ponds, and wastewater treatment plant effluent. Increased chloride concentrations in surface and groundwater leads to degraded water quality, increasing toxicity to fish and aquatic life, as well as degraded habitat.

Groundwater Quantity: Groundwater occurs when water infiltrates the soil, is stored in the soil voids, and moves underground through the aquifer. The availability of groundwater quantity may be influenced by aquifer storage capacity, soil permeability, municipal intake, and groundwater recharge volumes. Groundwater plays a key role in temperature regulation of streams and water bodies, providing appropriate habitat for aquatic species and reducing runoff volumes during flooding.

Degradation, Fragmentation, and Loss of Natural Features: Robust and diverse natural features provide many benefits to a watershed, including flood attenuation, erosion control, carbon storage, contaminant filtration, and wildlife habitat. Degradation, fragmentation, and loss of these features is one of the biggest threats faced by the watershed, as bio-diverse ecosystems are more resilient to the impacts of climate change.

Invasive Species: Non-native species that are introduced to an ecosystem, and cause harm to the local environment by killing, damaging or over-populating native species. Invasive species adapt easily, reproduce quickly and have a greater range of tolerance than native species. Invasion of non-native species may lead to degraded or fragmented habitat, decreased biodiversity, impaired ecosystem function, and loss of hospitable habitat for native wildlife.

Biodiversity Loss: Refers to the decrease or disappearance of various flora and fauna species, which may cause impaired ecosystem function, and reduced resilience against climate change. The loss of biodiversity within an ecosystem may cause impairment or shifts in range of species and impact their specific life cycles and increased risk to natural hazards.

Surface Water Quality: The main issues threatening the quality of surface water within Conservation Halton's watersheds are Total Suspended Solids (TSS), increased sedimentation, Total Phosphorus, and temperature (thermal pollution). The increased concentrations may be caused by several factors, such as natural weathering processes, exposure of chemicals to the environment, erosion, wastewater effluent and stormwater runoff from urban and rural areas, increased impermeable surfaces, degradation and loss of natural features, and climate change. Increased concentrations of these water quality parameters cause increased growth of harmful bacteria, degraded water quality, degraded/loss of aquatic habitat and species, increased flood risk, and less available drinking water sources.

Table 3 Watershed Issues and Vulnerable Areas

Watershed Issue	Vulnerable Areas within Conservation Halton
Riverine Flooding	• Southeast Oakville: Morrison-Wedgewood Diversion Channel Spills, Lower Wedgewood, Lower Morrison and Joshua Creeks • Southwest Oakville: Sheldon Creek Spill to Bronte Creek, Fourteen Mile, and McCraney Creeks • Southeast Burlington: Tuck, Shoreacres, Appleby and Sheldon Creeks • Southwest Burlington: Grindstone, Falcon, and Roseland Creeks, Hager-Rambo Creek and Diversion Channel System • Urban Milton: Sixteen Mile Creek • Lowvile, Carlisle, Progreston and Cedar Spring Community: Bronte Creek • Millgrove and Hidden Valley Community: Grindstone Creek • Highway 6 Corridor, Flamborough: Grindstone Creek, including spill from Bronte Creek

Watershed Issue	Vulnerable Areas within Conservation Halton

Drought	• Roseland and Rambo Creeks, East Branch of Hager Creek, Falcon Creek upstream of Highway 403, LaSalle Creek and Joshua's Creek in Oakville
	• Grindstone Creek tributaries
	    • Either near their upstream end, along their entire length or between their point of origin and their outlet
	• Tributaries northwest of Scotch Block reservoir, primarily in the northern reaches of Sixteen Mile Creek
	• Tributaries which flow through fine till plains
	    • Tributaries of Indian Creek
	    • Lowville, Mount Nemo and Lower Bronte Creek
	• Significant area of land above the Niagara Escarpment where groundwater aquifers are typically shallow
	• Areas with private shallow wells

Valley Erosion	• Areas with steep exposed slopes (North Oakville and Sixteen Mile Creek) and/or clay/shale and sand/gravel soils (Hidden Valley, Burlington and Grindstone) • Areas exposed to intense periods of high flow, listed below: • Downstream reach of Indian Creek below Hager-Rambo Diversion Channel, Burlington, North Shore • Sixteen Mile Creek downstream of concrete channel in downtown Milton • Small western tributaries of Grindstone Creek south of Highway 5
Surface and Groundwater Water Quality – Chloride	• Creeks downstream of or in urban areas, especially creek mouths • Indian Creek • Tributaries of Bronte Creek, West and East Branches of Sixteen Mile Creek and Fourteen Mile Creek at Lakeshore Road
Groundwater Quantity	• Subwatersheds that are stressed based on monthly and/or annual groundwater demand (Upper West Branch of the Sixteen Mile Creek and Willoughby Creek-Bronte Creek) • Potentially areas with shallow aquifers (some areas below the escarpment) • Areas where soil permeability is reduced due to land use change
Degradation, Fragmentation and Loss of Natural Features	• Urban areas below the Niagara Escarpment • Waterdown Woods and Fourteen Mile Creek (Jefferson Salamander and Redside Dace habitats) • Rural areas above the Niagara Escarpment in central and Eastern Grindstone Creek watershed

Invasive Species	• All Conservation Halton watersheds, in particular
	    o Natural areas used for human activity
	    o Natural areas adjacent to urban or agricultural areas
	    o Creeks that empty into Lake Ontario
	    o Ditches and natural areas adjacent to roads

Biodiversity Loss	• All Conservation Halton watersheds, in particular
	    o Natural areas fragmented by adjacent urban or agricultural areas (Bronte Burloak Woods, Town of Oakville)
	    o Natural areas sensitive to human uses (Waterdown Woods, Hamilton)
	    o Areas with species that have highly specialized requirements (Redside Dace, Fourteen Mile Creek)

Surface Water Quality	
Total Suspended Solids (TSS)	• Creeks downstream of or in urban and agricultural areas (East Branch of the Sixteen Mile Creek, Main Branch of Bronte Creek) • Creek mouths flowing into Lake Ontario (Fourteen Mile, Sixteen Mile, Bronte and Grindstone Creeks)

Watershed Issue	Vulnerable Areas within Conservation Halton
Sedimentation	• Some offline stormwater management ponds, numerous online ponds and dug out channels, behind dams and weirs throughout the watershed • Bronte and Hamilton Harbours
Total Phosphorus	• Creeks downstream of or in urban and /or agricultural areas (Indian Creek and Main Branch of Bronte Creek above the Niagara Escarpment, West and East Branches of Sixteen Mile Creek) • Creek mouths flowing into Lake Ontario (Fourteen Mile, Sixteen Mile, Bronte and Grindstone, Hamilton Harbour)
Temperature	• Central and downstream reaches of creeks that are not fed by cooler groundwater discharges and springs • Urbanized creeks (limited riparian vegetation, additional human impacts, warm water fed) • Creeks with intermittent water flow that typically become warmer before drying up

Source: Request for Public Input – Resource Issues in Conservation Halton's Watersheds Draft Report (Conservation Halton September 2023)

Understanding the key natural resource issues throughout the watershed, as defined by Conservation Halton, will help guide the Climate Change Vulnerability and Risk Assessment and cater it directly to the vulnerable areas and needs of Conservation Halton's watersheds. The specific vulnerable areas that experience these issues are further discussed at the watershed level in Section 6.2 – Watershed Vulnerabilities.

1.8 Natural Resource Inventory

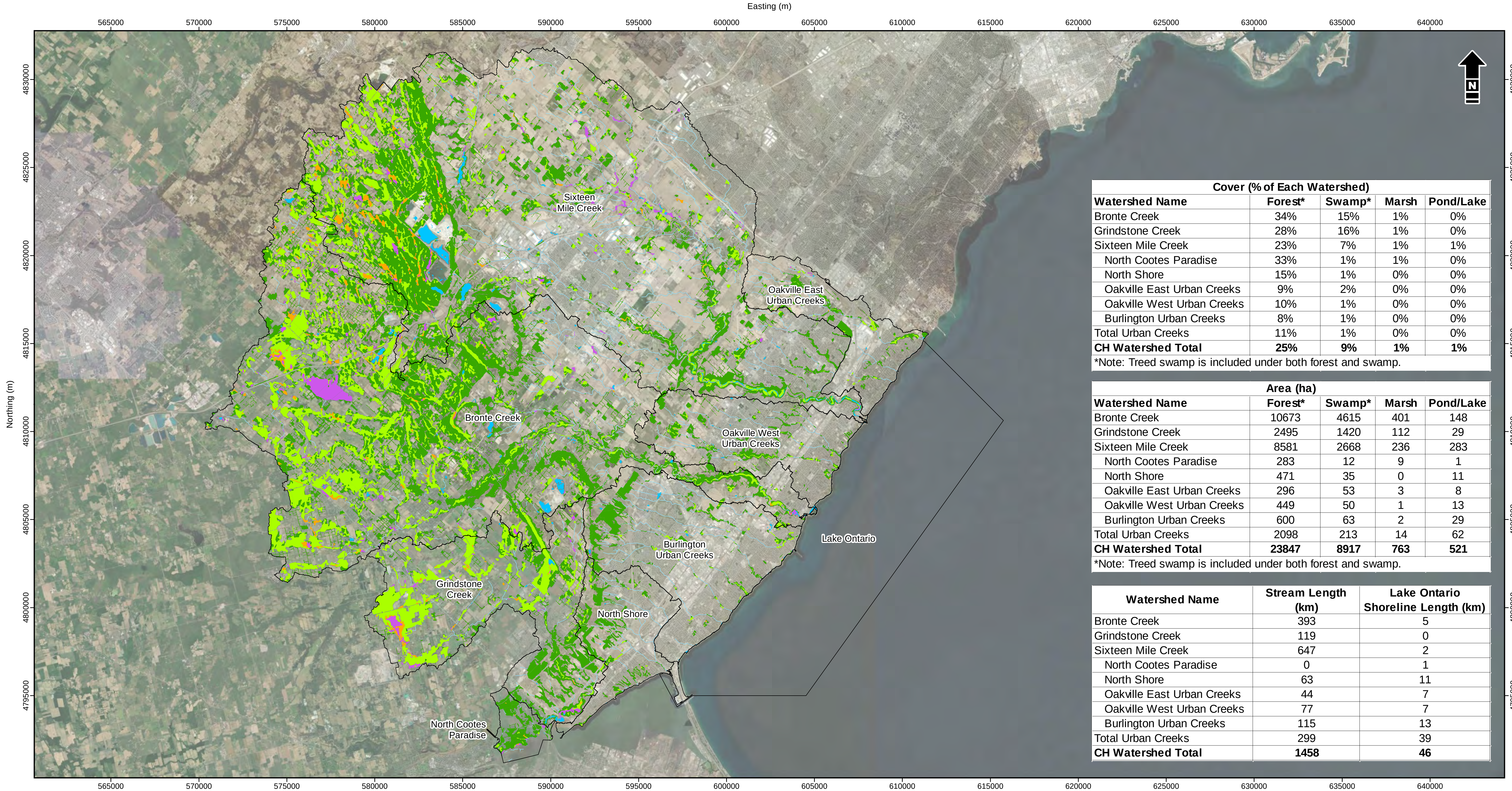
Early in the process of developing the Climate Change Vulnerability and Risk Assessment, Conservation Halton staff were consulted to establish the list of key natural resources to be evaluated. The natural resources identified all have significant presence and/or benefits of services throughout Conservation Halton's watersheds and are of importance to their connected ecosystem.

The list was cross-referenced against the spatial data provided by Conservation Halton for their natural resource inventory. Most of the natural resources were represented in the spatial data that was analyzed using Geographic Information System (GIS); however, there were some gaps in which no inventory data was available for the natural resource. The natural resource inventory list is compared against available datasets that were used to represent each resource, if applicable, is outlined in Table 4. Figure 5 below illustrates the natural resources throughout Conservation Halton's watersheds. Since the spatial data for the natural resources is smaller relative to the watershed scale they are illustrated on, four (4) additional figures are provided in Appendix E to illustrate the natural resource coverage on a smaller scale.

Table 4 Natural Resource Inventory and Spatial Data

Natural Resource	GIS Spatial Data Name
Stream	Ontario Hydro Network – Water Body (Updated July 12, 2018)
Pond/Lake	Water
Lakeshore	Lake Ontario Shoreline
Groundwater	Not available.
Wetland – Swamp	Swamp Treed Swamp
Wetland – Marsh	Marsh
Forest	Forest Treed Swamp
Meadow	Not available.
Vernal Pools	Incomplete for the entire jurisdiction.

Note:
Data received from Conservation Halton unless noted otherwise.



Cover (% of Each Watershed)				
Watershed Name	**Forest***	**Swamp***	**Marsh**	**Pond/Lake**
Bronte Creek	34%	15%	1%	0%
Grindstone Creek	28%	16%	1%	0%
Sixteen Mile Creek	23%	7%	1%	1%
North Cootes Paradise	33%	1%	1%	0%
North Shore	15%	1%	0%	0%
Oakville East Urban Creeks	9%	2%	0%	0%
Oakville West Urban Creeks	10%	1%	0%	0%
Burlington Urban Creeks	8%	1%	0%	0%
Total Urban Creeks	11%	1%	0%	0%
CH Watershed Total	**25%**	**9%**	**1%**	**1%**

*Note: Treed swamp is included under both forest and swamp.

Area (ha)				
Watershed Name	**Forest***	**Swamp***	**Marsh**	**Pond/Lake**
Bronte Creek	10673	4615	401	148
Grindstone Creek	2495	1420	112	29
Sixteen Mile Creek	8581	2668	236	283
North Cootes Paradise	283	12	9	1
North Shore	471	35	0	11
Oakville East Urban Creeks	296	53	3	8
Oakville West Urban Creeks	449	50	1	13
Burlington Urban Creeks	600	63	2	29
Total Urban Creeks	2098	213	14	62
CH Watershed Total	**23847**	**8917**	**763**	**521**

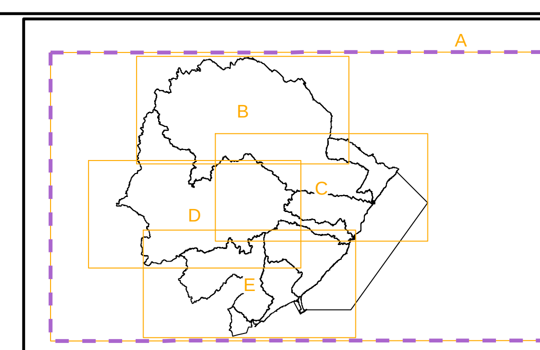
*Note: Treed swamp is included under both forest and swamp.

Watershed Name	Stream Length (km)	Lake Ontario Shoreline Length (km)
Bronte Creek	393	5
Grindstone Creek	119	0
Sixteen Mile Creek	647	2
North Cootes Paradise	0	1
North Shore	63	11
Oakville East Urban Creeks	44	7
Oakville West Urban Creeks	77	7
Burlington Urban Creeks	115	13
Total Urban Creeks	299	39
CH Watershed Total	**1458**	**46**

Watershed
Stream

Land Cover Type
- Forest
- Marsh
- Pond/Lake
- Swamp
- Treed Swamp (Forest/Swamp)*

*Treed swamp is represented in both Forest and Swamp data sets, therefore is shown as it's own entity.



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2,100 0 2,100 4,200
NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
A Montrose Environmental Company

Conservation Halton
Climate Change Vulnerability and Risk Assessment

Watershed-Based Natural Feature Inventory

Date: February 2024	Project: 36679	Submitter: A. Rafeiro	Reviewer: F. Tonto

Figure 5

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2 CONSERVATION HALTON'S FUTURE CLIMATE

2.1 Climate Hazards, Data, and Likelihood of Occurrence

For this assessment the selection of climate hazards was based on a review of the literature for climate risk assessments, best practice for natural resources and ecosystems, and in consultation with Conservation Halton subject matter experts. This involved identifying six climate hazards, that were supported by 26 different climate parameters and critical thresholds, including lake levels and ice cover. Further insights regarding individual climate hazards, climate parameters, and critical thresholds can be found in the climate hazard memo and accompanying appendix in excel format. The Climate Hazard Memo is included in Appendix C. Multiple climate parameters were used to inform six climate hazards which could also be described as interaction scenarios, that captured a fuller account of changing climate conditions that will impact natural resources and ecosystems, e.g., combination of precipitation and temperature conditions.

To compile these climate hazards, Matrix drew upon the nationally recognized climate data portals from the Canadian Centre for Climate Services, a collaboration between the federal government and regional climate centre consortiums (climatedata.ca). Matrix used a high emissions scenario (SSP5.85) as this represents the worst case of possible emission scenarios, and therefore expected to have the largest impacts on natural resources and ecosystems. The projections are generated through the CMIP6 ensemble of climate models. CMIP6 is a collaborative effort under the Coupled Model Intercomparison Project and represents the most current global climate model data available. The projections provide the foundation for the IPCC sixth assessment report and are typically applied to national and provincial assessments.

Future time periods selected are 2050 and 2080 that is consistent with climate impact assessments, and in practice within the medium-term and longer-term planning horizon adopted by municipal and conservation authority planning. It is noted that the historical data provided is modelled, rather than actual historical data, but a comparison between historical and modelled revealed that these numbers were identical on a 30-year average basis, noting for differences on a year-to-year basis. Data was drawn from multiple locations, where the data reflects those of an entire 10 x 6 km grid, recognizing that in some location's microclimates may cause variations in climate conditions. Given the granularity of this initial study is high level, any consideration of microclimates should be addressed in future work.

The two sites selected for the assessment were Burlington ON 43.37006ºN, 79.81403º W which was used to illustrate climate conditions below the Niagara Escarpment and was generally consistent to other grids/communities such as the Town of Oakville. Similarly, three grids were reviewed that represented the area above the Niagara Escarpment, which were adjacent to each other: Aberfoyle Creek (43.446312ºN, 80.182026º W), Aberfoyle (43.47083ºN, 80.14684º W), and Mountsberg Conservation Area (43.459648ºN, 80.030208º W). Given the consistency between these three grids, while there are minor differences among the historical and future projections, these differences are not significant enough to alter the likelihood scores.

Other data sets/portals were consulted that either confirmed/verified the direction and magnitude of projection or filled in any knowledge gaps, and a more thorough discussion of data can be found in the climate hazards memo and accompanying excel spreadsheets. This included, for example binational data portals on Great Lakes water levels, that also included trends for ice cover.

2.2 Likelihood

It has been our experience that the likelihood scoring method commonly applied in climate risk assessments using the ICLEI BARC method, IPCC method, and even the original PIEVC Protocol, can be applied inconsistently, and cause confusion in understanding future climate change relative to historical conditions. Advances in likelihood scoring methods have been made in the family of PIEVC program tools, that has shifted towards using the normal baseline approach (described in Table 5) and has been adopted into their High Level Screening Guide, the beta version of their Green Protocol, and soon to be included as an alternative method in the updated PIEVC Protocol. It has been found that this method resonates with decision makers responsible for managing assets, at the municipal and now conservation authority level.

Table 5 Likelihood Method – Normal Baseline

Likelihood	Method	Suggested Rationale
1	Likely to occur less frequently than current climate	50-100% reduction in frequency or intensity with reference to Baseline Mean
2		10-50% reduction in frequency or intensity with reference to Baseline Mean
3	Likely to occur as frequently as current climate	Baseline Mean Conditions or a change in frequency or intensity of +/-10% with reference to the Baseline Mean
4		10-50% increase in frequency or intensity with reference to Baseline Mean
5	Likely to occur more frequently than current climate	50-100% increase in frequency or intensity with reference to Baseline Mean

2.3 Climate Hazard Projections

In some cases, climate hazards can be defined by more than one climate parameter, and as a result as likelihood scores are assigned for each hazard, in some cases the number, representing the delta change from the historical normal, may be different for each parameter. In all cases the direct of change is the same under each climate hazard, but for seasonal changes there are differences in the projected magnitude of change that impact the likelihood score.

2.3.1 Dry Conditions

Dry conditions will be caused by increased temperatures and changes in precipitation patterns. Both average temperature and the number of days above 30C increase significantly. Annual precipitation increases, with rainfall or snow events expected to become more frequent and intense, while dry periods may similarly increase. In addition, increases in evapotranspiration will result in drier conditions for terrestrial and aquatic ecosystems. Seasonal reductions in infiltration will affect headwater streams.

Table 6 Dry Conditions Likelihood (2050 and 2080)

	Burlington		Aberfoyle	
Historical Baseline	2050	2080	2050	2080
3	4	4	4	4

2.3.2 Rainfall and Increased Flood Risk

An increase in rainfall intensities of both short duration, high frequency storms and less frequent large storms is projected. There is likely to be an increase in bank full, 1-year flows that cause stream erosion, in addition to a likely increase in larger storm events that cause floodplain inundation.

Table 7 Rainfall Likelihood (2050 and 2080)

	Burlington		**Aberfoyle**	
Historical Baseline	2050	2080	2050	2080
3	4	4	4	4

2.3.3 Heat Stress

There is projected to be a significant increase in virtually all metrics for heat and heat stress conditions. Average and maximum temperatures, in addition to humidex levels, are projected to significantly increase, resulting in heat stress for people, flora, and fauna. Stream temperatures are projected to increase as well, especially during lower water conditions.

Table 8 Heat Stress Likelihood (2050 and 2080)

	Burlington		**Aberfoyle**	
Historical Baseline	2050	2080	2050	2080
3	5	5	5	5

2.3.4 Seasonal Changes

Changes in multiple climate parameters can cause complex changes in the watersheds. These include, but are not limited to, shorter shoulder seasons, increase in growing degree days, and an earlier spring freshet. Overall, seasonal changes will be reflected by a warmer winter, hotter summer and shorter shoulder seasons, along with greater climate variability. Impacts may include conditions that are more hospitable to invasive species, while adversely affecting native species at risk.

Table 9 Seasonal Changes Likelihood (2050 and 2080)

	Burlington		Aberfoyle	
Historical Baseline	2050	2080	2050	2080
3	4	4-5	4	4-5

2.3.5 Snowpack Reduction

The amount of snowfall is a challenging climate variable to quantify with confidence, as it will be a function of the amount of precipitation – which is projected to increase over the winter season – and temperature – which is projected to increase. The key temperature threshold is 0°C where precipitation is expected to fall as rain when it is above 0°C and fall as snow when the temperature falls below 0°C. While the metric regarding snowfall would typically result in a dramatic drop and decline in snowfall amounts, resulting in likely scores declining from the historical baseline of 3, to a value of 2, if not down to 1 by the end of this century, snowfall reflects its greatest ecological impact.

In this case the impact and consequence for aquatic and terrestrial ecosystems is due to a decline in snowfall and accumulation, or its reverse defined as an increase in snowpack reduction. An increase in winter temperatures will lead to less snowfall, with more snowmelt expected and an increase in rain on snow events.

Table 10 Snowpack Reduction Likelihood (2050 and 2080)

	Burlington		Aberfoyle	
Historical Baseline	2050	2080	2050	2080
3	4	5	4	5

2.3.6 Wind

The climate science on changes in wind speeds is not strong, with a high degree of uncertainty and low level of confidence. However, based on the science that has been published on this topic, there is more confidence in the number of days when high wind gusts will occur, rather than a delta increase in maximum wind gusts. Based on the existing science, average wind speeds and high wind gusts are projected to increase. In the event that average wind speeds and the frequency of events remain relatively stable based on historical conditions, when it comes to the implications for shoreline erosion then there are other variables to consider. Wind direction is a major factor to consider with Conservation Halton's location at the western end of Lake Ontario. Easterly winds are much more damaging to Conservation

Halton's portion of shoreline along Lake Ontario compared to the typical westerly winds. It should be noted that water levels for Lake Ontario have been regulated since the late 1950s, and even with recent spikes in water levels due to increases in the water balance for the entire Great Lakes Basin, the high water levels are still relatively within the historical record. With less ice cover, and more evaporation expected, there is just as much likelihood for water levels (especially in Lake Superior and Lake Huron) to decline rather than increase. As a result, the likelihood of multiple effects caused by wind to increase slightly by 2050 and 2080, as reflected in managed water levels and decreased ice cover, resulting in a higher likelihood of coastal erosion.

Table 11 Wind Likelihood (2050 and 2080)

	Burlington		Aberfoyle	
Historical Baseline	2050	2080	2050	2080
3	4	4	4	4

3 VULNERABILITY AND RISK ASSESSMENT

3.1 Vulnerability and Risk Assessment Process

The vulnerability and risk assessment process provided an opportunity to apply existing knowledge and evidence about future climate projections and the natural functions of the watershed to identify and prioritize climate risks. This task followed a formal climate risk assessment process based on best practices (e.g., ISO 31000, ISO 14091, ICLEI BARC, and PIEVC Protocol). Conservation Halton staff played an essential role in this stage of the process and worked closely with the Project Team to quantify their perceived level of climate-related risks to watershed features, based on historical experiences and in relation to projected climate change conditions. The risk assessment process followed three main steps: risk identification, risk analysis, and risk evaluation. A breakdown of the process is provided the following sections through identifying risk hazards, designating those risks and rating the risks.

3.1.1 Risk Identification – Climate Hazard and Natural Resource Interactions

The first step in the assessment was to identify where there are interactions between climate hazards and the natural resources throughout Conservation Halton's watershed. This exercise does not consider the degree of the interaction, merely a choice between "yes" and "no" if there is a potential interaction. This was an important and initial "screening" phase to separate interactions of potential concern, from those where an increase in frequency or severity will have minimal if any impact on the function or health of natural resources. For example, a wetland-marsh may be affected by extreme heat but not by an acute weather event (high winds).

Prior to developing the consequence matrix, the Project Team and Conservation Halton Staff decided that if there was an interaction between a natural resource and a climate hazard, then some level of consequences should exist if that climate hazard occurred (e.g., at least a low consequence score).

Consequence rankings for the natural resources were evaluated against six climate hazards: dry conditions, heat stress, rainfall, seasonal changes, snowpack reduction and wind. Of the 54 total potential combinations of climate hazards and natural resource types, Conservation Halton staff confirmed that there was one case where no interactions existed, while there were 53 cases where interactions existed. The distribution of interactions provides some initial insights regarding the extent that the natural resources are exposed to the seven different climate hazards. The interactions between natural resources and the climate hazards are shown in Table 12.

Table 12 Natural Resource and Climate Hazard Interactions

Natural Resource	Climate Hazard					
	Dry Conditions	Heat Stress	Rainfall	Seasonal Changes	Snowpack Reduction	Wind
Stream	X	X	X	X	X	X
Pond/Lake	X	X	X	X	X	X
Lakeshore	X	X	X	X	X	X
Groundwater	X	X	X	X	X	
Wetland Swamp	X	X	X	X	X	X
Wetland Marsh	X	X	X	X	X	X
Forest	X	X	X	X	X	X
Meadow	X	X	X	X	X	X
Vernal Pools	X	X	X	X	X	X

3.1.2 Risk Analysis – Climate Hazard Consequences

Assessing consequences of individual interactions follows a standard approach where a consequence is typically described within a range of categories that includes economic, environmental, social, safety, and reputational impacts. For this watershed-based assessment, consequence categories were considered that represent the impacts faced by natural resources, such as terrestrial ecology, aquatic ecology, and water quality. Each consequence is classified by severity within a scale of 1 through 5. For this assessment specifically, the consequence rating was considered through the lens of each natural resource rather than a direct relationship between the climate hazards. The Project Team established the following seven consequence categories based on Conservation Halton's feedback:

- human health and property
- terrestrial ecology
- aquatic ecology
- water quality
- erosion and sedimentation

- flooding
- Conservation Halton services

Table 13a summarizes consequence screening questions posed to rank the consequence for each interaction.

Table 13a Consequence Ranking Screening Questions

Consequence Category	Screening Question
Human Health and Property	Will people be ill, injured, or killed due to the hazard's impact on the natural resources? Will the mental or emotional well-being of people be impacted due to the hazard's impact on the natural resource? Will property be damaged or destroyed due to the hazard's impact on the natural resources?
Terrestrial Ecology	Will there be damage or loss to land-based ecosystems, including the soil, water, air, and microbes that the ecosystem interacts with, due to the hazard's impact on the natural resources?
Aquatic Ecology	Will there be damage or loss to aquatic-based ecosystems, including the soil, water, air, and microbes that the ecosystem interacts with due to the hazard's impact on the natural resources?
Water Quality	Will there be higher water temperature or increased levels of nutrients, sedimentation, and reduced levels of oxygen due to the hazard's impact on the natural resources?
Erosion and Sedimentation	Will there be physical impacts to watercourses and shorelines, or changes to fluvial processes, that will increase erosion or degrade the ecological systems within the watershed due to the hazard's impact on the natural resources?
Flooding	Will there be an impact on the magnitude, frequency, and extent of flooding within the watershed due to the hazard's impact on the natural resources?
Conservation Halton Services	Will the ability of Conservation Halton to deliver community support services, generate income and the perception of Conservation Halton be impacted due to the hazard's impact on the natural resources?

The Project Team and Conservation Halton developed the consequence rating matrix summarized in Table 13b to score the potential severity of each interaction.

Table 13b Consequence Rating Matrix

Consequence Rating	Human Health and Property	Terrestrial Ecology	Aquatic Ecology	Water Quality	Erosion and Sedimentation	Flooding	Conservation Halton Services
None (1) Negligible impacts	Unlikely to result in injuries, illness, fatalities, and mental and emotional distress.	Unlikely to result in damage or loss of habitat or ecological function, negligible impact on biodiversity.	Unlikely to result in damage or loss of habitat or ecological function, negligible impact on biodiversity.	Unlikely to result in higher water temperature or increase in nutrients, sedimentation, or decrease in oxygen levels, negligible impact on water quality.	Unlikely to result in physical impacts to watercourses and shorelines or changes to the fluvial system.	Unlikely to result in increase in riverine or shoreline flooding magnitude, frequency, and extent.	Unlikely to impact community support services, result in political or reputational impacts or disrupt income generating activities.
Low (2) Minor and localized impacts in one or a few watersheds, few people impacted.	Minor injuries or illness. Short-term mental or emotional distress. Few individuals or properties affected. Localized areas affected in one or a few watersheds.	Short--term damage or loss. Short-term, recoverable impact on biodiversity. Few ecological features affected. Localized areas affected in one or a few watersheds.	Short--term damage or loss. Short-term, recoverable impact on biodiversity. Few ecological features affected. Localized areas affected in one or a few watersheds.	Short-term higher water temperature increases and in nutrients, sedimentation, or decrease in oxygen levels, recoverable impact. Few water quality parameters affected. Localized areas affected in one or a few watersheds.	Minor physical impacts to watercourses and shorelines or changes to the fluvial system. Slope undercutting on meander belts. Slight increases in erosion rates, but no measurable changes in fluvial sediment dynamics. Erosion and sedimentation changes are localized within small portion of the watershed area.	Minor increase in riverine or shoreline flooding magnitude, frequency, and extent. Localized flooding/ overland flow. Localized river or shoreline reaches affected in one or a few watersheds.	Short-term disruption to community support services and income generating activities. Short-term, localized, political or reputational damage, negative sentiment expressed on few media sources. Few services, individuals, or businesses affected. Small portion of the watershed area.
Medium (3) Minor and localized impacts in several watersheds, many people impacted.	Minor injuries or illness. Short-term mental or emotional distress. Many individuals or properties affected. Localized areas affected in several watersheds.	Short--term damage or loss. Short-term, recoverable impact on biodiversity. Few ecological features. Localized areas affected in several watersheds .	Short--term damage or loss. Short-term, recoverable impact on biodiversity. Few ecological features. Localized areas affected in several watersheds.	Short-term higher water temperature and increases in nutrients, sedimentation, or decrease in oxygen levels, recoverable impact. Few water quality parameters. Localized areas in several watersheds.	Minor physical impacts to watercourses and shorelines or changes to the fluvial system. Increases in erosion rates, including some evidence of changes in fluvial sediment dynamics. Tow erosion in valleys. Erosion and sedimentation impacts are evident within a few reaches of the watershed area, but not widespread.	Minor increase in riverine or shoreline flooding magnitude, frequency, and extent. Roadway overland flow overtopping Localized river or shoreline reaches in several watersheds affected.	Short-term disruption to community support services and income generating activities. Significant impact on public confidence, negative sentiment expressed on many media sources. Many services, individuals, or businesses affected. Small portion of the watershed area affected.

Consequence Rating	Human Health and Property	Terrestrial Ecology	Aquatic Ecology	Water Quality	Erosion and Sedimentation	Flooding	Conservation Halton Services
High (4) Major impacts in several watersheds, few people impacted.	Severe injuries, illness, or fatalities. Long-term mental or emotional distress. Few individuals and properties affected. Large portions in several watersheds.	Long-term damage or loss. Long-term, recoverable impact on biodiversity. Many ecological features impacted. Large portions in several watersheds.	Long-term damage or loss. Long-term, recoverable impact on biodiversity. Many ecological features impacted. Large portions in several watersheds.	Long-term higher water temperature and increases in nutrients, sedimentation, or decrease in oxygen levels, recoverable impact. Many water quality parameters impacted. Large portions in several watersheds.	Long-term, major physical impacts to watercourses and shorelines or changes to the fluvial system. Significant increases in erosion rates and substantive changes in fluvial sediment dynamics. Valley wall erosion. Erosion and sedimentation impacts are prevalent in many reaches and a large proportion of watershed area.	Long-term, major increase in riverine or shoreline flooding magnitude, frequency, and extent. Long-term roadway overland flow overtopping. Large stretches or river or shoreline reaches in several watersheds.	Long-term disruption to community support services and income generating activities for Conservation Halton. Long-term political or reputational damage, negative sentiment expressed on many media sources. Many services, individuals, or businesses affected. Major portions of the watershed area affected.
Very High (5) Major impacts in many watersheds, many people impacted.	Mass severe injuries, illness, and multiple fatalities. Mass long-term mental or emotional distress. Many individuals and properties affected. Large portions in many watersheds effected.	Widespread long--term damage or loss. Long-term, non-recoverable impact on biodiversity. Many ecological features. Large portions in many watersheds.	Widespread long--term damage or loss. Long-term, non-recoverable impact on biodiversity. Many ecological features. Large portions in many watersheds.	Widespread long-term higher water temperatures and increases in nutrients, sedimentation, or decrease in oxygen levels, non-recoverable impact. Many water quality parameters. Large portions in many watersheds.	Widespread, long-term physical impacts to watercourses and shorelines or changes to the fluvial system. Extreme increases in erosion rates and permanent changes in fluvial sediment dynamics. Valley failure. Erosion and sedimentation impacts are prevalent in most reaches throughout the watershed area.	Widespread long-term increase in riverine or shoreline flooding magnitude, frequency, and extent. Widespread long-term roadway overland flow overtopping. Large stretches of river or shoreline reaches in many watersheds.	Widespread long-term disruption to community support services and income generating activities. Sustained loss of confidence, widespread long-term political or reputational damage, negative sentiment expressed on many media sources. Many services, individuals, or businesses affected. Throughout the watershed area with impacts to the Region and province.

The Project Team worked with Conservation Halton subject matter experts to gather input and assign values of consequences for the natural resource and climate hazard interactions under each of the seven (7) pillar categories of concern. During the Risk Assessment Workshop, Conservation Halton subject matter experts were walked through the process of developing a consequence rating, including justification for the ratings based on evaluating the impact of a climate hazard through the services of a natural resource as it relates to the specific consequence category. The consequence rating matrix was then circulated to each Conservation Halton subject matter expert for them to populate and include justification based on their respective topics of expertise. All the consequence ratings from each subject matter expert were averaged to establish a singular all-encompassing rating.

The consequence ratings for each climate hazard against the natural resources are shown in Table 14.

Table 14 Consequence Rating (1-5) by Natural Resource and Climate Hazard

Natural Resource	Climate Hazard	Interaction	Human Health and Property	Terrestrial Ecology	Aquatic Ecology	Water Quality	Erosion & Sedimentation	Flooding	Conservation Halton Services
Wetland-Swamp	Dry Conditions	Y	3	4	3	3	2	3	2
Wetland-Marsh	Dry Conditions	Y	3	4	3	3	2	3	2
Stream	Dry Conditions	Y	2	3	5	4	3	3	2
Vernal Pools	Dry Conditions	Y	2	4	3	2	1	2	1
Pond/Lake	Dry Conditions	Y	2	3	4	4	3	3	3
Meadow	Dry Conditions	Y	2	3	2	2	2	2	1
Lakeshore	Dry Conditions	Y	2	3	4	4	3	2	2
Groundwater	Dry Conditions	Y	4	3	4	4	2	1	3
Forests	Dry Conditions	Y	2	4	2	2	2	2	3
Wetland-Swamp	Rainfall	Y	2	3	3	3	3	3	2
Wetland-Marsh	Rainfall	Y	2	3	3	3	3	3	2
Stream	Rainfall	Y	4	3	5	4	5	5	3
Vernal Pools	Rainfall	Y	2	3	3	2	2	2	2
Pond/Lake	Rainfall	Y	2	2	4	4	4	4	2

Natural Resource	Climate Hazard	Interaction	Human Health and Property	Terrestrial Ecology	Aquatic Ecology	Water Quality	Erosion & Sedimentation	Flooding	Conservation Halton Services
Meadow	Rainfall	Y	3	3	2	2	3	2	2
Lakeshore	Rainfall	Y	3	2	4	3	4	5	3
Groundwater	Rainfall	Y	3	2	4	3	2	2	3
Forests	Rainfall	Y	2	3	2	3	2	2	2
Wetland-Swamp	Heat Stress	Y	3	3	3	3	2	2	2
Wetland-Marsh	Heat Stress	Y	3	3	3	3	2	2	2
Stream	Heat Stress	Y	2	3	5	5	2	2	2
Vernal Pools	Heat Stress	Y	2	4	3	3	1	1	1
Pond/Lake	Heat Stress	Y	3	2	4	5	1	1	3
Meadow	Heat Stress	Y	2	3	2	2	1	1	2
Lakeshore	Heat Stress	Y	3	2	3	4	2	2	3
Groundwater	Heat Stress	Y	3	3	4	4	1	1	3
Forests	Heat Stress	Y	4	4	3	3	2	2	3
Wetland-Swamp	Seasonal Changes	Y	3	4	4	4	3	3	1
Wetland-Marsh	Seasonal Changes	Y	2	4	4	4	3	3	2

Natural Resource	Climate Hazard	Interaction	Human Health and Property	Terrestrial Ecology	Aquatic Ecology	Water Quality	Erosion & Sedimentation	Flooding	Conservation Halton Services
Stream	Seasonal Changes	Y	3	3	4	4	3	3	3
Vernal Pools	Seasonal Changes	Y	2	4	3	1	2	2	1
Pond/Lake	Seasonal Changes	Y	2	4	4	4	3	3	2
Meadow	Seasonal Changes	Y	3	3	1	1	1	1	2
Lakeshore	Seasonal Changes	Y	3	3	5	4	3	3	3
Groundwater	Seasonal Changes	Y	4	3	4	5	2	1	3
Forests	Seasonal Changes	Y	3	4	3	3	1	1	3
Wetland-Swamp	Snowpack Reduction	Y	3	3	4	4	2	2	2
Wetland-Marsh	Snowpack Reduction	Y	2	3	4	4	2	2	2
Stream	Snowpack Reduction	Y	3	3	4	4	3	3	3
Vernal Pools	Snowpack Reduction	Y	2	4	4	2	2	2	2
Pond/Lake	Snowpack Reduction	Y	3	2	4	4	2	2	2
Meadow	Snowpack Reduction	Y	2	2	2	1	1	2	1
Lakeshore	Snowpack Reduction	Y	2	2	3	3	3	3	2

Natural Resource	Climate Hazard	Interaction	Human Health and Property	Terrestrial Ecology	Aquatic Ecology	Water Quality	Erosion & Sedimentation	Flooding	Conservation Halton Services
Groundwater	Snowpack Reduction	Y	3	3	3	2	2	1	1
Forests	Snowpack Reduction	Y	3	3	2	2	2	2	2
Wetland-Swamp	Wind	Y	3	3	2	2	1	1	2
Wetland-Marsh	Wind	Y	2	2	1	2	1	1	1
Stream	Wind	Y	2	2	2	2	2	3	2
Vernal Pools	Wind	Y	1	2	1	1	1	1	1
Pond/Lake	Wind	Y	2	2	2	2	2	2	2
Meadow	Wind	Y	1	2	1	1	1	1	1
Lakeshore	Wind	Y	3	2	3	2	4	3	3
Forests	Wind	Y	2	3	3	2	2	1	3

3.1.3 Risk Evaluation – Risk Rating for Natural Resources

Once there was agreement in the consequence scores, the next step in the process was to calculate the risk scores. The risk rating was calculated using consequence (severity) × likelihood (probability) of occurrence (R = S × P) to determine individual risk scores ranging from low to very high (e.g., low: 1-5; moderate: 6-12; high: 15 -16; and very high: 20-25), as outlined in the risk matrix (Figure 6).

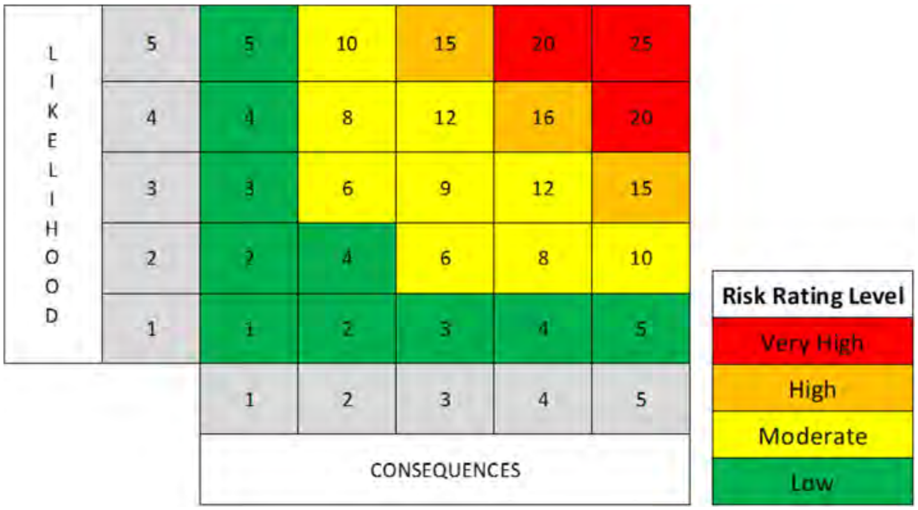


Figure 6 Risk Matrix

A summary of the final risk scores for each natural resource by climate hazard for 2050 is provided in Table 15.

Table 15 Summary of Final Risk Ratings (2050)

Natural Resource	Climate Hazard	Climate Hazard Likelihood Rating	Human Health and Property Risk	Terrestrial Ecology Risk	Aquatic Ecology Risk	Water Quality Risk	Erosion and Sedimentation Risk	Flooding Risk	Conservation Halton Risk
Forests	Dry Conditions	4	12	16	12	12	8	8	12
Forests	Heat Stress	5	20	20	15	15	10	10	20
Forests	Rainfall	4	8	12	8	12	8	8	12
Forests	Seasonal Changes	4	12	16	12	12	4	4	12
Forests	Snowpack Reduction	4	12	12	12	8	8	8	12
Forests	Wind	4	8	12	12	8	8	4	12
Groundwater	Dry Conditions	4	16	16	20	16	8	8	12
Groundwater	Heat Stress	5	20	15	25	25	10	10	15
Groundwater	Rainfall	4	12	12	16	16	12	12	12
Groundwater	Seasonal Changes	4	16	16	16	20	8	4	12
Groundwater	Snowpack Reduction	4	12	12	12	12	8	4	4
Lakeshore	Dry Conditions	4	8	12	16	16	12	12	8
Lakeshore	Heat Stress	5	15	15	20	25	10	10	15
Lakeshore	Rainfall	4	16	8	16	16	20	20	12
Lakeshore	Seasonal Changes	4	12	16	20	16	12	12	12
Lakeshore	Snowpack Reduction	4	12	8	12	16	12	12	12
Lakeshore	Wind	4	16	8	12	12	16	16	16
Meadow	Dry Conditions	4	8	12	8	8	8	8	4
Meadow	Heat Stress	5	10	20	10	10	5	5	10
Meadow	Rainfall	4	12	12	8	8	12	8	8
Meadow	Seasonal Changes	4	12	12	4	4	4	4	8
Meadow	Snowpack Reduction	4	8	8	8	8	4	8	4
Meadow	Wind	4	8	8	8	8	4	4	4

Natural Resource	Climate Hazard	Climate Hazard Likelihood Rating	Human Health and Property Risk	Terrestrial Ecology Risk	Aquatic Ecology Risk	Water Quality Risk	Erosion and Sedimentation Risk	Flooding Risk	Conservation Halton Risk
Pond/Lake	Dry Conditions	4	12	12	16	16	12	12	12
Pond/Lake	Heat Stress	5	15	15	20	25	5	5	15
Pond/Lake	Rainfall	4	12	12	16	16	16	16	12
Pond/Lake	Seasonal Changes	4	12	16	20	16	12	12	8
Pond/Lake	Snowpack Reduction	4	12	12	16	16	8	8	12
Pond/Lake	Wind	4	12	8	8	12	8	8	12
Vernal Pools	Dry Conditions	4	8	16	12	8	8	8	8
Vernal Pools	Heat Stress	5	10	20	20	15	5	5	5
Vernal Pools	Rainfall	4	8	16	12	8	8	8	8
Vernal Pools	Seasonal Changes	4	8	16	16	4	8	8	4
Vernal Pools	Snowpack Reduction	4	8	16	16	12	8	8	8
Vernal Pools	Wind	4	4	12	8	4	4	4	4
Stream	Dry Conditions	4	12	12	20	16	12	16	8
Stream	Heat Stress	5	15	15	25	25	10	10	10
Stream	Rainfall	4	16	12	20	16	20	20	12
Stream	Seasonal Changes	4	12	16	20	20	12	12	12
Stream	Snowpack Reduction	4	12	12	16	16	12	12	12
Stream	Wind	4	8	8	8	8	8	12	8
Wetland-Marsh	Dry Conditions	4	12	16	16	12	8	16	8
Wetland-Marsh	Heat Stress	5	15	15	20	15	15	15	10
Wetland-Marsh	Rainfall	4	12	12	12	12	12	12	8
Wetland-Marsh	Seasonal Changes	4	8	16	16	16	12	12	8
Wetland-Marsh	Snowpack Reduction	4	12	12	16	16	8	8	12
Wetland-Marsh	Wind	4	8	12	4	8	4	4	4

Natural Resource	Climate Hazard	Climate Hazard Likelihood Rating	Human Health and Property Risk	Terrestrial Ecology Risk	Aquatic Ecology Risk	Water Quality Risk	Erosion and Sedimentation Risk	Flooding Risk	Conservation Halton Risk
Wetland-Swamp	Dry Conditions	4	12	16	12	12	8	12	8
Wetland-Swamp	Heat Stress	5	15	20	20	15	15	15	10
Wetland-Swamp	Rainfall	4	12	16	16	12	12	12	8
Wetland-Swamp	Seasonal Changes	4	12	16	16	16	12	12	8
Wetland-Swamp	Snowpack Reduction	4	12	12	16	16	8	8	12
Wetland-Swamp	Wind	4	12	12	8	8	4	4	8

3.2 Risk Assessment Results

Based on the methodology applied, each interaction between natural resource and climate hazard could generate up to seven possible risk scores. The Project Team consulted Conservation Halton to establish a method to further prioritize risks. This method involved extracting the interactions having one or more “high” (15+) and/or “very high” (20+) risk ratings.

The screening method resulted in 38 natural interactions for 2050 climate hazard projections and 41 interactions for 2080 climate hazard projections. The only change observed between 2050 and 2080 was the difference in likelihood scores for snowpack reduction and seasonal changes, which increased risk ratings. Tables 16 and 17 list the complete list of interactions with high and very high-risk ratings for 2050 and 2080 climate projections, respectively.

There were a few emerging trends amongst the identified high- and very high-risk resources. Top three climate hazards resulting in high and very high-risk ratings are heat stress, rainfall, and seasonal changes.

Table 16 High- and Very High-Risk Ratings for 2050

Natural Resource	Climate Hazard	Climate Hazard Likelihood Score	Human Health and Property Risk	Terrestrial Ecology Risk	Aquatic Ecology Risk	Water Quality Risk	Erosion and Sedimentation Risk	Flooding Risk	Conservation Halton Risk Score
Forests	Dry Conditions	4	12	16	12	12	8	8	12
Forests	Heat Stress	5	20	20	15	15	10	10	20
Forests	Seasonal Changes	4	12	16	12	12	4	4	12
Groundwater	Dry Conditions	4	16	16	20	16	8	8	12
Groundwater	Heat Stress	5	20	15	25	25	10	10	15
Groundwater	Rainfall	4	12	12	16	16	12	12	12
Groundwater	Seasonal Changes	4	16	16	16	20	8	4	12
Lakeshore	Dry Conditions	4	8	12	16	16	12	12	8
Lakeshore	Heat Stress	5	15	15	20	25	10	10	15
Lakeshore	Rainfall	4	16	8	16	16	20	20	12
Lakeshore	Seasonal Changes	4	12	16	20	16	12	12	12
Lakeshore	Snowpack Reduction	4	12	8	12	16	12	12	12
Lakeshore	Wind	4	16	8	12	12	16	16	16
Meadow	Heat Stress	5	10	20	10	10	5	5	10
Pond/Lake	Dry Conditions	4	12	12	16	16	12	12	12
Pond/Lake	Heat Stress	5	15	15	20	25	5	5	15
Pond/Lake	Rainfall	4	12	12	16	16	16	16	12
Pond/Lake	Seasonal Changes	4	12	16	20	16	12	12	8
Pond/Lake	Snowpack Reduction	4	12	12	16	16	8	8	12
Vernal Pools	Dry Conditions	4	8	16	12	8	8	8	8
Vernal Pools	Heat Stress	5	10	20	20	15	5	5	5
Vernal Pools	Rainfall	4	8	16	12	8	8	8	8
Vernal Pools	Seasonal Changes	4	8	16	16	4	8	8	4
Vernal Pools	Snowpack Reduction	4	8	16	16	12	8	8	8
Stream	Dry Conditions	4	12	12	20	16	12	16	8

Natural Resource	Climate Hazard	Climate Hazard Likelihood Score	Human Health and Property Risk	Terrestrial Ecology Risk	Aquatic Ecology Risk	Water Quality Risk	Erosion and Sedimentation Risk	Flooding Risk	Conservation Halton Risk Score
Stream	Heat Stress	5	15	15	25	25	10	10	10
Stream	Rainfall	4	16	12	20	16	20	20	12
Stream	Seasonal Changes	4	12	16	20	20	12	12	12
Stream	Snowpack Reduction	4	12	12	16	16	12	12	12
Wetland-Marsh	Dry Conditions	4	12	16	16	12	8	16	8
Wetland-Marsh	Heat Stress	5	15	15	20	15	15	15	10
Wetland-Marsh	Seasonal Changes	4	8	16	16	16	12	12	8
Wetland-Marsh	Snowpack Reduction	4	12	12	16	16	8	8	12
Wetland-Swamp	Dry Conditions	4	12	16	12	12	8	12	8
Wetland-Swamp	Heat Stress	5	15	20	20	15	15	15	10
Wetland-Swamp	Rainfall	4	12	16	16	12	12	12	8
Wetland-Swamp	Seasonal Changes	4	12	16	16	16	12	12	8
Wetland-Swamp	Snowpack Reduction	4	12	12	16	16	8	8	12

Table 17 Risk Ratings for 2080 – Snowpack Reduction and Seasonal Changes

Natural Resource	Climate Hazard	Climate Hazard Likelihood Score	Human Health and Property Risk Score	Terrestrial Ecology Risk Score	Aquatic Ecology Risk Score	Water Quality Risk Score	Erosion and Sedimentation Risk Score	Flooding Risk Score	Conservation Halton Risk Score
Forests	Seasonal Changes	5	15	20	15	15	5	5	15
Forests	Snowpack Reduction	5	15	15	15	10	10	10	15
Groundwater	Seasonal Changes	5	20	20	20	25	10	5	15
Groundwater	Snowpack Reduction	5	15	15	15	15	10	5	5
Lakeshore	Seasonal Changes	5	15	20	25	20	15	15	15
Lakeshore	Snowpack Reduction	5	15	10	15	20	15	15	15
Meadow	Seasonal Changes	5	15	15	5	5	5	5	10
Meadow	Snowpack Reduction	5	10	10	10	10	5	10	5
Pond/Lake	Seasonal Changes	5	15	20	25	20	15	15	10
Pond/Lake	Snowpack Reduction	5	15	15	20	20	10	10	15
Vernal Pools	Seasonal Changes	5	10	20	20	5	10	10	5
Vernal Pools	Snowpack Reduction	5	10	20	20	15	10	10	10
Stream	Seasonal Changes	5	15	20	25	25	15	15	15
Stream	Snowpack Reduction	5	15	15	20	20	15	15	15
Wetland-Marsh	Seasonal Changes	5	10	20	20	20	15	15	10
Wetland-Marsh	Snowpack Reduction	5	15	15	20	20	10	10	15
Wetland-Swamp	Seasonal Changes	5	15	20	20	20	15	15	10
Wetland-Swamp	Snowpack Reduction	5	15	15	20	20	10	10	15

Note:
The only changes between 2050 and 2080 are under snowpack and seasonal changes. All other risk scores for 2080 are the same as 2050.

3.2.1 Natural Resources and Climate Change

A goal of the Climate Vulnerability and Risk Assessment is to identify and understand the consequences of climate change to the natural resources at the watershed level. The report on the *Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds* (Conservation Halton, September 2023) provided significant coverage on the services that natural resources deliver, and their benefits to the surrounding ecosystem. The benefits and services for each natural resource, as outlined in the background documents reviewed, are summarized in the following subsections.

3.2.2 Streams – Benefits

Streams are a key connective pathway for biota between habitat locations within the watershed and also provide a multitude of hydrologic and recreational benefits. The role and benefit that streams provide to their surrounding ecosystem are summarized below:

- Provide habitat for aquatic and amphibian species.
- Operate as the main habitat corridor (i.e. Aquatic or terrestrial connection pathway between habitat locations).

3.2.3 Ponds and Lakes – Benefits

Ponds and Lakes are located throughout Conservation Halton's watersheds and provide varying recreational, hydrologic and ecological benefits. For discussion purposes, ponds and lakes herein will be considered as Conservation Halton's jurisdictional boundary through Lake Ontario. The role and benefit that ponds and lakes provide to their surrounding ecosystem are summarized below:

- Provide habitat for aquatic and amphibian species.
- Retaining and detaining water to manage the hydrologic response to precipitation events.
- Maintain the biological health of wetlands and watercourses.
- Attenuate flows and reduce erosion rates downstream.
- Improve water quality by removing pollutants.
- Contribute sediment to downstream reaches.

3.2.4 Lakeshore – Benefits

Lakeshores provide unique habitat for aquatic ecosystems in the watersheds, and recreational services for the residents in Conservation Halton's jurisdiction. For this assessment, lakeshores include the shoreline along Lake Ontario and a portion of Hamilton Harbour. The role and benefit that lakeshores provide to their surrounding ecosystem are summarized below:

- Contribute sediment supply (bedload) to downstream reaches, which helps maintain ecological functions of aquatic ecosystems.

- Maintain suitable habitat for aquatic invertebrates, which are an important diet component of fish.

- Provide allochthonous organic material inputs downstream through riparian vegetation.

3.2.5 Groundwater – Benefits

Groundwater is a key component of the watershed and its ability to be resilient against climate change. The role and benefit that groundwater provides to the surrounding ecosystem are summarized below:

- Recharge/discharge of groundwater maintains cooler temperatures in streams.
  - Coldwater refugia in summer
  - Warmwater refugia in winter
- Thermal moderation maintains optimal conditions for species with sensitive habitat requirements.
- Integral in part of offsetting climate change impacts.

3.2.6 Wetlands – Benefits

Wetlands, both swamps and marshes, are a significant natural resource that contribute to the health of a watershed. The role and benefit that wetlands provide to their surrounding ecosystem are summarized below:

- Contribute to groundwater recharge via infiltration, reducing water temperatures.
- Carbon, methane, and nutrient storage within the soils.
- Regulate stream flows and moderate flooding by storing and slow release of water.
- Provide habitat for aquatic, amphibians, and species with specific habitat requirements.
- Provide habitat for hibernating species in the mud cover layer during winter months.
- Reduce sedimentation by trapping soils.

3.2.7 Forests – Benefits

Forests are another significant contributor to the biodiversity of Conservation Halton's watersheds, which increases the resiliency of an ecosystem against climate change. The role and benefit that forests provide to their surrounding ecosystem are summarized below:

- Act as carbon sinks, which absorb more carbon dioxide from the atmosphere than they release (air purification).

- Provide a variety of distinct and specialized habitats, such as vernal pools, snags, or interior habitat that are necessary for refuge or breeding of numerous species.
- Soil type, moisture and condition influence the plants that are able to grow in that area, which influences the habitats available.
- The species composition of trees within a forest influence nutrient cycling
- Provide habitat for terrestrial and amphibian species.
- Provide permeable surfaces that allow for infiltration and groundwater recharge.

3.2.8 Meadows – Benefits

Meadows provide specific ecological habitats and benefits to the watershed. The role and services that meadows provide to their surrounding ecosystem are summarized below:

- Foraging/nesting habitat for species associated with woodlands and wetlands, as well as a possible linkage between these two habitats.
- Support habitat for grassland-specialized flora and fauna (i.e. open habitat).
- Provide permeable surfaces that allow for infiltration and groundwater recharge.

3.2.9 Vernal Pools – Benefits

Vernal Pools are temporary contributors to a healthy watershed but play a significant role for certain species biodiversity and habitat. The role and benefit that vernal pools provide to their surrounding ecosystem are summarized below:

- Provide habitat diversity to forests for flora and fauna.
- Serve as breeding habitat for amphibians.
- Contribute to the enrichment of the forest floor.
- Provide increased flow detention, attenuation, and moderation within the stream network.
- Reduce erosion potential downstream.
- Assist in maintaining thermal water quality benefits.

3.3 Climate Change Hazard and Natural Resource Interactions

Climate change hinders the ability of natural resources to deliver their services and benefits to the surrounding ecosystem, and the degree to which natural resources experience consequences from climate change has been evaluated through this risk assessment. The consequences of climate change were identified as outlined in Conservation Halton's documentation, particularly their report on the *Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds* (September 2023), and by gathering input through the risk assessment process, to understand how climate change will impact natural resources.

As mentioned in Section 5.1 – Risk Assessment Results, the climate hazard and natural resource pair that scored a minimum of one "high" (15+) or "very high" (20+) ranking is screened through for further analysis. The natural resources and climate hazards that were screened through and their impacts on each consequence category are summarized in the subsequent sections, as outlined by Conservation Halton's subject matter experts. Appendix D contains a detailed reporting of the input provided by Conservation Halton subject matter experts that outlines the impacts of climate hazards on natural resources, organized by consequence category.

Refer to Table 16 and 17, in Section 3.2 for the risk ratings for each natural resource and climate hazard interaction.

3.3.1 Forests

Forests in Conservation Halton's watershed are under imminent threat from climate change, with a prominent risk being heat stress, leading to increased vegetation mortality and fires. This risk assessment found that forests are at risk of heat stress, dry conditions, and seasonal changes through 2050, and snowpack reduction through 2080.

Beyond endangering human safety and property, these hazards affect park accessibility and residents' well-being, necessitating urgent attention, particularly given the expected escalation of heat stress through 2050. Additional risks from snowpack reduction and seasonal changes intensify threats like tree drying and property damage due to flood risk, creating challenges for forest and watershed health. The broader impact on terrestrial ecology involves diminished biodiversity, affecting the forests' ability to provide essential benefits to ecosystems. Addressing these multifaceted risks is imperative to preserve the invaluable services offered by forests in Conservation Halton's watersheds amid the evolving challenges posed by climate change. Refer to Appendix D for further discussion on the consequences of each climate hazard.

Climate change contributes to continued loss and/or degradation of forests throughout the watershed. The consequences due to the impacts of climate change on forests are outlined as follows:

- Increased evapotranspiration in response to higher temperatures, resulting in reduction in soil moisture, stress of vegetation and habitat.
- Degraded water quality due to lack of vegetation in stream corridors and throughout the watershed, a result of increased erosion and flooding.
- Changes to the forest disturbance regimes, by affecting the abundance and distribution of pests and pathogens, which can trigger widespread tree mortality and release carbon into the atmosphere.
- Changes in soil biological processes during winter, affecting greenhouse gas fluxes.
- Decreased ability to attenuate downstream hydrographs by reducing surface flow and overbank flows due to decreased forest area.
- Changes to temporal soil moisture patterns resulting from seasonal precipitation and temperature changes and flooding, which enhances conditions for reproduction and spread of organisms that attack trees.
- Decreased storage within floodplains due to decreased infiltration and less sediment deposition.

3.3.2 Groundwater

Climate change poses severe threats to groundwater in Conservation Halton's watersheds. The risk assessment identifies multiple risks, including dry conditions, heat stress, seasonal changes, and snowpack reduction, which collectively endanger groundwater wells, leading to potential decreases in recharge and water supply. The risks intensify through 2050 and 2080, potentially causing distress to residents and impacting domestic water supply. Additionally, these climate scenarios affect terrestrial ecology, altering wetland hydroperiods and vegetation, diminishing habitat quality for terrestrial species. Aquatic ecosystems connected to groundwater face habitat loss, increased water temperatures, and contamination risks. The importance of groundwater for water quality is underscored, with potential consequences including elevated contaminant concentrations and temperature variations. Conservation Halton's services, dependent on groundwater, are at risk, impacting the delivery of recreational spaces in parks and conservation areas. The interconnected nature of these threats necessitates urgent attention to safeguard groundwater resources amidst the challenges posed by climate change. Refer to Appendix D for further discussion on the consequences of each climate hazard.

Climate change contributes to significant changes in groundwater recharge and input throughout the watershed. The consequences due to the impacts of climate change on groundwater are outlined as follows:

- Decreased groundwater recharge and input, due to decreased infiltration and increased drought. Decreased groundwater supply may also be due to shallow, dried up, or unstable wells due to increased drought. These impacts may cause:
  - Decreased ability for aquatic species to live and thrive in different downstream habitats.
  - Decreased water quality due to increased concentration of contaminants and bacteria.

3.3.3 Lakeshore

Climate change poses a multitude of threats to Conservation Halton's lakeshore area, impacting various aspects within the watershed. Through this risk assessment, it was found that lakeshores are at risk of dry conditions, heat stress, rainfall, wind, seasonal changes, and snowpack reduction through both 2050 and 2080. The lakeshore is heavily populated and frequently visited, facing risks such as water level increase, rainfall, and wind, which may impede access, increase physical hazards. Algal blooms and shoreline erosion are additional concerns resulting from heat stress and increased wind and possible high lake levels. The interconnected impacts of these climate scenarios contribute to potential flooding, erosion, property damage, and reduced access along the lakeshore.

Terrestrial ecology along the lakeshores is vulnerable to seasonal changes, affecting wildlife habitats, species migration, and breeding grounds, thereby impacting biodiversity. Aquatic ecology, vital for maintaining water quality, faces risks from heat stress, increased rainfall, and seasonal changes (ice cover), with potential consequences including degraded aquatic ecosystems.

Erosion and sedimentation risks are heightened due to increased runoff, storm surges, and wave action, impacting shoreline integrity. Conservation Halton's services related to the lakeshores, including beach closures, visitor experiences, and infrastructure maintenance, are at risk from heat stress, wind, seasonal changes, and possible high lake levels emphasizing the urgency of addressing these climate threats to safeguard the lakeshores and their vital services. Refer to Appendix D for further discussion on the consequences of each climate hazard.

Climate hazards may contribute to continued loss and/or degradation of lakeshores throughout the watershed. The consequences due to the impacts of climate change on lakeshores are outlined as follows:

- Increased water temperatures due to changes in the upstream tributaries. This may cause:
  - Algal blooms due to increased levels of Total Phosphorus from the upstream watershed, decreasing the available dissolved oxygen and impairing fish habitat.

- Increased hazard events due to decreased resiliency of the lakeshore, including: shoreline flooding, damage and erosion, disruption of transport services, damage to homes and buildings, increased risk of illness from mold growth, damage to lakeshore infrastructure and facilities.

3.3.4 Meadow

Meadows within Conservation Halton's watershed face climate-related threats that have implications for both human health and terrestrial ecology. While the risk to human health, particularly the increased presence of ticks and an extended tick season due to seasonal changes and snowpack reduction by 2080, is a concern, meadows also play a significant role in supporting terrestrial ecosystems. Heat stress, identified as a risk for both 2050 and 2080, may predispose meadow terrestrial species to drying, potentially leading to die-offs and a loss of biodiversity. Additionally, seasonal changes in 2080 pose challenges for meadows by disrupting the synchronization of food and habitat availability for both meadow and migrating species. Although meadows may not cover extensive areas within the watershed, their ecological importance underscores the need to address these climate-induced risks to ensure the continued well-being of both human communities and the broader terrestrial ecosystem. Refer to Appendix D for further discussion on the consequences of each climate hazard.

Climate change contributes to continued loss and/or degradation of meadows throughout the watershed. The consequence due to the impacts of climate change on meadows are outlined as follows:

- Dried out grassland/meadow soil due to increased drought conditions, which may lead to:
  - Released carbon and methane into the atmosphere from soils.
  - Reduced infiltration ability and subsequent increased surface runoff.
  - Changes in grassland plant composition due to decreased soil nutrients.

3.3.5 Ponds and Lakes

The ponds and lakes within Conservation Halton's watersheds are dispersed across conservation areas, parks and local private properties. They confront a spectrum of climate-related challenges. Heat stress emerges as a pertinent threat by inducing elevated sediment, nutrient concentrations, and algae blooms, potentially diminishing aesthetic appeal, and curtailing public access to water bodies. This risk assessment found that ponds and lakes are at risk of dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction through 2050 and 2080.

Seasonal changes and snowpack reduction heighten risks, leading to the potential drying of water bodies, variable lake levels, and increased algae concentrations, limiting accessibility and impacting physical and mental well-being. These water features, integral to terrestrial ecology, also face risks from heat stress and seasonal changes, affecting wetland vegetation, wildlife breeding habitats, and food availability. Furthermore, aquatic ecology within ponds and lakes is jeopardized by drying conditions, increased temperatures, altered oxygen levels, and decreased habitat for aquatic species.

There is a natural/global heritage aspect to Crawford Lake in particular as it represents a point of interest for scientists studying human impact on the planet. Care must be taken to preserve this resource.

Water quality is compromised by dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction, impacting algae content, contaminant concentrations, and temperature fluctuations. Erosion and sedimentation risks arise from factors such as rainfall and seasonal changes, contributing to shoreline instability and structural degradation.

The potential for flooding in these water bodies is heightened by increased water levels caused by rainfall and seasonal changes, jeopardizing nearby areas and ecosystem support. Lastly, recreational swimming services face threats from heat stress influencing water quality, beach closures, and flood control infrastructure operations. Refer to Appendix D for further discussion on the consequences of each climate hazard.

Increased frequency of climate hazards may contribute directly to degradation of ponds and lakes throughout the watershed and indirectly to other natural assets relying on them for habitat or function. Some of the consequences due to the impacts of climate change on ponds and lakes are outlined as follows:

- Increased water temperature and loading of sediment and contaminants, due to changes in the flow regime and water quality of contributing tributaries. This may result in negative impacts to ecological function associated with the ponds and lakes.

- Increased erosion potential due to increased fluctuations in water levels and temperatures. This may impair fish habitat.

- Altered heat exchange between the atmosphere and Great Lakes, changing the overall lake temperature, ice cover, and the seasonal mixing of lake water.

3.3.6 Streams

Streams in Conservation Halton's watershed face multifaceted threats from climate change. Increased rainfall poses risks to human health and property and may lead to flooding risking human health and causing property damage. Through 2080, seasonal changes and snowpack reduction exacerbate these risks, affecting spring freshet, increasing runoff volumes, and elevating the potential for ice jams and erosion. Climate scenarios through 2050 and 2080 heighten the potential for flashier systems and increased water levels. In particular, this risk assessment found that streams are at risk of dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction through 2050 and 2080.

Crucial for aquatic ecosystems, streams are at risk of habitat loss, die-offs, and altered processes due to dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction. Water quality is jeopardized by higher temperatures, sediment, nutrient, and contaminant concentrations. Vulnerable to erosion, streams face bank destabilization and sedimentation.

Conservation Halton's services related to streams face challenges in accuracy and operational requirements, impacting their reputation for environmental hazard protection. Snowpack reduction complicates flood infrastructure operation and stresses the organization's ability to safeguard the public from climate-related hazards. Refer to Appendix D for further discussion on the consequences of each climate hazard.

Increased occurrence of Climate hazards contributes directly to loss and/or degradation of streams throughout the watershed. The consequences due to the impacts of climate change on streams are outlined as follows:

- Alterations in water temperature due to decreased groundwater recharge, increased runoff volume, and increased ambient temperatures. This may cause:
  - Increased stream water temperatures
  - Decreased thermal diversity of streams, reducing the distribution of freshwater fishes
- Changes in flow regime due to increased extreme events and seasonality may result in erosion and/or flooding and may also cause:
  - Changes in physical geomorphic characteristics of a stream
  - Destabilization throughout the watercourse and bank erosion, compromising aquatic habitat and nearby physical infrastructure (e.g., private property, culverts, bridges).
  - Poor terrestrial conditions along streams, causing fluctuations in baseflow and nutrient supply.
  - Loss of vegetation, which may change the structure of a stream reach and create deposition of large volumes of sediment, which causes increased turbidity and affects the livelihood of fish.
- Species mortality due to increased water temperatures and flows. Species such as the Brook Trout, that require cold-water habitats are expected to experience a 49% decrease in distribution across Canada by 2050 due to the impacts of climate change (Conservation Halton, September 2023).

3.3.7 Vernal Pools

Vernal pools are critical for various terrestrial and amphibian species and face significant climate threats. Through this risk assessment, it was found that vernal pools are at risk of dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction through 2050 and 2080. Dry conditions pose risks such as long-term damage to species if pools prematurely dry up, impacting breeding habitats and causing die-offs. Heat stress increases water temperatures, reducing breeding habitats and causing further mortality. Increased rainfall raises water levels, potentially leading to species die-offs. Seasonal changes impact wildlife habitats, migration, and breeding, contributing to the degradation of vernal pools. Snowpack reduction may affect the spring freshet crucial for early spring breeding amphibians. Refer to Appendix D for further discussion on the consequences of each climate hazard.

Climate change contributes to continued loss and/or degradation of vernal pools throughout the watershed. The consequence due to the impacts of climate change on vernal pools are outlined as follows:

- Reduced habitat diversity for species that require cool water breeding habitats.
- Changes to the composition of vernal pools and loss of specialist species (Jefferson Salamander). This may be due to increased flooding, spring freeze, increased drought, mid-winter thaws.
- Decreased water quality within the pools due to increased flooding and erosion and sedimentation.

3.3.8 Wetland – Swamp

Wetland swamps in Conservation Halton's watershed are under multiple climate threats, including dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction (2080). These threats, particularly dry conditions, and heat stress, may reduce water levels, potentially causing long-term damage or complete dry-out. Excessive rainfall, on the other hand, can lead to flooding, negatively impacting terrestrial vegetation and wildlife. Snowpack reduction poses a risk similar to that for vernal pools, potentially affecting early spring breeding amphibians. The aquatic ecology risk assessment for swamps showed inconclusive results, with varying opinions on consequences for heat stress, rainfall, seasonal changes, and snowpack reduction through 2050 and 2080. Despite their scarcity, swamps, which are more expansive than marshes, significantly impact surface water quality, soil stability, and erosion reduction. They face high risks of heat stress and seasonal changes through 2080, potentially causing degradation of these vital ecosystems and their ability to provide essential services to the watershed, including flood mitigation. Refer to Appendix D for further discussion on the consequences of each climate hazard.

Climate change contributes to continued loss and/or degradation of wetlands throughout the watershed. The consequences due to the impacts of climate change on wetlands are outlined as follows:

- Increased evapotranspiration in response to higher temperatures, resulting in reduction in soil moisture, stress of vegetation and habitat, and potential impacts to size and extent of wetland features.

- Released stored carbon and methane into the atmosphere due to vegetation impacts, drought conditions, wetland fragmentation, and major changes in the hydroperiod.

- Decreased ability of the watershed to store and slow-release water due to degraded or lost wetlands, causing irregular stream flows and more intense flooding.

- Decreased biodiversity due to habitat loss in wetlands.

3.3.9 Wetland – Marsh

Marshes in Conservation Halton's watershed face multiple climate change threats. The risk assessment reveals that, through 2050, marshes are at risk of dry conditions, heat stress, and seasonal changes, impacting terrestrial and aquatic ecology. Dry conditions and heat stress may lead to reduced water levels, affecting vegetation communities and habitats for terrestrial species. Seasonal changes contribute to wildlife habitat disruptions, migration challenges, and altered breeding conditions. Furthermore, snowpack reduction poses risks, potentially affecting spring freshet crucial for early spring breeding amphibians. Looking ahead to 2080, marshes face an elevated risk of snowpack reduction, potentially intensifying these challenges. These climate-induced threats not only impact terrestrial and aquatic ecosystems but also affect water quality, erosion, sedimentation, and flooding risks, highlighting the significance of marshes and the potential consequences for Conservation Halton's watershed health, human health, and biodiversity. Refer to Appendix D for further discussion on the consequences of each climate hazard.

Climate change contributes to continued loss and/or degradation of wetlands throughout the watershed. The consequences due to the impacts of climate change on wetlands are outlined as follows:

- Increased evapotranspiration in response to higher temperatures, resulting in reduction in soil moisture, stress of vegetation and habitat, and potential impacts to size and extent of wetland features.

- Released stored carbon and methane into the atmosphere due to vegetation impacts, drought conditions, wetland fragmentation, and major changes in the hydroperiod.

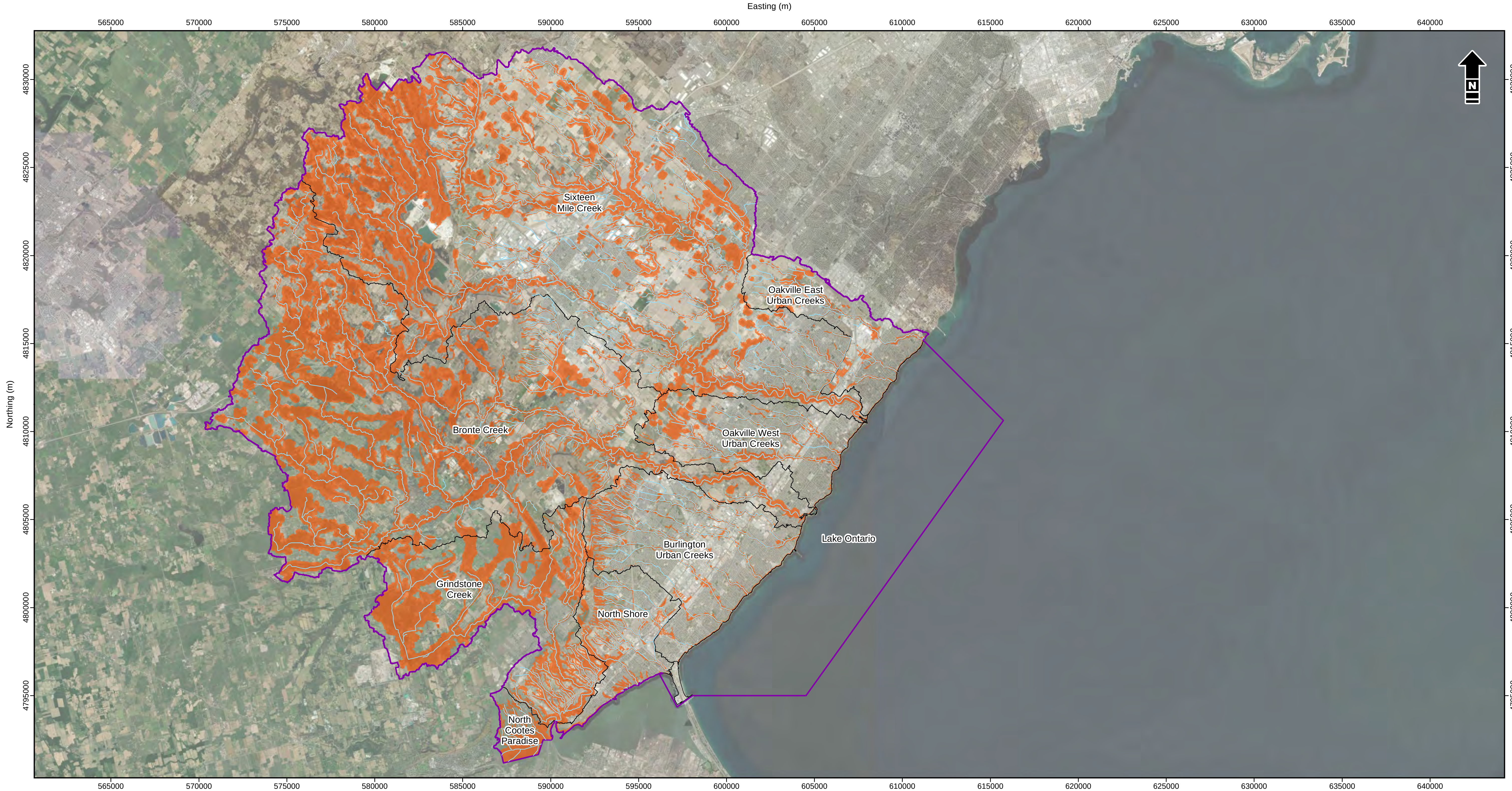
- Decreased ability of the watershed to store and slow-release water due to degraded or lost wetlands, causing irregular stream flows and more intense flooding.

- Decreased biodiversity due to habitat loss in wetlands.

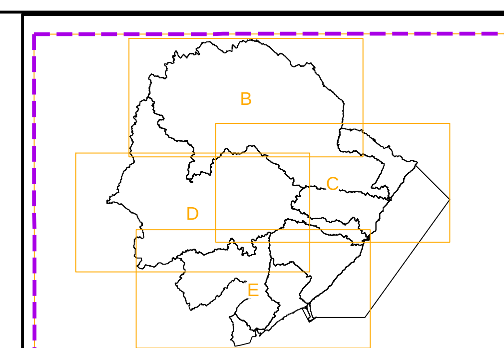
3.4 Application at the Watershed Level

3.4.1 Approximate Regulated Areas

Conservation Halton enforces regulations and guidelines under the Conservation Authorities Act throughout their regulation jurisdiction, which is defined as their approximate regulation limit. Flood protection is a major service provided by Conservation Halton to the watershed and is a large factor in their jurisdictional power. The regulated areas throughout the watershed are associated with waterflow features (streams, creeks etc.) and their associated floodplain, as well as other environmental, heritage and water-related hazards. These regulated areas, in which Conservation Halton has authority, may act as a tool for conservation and mitigation measures to enhance the adaptive capacity throughout the watershed. As shown in Figure 7, the approximate regulation limit associated with Conservation Halton has a significant area coverage throughout the watershed, presenting the opportunity to use the regulation areas as an important tool for implementing the recommendations established as part of this Climate Change Vulnerability and Risk Assessment. Refer to Appendix E for additional figures that illustrate the approximate regulation limits at smaller scales.



Conservatino Halton Jurisdictional Boundary
Watershed
Approximate Regulated Areas
Stream



1:215,000
metres
2,100 0 2,100 4,200
NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
A Montrose Environmental Company

Conservation Halton
Climate Change Vulnerability and Risk Assessment

Approximate Regulation Limits

Date:	Project:	Submitter:	Reviewer:
February 2024	36679	A. Rafeiro	F. Tonto

Figure 7

Reference: Data provided by Conservation Halton GIS Department (2023). Contains information licensed under the Open Government Licence - Ontario. Data obtained from GeoBase® used under license. Imagery (2021) Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

I:\ConservationHalton\36679\FiguresAndTables\CRA\2023\Report\Figure-2-Regulated_Floodplain_Limits.mxd - Tabloid_L - 09-Feb-24, 09:07 AM - eveenman - TID004

3.4.2 Watershed Land Uses

The Official Plan schedules and maps for Halton Region, Wellington County, the Region of Peel and the City of Hamilton were reviewed to gather a general understanding of the designated land uses throughout Conservation Halton's jurisdiction. This review found that generally, the southern quarter of Conservation Halton's watersheds is primarily urban, with the exception of North Cootes Paradise. Further upstream towards the middle half of the watershed, the land uses become more diversified, consisting of the Greenbelt, some natural areas, rural settlement areas and urban land uses in North Oakville and Milton. In the upstream locations within the top quarter of Conservation Halton's watershed, the land use is largely agricultural with small urban sections to the east and rural-residential and natural areas further towards the west.

Overall, the land use throughout Conservation Halton's watersheds consists of large portions of urban areas, but there is also significant presence of the Greenbelt and other non-urban areas. Another factor related to urban land uses is impervious cover throughout the watershed. With increased urban land use designations comes increased impervious cover, which can have a significant negative impact on aquatic and terrestrial ecosystem health. Conservation Halton's Story Maps (How Much Habitat is Enough? Conservation Halton 2021) were reviewed for statistics on impervious cover and found that only Bronte Creek and North Cootes Paradise watersheds have an impervious cover below 10%. The other watersheds, for the most part, have an impervious cover percentage around 50%.

Establishing a general understanding of land use and impervious cover through Conservation Halton's watersheds further informs which are the vulnerable areas with respect to urban development and population increase.

3.4.3 Greenbelt Distribution

Ontario's Greenbelt is 2 million acres of protected land that ranges from Niagara-on-the-Lake to the Bruce Peninsula, and protects forests, wetlands, rivers, lakes, and farmland. The Greenbelt may be a useful tool for Conservation Halton when considering climate adaptation opportunities through pursuing preservation of the Greenbelt as it overlaps with Conservation Halton's jurisdiction. Permanent protection of the Greenbelt is essential for climate resilient communities in Ontario.

The Greenbelt Area officially consists of six different area classifications, three of which are present throughout Conservation Halton's watershed: Protected Countryside, the Niagara Escarpment, and Urban River Valley. The Greenbelt Area throughout Conservation Halton's watersheds was approximately measured for general discussion purposes using the Greenbelt Plan (Greenbelt Foundation, 2017), and the breakdown by watershed is outlined in Table 18.

Table 18 Greenbelt Distribution

Conservation Halton Watershed Name	Watershed Area (km^2)	Greenbelt Area (km^2)	Greenbelt Coverage (%)
Bronte Creek	300	290	97%
Grindstone Creek	100	90	90%
Sixteen Mile Creek	360	185	51%
North Cootes Paradise	6	6	100%
Urban Creeks			
North Shore	31	7	23%
Burlington Urban	72	13	18%
Oakville West Urban	47	20	43%
Oakville East Urban	34	0	0%
Urban Creeks Total	184	40	22%
Watershed Total	**950**	**611**	**64%**

3.4.4 Watershed Vulnerabilities

As is typical in southern Ontario, Conservation Halton's jurisdiction faces many watershed vulnerabilities, necessitating careful management to safeguard the ecological health of the region. These vulnerabilities are likely to be exacerbated with the onset of climate change. The vulnerabilities of concern for Conservation Halton’s watersheds (Request for Public Input – Resource Issues in Conservation Halton’s Watersheds Draft Report, Conservation Halton September 2023) as a whole are summarized below, and further split up by subwatershed in the following subsections.

Riverine flooding is prevalent in Conservation Halton’s urban creek watersheds, particularly in rivers, creeks, and channels throughout Southeast and Southwest Oakville and Southeast and Southwest Burlington. These urban areas, as well portions of the upper watersheds (Bronte, Sixteen Mile, and Grindstone Creeks) may be at a higher risk of infrastructure damage, slope failure, bank and overland erosion, degraded water quality and degraded and/or loss of natural features caused by flooding.

Drought vulnerability is pronounced in areas with private shallow wells and locations above the Niagara Escarpment, or where groundwater aquifers are typically shallow. These areas may experience water shortages, impacting domestic water supply, and require sustainable water use and management practices.

Water quality is a significant concern for conservation authorities, especially in creeks downstream of urban and agricultural areas, such as the East Branch of Sixteen Mile Creek and the Main Branch of Bronte Creek, as well as at creek mouths flowing into Lake Ontario, including Fourteen Mile, Sixteen Mile, Bronte, and Grindstone Creeks. These areas are susceptible to increased concentrations of contaminants, nutrients, and sediments, posing risks to aquatic habitats, water treatment costs, and overall creek aesthetics.

Sedimentation is prevalent in stormwater management ponds, online ponds, and dugout channels, as well as behind dams and weirs throughout the watersheds, including Bronte and Hamilton Harbours. This poses threats such as increased flood risk, aquatic habitat damage, and compromised water quality due to elevated levels of nutrients and contaminants.

Waterbodies are at risk of ***thermal pollution*** in central and downstream reaches of creeks that lack cooler groundwater discharges and springs. Urbanized creeks, those receiving warmer runoff from stormwater management ponds and overland runoff, as well as creeks with limited riparian vegetation or additional human impacts, face increased water temperatures that can negatively impact aquatic species and habitat.

Low groundwater levels pose vulnerabilities in areas with shallow aquifers, particularly in locations below the Niagara Escarpment where overlying shale is close to or at the surface. Reduced discharge rates affecting baseflow and cold-water inputs to surface water features can lead to compromised aquatic ecosystems and risk to drinking water supplies.

Urban areas below the Niagara Escarpment are at risk of ***degradation and loss of natural features***, threatening the watershed's biodiversity and ability to deliver core ecosystem services. Invasive species pose a substantial threat, particularly in natural areas used for human activities, adjacent to urban or agricultural areas, along creek corridors, and in ditches and natural areas adjacent to roads. These invasive species can disrupt local ecosystems, affect human health (e.g., giant hogweed), and lead to increased management costs.

Biodiversity loss is a significant concern throughout the watershed in natural areas fragmented by adjacent urban or agricultural development, areas sensitive to human use, and locations with species with highly specialized requirements, such as the Redside Dace in Fourteen Mile Creek. These vulnerabilities highlight the need for comprehensive conservation and restoration efforts to maintain the resilience of the watershed and promote sustainable land and water management practices.

Drought, water quality, sedimentation, thermal pollution, low groundwater levels, degradation and loss of natural features, invasive species, and biodiversity loss are all vulnerabilities that will add additional stress to the natural resources. To gather a qualitative understanding of where the vulnerabilities may be more significant, an inventory of the natural resources throughout Conservation Halton's watersheds was gathered, and is presented in Table 19 and 20.

Table 19 Conservation Halton Watershed – Natural Resource Area Coverage

Watershed Name	Watershed Area (km²)	Total Natural Resource Coverage (km²)	Forest* (ha)	Swamp* (ha)	Marsh (ha)	Pond/Lake (ha)	Stream (km)	Lake Ontario Shoreline (km)
Bronte Creek	300	158	10,673	4,615	401	148	393	5
Grindstone Creek	100	41	2,495	1,420	112	29	119	0
Sixteen Mile Creek	360	118	8,581	2,668	236	283	647	2
North Cootes Paradise	6	3	306	12	9	1	0.0	1
North Shore	31	5	465	35	0	11	63	11
Oakville East Urban Creeks	72	4	296	53	3	8	44	7
Oakville West Urban Creeks	47	5	449	50	1	13	77	7
Burlington Urban Creeks	34	7	600	63	2	29	115	13
Total Urban Creeks	184	24	2,116	213	14	62	299	39
CH Watershed Total	**950**	**340**	**23,864**	**8,917**	**763**	**521**	**1,458**	**46**

*Note: Treed swamp is included under both forest and swamp.

Table 20 Conservation Halton Watershed – Natural Resource Land Cover Percentage

Watershed Name	Forest* (%)	Swamp* (%)	Marsh (%)	Pond/Lake (%)	Total Natural Resource Coverage (%)
Bronte Creek	34%	15%	1%	0%	51%
Grindstone Creek	28%	16%	1%	0%	45%
Sixteen Mile Creek	23%	7%	1%	1%	32%
North Cootes Paradise	33%	1%	1%	0%	36%
North Shore	15%	1%	0%	0%	16%
Oakville East Urban Creeks	9%	2%	0%	0%	11%
Oakville West Urban Creeks	10%	1%	0%	0%	11%
Burlington Urban Creeks	8%	1%	0%	0%	10%
Total Urban Creeks	11%	1%	0%	0%	12%
CH Watershed Total	**25%**	**9%**	**1%**	**1%**	**35%**

*Note: Treed swamp is included under both forest and swamp.

3.4.5 Bronte Creek Watershed

Bronte Creek watershed faces several vulnerabilities across different environmental scenarios, highlighting the importance of comprehensive watershed management. Historic flooding events in 1980, 2009, and 2022, particularly in Lowville, have marked the creek as flood prone. Vulnerable areas include Lowville, Carlisle, Progreston, and Cedar Spring Community along Bronte Creek, as well as the Highway 6 Corridor in Flamborough. The impacts of flooding encompass risks to life and property, bank erosion, degraded water quality, and potential habitat loss.

In terms of drought vulnerabilities, specific tributaries that flow through fine till plains, particularly the lower Bronte Creek, are identified. These areas may experience surface and groundwater supply shortages, degraded water quality, and habitat loss during periods of low water availability. This can lead to crop stress, insufficient water for irrigation, and increased costs associated with water importation.

Low groundwater levels present another significant vulnerability, especially in subwatersheds that are under stress due to monthly and/or annual groundwater demand. Willoughby Creek, a tributary of Bronte Creek, falls into this category. The consequences of low groundwater levels include depleted groundwater sources, reduced discharge rates affecting surface water features, and potential land subsidence. This vulnerability can result in dry or unusable shallow wells, increased costs for drilling reliable wells, and risks to drinking water supplies.

In summary, Bronte Creek is vulnerable to historic flooding in specific communities, drought in tributaries flowing through fine till plains, and low groundwater levels in subwatersheds stressed by groundwater demand. Addressing these vulnerabilities is essential for effective watershed management, ensuring the resilience of the ecosystem, and minimizing potential socio-economic impacts. To gather a qualitative understanding of where the vulnerabilities may be more significant, an inventory of the natural resources throughout Bronte Creek watershed was gathered and is presented in Tables 21 and 22.

Table 21 Bronte Creek Watershed – Natural Resource Area Coverage

Watershed Name	Watershed Area (km^2)	Total Natural Resource Coverage (km^2)	Forest* (ha)	Swamp* (ha)	Marsh (ha)	Pond/Lake (ha)	Stream (km)	Lake Ontario Shoreline (km)
Bronte Creek	300	158	10,673	4,615	401	148	393	5
CH Watershed Total	**950**	**340**	**23,864**	**8,917**	**763**	**521**	**1,458**	**46**

*Note: Treed swamp is included under both forest and swamp.

Table 22 Bronte Creek Watershed – Natural Resource Land Cover Percentage

Watershed Name	Forest* (%)	Swamp* (%)	Marsh (%)	Pond/Lake (%)	Total Natural Resource Coverage (%)
Bronte Creek	34%	15%	1%	0%	51%
CH Watershed Total	**25%**	**9%**	**1%**	**1%**	**35%**

*Note: Treed swamp is included under both forest and swamp.

3.4.6 Grindstone Creek Watershed

Grindstone Creek exhibits several vulnerabilities, requiring a careful approach to watershed management. The creek is susceptible to flooding, particularly in Southwest Burlington, the Millgrove and Hidden Valley Community, and along the Highway 6 Corridor in Flamborough. Vulnerable flooding areas like these face risks to life and property, bank erosion, degraded water quality, and potential habitat loss during high-intensity storm events.

Drought-prone areas include Grindstone Creek tributaries, either near their upstream end, along their entire length, or between their point of origin and outlet. These areas may experience surface and groundwater supply shortages, degraded water quality, and habitat loss during periods of low water availability. The impacts extend to agricultural activities, causing crop stress and failure and increasing costs associated with water importation.

Valley erosion is another significant vulnerability, particularly in areas with steep exposed slopes, such as those with clay/shale and sand/gravel soils, as seen in Hidden Valley, Burlington, and Grindstone Creek. Furthermore, areas exposed to intense periods of high creek flow, such as small western tributaries of Grindstone Creek south of Highway 5, are prone to erosion. This may result in the risk of slope failure, loss of land, degraded water quality due to sedimentation, and potential changes in channel form.

Lastly, areas at risk of degradation and loss of natural features include rural areas above the Niagara Escarpment in the central and eastern Grindstone Creek watershed. These areas face increased natural hazard risks, reduced resiliency to climate change impacts, and potential degradation of water quality and habitat. The socio-economic impacts encompass increased costs for remedial measures and infrastructure and heightened land management expenses.

In summary, Grindstone Creek is vulnerable to flooding in specific communities, drought in tributaries, valley erosion in areas with steep slopes and intense creek flow, and the degradation and loss of natural features in rural areas above the Niagara Escarpment. Addressing these vulnerabilities is crucial for effective watershed management, ensuring the resilience of the ecosystem, and minimizing potential socio-economic impacts in a changing climate. To gather a qualitative understanding of where the vulnerabilities may be more significant, an inventory of the natural resources throughout Bronte Creek watershed was gathered and is presented in Tables 23 and 24.

Table 23 Grindstone Creek Watershed – Natural Resource Area Coverage

Watershed Name	Watershed Area (km^2)	Total Natural Resource Coverage (km^2)	Forest* (ha)	Swamp* (ha)	Marsh (ha)	Pond/Lake (ha)	Stream (km)	Lake Ontario Shoreline (km)
Grindstone Creek	100	41	2,495	1,420	112	29	119	0
CH Watershed Total	**950**	**340**	**23,864**	**8,917**	**763**	**521**	**1,458**	**46**

*Note: Treed swamp is included under both forest and swamp.

Table 24 Grindstone Creek Watershed – Natural Resource Land Cover Percentage

Watershed Name	Forest* (%)	Swamp* (%)	Marsh (%)	Pond/Lake (%)	Total Natural Resource Coverage (%)
Grindstone Creek	28%	16%	1%	0%	45%
CH Watershed Total	**25%**	**9%**	**1%**	**1%**	**35%**

*Note: Treed swamp is included under both forest and swamp.

3.4.7 Sixteen Mile Creek Watershed

Sixteen Mile Creek faces several vulnerabilities across different environmental scenarios. In terms of historic flooding, the town of Milton experienced significant flooding in 1950, particularly impacting Sixteen Mile Creek. Urban Milton, situated along Sixteen Mile Creek, is identified as a flood-vulnerable area. The potential consequences include risks to life and property, erosion of banks, degraded water quality, and potential habitat loss.

Drought poses another set of vulnerabilities, particularly in tributaries northwest of Scotch Block reservoir, in the northern reaches of Sixteen Mile Creek. These areas may experience surface and groundwater supply shortages, degraded water quality, and habitat loss during periods of low water availability. The impacts extend to agricultural activities, as crop stress and failure, along with increased costs associated with water importation, become significant concerns.

Valley erosion is a notable vulnerability, especially in areas with steep exposed slopes, such as North Oakville and Sixteen Mile Creek. Additionally, areas exposed to intense periods of high creek flow, like Sixteen Mile Creek downstream of the concrete channel in downtown Milton, are susceptible to erosion. The key impacts include the risk of slope failure, loss of land, degraded water quality due to sedimentation, and potential changes in channel form, which may adversely affect aquatic habitats.

Low groundwater levels present another vulnerability, particularly in subwatersheds stressed based on monthly and/or annual groundwater demand, such as the Upper West Branch of Sixteen Mile Creek. This vulnerability can lead to depleted groundwater sources and reduced discharge rates affecting surface water features. The socio-economic impacts encompass dry or unusable shallow wells, increased costs for drilling reliable wells, and potential risks to drinking water supplies.

In summary, Sixteen Mile Creek is vulnerable to historic flooding in urban areas, drought in specific tributaries, valley erosion in areas with steep slopes and intense creek flow, and low groundwater levels in subwatersheds stressed by groundwater demand. Understanding and addressing these vulnerabilities are crucial for effective watershed management and resilience planning. To gather a qualitative understanding of where the vulnerabilities may be more significant, an inventory of the natural resources throughout Bronte Creek watershed was gathered and is presented in Tables 25 and 26.

Table 25 Sixteen Mile Creek Watershed – Natural Resource Area Coverage

Watershed Name	Watershed Area (km^2)	Total Natural Resource Coverage (km^2)	Forest* (ha)	Swamp* (ha)	Marsh (ha)	Pond/Lake (ha)	Stream (km)	Lake Ontario Shoreline (km)
Sixteen Mile Creek	360	118	8,581	2,668	236	283	647	2
CH Watershed Total	**950**	**340**	**23,864**	**8,917**	**763**	**521**	**1,458**	**46**

*Note: Treed swamp is included under both forest and swamp.

Table 26 Sixteen Mile Creek Watershed – Natural Resource Land Cover Percentage

Watershed Name	Forest* (%)	Swamp* (%)	Marsh (%)	Pond/Lake (%)	Total Natural Resource Coverage (%)
Sixteen Mile Creek	23%	7%	1%	1%	32%
CH Watershed Total	**25%**	**9%**	**1%**	**1%**	**35%**

*Note: Treed swamp is included under both forest and swamp.

3.4.8 Urban Creeks

Urban creeks within Conservation Halton's jurisdiction face a spectrum of vulnerabilities, necessitating comprehensive management strategies. For the purposes of this discussion, the urban creek watersheds are considered as North Cootes Paradise, North Shore, Oakville East and West Urban Creeks, and Burlington Urban Creeks. Although North Cootes Paradise watershed is not urban and is heavily naturalized, due to its size and proximity to the other urban watersheds it has been grouped into urban creeks for discussion purposes.

The occurrence of historic flooding events, such as the 2014 flooding in Burlington (centred over Roseland and Tuck Creeks) and the 2000 flooding in Oakville (Fourteen Mile Creek), underlines the vulnerability of these urban waterways. Specific flood prone areas include Southeast Oakville, Southwest Oakville, Southeast Burlington, and Southwest Burlington, where various creeks and diversion channels are at risk. The consequences of such flooding events encompass threats to life and property, bank erosion, degraded water quality, and potential habitat loss.

Drought vulnerability is another critical aspect, affecting tributaries that flow through fine till plains and urban creeks in Oakville. Areas such as the upper reaches of Roseland, Rambo and Creeks, the east branch of Hager Creek, and Falcon Creek upstream of Highway 403 may experience surface and groundwater supply shortages, degraded water quality, and habitat loss during periods of low water availability. This can lead to crop stress, insufficient water for irrigation, and increased costs associated with water importation.

Valley erosion poses a significant risk, especially in areas exposed to intense periods of high creek flow, such as the downstream reach of Indian Creek below the Hager-Rambo Diversion Channel, Burlington, and North Shore. The impacts of valley erosion include the risk of slope failure, loss of land, and potential changes in channel form, which may adversely affect aquatic habitats.

Furthermore, areas within Conservation Halton's jurisdiction are at risk of degradation and loss of natural features, particularly those sensitive to human disturbance, such as Waterdown Woods in Hamilton and areas around Fourteen Mile Creek, which is home to the Redside Dace. Biodiversity loss is also a concern in areas with species that have highly specialized requirements, exemplified by the Redside Dace in Fourteen Mile Creek. The potential impacts encompass reduced habitat quality, increased human-wildlife conflict, and potential declines in biodiversity.

In summary, the urban creeks along Lake Ontario, within Conservation Halton's jurisdiction are vulnerable to historic flooding, drought, valley erosion, and the degradation and loss of natural features and biodiversity. Addressing these vulnerabilities is essential for effective watershed management, ensuring the resilience of these urban ecosystems, and minimizing potential socio-economic and ecological impacts. To gather a qualitative understanding of where the vulnerabilities may be more significant, an inventory of the natural resources throughout Bronte Creek watershed was gathered and is presented in Tables 27 and 28.

Table 27 Urban Creeks Watershed – Natural Resource Area Coverage

Watershed Name	Watershed Area (km^2)	Total Natural Resource Coverage (km^2)	Forest* (ha)	Swamp* (ha)	Marsh (ha)	Pond/Lake (ha)	Stream (km)	Lake Ontario Shoreline (km)
North Cootes Paradise	6	3	306	12	9	1	0.0	1
North Shore	31	5	465	35	0	11	63	11
Oakville East Urban Creeks	72	4	296	53	3	8	44	7
Oakville West Urban Creeks	47	5	449	50	1	13	77	7
Burlington Urban Creeks	34	7	600	63	2	29	115	13
Total Urban Creeks	184	24	2,116	213	14	62	299	39
CH Watershed Total	**950**	**340**	**23,864**	**8,917**	**763**	**521**	**1,458**	**46**

*Note: Treed swamp is included under both forest and swamp.

Table 28 Urban Creeks Watershed – Natural Resource Land Cover Percentage

Watershed Name	Forest* (%)	Swamp* (%)	Marsh (%)	Pond/Lake (%)	Total Natural Resource Coverage (%)
North Cootes Paradise	33%	1%	1%	0%	36%
North Shore	15%	1%	0%	0%	16%
Oakville East Urban Creeks	9%	2%	0%	0%	11%
Oakville West Urban Creeks	10%	1%	0%	0%	11%
Burlington Urban Creeks	8%	1%	0%	0%	10%
Total Urban Creeks	11%	1%	0%	0%	12%
CH Watershed Total	**25%**	**9%**	**1%**	**1%**	**35%**

*Note: Treed swamp is included under both forest and swamp.

3.5 Adaptation Opportunities

3.5.1 Adaptive Capacity

One goal of this Climate Change Vulnerability and Risk Assessment is to understand Conservation Halton's watersheds current adaptive capacity and provide feasible recommendations to strengthen it. In this context, adaptive capacity is defined as a system's ability to adjust to climate change and avoid or reduce damages while taking advantage of opportunities. Essentially, adaptive capacity demonstrates how well a system (natural resource or ecosystem) can manage a change or disturbance.

As described, Matrix took a natural resource-based approach to readily quantify and analyze Conservation Halton's current adaptive capacity. After completing the risk rating and assessment, Conservation Halton's Annual Report and background studies were reviewed to determine current adaptive capacity measures and actions in place.

3.6 Current Adaptive Capacity Measures

Conservation Halton already has several programs and services in place that are related to the adaptive capacity of the watershed with respect to climate change adaptation, particularly related to flood protection. The current and planned adaptive capacity measures, as outlined by Conservation Halton's reports and website, are summarized below.

The adaptive capacity measures summarized below are sourced from Conservation Halton's Annual Report (2022) and their report on the Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds (September 2023) and may not include programs or services put in place since these documentations.

Watershed Monitoring: Long-standing watershed monitoring program to inventory, monitor, assess and report on watershed conditions, trends, and risks. This information is used to support natural hazards management and watershed planning, and to inform decisions such as strategic implementation of terrestrial and aquatic restoration projects.

Water Control Operations: Responsible for management, operation, and maintenance of water control infrastructure such as dams and channels. This is integrated with supporting the municipal emergency response to flooding by monitoring local watershed conditions and weather forecasts, predicting flooding potential and providing flood messaging.

Watershed Planning: Undertaking a watershed-based resource management strategy and renewing the watershed planning program, which will identify management priorities and actions to address key natural resource issues, including climate change effects within individual watersheds.

Restoration Programs: Collaborate with governments, municipalities, and individuals to fund restoration projects that help manage natural hazards, improve natural heritage, and reduce or buffer the impacts of climate change. Restoration programs may include planting trees, and may be implemented watershed-wide or on private lands.

Forestry Management: Deliver strategic forest management operations, tree planting services, and support the technical management of forests. Over 4.5 million trees have been planted since the implementation of these programs, which have provided habitat for various species, mitigated the impacts of climate change, and provided more resiliency against flooding. The forestry management team also monitors invasive forest pests and delivers the Emerald Ash Borer program, as well as provide an operation focus on forest management and hazard tree management.

Landowner Outreach: Provide educational and stewardship services to watershed residents to promote watershed health. These programs include one-on-one consultation for implementing restoration programs for private lands and hand-on educational workshops to encourage landowners to take action on their own property.

Land Management: Own and manage over 11,000 acres of land, which supports a large percentage of the area's biodiversity. Conservation Halton monitors and manages forest health, including invasive species, and implements Master Plans to guide the management of the important watershed resources.

Planning and Regulations: Administer Ontario Regulation (O. Reg.) 162/06 under the Conservation Authorities Act to restrict development activities within regulated areas such as streams, wetlands, shorelines, and other hazard lands. Review a range of planning and development applications and technical studies, and provide input on federal, provincial, and municipal policies and initiatives as they relate to watershed health and operation.

3.6.1 Conservation Halton's Programs and Services

Ontario Conservation Authorities play a crucial role in increasing adaptive capacity to climate change in the province's communities through their programs and services, which are designed to address and mitigate environmental challenges. These services contribute significantly to building resilience within watersheds and communities. The following sections outline Conservation Halton's programs and services and how each supports the adaptive capacity of the watershed.

3.6.2 Flood Forecasting and Warning

Conservation Halton actively manages natural hazards in the region, providing early warning systems and implementing measures to minimize the impact of extreme weather events. Conservation Halton has been improving their flood forecasting and warning program through integrating flood forecasting into hydrologic and hydraulic modelling increase flood forecast precision. This enhances the authority's preparedness and response capabilities which are crucial aspects of adapting to the changing climate and the expected increase in flood events.

3.6.3 Flood and Erosion Control

Conservation Halton maintains a high level of adaptive capacity to climate change impacts on flooding and erosion. This is achieved through comprehensive initiatives such as floodplain mapping, advanced floodplain modelling, and continuous monitoring of streamflow, rainfall, and snowpacks. The organization collaborates closely with municipalities and the province to regulate development in flood prone areas, providing essential planning support and advice to minimize flood impacts.

Conservation Halton, operates over 900 dams, dykes, channels, and erosion control structures, plays a crucial role in acquiring significant floodplain lands and safeguarding vulnerable structures. Their watershed management activities encompass monitoring, data collection, modelling, studies, plans, assessments, and strategies, complemented by watershed-wide actions involving stewardship, communications, outreach, and education. Through these comprehensive efforts, Conservation Halton mitigates immediate flooding and erosion risks and establishes a resilient foundation for adapting to evolving precipitation patterns and heightened flood risks associated with climate change. There is an ongoing program of updating of floodplain maps, utilizing new tools and technologies to reduce flood risk. Conservation Halton continues to work to identify hazard areas and to refine regulation limits based on the latest results from technical studies and modelling.

3.6.4 Drought/Low Water Program

Conservation Authorities engage with water scarcity challenges through programs dedicated to drought and low water management. These efforts are designed to foster sustainable water practices, empowering communities to navigate shifting precipitation patterns and prolonged dry spells. In collaboration with the Ministry of Natural Resources, and Forestry, Conservation Halton plays a pivotal role in coordinating and supporting local responses during drought events. Conservation Halton monitors regional water levels and precipitation. If necessary, Conservation Halton collaborates with local water users to curtail demand and alleviate the impact of water shortages. Emphasizing the importance of voluntary water conservation measures, Conservation Halton orchestrates a Water Response Team comprising representatives from the province, municipalities, conservation authorities, local water users, and interest groups within its watershed.

3.6.5 Management of Conservation Authority-owned Land

Through the management of its owned lands, Conservation Halton actively enhances its adaptive capacity to climate change impacts. Through the strategic management of Conservation Authority land, the organization significantly contributes to the preservation of biodiversity, effective carbon sequestration, and the maintenance of robust ecosystems. These conservation practices play an important role in elevating the overall resilience of the watershed. Conservation Halton employs rigorous environmental monitoring and data collection processes to assess and report on various watershed resource issues, conditions, trends, and risks. This includes the development and management of a Geographic Information System (GIS) to facilitate efficient data management and analysis. Additionally, the acquisition and careful management of ecologically sensitive lands, encompassing wetlands, source areas, and valley lands, further extend to the responsible stewardship of over 11,000 acres owned by Conservation Halton. Through these comprehensive measures, the organization not only safeguards its natural assets but also actively contributes towards building a resilient ecosystem that can effectively withstand and adapt to the impacts of climate change.

3.6.6 Drinking Water Source Protection (Under the Clean Water Act)

Conservation Halton's administration of the Halton-Hamilton Source Protection Program plays a crucial role in enhancing its adaptive capacity to climate change. While the provincial government spearheads the initiative to protect water sources, source waters interconnected nature, unaffected by municipal boundaries, necessitates a cooperative approach. Conservation authorities, operating on a watershed basis, are integral to source water protection. Through coordinated efforts, Conservation Halton actively participates in developing source water protection plans, leveraging technical expertise and providing essential advice. These plans manage human and natural influences on water quality and quantity. In collaboration with Hamilton Conservation Authority, Conservation Halton actively shapes and coordinates the source water protection plan for their watersheds, covering significant areas in Halton, Hamilton, and parts of Peel and Wellington County. Recognizing the universal importance of water and the collective responsibility to protect it, Conservation Halton actively engages diverse stakeholders, including municipal partners, community members, Indigenous communities, business owners, community groups, and public health, in the development of these source water protection plans. This inclusive approach ensures a comprehensive strategy that reinforces the adaptive resilience of Conservation Halton to potential climate change impacts on its water sources.

3.6.7 Surface Water and Groundwater Monitoring Programs

The adaptive capacity of Conservation Halton's watersheds to climate change is significantly enhanced through comprehensive monitoring efforts focused on key environmental parameters. Conservation Halton employs a robust monitoring system that includes regular assessments of stream levels, rainfall patterns, water temperature, erosion dynamics, and water quality. By continuously collecting and analyzing data related to these critical aspects, Conservation Halton gains valuable insights into the changing climate and its impacts on the watershed.

Monitoring for drought allows for early detection of prolonged dry periods, enabling timely responses to mitigate potential water shortages for source water protection. Conservation Halton monitors groundwater quantity through the Provincial Groundwater Monitoring Program and at selected wetland locations. Suspended solids concentrations in surface water are also monitored as part of the Provincial Water Quality Monitoring Network and through their surface water quality monitoring program. Stream level and rainfall monitoring provide crucial information for flood and erosion control, allowing for the development of effective strategies to manage extreme weather events. Water temperature assessments contribute to understanding habitat conditions and potential stress on aquatic ecosystems.

Erosion monitoring helps in identifying vulnerable areas and implementing targeted measures to prevent or mitigate soil erosion thereby preserving the integrity of landscapes preventing valley failure.

Additionally, ongoing water quality monitoring ensures a comprehensive understanding of the health of aquatic ecosystems and helps identify any emerging issues related to contamination or degradation.

Through this holistic approach to environmental monitoring, Conservation Halton not only provides resilience to the immediate challenges posed by climate change but also builds a foundation for informed decision making and the development of long-term resilience strategies. The data collected serves as a vital tool in shaping adaptive management practices, fostering a proactive response to the dynamic and evolving impacts of climate change within Conservation Halton’s watersheds.

3.6.8 Regulate Impacts of Development and Activities in Hazardous Land

Conservation Halton plays a crucial role in increasing adaptive capacity to climate change through its regulatory oversight of land development in hazardous areas. By administering Ontario Regulation 162/06 under the Conservation Authorities Act, Conservation Halton ensures that new developments consider the risks associated with natural hazards.

Under the current regulation (O. Reg. 162/06), Conservation Halton regulates development in stream and creek valleys, shorelines, wetlands and lands adjacent to them, and other hazardous lands. O. Reg. 162/06 also regulates alterations to and interference with wetlands and watercourses. Permission from Conservation Halton is required to undertake works in regulated areas. Board-approved policies for the administration of O.Reg. 162/06 are used to guide decisions about permissions. Proponents seeking permission must demonstrate to the satisfaction of Conservation Halton that their proposed development, alteration, or interference will not adversely affect the control of flooding, erosion, dynamic beaches, pollution, or the overall conservation of the area. This process ensures that development activities align maintain the long-term resilience of the watershed. Through its regulatory authority, Conservation Halton plays a pivotal role in shaping sustainable and climate resilient land use practices within its jurisdiction.

3.6.9 Watershed Strategies

Conservation Halton is actively developing a Watershed-based Resource Management Strategy, referred to as a "Watershed Strategy." This strategic initiative aims to comprehensively identify and assess natural resource issues and risks within Conservation Halton's jurisdiction, particularly focusing on climate change-related challenges. The identified key natural resource issues within Conservation Halton's watersheds encompass a range of concerns such as Flooding-Riverine, Drought, Valley Erosion, Surface and Groundwater Water Quality—Chloride, Surface Water Quality—Suspended Solids, Surface Water Quality—Sedimentation, Surface Water Quality—Total Phosphorus, Surface Water Quality—Temperature (Thermal Pollution), Groundwater Quantity, Degradation, Fragmentation and Loss of Natural Features, Invasive Species, and Biodiversity Loss.

In alignment with recent changes to the Conservation Authorities Act and associated regulations, all conservation authorities in Ontario are mandated to undertake a Watershed Strategy by the end of 2024. This strategic planning initiative equips Conservation Halton with a systematic approach to identify and assess critical natural resource issues specific to its watersheds. By proactively addressing these challenges, the strategy enables the organization to identify best management actions and implement mitigation measures to enhance adaptive capacity and resilience to climate change impacts.

Through the Watershed Strategy, Conservation Halton ensures a comprehensive understanding of the interconnected ecological factors and risks that may arise due to climate change. This strategic approach not only facilitates effective management and mitigation but also lays the foundation for sustainable programs and services that contribute to the long-term health and resilience of the watershed.

3.7 Current Programs

3.7.1 Restoration

Conservation Halton's restoration program is a vital component for enhancing adaptive capacity to climate change. Through collaboration with governments, and individuals, Conservation Halton secures funding for restoration projects aimed at managing natural hazards, improving natural heritage, and mitigating the impacts of climate change. These projects encompass a range of initiatives, including tree planting, and are implemented watershed-wide.

Recognizing the significance of restoration in conservation efforts, Conservation Halton prioritizes identifying strategic opportunities that yield the maximum benefits for ecosystem function. Restoration projects extend beyond Conservation Halton owned properties to privately owned and publicly owned lands.

The outcomes of these restoration projects contribute to creating more resilient communities by providing habitats for wildlife species, enhancing the natural functions of environments, and fortifying the watershed against the impacts of climate change. Conservation Halton's restoration program is instrumental in fostering sustainability, biodiversity, and climate resilience within its jurisdiction.

3.7.2 Ecological Monitoring

Conservation Halton's Long-term Environmental Monitoring Program (LEMP), initiated in 2005, serves as a crucial component in enhancing adaptive capacity to climate change within the watershed. This program employs science-based protocols to monitor aquatic and terrestrial species, along with their habitats and water quality, to address pivotal questions related to the impact of changes in the watershed on natural heritage features. Conservation Halton's dedicated staff systematically assess how these features evolve and identify the driving factors behind these changes.

By monitoring a range of parameters across diverse habitats, including forests, streams, and wetlands, the LEMP generates a comprehensive understanding of the structure and function of local ecosystems. This knowledge is indispensable for evaluating the long-term health of the watershed. The information collected through this program contributes to the assessment of impacts resulting from watershed changes, informs and supports planning and management decisions, and guides restoration and outreach initiatives.

In addition to LEMP, Conservation Halton undertakes monitoring of invasive species, recognizing the potential threats they pose to biodiversity. The commitment to environmental monitoring is further underscored by the Ecological Land Classification (ELC) and Natural Areas Inventories, providing a holistic assessment of biodiversity trends. This integrated approach to monitoring reflects Conservation Halton's commitment to the preservation and sustainable management of watershed resources, establishing a solid foundation for informed decision making and adaptive strategies to effectively address emerging ecological challenges.

Within the Conservation Halton watershed, forests cover over 26,000 hectares of land, ranging from small urban woodlots to extensive contiguous forests. Forest health is closely monitored by assessing vegetation and tree health, forest birds, and forest salamanders. These monitoring efforts ensure the vitality of the forests, which not only provide habitat for a diverse array of species but also deliver essential ecosystem services of economic and non-monetary value to society.

Wetlands, characterized by marshes and treed swamps, are vital natural heritage features that offer quality habitat for various species and contribute to local water quality and quantity protection. Conservation Halton conducts comprehensive monitoring within marsh wetlands, focusing on marsh birds and marsh amphibians in addition to the wetland hydrology monitoring program.

The extensive network of streams, spanning over 3,000 km within the Conservation Halton watershed, is carefully monitored to safeguard water quality, stream health, and overall biodiversity. This watershed-based planning and management approach ensures the protection of these vital water resources. Parameters monitored within streams include fish, benthic invertebrates, water temperature, and chemical water quality. Through these monitoring initiatives, Conservation Halton actively contributes to the adaptive capacity of the watershed to climate change impacts.

3.8 Studies with Future Recommendations

3.8.1 Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds

The *Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds* (Conservation Halton, September 2023) report provides a comprehensive exploration of the impacts of climate change on local biodiversity within Conservation Halton's jurisdiction. Conservation Halton's jurisdiction covers more than 1000 square kilometres, incorporating the Grindstone, Bronte, and Sixteen Mile Creek watersheds and 18 smaller urban watersheds draining into Lake Ontario.

The report underscores the interconnection between climate change and declining biodiversity on a global scale, with up to one million species facing extinction. Conservation Halton observes shifts in local ecosystems, experiencing warmer, wetter, and wilder conditions. The disappearance of species like Loggerhead Shrike and Timber Rattlesnake highlights the critical challenges posed by biodiversity loss.

Outlined in the report are the essential ecosystem services provided by biodiversity, such as contaminant filtration, flood prevention, temperature regulation, and carbon capture. Climate change acts as a 'threat multiplier,' exacerbating existing stressors like habitat fragmentation, uneven distribution of wetland and forest cover, and suboptimal ecological health thresholds.

The report emphasizes the differential impact of climate change on species, creating winners and losers, with specialized species being most vulnerable. Interactions between species are amplified, affecting migration, cold-blooded species, and habitat fragmentation, contributing to reduced genetic diversity.

The vulnerability of specific species, notably Redside Dace and Brook trout, is highlighted, emphasizing the ongoing efforts required by Conservation Halton. The report concludes that Conservation Halton's work serves as a foundation for adaptive strategies, providing valuable insights into the intricate challenges posed by climate change on biodiversity within its watersheds.

3.8.1.1 Recommendations

The following are the recommendations outlined in Conservation Halton's 2023 report *Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds.*

1. Assess the watershed monitoring program to determine whether it adequately represents biophysical functions and sensitive sentinel species that can provide early detection of climate change impacts and, if required, adjust the monitoring program to include those that are most susceptible to the effects of climate change.

2. Provide additional data analysis, through a climate change lens, which connects physical (hydrometric, meteorologic, and hydrologic) data and observed biological responses to understand biodiversity conditions, trends, and risks linked with climate change.

3. Establish a regular cycle to report on climate change conditions, trends, risks, and management outcomes to inform watershed planning and management actions.

4. Partner with researchers from post-secondary institutions to advance scientific research on climate change impacts relevant to Conservation Halton's watersheds and guide management actions which promote climate change mitigation and adaptation through nature-based solutions.

5. Develop a Seed Strategy for Conservation Halton's tree planting program to ensure that planting stock is adapted to future climate conditions.

6. Assess and implement new technologies and best approaches that can provide insight into the connection between changes in the biophysical environment and biological responses (e.g., application of Nature Serve's Climate Change Vulnerability Index to additional species, use of updated or more localized climate projections, predictive modelling, etc.).

7. Develop species-specific monitoring and restoration strategies for target species at risk and climate-vulnerable species on Conservation Halton lands.

8. Develop a restoration prioritization tool to support watershed planning and allow for more strategic selection and identification of restoration opportunities to address specific goals related to climate change and other watershed stressors.

3.8.2 Strategic Forest Management Plan - 2020

Conservation Halton's Strategic Forest Management Plan (Conservation Halton, 2020) emphasizes their commitment to sustainable forest management over the next 20 years. Conservation Halton has been protecting, restoring, and managing forests, having planted over 4 million trees and safeguarded 10,840 acres of forested lands.

The plan focuses on a landscape approach to forest management, prioritizing forest health, and addressing key challenges faced by local forests. It incorporates this 20-year vision, driven by goals to improve forest health, maximize the value of forests in delivering environmental benefits, and maintain or increase forest cover across the watershed.

The plan envisions continuous updates to the inventory through GIS technology, ensuring accurate and current information. It is designed to be agile, with a rolling five-year outlook and forest management prescriptions developed for each stand. The report emphasizes a commitment to excellence and leadership in sustainable forest management, ensuring the health and resilience of forests for environmental and community benefits.

3.8.2.1 Recommendations

The following are the recommendations outlined in Conservation Halton's 2020 *Strategic Forest Management Plan*.

1. Update Forest Inventory to inform strategic forest management.

2. Continue to build, support, and develop relationships with partners and agencies where there is a joint benefit.

3. Develop and sustain meaningful relationships with First Nation, Métis, and Indigenous partners that seek opportunities for increased engagement and mutually beneficial partnerships.

4. Support active land securement by building relationships with private landowners through landowner education regarding Ecogifts program and/or designate a percentage of timber revenues to the Land Securement budget.

5. Ensure that the 'value' provided by the forest infrastructure on Conservation Halton lands is reflected in the emerging asset management framework.

6. Establish a Forest Reserve Budget to enable timber revenues to be dedicated toward the continued growth and improvement in Conservation Halton Forests.

7. Monitor and improve overall forest health and wildlife habitat throughout Conservation Halton forests.

8. Maintain current forest cover percentage through the management of the Conservation Halton forests and by working with watershed partners

9. Promote private landowner tree planting programs to engage a wider community in the importance and value of forested landscapes.

10. Continue to support a vibrant local seed stock within southern Ontario nurseries by providing a reliable, local seed source.

11. Manage for long-term forest health by promoting and utilizing Sustainable Forest Management principles and practices that meet or exceed current standards.

12. Identify and manage appropriate stands toward 'old growth' characteristics recognizing that the human environment surrounding our forests will rarely allow for true old growth forests.

13. Build resiliency in our forests with climate change mitigation and adaptation by maintaining and enhancing forest science knowledge for forest management practices.

14. Establish an Invasive Species Management Program and manage invasive and non-native plant species on Conservation Halton properties, where possible.

15. Adopt leading practice through sustainable forest management to conserve and improve forest habitat for the benefit of Species at Risk.

16. Maintain a responsive hazard tree program and reduce risk of hazard trees through proactive Sustainable Forest Management.

17. Continue to monitor for forest pests and diseases, including invasive species, and establish greater interdepartmental collaboration on monitoring programs

3.8.3 Grindstone Creek Watershed Natural Assets Management Project - 2022

The *Grindstone Creek Watershed Natural Assets Management Project* (NAI, September 2022) report addresses possible infrastructure challenges faced by local governments and watershed agencies due to the increasing impact of climate change. Focusing on the Grindstone Creek Watershed, the project involved collaboration among the City of Burlington, the City of Hamilton, Conservation Halton, and Royal Botanical Gardens and the Natural Assets Initiative (NAI). The objectives were to identify, understand, and quantify the roles of natural assets in the watershed for services such as flood mitigation, stormwater management, and water quality control along with several co-benefits.

The project produced valuable data, modelling, and valuation of stormwater management benefits, scenario development for future watershed states, and recommended next steps for comprehensive natural asset management. The estimated value of natural assets for stormwater management is significant, highlighting the cost-effectiveness of maintaining natural infrastructure compared to replacing with engineered alternatives. The report emphasizes the wide range of co-benefits provided by natural assets, such as recreation, soil retention, climate mitigation, habitat and biodiversity support, and atmospheric regulation.

The report underscores the significance of considering natural assets as integral components in long-term asset management strategies, providing economic, social, and environmental benefits.

3.8.3.1 Recommendations

The following are the recommendations outlined in Conservation Halton's 2022 report *Grindstone Creek Watershed Natural Assets Management Project.*

1. Review policies to protect existing natural assets.

2. Develop a collaborative watershed management strategy and plan for Grindstone Creek watershed.

3. Develop a collaborative watershed management approach for the Grindstone Creek watershed.

4. Develop a collaborative monitoring plan.
5. Advance priority restoration projects.
6. Install low impact development projects in priority areas.
7. Strengthen assessment of natural assets in the Grindstone Creek.
8. Develop a communications plan and presentation to build awareness of natural asset management needs in the Grindstone Creek watershed.
9. Better integrate natural asset management into overall asset management practices.
10. Identify additional watersheds within Conservation Halton's jurisdiction for natural asset management.

4 CONCLUSION AND RECOMMENDATIONS

This section provides the recommendations emerging from this risk assessment, supported by input from subject matter experts across diverse fields from Conservation Halton and Matrix. Most of these recommendations are not standalone initiatives but represent the continuation of ongoing efforts and commitments already made by Conservation Halton. Examples of ongoing and relevant programs include the 2020 *Strategic Forest Management Plan* and the 2023 report *Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds*.

The findings from the Natural Asset Management Study of Grindstone Creek underscore the invaluable role that natural systems play in supporting the communities within Conservation Halton's jurisdiction. In implementing these recommendations, a primary emphasis should be placed on actions that directly impact human health and property (e.g., flood risk mitigation). Secondary priorities should consider multiple benefits (e.g., ecology, recreation). While climate change risks are the focal point of this report, the cumulative impacts from urbanization and other land activities should also be considered when looking at impacts to natural systems. The following sections summarize recommendations in each of the following areas relating to climate risk.

- flooding
- erosion and sedimentation
- water quality
- aquatic ecology
- terrestrial ecology
- Conservation Halton services

4.1 General Recommendations

These initial general recommendations are provided to give overarching guidance to assist in building Conservation Halton's adaptive capacity to a changing climate. More detailed recommendations follow.

- Review all monitoring programs to integrate climate change considerations by evaluating monitoring network density, data collection methods, measurement parameters, and monitoring protocols. Identify key indicators and assess spatial and temporal scales for aligning with projected climate change impacts. Enhance monitoring efforts with emerging technologies and data sharing mechanisms to inform adaptive strategies and sustainable management practices.

- Renew Watershed Plans for each of Conservation Halton's watersheds to encompass scenarios integrating climate change projections, land use changes, and natural resource scenarios reflecting climate change impacts. These plans will anticipate hydrological shifts and ecological impacts within the watershed. Integrate land use and natural resource scenarios to assess potential stressors and inform adaptive management strategies for sustainable watershed management amidst evolving environmental conditions.

- Model hydrologic impacts of climate change on a watershed scale. Utilize climate projections and hydrological models to simulate changes in rainfall intensity, duration, and frequency over time. Incorporate Intensity-Duration-Frequency (IDF) curve shifts into planning and risk assessment frameworks to enhance resilience against extreme weather events and mitigate potential flood risks associated with climate variability.

- Continue to coordinate with municipal partners to share climate change data and develop collaborative strategies. Create a hub for climate change data and watershed-scale assessments to facilitate information sharing and decision making among stakeholders. Ensure accessibility and compatibility of data formats to allow for analysis and integration into municipal planning processes. Foster informed actions and resilience-building efforts across interconnected communities and watersheds.

4.2 Flooding

Climate change increases flood risk within Conservation Halton's watersheds, with streams identified as the most vulnerable natural resource in this context. The risk assessment suggests that streams face heightened risks of flooding due to higher frequency of precipitation events, seasonal changes in rainfall and snowmelt, and dry conditions and heat stress. Seasonal changes and snowpack reduction contribute to increased runoff during winter months and more extreme storms in spring and summer, elevating water levels in streams, especially during a rain on snow event. While an overall drying of stream beds may initially decrease flooding on a day-to-day basis, completely dried out stream beds can lead to faster runoff, creating flashier systems and potential flooding.

Areas identified as susceptible to flooding include Southeast Oakville, Southwest Oakville, Southeast Burlington, Southwest Burlington, Urban Milton, Lowville, Carlisle, Progreston, Cedar Spring Community, Millgrove, Hidden Valley Community, and the Highway 6 Corridor in Flamborough. These areas encompass various creeks and spill systems associated with streams, posing significant risks of flooding.

The following recommendations are proposed to address and mitigate the impacts of climate change on flooding within Conservation Halton's watersheds.

5. **Operations:**

   - Consider how climate change impacts in flood risk and may necessitate changes in flood control infrastructure operations.

   - Continue updating Conservation Halton’s flood forecasting and warning system to reflect any changes in seasonality or rainfall patterns that may emerge from climate change.

- Consider reviewing the operational requirements for flood control infrastructure to meet the seasonal, recreational, and flood mitigation needs while considering the potential of low water levels due to climate change.

6. **Monitoring**:

   - Continue to monitor ice jams as seasonal changes and snowpack reduction exacerbate risks, reducing spring freshet, increasing runoff volumes, and elevating the likelihood of ice jams, erosion, and flooding.

   - Expand weather station network to provide coverage over a greater area of the jurisdiction to capture high-intensity, short duration, and localized storm events to enable timely responses to flood threats. This will increase the data for flood forecasting and warning, as well as hydrologic model calibration.

7. **Manage**: Maintain and expand natural areas (forest, wetland, etc.) to help maintain the hydrologic conditions in the watershed. The water retention services of these areas help mitigate current flood risk and will be crucial in providing adaptive capacity to intensive rainfall events under future climate conditions.

8. **Modelling:** Regularly update regulatory flood hazard mapping around ponds and streams to reflect the changes due to climate change.

   - Continue updating regulatory flood hazard mapping around streams to reflect the potential changes due to climate change. Consider implementing flood risk mapping to support municipal emergency preparedness. This will reduce risks to human health and property, with increased flooding potential impacting emergency services and property damage.

   - Use future climate scenarios, natural resource scenarios, and hydrologic and hydraulic models to identify potential flood risk zones. This would identify possible water depth and velocity in flooded areas. This information can be used for emergency preparedness and risk management.

   - Use hydrologic modelling to measure the potential impacts and help inform possible mitigation measures of climate change on wetlands. This would include reviewing ecologic impacts to wetlands and the ability of wetlands to mitigate flooding through vegetation changes and potential degradation.

4.3 Erosion and Sedimentation

Climate change increases risks to the stability of Conservation Halton's watersheds, particularly in terms of erosion and sedimentation risks. Streams, characterized by steep banks, face vulnerability to erosion and sedimentation due to increased rainfall, seasonal changes, and snowpack reduction. Elevated rainfall increases erosion risk along stream banks as water travels down slopes, carrying sediment into the streams. Seasonal variations, including more extreme storms and drier soils in summer, contribute to increased runoff in winter months, intensifying erosion. The timing and variability of streamflow, critical for bank weathering and vegetation dynamics, are altered by seasonal changes, exacerbating the risk of erosion and sedimentation.

The lakeshore, already susceptible to wave and ice movement, may face elevated risks with possibly reduced ice cover, higher water levels, storm surges, and wave action, leading to slope failure issues and shoreline erosion.

Areas at high-risk of streamflow erosion include those with steep slopes, clay/shale and sand/gravel soils in locations like North Oakville, Sixteen Mile Creek, Hidden Valley, Burlington, and Grindstone. Additionally, downstream reaches of Indian Creek, Sixteen Mile Creek in downtown Milton, and small western tributaries of Grindstone Creek south of Highway 5 face increased vulnerability due to exposure to intense periods of high flow. Considering these challenges, the following recommendations are proposed to address and mitigate the impacts of climate change on erosion and sedimentation risks within Conservation Halton's watersheds.

1. **Monitoring**:

   - Monitor the rate of shoreline erosion. Study the potential for an increase in shoreline erosion from intensified storm surges, and wave action, compromising shoreline integrity. Investigate strategies to mitigate shoreline erosion.
   - Monitor stream and valley stability to provide crucial information for flood and erosion control to allow for the development of effective strategies to manage the impacts of increased erosion flow events.
   - Undertake regular recurring watercourse erosion surveys and mitigate situations that introduce or aggravate the erosion hazard and associated impacts on infrastructure and valley ecology along accessible creek reaches.

4.4 Groundwater

1. **Monitoring:** Continue monitoring groundwater quantity through the Provincial Groundwater Monitoring Program and expanded locations at selected wetlands.
2. **Groundwater Discharge:** Utilize, and where needed, enhance existing groundwater models to better understand the interactions between surface and groundwater and assess and map out important groundwater discharge reaches throughout the watersheds. Validate modelling with surface water monitoring and aquatic information.

4.5 Water Quality

The impact of climate changes on water quality cascade a number of conditions including: dry conditions, heat stress, increased rainfall, seasonal changes, and snowpack reduction. These conditions collectively compromise water quality, affecting algae content, contaminant concentrations, and temperature fluctuations. Water quality degradation would result from erosion and sedimentation risks, fueled by factors like rainfall and seasonal changes.

The effects of water quality degradation are currently observed across the watershed and are likely to be exasperated in response to climate change. Water quality impacts are currently identified in creeks downstream of urban and agricultural zones, creek mouths flowing into Lake Ontario, stormwater management ponds, and Hamilton and Bronte Harbours. Elevated total phosphorus levels are observed in creeks downstream of urban or agricultural areas, as well as in creek mouths flowing into Lake Ontario. Furthermore, temperature pollution is found in central and downstream reaches of creeks lacking cooler groundwater discharges, urbanized creeks with limited riparian vegetation, and those with intermittent water flow prone to warming before drying up. The following recommendations aim to address and mitigate the impacts of climate change on water quality and ecosystem health within Conservation Halton's watersheds.

1. **Planning**: Continue to incorporate groundwater quality and quantity planning in the development of the Watershed Strategies for the watersheds within Conservation Halton’s jurisdiction.

2. **Surface Water Monitoring**: Identify gaps in the surface water quality monitoring network and expand the monitoring network with a goal of identifying and possibly mitigating trends resulting from climate change. Assess the monitoring network for its ability to capture water quality trends. Continue monitoring surface water for the temperature impacts associated with reduced groundwater flow or the impacts of higher temperature groundwater. Continue monitoring water temperatures, water levels, erosion and pollutant loading in ponds/lakes for any negative impacts on biodiversity due to climate change.

3. **Wetlands Monitoring and Improvement:** Expand wetland monitoring, preservation, and improvement programs to mitigate against water quality impacts. Monitor outfall of swamps that have historic records of water quality monitoring for the measurement of any reduction in water quality due to the impacts of climate change on the ability of swamps to provide the service of water quality improvement. Preserve and enhance natural wetlands to maintain the water quality improvements provided by these ecosystems, wherever possible. Increase wetland habitat to increase the water quality benefits and mitigate potential impacts from climate change on existing wetlands and possibly improve the water quality by a greater degree.

4.6 Aquatic Ecology

A healthy aquatic ecology environment relies on a number of factors including; stable and consistent streamflow conditions, consistent physical streamflow channel conditions, and acceptable water quality. The combined climate change risks to water quantity and water quality increases the climate change risks to aquatic ecology, potentially degrading aquatic habitat, and introducing opportunities for invasive species. Streams, acting as crucial connective pathways and cool water habitats, face imminent risks. Climate change introduces threats such as dry conditions, heat stress, increased rainfall, seasonal changes, and snowpack reduction. Climate stressors not only impact streams influence vital wetland ecosystems, including marshes and swamps. The potential consequences include disruptions to fish spawning and migration, posing a direct threat to biodiversity and the services these ecosystems provide.

Areas with species that have highly specialized requirements such as Redside Dace in Fourteen Mile Creek are especially susceptible to changes in stream temperature. There is an urgency to mitigate the effects of climate change on aquatic ecosystems, as targeted conservation efforts are essential to safeguard the resilience and functionality of aquatic ecosystems within Conservation Halton's watersheds.

1. **Monitoring:** Continue and adjust, if needed, various monitoring programs being executed within the watersheds and implement a process to identify climate change impacts through these programs. Specific monitoring programs include:

    - Continue and adjust, if needed, the aquatic monitoring system that includes regular assessments of stream levels, rainfall patterns, water temperature, erosion dynamics, and water quality to assess aquatic biodiversity for changes due to climate change.

    - Continue and adjust, if needed, monitoring for impacts of climate change causing a reduction in fish spawning habitats due to the degraded quality of aquatic ecosystems in marshes.

2. **Restoration**: Implement the recommendations in the report *Effects of Climate Change on Biodiversity within Conservation Halton's Watersheds* to "Develop species-specific monitoring and restoration strategies for target species at risk and climate-vulnerable species on Conservation Halton lands." Implement this recommendation for species impacted by the climate change effects on aquatic habitat including vernal pools.

3. **Modelling:** Undertake modelling of future climate scenarios to better understand and predict the impacts of climate change on the thermal dynamics of streams. Identify the risk of specific streams no longer being refugia for cold-water species. This will allow for identification of reaches where targeted restoration efforts would be beneficial to maintain a cold-water status under future climatic conditions.

4.7 Terrestrial Ecology

Climate change introduces a number of risks to terrestrial ecology. Changes in temperature and precipitation may alter the distribution and abundance of species, as well as their interactions with each other and the environment; thus, introducing opportunities for invasive species to thrive. Extreme events, such as droughts, floods, storms, and heat waves can damage habitats, reduce food availability, and increase mortality and disease risks. Finally, changes in the seasonality of weather can disrupt the interactions between plants and animals, flowering and pollination, migration and breeding, and hibernation and emergence. Forests face risks such as dry conditions and heat stress. Lakeshores and meadows and wetland marshes and swamps are not exempt from these risks. The following recommendations aim to address these vulnerabilities strategically, emphasizing the preservation and restoration of diverse ecosystems. These proposed measures are essential to fortify the resilience of terrestrial ecology in the face of evolving climate challenges within Conservation Halton's watersheds.

4.7.1 Forests

Recommendations for forests are particularly relevant for the large tracts of forest located above the Niagara Escarpment in northern Bronte Creek and the northwestern areas of Sixteen Mile Creek. These represent the largest areas of forest cover in Conservation Halton’s jurisdiction.

1. **Monitoring**: Continue monitoring forest health using the LEMP and other monitoring initiatives, including invasive species

2. **Wetland Monitoring:** Continue and adjust, if needed, Conservation Halton's LEMP to monitor vernal pool, swamp, and marsh habitats particularly for early spring breeding amphibians due to changes in snowpack and seasonality.

3. **Habitat Corridors:** Model the impact of climate change on wildlife corridors and migration patterns by integrating species-specific habitat suitability models, climate projections, and landscape connectivity analyses. Incorporate future climate scenarios to assess potential shifts in habitat ranges and corridor effectiveness.

4. **Build Resiliency**: Continue with existing programs designed to build resilient forests within the watersheds:

    - Implement the recommendations outlined in the 2020 *Strategic Forest Management Plan* to build forest resiliency against climate change. This will be accomplished through building the forest’s resilience using effective management practices and by incorporating mitigation and adaptation strategies.

    - Implement recommendations from the *Effects of Climate Change on Biodiversity within Conservation Halton’s Watersheds* report, focusing on enhancing forest resilience in particular

Recommendation 5: “Develop a Seed Strategy for Conservation Halton's tree planting program to ensure that planting stock is adapted to future climate conditions.”

5. **Expand Forests:** Expand forested areas through strategic land acquisition, when possible, to mitigate any forest losses due to climate change or even expand forested area to improve habitat connectivity and provide high quality contiguous habitat.

6. **Protect Against Fire**: Prepare for the onset of forest fire conditions due to heat stress and precipitation changes on Conservation Halton owned lands.

4.7.2 Biodiversity Loss

Stresses on an ecological environmental may have a greater impact on specific species, and most likely on some species at risk and lead to biodiversity loss. The preservation of biodiversity in certain critical areas is paramount to watershed and environmental protection and conservation efforts. This urgency is particularly pronounced in natural areas that find themselves fragmented by adjacent urban or agricultural areas, as shown by the Bronte and Burloak Woods in the Town of Oakville. Similarly, natural areas that are inherently sensitive to human uses, such as Waterdown Woods in Hamilton, stand as ecosystems at risk. The following recommendations are intended to counteract the risks on biodiversity imposed by climate change:

1. **Monitoring**: Maintain ongoing wildlife habitat monitoring in the LEMP and other monitoring initiatives.

2. **Implement the recommendations in the Conservation Halton study**: *Effects of Climate Change on Biodiversity within Conservation Halton’s Watersheds*, pertaining to terrestrial biodiversity loss and climate change.

3. **Develop Invasive Species Strategy**: Develop an Invasive Species strategy and cooperate with other levels of government to coordinate efforts on detection, protection against, and destruction of invasive species.

4.8 Conservation Halton Services

Climate change poses substantial risks to Conservation Halton's services. Heat stress, seasonal changes, and snowpack reduction present specific challenges to Conservation Halton Park infrastructure. There is also the potential for beach closures due to algal blooms affecting lakes and lakeshores. Groundwater faces diminished recharge and increased demand, impacting water supply and recreational spaces. The lakeshore may experience erosion, influencing visitor safety and infrastructure. Ponds and lakes confront water quality issues and reduced flood control infrastructure operations. Recommendations will be crucial to mitigating these impacts and ensuring the resilience of Conservation Halton's essential services in the face of climate change.

1. **Adapt services:**

   - Assess potential alterations to visitor experiences, considering the potential impact on park revenue due to the lack of forest cover or degraded natural areas.

   - Prepare for potential impacts on Conservation Halton's services, including beach closures, infrastructure maintenance, reduction in availability of snow for skiing, and visitor experiences, due to heat stress, wind, and seasonal changes.

2. **Safety:**

   - Continue to implement signage and safety programs warning users of Conservation Halton’s trails and natural areas to inform of ticks and the potential for Lyme disease.

   - Consider addressing the potential of safety concerns on lakeside authority property due to the potential for increased risk of tripping and falling due to precipitation, waves, and wind, impacting human health and safety.

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Appendix A
Communication Plan

Version 2.0
Matrix 36679-558

August 29, 2023

Martin Keller
CONSERVATION HALTON
2596 Britannia Rd. W
Burlington, ON L7P 0G3

Subject: Work Plan for Conservation Halton Watershed Climate Change Vulnerability and Risk Assessment

Dear Martin Keller:

1 OBJECTIVE

- propose a comprehensive meeting plan to establish effective communication and collaboration channels between Matrix Solutions Inc., a Montrose Environmental company, and Conservation Halton (CH) project managers, including core team members, to ensure the successful execution of the project
- outline a structured consultation plan targeting CH's municipal partners
- present a draft outline for a survey to engage with the municipal partners and gather relevant data

2 BACKGROUND AND PURPOSE

CH recently launched a Watershed Climate Change Vulnerability and Risk Assessment project. This work represents the first step in developing a Watershed Climate Resiliency Strategy for CH's jurisdiction. The goal of the Watershed Climate Resiliency Strategy is to identify actions which will improve the adaptive capacity and resiliency of the watersheds to cope with and adapt to the impacts of warmer, wetter, and wilder weather.

This Watershed Climate Resiliency Strategy will also support the Watershed-based Resource Management Strategy (Watershed Strategy). The Watershed Strategy will identify and evaluate resource issues and risks within CH's jurisdiction in support of CH's programs and services. The Watershed Strategy is required by the Province to be completed by CH by the end of 2024.

3 CONSERVATION HALTON-MATRIX MEETING PLAN

3.1 Participants

3.1.1 Project managers:

- Matrix project manager: Fabio Tonto
- CH project manager: Martin Keller

3.1.2 Core team members:

- Matrix: Melani-Ivy Samson, Quentin Chiotti, David Van Vliet
- CH: Barbara Veale, Brad Rennick, Kim Barrett

3.1.3 Subject matter experts:

- Matrix: Roger Phillips
- CH: see Table A (the personnel listed may change based on interest and availability)

TABLE A Conservation Halton Subject Matter Experts

Name	Title	Email address
Adrian Bryant	Coordinator, Forestry	abryant@hrca.on.ca
Andrea Dunn	Coordinator, Monitoring Ecology	adunn@hrca.on.ca
Brad Rennick[a]	GIS Analyst Lead	brennick@hrca.on.ca
Craig Machan	Director, Parks & Operations	cmachan@hrca.on.ca
Glenn Farmer	Manager, Flood Forecasting & Operations	gfarmer@hrca.on.ca
Ilona Feldmann	Resource Planning Coordinator	ifeldmann@hrca.on.ca
Jacek Strakowski	Hydrogeologist	jstrakowski@hrca.on.ca
Jennifer Young	Senior Water Resources Engineer	jyoung@hrca.on.ca
Jennifer Roberts	Forest Technician Lead	jroberts@hrca.on.ca
Leah Smith	Policy and Special Initiatives Lead	alsmith@hrca.on.ca
Brenna Bartley	Education Manager	bbartley@hrca.on.ca

(a) Also a member of the core project team

3.1.4 Municipalities:

- City of Burlington
- Town of Halton Hills
- City of Hamilton
- Town of Milton
- City of Mississauga
- Town of Oakville
- Township of Puslinch
- Regional Municipality of Halton
- Wellington County
- Regional Municipality of Peel

3.2 Frequency

Biweekly meetings will be held between Matrix and CH project managers. These meetings will offer a structured platform to discuss project updates, address challenges, and make decisions. Core team members will be invited but their attendance is optional.

3.3 Meeting Structure

- **Project updates:** Managers will share updates on their respective areas and action items.
- **Issue resolution:** Challenges will be discussed, and collaborative solutions will be brainstormed and documented.
- **Decision making:** Key decisions will be made collaboratively during the meetings.
- **Action items:** Tasks for the upcoming period will be identified, assigned, and tracked.

3.4 Communication Channels

- **Biweekly meetings:** The primary mode for real-time interaction, problem-solving, and updates.
- **Email updates:** After each meeting, a summary email will be sent, outlining decisions and action items.
- **Ad-hoc communication:** Team members are encouraged to communicate for urgent matters and critical updates.
- **Escalation process:** If required, project managers will collaborate to address issues, involving higher management when necessary.
- **Feedback and continuous improvement:** Regular feedback will be collected to enhance communication and collaboration. Adjustments will be made based on the feedback and lessons learned.

4 MUNICIPAL ENGAGEMENT PLAN

4.1 Objective

Engage municipal stakeholders to gather input, insights, and data for the Watershed Climate Change Vulnerability and Risk Assessment. Municipal engagement will help better understanding of the work CH is undertaking, provide opportunities for feedback and comments, and help with municipal buy in / relationship building with key municipal staff. The plan includes survey distribution, presentations, and feedback sessions to foster communication, data collection, and partnerships.

4.2 Survey Steps

- CH will collect municipal contacts, introduce the project, and assess municipal interest.

- Matrix will design a comprehensive survey in Microsoft® Forms to gather insights on municipal perspectives, data availability, and interest in the project. Suggested draft questions can be found below. The intent is to have ten simple questions in the survey. Please specify which ten questions you would like to see in the survey, including any additions or edits that you may have.

- The survey will be distributed among key municipal stakeholders in environmental management, planning, and decision-making.

- Survey will outline how municipalities are engaged.

- Questions include:

  1. Have you conducted vulnerability assessments for your municipal natural heritage system (i.e., key resources, ecosystems, and other features) as part of your climate change strategy?

  2. Do you have any studies, reports, or data that would help us assess climate change risk for the natural features in your municipality? If so, would you be willing to provide them to CH? Please let us know if you require a data sharing agreement. ?

  3. What are your primary concerns regarding natural resources/ecosystems resilience and risk management?

  4. Which natural features/ecosystems do you think are most important for assessment?

  5. How would this assessment benefit your municipality and residents?

5 WORKSHOP UPDATES

After each of the main workshops (Natural Resources Workshop and Risk Assessment Workshop), outreach will occur. A workshop memo will be shared with interested municipal partners, followed by a presentation summarizing workshop outcomes. Municipal participants will have the opportunity to comment and provide feedback during these sessions.

5.1 Workshop Memos and Comment Period

Workshop memos will succinctly summarize key discussions, decisions, and outcomes of the workshops. A review period will allow municipal partners to provide feedback on the memos during a 2 week period after their distribution. The memo will be circulated before the workshop presentation.

5.2 Workshop Presentation

Post-workshop, a 1 hour presentation will be delivered to municipal participants, highlighting workshop outcomes, and allowing for a question and answer period and discussion. The meeting will be recorded in case participants are unable to join.

5.3 Final Report

Upon completion, the final report will be presented in a 1-hour online session with municipal partners. This presentation will serve as an outward communication session and will not involve report review, as partners have previously had the opportunity to review and comment on the work leading up to the final report and conclusions.

6 CLOSURE

By implementing this communication plan and consultation strategy, Matrix and CH aim to ensure effective collaboration, data collection, and successful project execution.

We trust that this work plan suits your present requirements. If you have any questions or comments, please call either of the undersigned at 647.523.3157.

Yours truly,

MATRIX SOLUTIONS INC.
A Montrose Environmental Company

Fabio Tonto, P.Eng., MEPP
Senior Water Resources Engineer
Practice Lead, Climate Risk and Resilience

Reviewed by

Quentin Chiotti, Ph.D.
Technical Lead, Climate Risk

FT/vc
Attachment: Revised Schedule

copy: Martin Keller, Conservation Halton, Burlington, ON

CONTRIBUTORS

Name	Job Title	Role
Fabio Tonto, P.Eng., MEPP	Senior Water Resources Engineer, Technical Lead, Climate Risk	Primary author
Quentin Chiotti, Ph.D.	Practice Lead, Climate Risk and Resilience	Reviewer
Melani-Ivy Samson, M.A.Sc., EIT	Water Resource Engineer-in-Training	Contributor

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V1.0	25-Aug-2023	Final	36679-558 CH WP 2023-08-25 final V0.1.docx	Issued to client for review

Table 1: Watershed Climate Change Vulnerability and Risk Assessment Schedule
Client: Conservation Halton

Matrix Solutions Inc.
A Montrose Environmental Company

Updated on: August 24, 2023

Task	2023				
	August	September	October	November	December
Project Management					
Project Coordination and Aministration					
Kick-off Meeting					
Biweekly Calls					
Background					
Examine Policy Documents, Watershed Reports, and White Papers					
Communication Plan					
Data Collection					
Background Memo					
Natural Feature Inventory					
Design GIS Data Source					
Develop Inventory of Natural Hazards, Key Natural Resources/Assets,					
Climate Hazard Review					
Downscaled RCM Download from climatedata.ca					
Prepare Future Climate Scenarios					
Document Historical and Projected Climate Data and Trends					
Calculate Relative Hydrologic Effects of Climate Change					
Climate Hazard Memo					
Natural Asset Workshop					
Workshop Preparation					
Initial Workshop to confirm Consultation Plan, Inventory, and Data					
Workshop Summary					
Presentation to Municipalities					
Risk Assessment Workshop					
Workshop Preparation					
Workshop with Staff					
Risk Assessment					
Presentation to Municipalities					
Watershed Assessment					
Map Medium, High, and Very High Risks					
Assess Watershed Individual Vulnerability					
Evaluate Individual Adaptive Capacity					
Development of Adaptation Measures					
Final Deliverables					
Draft Table of Contents					
Draft Report					
Presentation					
Presentation to Municipalities					
Final Report					

Project Award
Task
Kick-off Meeting and Workshops
Biweekly Calls

Appendix B
Municipal Engagement Survey Results

Appendix B

Municipal Engagement Survey Results

Municipalities and stakeholders within the jurisdiction of the Conservation Halton watershed were consulted for their input with respect to climate risk for their individual municipal natural heritage systems. The municipalities and stakeholders engaged in this survey are listed in Table 1, along with the status of response received reflecting their participation. We note that in some cases municipalities that did not provide input through the survey were engaged via a meeting/workshop held on October 17, 2023. Further, there has been additional focused engagement with the City of Hamilton and the City of Burlington that has been supported by the Greenbelt Foundation.

TABLE 1 Municipalities and Stakeholders Survey Engagement Results

Municipality/Stakeholder	Response Received?
City of Burlington	Yes
Town of Halton Hills	Yes
City of Hamilton	No
Town of Milton	Yes
City of Mississauga	No
Town of Oakville	Yes
Township of Puslinch	Yes, by Wellington County.
Regional Municipality of Halton	Yes
Wellington County	Yes
Regional Municipality of Peel	No
Hamilton Naturalists' Club	Yes
Royal Botanical Gardens	Yes

The request for engagement sent out to municipalities and stakeholders was presented in the form of a survey, which yielded the results summarized below.

Have you conducted vulnerability assessments for your municipal heritage system as part of your climate change strategy?

Several municipalities had conducted studies related to their climate change strategy, such as:

- Climate Change Adaptation/Mitigation Plans (either completed or in development),
- Climate Change Vulnerability and Risk Assessments,

    - Did not include specific assessments for their natural heritage system.

Do you have any studies, reports, or data that would help us assess climate change risk for natural features in your municipality?

Generally, most municipalities had documents that would provide helpful insights regarding climate change risk and natural resources in their community. The documents included:

- Tree Management Strategies and Forest Management Plans
- Individual Environmental Impact Assessments for development applications
- Climate Resilient Burlington Plan, State of the Urban Forest, Burlington Woodlands Management Strategy
- Natural Heritage System Study

What are your primary concerns regarding natural resources/ecosystems resilience and risk management?

The municipalities and stakeholders provided valuable input regarding their areas of primary concern, with various overlapping topics. The primary concerns were identified as follows:

- protecting, preserving, and enhancing the environment as outlined in municipal strategic plans
- increased urban flooding, increased impervious surfaces, and inadequate management of urban stormwater runoff
- increased effects of invasive species
- impact of increased population and urban development on natural resources
- impact of climate change on ecosystem resilience, and how natural resources will handle increased extreme conditions
- inadequate management of increased runoff volumes under climate change
- tree species diversity and resiliency, canopy cover
- resiliency of forest and wetland habitats
- fragmentation of natural resources by roads
- decreased numbers of top predators which maintain ecosystem balance
- degraded natural resources and decreased resiliency, causing habitat and biodiversity loss
- neglecting areas of concern if they aren't classified as ecologically significant
- the role of natural assets to support natural infrastructure for flooding and stormwater management
- resiliency of the natural resources and recommended mitigation measures
- identifying the watersheds greatest vulnerabilities

Which natural features/ecosystems do you think are most important for assessment?

According to the survey results, the areas identified as important for the assessment are summarized in the following list:

- the Niagara Escarpment
- small tributaries/subwatersheds within the Niagara Escarpment that are vulnerable to erosion
- floodplains and wetlands, and their use in flood attenuation
- areas that form natural corridors and key linkages
- forests, forest cover, tree canopy, and riparian areas
- streams and rivers
- the Paris Galt Moraine

How would this assessment benefit your municipality and residents?

The survey responses identified the following list of benefits that this assessment may provide:

- Complement already approved climate change plans and strategies, providing more data and technical focus on the watershed and its waterways.
- Help understand which Official Plan policies are needed and provide evidence to support protection and enhancement policies.
- Assist in developing a City-wide biodiversity plan and assess the health of natural assets.
- Address benefits of maintaining natural resources, provide a case for investment in green infrastructure.
- Lake Ontario Fishery re-established.
- Help in highlighting properties that stakeholders may want to acquire for protection over the coming years.
- Highlight the need for additional forest cover to prevent significant erosion and flooding.
- Provide additional information to look at sequestration for the purposes of offsets and municipal greenhouse gas reduction targets.
- Support evaluation of Natural Assets Inventory, and provide a greenhouse gas baseline for the analysis.
- Prioritize restoration areas.
- Provide understanding about the natural environment that are vulnerable to changes in climate.

- Articulate the expectations of Conservation Halton for municipalities implementing any recommendations.
- Provide modelling of the natural resources throughout the watershed.
- Identify the financial value of natural assets

Do you have any additional questions and/or concerns?

- How are you going to authentically engage with your partners?
- What resources are you considering providing as part of this initiative?
- How will data be shared and/or used?
- Does Conservation Halton have any other information, data, resources, etc. that they would be requesting of Halton Region for this initiative?
- It would be beneficial to have a better understanding of the full scope of the project and the intended deliverables and the needs and expectations regarding regional involvement (Halton Region). This will also assist the Region in providing more information and to identify synergies with work already being completed by the Region.

The documents received from the survey and throughout the background review that are related to other municipalities are summarized in Table 2 below.

TABLE 2 Municipalities and Other Stakeholders Documents

Year	Name of Document	Source of Information
2023	Climate Resilient Burlington: A Plan for Adapting to Our Warmer, Wetter and Wilder Weather	Original RFP
2020	Pilot climate change vulnerability and risk assessment for the Burlington drinking water intake [Appendix B1 and Appendix B2].	Original RFP
2006	Halton Natural Areas Inventory	Added by CH
2014	Hamilton Natural Areas Inventory	Added by CH
2006-2014	Forest Health at Waterdown Woods Resource Management Area	Added by CH
2023	Woodland Management Strategy - Interim Update (City of Burlington)	Added by City of Burlington (survey)
2022	State of the Urban Forest Report (City of Burlington)	Added by City of Burlington (survey)
2021	Climate Resilient Burlington: Climate Change Vulnerability and Risk Assessment	Added by City of Burlington (survey)

A key takeaway from the survey was that municipalities are interested in more information regarding this Climate Change Vulnerability and Risk Assessment and identifying synergies with work already being completed within their own jurisdiction. Further, the conversation with municipalities highlighted that the work done in this assessment is providing a starting point to start climate change modelling on a watershed basis and develop a collaborative, forward-thinking climate change initiative. This proves the importance of engagement throughout the entire process and sharing of information.

Appendix C
Climate Hazard Memo

x

CONSERVATION HALTON
CLIMATE HAZARDS, DATA, AND LIKELIHOOD

Prepared for:
CONSERVATION HALTON

Prepared by:
MATRIX SOLUTIONS INC.

Version 0.1
January 2024
Guelph, Ontario

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CONSERVATION HALTON

CLIMATE HAZARDS, DATA AND LIKELIHOOD

Prepared for Conservation Halton, January 2024

Quentin Chiotti, Ph.D.
Practice Lead, Climate Risk and Resilience

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	07-Oct-2022	Draft	34718-558 Climate Hazards R 2022-10-07 draft V0.1.docx	Issued to client for review
V1.0	16-Dec-2022	Final	34718-558 Climate Hazards R 2022-11-01 Final V1.0	Issued to client

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APPENDICES

1 INTRODUCTION

As part of the strategic context review, climate hazards have been identified that will inform the risk assessment stage as part of the process to develop a Climate Adaptation Plan (CAP) for Conservation Halton. While there tends to be broad consensus regarding what constitutes climate hazards of concern (e.g., high precipitation, floods, drought, high temperatures, etc.), the calculation of how each will change under future climate conditions, and thus impact natural assets and ecosystems, is a complicated procedure. This involves selecting the climate variables or parameters that best illustrate or represent the climate conditions that define and capture a specific hazard, drawing information from climate data portals and published material to identify future changes in these variables relative to past conditions, and then determining how their occurrence (likelihood) will change in the mid-term (30 years) and long-term (60 years) future. We note that while in some cases there are subtle differences in the historical record and future projections across the watersheds of Conservation Halton (e.g., above and below the Niagara Escarpment), overall, there is a high level of uniformity in the delta changes in future climate conditions and the likelihood of occurrence between data portals and previous studies. The likelihood scores will then be combined with consequence scores to determine the level of risk that Conservation Halton is facing regarding future climate conditions that can adversely impact natural assets and ecosystems, and the services dependent upon them.

This discussion outlines the steps taken in the process to select climate hazards, climate variables and parameters, climate data (historical baseline and future projections), and the likelihood of occurrence. It is intended to provide a transparent account of how the likelihood scores for each climate hazard are based on credible data and information, and that the projections in occurrence are accurate and defensible. It is noted that the process to calculate future changes in the likelihood of climate hazards is well established and, for the most part, is objective and based on sound science. However, there is much uncertainty regarding climate projections and, in some cases, the likelihood of occurrence involves using expert judgement that can be subjective in nature. Detailed tables of climate information and scoring criteria that were used to inform this discussion, to support the calculation of likelihood scores, and provide transparency to the process are provided in Appendix A. The tables may be deemed useful to those wishing to take a deeper dive into the data and can serve as a useful resource for Conservation Halton staff regarding future needs to consider relevant climate information.

In a climate that is becoming warmer, wetter, and wilder, we can expect that changes in likelihood for the future occurrence of climate hazards will generally decrease in the winter season, increase in the spring and summer seasons, and that changes in the frequency and intensity of acute and chronic conditions will become even greater as this century unfolds (depending upon global efforts to mitigate greenhouse gas [GHG] emissions). Changes (or the rate of change) may not be linear or consistent over time, noting that some climate variables, such as snowfall and freezing rain, are driven by both precipitation and temperature conditions, resulting in a trajectory that increases and then decreases by the 2050s or 2080s. It should also be noted that climate model projections do not capture extreme events and conditions very well, even if ranges in uncertainty (e.g., 10^{th} and 90^{th} percentiles) are considered. What could happen in the future then could exceed or amplify the projections of likelihood of occurrence outlined in this report. Nonetheless, for the purposes of developing climate adaptation strategy, the likelihood scores should suffice in determining the projected levels of risk.

Geography is also expected to play a role in how changes in acute and chronic climate conditions will impact natural infrastructure and ecosystems. Generally, areas above the Niagara Escarpment will be wetter and cooler compared to areas below the Niagara Escarpment that will be drier and warmer. However, the delta change in climate conditions (future climate conditions in 2050 and 2080 compared to the historical baseline (1981-2010) is expected to be fairly consistent and uniform. More localized climate data may capture spatial variations in the landscape and elevation that slightly deviates from these projected changes, but generally the delta increase or decrease is expected to be uniform across the region, with any changes having minimal, if any, impact on probability scores.

This report is organized into the following sections:

- selection of climate hazards
- selection of climate variables or parameters
- future climate projections
- likelihood scores

Since the purpose of this report is to calculate the likelihood scores of the climate hazards and the associated climate variables and parameters for the purposes of informing the risk workshop, its focus is to communicate the process in a transparent manner, rather than provide a detailed explanation for how the scores are justified.

2 SELECTION OF CLIMATE HAZARDS

The selection of climate hazards was based on a review of the literature and engagement with Conservation Halton staff. As such the climate hazards are informed by the historical experience across Conservation Halton's watersheds, natural infrastructure and ecosystems, whose experts have encountered a wide range of acute (extreme weather) and chronic (longer term) conditions in weather and climate. A provisional list of proposed climate hazards was provided to the core advisory group. After some discussion, a list of six climate hazards was proposed for the first workshop: dry conditions, rainfall/riverine flooding, heat stress, seasonal changes, snowpack reduction, and wind. In addition two new hazards were added to the list by the project team to capture climate conditions that may be a concern for unique ecosystems along the coastal areas, specifically lake levels and coastal erosion.

In brief, the climate hazards can be described as:

- Dry Conditions: Dry conditions will be caused by increased temperatures and changes in precipitation patterns. Both average temperature and number of days above 30 degrees increase significantly.

Annual precipitation increases, with rainfall or snow events becoming more frequent and intense, while dry periods may similarly increase. In addition, increases in evapotranspiration will result in drier conditions. Seasonal reductions in infiltration will affect headwater streams.

- Rainfall/Riverine Flooding: Increase in rainfall intensities of both short duration, high frequency storms and less frequent large storms. Likely in increase in bank full, 1-year flows that cause stream erosion. Increase in larger events that cause floodplain inundation.

- Heat Stress: Increase in average temperatures and humidex levels, whereby hot days will cause heat stress in people, flora and fauna. Stream temperatures will increase, especially during low water conditions.

- Seasonal Changes: Changes in multiple climate parameters cause complex changes in the watersheds. These include, but are not limited to, shorter shoulder seasons, increase in growing days, earlier spring freshette. Overall, seasonal changes will be reflected by a warmer winter, hotter summer and shorter shoulder seasons, along with greater climate variability. Impacts may include conditions that are more hospitable to invasive species while adversely affecting native species at risk.

- Snowpack Reduction: An increase in winter temperatures will lead to less snowfall, more snowmelt and an increase in rain on snow events.

- Wind: An expected increase on average wind speeds and wind gusts. Coupled with longer periods of exposed water due to less lake ice, and possible higher lake levels may cause an increase in shoreline erosion.

3 CLIMATE HAZARDS AND PROJECTIONS

The primary data source for the climate hazards selected and their future projections was climatedata.ca, which is becoming recognized as the defacto data portal for climate data in Canada. The data includes the modelled historical baseline (1981-2010), 2050 AND 2080 under a high emissions SSP5.85 scenario. In some cases other emission scenarios were presented in order to illustrate the levels of uncertainty that could occur in the future, depending upon the direction and achievement of GHG emission reductions on a global level. We note that the historical modelled data matches very closely the actual climate record, not necessarily on a year by year basis, but over the 30 year baseline period the means are virtually the same.

Other technical reports were also consulted, in order to fill in gaps and/or compare changes in direction and delta differences with the historical baseline. We note that the Burlington Projections Report (2021) was reviewed, given that the data source was climateatlas.ca, the Federally supported data portal that is part of the Canadian Centre for Climate Services suite of data portals (including climatedata.ca). This included other climate change assessment reports that were municipally based, including Halton Hills, the

Town of Oakville, and the Region of Peel. Studies that have applied the PIEVC (Public Infrastructure Engineeering Vulnerability Committee) Protocol to infrastructure assets located within the Greater Toronto and Hamilton Area were also consulted, in order to capture climate hazards and parameters that are not covered in the climatedata.ca data portal, tend to be low probability and high impact, and where the science and degree of confidence is relatively low regarding future changes in frequency. Lastly, other sources such as the latest two Ontario climate change impact and vulnerability assessments were also reviewed, in order to align our climate hazards to the most up to date science and interpretation of future conditions.

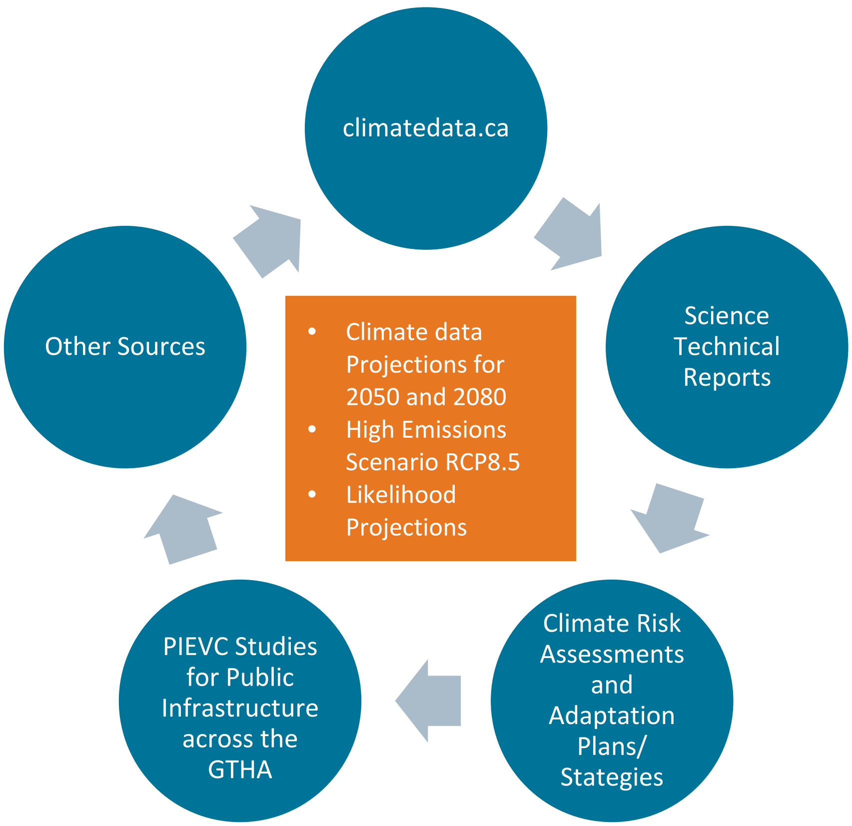


Figure 1 Review Process to Determine Climate Variable/Parameter Thresholds/Definitions and Historical Baseline and Future Projections

There are a number of data challenges that should be highlighted that helps explain the wide range of climate variables and parameters vis-à-vis the number of climate hazards. Not all climate hazards have a single climate variable/parameter that captures how they will change over time, and in some cases hazards or variables are missed/ignored altogether. In the former case, for example, the number of hot days will be dependent upon the climate threshold selected (e.g., 30°C, 32°C or 40°C), while risk to flooding could be captured by rainfall over different time periods (e.g., 24 hours or over 5 days), or the number of days when rainfall exceeds a specific threshold (e.g., number of wet days >20 m of rain). IDF information was provided but not assessed across the full range of statistics, more as a resource and illustration of uncertainty. There is no right or wrong choice in the climate variable or parameter, other than to consider what is the applied convention from other studies or what resonates with Conservation Halton staff who manage natural infrastructure assets and ecosystems. In the latter case, for example, there is a scarcity of winter precipitation projections in the climatedata.ca portal, where the occurrence of precipitation and temperatures would determine the amount of snowfall and accumulation. Nonetheless, climate variables/parameters could still be considered even where there is a high level of uncertainty and/or combination of conditions that are needed to generate the hazard, and where expert judgement could estimate magnitude and direction. For example, it is widely accepted that freezing rain events could increase in the short to medium future, and then decline over the longer term. Aside from direct projections of freezing rain events, an increased likelihood of occurrence by 2050 would be based on increases in precipitation being the primary factor, with rising minimum temperatures as a secondary factor.

4 FUTURE CLIMATE PROJECTIONS

Climate projections are provided in Appendix A for the wide range of climate variables and parameters, as captured in climatedata.ca, science-technical reports, and other sources. Appendix A includes a detailed guide in Tab 1, that outlines and explains the climate data in Tabs 2 through 10. The summary table provides a comprehensive account/record of historical baseline data and future climate projections for the high emissions scenarios (e.g., RCP8.5) and for two future time periods (e.g., 2050 and 2080) for individual reports, noting the actual values, and the likelihood of occurrence.

4.1 Climate Hazards

There are a wide range of climate hazards that could affect natural resources and ecosystems, and after a review of the literature and discussions with Conservation Halton staff the following climate hazards have been identified for this risk assessment: Lake levels, high precipitation, low precipitation, high temperatures, low temperatures, seasonal changes, and winds. Within each of these climate hazards are a number of climate parameters as defined by the data portal www.climatedata.ca that can illustrate the direction and degree of change that is projected for future climate conditions vis-à-vis historical conditions. As we move forward in this climate risk assessment the historical baseline period will be 1981-2010, and future climate conditions will be for 2050 and 2080. Additional climate parameters are also provided to reflect the broad categories of Lake Levels and Seasonal Changes, since the manifestation of these hazards are complex and can impact natural resources and ecosystems in various ways. This includes, for example, freeze/thaw cycles and the number of icing days (that may affect lake ice cover), whereas other combinations of conditions, such as rain on snow, will require expert judgement and involve more qualitative information. In addition, cascading/compounding/cumulative effects will also be considered that can be captured as “scenarios” where a combination of otherwise discrete weather conditions can occur simultaneously or in sequence to generate impacts and effects where the outcomes are greater than the changes in the individual climate parameters.

4.2 Lake Levels

Although the overall Great Lakes watershed may experience both higher and lower water levels in the future due to climate change, along the regulated portions (e.g., including Lake Ontario) water levels have been less variable since the late 1950s and future conditions are projected to continue within the regulated range throughout this century. Within the regulated range involving high water levels there could be increases in the impacts along coastal areas in association with high wind gusts and/or storm surges.

Metric:

- Water levels for Lake Ontario compared to historical regulated and non-regulated levels, have been relative stable since the late 1950s compared to other lakes

- Lakes levels in 2019 were highest ever recorded, reaching 75.91 metres, compared to the historical average (1918-present) of 74.77 metres

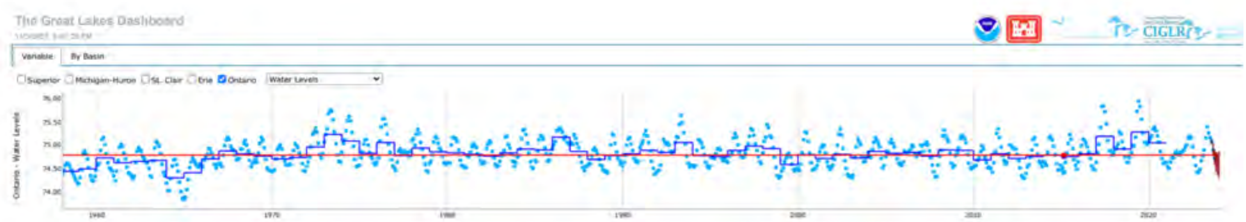


Figure 2 Lake Ontario water levels: 1958-2023

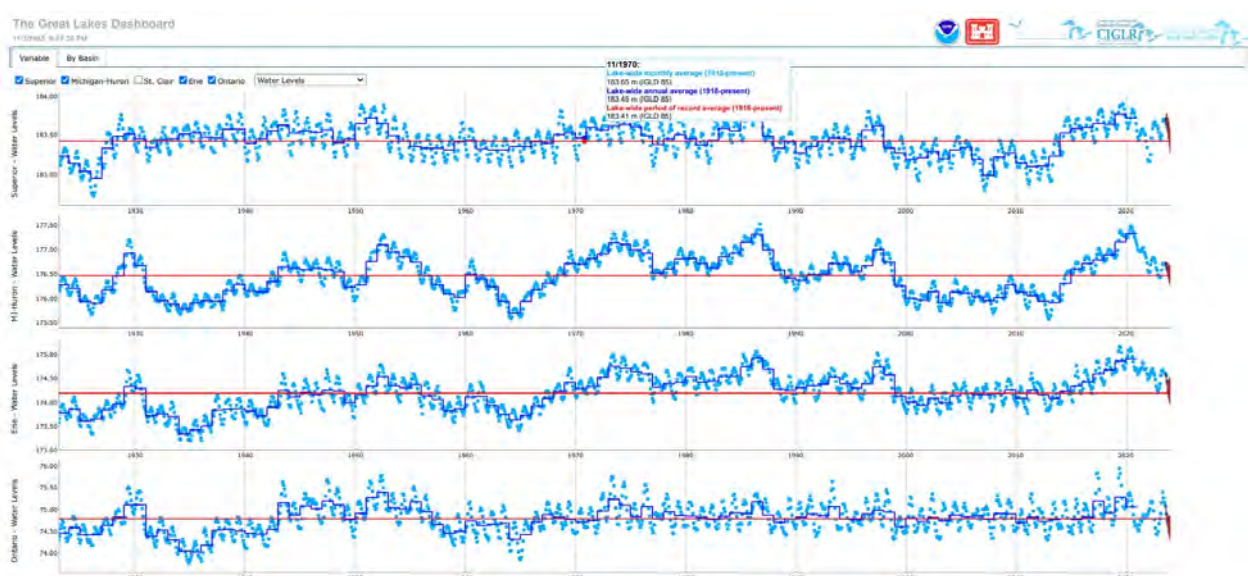


Figure 3 Lake Superior, Lakes Michigan-Huron, Lake Erie and Lake Ontario 1923-2023

Figure 4 Lake Ontario 2000 – 2023

- Light blue points: Lake-wide monthly average (1918-present) with 75.91 m highest on record, recorded in 6/2019
- Purple Line: Lake-wide annual average (1918-present) 75.26 m
- Red Line: Lake-wide period of record average (1918-present) 74.77 m
- 5/17 previous high 75.81 m

4.3 High Precipitation:

With warmer temperatures, annual levels of precipitation are expected to increase about 10% by the middle to end of this century. However, extreme conditions are also projected to increase in severity and frequency, resulting in rainfall events becoming more intense and occurring more often.

Metric:

- Annual precipitation (mm)
  - Describes the total amount of precipitation (rain and snow combined) that falls over a calendar year.
- Maximum 1-day precipitation (mm)
  - Describes the largest amount of precipitation (rain and snow combined) that falls within a 24-hour period over the course of a year.
- Maximum 5-day precipitation (mm)
  - Describes the largest amount of precipitation (rain and snow combined) to fall over 5 consecutive days.
- Number of Heavy Precipitation Days above 10 mm
  - Describes the number of days where at least 10 mm of precipitation (rain and snow combined) falls over 24 hours/single day.

- Number of Heavy Precipitation Days above 20 mm
    - Describes the number of days where at least 20 mm of precipitation (rain and snow combined) falls over 24 hours/single day.
- IDF Curves: Uncertainty boundaries and return periods
    - Western IDF Climate Change Tool

Using the IDF curves generated through the Western IDF Climate Change Tool, intense storm events defined as the historically based 10-year, 1-hour storm and the 100-year, 2-hour storm are projected to occur much more frequently by 2050 and 2080. These are the types of short duration high intensity storms that are known to cause severe overland flooding. We note that the latest version of the IDF CC tool (Version 7) generates IDF statistics that are less extreme than those provided through the climatedata.ca data portal, which are generated based on temperature scaling, following the Clausius-Clapeyron method.

For Aberfoyle Creek (Tab 6) the 10-year, 1-hour storm event based on the historical baseline is 41.67 mm. This type of storm event is projected to become a 6-year storm event by 2050, and a 5-year storm event by 2080.

Similarly, for the 100-year, 2-hour storm event for Aberfoyle Creek, the historical baseline is 71.42 mm. This type of storm event is projected to become a 35-year storm event by 2050 and a 30-year storm event by 2080.

Comparable changes in these storm events are projected for Burlington (Tab 7), where the historical baseline for the 10-year, 1-hour storm event is 42.13 mm, and is projected to become a 6-year event by 2050 and a 5-year event by 2080.

The historical 100-year, 2-hour storm event is 76.46 mm for Burlington and is projected to become a 35-year storm event by 2050 and a 30-year storm event by 2080.

Full IDF curve information is provided in the tables and graphs below.

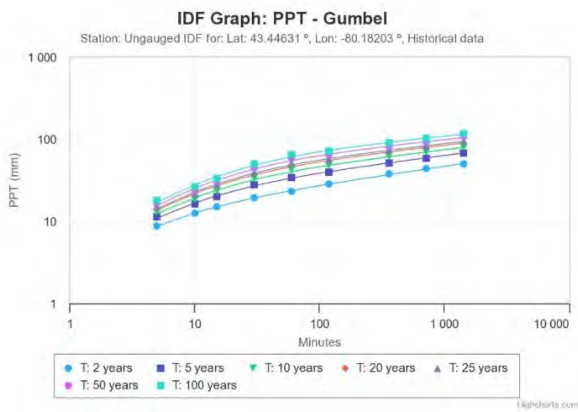
For Riverine flooding that occurs relatively frequently, the amount of rainfall for a 2-year storm, over a 12-hour and 24-hour period will also increase in total amount for both Aberfoyle Creek and Burlington.

In the case of Aberfoyle Creek, the historical baseline for the 2-year storm lasting 12 hours is 43.81 mm and is projected to increase to 49.99 mm by 2050 and 53.03 mm by 2080. The historical 2-year, 24-hour storm is 50.32 mm, and is projected to increase to 57.43 mm by 2050 and 60.91 mm by 2080.

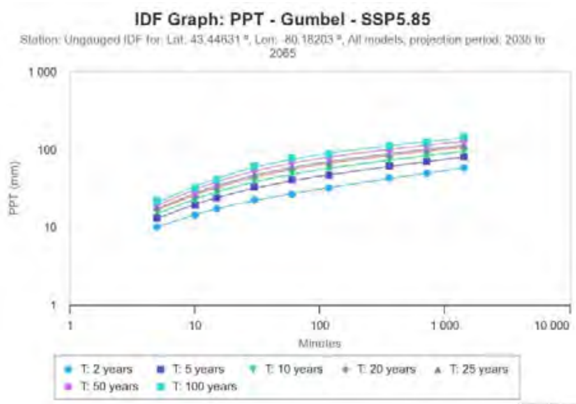
Similarly, in the case of Burlington, the historical baseline for the 2-year storm lasting 12 hours is 44.37 mm and is projected to increase to 50.93 mm mm by 2050 and 53.45 mm by 2080. The historical 2-year, 24-hour storm is 49.94 mm, and is projected to increase to 57.32 mm by 2050 and 60.16 mm by 2080.

Table 1 Heavy Precipitation Statistics for Burlington and Aberfoyle Creek, 2050 and 2080, high emissions scenario

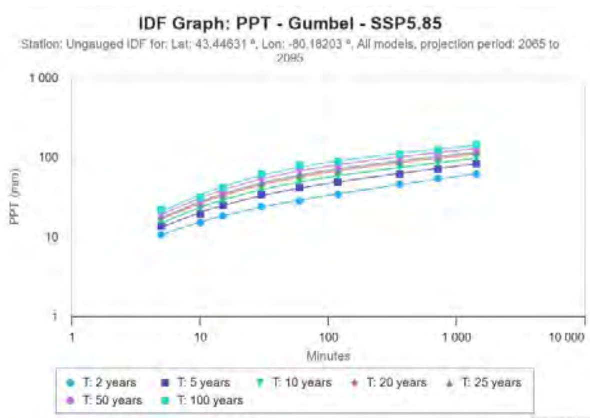
Climate Parameters		Climatedata.ca					
		Burlington			Aberfoyle Creek		
		Historical Baseline (1981-2010)	2050	2080	Historical Baseline (1981-2010)	2050	2080
Maximum Precip (e.g., # days > Xmm)	Maximum 1-day precipitation (mm)	34.54	37.62	40.25	38.3	43.39	46.84
	Maximum 5-day precipitation (mm)	64.33	72.16	77.13	65.87	73.1	78.8
Annual Precipitation	Total amount of precipitation (mm)	798.53	858.16	904.16	852.3	919	958.74
Heavy Precipitation	Heavy Precipitation Days (10 mm)	25.67	27.74	29.42	27.33	29.32	30.94
	Heavy Precipitation Days (20 mm)	6.53	7.97	9.52	6.53	8.19	9.52



T (years)	2	5	10	20	25	50	100
5 min	8.8	11.25	12.88	14.37	14.97	16.5	18
10 min	12.44	16.13	18.56	20.73	21.6	23.89	26.14
15 min	15.09	20.1	23.36	26.36	27.55	30.61	33.69
30 min	19.63	27.8	33.2	38.1	40.05	45.12	50.39
1 h	23.44	34.35	41.67	48.25	50.87	57.75	64.53
2 h	28.22	39.75	47.39	54.32	57.08	64.26	71.42
6 h	37.64	51.8	61.16	69.65	73.03	81.86	90.64
12 h	43.81	59.18	69.37	78.6	82.27	91.78	101.3
24 h	50.32	68.45	80.43	91.3	95.62	106.87	118.07

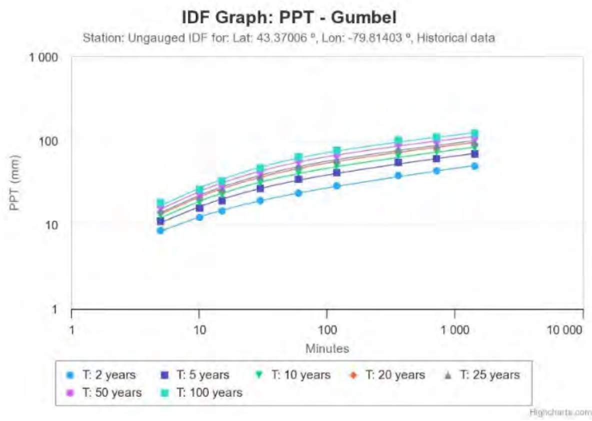


T (years)	2	5	10	20	25	50	100
5 min	10.04	13.22	15.35	17.3	18.06	20.06	22.02
10 min	14.19	18.96	22.12	24.95	26.06	29.04	31.97
15 min	17.22	23.62	27.83	31.72	33.25	37.21	41.2
30 min	22.41	32.67	39.56	45.85	48.33	54.85	61.62
1 h	26.75	40.37	49.65	58.07	61.38	70.2	78.9
2 h	32.21	46.71	56.47	65.37	68.88	78.12	87.33
6 h	42.96	60.88	72.88	83.83	88.13	99.51	110.83
12 h	49.99	69.55	82.66	94.59	99.28	111.57	123.87
24 h	57.43	80.45	95.83	109.88	115.39	129.91	144.37

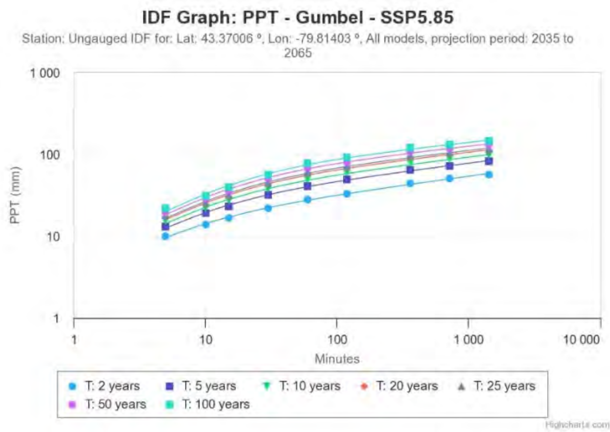


T (years)	2	5	10	20	25	50	100
5 min	10.65	13.52	15.46	17.36	18.1	19.96	21.77
10 min	15.05	19.39	22.28	25.04	26.13	28.9	31.61
15 min	18.26	24.15	28.04	31.83	33.33	37.04	40.74
30 min	23.77	33.4	39.85	46.01	48.44	54.6	60.94
1 h	28.37	41.27	50.02	58.27	61.53	69.87	78.03
2 h	34.16	47.76	56.89	65.6	69.04	77.75	86.37
6 h	45.56	62.24	73.41	84.12	88.34	99.05	109.6
12 h	53.03	71.1	83.27	94.92	99.51	111.05	122.49
24 h	60.91	82.25	96.54	110.26	115.67	129.3	142.77

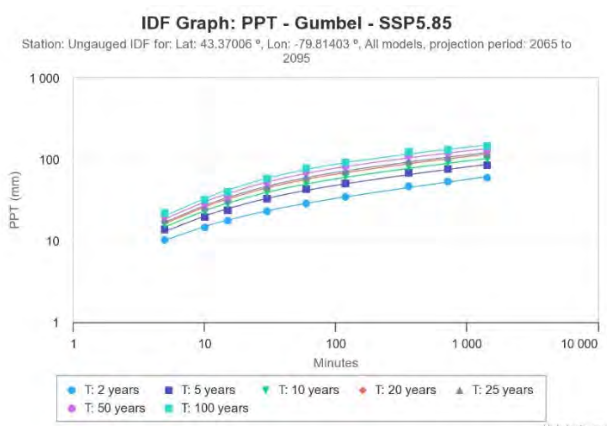
Figure 5 and Table 2 Aberfoyle Creek: IDF Graph Total Precipitation Gumbel Distribution for Historical, and Projections for SSP5.85 for 2050 and 2080



T (years)	2	5	10	20	25	50	100
5 min	8.64	11.2	12.92	14.48	15.1	16.74	18.35
10 min	12.21	15.99	18.49	20.75	21.65	24.03	26.39
15 min	14.72	19.6	22.81	25.74	26.9	29.92	32.95
30 min	19.35	26.86	31.87	36.46	38.29	43.07	47.92
1 h	24.17	34.91	42.13	48.71	51.33	58.22	65.05
2 h	29.08	41.64	50.02	57.62	60.65	68.57	76.46
6 h	38.41	55.36	66.65	76.95	81.04	91.76	102.45
12 h	44.37	61.88	73.52	84.04	88.22	99.15	110.01
24 h	49.94	69.09	81.83	93.35	97.94	109.88	121.76



T (years)	2	5	10	20	25	50	100
5 min	9.92	13.25	15.25	17.16	17.92	19.92	21.9
10 min	14.01	18.92	21.83	24.6	25.69	28.6	31.49
15 min	16.9	23.19	26.92	30.51	31.92	35.61	39.32
30 min	22.21	31.77	37.62	43.22	45.43	51.26	57.18
1 h	27.74	41.29	49.72	57.73	60.91	69.3	77.62
2 h	33.38	49.26	59.03	68.3	71.96	81.61	91.24
6 h	44.09	65.49	78.67	91.2	96.16	109.22	122.24
12 h	50.93	73.21	86.78	99.61	104.69	118.01	131.27
24 h	57.32	81.74	96.58	110.64	116.21	130.78	145.29



T (years)	2	5	10	20	25	50	100
5 min	10.41	13.71	15.78	17.53	18.24	20.14	22.1
10 min	14.71	19.58	22.58	25.12	26.15	28.92	31.78
15 min	17.74	23.99	27.86	31.15	32.48	36	39.68
30 min	23.31	32.87	38.92	44.13	46.23	51.83	57.72
1 h	29.12	42.73	51.45	58.96	61.98	70.06	78.34
2 h	35.04	50.96	61.08	69.75	73.23	82.51	92.09
6 h	46.27	67.76	81.4	93.13	97.85	110.43	123.38
12 h	53.45	75.74	89.79	101.72	106.53	119.32	132.49
24 h	60.16	84.57	99.93	112.99	118.25	132.23	146.64

Figure 6 and Table 3 Burlington: IDF Graph Total Precipitation Gumbel Distribution for Historical, and Projections for SSP5.85 for 2050 and 2080

4.4 Low Precipitation:

Along with an increase in more extreme precipitation events, drought conditions are projected to last longer and occur more frequently. This is projected to result in more days where no rainfall or trace amounts (less than 1 mm) will occur. We note that the metrics for low precipitation does not necessarily translate directly to reflect drought risk, noting that seasonal rainfall, temperature, and water balance can have a significant impact on ecosystems. Even if low precipitation does not significantly change over time, changes in seasonal climate conditions, and increasing temperatures are likely to support drought conditions.

Metrics:

- Maximum number of consecutive dry days
    - Describes the longest spell of dray days where less than 1 mm of precipitation falls daily
- Number of periods with more than 5 consecutive dry days
    - Describes the number of times when daily precipitation totals are less than 1 mm a day for six or more days straight

Table 4 Low precipitation for Burlington and Aberfoyle Creek, 2050 and 2080

Climate Parameters		Climatedata.ca					
		Burlington			Aberfoyle Creek		
		Historical Baseline (1981-2010)	2050	2080	Historical Baseline (1981-2010)	2050	2080
Low Precipitation	Maximum Number of Consecutive Dry Days	15.9	15.71	16.45	14.47	14.39	15.35
	Number of Periods with more than 5 Consecutive Dry Days	13.9	13.39	13.74	12.27	11.84	12.1

4.5 High Temperatures

While global mean temperatures are projected to increase another 1-3 degrees Celsius by the middle and end of this century, on a regional scale temperature increases will be more significant. Generally, warming in winter will be greater than in the summer, while increases for nighttime temperatures will be greater than daytime increases. The maximum temperatures are projected to increase, with hot days occurring more frequently, and lead to longer and more frequent heat waves. Beginning with mean, minimum and maximum temperatures, Burlington is warmer than Aberfoyle, and in all cases the annual average temperatures increase by 2050 and 2080 compared to the historical baseline of 1981-2010.

Metrics:

- Mean Temperature
  - Describes the average temperature for the 24-hour day
- Minimum temperature
  - Describes the coldest temperature of the 24-hour day, which typically occurs at night
- Maximum Temperature
  - Describes the warmest temperature of the 24-hour day, which typically occurs during the day
- Number of days >30°C
  - Describes the number of days where the daytime high temperature is warmer than 30°C
- Number of days with Humidex >30°C
  - Describes the number of days when the Humidex is greater than 30.
- Number of days with Humidex >40°C
  - Describes the number of days when the Humidex is greater than 40.
- Number of heat waves (defined as two consecutive days with Tmax >31°C and Tmin >20°C)
  - Describes the number of two consecutive days when the daytime maximum temperature exceeds 31°C and the night time minimum is greater than 20°C
- Hottest day
  - Describes the warmest daytime temperature recorded over the year

Table 5 High temperatures for Burlington and Aberfoyle Creek, 2050 and 2080

Climate Parameters		Climatedata.ca					
		Burlington			Aberfoyle Creek		
		Historical Baseline (1981-2010)	2050	2080	Historical Baseline (1981-2010)	2050	2080
Mean Temperature		8.8	12.02	14.39	7.31	10.55	12.92
Minimum Temperature		4.2	7.45	9.83	2.33	5.62	7.98
Maximum Temperature		13.42	16.6	18.93	12.3	15.5	17.84
Number of days >30°C	Number of days >30°C	54.5	92.39	118.48	10.2	38.03	70.65
	Number of heat waves	0.83	4.74	7.32	0	2.68	6.29
	Average Length of Heat Waves						
	# Days with Humidex > 30°C	54.5	92.39	118.48	47.03	86.84	115.32
	# Days with Humidex > 40°C	0.87	12.61	38.97	0.43	8.9	30.65
	Hottest Day	34.54	37.62	40.25	33.14	36.25	38.91

We note that temperature projections have a wide range of uncertainty across the ensemble of models, that extends beyond GHG emission scenarios.

Table 6 High temperatures and uncertainty for Aberfoyle Creek

Temperature: Days with Tmax > 30°C							
Aberfoyle Creek							
Time Period	Emissions Scenario				Percentiles High Emissions		
	Low	Medium	High		High SSP5-8.5		
	SSP1-2.6	SSP2-4.5	SSP5-8.5		Low	Median	High
Historical	10.2				10.2		
2050	27.16	32.81	**38.03**		19.71	**38.03**	68.74
2080	29.71	43.77	**70.65**		44.26	**70.65**	105.68

4.6 Low Temperatures:

Minimum temperatures are projected to increase (e.g., become less cold), while a decrease in frequency and duration (e.g., fewer cold spells, lasting shorter periods) of cold temperatures are projected to occur by the middle through end of this century. However, in contrast changes in the intensity of the Polar Vortex could bring extreme cold temperatures to the region, but the long term trends associated with this atmospheric phenomena is uncertain.

Metrics:

- Number of days <-15°C
    - Describes the number of days where the lowest temperature of the day is colder than – 15°C, giving an indication of the number of very cold days over the winter season.

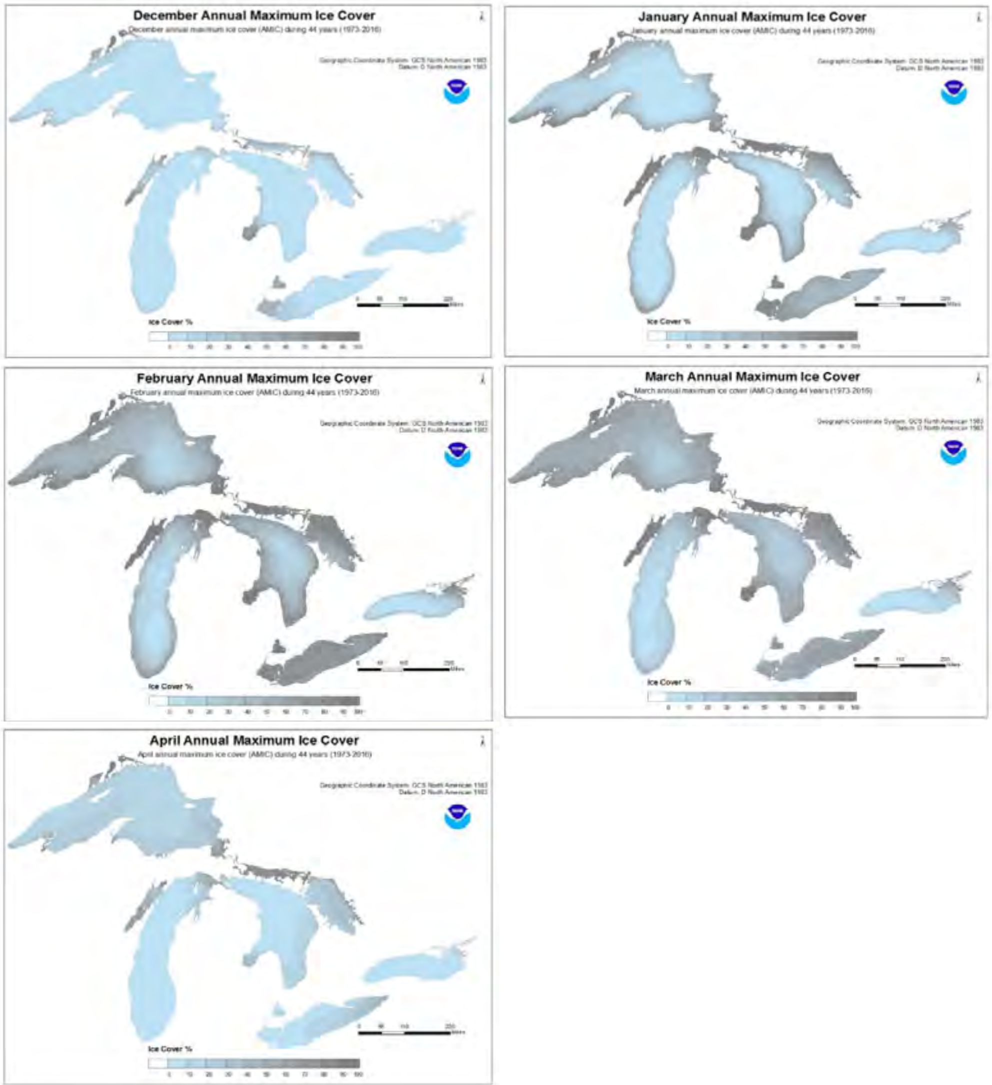
Table 7 Low temperatures, number of days < - 15°C for Burlington and Aberfoyle Creek

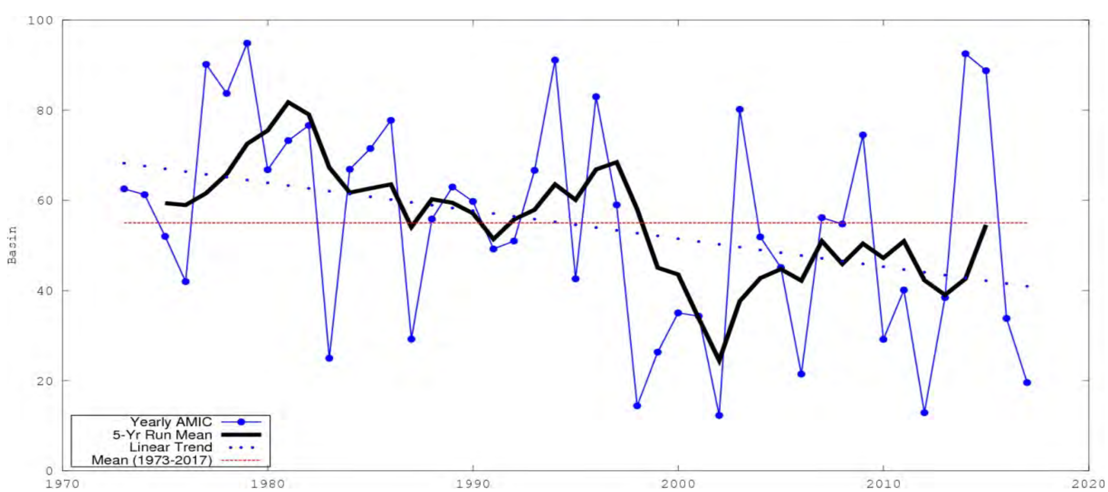
Climate Parameters		Climatedata.ca					
		Burlington			Aberfoyle Creek		
		Historical Baseline (1981-2010)	2050	2080	Historical Baseline (1981-2010)	2050	2080
Number of days <-15°C	Winter days <-15°C	9.23	0.39	0	18.73	2.71	0.03

4.7 Lake Ice Cover

Generally ice cover across the Great Lakes Basin varies from year to year, and the extent is also variable for any given year. Lake Ontario tends to have the least ice cover of all the Great lakes due to its extreme depth and relatively small surface area for heat loss, in addition to the moderating effects by the waters of Lakes Superior, Michigan and Huron of cold air masses from the northwest and west. From 1973-2018 annual maximum ice cover has varied from 1.9% in 2012 to 86.2% in 1979. Maximum ice cover typically occurring between mid-February and early March, and first occurs near or along the shoreline.

A 2018 study found a downward trend in ice cover over 44 years, where average ice cover on the Great Lakes declined 69 percent between 1973-2017. While anthropogenic warming has played a role in this decades-long decline, a larger factor has been the natural patterns of climate variability over the Pacific and Atlantic oceans: the North Atlantic Oscillation, the Atlantic Multidecadal Oscillation, the Pacific Decadal Oscillation, and the El Niño-Southern Oscillation.





Figures 7a and 7b Time Series of Annual Mean Ice Cover for the Great Lakes Averaged from December 1 to April 30, 1973-2017

This decline has also been reflected in annual mean and maximum ice cover for Lake Ontario.

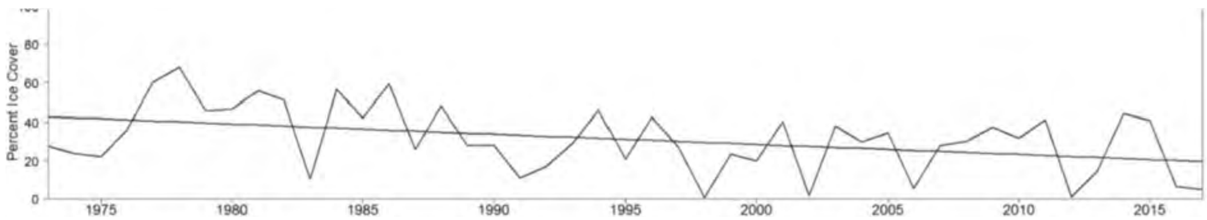


Figure 8 Annual Mean Ice Cover over Lake Ontario, 1973-2017

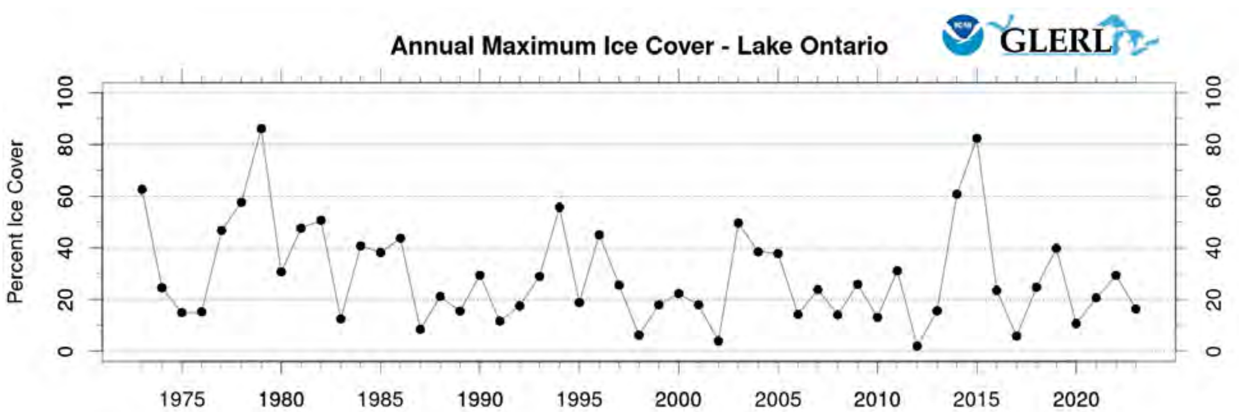


Figure 9 Annual Maximum Ice Cover – Lake Ontario (1973-2023)

There is no projection of Lake Ice Cover provided in the climatedata.ca portal, but the Burlington Climate Projections (2021) report that drew upon the climateatlas.ca portal indicated that "heavy ice seasons will no longer occur as early as the 2050s with very light ice seasons going from 10 percent in the baseline period (1981-2010) to 100 percent by the 2080s under a high emissions RCP8.5 scenario.

A combination of stable water levels, less ice cover, and higher wind gusts and storm surges will increase the likelihood of coastal erosion, but the exact extent of that increase is highly uncertain.

4.8 Seasonal Changes:

There are various climate parameters that can be used to illustrate changes in seasonal precipitation and temperature. This may involve the extension of winter or summer seasons, restrictions in shoulder seasons, or some combination of climate parameters that come together to generate seasonally unique hazards (e.g., ice jams along rivers). Some of these are relatively straightforward, such as the total number of growing degree days (with a base of 5°C), but in other cases it reflects changes in multiple climate parameters that result in complex outcomes (e.g., more snowmelt, rain on snow, leading to high spring freshette; warmer winter temperatures, allowing ticks to survive the winter, emerge earlier and stick around longer). As a result projections of seasonal changes tend to be based on expert judgement and involve qualitative information and outcomes, and may be addressed as complex “scenarios”. Freeze-thaw cycles are projected to decrease over time, especially during the shoulder months, and may even increase by 2050 for January and/or February.

Metrics:

- Growing Degree Days above 5°C
    - Describes the days when climate conditions are warm enough to support plant and insect growth, when the daily average temperature is warmer than 5°C, growing degree days are accumulated.
- Freeze/Thaw Cycles
    - This is a simple count of the days when the air temperature fluctuates between freezing and non-freezing temperatures on the same day. A freeze-thaw cycle occurs when the daily maximum temperature (Tmax) is higher than 0°C and the daily minimum temperature (Tmin) is less than or equal to -1°C.
- Number of Icing Days when the maximum temperature is at or below 0°C

Table 8 Seasonal Changes for Select Climate Parameters, for Burlington and Aberfoyle Creek, 2050 and 2080

Climate Parameters		Climatedata.ca					
		Burlington			Aberfoyle Creek		
		Historical Baseline (1981-2010)	2050	2080	Historical Baseline (1981-2010)	2050	2080
Frost free days	Frost-free season: The approximate length of the growing season (from thje last spring frost to the first fall frost), during which there are no freezing temperatures to kill or damage plants	188.2	218.58	246.52	158.4	191.19	216.84
Growing degree days (Base 5°C)		2382.3	3090.97	3738.48	2124.27	2786.16	3329.29
Freeze/thaw cycles	Number of days when the air temperature fluctuates between freezing and non-freezing temperatures	63	47.55	31.94	69.7	59.81	49.55
# Ice Days	Icing Days: A day when the maximum temperature is at or below 0°C	46.1	17.52	4.68	64.97	33.55	14.29

4.9 Seasonal Precipitation and Temperature

There is much uncertainty regarding the amount of snowfall that is projected to occur during the winter months, since this type of weather is dependent upon temperature and precipitation. Using Aberfoyle Creek to illustrate seasonal changes, the winter season precipitation has been stable (or minor increases) since 1981, with snowfall declining and rainfall increasing. Other studies have noted shorter snow seasons, uncertain changes in the frequency of snowfall events, and likely less snowfall overall, but higher amounts during heavy snowfall events.

There is higher confidence and certainty in the individual climate parameters that determine snowfall, specifically the seasonal precipitation amount (snowfall and rainfall), and warming temperatures as reflected by the average minimum winter season temperature and the number of days above 0°C. In combination, precipitation events are likely to fall more as rain than snow, there will be more rain on snow events, and for the short- and medium term (2050) likely an increase in freezing rain events in the medium-term future due to greater influence of increasing precipitation vis-à-vis increases in temperatures.

The winter season precipitation is projected to increase from the modelled historical baseline of 191.46 mm (1981-2010) to 215.43 mm by 2050 and 242.14 mm by 2080. The average minimum temperature during the winter season is projected to increase from the modelled historical baseline of -8.87°C (1981-2010) to -4.35°C by 2050 and -1.67°C by 2080. Increases in the temperature conditions that support precipitation falling as rain rather than snow is more clearly reflected in the number of days during the winter season when the minimum temperature is above 0°C. These days are projected to rise from the modelled historical baseline of 4.63 days to 17.23 days by 2050 and 32.13 days by 2080.

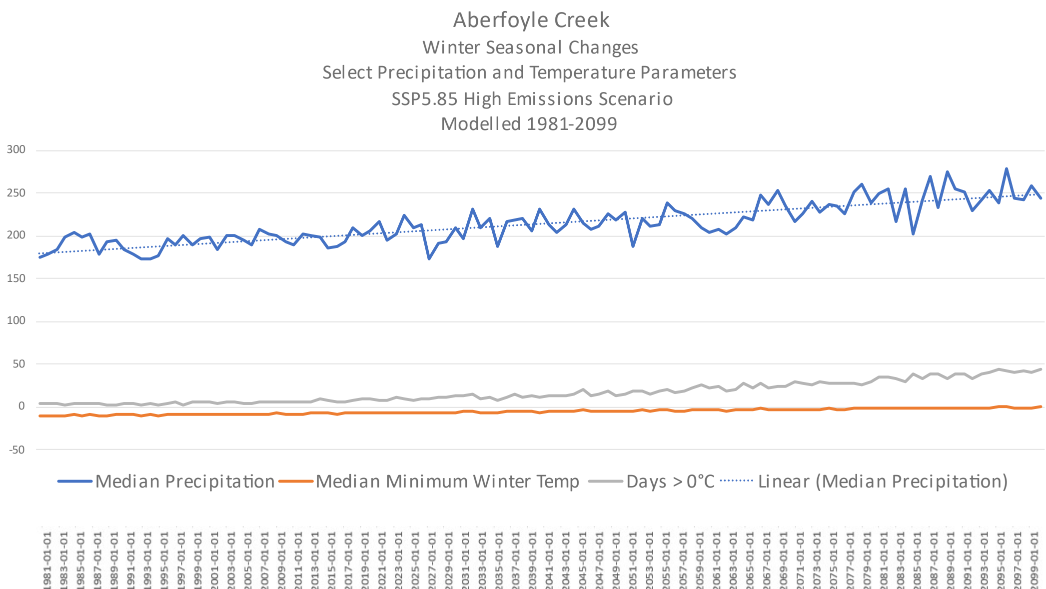


Figure 10 Winter Season Precipitation and Temperature, Aberfoyle Creek modelled 1981-2099, high emissions scenario

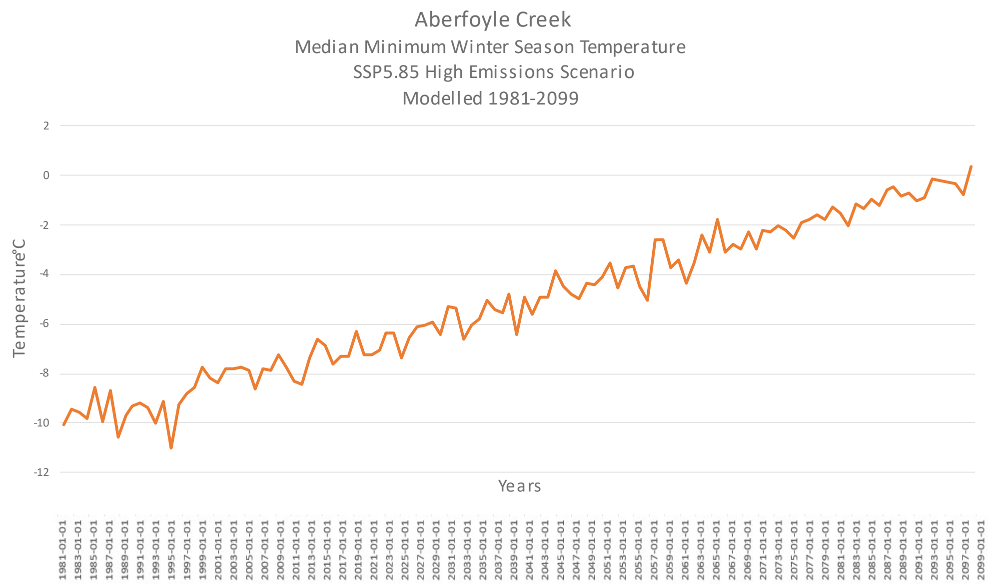


Figure 11 Median Minimum Winter Season Temperature, Aberfoyle Creek, modelled 1981-2099, high emissions scenario

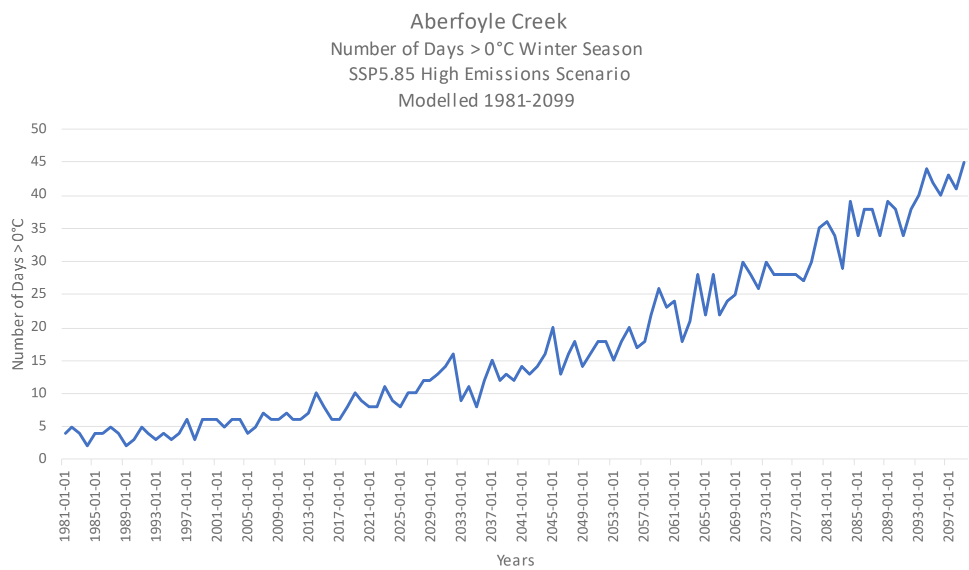


Figure 12 Number of Days > 0°C during the Winter Season, Aberfoyle Creek, modelled 1981-2099, high emissions scenario

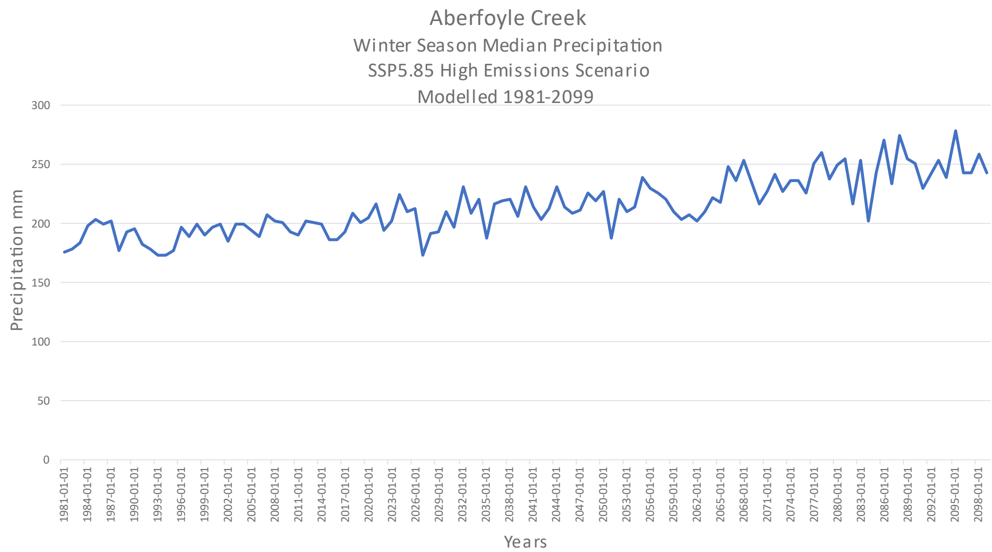


Figure 13 Winter Season Median Precipitation in mm, Aberfoyle Creek, modelled 1981-2099, high emissions scenario

4.10 Winds:

The science is quite uncertain regarding projected changes in average wind speeds and wind gusts.

- Average wind speeds
- Changes in wind gusts above a specific threshold, e.g. >70 km/hour

According to the Burlington Projections Report (2021), the climateatlas.ca projects an increase of 14% in daily wind gusts for Burlington from 2046 – 2065, increasing to 22% by 2081-2100. Hourly wind gusts are projected to increase as well, by 17% by 2046-2065 and 19% by 2081-2100. Other studies, with less confidence, have projected increases in tornadoes, increasing high wind gusts of 70 km/hr or more, and the need to plan for more extreme wind events.

5 LIKELIHOOD CRITERIA

There are various criteria used in the literature to define likelihood. In the Intergovernmental Panel on Climate Change (IPCC) process and PIEVC studies, a seven-point likelihood scale is adopted, but these are rarely referenced in local and regional studies, with the exception of the Regional Municipality of Peel. We also note that in most, if not all, municipal-based climate adaptation plans and strategies that adopt the International Council for Local Environmental Initiatives (ICLEI) Building Adaptive and Resilient Cities (BARC) method, likelihood scores are only indirectly revealed through the vulnerability scoring exercise. We found no studies that followed the ICELI BARC method included likelihood scores that were explicated stated. Consequently, it is left to the reader to directly infer the changes in likelihood for each climate hazard, based on the historical baseline record and the data provided for future climate projections.

ICLEI BARC studies typically follow a five-point rating scale, ranging from rare (1) to almost certain (5) (Table 9).

Table 9 Likelihood Criteria and Scoring Recommended by International Council of Local Environmental Initiatives Building Adaptive and Resilient Cities

Likelihood Rating	Recurrent Impact
Almost Certain (5)	Could occur several times per year
Likely (4)	May arise about once per year
Possible (3)	May arise once in 10 years May arise once in 5 years
Unlikely (2)	May arise once in 10 years to 25 years May arise once in 5 years to 10 years
Rare (1)	Unlikely during the next 10+ years Unlikely during the next 25 years

The exception are PIEVC studies where likelihood is a key component of the assessment reporting process, and both historical baseline and future probabilities are typically included in their published reports. However, their scoring criteria is not without flaws, as it is skewed toward the lower probability categories (40% and below) and underestimates differences between higher probabilities (70% and above; Table 10).

A variation of the ICLEI BARC method is also recommended in the federal Climate Lens Guidance, with differing terms for likelihood rating (e.g., very low to very high) and different time periods for probability (e.g., not likely to will become critical within several years). We note that the probability metric categories vary slightly between municipalities for three of the five categories (as noted above). However, last year Infrastructure Canada commissioned the creation of a climate risk screening guide, based on the original PIEVC Protocol, to be used in future climate risk assessments for new public infrastructure projects required under the Climate Lens Guidance process. The PIEVIC High Level Screening Guide (HLSG) is being promoted as the de facto approach to assess the physical climate risks to public infrastructure, as well as the comparable PIEVC Green Protocol that is being promoted for application to natural resources and ecosystems. The need for a new approach reflected the need to simplify and clarify the risk assessment methodology used in the original PIEVC Protocol and included a revamp of the likelihood criteria. The new and improved scoring method is described as being appropriate for a screening level assessment, which has applicability to this climate vulnerability and risk assessment, given the focus and consideration of natural resources and ecosystems.

Table 10 Public Infrastructure Engineering Vulnerability Committee Likelihood Criteria

PIEVC Probability Scoring Methods		
Score	Method A	Method B (years)
0	Negligible Not Applicable	<0.1% <1 in 1,000
1	Highly Unlikely Improbably	1% 1 in 100
2	Remotely Possible	5% 1 in 20
3	Possible Occasional	10% 1 in 10
4	Somewhat Likely Normal	20% 1 in 5
5	Likely Frequent	40% 1 in 2.5
6	Probably Often	70% 1 in 1.4
7	Highly Probably	>99%

The alternative approach is outlined in the PIEVC HLSG that was released early in 2022. The approach assigns the likelihood to hazard indicators relative to the baseline conditions in the historical period, with the mean conditions projected in the future. The emphasis is on the change in future risk relative to past conditions, rather than calculating probability based on a somewhat arbitrary scale. A five-point scale is also adopted, but the degree of change (and significance in likelihood) is grounded in the current climate baseline, with likelihood scores related to changes from the baseline value (Table 11). For example, any change in future conditions that fall within ±10% of the baseline mean is scored a 3. In cases where likelihood is projected to experience a noticeable change is scored a 2 or a 4 where a 10% to 50% reduction in frequency or intensity relative to the baseline mean occurs, or an increase in frequency or intensity of 10% to 50%, respectively. Similarly, any significant changes will be reflected in likelihood scores of 1 or 5, where there will be a reduction or increase in the frequency or intensity relative to the baseline mean of 50% to 100%. From the perspective of operation planning and asset management, this approach may be more effective in communicating changes in likelihood given that asset owners and operators tend to be influenced by climate conditions and impacts that have occurred most recently.

Table 11 Simplified Middle Baseline Likelihood Scoring Approach in the Public Infrastructure Engineering Vulnerability Committee High Level Screening Guide

PIEVC HLSG Probability Scoring			
Likelihood	**Middle Baseline Approach**	**Method**	**Suggested Rational**
1	↑	Likely to occur less frequently than current climate	50% to 100% reduction in frequency or intensity with reference to baseline mean
2			10% to 50% reduction in frequency or intensity with reference to baseline mean
3	Establish Current Climate Baseline Per Parameter	Likely to occur as frequently as current climate	Baseline mean conditions or a change in frequency or intensity of ±10% with reference to the baseline mean
4			10% to 50% increase in frequency or intensity with reference to baseline mean
5	↓	Likely to occur more frequently than current climate	50% to 100% increase in frequency or intensity with reference to baseline mean

6 LIKELIHOOD SCORES

Applying the likelihood scoring method outlined in the PIEVC HLSG to the science-based climate projections that can be distilled down to 6 climate hazards, the following likelihood scores apply for the City of Burlington and Aberfoyle Creek/Mountsberg Conservation Area reflecting the areas below and above the Niagara Escarpment respectively, for 2050 and 2080.

Table 12 Likelihood Scorings for the 2050s and 2080s by Climate Hazard Type

Scenarios	Description	Burlington		Aberfoyle Creek/ Mountsberg Conservation Area	
		2050	2080	2050	2080
Dry Conditions	Dry conditions will be caused by increased temperatures and changes in precipitation patterns. Both average temperature and number of days above 30 degrees increase significantly. Annual precipitation increases, with rainfall or snow events becoming more frequent and intense, while dry periods may similarly increase. In addition, increases in evapotranspiration will result in drier conditions. Seasonal reductions in infiltration will affect headwater streams.	4	4	4	4
Rainfall/Riverine Flooding	Increase in rainfall intensities of both short duration, high frequency storms and less frequent large storms. Likely in increase in bank full,1-year flows that cause stream erosion. Increase in larger events that cause floodplain inundation.	4	4	4	4
Heat Stress	Increase in average temperatures and humidex levels, whereby hot days will cause heat stress in people, flora and fauna. Stream temperatures will increase, especially during low water conditions.	5	5	5	5
Seasonal Changes	Changes in multiple climate parameters cause complex changes in the watersheds. These include, but are not limited to, shorter shoulder seasons, increase in growing days, earlier spring freshette. Overall, seasonal changes will be reflected by a warmer winter, hotter summer and shorter shoulder seasons, along with greater climate variability. Impacts may include conditions that are more hospitable to invasive species while adversely affecting native species at risk.	4	4-5	4	4-5
Snowpack Reduction	An increase in winter temperatures will lead to less snowfall, more snowmelt and an increase in rain on snow events.	4	5	4	5
Wind	An expected increase on average wind speeds and wind gusts. Coupled with longer periods of exposed water due to less lake ice, and possible higher lake levels may cause an increase in shoreline erosion.	4	4	4	4

For the purposes of the upcoming risk assessment of existing infrastructure assets, the likelihood scores for the 2080s will be adopted. This is based on the assumption that existing or legacy infrastructure assets will have remaining lifecycle expectancies up to another 30 to 60 years depending upon their age and condition, while likelihood scores for 2080s should be considered in cases where new infrastructure is being planned or proposed, where lifecycle expectancy will also extend for another 30 to 60 years, or beyond. We note that likelihood scores are consistent for most climate hazards for 2050 and 2080, although they differ slightly for hazards that are either more rare or difficult to project changes (e.g., snow, freezing rain, and acute weather events).

Appendix A: Climate Data Summary, from Tab 3

Climate Hazards	Climate Parameters		Climatedata.ca					
			Burlington			Aberfoyle Creek		
			Historical Baseline (1981-2010)	2050	2080	Historical Baseline (1981-2010)	2050	2080
				CMIP6			CMIP6	
High Precipitation	Maximum Precip (e.g., # days > Xmm)	Maximum 1-day precipitation (mm)	34.54	37.62	40.25	38.3	43.39	46.84
		Maximum 5-day precipitation (mm)	64.33	72.16	77.13	65.87	73.1	78.8
	Annual Precipitation	Total amount of precipitation (mm)	798.53	858.16	904.16	852.3	919	958.74
	IDF Curves	IDF Curves						
		Heavy Precipitation Days (10 mm)	25.67	27.74	29.42	27.33	29.32	30.94
		Heavy Precipitation Days (20 mm)	6.53	7.97	9.52	6.53	8.19	9.52
Low Precipitation		Maximum Number of Consecutive Dry Days	15.9	15.71	16.45	14.47	14.39	15.35
		Number of Periods with more than 5 Consecutive Dry Days	13.9	13.39	13.74	12.27	11.84	12.1
High Temperatures	Mean Temperature		8.8	12.02	14.39	7.31	10.55	12.92
	Minimum Temperature		4.2	7.45	9.83	2.33	5.62	7.98
	Maximum Temperature		13.42	16.6	18.93	12.3	15.5	17.84
	Number of days >30°C	Number of days >30°C	54.5	92.39	118.48	10.2	38.03	70.65
		Number of heat waves	0.83	4.74	7.32	0	2.68	6.29
		Average Length of Heat Waves						
		# Days with Humidex > 30°C	54.5	92.39	118.48	47.03	86.84	115.32
		# Days with Humidex > 40°C	0.87	12.61	38.97	0.43	8.9	30.65
		Hottest Day	34.54	37.62	40.25	33.14	36.25	38.91
Low Temperatures	Frost free days	Frost-free season: The approximate length of the growing season (from thje last spring frost to the first fall frost), during which there are no freezing temperatures to kill or damage plants	188.2	218.58	246.52	158.4	191.19	216.84
	Number of days <-15°C	Winter days <-15°C	9.23	0.39	0	18.73	2.71	0.03
Seasonal Changes	Growing degree days (Base 5°C)		2382.3	3090.97	3738.48	2124.27	2786.16	3329.29
	# Ice Days		46.1	17.52	4.68	64.97	33.55	14.29
	Freeze/thaw cycles	Number of days when the air temperature fluctuates between freezing and non-freezing temperatures	63	47.55	31.94	69.7	59.81	49.55
		Icing Days: A day when the maximum temperature is at or below 0°C	46.1	17.52	4.68	64.97	33.55	14.29

Appendix D
Consequences of Climate Hazards – Report Detail

Appendix D
Consequences of Climate Hazards – Report Detail

1 Human Health and Property Consequences

The impact to human health and property in Conservation Halton's watersheds was evaluated considering people's mental, physical, and emotional well-being and any property damage.

1.1 Forests

Forests are one of the more abundant natural resources throughout Conservation Halton's watersheds and are frequently exposed to human activity through parks and conservation areas. Through the risk assessment, heat stress was found to have significant impact on forests as it relates to human health and property, with a risk rating of 20 ("very high") through 2050. Heat stress creates more potential of forest fires and tree drying, which may lead to tree mortality and tree falling. Forest fires pose an obvious risk to physical human well-being with increased exposure to fire hazards, and tree falling creates potential for physical injuries of people using the parks and conservation areas. Both forest fires and tree falling would reduce the ability of people to access natural areas, which can negatively impact the mental and emotional well-being of residents within the watershed.

Through 2080, the risk ratings for snowpack reduction and seasonal changes increased from 2050 and were screened through the risk assessment. Seasonal changes cause the summer months to be longer, which can increase tree drying and mortality, causing potential property damage and physical hazards of falling trees. Snowpack reduction increases exposure of the forest floor, which increased the risk from 2050 to 2080.

1.2 Groundwater

Groundwater sources provide domestic water for one in eight Halton Region residents (Halton Region Groundwater, accessed 2023), a jurisdiction that is a large majority of Conservation Halton's watershed. The other regional municipalities within the watershed are largely rural-residential and also likely supplied by groundwater. The risk assessment found that groundwater is at risk to dry conditions, heat stress, and seasonal changes as they relate to human health and property. Each of these climate hazards may lead to less recharge for groundwater wells, either by increasing risk of drying out wells, reducing the infiltration by increased evapotranspiration, or increasing variability in wells drying out. All of the climate hazards reduce groundwater recharge and therefore decrease available water supply, which can cause significant mental, emotional and physical distress for those affected. It is for these reasons that the groundwater interaction with dry conditions, heat stress, and seasonal changes were ranked 16-20 (“high” and “very high”) for 2050 and 2080.

Through 2080, the risk ratings for snowpack reduction and seasonal changes increased from 2050 and were screened through for groundwater as they relate to human health and property. Longer summers and shorter shoulder seasons increase potential for less groundwater recharge and snowpack reduction increases risk to drying wells and less recharge. Both climate hazards increase the risk discussed above of distress due to lack of domestic water supply.

1.3 Lakeshore

Conservation Halton’s lakeshore, present in the urban creek watersheds (Burlington Urban Creeks, Oakville East and West Creeks, North Shore and North Cootes Paradise), is within a heavily populated area and exposed to frequent human activity. The risk assessment found that the lakeshore is at risk of heat stress, rainfall, and wind as they relate to human health and property. All of these climate hazards increase the risk and ability of people accessing the lakeshore, whether its due to increased precipitation, decreased water levels, or increased wave and wind. These hazards may increase the risk of people tripping or falling due to precipitation, waves or wind, and increase the amount of beach closures. Heat stress can also increase the algae and algal blooms along the lakeshore, and the potential for blue-green algae, which are toxic and warrant lakeshore closures in certain conditions. Increased wind along the lakeshore results in shoreline erosion potential, which is an additional safety hazard to human health. Rainfall along the lakeshore may increase flooding of shoreline properties, which is a risk to property as well as human physical health. Generally, these climate hazards all result in lack of access to the lakeshore areas, which can have an impact on mental and emotional well-being of visitors.

Through 2080, the risk ratings for snowpack reduction and seasonal changes increased from 2050 and were screened through for lakeshore as they relate to human health and property. The impacts of both climate hazards are similar to the risk outlined for 2050, being changing lake levels that may increase flooding along the lakeshore, resulting in potential property damage and reduced access to the shoreline.

1.4 Meadow

For climate hazards through 2050, meadows were not identified as high risk as it relates to human health and property. However, the likelihood of seasonal changes and snowpack reduction for 2080 increased the risk rating and were screened through. Seasonal changes and snowpack reduction both caused increase exposure of meadows by shorter winter months and decreased snow coverage. This cause increased tick populations and a longer tick season, which poses a risk to human health as peoples access or live adjacent to meadow features.

1.5 Pond/Lake

Ponds and lakes of varying sizes are scattered throughout Conservation Halton's watershed, located often within conservation areas or parks with exposure to human activity. Through the risk assessment, ponds and lakes were identified as being at risk to heat stress as it relates to human health and safety. Heat stress on ponds can cause an increase in sediment and nutrient concentrations, as well as increased algae and algal blooms. An increase of these parameters reduces the aesthetic appeal of the ponds/lakes, which can lead to decreased amounts of people accessing these natural areas, which may in turn impact mental and physical well-being.

Through 2080, the risk ratings for seasonal changes and snowpack reduction increased from 2050 and were screened through for ponds/lakes as they relate to human health and property. Seasonal changes and snowpack reduction increase the risk of ponds/lakes drying up, increase the variability of lake levels, and also increase algae concentrations. All of these factors result in decreased ability or increased variability to using ponds/lakes, and may change what activities the ponds/lakes are able to accommodate. Decreased accessibility to ponds/lakes has an impact on physical and mental health and well-being as people have less access to natural areas and outdoor activities.

1.6 Stream

Streams are connective pathways throughout Conservation Halton's watershed, from the lakeshore to north of the Niagara Escarpment. The risk assessment found that streams are at risk of rainfall as it relates to human health and property, both with a risk rating of 15 or higher ("high") for 2050. Increase in rainfall on streams presents a risk to physical well-being and safety due to the potential increase in flooding, which may impact accessibility of emergency services, potentially causing loss of life. There is also risk to property damage for residents along the creek banks due to increased rainfall and flooding potential.

Through 2080, seasonal changes and snowpack reduction were identified to have significant impact on streams and human health and property. The reduction of snowpack through the watershed reduces the spring freshet, a typically low-flow runoff, and is replaced with rainfall and higher runoff volumes. Higher runoff volumes reduce infiltration abilities and groundwater recharge, which increases distress due to lack of domestic groundwater supply. Seasonal changes increase the frequency of ice jams, erosion, winter runoff, and mid-winter melt, all of which increase the potential for flooding within and along creek banks. Increased flooding creates safety hazards for physical human health and increases the potential for property damage.

2 Terrestrial Ecology Consequences

The impact to terrestrial ecology in Conservation Halton's watersheds was evaluated considering damage or loss to land-based ecosystems, including soil, water, air, and microbes that the ecosystem interacts with

2.1 Forests

Forests are an integral component of terrestrial ecology in Conservation Halton's watershed. This risk assessment found that dry conditions, heat stress, and seasonal changes have an impact on forests as they relate to terrestrial ecology. The risk rating for snowpack reduction increased to 15 ("high") for the year 2080. Dry conditions and heat stress increase potential fore fires and tree drying, causing plant mortality and species loss. Prolonged dry conditions may predispose terrestrial ecology, particularly trees, to compounded damage from other stressors such as invasive species and pathogens. Both of these consequences lead to reduced biodiversity throughout the watershed and weakens the ability of forests provide their benefits and services. Seasonal changes affect the availability of food for migrating species, making conditions unsuitable for wildlife to find habitat. Decreased availability of forests as a result of these impacts may lead to loss of water needed for wildlife breeding as streams, lakes, and ponds become less shaded.

Snowpack reduction impacts terrestrial ecology through forests by altering the predator-pray relationship as wildlife will have less available habitat in snowpack. Reduction in snowpack may also result in misaligned migration and plant growth.

2.2 Groundwater

Groundwater is a source to many streams, ponds, and lakes that robust terrestrial ecology systems interact with. This risk assessment found that groundwater is at risk of exposure to dry conditions, heat stress, seasonal changes, and snowpack reduction (2080) as they relate to terrestrial ecology. Dry conditions and heat stress can lead to increased surface water temperatures and reduced groundwater recharge, both of which impact the hospitability of wetlands required for terrestrial species and wildlife breeding. Additionally, lower groundwater levels as a result of higher evapotranspiration and reduced infiltration may impact vegetation quality and variety throughout the watershed. Seasonal changes have a similar impact on groundwater, altering wetland hydroperiods and creating changes in the vegetation that is able to thrive in wetland areas.

Through the year 2080, the risk rating for snowpack reduction and groundwater increased from “moderate” to “high” (15) as it relates to terrestrial ecology. Snowpack reduction may reduce the low-flow infiltration of snowmelt during the spring, reducing groundwater recharge and having similar impacts to terrestrial ecology as described for dry conditions, heat stress, and seasonal changes. However, it was found that the impacts of snowpack reduction on groundwater will be felt greater below the Niagara Escarpment.

2.3 Lakeshore

The lakeshore within Conservation Halton’s watersheds is home to many terrestrial ecology systems with specific habitat requirements. This risk assessment found that the lakeshore is at risk of seasonal changes for both 2050 and 2080 as it relates to terrestrial ecology. Seasonal changes may result in wildlife being unable to find a suitable habitat along the lakeshore, early arrival of migrating species without food availability, and loss of water along the lakeshore needed for breeding. All these factors have significant impact on the biodiversity of terrestrial ecosystems, increasing their risk and vulnerability to climate changes.

2.4 Meadow

Meadows are not a significant resource in Conservation Halton’s watersheds with respect to area coverage, however, they are significant to terrestrial ecology and the services and benefits they provide. This risk assessment found that meadows are at risk to heat stress for 2050/2080, and seasonal changes for 2080 as they relate to terrestrial ecology. Heat stress may predispose meadow terrestrial species to drying, and potential die-off or biodiversity loss. Seasonal changes have a similar impact on meadows as the other natural resources, being that they result in mismatched food and habitat availability for meadow and migrating species.

2.5 Pond/Lake

Ponds and lakes are scattered throughout Conservation Halton’s watersheds and provide habitat for terrestrial ecology ecosystems. The risk assessment found that ponds and lakes are at risk of heat stress for and seasonal changes for 2050 and 2080. Heat stress on ponds and lakes can lead to increased water temperatures, which may impact wetlands that are pond/lake fed through connected systems. These effects can lead to stress on wetland vegetation, in turn impacting wildlife breeding as they require specific habitats. Seasonal changes have a similar effect on ponds/lakes as the rest of the natural resources with respect to terrestrial ecology. Seasonal changes may cause wildlife impacts such as being unable to find suitable habitat within/along ponds and lakes, early arrival of migrating species without sufficient food availability, or loss of water within the water bodies needed for breeding.

2.6 Special Features – Vernal Pools

Special features such as vernal pools provide specific habitat conditions for various terrestrial and amphibian species. This risk assessment found that vernal pools are at risk of dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction for both 2050 and 2080 as they relate to terrestrial ecology. Dry conditions have several impacts on vernal pools and terrestrial ecology, the most significant being the risk of long-term damage to terrestrial and amphibian species if vernal pools were to dry up completely. Drying of vernal pools without complete dry out may result in less available breeding habitat for amphibians, which will reduce the availability of food for other wildlife. Additionally, if vernal pools were to dry up sooner due to increased dry conditions, there would be insufficient time for tadpoles/larva living in vernal pools to go through metamorphosis and develop lungs to leave the pools, which causes species die off. Heat stress on vernal pools causes increased water temperatures of habitat that is typically cold, reducing available breeding habitat for amphibians causing further species mortality. Increased rainfall inevitably causes water levels in vernal pools to increase, which may lead to species die off as shallow water is required for vernal pools species to survive.

Seasonal changes, as may be expected, have similar impacts on vernal pools and terrestrial ecology as the other natural resources. Seasonal changes may cause wildlife impacts such as being unable to find suitable habitat, early arrival of migrating species without food availability, and changes in water levels needed for breeding. Snowpack reduction may reduce or eradicate the spring freshet which produces water needed for early spring breeding amphibians. All of these climate hazards have significant impact on already sensitive vernal pools, and may contribute to continued degrading and decreased services provided by the natural resource to terrestrial ecology.

2.7 Wetland – Marsh

Marshes provide specific habitat for herbaceous vegetation and amphibians and are largely present along and above the Niagara Escarpment. Marshes are generally more tolerant to changes than swamps, however, this risk assessment found that marshes are at risk of dry conditions, heat stress, and seasonal changes through 2050 as they relate to terrestrial ecology. Dry conditions and heat stress may reduce water levels in marshes, causing changes in vegetation communities and mismatched availability in food and habitat for terrestrial species in marsh areas.

Seasonal changes, as may be expected, have similar impacts on marshes and terrestrial ecology as the other natural resources. Seasonal changes may cause wildlife impacts such as being unable to find suitable habitat, early arrival of migrating species without food availability, and changes in water levels needed for breeding. Through 2080, the risk for snowpack reduction and marshes as it relates to terrestrial ecology increased to "high" (15). Similar to the impact on vernal pools, snowpack reduction may reduce or eradicate the spring freshet which produces water needed for early spring breeding amphibians in marshes.

2.8 Wetland – Swamp

Wetland swamps are an integral component of terrestrial ecology in Conservation Halton's watersheds and have nearly double the area coverage of wetland marshes. Through this risk assessment, it was found that swamps are at risk of dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction (2080 only) as they relate to terrestrial ecology. Dry conditions and heat stress can lead to reduced water levels, which increases the potential of swamps drying out completely, causing long-term damage. As the water level decreases and swamps dry out, the vegetation communities that live within or adjacent to swamps change and die off. Contrary to water levels lowering, rainfall can increase water levels which also has a negative impact. Too much water or flooded can result in die-off of terrestrial vegetation and wildlife species. Like the impact on vernal pools and marshes, snowpack reduction may reduce or eradicate the spring freshet which produces water needed for early spring breeding amphibians in swamps.

3 Aquatic Ecology Consequences

The impact to aquatic ecology in Conservation Halton's watersheds was evaluated considering damage or loss to water-based ecosystems, including soil, water, air, and microbes that the ecosystem interacts with.

3.1 Forests

Riparian vegetation is an indicator of healthy water-based ecosystems and forests that interact with water-based ecosystems have an impact on their aquatic ecology. This risk assessment found that forests are at risk of heat stress through 2050, and seasonal changes through 2080 as they relate to aquatic ecology. The impacts of heat stress and seasonal changes on forests can cause vegetation die-off, warming the water temperatures of aquatic ecosystems that pass through forested areas. Warmer temperatures in aquatic ecosystems makes conditions less hospitable for amphibians and fish, causing species die off. All these consequences lead to reduced health and biodiversity of aquatic ecosystems due to degradation of forests.

3.2 Groundwater

Groundwater sources feed cold water to aquatic ecosystems throughout Conservation Halton's watershed. This risk assessment found that groundwater is at risk of dry conditions, rainfall, and heat stress through 2050 and 2080, and seasonal changes and snowpack reduction through 2080. Aquatic ecology is impacted by dry conditions and heat stress on groundwater as a result of less groundwater recharge to surface water bodies. Less groundwater recharge to creeks and cool-water bodies causes water temperatures to rise, resulting in less living and breeding habitat available for cool-water aquatic species. Rainfall has similar consequences to aquatic habitat as dry conditions and heat stress, but as a result of increased rainfall causing decreased infiltration ability and subsequent decreased groundwater discharge to aquatic systems.

Seasonal changes through the year 2080 present risk to aquatic ecology through groundwater as a result of warming water temperatures. Warmer water temperatures in groundwater feed to aquatic systems, which impact the habitat available for fish spawning that requires cool water. Seasonal changes such as decreased groundwater discharge in typical recharge season, and more losses of surface water to groundwater during dry seasons, can lead to negative impacts on groundwater fed wetland hydroperiod species (e.g., tadpoles, larvae). For snowpack reduction, the risk is felt at a greater magnitude below the Niagara Escarpment compared to above. Fractured bedrock above the escarpment allows for higher groundwater recharge, making the aquatic ecosystems more resilient to groundwater changes in general. Snowpack reduction reduces infiltration and groundwater recharge, creating similar effects on aquatic ecology as dry conditions, heat stress and seasonal changes.

3.3 Lakeshore

Lakeshores provide distinct habitat requirements for native aquatic vegetation and are a downstream receiver of runoff from Conservation Halton's urban creek watersheds. Vegetation along the shore and aquatic vegetation beds act as a buffer zone, intercepting nutrients from runoff that effect the quality of aquatic ecosystems (Sandborn, D., 2017). This risk assessment found that lakeshores are at risk of dry conditions, heat stress, rainfall, and seasonal changes through 2050, and snowpack reduction through 2080 as they relate to aquatic ecology. Increased dry conditions and heat stress along lakeshores may result in vegetation drying, causing less available habitat required for fish spawning. Increased rainfall causes increased runoff from the urban creek watersheds, causing lake temperatures to increase. Increased temperatures lead to higher nutrient and algae concentrations, reducing available dissolved oxygen. These impacts cause the quality and health of aquatic ecosystems to degrade.

Seasonal changes cause changes in aquatic ecology along lakeshores due to temperature alteration during the critical life stages, causing different water levels and lake processes occurring at different times than usual. Snowpack reduction along lakeshores reduces the available water needed for early spring spawning and migrating fish. These impacts lead to the quality of aquatic ecosystems to degrade and reduces the ability of lakeshores to provide their services and benefits to the watershed.

3.4 Pond/Lake

Ponds and lakes provide a significant volume of habitat for aquatic ecosystems in Conservation Halton's watershed. This risk assessment found that ponds and lakes are at risk of dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction as it relates to aquatic ecology through both 2050 and 2080. Drying of lakes due to increased dry conditions will result in less available overall habitat for aquatic ecosystems. Heat stress causes water temperatures to increase, impacting oxygen levels within ponds and lakes. Changes to oxygen levels leads to habitat consequences for aquatic species such as turtles. Increased rainfall causes increased urban runoff, which may lead to pond and lake temperatures to increase. Increased temperatures lead to higher nutrient and algae concentrations, reducing available dissolved oxygen. These impacts cause the quality and health of aquatic ecosystems to degrade.

Seasonal changes cause changes in aquatic ecology within ponds and lakes due to temperature alteration during the critical life stages, causing different water levels and lake processes occurring at different times than usual. Snowpack reduction reduces the available water needed in ponds and lakes for early spring spawning and migrating fish. These impacts lead to the quality of aquatic ecosystems to degrade and reduces the ability of ponds and lakes to provide their services and benefits to the watershed.

3.5 Special Features – Vernal Pools

The results of the risk assessment that summarize the impact of climate hazards on vernal pools as they relate to aquatic ecology were not conclusive. The risk ratings showed that based on an average of the consequence scores, vernal pools are at risk of heat stress through 2050 and seasonal changes and snowpack reduction through 2080 as they relate to aquatic ecology. However, there was a significant gap in opinions and consequence ratings that generated this average. For example, there were differing opinions from two terrestrial ecology subject matter experts, one that identified only dry conditions as a risk and another that identified dry conditions, heat stress, rainfall, seasonal changes and snowpack reduction as high risk. Therefore, the risk on vernal pools and aquatic ecology was not able to be quantified and the consequences vary. However, as previously mentioned, there is general agreement that heat stress, seasonal changes and snowpack reduction will have an impact on vernal pools and aquatic ecology, although the specifics of these impacts are up for debate.

3.6 Stream

Streams provide cool water habitat for aquatic ecosystems and connective pathways between natural areas and ecosystems throughout Conservation Halton's watershed. This risk assessment found that streams are at risk dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction through 2050 and 2080 as they relate to aquatic ecology. The impacts of these climate hazards on streams and aquatic ecology will be widespread and impact biodiversity throughout large portions the watershed, as streams are such an integral and interconnected component of the aquatic ecosystem. Dry conditions and heat stress lead to increased water temperatures in streams or complete dry out, severely impacting aquatic habitat and cool-water requirements. Increased rainfall has a similar impact of increasing water temperatures, causing aquatic species to die off.

Seasonal changes cause changes in aquatic ecology within streams due to temperature alteration during the critical life stages, causing different water levels and stream processes occurring at different times than usual. Snowpack reduction reduces the available water needed in streams for early spring spawning and migrating fish. These impacts lead to the quality of aquatic ecosystems to degrade and reduces the ability of streams to provide their services and benefits to the watershed.

3.7 Wetland – Marsh

Marshes provide shallow water habitat for aquatic ecosystems in non-forested areas throughout Conservation Halton's watershed. This risk assessment determined that marshes are at risk of dry conditions, heat stress, seasonal changes, and snowpack reduction through 2050 and 2080. Dry conditions, heat stress, and seasonal changes have significant impact on aquatic ecology in marshes as they lead to dry out of the marsh, reducing the ability of fish to spawn in their typical habitat. Snowpack reduction reduces the available water needed in marshes for early spring spawning and migrating fish. These impacts lead to the quality of aquatic ecosystems to degrade and reduces the ability of marshes to provide their services and benefits to the watershed.

3.8 Wetland – Swamp

Like vernal pools, the results of the risk assessment that summarize the impact of climate hazards on swamps as they relate to aquatic ecology were not conclusive. The risk ratings showed that based on an average of the consequence scores, swamps are at risk of heat stress and rainfall through 2050 and seasonal changes and snowpack reduction through 2080 as they relate to aquatic ecology. However, there was a significant gap in opinions and consequence ratings that generated this average. For example, there were differing opinions from two terrestrial ecology subject matter experts, one that identified seasonal changes as a higher risk and another that identified rainfall, seasonal changes and snowpack reduction as high risk. Therefore, the risk on swamps and aquatic ecology was not able to be quantified and the consequences vary. However, as previously mentioned, there is general agreement that heat stress, rainfall, seasonal changes and snowpack reduction will have an impact on swamps and aquatic ecology, although the specifics of these impacts are up for debate.

4 Water Quality Consequences

The impact to water quality in Conservation Halton’s watersheds was evaluated considering increased water temperature, increased levels of nutrients, sedimentation, and reduced levels of dissolved oxygen.

4.1 Forests

Forested areas along water bodies such as streams (the riparian zone) provides a vegetated buffer that filters contaminants, sediment, and nutrients from entering the water. This risk assessment found that forests are at risk of heat stress as it relates to water quality. Heat stress can cause loss of vegetation adjacent to creeks due to drying or fires, which may result in increased water temperatures due to lack of shade coverage. Loss of vegetation in the riparian zone as a result of forests drying may also lead to loss of bank stability, increasing sedimentation concentration in streams due to erosion.

4.2 Groundwater

Groundwater throughout Conservation Halton's watersheds may be classified into three groups of concern: Significant Groundwater Recharge Area, Wellhead Protection Area, and Highly Vulnerable Aquifer (Conservation Halton Open Data Hub, July 2023) that are largely present along the pathway of the Niagara Escarpment. These protection areas demonstrate the impact and importance of groundwater on water quality throughout Conservation Halton's watershed. This risk assessment found that groundwater is at risk of dry conditions, heat stress, rainfall, and seasonal changes through 2050 and 2080 as they relate to water quality. All these climate hazards, whether through drying out soil, increased rainfall and runoff, or varying seasonal conditions result in less groundwater recharge due to decreased infiltration abilities. Less groundwater recharge volume results in increased contaminant concentrations, concentrations and increased temperatures in groundwater-fed wells, streams, ponds, lakes, and wetlands. More specifically, heat stress can cause water quality issues where groundwater is up-welling, short-term water quality impacts mentioned above, reduction in groundwater discharge and cause lower base flows in streams. Seasonal changes can also cause groundwater up-welling, which impacts both groundwater and surface water quality and temperature.

4.3 Lakeshore

Lakeshores provide a unique benefit to water quality; the vegetation along the shore and aquatic vegetation beds act as a buffer zone, intercepting nutrients, and contaminants from entering lakes (Sandborn, D., 2017). This risk assessment found that lakeshores are at risk of dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction through 2050 and 2080 as they relate to water quality. Increased dry conditions and heat stress along lakeshores may result in vegetation drying, decreasing the ability of shoreline vegetation to filter contaminants and nutrients. Increased rainfall creates increased runoff from the urban creek watersheds, which ma cause lake water temperatures to increase. Increased water temperatures lead to higher nutrient and algae concentrations (toxic algal blooms), reducing available dissolved oxygen. These impacts deteriorate the water quality of the lake.

Seasonal changes cause changes in water quality along lakeshores due to temperature alteration during the critical life stages, causing different water levels and lake processes occurring at different times than usual. Snowpack reduction changes the magnitude of the spring freshet, which typically will convey chlorides from the winter months through the drainage system quickly. Without the spring freshet due (snowmelt and runoff) to snowpack reduction, the chloride concentrations will remain in the water system for a longer period of time and create water quality concerns. These impacts cause water quality to degrade and reduces the ability of lakeshores to provide their services and benefits to the watershed.

4.4 Pond/Lake

Clean, healthy water in ponds and lakes helps to support a diversity of plants and wildlife, making water quality one of the most important factors in pond/lake systems. This risk assessment found that ponds and lakes are at risk of dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction as it relates to water quality through both 2050 and 2080. Dry conditions in ponds and lakes can contribute to increased algae contents, increasing the potential for our amount of toxic algal blooms in the water. Heat stress on ponds and lakes leads to increased water temperatures, which also increases the contaminant and nutrient concentration in the water. Increased rainfall causes increased runoff volumes, which carries additional contaminants and higher temperature water from surface runoff into ponds and lakes. Increased water temperatures, like heat stress and dry conditions, lead to higher nutrient and algae concentrations, reducing available dissolved oxygen.

Seasonal changes on ponds and lakes induce water temperature alterations during critical life stages of the water body and cause more extreme fluctuations in water levels. Intense water level fluctuations can lead to erosion along the shore, causing increased sediment concentrations in the pond or lake. Additionally, seasonal changes and snowpack reduction lead to increased winter runoff volumes and reduced spring melt, which delays or eradicates the spring freshet that typically moves chlorides accumulated through the winter from the drainage system quickly.

4.5 Stream

Streams connect the upper and lower reaches of a watershed, easily providing connective pathways between natural areas. This makes them a key player in water quality, because issues observed in streams are quickly spread watershed wide. This risk assessment found that streams are at risk dry conditions, heat stress, rainfall, seasonal changes, and snowpack reduction through 2050 and 2080 as they relate to water quality. Dry conditions and heat stress lead to increased water temperatures in streams and may cause complete dry out, both severely impacting water quality by lowering water levels and subsequently making sediment, nutrient and contaminant concentrations higher. Increased rainfall and runoff may lead to combined sewer overflow being conveyed throughout the drainage system and to streams, which would considerably degrade surface water quality. Additionally, increased runoff due to rainfall, heat stress and dry conditions leads to winter salt on paved surfaces to be conveyed into the drainage system, further degrading water quality in streams.

Seasonal changes cause changes in water quality within streams due to temperature alteration during the critical life stages, causing different water levels and stream processes occurring at different times than usual. Additionally, seasonal changes and snowpack reduction lead to increased winter runoff volumes and reduced spring melt, which delays or eradicates the spring freshet that typically moves chlorides accumulated through the winter through the system quickly. These impacts all degrade the water quality in streams, reducing their ability to provide their key benefits and services for the watershed.

4.6 Wetland – Marsh and Swamp

Marshes influence many aspects of water quality, making their impact significant on surface water quality. This risk assessment found that marshes are at risk of heat, seasonal changes, and snowpack reduction through 2050 and 2080 as they relate to water quality. Heat stress and seasonal changes cause water temperatures in marshes to increase, which has an impact throughout the watershed as marshes help to enhance and filter the quality of surface runoff. Snowpack reduction has a similar impact as on streams, ponds, and lakes, being that the spring freshet will be delayed or eradicated. Absence of the spring freshet means that chlorides from the winter will accumulate in wetland marshes, causing the water quality to degrade. Degraded water quality in wetland marshes significantly impacts their ability to provide their benefits and services and contribute to the health and biodiversity of the watershed.

The risk assessment found that swamps are at risk of the same climate hazards; heat, seasonal changes, and snowpack reduction for 2050 and 2080 and yield the same impact to swamps as marshes. Swamps, typically older than marshes, may have more resilience to the water quality consequences but are a more significant resource to the watershed by area coverage.

5 Erosion and Sedimentation Consequences

The impact to erosion and sedimentation in Conservation Halton's watersheds was evaluated considering physical impacts to watercourses and shorelines, or changes to fluvial processes that would increase erosion or degrade ecological systems.

5.1 Lakeshore

Lakeshores are frequently exposed to wave and ice movement even without the additional impacts of climate change, which predisposes shorelines to erosion and sedimentation. This risk assessment found that lakeshores are at high risk of rainfall and wind through 2050, and seasonal changes and snowpack reduction through 2080 as they relate to erosion and sedimentation. Rainfall, as may be expected, causes an increase in water levels which are a very important factor in lakeshore erosion. Increased water levels, storm surges, and wave action due to increased rainfall lead to slope failure issues along the lakeshore as a result of shoreline erosion. Further, wind significantly increases wave action and is a major contributor to lakeshore erosion.

Seasonal changes and snowpack reduction can increase runoff in the winter months, increasing lake water levels and causing potential erosion issues associated with high water levels. Additionally, seasonal changes cause more intense storms and dryer soils along the lakeshore in the summer months. Intense storms increase wave action and degrade the slopes along a shoreline, and dried out soils are weaker and have less capability to hold shoreline banks in place. Snowpack reduction, in addition to causing increased runoff can also lead to reduced ice along the shoreline, increasing the impact felt by storm surges and wave action that would have been protected by ice cover. All these impacts lead to degradation of lake shorelines and reduce their area coverage in the watershed, making shoreline areas at higher risk of climate change.

5.2 Pond/Lake

Ponds and lakes can be a major contributor to shoreline erosion within Conservation Halton's watershed, as they expose the banks to wave action that degrades the surface. This risk assessment found that in addition to existing factors that play on ponds/lakes and shoreline erosion, ponds and lakes are at risk of rainfall through 2050 and seasonal changes through 2080 as they relate to erosion and sedimentation. Rainfall and seasonal changes have a similar impact on ponds/lakes as they do lakeshores, by increasing water levels and causing storm surges. Increased water levels and storm surges lead to higher magnitude wave action that erodes the pond/lake banks and carries sediment into the water. Seasonal changes also cause an increase in winter runoff and drying of soils along the banks of ponds and lakes. Increased winter runoff carries sediment from impervious surfaces into the ponds and lakes, and also increases the volume of water travelling down the banks and causing erosion. Additionally, winter runoff reduces the ice cover throughout ponds and lakes, which exposes the banks to erosion that would have been protected by ice in the winter months. Dry soil conditions along the bank of ponds and lakes causes the slope to weaken, predisposing them to erosion from wave action. Continued and increased eroding of the banks along ponds and lakes can lead to full slope failure and degrade the structural integrity of the ecosystem.

5.3 Stream

Streams corridors are often associated with a steep slope along their banks, making streams vulnerable to erosion and sedimentation. Through this risk assessment, it was found that streams are at risk of rainfall through 2050 and seasonal changes and snowpack reduction through 2080 as they relate to erosion and sedimentation. Increased rainfall along the banks of streams causes increased erosion as more water travels along the slope and carries sediment into the streams. Seasonal changes, as similarly discussed with lakeshore and ponds/lakes, creates more runoff in winter months, more extreme storms, and dryer soils in the summer. Additional runoff in winter months and extreme storms further contribute to bank erosion as increased volumes of water flow down the slope and into the stream. Snowpack reduction also increases the winter runoff and has a similar impact on streams and erosion. Dry soils along the banks of streams cause the soils to weaken and riparian vegetation to die off, which makes the slope integrity degrade and leads to erosion. Variability and timing of stream flow are an important factor in weathering of banks and vegetation dynamics, two factors that are altered as seasonal changes increase. With stream flow changes and weathered banks due to seasonal changes, the potential for erosion and sedimentation along the stream increase. Overall, this risk assessment found that streams are at high risk with respect to erosion and being able to provide their benefits and services to the watershed.

5.4 Wetland – Marsh

Wetland marshes provide valuable benefits and services to the ecosystem and are vulnerable to erosion if they are not fully developed. This risk assessment found that marshes are at high risk of heat stress through 2050 and seasonal changes through 2080 as they relate to erosion and sedimentation. Heat stress may have an indirect impact on marshes by deteriorating vegetation growth and quality, causing soils to weaken increasing the potential for erosion and sedimentation within the marsh. Seasonal changes, as previously mentioned, cause changes in the timing and volume of spring freshet. The variability in this typically high-volume spring runoff can increase erosion in marshes and increase sediment volumes in the water. Increased sedimentation in marshes can reduce the open water area and cause the marsh to be choked with aquatic vegetation. These impacts on erosion and sedimentation in marshes all cause degradation of the natural resource and biodiversity throughout the watershed.

5.5 Wetland – Swamp

Swamps and wetlands in general help to stabilize the soil in their local ecosystem and reduce erosion by infiltrating excess surface water runoff. Through this risk assessment, it was found that wetland swamps are at high risk of heat stress through 2050 and seasonal changes through 2080 as they relate to erosion and sedimentation. The impacts of climate hazards on swamps and erosion and sedimentation are almost identical to those outlined for marshes. However, swamps may be more resilient to changes than marshes due to their different vegetation and water depth. Heat stress may have an indirect impact on swamps by deteriorating vegetation growth and quality, causing soils to weaken increasing the potential for erosion and sedimentation within the swamp. Seasonal changes, as previously mentioned, cause changes in the timing and volume of spring freshet. The variability in this typically high-volume spring runoff can increase erosion in swamps and increase sediment volumes in the water. Increased sedimentation in swamps can reduce the open water area and cause the swamp to be choked with aquatic vegetation. These impacts on erosion and sedimentation in swamps all cause degradation of the natural resource and biodiversity throughout the watershed.

6 Flooding

The impact to flooding in Conservation Halton's watersheds was evaluated considering change to the magnitude, frequency, and extent of flooding.

6.1 Lakeshore

Due to close proximity to large water bodies such as Lake Ontario, the lakeshores throughout Conservation Halton's watersheds are spatially vulnerable to flooding. Through this risk assessment it was found that lakeshores are at risk of rainfall and wind through 2050, and seasonal changes and snowpack reduction through 2080 as they relate to flooding. To elaborate further, rainfall causes lake levels to increase which directly increases the amount of flooding along the lakeshore. Wind can increase the potential for storm surges in lakes, which cause an intense increase in water level within a lake over a short period of time and lead to flash flooding along the lakeshore. As previously mentioned, seasonal changes increase the amount of runoff in winter, cause more extreme storms and dryer soils in the summer months. These changes all lead to increased water levels due to decreased infiltration abilities, either by increasing rainfall or reducing ability of soils to infiltrate, and ultimately cause flooding along the lakeshore. Snowpack reduction has a similar effect in the winter months by increasing runoff and decreasing ice cover along the lakeshore. These consequences lead to flooding along the lakeshore and degrade lakeshores and their ability to provide their benefits and services to the surrounding ecosystem.

6.2 Pond/Lake

Ponds and lakes are the larger bodies of water in Conservation Halton's watersheds and can have significant influence on flooding. This risk assessment determined that ponds and lakes are at risk of rainfall through 2050 and seasonal changes through 2080 as they relate to flooding. Rainfall has a direct impact on flooding in ponds and lakes by causing an increase in water levels and subsequent increase in flooding. Seasonal changes increase the amount of runoff in the winter, cause more extreme storms and dryer soils in the summer throughout the entire watershed. These changes all lead to water levels in ponds and lakes to increase due to increased runoff volumes and decreased ability for infiltration, directly influencing flooding. As the water levels in ponds and lakes increase, the potential for flooding nearby areas is higher and they become unable to properly support the aquatic and nearby terrestrial ecosystems.

6.3 Stream

Streams travel throughout the entirety of Conservation Halton's watersheds and are interconnected to several natural and anthropogenic systems, making their impact on flooding throughout the watershed significant. This risk assessment found that streams are at risk of dry conditions and heat stress through 2050, and seasonal changes and snowpack reduction through 2080 as they relate to flooding. Based on the results of this risk assessment, streams are the most at-risk natural resource to climate hazards with respect to flooding. Dry conditions can lead to more runoff being received by streams due to decreased infiltration abilities of dry soils. Further, overall drying of stream beds can result in less flooding day-to-day as the stream empties and has more storage volume. However, a completely dried out stream bed can lead to runoff passing through the stream at a faster rate, causing flashier systems and potential flooding.

Seasonal changes and snowpack reduction have a similar impact on streams as they do the other aquatic resources such as lakeshores, ponds and lakes. Seasonal changes increase the amount of runoff in winter, cause more extreme storms and dryer soils in the summer months. These changes all lead to increased water levels due to decreased infiltration abilities as water travels throughout the system to streams. Water levels are increased by seasonal changes either by increasing rainfall or reducing ability of soils to infiltrate, and ultimately cause flooding within streams. Snowpack reduction has a similar effect in the winter months by increasing runoff and reducing the typical low-flow runoff of snowmelt.

6.4 Wetland – Marsh

Healthy marshes play a key role in flooding as they are able to detain and infiltrate runoff as it flows through the drainage system. Through this risk assessment it was found that marshes are at risk of dry conditions and heat stress through 2050, and seasonal changes through 2080 as they relate to flooding. Wetland marshes are slightly more vulnerable to drying compared to swamps due to their typically shallower water levels. If marshes were to dry out completely, the impact on flooding would be significant as runoff will not be retained and infiltrated within marshes as it typically would. Further, a large storm during a dry period (not complete dry out) can increase the risk of flooding as the marsh will be dry and have less ability to infiltrate water. Heat stress has an indirect impact on flooding through marshes as it can lead to vegetation changes and degradation. If vegetation is affected, the infiltration ability and structural integrity of the marsh is decreased and degraded. Decreased infiltration and degraded structural integrity of the marsh can cause channelization and increase flooding. Seasonal changes cause alterations in the timing and volume of spring freshet. The variability in this typically high-volume spring runoff can increase flooding in marshes by increasing the runoff that travels throughout the watershed at different times. All these factors have an impact on flooding of marshes and throughout Conservation Halton's watershed.

6.5 Wetland – Swamp

Swamps naturally protect their surrounding environment flooding as they infiltrate a significant amount of water and temporarily store it, similar to marshes. This risk assessment found that swamps are at risk of heat stress through 2050 and seasonal changes through 2080 as they relate to flooding. Like marshes, heat stress has an indirect impact on flooding through swamps as it can lead to vegetation changes and degradation. If vegetation is affected, the infiltration ability and structural integrity of the swamp is decreased and degraded. Decreased infiltration and degraded structural integrity of the swamp can cause channelization of flows and increase flooding. Seasonal changes cause alterations in the timing and volume of spring freshet. The variability in this typically high-volume spring runoff (spring freshet) can increase flooding in swamps by increasing the runoff that travels throughout the watershed at different times. Swamps are typically more resilient to changes compared to marshes, however, the impacts of the different climate hazards discussed can significantly affect the ability of swamps to provide their key services and benefits to the watershed as it relates to flood mitigation.

7 Conservation Halton Services Consequences

The impact to Conservation Halton's services was evaluated considering the ability to deliver community support services, to generate income, and the perception of Conservation Halton.

7.1 Forests

Forests are a significant part of the services offered by Conservation Halton, forming their conservation areas and trails and adjacent to many natural areas and ski slopes. Through this risk assessment it was found that forests are at risk of heat stress through 2050, and seasonal changes and snowpack reduction through 2080 as they relate to Conservation Halton's services. Heat stress can increase the risk of forest-generated fire in areas owned by Conservation Halton as vegetation dries out and dies off. This risk also applies to any infrastructure that is owned by Conservation Halton and located within forested areas that are at risk of heat stress. Further, heat stress can also increase the operational services of Conservation Halton that are required for hazard tree removal, invasive species management and trail closures due to heat stress on vegetation. Heat stress increases the amount of trees that are dying that require removal (hazard), makes conditions favourable for invasive species and can cause trail closures as a result of increased sensitive areas from trees dying or drying out.

Seasonal changes impact the timing and duration of tree colour changes, which may typically be associated with an increased number of visitors at Conservation Halton parks. Changes to the timing and duration of tree colour changes may decrease the number of visitors seen at Conservation Halton parks during certain seasons and impact revenue. Another factor that may impact revenue generated from parks is changes to forest ecosystems as a result of seasonal changes that influence visitor experience. Snowpack reduction in forests can increase the risk of spring fires due to lack of snowmelt runoff that moistens the forest soils. A reduction in snowpack can also impact winter sport offerings at Conservation Halton parks as less snow is available along their forested ski slopes.

7.2 Groundwater

Groundwater is the source of domestic water supply for the head office of Conservation Halton and their park facilities. This risk assessment determined that groundwater is at risk of heat stress through 2050 and seasonal changes through 2080 as they relate to Conservation Halton's services. Heat stress and seasonal changes have the same impact on groundwater by reducing the amount of groundwater recharge and increasing groundwater extraction as demand goes up. Less groundwater recharge and increased demand will impact the groundwater available to supply Conservation Halton's head office and park facilities. Stressed groundwater supply will directly impact the ability of Conservation Halton to deliver their services and provide safe recreational spaces in their parks and conservation areas.

7.3 Lakeshore

The main stretch of lakeshore within Conservation Halton's watersheds is along the coast of Lake Ontario, which is already vulnerable as a result of pollution from the heavily urbanized coastal communities. This risk assessment found that lakeshores are at risk of heat stress and wind through 2050, and seasonal changes and snowpack reduction through 2080 as they relate to Conservation Halton's services. Heat stress and seasonal changes can cause an increase in algae and algal blooms along lakeshores, particularly at Burlington Beach where there are current algal issues. When algae contents are too high and toxic, Conservation Halton services are required to be involved in beach closures. Even when beach closures may not be necessary, the aesthetics of the lakeshore can be significantly impacted by algae content and influence the number of visitors at lakeshore areas. Seasonal changes can also cause extreme weather events that may erode the lakeshore, which would increase the permitting requirements through Conservation Halton to deal with the erosion. High winds can influence the visitor experience in parks along the lakeshore due to safety hazards and poor swimming conditions. Further, wind can cause significant impact to shoreline infrastructure that allows visitors in lakeshore areas owned by Conservation Halton. Snowpack reduction throughout the watershed causes less spring runoff that increases water levels prior to the summer, impacting the swimming abilities along the lakeshore. These consequences all significantly impact the ability of Conservation Halton to deliver their services related to the lakeshore.

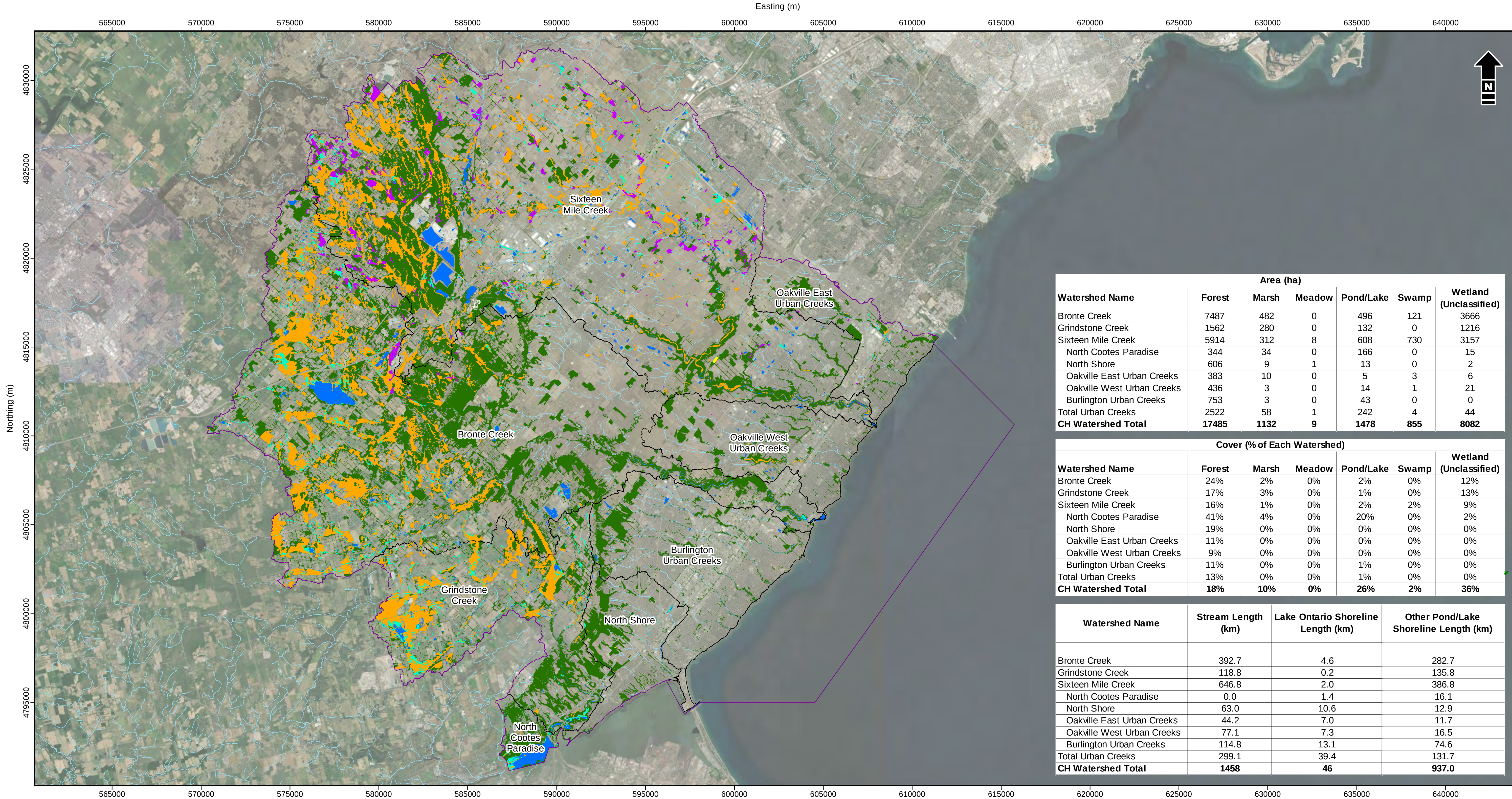
7.4 Pond/Lake

Ponds and lakes provide recreational swimming services through Conservation Halton's jurisdiction, a service that is not common in primarily land-locked communities or those adjacent to the polluted Lake Ontario. This risk assessment found that ponds and lakes are at risk of heat stress through 2050 and snowpack reduction through 2080. Heat stress can impact several water quality factors that relate to nutrient concentration, water temperature, and algae content. Increased water quality issues within ponds and lakes will cause more beach closures, requiring efforts from Conservation Halton's operations and limiting the ability of visitors to access recreational swimming features that are typically offered. Snowpack reduction can also impact recreational swimming at ponds and lakes by reducing water levels as there will be less spring snowmelt that would typically increase water levels for the summer. Additionally, snowpack reduction can affect the operations of Conservation Halton's flood control infrastructure. With increased variability in the timing and volumes of spring runoff, the typical operations for flood control infrastructure will have to change and will require input from various departments throughout Conservation Halton.

7.5 Stream

The final relationship that was screened through this risk assessment was that of streams and Conservation Halton's services. Streams were identified to not be at risk of climate hazards through 2050 with respect to Conservation Halton's services, however, through 2080 it was found that streams are at risk of seasonal changes and snowpack reduction. Seasonal changes can increase the amount of runoff in winter, cause more extreme storms and dryer soils in the summer months. These changes present challenges for flood and low-water level forecasting operations as weather and flow predictions in streams become more variable and Conservation Halton's models become less accurate with unpredictable, changing climate. Lack of accuracy in stream-related flood and low-water level forecasting services that Conservation Halton provides can impact their reputation in communities that expect Conservation Halton to provide flood protection insights. This could also increase the operational requirements of Conservation Halton as they adjust and develop their flood and water level forecasting procedures to accommodate the new climate. Snowpack reduction and lack of spring melt runoff directed to streams can create challenges with filling reservoirs throughout the watershed as water levels in streams decrease. All these climate impacts on streams cause stress on Conservation Halton's services and can damage their reputation of protecting the public from environmental- and climate-related hazards.

Appendix E
Figures – Natural Resource Inventory and Approximate Regulation Limit



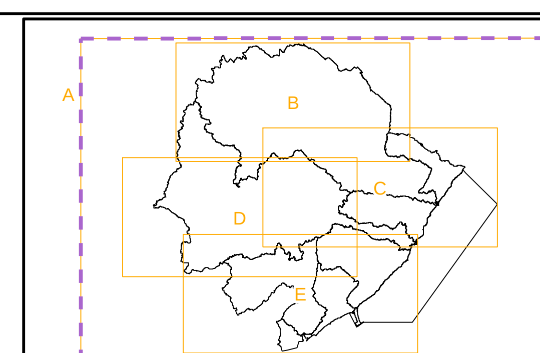
Area (ha)						
Watershed Name	**Forest**	**Marsh**	**Meadow**	**Pond/Lake**	**Swamp**	**Wetland (Unclassified)**
Bronte Creek	7487	482	0	496	121	3666
Grindstone Creek	1562	280	0	132	0	1216
Sixteen Mile Creek	5914	312	8	608	730	3157
North Cootes Paradise	344	34	0	166	0	15
North Shore	606	9	1	13	0	2
Oakville East Urban Creeks	383	10	0	5	3	6
Oakville West Urban Creeks	436	3	0	14	1	21
Burlington Urban Creeks	753	3	0	43	0	0
Total Urban Creeks	2522	58	1	242	4	44
CH Watershed Total	**17485**	**1132**	**9**	**1478**	**855**	**8082**

Cover (% of Each Watershed)						
Watershed Name	**Forest**	**Marsh**	**Meadow**	**Pond/Lake**	**Swamp**	**Wetland (Unclassified)**
Bronte Creek	24%	2%	0%	2%	0%	12%
Grindstone Creek	17%	3%	0%	1%	0%	13%
Sixteen Mile Creek	16%	1%	0%	2%	2%	9%
North Cootes Paradise	41%	4%	0%	20%	0%	2%
North Shore	19%	0%	0%	0%	0%	0%
Oakville East Urban Creeks	11%	0%	0%	0%	0%	0%
Oakville West Urban Creeks	9%	0%	0%	0%	0%	0%
Burlington Urban Creeks	11%	0%	0%	1%	0%	0%
Total Urban Creeks	13%	0%	0%	1%	0%	0%
CH Watershed Total	**18%**	**10%**	**0%**	**26%**	**2%**	**36%**

Watershed Name	**Stream Length (km)**	**Lake Ontario Shoreline Length (km)**	**Other Pond/Lake Shoreline Length (km)**
Bronte Creek	392.7	4.6	282.7
Grindstone Creek	118.8	0.2	135.8
Sixteen Mile Creek	646.8	2.0	386.8
North Cootes Paradise	0.0	1.4	16.1
North Shore	63.0	10.6	12.9
Oakville East Urban Creeks	44.2	7.0	11.7
Oakville West Urban Creeks	77.1	7.3	16.5
Burlington Urban Creeks	114.8	13.1	74.6
Total Urban Creeks	299.1	39.4	131.7
CH Watershed Total	**1458**	**46**	**937.0**

Conservation Halton Jurisdictional Boundary
Watershed
Stream

Land Cover Type
- Lakeshore
- Forest
- Meadow
- Pond/Lake
- Wetland - Marsh
- Wetland - Swamp
- Wetland (Unclassified)



1:215,000 metres
2,100 0 2,100 4,200
NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
A Montrose Environmental Company

Conservation Halton
Climate Change Vulnerability and Risk Assessment

Watershed-Based Natural Feature Inventory

Date:	Project:	Submitter:	Reviewer:
January 2024	36679	A. Rafeiro	Q. Chiotti

Figure A

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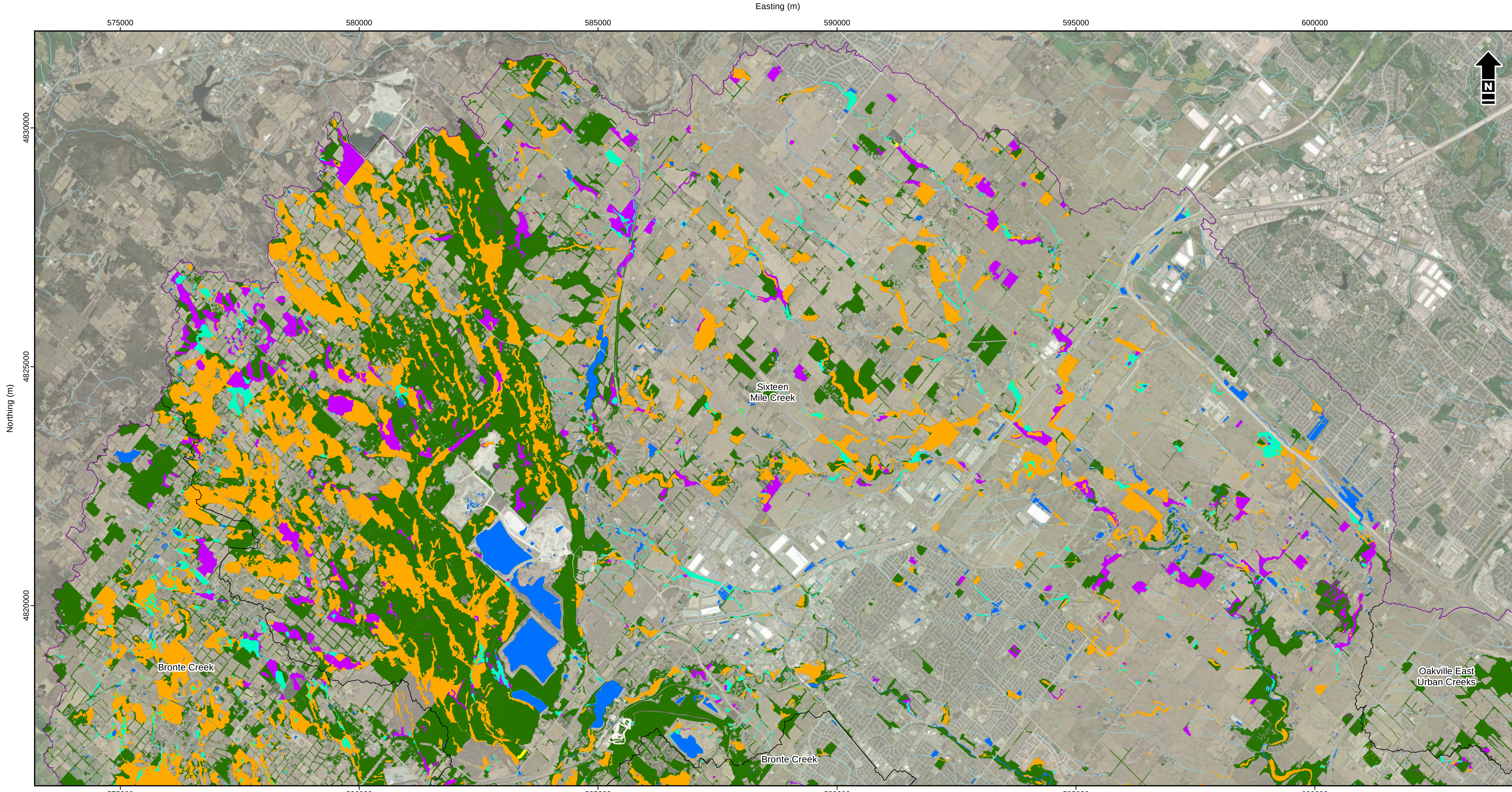
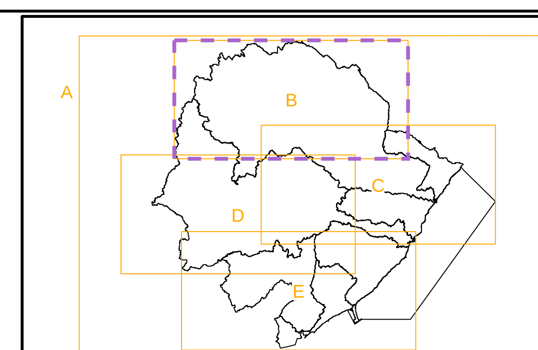


Conservation Halton Jurisdictional Boundary
Watershed
Stream

Land Cover Type
- Forest
- Meadow
- Pond/Lake
- Wetland - Marsh
- Wetland - Swamp
- Wetland (Unclassified)



1:80,000 metres
825 0 825 1,650
NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
A Montrose Environmental Company

Conservation Halton
Climate Change Vulnerability and Risk Assessment

Watershed-Based Natural Feature Inventory

Date:	Project:	Submitter:	Reviewer:
January 2024	36679	A. Rafeiro	Q. Chiotti

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Figure B

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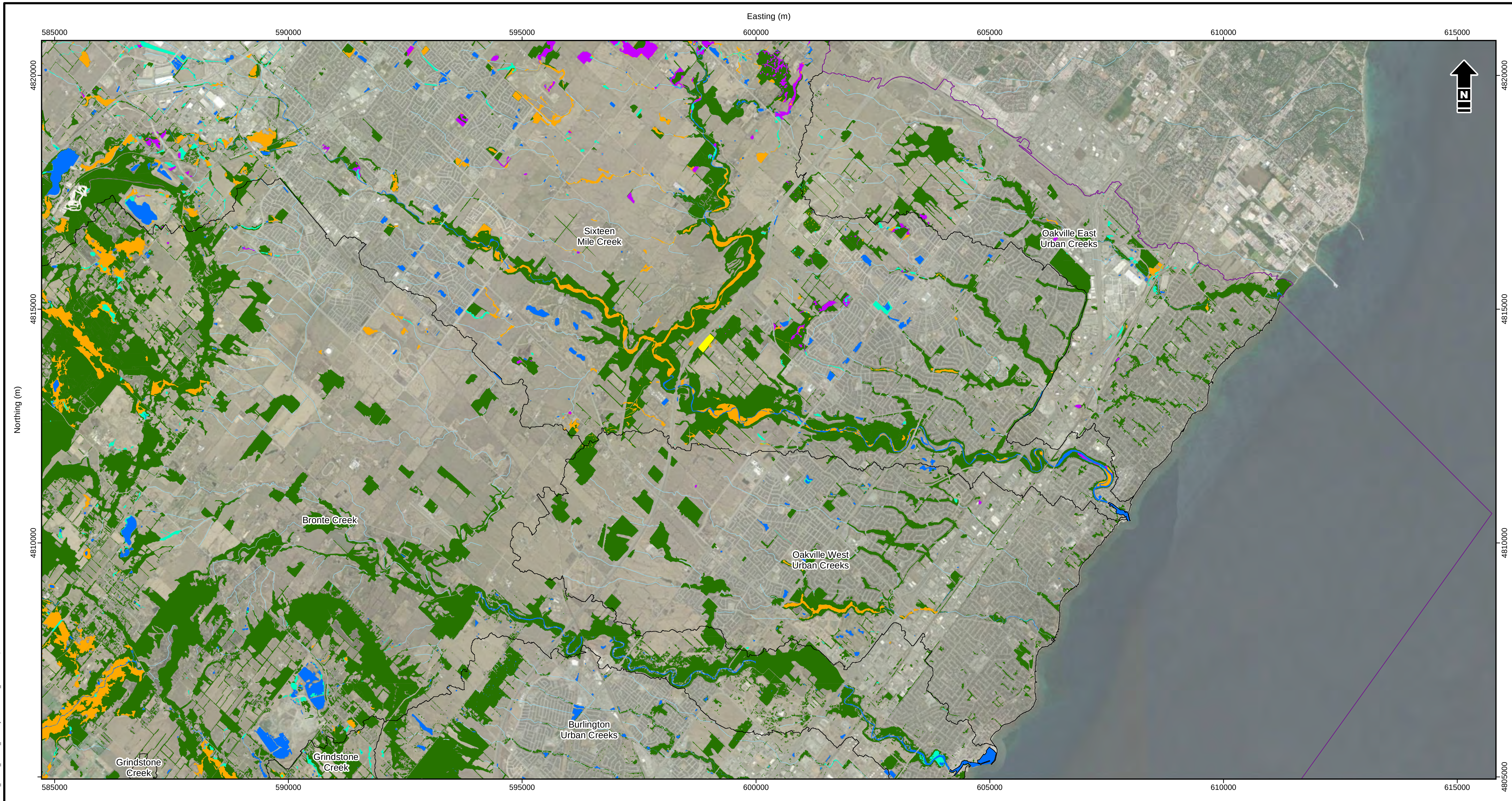
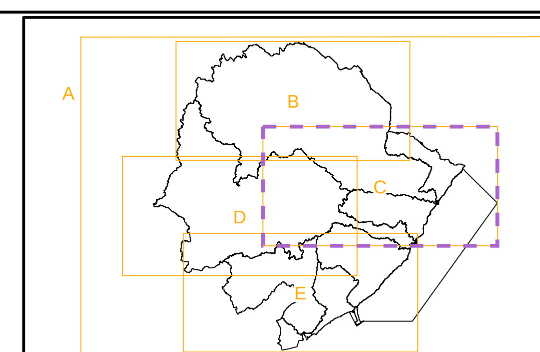


Conservation Halton Jurisdictional Boundary
Watershed
Stream

Land Cover Type

- Forest
- Meadow
- Pond/Lake
- Wetland - Marsh
- Wetland - Swamp
- Wetland (Unclassified)



1:80,000

metres

825 0 825 1,650

NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
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Conservation Halton
Climate Change Vulnerability and Risk Assessment

Watershed-Based Natural Feature Inventory

Date:	Project:	Submitter:	Reviewer:
January 2024	36679	A. Rafeiro	Q. Chiotti

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Figure C

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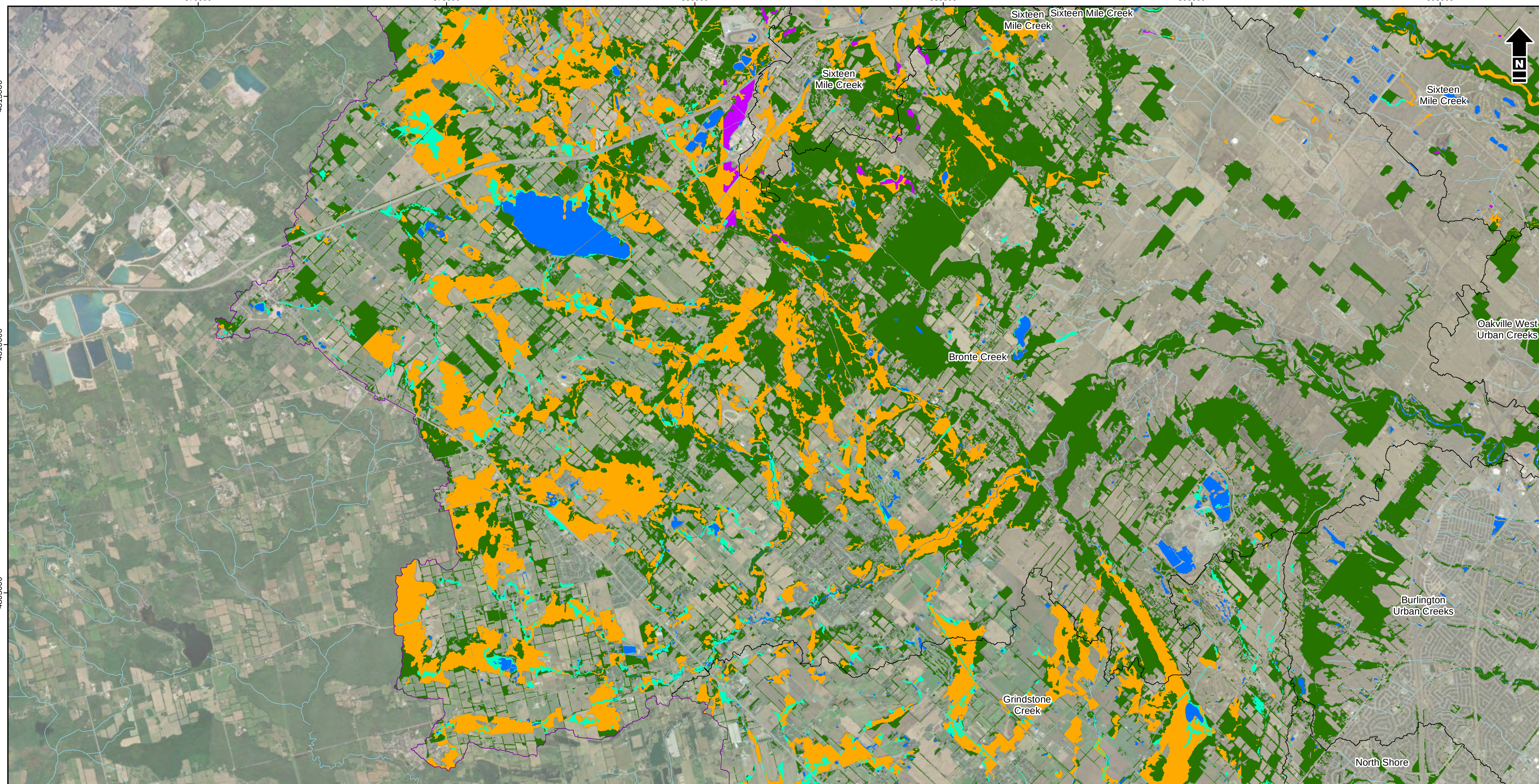
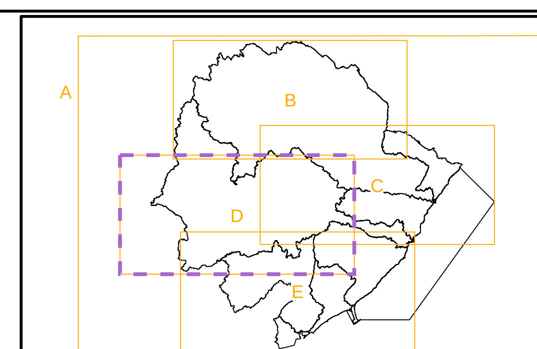
I:\ConservationHalton\36679\FiguresAndTables\CRA\2023\Report\Figure-1-Watershed_Natural_Feature_Inventory.mxd - Tabloid_L - 02-Jan-24, 01:20 PM - evenman - TID004



Conservation Halton Jurisdictional Boundary
Watershed
Stream

Land Cover Type
- Forest
- Meadow
- Pond/Lake
- Wetland - Marsh
- Wetland - Swamp
- Wetland (Unclassified)



1:80,000 metres
825 0 825 1,650
NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
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Conservation Halton
Climate Change Vulnerability and Risk Assessment

Watershed-Based Natural Feature Inventory

Date: January 2024	Project: 36679	Submitter: A. Rafeiro	Reviewer: Q. Chiotti

Figure D

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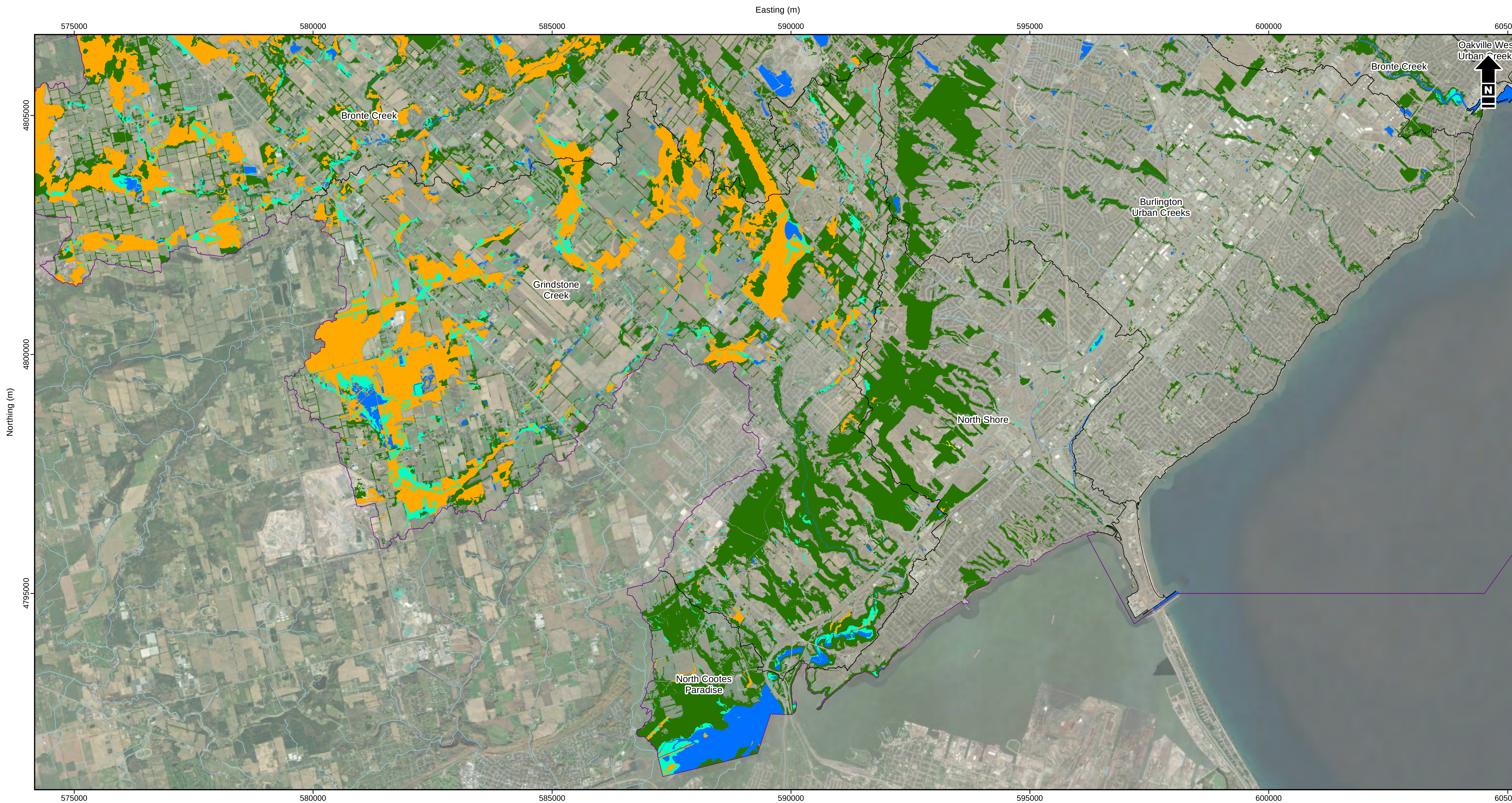
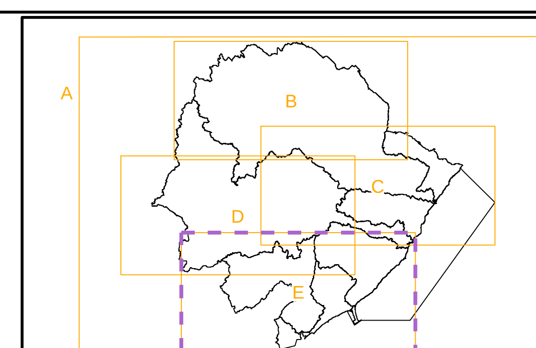


Conservation Halton Jurisdictional Boundary
Watershed
Stream

Land Cover Type

- Lakeshore
- Forest
- Meadow
- Pond/Lake
- Wetland - Marsh
- Wetland (Unclassified)



1:80,000 metres
825 0 825 1,650
NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
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Conservation Halton
Climate Change Vulnerability and Risk Assessment

Watershed-Based Natural Feature Inventory

Date: January 2024	Project: 36679	Submitter: A. Rafeiro	Reviewer: Q. Chiotti

Figure E

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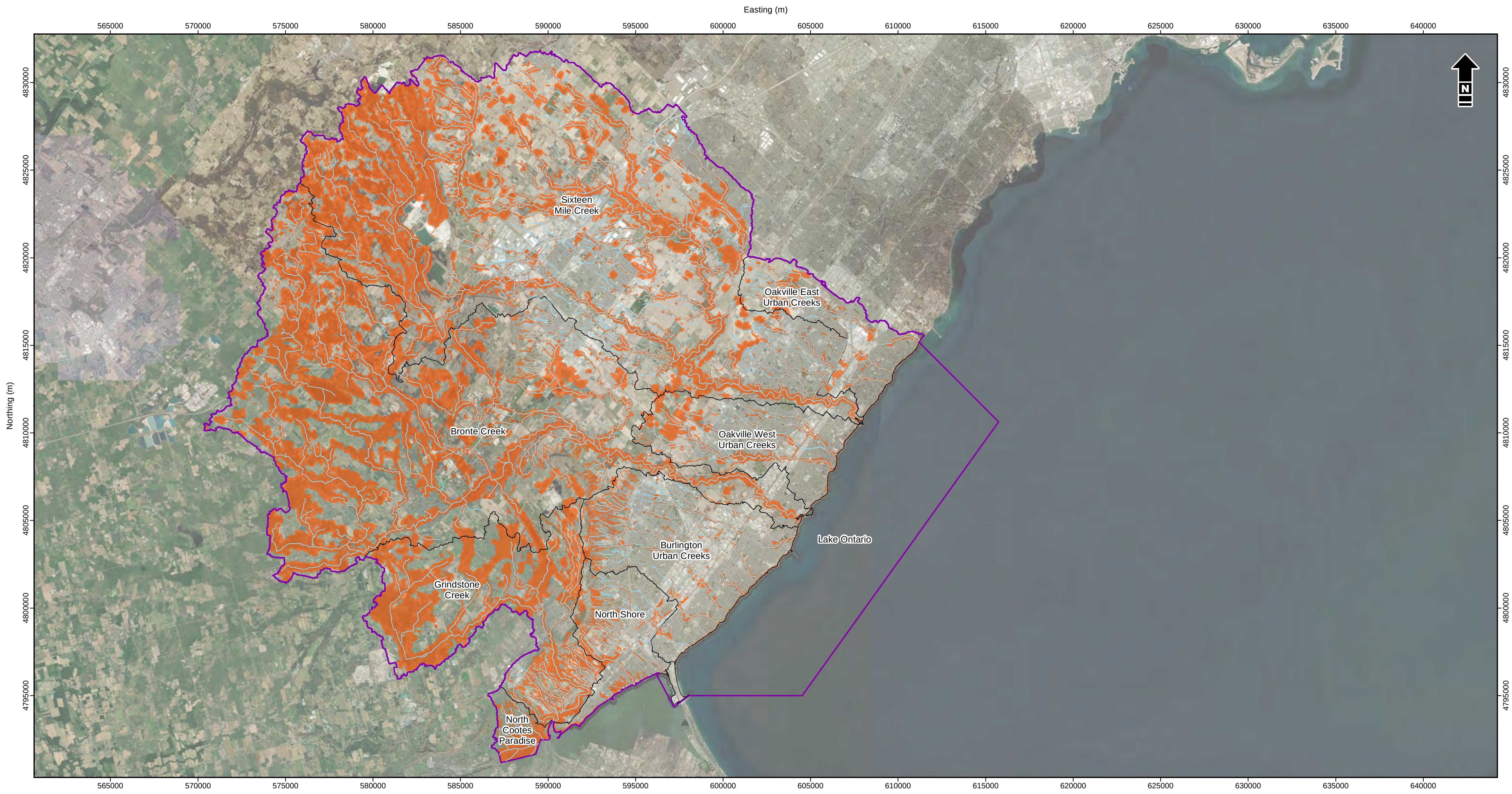
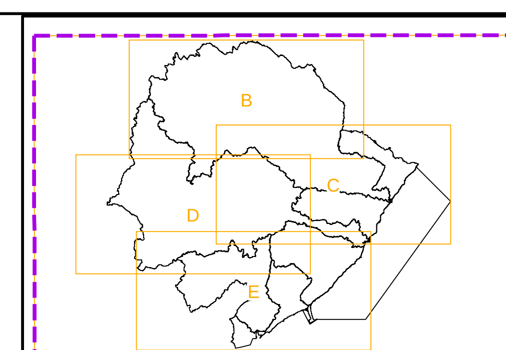


Conservatino Halton Jurisdictional Boundary

Watershed

Approximate Regulated Areas

Stream



1:215,000 metres

2,100 0 2,100 4,200

NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
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Conservation Halton
Climate Change Vulnerability and Risk Assessment

Approximate Regulation Limits

Date:	Project:	Submitter:	Reviewer:
February 2024	36679	A. Rafeiro	F. Tonto

Figure 2A

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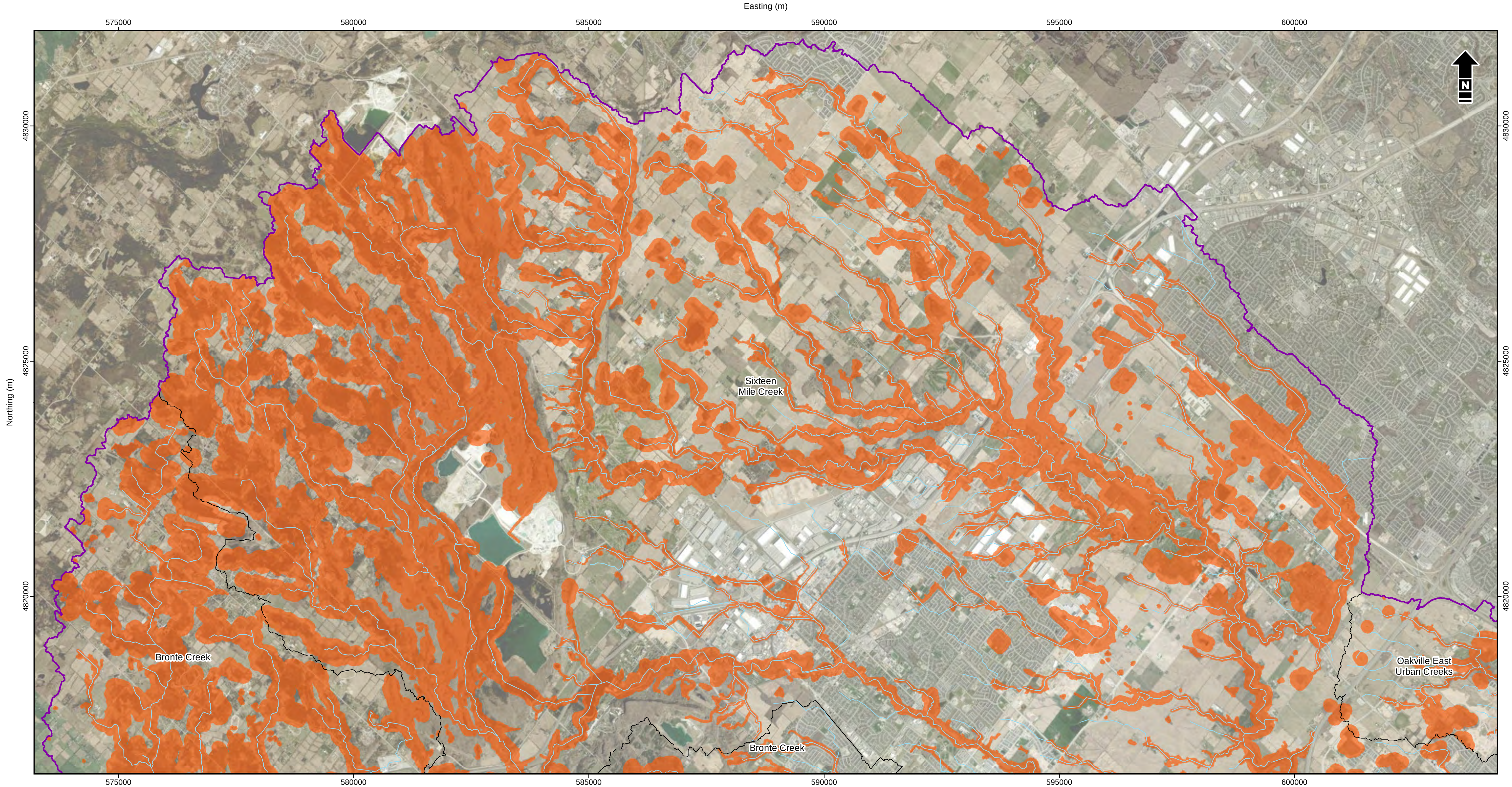
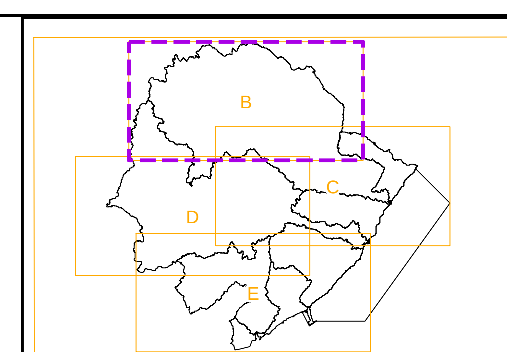


- Conservatino Halton Jurisdictional Boundary
- Watershed
- Approximate Regulated Areas
- Stream



1:80,000 metres

825 0 825 1,650

NAD 1983 UTM Zone 17N

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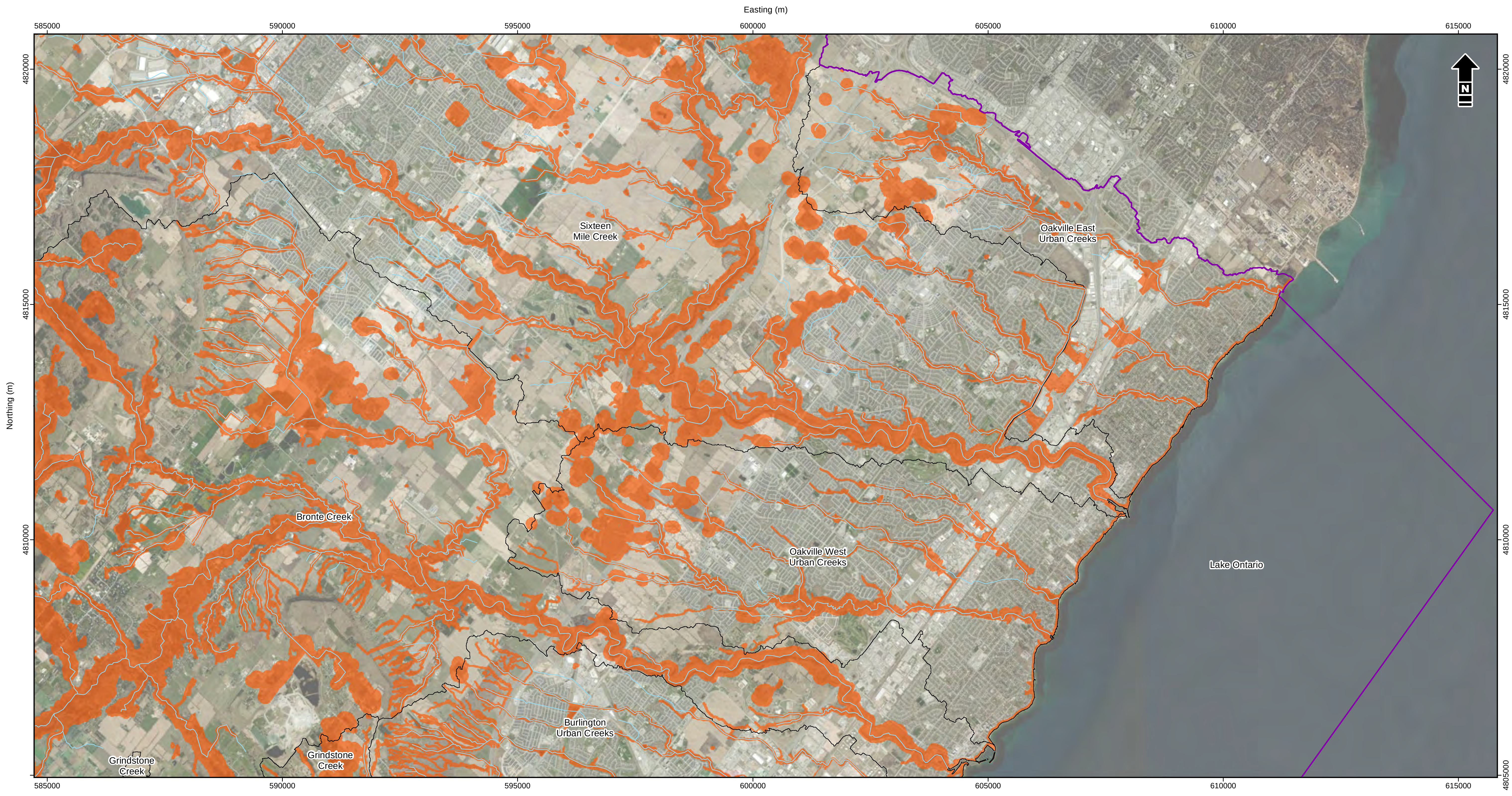
Conservation Halton
Climate Change Vulnerability and Risk Assessment

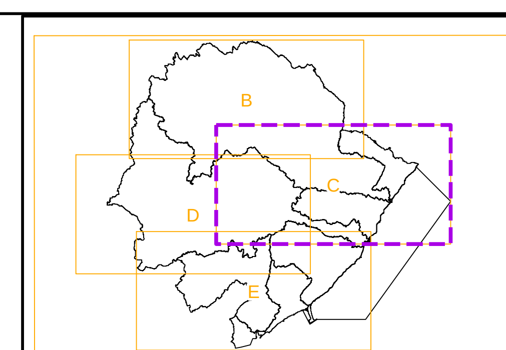
Approximate Regulation Limits

Date:	Project:	Submitter:	Reviewer:
February 2024	36679	A. Rafeiro	F. Tonto

Figure 2B



Conservatino Halton Jurisdictional Boundary
Watershed
Approximate Regulated Areas
Stream



1:80,000 metres
825 0 825 1,650
NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
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Conservation Halton
Climate Change Vulnerability and Risk Assessment

Approximate Regulation Limits

Date: February 2024	Project: 36679	Submitter: A. Rafeiro	Reviewer: F. Tonto

Figure 2C

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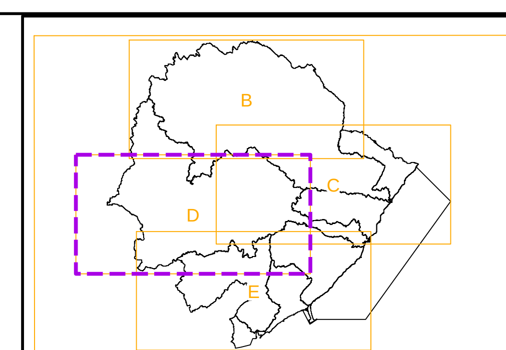
Approximate Regulation Limits

Conservatino Halton Jurisdictional Boundary
Watershed
Approximate Regulated Areas
Stream



1:80,000 metres
825 0 825 1,650
NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
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Conservation Halton
Climate Change Vulnerability and Risk Assessment

Date:	Project:	Submitter:	Reviewer:
February 2024	36679	A. Rafeiro	F. Tonto

Figure 2D

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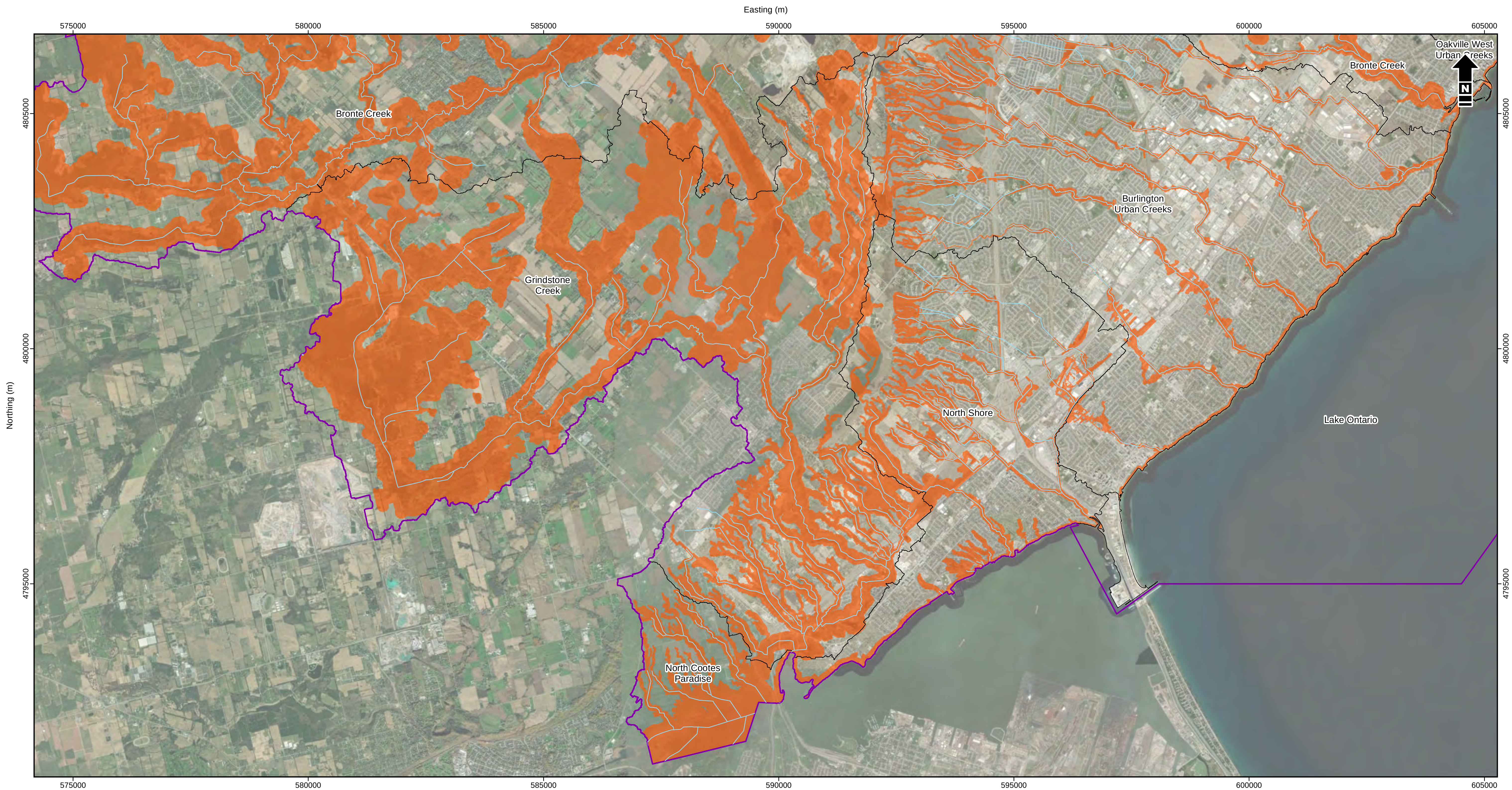
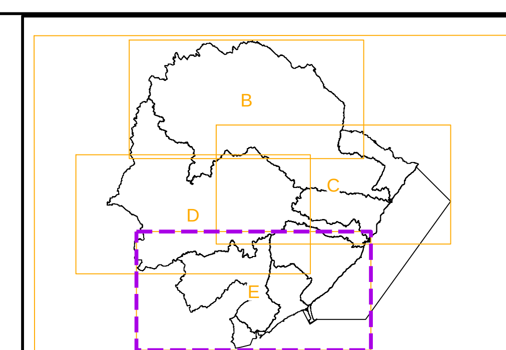


Conservatino Halton Jurisdictional Boundary
Watershed
Approximate Regulated Areas
Stream



1:80,000 metres
825 0 825 1,650
NAD 1983 UTM Zone 17N

Matrix Solutions Inc.
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Conservation Halton
Climate Change Vulnerability and Risk Assessment

Approximate Regulation Limits

Date:	Project:	Submitter:	Reviewer:
February 2024	36679	A. Rafeiro	F. Tonto

Figure 2E

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