Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

LAKESHORE TRANSPORTATION STUDIES - LAKESHORE BUS RAPID TRANSIT (BRT) STUDY
CLIMATE CHANGE AND SUSTAINABILITY REPORT
MISSISSAUGA, ONTARIO

Prepared for:
HDR CORPORATION

Prepared by:
MATRIX SOLUTIONS INC.

Version 1.0
June 2023
Guelph, Ontario

Suite 3001, 6865 Century Ave.
Mississauga, ON, Canada L5N 7K2
T 905.877.9531 F 289.323.3785
www.matrix-solutions.com

LAKESHORE TRANSPORTATION STUDIES - LAKESHORE BUS RAPID TRANSIT (BRT) STUDY

CLIMATE CHANGE AND SUSTAINABILITY REPORT

MISSISSAUGA, ONTARIO

Prepared for HDR Corporation, June 2023

Natalie Burrows, M.A.Sc., P.Eng.
Water Resource Engineer

reviewed by
David Van Vliet, M.A.Sc., P.Eng.
Senior Vice President, Technical Excellence & Innovation

DISCLAIMER

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	23-Mar-2023	Draft	33023-512 Lakeshore BRT Study Climate and Sustainability R 2023-03-23 draft V0.1.docx	Issued to client for review
V1.0	06-June-2023	Final	33023-512 Lakeshore BRT Study Climate and Sustainability R 2023-06-06 final V01.0.docx	Issued to client

EXECUTIVE SUMMARY

HDR Corporation and the City of Mississauga (the City) retained Matrix Solutions Inc. to complete a climate and sustainability report to support the Transit Project Assessment Process (TPAP) and environmental assessment (EA) for the Lakeshore Bus Rapid Transit (BRT) Study. The Lakeshore BRT Study includes dedicated public bus transit lanes and designated bike lanes for a 2 km segment along Lakeshore Road from Etobicoke Creek to East Avenue. HDR is developing the preliminary design and completing the TPAP for the Lakeshore BRT Study. A TPAP is an expedited EA process in which the environmental effects of the project are analyzed, including climate change considerations.

This report follows the provincial guide *Considering climate change in the environmental assessment process* (MOECC 2017) and builds upon the assessments completed for the Climate Lens. This report is comprised of three parts:

- Part One describes how the TPAP incorporates the provincial guidance for considering climate change in EAs/TPAPs.
- Part Two highlights the broader sustainability initiatives that the City has planned in relation to the construction and operation of the Lakeshore BRT with the goal of improving environmental and social outcomes.
- Part Three summarizes the design considerations, mitigation measures, and other initiatives outlined in Parts One and Two that are helping to meet the provincial expectations and sustainability goals.

Summary of Part One

Part One assesses the effects of the Lakeshore BRT Study project on climate change (mitigation) for both greenhouse (GHG) emissions and the impacts to carbon sinks. GHG emissions are quantified for the existing infrastructure (baseline scenario), construction, and the project duration. The GHGs quantified include carbon dioxide, methane, and nitrous oxide from the combustion of diesel fuel and gasoline and from offsite electricity production. Project construction will result in approximately 12,481 t of carbon dioxide equivalent (CO_2e) emissions. Once built, the project is estimated to result in ongoing reductions of GHG emissions, based primarily on lower vehicle fuel use relative to the baseline scenario. Cumulatively, GHG emissions are estimated to reduce by 968 t CO_2e emissions over the 60-year lifetime of the project as compared to the baseline scenario. The project impact on carbon sinks is relatively small compared to GHG emissions, as the area is already highly urbanized and road widening is offset with wide boulevards and tree planting.

The potential effects of climate change on the Lakeshore BRT project (adaptation) are evaluated through a Climate Risk Assessment. Matrix (2021) completed an original Climate Lens Climate Risk Assessment to determine the impact of climate hazards on key project infrastructure components. Matrix updated the climate risk assessment to focus on mitigations for high-risk interactions that are addressed in the preliminary design phase. The climate risk assessment focused on future climate conditions for the 2051-2080 period using an ensemble of climate models under the high-emissions representative concentration pathway (RCP) 8.5. The greatest risks identified through the climate risk assessment process relate to extreme heat, extreme rainfall, riverine flooding, and wind, as these have the greatest potential for injury or loss of life. High risks mitigated through the preliminary design include extreme high temperatures, extreme rainfall, and extreme flooding. Additional mitigation measures are identified for high-risk interactions, including remedial engineering actions outstanding for detailed design and future monitoring actions and management actions.

Summary of Part Two

Part Two identifies several sustainability initiatives that may be relevant to the completion of this project. The Lakeshore BRT project could contribute to advancing some of the environmental and social outcomes identified by these initiatives. These relevant initiatives include *Our Future Mississauga, Strategic Plan* (City of Mississauga 2009), *Living Green Master Plan* (City of Mississauga 2012a), *Green Development Standards, Going Green in Mississauga* (City of Mississauga 2012b), I*nvasive Species Management Plan and Implementation Strategy* (City of Mississauga 2021a), *Cycling Master Plan* (City of Mississauga 2018), *Climate Change Action Plan* (City of Mississauga 2019a), *Mississauga Transportation Master Plan* (City of Mississauga 2019b), *Mississauga Official Plan* (City of Mississauga 2021b). External sustainability initiatives considered include *Climate Change Strategy: Protecting Today for Resilience Tomorrow 2019-2023* (CVC 2019) and *Climate Change Master Plan: Lead, Influence, Transform 2020-2030* (Region of Peel 2019).

Summary of Part 3

Part Three includes a table (Table 22) summarizing how the preliminary design is helping to meet the provincial expectations in relation the City's sustainability goals and mitigation measures described in Part Two. Mitigations are described for each identified sustainability strategy goal for both mitigating the effects of the Lakeshore BRT project on climate change and the effects of climate change on the Lakeshore BRT project (adaptation) as it relates to the preliminary design of project components.

TABLE OF CONTENTS

IN-TEXT FIGURES

IN-TEXT TABLES

APPENDICES

INTRODUCTION

HDR Corporation and the City of Mississauga (the City) retained Matrix Solutions Inc. to complete a climate and sustainability repot as part of the Lakeshore Transportation Studies for Lakeshore Road East and Royal Windsor Drive (the project). The project includes the following parts:

- Lakeshore Bus Rapid Transit (BRT) Study: Transit Project Assessment Process (TPAP) and preliminary design for a 2 km section of Lakeshore Road from Etobicoke Creek to East Avenue.

- Lakeshore Complete Streets Study: Schedule C Class Environmental Assessment (EA) study and preliminary design for Lakeshore Road and Royal Windsor Drive from East Avenue to the Oakville border.

- New Credit River Active Transportation (AT) Bridge Study: Schedule B Class EA study and preliminary design for an active transportation bridge crossing over the Credit River north of Lakeshore Road.

Matrix has completed this climate change and sustainability report for the Lakeshore BRT Study of the project.

A TPAP is an expedited environmental assessment (EA) process in which the environmental effects of a project are analyzed. The Lakeshore BRT is planned to extend for 2 km along Lakeshore Road from Etobicoke Creek to East Avenue (Figure 1). This segment of Lakeshore Road was previously referred to as Segment 7 (City of Mississauga & HDR Inc. 2019).

Climate change consideration is required as part of the EA TPAP process. Matrix (2021) previously completed a Climate Lens Assessment for this project. The Climate Lens Assessment addressed the greenhouse gas (GHG) emissions and climate resilience requirements needed to support a funding application for the project.

This climate and sustainability report is prepared to support the TPAP in considering climate change in the EA. This report follows the Ministry of the Environment, Conservation and Parks' (MECP; previously known as the Ontario Ministry of Environment and Climate Change) guide *Considering Climate Change in the Environmental Assessment Process* (CCCEAP; MOECC 2017) and builds upon the assessments completed for the Climate Lens. This report comprises three parts:

- Part One describes how the TPAP incorporates the MECP guidance for considering climate change in EAs/TPAPs.

- Part Two highlights the broader sustainability initiatives that the City has planned in relation to the construction and operation of the BRT, with the goal of improving environmental and social outcomes.

- Part Three summarizes the design considerations, mitigation measures, and other initiatives outlined in Parts One and Two that are helping to meet the MECP's expectations and sustainability goals.

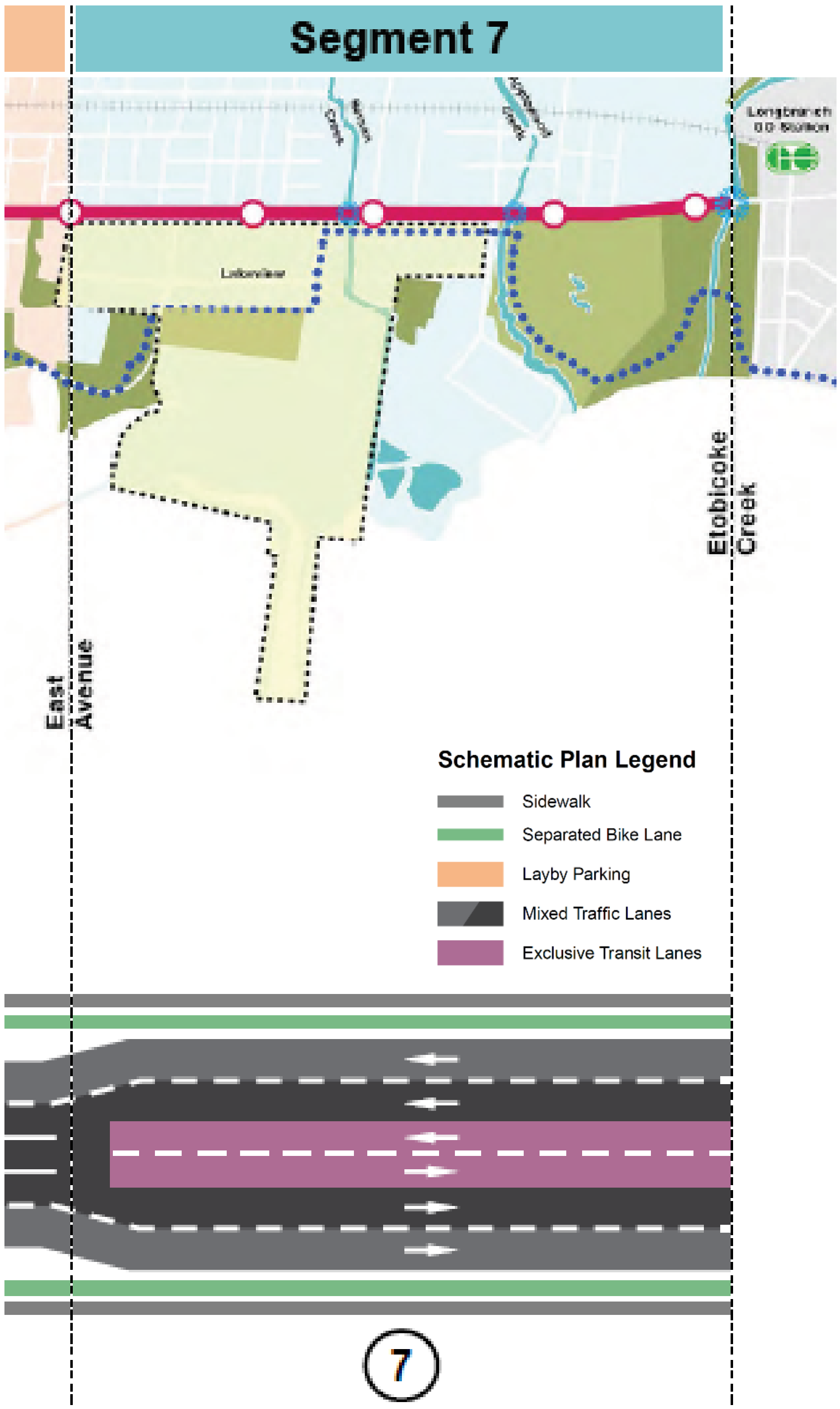


FIGURE 1 Lakeshore Corridor Project Location (City of Mississauga & HDR Inc. 2019)

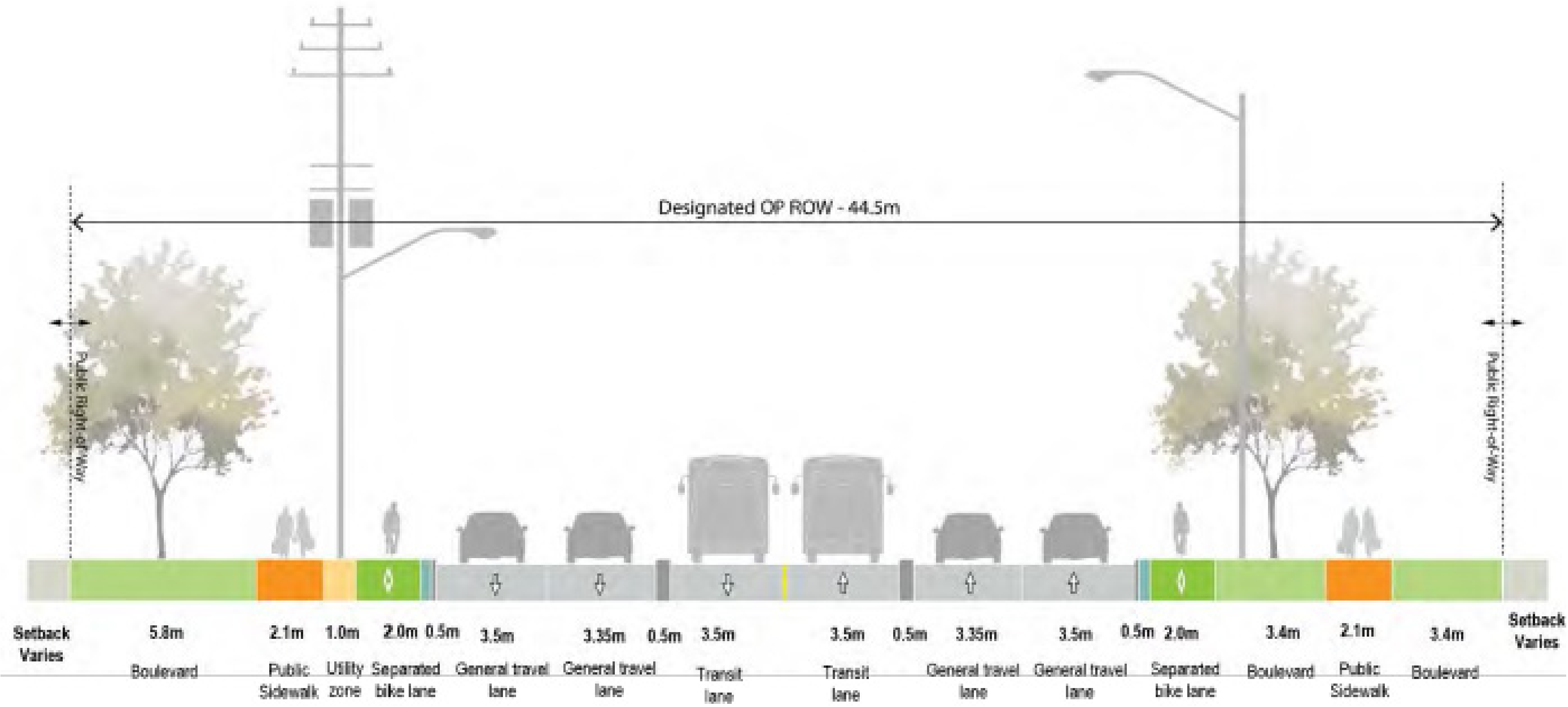


FIGURE 2 Bus Rapid Transit Segment Preferred Right-of-way Alternative (City of Mississauga & HDR Inc. 2019)

PART 1: CLIMATE CHANGE MITIGATION AND ADAPTATION

The CCCEAP guide (MOECC 2017) was created as a companion to the provincial codes of practice that guide key aspects of the EA process. The guide supports the province's Climate Change Action Plan and complements and supports climate focused policies of the *Provincial Policy Statement, 2020* (MMAH 2020; e.g., green infrastructure, energy conservation, flooding risks under climate change).

The CCCEAP guide specifies that, when preparing an EA, consideration should be given to the impacts of a project on climate change, the impacts of climate change on a project, and the means of minimizing negative impacts during project implementation. The CCCEAP guide provides several approaches to consider climate change in project planning, an overview of tools and methodologies for climate change adaptation and resiliency, and examples of how climate change vulnerability has been assessed for existing projects. Climate change considerations should include:

- **Mitigation:** consider alternative methods to reduce a project's expected GHGs emissions and impacts on carbon sinks.
- **Adaptation:** consider future changes in climate to increase resilience of a project to changing climatic conditions.

The following sections detail the climate change mitigation and adaptation considerations for the Lakeshore BRT TPAP. Sections 2 and 3 summarise the GHG Assessment and Climate Change Resiliency Assessments respectfully, completed as part of the Climate Lens Assessment. For further details, refer to Matrix (2021).

1 EFFECTS OF THE TRANSIT PROJECT ON CLIMATE CHANGE (MITIGATION)

Infrastructure and transit projects can impact the atmosphere by altering emissions of GHGs and by changing the landscape altering the ecosystems ability to remove carbon dioxide (CO_2) from the atmosphere (carbon sinks). This section details the project's expected production of GHG emissions and impacts on carbon sinks. The Climate Lens Assessment (Matrix 2021) estimated the GHG emissions from the existing infrastructure (baseline scenario), construction, and the project.

Matrix Solutions quantified GHG emissions using the 2020 National Inventory Report (ECCC 2020) and the Life Cycle Analysis Reporting Template (NRCan 2020a). The Climate Lens Assessment considered a shift toward public transit and bike use as a result of the project. The project's expected lifetime was assumed to be 2027-2086.

Construction, baseline scenario, and project data were provided by the project designers, HDR, and the City (the project proponent).

1.1 Greenhouse Gases

The GHGs quantified included carbon dioxide, methane, and nitrous oxide from the combustion of diesel fuel, gasoline, and from offsite electricity production.

1.2 Boundary Assessment

GHG emissions were quantified following the *Global Protocol for Community-scale Greenhouse Gas Emission Inventories* (WRI 2014). Table 1 describes the direct and indirect emissions included in the project.

TABLE 1 Direct and Indirect Emissions

Scope Type	Scope Description	Project Scope
Scope 1 Direct	GHG emissions occurring from sources located within the assessment boundary.	• GHG emissions from combustion of fossil fuels during the construction of the project • GHGs emissions from combustion of fossil fuels for vehicles travelling along the BRT segment • GHGs from maintenance vehicles and equipment completing maintenance activities on the BRT segment
Scope 2 Indirect	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam, and/or cooling within the city boundary.	• purchase of electricity for construction equipment • vehicles travelling around the BRT segment • streetlights and other small electrical fixtures
Scope 3 Upstream/ Downstream	Indirect GHG emissions occurring in the value chain, including both upstream and downstream emissions.	• upstream effects include an expected shift in fuel sources toward electric vehicles • downstream effects: impacts on traffic through increased capacity for cyclists and public transit movement of people • shift toward public transit and bike use as a result of the project

Notes:
BRT - bus rapid transit
GHG - greenhouse gas

As described in following sections, indirect emissions (Scope 2) and maintenance emissions from both the project and baseline scenarios were considered insignificant (<1%) and were excluded from the assessment.

The project GHG assessment considers both upstream and downstream effects. The project design includes two dedicated transit lanes and dedicated cycling lanes on each side of the road. GHG emissions considered in the assessment include the shift toward public transit and bike use as a result of the project. Upstream effects include an expected shift in fuel sources toward electric vehicles. Downstream effects of the project will show impacts on traffic through increased capacity for cyclists and public transit movement of people.

The Climate Lens project only focussed on emissions of vehicles passing through the project and did not further assess the impact of the project on future traffic patterns and any resulting effects on GHG emissions.

1.3 Assessment Scenarios

In accordance with Climate Lens guidance (Infrastructure Canada 2019), two scenarios have been considered for GHG quantification:

- **Baseline scenario:** The BRT segment continues with the current infrastructure with no change in relative car/bus/bike use.

- **Project scenario:** The BRT segment is developed in accordance with Option 3 of the Master Plan (including designated transit lanes and bike lanes)

Since the existing segment of Lakeshore Road is near its design traffic capacity, it is not feasible to realistically project the GHG emissions associated with the baseline scenario for the design lifetime of the project. However, a hypothetical scenario where the baseline emission intensity is used to extrapolate the baseline GHG emissions based on future passenger-kilometres can be directly compared to the projected project GHG emissions. It was assumed that the total passenger-kilometres each year for the baseline scenario would match the projected total project scenario passenger-kilometres. This approach effectively assumes that while the baseline scenario passenger-kilometres increase year-to-year, relative number of cars and buses will remain the same as 2011 baseline data (status quo). This hypothetical scenario could be achieved by increasing the number of vehicle lanes to meet future demand but not designating new lanes for public transit or bikes (as is the case for the project scenario).

1.4 Assumptions

Table 2 shows the assumptions made in quantifying GHG emissions in the assessment.

TABLE 2 Assessment Assumptions

Baseline Scenario Assumptions	Project Scenario Assumptions
Cars run on gasoline and buses run on diesel fuel.	Cars run on gasoline and buses run on diesel fuel.
No commercial vehicle use (e.g., transport trucks) was included.	No commercial vehicle use (e.g., transport trucks) was included.
Net GHG emissions from maintenance is negligible.	Net GHG emissions from maintenance is negligible.
Traffic volumes exclude travel during the hours of midnight to 6 a.m.	Traffic volumes exclude travel during the hours of midnight to 6 a.m.
Hybrid cars have the same emissions as electric cars in future projections.	Hybrid cars have the same emissions as electric cars in future projections.

Baseline Scenario Assumptions	Project Scenario Assumptions
Electricity production emission factors are assumed to vary through the life of the project.	Electricity production emission factors are assumed to vary through the life of the project.
Bike usage will increase by 0.3% every 5 years in the baseline scenario.	Bike usage will double in the project scenario from the baseline scenario.
The estimated baseline emission intensity was constant through the project lifetime (2027 to 2086).	The estimated 2041 emission intensity was constant through the project lifetime (2027 to 2086).
Baseline construction emissions were similar to project construction emissions.	
For comparison, the total passenger-kilometres for the baseline scenario matches the projected total passenger-kilometres from the project scenario.	

Notes:
GHG - greenhouse gas

1.5 Corridor Usage

1.5.1 Vehicle Usage

The major sources of GHG emissions on Lakeshore Road are the vehicles that drive on it daily. Vehicles include passenger cars, motorcycles, sport utility vehicles, and trucks as well as commercial trucks and transit buses. HDR tabulated car and bus usage on the proposed BRT segment of Lakeshore Road for 2011, which is the basis of baseline vehicle emissions as shown in Table 3. HDR projected car and bus usage on the segment for year 2041. The total number of passenger-kilometres were calculated from multiplying the bus travel distance per day and number of passengers per bus.

TABLE 3 2011 and 2041 Car and Bus Usage of the Bus Rapid Transit Segment

	2011 Data	2041 Data
Car travel	31,993 km/d	55,642 km/d
Average passengers per car	1.23 (1)	1.18 (1)
Total car passenger kilometres	39,351 pkm/d(2)	65,658 pkm/d
Transit bus travel	866 km/d	1,571 km/d
Average passengers per bus	11.94 (1)	14.01
Total bus passenger kilometres	10,340 pkm/d	22,010 pkm/d

Notes:
(1) Average passengers considered as fractions to accurately estimate passenger-kilometres with provided data.
(2) pkm/d - passenger-kilometres per day

1.5.2 Bike Usage

In addition to motor vehicle travel, bike riders using the BRT segment were quantified. The *2018 Mississauga Cycling Master Plan* (City of Mississauga 2018) specifies that 0.3% of all trips were via bikes in 2011 and 0.6% in 2016. A bike use growth rate of 0.3% every 5 years was assumed for the baseline scenario. The *2018 Mississauga Cycling Master Plan* indicates that 30% of people are comfortable biking on most roadways but prefer bike lanes, whereas 61% of people are curious about cycling but afraid of sharing roadways with cars (City of Mississauga 2018). These statistics indicate that over three times as many people would consider using bike lanes compared to sharing roadways. For the project, it was conservatively assumed that bike travel would double for the project scenario compared to the baseline scenario. For further details on calculated usage refer to Climate Lens Assessment (Matrix 2021).

1.5.3 Usage Trends

Figure 3 illustrates the future corridor usage under the baseline and project and highlights both the increased future corridor usage and the shift to public transit and bike ridership from cars.

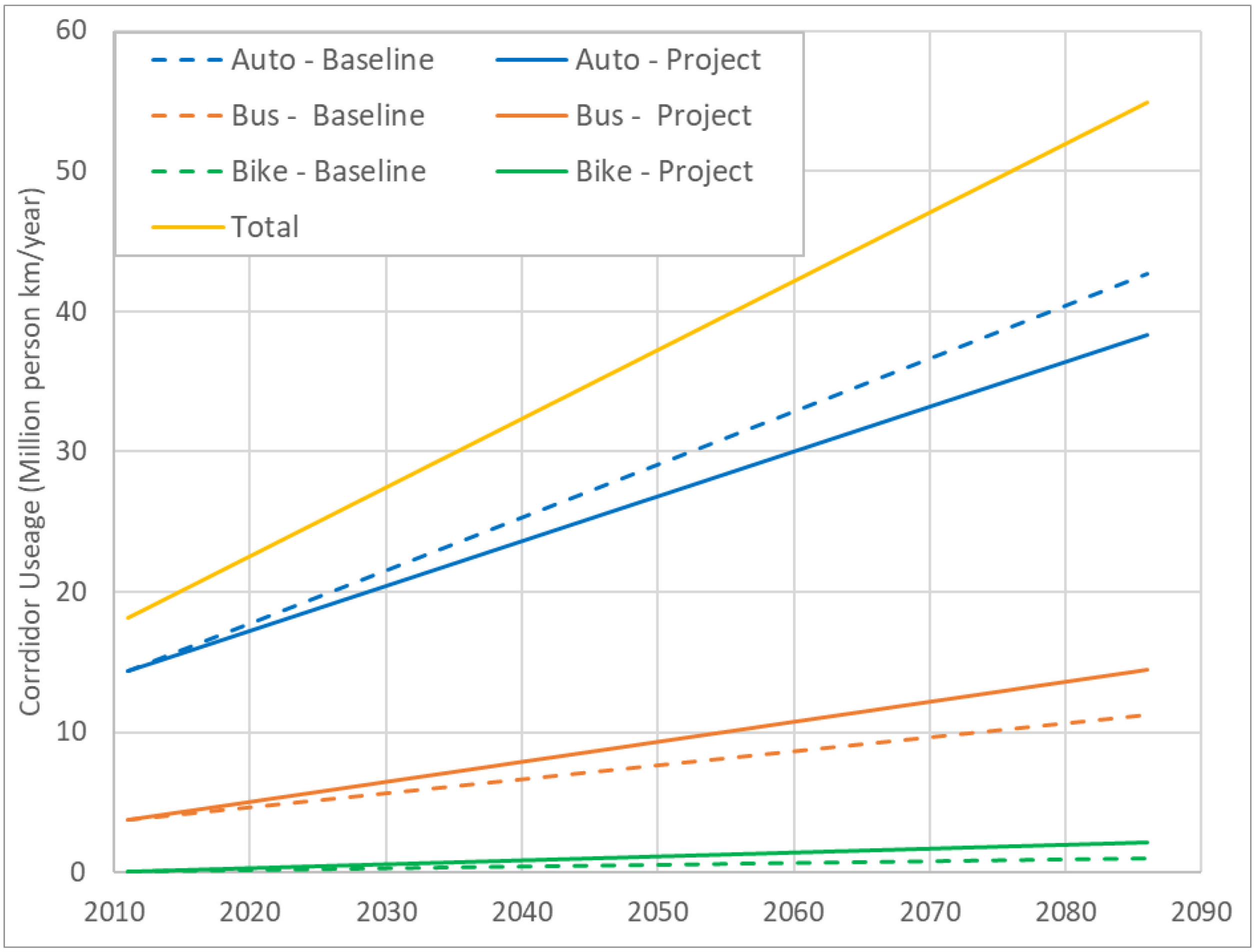


FIGURE 3 Projected Corridor Usage

Since the project lifetime was predicted to be 2027-2086, passenger-kilometres for each mode of transportation for each year were estimated for both the baseline and project cases. Using the 2011 and the 2041 data presented in Table 3, the total number of passenger-kilometres travelled was linearly interpolated between 2011 and 2041 and linearly extrapolated from 2041 to 2086. The total number of passenger-kilometers was assumed to be the same in the baseline and project cases. However, the allocation of car, bus, and bike travel varied between the baseline and project cases to reflect the shift from car travel to bus and bike travel (caused by the dedicated transit lanes and bike lanes) in the project case.

1.5.4 Energy Transition

During the lifetime of the project scenario (years 2027-2086), the balance of fossil fuel driven vehicles and electric vehicles is expected to change. The City has generated the following milestones for cars:

- In 2018, 0.6% of cars were electric.
- By 2030, 10% of cars will be electric or hybrid (assumed as electric).
- By 2050, 100% of cars will be electric or hybrid (assumed as electric).

The percentage of electric car driven passenger-kilometres was linearly interpolated.

Similarly, the City has generated the following milestones for buses:

- In 2020, all buses were assumed to be diesel driven.
- By 2030, 30% of buses will be electric and 70% will be hybrid.
- By 2050, 80% of buses will be electric and 20% will be hybrid.
- By 2060, all buses will be electric.

The percentage of diesel/hybrid/electric bus driven passenger-kilometres was linearly interpolated.

For both the baseline and the project scenarios, emissions were calculated for both fossil fuel burning vehicles and electric vehicles to account for this energy source transition when quantifying traffic emissions.

1.6 Emissions

GHG emissions were quantified for baseline and project. The following sections detail the different contributing emissions sources along the corridor.

1.6.1 Vehicle Emissions

To quantify vehicle emissions in the baseline scenario, all personal vehicles were assumed to be compact cars, which is a conservative assumption that lowers estimated baseline emissions. In addition, gasoline cars and diesel/hybrid buses were assumed to transition to electric drivetrains as per the City's projections (Section 1.5.4). Table 4 shows the fuel efficiency parameters used to estimate 2011 emissions and Table 5 shows emission factors used.

TABLE 4 Emission Parameters

Fuel and Vehicle Type	Baseline
Average gasoline fuel efficiency of cars	9.0 L/100 km; 0.09 L/km [(1)]
Average electric efficiency of cars	17.0 L/100 km; 0.17 L/km [(1)]
Average diesel fuel efficiency of buses	0.488 L/km [(2)]
Average hybrid fuel efficiency of buses	0.403 L/km [(2)]
Average electric efficiency of buses	1.26 kWh/km [(2)]

Notes:
(1) Data from the *2020 Fuel Consumption Guide* (NRCan 2020b).
(2) Data from the Union of Concerned Scientists (UCS 2018).

TABLE 5 Greenhouse Gas Emission Factors

	Carbon Dioxide g CO_2/L [(1)]	Methane g CH_4/L [(1)]	Nitrous Oxide g N_2O/L [(1)]	Carbon Dioxide Equivalent kg CO_2e/kWh [(2)]
Emission factors for light-duty gasoline vehicles	2,307	0.14	0.022	
Emission factors for heavy-duty diesel vehicles	2,681	0.11	0.151	
Emission factor for electricity use in Ontario 2025-2035				0.03

Notes:
(1) Data from Canada's official national GHG inventory (ECCC 2020).
(2) Data from the Life Cycle Analysis Reporting Template (NRCan 2020a).
CO_2 - carbon dioxide
CH_4 - methane
N_2O - nitrous oxide
CO_2e - carbon dioxide equivalent

An example of the baseline emission calculations (carbon dioxide emissions from bus travel) is below:

$$kilometres\ travelled * fuel\ efficiency * emission\ factor = emissions$$

$$866\ \frac{km}{d} * 0.488\ \frac{L}{km} * 2{,}681 \frac{g\ CO_2}{L} = 1{,}133{,}005\ \frac{g\ CO_2}{d}$$

To account for all the GHG quantified from fossil fuel use, global warming potentials (GWP; GoC 2019) were used to convert methane and nitrous oxide emissions to carbon dioxide equivalent (CO_2e) emissions. The GWP used and vehicle emissions are shown in Table 6.

TABLE 6 Global Warming Potentials and 2011 Fossil Fuel Vehicle Emissions

Emissions	Carbon Dioxide (kg/d)	Methane (kg/d)	Nitrous Oxide (kg/d)	Carbon Dioxide Equivalent (kg/d)
Global warming potentials	1	25	298	
Car emissions	6,642	0.40	.06	6,671
Transit bus emissions	1,133	.046	.06	1,153
Bike emissions	0	0	0	0
TOTAL 2011 VEHICLE EMISSIONS (kg CO_2e/d (2))				**7,824**
TOTAL 2011 VEHICLE EMISSIONS (t CO_2e/year)				**2,856**

Notes:
(1) Values in table may not add up precisely due to rounding.
(2) Kilograms of equivalent CO_2 per day.
CO_2e - carbon dioxide equivalent

1.6.1.1 Vehicle Emissions Intensity

The assessment assumes that no electric vehicles operated in 2011. To account for ongoing changes to the vehicle profile from 2027 to 2086 in the baseline case, emission intensities were calculated and are shown in Table 7. Emission intensities were computed as the ratio of baseline emissions total divided by the passenger kilometres. To quantify vehicle emissions in the project scenario, the same assumptions were made as in the baseline scenario for emission parameters and emission factors. The same calculations were used with the 2041 data shown in Section 1.5.

TABLE 7 Emission Intensity Comparison (Equivalent Grams of Carbon Dioxide Per passenger Kilometer, g CO_2e/pkm)

	Baseline Case (g CO_2e/pkm)	Project Case (g CO_2e/pkm)
Gasoline Car Emission Intensity	169.5	176.7
Electric Car Emission Intensity	4.1	4.3
Diesel Bus Emission Intensity	111.5	96.7
Hybrid Bus Emission Intensity	92.0	79.8
Electric Bus Emission Intensity	3.2	2.7
Bike Emission Intensity	0.0	0.0

Notes:
CO_2e - carbon dioxide equivalent

In summary, Table 7 shows a comparison of the emission intensities for the baseline case (based on 2011 data) and for the project case (based on projected 2041 data). Higher car emission intensity in the project case compared to the baseline case is due to a lower occupancy projected per vehicle in the project case (Table 3). Conversely, there is higher projected occupancy for buses in the project case (Table 3). and, therefore, lower bus emission intensities. Refer to the Climate Lens Assessment (Matrix 2021) for sample calculations. Emission intensities along with usage trends (Section 1.5.3) and energy transition (Section 1.5.4) were used to compute the emissions in each year for each vehicle type. The annual and net difference in baseline and project emissions are presented in Section 1.7

1.6.2 Non-vehicle Electricity Emissions

Non-vehicle electricity use constitutes a portion of the GHG emissions from the baseline scenario. Along Lakeshore Road there are streetlights, traffic lights, and other small electrical fixtures that contribute indirectly to the total baseline GHG emissions. Since streetlight electricity use constitutes much less than 1% of baseline emissions, it was assumed that non-vehicle electricity use emissions are insignificant compared to vehicle emissions and they were not considered further in the assessment (Table 8).

TABLE 8 Baseline Offsite Electricity Use and Emissions

	Electricity Use
Estimated number of streetlights	131
Streetlamp power rating	0.045 kW (1)
TOTAL EMISSIONS FROM STREETLIGHT ELECTRICITY USE (g CO_2e/d)	**5,659**
TOTAL STREETLIGHT EMISSIONS AS A PERCENTAGE OF VEHICLE EMISSIONS	**0.07%**

Notes:
(1) Power rating from *Mississauga LED Streetlight Scale-up Case Study No. 3* (City of Mississauga 2013).
CO_2e - carbon dioxide equivalent

1.6.3 Maintenance Emissions

For maintenance emissions, there will be vehicles required for routine maintenance such as snow clearing and street sweeping as well as occasional repairs of the road. The routine maintenance would produce negligible emissions compared to daily traffic. Road resurfacing reduces GHG emissions since the road construction emissions are offset by improved fuel efficiency, reduced tire wear, and reduced vehicle maintenance of vehicles using resurfaced roads (Wang et al. 2019). For these reasons, maintenance emissions were considered negligible and were not quantified for either the baseline or project scenarios.

1.6.4 Construction

Construction GHG emissions will result from the operation of heavy machinery and purchased electricity at the project. Construction is expected to occur from 2024-2026. Data regarding specific construction equipment for the project is unavailable; however, road construction is a common activity in North America and emission factors based on road, bridge, and highway construction have been developed as shown in Table 9. Construction costs have been referenced to 2020 dollars to estimate GHG emissions based on the current project budget.

TABLE 9 Construction Emission Factors

Basis	Emission Factor
	kg CO_2e/\$1[(1)]
Tonnes of GHG emissions per 2002 American dollars of construction cost (Highway, street, and bridge construction)	0.49 [(1)]
Tonnes of GHG emissions per 2020 American dollars of construction cost	0.34 [(2)]
Tonnes of GHG emissions per 2020 Canadian dollars of construction cost	0.26 [(2)]

Notes:
(1) Kilograms of equivalent carbon dioxide per dollar of construction cost
Assume the carbon dioxide equivalent (CO_2e) has remained constant to be conservative for every dollar spent over time
(1) From *Potential for Reducing Greenhouse Gas Emissions in the Construction Sector* (US EPA 2009).
(2) Converted based on inflation of the United Station dollar (USD) from 2002 to 2020 from $1 to $1.45 (Inflation Tool 2020) and the conversion of the 2020 USD to 2020 Canadian dollar (CAD; $1 USD = $1.32 CAD) (XE.com Inc. 2020).

To calculate the construction GHG emissions, the emission factor of 0.26 kg CO_2e/\$1 was applied to the projected average project construction cost of $48,895,500 (City of Mississauga & HDR Inc. 2019). The calculation is shown below:

$$project\ construction\ cost\ estimate * emission\ factor * unit\ conversion = GHG\ emissions$$

$$\$48{,}895{,}500 * 0.26\ \frac{kg\ CO_2e}{\$} * \frac{1\ t}{1{,}000\ kg} = 12{,}713\ t\ CO_2e$$

The total construction emissions associated with the project are estimated at 12,713 t CO_2e.

1.6.5 Operations and Maintenance

The operation of the project will include one major source of GHG emissions: emissions from vehicle traffic (Scope 1, Scope 2, and Scope 3).

Non-vehicle electricity emissions and maintenance emissions are considered negligible for the project and baseline scenario.

1.7 Estimated Net Change in Emissions

Figure 4 shows the yearly emissions comparison based on projected passenger-kilometres and the emission intensities. In addition, the energy source transition from fossil fuel to electric-driven vehicles is accounted for as described in Section 1.5.4. GHG emissions decline significantly by 2050 as vehicles transition to electric.

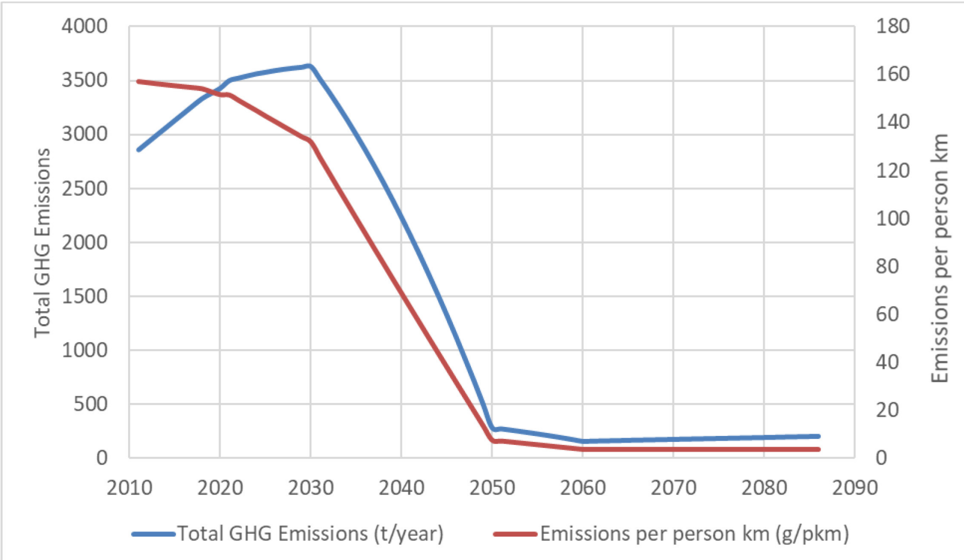


FIGURE 4 Projected Corridor Emissions

The project and baseline emissions, along with net emissions reduction are shown in Figure 5. The estimated net GHG emission reduction in 2030 due to the project is 38 t CO_2e and the total estimated net reduction over the lifetime of the project is 968 t CO_2e. The net GHG emission reductions from the project are primarily due to the increased public transit capacity and bike travel accessibility for the project. Since vehicle fossil fuel consumption is the largest source of GHGs for Lakeshore Road, improvements in public transit and bike travel accessibility result in the largest reductions of GHG emissions.

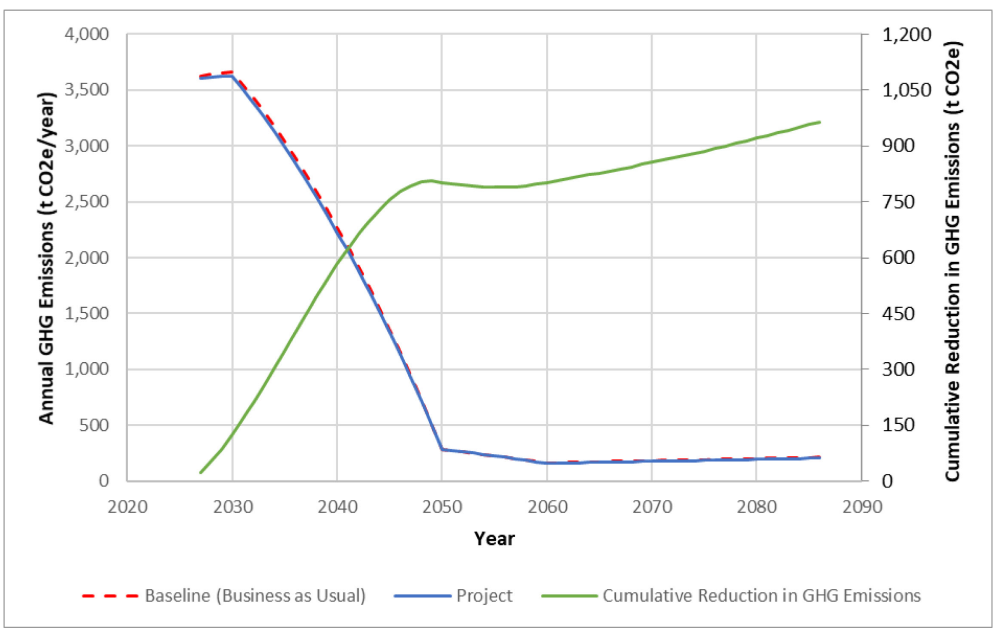


FIGURE 5 Annual Greenhouse Gas Emissions and Net Project Reduction in Greenhouse Gas Emissions

1.8 Carbon Sinks

The project impact on carbon sinks is relatively small compared to GHG emissions for this project. The Lakeshore corridor is already highly urbanized. Part of the plan includes road widening which may increase the amount of paved area, but will not significantly reduce green areas. The wide boulevards can accommodate generous tree planting (City of Mississauga & HDR Inc. 2019). Climate resilient trees will be selected to withstand drought and road salt. Adequate spacing will ensure long-term canopy development. Species will be varied to minimize the spread of disease and pests (City of Mississauga & HDR Inc. 2019).

1.9 Conclusion

The City of Mississauga plans to upgrade Lakeshore Road BRT segment for 60 years to meet increasing passenger volume requirements. Construction of the project is estimated to produce 12,481 t CO_2e of GHG emissions from construction vehicles and machinery. Once built, the project is estimated to result in ongoing reductions of GHG emissions, based primarily on lower vehicle fuel use relative to the baseline scenario, for the projected lifetime of the project. Cumulatively, the GHG emissions reduction is estimated at 968 t CO_2e over the lifetime of the project as compared to the baseline scenario.

2 EFFECTS OF CLIMATE CHANGE ON THE TRANSIT PROJECT (ADAPTATION)

The climate risk assessment for the BRT Segment is based on Infrastructure Canada's Climate Lens General Guidance (Infrastructure Canada 2019) as follows:

1. Establishing the context
2. Risk identification
3. Risk analysis
4. Risk evaluation
5. Risk mitigation

The Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol (the PIEVC Protocol; ICLR 2016) is one of the methodologies identified by Infrastructure Canada (2019) as a methodology for assessing climate change resilience consistent with International Organization for Standardization (ISO) 31000 and was selected for use in this assessment. The PIEVC program is operated jointly by the Institute for Catastrophic Loss Reduction (ICLR), the Climate Risk Institute, and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

2.1 Infrastructure

The preferred right-of-way alternative for the project is shown on Figure 6. The project infrastructure was identified to include the following components:

- roadway (transit lanes, auto lanes, intersections, signals, transit stations/stops)
- boulevard (sidewalks, lighting, bus shelters, cycle track, waterfront trail)
- bridges and culverts (Applewood Creek, Serson Creek, and Etobicoke Creek crossings)
- green infrastructure (e.g., trees)
- stormwater infrastructure
- sanitary infrastructure
- utilities (electrical, gas, water distribution, telecommunications)

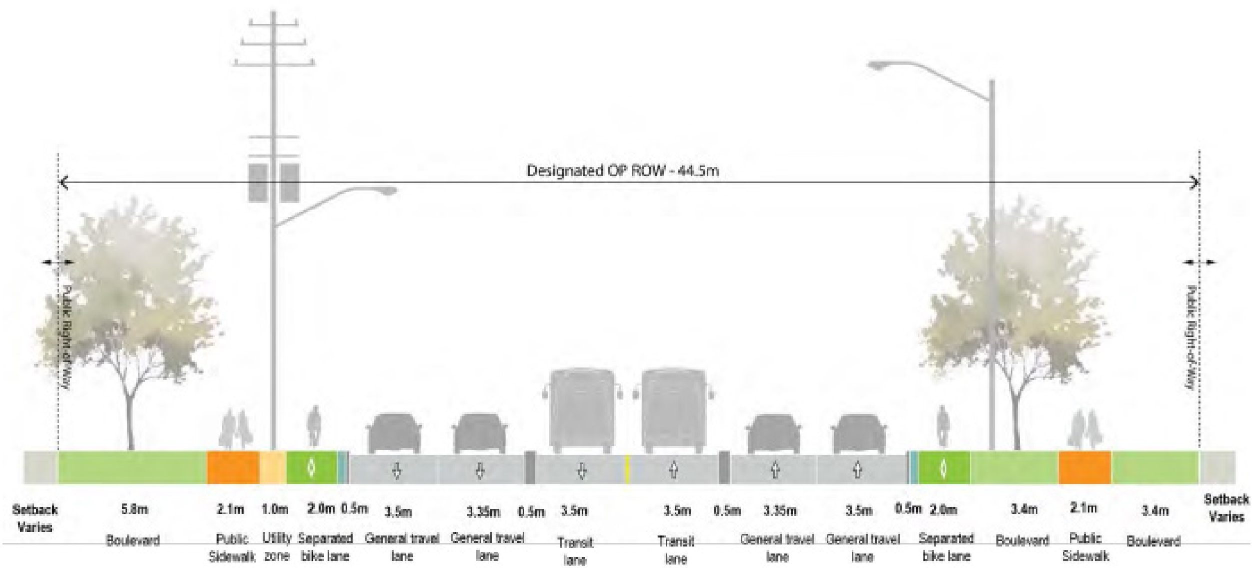


FIGURE 6 Bus Rapid Transit Segment Preferred Right-of-way Alternative (City of Mississauga & HDR Inc. 2019)

Indirect infrastructure includes operations personnel and equipment to construct, operate, and maintain the project infrastructure as well as existing upstream and downstream infrastructure and watercourses that are connected through major drainage and may interact under flooding events. The following upstream and downstream infrastructure and watercourses were identified to have potential interaction with the project infrastructure:

- intersecting streets, which may be connected through the major drainage system
- urban landscape within the regional floodplain, which may be affected through any flooding-related impacts
- Etobicoke Creek, Applewood Creek, Serson Creek

- Marie Curtis Park
- Lakeview Water Treatment Plant and Lakeview Wastewater Treatment Plant
- Waterfront Trail, which intersects and becomes part of the project

2.2 Climate Hazards, Extreme Weather Events, and Hydrology

2.2.1 Climate Hazards

The climate hazards with the potential to interact with the proposed transit corridor infrastructure and adjacent upstream/downstream infrastructure components were identified as follows:

- extreme high temperatures
- extreme cold temperatures
- extreme rainfall
- flooding
- drought
- ice accretion
- snow
- freezing rain
- freeze-thaw
- high groundwater
- hail
- winds
- lightning

2.2.2 Climate Normals and Historical Extreme Events

The baseline period for assessment of 1981-2010 was selected to align with the most recent available climate normals (1981-2010). Relevant climate normal parameters for Toronto Pearson International Airport climate stations are summarized in Table 10. This includes average temperature, rainfall and snowfall, and wind over the 1981-2010 period as well as extreme temperature, precipitation, and wind over the climate station period of record (1937-2013).

TABLE 10 Climate Normal Summary for Toronto Pearson International Airport (Station 6158733)

Climate Variable	Value	Date (1)
Average Daily Temperature (°C)	8.2	1981-2010
Average Annual Rainfall (mm)	682	1981-2010
Average Annual Snowfall (cm)	108	1981-2010
Average Annual Precipitation (mm)	786	1981-2010
Average Wind Speed (km/h)	15	1981-2010
Extreme Maximum Temperature (°C)	38.3	August 25, 1948
Extreme Minimum Temperature (°C)	-31.3	January 4, 1981
Extreme Wind Chill (°C)	-44.7	January 4, 1981
Extreme Daily Snowfall (cm)	40	February 25, 1965
Extreme Daily Precipitation (2) (mm)	121	October 15, 1954
Extreme Snow Depth (cm)	67	January 15, 1995

Climate Variable	Value	Date (1)
Maximum Hourly Speed (km/h)	97	March 15, 1959
Maximum Gust Speed (km/h)	135	July 1, 1956

Note:
(1) Toronto Pearson International Airport Station 6158733 Record: November 1937-June 2013
(2) 128 mm captured at Toronto Pearson International Airport Station 6158731 on July 8, 2013 (Station Record: July 2013-2020)
Source:
Government of Canada (2020)

Two recent extreme rainfall events in the study area have had rainfall intensities exceeding the current 100-year intensity-duration-frequency (IDF) curves. These events include the August 4, 2009, and July 8, 2013, storms. The total rainfall, duration, and maximum 1-hour intensity are shown in Table 11 for comparison against the 100-year design storm and Regional storm (Hurricane Hazel).

TABLE 11 Extreme Rainfall in Project Study Area Compared to Regulatory Events

Rainfall Event	Total Rainfall Amount (mm)	Duration (hour)	1-hour Maximum Intensity (mm/hour)
Mississauga (Cooksville), August 4, 2009	68.0	1.0	68.0
West-central Greater Toronto Area (Pearson), July 8, 2013	126.0	3.0	96.0
Hurricane Hazel, October 15, 1954	285.0	48.0	52.5
100 Year Design Storm	118.0	24.0	50.0

Source:
CVC (2014)

2.2.3 Climate Change

2.2.3.1 Methods, Assumptions, and Data

In their Fifth Assessment Report, the Intergovernmental Panel on Climate Change introduced the concept of representative concentration pathways (RCPs). RCPs are a set of future carbon emissions scenarios and time-dependent projections of the resulting GHG concentrations. GHG emissions have been trending along the pathway of RCP 8.5 (Figure 7), the worst-case scenario with unabated carbon emissions.

The high-carbon emission scenario (RCP 8.5) was selected for this climate assessment. RCP 8.5 is a conservative “worst-case” scenario and may be most likely if significant reductions in GHG are not achieved in the next few decades. The far-future period (2051-2080) was selected, as it aligns with the later period of the 60-year design life of the project.

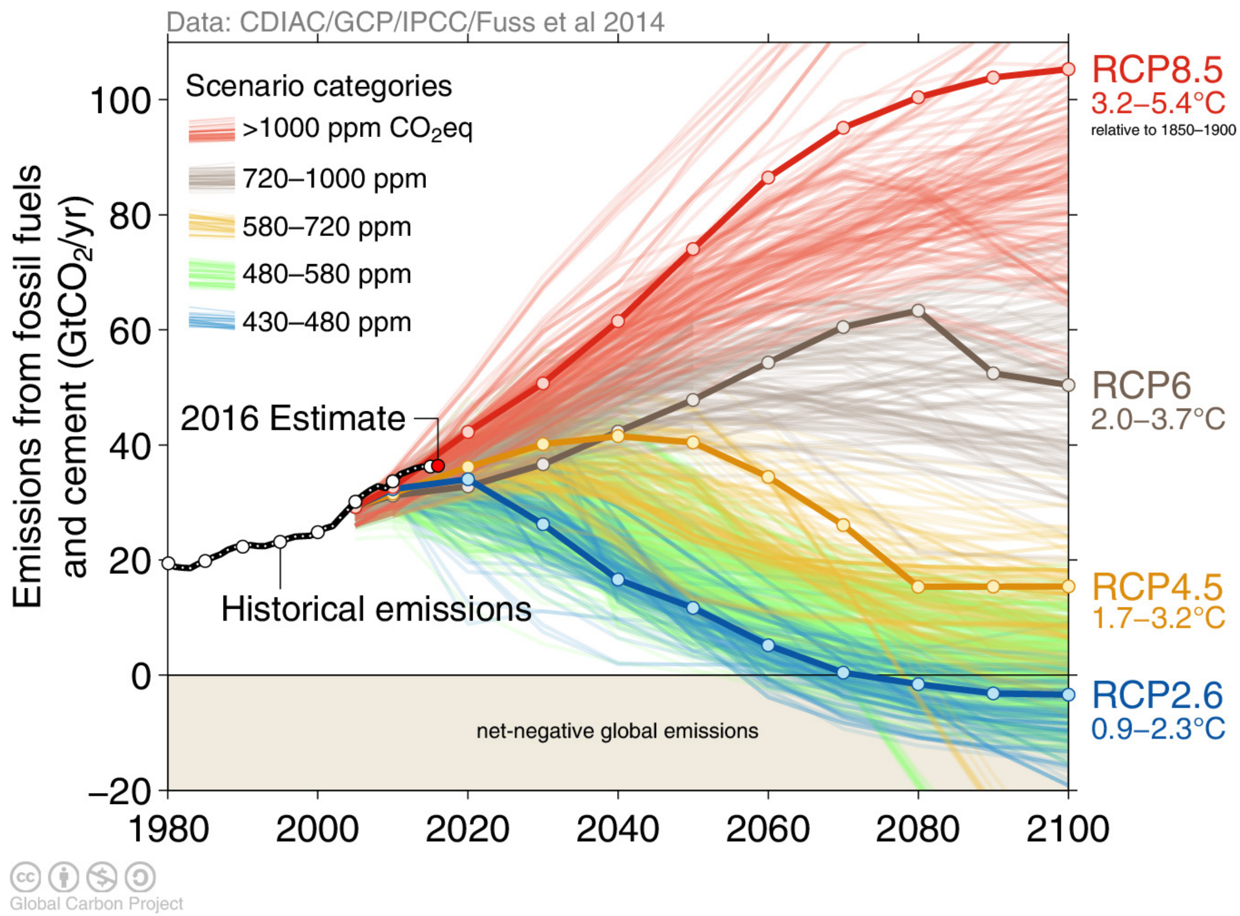


FIGURE 7 Observed Emissions and Emissions Scenarios (Global Carbon Project 2016)

Climate projections were obtained from the *Climate Atlas of Canada* (Prairie Climate Centre 2020) and the *Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change* (IDF_CC; Western University 2018), which are based on an ensemble, or a collection, of Coupled Model Intercomparison Project Phase 5 (CMIP5) Global Climate Models (GCMs).The ensemble approach recognizes that there is considerable uncertainty for a single climate model and averaging over a group of models considers the range of possible scenarios. A literature review was conducted to establish sources for climate change for climate hazards not found within the *Climate Atlas of Canada* or IDF_CC sources.

2.2.3.2 Climate Atlas of Canada, Version 2

Future climate variables relating to temperature, precipitation, hot and cold weather, and growing season are provided by the *Climate Atlas of Canada* for the project area (Prairie Climate Centre 2020). The climate projections are based on an ensemble of 24 CMIP5 GCMs from the Pacific Climate Impacts Consortium. *Climate Atlas of Canada* projections were selected for the RCP 8.5 emissions scenarios for the 2051-2080 future period for the Brampton Region which includes Mississauga and includes the areal average of 18 climate model grid points (Prairie Climate Centre 2020). The 10^{th} and 90^{th} percentile estimates represent low and high ranges of the projections and are considered along with the average and median ensemble prediction to represent the variability and uncertainty in future projections. Table 12 summarizes the baseline, 10^{th} percentile, median (50^{th} percentile), 90^{th} percentile, and average future ensemble projections for the RCP 8.5 scenario. The change in future relative to baseline is computed from the median of the future ensemble.

The climate models project a warmer wetter future, with 4°C increase in average temperature and 6% more precipitation annually under the median projection. Temperature increases are fairly consistent across seasons. The greatest increase in precipitation is in winter and spring, with a reduction in summer and fall precipitation. The number of wet and dry days remains relatively constant in the future period.

The future climate models project a significant increase in very hot days and heatwaves. Decreased summer precipitation and increased summer temperature will result in an increase in evapotranspiration and may result in more frequent drought events. Longer growing season and shorter frost periods are also forecasted with increased average temperatures across all months.

Groundwater infiltration and recharge rates are likely to increase with the projected increase in winter and spring precipitation and fewer days with frozen ground, resulting in higher water table more frequent saturated soil conditions during winter and spring periods.

Warming winters will result in a significant decrease in the number of extreme cold days. Increased winter precipitation coinciding with warmer temperatures will result in less precipitation falling as snow and more as rainfall. There have been some anecdotal observations of recent increases in freeze thaw cycles, contrary to projected decreases. Although freeze-thaw events are projected to decrease substantially over the lifespan of the project on an annual basis, the changing winter seasonality may mean more mid-winter (January/February) freeze thaw and snowmelt events which normally occur during the shoulder season.

TABLE 12 Climate Atlas Baseline and Future Projections (Representative Concentration Pathway 8.5) for Brampton/Mississauga Region

Category	Variable	Baseline (1981-2010)	Future (2051-2080) Ensemble				Future Change	
			10th	Median	90th	Average	△	%
Seasonal Temperature	Mean Temperature - Annual	8.03	10.6	12.1	13.8	12.1	4.1	
	Mean Temperature - Spring	6.52	7.90	10.0	12.3	10.1	3.5	
	Mean Temperature - Summer	19.8	22.2	24.0	25.9	24.0	4.2	
	Mean Temperature - Fall	9.62	12.0	13.9	15.7	13.8	4.3	
	Mean Temperature - Winter	-3.13	-2.31	0.40	3.11	0.41	3.5	
	Maximum Temperature - Annual	12.9	15.2	17.0	18.8	17.0	4.1	
	Maximum Temperature - Spring	11.8	12.7	15.2	17.9	15.2	3.4	
	Maximum Temperature - Summer	25.5	27.9	30.1	32.1	30.1	4.6	
	Maximum Temperature - Fall	14.1	16.7	18.8	20.8	18.8	4.6	
	Maximum Temperature - Winter	-0.23	1.00	3.60	6.40	3.65	3.8	
	Minimum Temperature - Annual	3.23	5.80	7.20	8.91	7.26	4.0	
	Minimum Temperature - Spring	1.44	3.00	4.80	7.00	4.90	3.4	
	Minimum Temperature - Summer	14.2	16.3	17.8	19.8	18.0	3.6	
	Minimum Temperature - Fall	4.89	7.20	8.90	10.60	8.94	4.0	
	Minimum Temperature - Winter	-7.81	-5.90	-2.80	-0.10	-2.90	5.0	
High Temperature	Very Hot Days (+30°C)	13.1	34.1	58.2	82.7	58.3	45.0	+343
	Tropical Nights	5.57	17.1	32.8	56.6	34.9	27.2	+489
	Warmest Maximum Temperature	33.5	35.6	38.5	41.9	38.6	5.04	+15
	Summer Days	63.0	95.4	115	133	114	51.9	+82
	Cooling Degree Days	265	503	711	958	725	446	+169
	Number of Heat Waves	1.55	3.80	6.40	9.11	6.46	4.85	+312
	Avg Length of Heat Waves	2.63	4.70	7.20	12.10	8.03	4.57	+174
	Longest Spell of +30°C Days	2.75	6.39	14.8	34.9	17.8	12.1	+438
	Hot (+30°C) Season	68.9	90.8	120.0	151.0	121.0	50.8	+74
	Extremely Hot Days (+32°C)	4.83	14.6	34.70	59.60	36.20	29.90	+619
	Extremely Hot Days (+34°C)	1.23	4.00	17.10	37.80	19.30	15.90	+1,290

Category	Variable	Baseline (1981-2010)	Future (2051-2080) Ensemble				Future Change	
			10th	Median	90th	Average	△	%
Cold Temperature	Very Cold Days (-30°C)	0.06	0	0	0	0	-0.06	-100
	Coldest Minimum Temperature	-23.30	-19.70	-15.40	-10.50	-15.20	7.90	-34
	Heating Degree Days	3,910	2,410	2,870	3,280	2,870	- 1,030	-27
	Mild Winter Days (-5°C)	74.1	16.2	35.3	57.6	36.7	-38.8	-52
	Winter Days (-15°C)	15.2	0	1.20	6.90	2.41	-14.0	-92
	Frost Days	137	61.4	88.9	112.0	87.4	-48.1	-35
Freeze-Thaw	Freeze-Thaw Cycles	70.3	37.4	52.6	66.7	52.0	-17.7	-25
Ice & Snow	Precipitation - Winter	175	141	206	285	210	30.9	+18
	Freezing Degree Days	512	65.1	176.0	347	193	-336	-66
	Icing Days	51.9	6.6	20.8	40.7	22.7	-31.1	-60
Seasonal Precipitation	Precipitation - Annual	823	719	873	1,060	887	49.4	+6
	Precipitation - Spring	200	161	236	326	241	36.4	+18
	Precipitation - Summer	220	125	206	307	212	-14.1	-6
	Precipitation - Fall	223	143	215	316	224	-8.24	-4
	Precipitation - Winter	175	141	206	285	210	30.9	+18
Extreme Precipitation	Heavy Precipitation Days (10 mm)	24.3	20.7	27.3	34.5	27.4	3.01	+12
	Heavy Precipitation Days (20 mm)	6.22	4.50	8.10	12.10	8.17	1.88	+30
	Maximum 1-day Precipitation	37.4	31.2	44.3	76.6	51.4	6.86	+18
	Maximum 3-day Precipitation	46.3	41.2	57.9	95.4	64.6	11.6	+25
	Maximum 5-day Precipitation	54.8	49.3	68.9	110	75.8	14.1	+26
Growing Season and Drought	Frost-free Season	162	185	211	241	212	49.2	+30
	Date of First Fall Frost	286	297	315	333	315	29.0	+10
	Date of Last Spring Frost	122	81.8	101	116	100	-21.4	-18
	Corn Heat Units	3,300	4,100	4,590	5,140	4,590	1,290	+39
	Growing Degree Days (Base 5°C)	2,210	2,770	3,160	3,610	3,180	945	+43
	Growing Degree Days (Base 10°C)	1,260	1,720	2,010	2,380	2,040	754	+60
	Growing Degree Days (Base 15°C)	558	888	1,130	1,420	1,150	571	+102
	Growing Degree Days (Base 4°C)	2,440	3,020	3,430	3,890	3,440	988	+41
	Precipitation - Growing Season	511	384	513	675	521	1.97	0
	Dry Days[1]	206	192	207	222	207	1.10	+1
	Wet Days[1]	159	143	158	172	158	-1.00	-1

Category	Variable	Baseline (1981-2010)	Future (2051-2080) Ensemble				Future Change	
			10th	Median	90th	Average	△	%
Groundwater	Precipitation - Winter	175	141	206	285	210	30.9	+18
	Precipitation - Spring	199.5	161.0	235.9	325.6	241.4	36.4	+18
	Mean Temperature - Winter	-3.13	-2.31	0.40	3.11	0.41	3.53	-
	Mean Temperature - Spring	6.52	7.90	10.0	12.3	10.1	3.48	-

Notes:
(1) No historical data from Natural Resources Canada. Baseline presented is ensemble model median from 1981-2010.
Δ - delta

2.2.3.3 Intensity-Duration-Frequency Curves under Climate Change - Version 4.0

This assessment estimates changes to rainfall intensity for short durations using current and future IDF curves obtained from the IDF_CC Tool v4.0 (Western University 2018). Similar to the *Climate Atlas of Canada*, this online tool uses an ensemble of 24 downscaled CMIP5 GCMs from the Pacific Climate Impacts Consortium. The current and future IDF curves were evaluated at the Environment and Climate Chance Canada Toronto Pearson International Airport climate station (6158731). Table 13 compares the 1-hour historical IDF data to the median ensemble projected future IDF curve. Appendix A provides IDF curve data for all durations.

TABLE 13 Projected Changes in 1-hour Extreme Rainfall (mm) at Pearson Airport

Return Period	Baseline (1950-2017)	Future (2051-2080)	Change	
			△	%
2-year	23.1	26.7	3.6	+16%
5-year	32.0	37.3	5.3	+17%
10-year	38.1	44.9	6.8	+18%
20-year	44.1	51.9	7.8	+18%
25-year	46.0	54.3	8.3	+18%
50-year	52.0	61.9	9.9	+19%
100-year	58.1	70.5	12.4	+21%

Notes:
Δ - delta
Source: Western University 2018

The above results illustrate that the intense rainfall events represented by IDF data are projected to increase by 13% to 22% for all durations and return periods in the 2051-2080 period compared to baseline. This increase in intensity translates to a shift in the future return period as compared to current return periods. As an example, the future 5-year event is similar to the present 10-year event, and the future 10-year event is similar to the present 20-year and 25-year event.

2.2.3.4 Literature Studies & Other Sources

Where the *Climate Atlas of Canada* does not contain data for a given climate variable, a search in the literature was conducted to identify future projections or any historical trends which might continue in the future. Additional climate hazards freezing rain and wind and are described in the following sections.

Freezing Rain

Freezing rain trends and projections were assessed in the *Climate Trends and Future Projections in the Region of Pee*l (Auld et al. 2016). A decreasing trend has been observed historically at Toronto Pearson International Airport between 1950-2000. Future freezing rain events are expected to decrease in the fall and spring and increase in the winter months, for a relatively unchanged annual frequency.

Wind

There has been no visible increase in average or maximum annual wind gusts at Toronto Pearson international Airport (Auld et al. 2016). Cheng et al (2012) found that winds > 70 km/hour would increase by 17% by the 2050s in the Windsor-Toronto corridor under high carbon emissions scenarios. While the frequency of events is projected to increase more for higher winds (>90 km/hour) the uncertainty is greater than the projected increase due to limited historical observations of gusts of this magnitude. There has also been less consensus between different studies on wind projections, further highlighting the uncertainties around projections of this climate variable.

2.2.4 Screening of Potential Climate Hazards

This section describes the potential climate hazards identified in Section 3.2 and some of the potential impacts on BRT infrastructure. After further review of the specific infrastructure components, available climate data, and future climate projections, some hazards are screened out and not carried forward into the risk assessment. A summary of the climate screening and rationale for including a specific variable is provided below in Table 14.

TABLE 14 Climate Hazard Screening

Climate Hazard	Rational
Extreme High Temperatures	Extreme high temperatures will be considered in the risk assessment. The future climate variables all tend to project a significant increase in the annual number of days with extreme high temperatures.
Decrease in Extreme Cold Days (pest die off)	The future climate variables all tend to project a large decrease in the annual number of days with extreme low temperatures. A reduction in the number of extreme low temperature days poses a threat to green infrastructure by not triggering pest die-off events.
Extreme Rainfall	The *Climate Atlas of Canada* and *Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change* (Western University 2018) projects an increase in all measures relating to extreme rainfall. The future intensity-duration-frequency (IDF) curve projections illustrate trends where the current 1:2-year storm intensity may become the future 1:1-year storm intensity, the current 1:5-year storm intensity may become the future 1:2-year storm intensity, and the current 1:10-year storm intensity may become the future 1:5-year storm intensity. An appropriate measure of a threshold for storm intensity is the 1:10-year storm, as this reference is used to design stormwater management infrastructure. Higher-intensity storm events may result in the stormwater management infrastructure reaching capacity and flooding of the major drainage system.
Riverine Flooding	A large portion of the project is located within the regulated floodplain and therefore there is a risk to the project due to riverine flooding. Riverine flood events are thought of being significant at a 1:50-year return period. The future IDF curve analysis suggests that the flows associated with the current 1:100- and 1:50-year flood event may be experienced as a future 1:25-year flood event.
Drought	The future climate projections predict a significant number of increased hot days, annual degree days, and overall, less summer precipitation. As a result, there is a likelihood of additional drought periods in the future that may pose additional risks to trees and vegetation.

Climate Hazard	Rational
Ice, Snow and Freezing Rain	The future climate projections all predict a significant decrease in the potential for ice and snow. Although increased winter precipitation is predicted, higher temperatures will result in much of this precipitation falling as rainfall. It is likely, however, that while the amount and frequency of snow in southern Ontario will diminish, there will be snowstorms and events that cause disruption to traffic and transit. There is a potential for the severity of these events to increase if municipalities make decisions to reduce winter maintenance capacity.
High Groundwater	A combination of warmer springs and winters coupled with greater winter and spring precipitation introduces the potential of higher soil infiltration groundwater rates under wet conditions. These conditions will raise the water table and generally result in wetter shallow soils.
Freeze-Thaw	The *Climate Atlas of Canada* projects that a significant decrease in freeze-thaw days, or days where the temperature fluctuates above freezing and thawing. While the current design standards should be adequate for future decreasing likelihood of freeze/thaw events, this climate parameter is included in the risk assessment, given that anecdotally more freeze-thaw cycles may be observed in the short term.
Winds	The *Climate Atlas of Canada* does not make projections of high wind events. Based on available research projections of increased high wind events is mixed. Cheng et al (2012) found that winds >70 km/hour would increase by 17% by the 2050s in the Windsor-Toronto corridor. While the frequency is projected to increase more for higher winds (>90 km/hour) the uncertainty is greater than the projected increase due to limited historical observations of gusts of this magnitude. Other studies have found little change in wind projections. There is speculation that with increased convective storms associated with a changing climate, there will also be a higher likelihood of high wind events. The City of Mississauga has recognized that wind is a risk, particularly given the study areas location relative to the lake (lake effect winds).

2.3 Risk Assessment

2.3.1 Climate Infrastructure Interactions

Potential interactions between the climate hazards and the proposed transit corridor components were reviewed and identified. Table 15 identifies the interactions selected as being important to evaluate within the risk assessment.

TABLE 15 Potential Climate Infrastructure Interaction Summary

Infrastructure Components		Extreme High Temperatures	Decrease in Cold Temperatures	Extreme Rainfall	Riverine Flooding	Ice, Snow and Freezing Rain	Freeze Thaw	High Groundwater	Winds	Drought
Boulevard	Sidewalk	Y	N	Y	Y	Y	Y	Y	Y	N
	Street Lighting	N	N	N	N	N	N	N	Y	N
	Cycle Track	Y	N	Y	Y	N	Y	N	N	N
	Bus Shelter	Y	N	N	Y	Y	N	N	Y	N
	Waterfront Trail	Y	N	Y	Y	N	Y	N	N	N
Bridges and Culverts	Etobicoke Creek Bridge	Y	N	Y	Y	Y	Y	N	N	N
	Creek Culverts	Y	N	Y	Y	Y	Y	N	N	N
Green Infrastructure	Trees	Y	Y	N	N	Y	N	N	Y	Y
	Landscape design around stations	Y	Y	N	N	Y	N	N	Y	Y
Roadway	Curb	N	N	N	N	N	Y	N	N	N
	Signage	N	N	N	N	N	N	N	Y	N
	Sub-Base	Y	N	N	N	N	Y	Y	N	N
	Surface	Y	N	Y	Y	Y	Y	N	N	N
	Transit Stations/Stops	N	N	Y	Y	Y	N	N	Y	N
	Signals)	N	N	Y	N	Y	N	N	Y	N
	Intersections	N	N	Y	Y	Y	N	N	N	N
Sanitary Infrastructure	Sanitary Sewers	N	N	Y	N	N	N	Y	N	N
	Pump Stations & Wet Wells	N	N	Y	Y	N	N	Y	N	N
	Maintenance Holes	N	N	Y	N	N	N	Y	N	N
	Flow & Level Monitors	N	N	Y	N	N	N	N	N	N
	Flow Control Structures	N	N	Y	N	N	N	N	N	N
Stormwater Infrastructure	Storm Sewer	N	N	Y	Y	Y	Y	Y	N	N
	Storm Sewer Outfalls	N	N	Y	Y	Y	N	N	N	N
	Catch Basins	N	N	Y	N	Y	Y	N	N	N
	Pump Stations & Wet Wells	N	N	Y	Y	N	N	N	N	N
	Maintenance Holes	N	N	Y	N	N	N	N	N	N
	Flow & Level Monitors	N	N	Y	N	N	N	N	N	N
	Flow Control Structures	N	N	Y	N	N	N	N	N	N

Infrastructure Components		Extreme High Temperatures	Decrease in Cold Temperatures	Extreme Rainfall	Riverine Flooding	Ice, Snow and Freezing Rain	Freeze Thaw	High Groundwater	Winds	Drought
Utilities	Water Distribution Infrastructure	N	N	N	N	N	N	N	N	N
	Electrical - Transformers	Y	N	Y	Y	Y	N	N	Y	N
	Electrical - Aboveground Distribution	N	N	Y	N	Y	N	N	Y	N
	Utility Poles	N	N	N	N	Y	N	N	Y	N
	Maintenance Holes	N	N	Y	Y	N	Y	N	N	N
	Underground Utilities	N	N	Y	Y	N	Y	Y	N	N
Administration and Operations	Maintenance	Y	N	Y	Y	Y	N	N	Y	N
	Construction	Y	N	Y	Y	Y	N	N	Y	N
Upstream and Downstream	Creeks	N	N	Y	N	N	N	N	N	N
	Downstream Connected Storm Sewers	N	N	Y	Y	N	N	N	N	N
	Urban Landscape - Buildings	N	N	Y	Y	N	N	N	N	N
	Urban Landscape - Business and Commerce	N	N	Y	Y	N	N	N	N	N
	Urban Landscape - Roadways	N	N	Y	Y	N	N	N	N	N
	Urban Landscape - Boulevards	N	N	Y	Y	N	N	N	N	N
	Waterfront Trail	N	N	Y	Y	N	N	N	N	N
	Park	N	N	Y	Y	N	N	N	N	N
	Lakeview Wastewater Treatment Plant	N	N	N	N	N	N	N	N	N

2.3.2 Risk Scoring

A risk assessment was conducted for the Climate Lens Assessment to evaluate the level of risk and identify where mitigation is needed to reduce risk levels. Risk profiles were developed for each infrastructure component and climate interaction. Table 16 shows the five-scale risk matrix (heat map), where risk is evaluated as the multiplication of the likelihood of a climate event and the severity of each climate infrastructure interaction. Risk is then categorized into negligible, low, moderate, high and extreme risk.

TABLE 16 Risk Matrix

Consequences	Very High	5	10	15	20	25
	High	4	8	12	16	20
	Moderate	3	6	9	12	15
	Low	2	4	6	8	10
	Very Low	1	2	3	4	5
		Very Low	Low	Moderate	High	Very High
	Likelihood					

Notes:
Extreme Risk (20-25) Immediate Controls Required
High Risk (10-16) High Priority Control measures required
Moderate Risk (5-9): Some controls may be required to reduce risks to lower levels
Low Risk (3-4): Controls likely not required
Negligible Risk (1-2): Risk events do not require further consideration

2.3.2.1 Likelihood

The likelihood that a climate parameter may increase in the future to a level that may influence the design performance of the infrastructure was assessed using the PIEVC Protocol qualitative scoring approach. The scoring system was modified to a 5-scale version and is consistent with the Climate Lens General Guideline and ISO 31010 Method B.29.

Professional judgement is used to consider if and how a hazard may change over the design life, the change in magnitude and frequency of the event, and the robustness of the forecast. The resulting climate hazard likelihood scores and supporting rational are shown in Table 17.

TABLE 17 Climate Hazard Likelihood

Climate Parameter	Likelihood Score	Professional Judgement/Comments
Extreme High Temperatures	*5*	The average number of extreme hot days is projected to increase by more than 600%.
Decrease in Extreme Cold Days (pest die off)	*5*	Number of annual extreme and very cold days will decrease significantly over the life-cycle. None of the climate predict any days below -30°C for 2051-2080.
Extreme Rainfall	*4*	The analysis predicts that the 1:10-year event used for stormwater design will occur on a 1:5-year frequency.
Riverine Flooding	*2*	The analysis predicts that the 50-year event and 100-year flood events may become a 25-year event. Flooding may also increase during winter events.
Drought	*4*	Longer periods of drought (over 4 weeks) have historically occurred every 3 years in Ontario (Gabriel and Kreutzwiser 1993). Similar number of dry days and an increase in annual precipitation are projected. Drought or periods of stress may increase in the future with increases in high temperature days and small decrease in summer precipitation.
Ice, Snow and Freezing Rain	*3*	Decreased ice and snow due to increased winter temperatures. Consequences may be significant in the future with reduced maintenance
High Groundwater	*4*	Increased annual groundwater recharge due to increased winter temperature and precipitation. Spring and winter precipitation increasing by 18%. Summer evapotranspiration higher due to increased temperatures.
Freeze-Thaw	*5*	Freeze thaw cycles decrease at the end of the project life due to shortened cold season. Anecdotal evidence of having more observations of freeze thaw during historically cold weather months (January/February). Freeze/thaw may be a short-term issue but less of an issue during later stages of the project life cycle.
Winds	5	More convective atmospheric activity may translate to higher wind activity. There is low confidence for higher return winds due to limited historical observations. Uncertainties are significant

2.3.2.2 Consequence Table

Consequence is a measure of potential significance of an interaction between climate hazard and infrastructure component. A consequence scoring table was developed through collaboration with City staff as part of the Climate Lens project and is presented in Table 18. A consequence score was assigned for each climate infrastructure interaction. The consequence scores range from a rating of 0 (no effect) to a rating of 5 (very high severity). The consequences of risks were separated into the three main components:

- people: includes accessibility of the corridor roadway and boulevard, transit disruptions, and healthy and safety

- economic: includes infrastructure damage, repair and operation and maintenance costs, as well as access to public services and business and impacts to damage to private property

- environment: includes environmental and ecological damage

A full definition of the consequence scoring is provided in Table 18. A separate score was applied to each component if there was a consequence associated with the infrastructure-climate interaction.

TABLE 18 Infrastructure Consequence Scoring Descriptions

Rating	Descriptor	People	Infrastructure/Economic	Environment
0	No Effect	• No effects (not evaluated)	• No economic loss, cost to city, or cost to businesses	• No environmental/ ecological damage
1	Very Low	• Temporary impacts only • Full access to roadway and boulevard maintained • No transit service disruption • No health and safety impacts	• No structural or property damage to City or private infrastructure • Can be corrected during the City's regular maintenance cycle • Access to public services and business	• No environmental/ ecological damage
2	Low	• Roadway and boulevard still operable and accessible, but impeded (sidewalk or lane closures, etc.) • No transit service disruption, but potentially reduced localized access • No health and safety impacts	• Minor infrastructure damage (e.g., weathering) • Some extra costs to repair but can be covered within current operations and maintenance and capital budgets • Impeded public and service access to some business	• Minor instances of environmental/ecological damage that could be reversed
3	Moderate	• Temporary loss of access and/or usage of roadway and boulevard and transit stations (hours). • Brief transit service disruption may be possible (hours) • No health and safety impacts	• Manageable infrastructure damage but repair costs may be slightly beyond current operations and maintenance and capital budgets • Brief disruption in public and services access to some businesses	• Isolated but significant instances of environmental/ ecological damage that might be reversed with intensive effort
4	High	• Infrastructure still operable but longer-term localized loss of access (e.g., intersections, laneways) • Lengthy transit service disruption and station closures (days) • Potential health and safety impacts to public users and maintenance staff	• Cost to repair infrastructure outside current O&M and Capital Budgets (people, equipment, services) • Lengthy disruption in public or services access to some business (days) • Damage to private property	• Severe loss of environment/ ecological amenity and a danger of continuing environmental damage

Rating	Descriptor	People	Infrastructure/Economic	Environment
5	Very High	• Loss of life, mobility, access to emergency services • Complete roadway or boulevard replacement due to inability to replace or repair local components • Transit service disruptions (weeks) through the entire length of the project, until repair work of project can be completed	• Loss of public infrastructure, replacement costs outside current operations and maintenance and capital budgets • Lengthy disruption in public or services access to some businesses (weeks) • Damage to private property	• Major widespread loss of environmental/ ecological amenity and progressive irrecoverable environmental damage

2.3.3 Risk Assessment

The product of likelihood and consequence was assessed for each climate interaction to determine the risk score as per Table 16 in Section 2.3.2.

The resulting risk products were screened to identify high risk interactions. High-risk interactions were identified for the following infrastructure-climate interactions in Table 19. The complete risk assessment tables, including the likelihood, severity, and risk scoring for each interaction, refer to Appendix A.

TABLE 19 Risk Assessment - Summary of High-risk Interactions

Infrastructure Category	People	Economic	Environment
Boulevard	• high temperatures • extreme rainfall • riverine flooding • ice, snow, and freezing rain • winds	• high temperatures,	
Roadway	• extreme rainfall • riverine flooding • ice, snow, and freezing rain • winds	• high temperatures	
Bridges & Culverts	• extreme rainfall • riverine flooding • ice, snow, and freezing rain	• high temperatures • riverine flooding	
Green Infrastructure	• winds • ice, snow, and freezing rain	• high temperatures • drought	• high temperature • decrease in cold temperatures • drought
Utilities	• high temperatures • extreme rainfall • ice, snow, and freezing rain • winds	• high temperatures	
Operations	• high temperatures • extreme rainfall • ice, snow, and freezing rain • winds		• extreme rainfall
Upstream and Downstream	• extreme rainfall • riverine flooding	• extreme rainfall	

2.3.4 Risk Mitigation

The Climate Lens framework requires that risk mitigations are specified or recommended for high scoring risks. Infrastructure components with a rating below 5 are considered low risk and likely do not need controls. A risk rating of 5 indicates a special case where the probability is very low, but the severity is very high, or the probability is very high and the severity is very low. Risks between 5 and 9 are moderate and may require some controls. Risk ratings equal to or above 10 are considered high risk and require controls. Table 20 presents a summary of potential mitigations for high and very high-risk interactions based on the risk assessment.

TABLE 20 High and Extreme Risks with Potential Mitigations

Climate Hazard	Infrastructure Impacted	Consequence Category	Risk Rating	Impact	Remedial Engineering Actions Addressed in Preliminary Design Phase	Remedial Engineering Actions Outstanding for Detailed Design Phase	Monitoring Activities	Management Actions
Extreme High Temperatures	Sidewalk, Cycle Track, Bus Shelter, Waterfront Trail, Transformers, Maintenance, Construction	People	Extreme	• reduced usage of sidewalk and cycle track and trail • health impacts to public users • health effects on maintenance and construction personnel • heat waves can also limit construction activities	• Street tree plantings throughout, wherever possible, to provide shade for pedestrians/cyclists • Air conditioning on buses • Passenger shelters at all bus stops in corridor • Enhanced passenger shelters at BRT stops	• consider boulevard and roadway surface materials, bus shelter materials, and that are resilient to high temperatures at design stage	• monitor heat to notify maintenance staff	• policies on working during extreme heat for maintenance staff
	Sidewalk, Cycle Track, Bus Shelter, Waterfront Trail, Etobicoke bridge, Creek Culverts, Trees, Sub-base, Surface, Transformers, Maintenance, Construction	Economic	High	• expansion of sidewalk and cycle track and cracking of surface • expansion of subbase and surface and cracking of surface • expansion of concrete bridge/road above culvert and cracking of surface • heating effects on bus shelter materials	• Not addressed in preliminary design.	• consider boulevard and roadway surface materials (green or cool pavement), and bus shelter materials, that are resilient to high temperatures at detailed design stage (low risk/special case, controls not required)	• monitoring of infrastructure for repairs due to expansion/ cracking	• study monitoring results to identify trends or instances in the City of Mississauga where weathering or failure may be resulting from extreme heat
	Trees Landscape design around stations (trees, public spaces improvements)	Environment	High	• stress on trees and other vegetation • Increased maintenance requirements/operational impact (e.g., watering)	• Tree plantings provided in dedicated soil cells per City standards. • City watering of plants on as-needed basis	• plant drought resilient trees and green infrastructure	• monitoring weather for drought conditions and trees for stress	• increased watering of trees and vegetation
Decrease in Extreme Cold Days (pest die off)	Trees Landscape design around stations (trees, public spaces improvements)	Environment	Extreme	• stress on trees due to less pest/insect die-off	• Not addressed in preliminary design.	• plant pest resilient trees and vegetation trees	• increased monitoring of green infrastructure/ trees for pests	• consider chemical or biological treatments to kill pests if monitoring detects outbreak to prevent further loss of vegetation
Extreme Rainfall	Sidewalk, Cycle Track, Waterfront Trail, Etobicoke bridge, Creek Culverts, Roadway surface, transit stations/stops, signals, intersections, transformers, maintenance and construction, upstream and downstream urban landscape roadways	People	High/Extreme	• flash-flooding of cycle track, waterfront trail, sidewalk • reduced visibility of cyclists and pedestrians during intense rainfall events • intense rainfall causing local flooding of road • intense rainfall causing local visibility problems at intersections and interaction with transit/cyclists/ pedestrians • visibility of signals and signage reduced during high rainfall events	• stormwater management system designed to accommodate runoff from the larger of the 100-year or Regional storm (City of Mississauga's design standards for arterial road) • cycle track and sidewalk set back from roadway, with dedicated roadway crossings (separate cyclist and pedestrian crossings) at intersections • stop bars set back from crosswalks at BRT stops to provide increased visibility for pedestrians crossing Lakeshore	• revision of stormwater design standards (including culverts, outfalls) to account for future climate changes • assess capacity of downstream sewers to accept additional flows • design/construct high visibility signaling and signage	•	• implement appropriate safety procedures for construction and maintenance staff to identify and manage risks from heavy rainfall
	Construction	Environmental	High	• Increased precipitation leading to erosion and sediment impacts to surface water	• Not addressed in preliminary design.	• appropriate erosion and sediment control techniques during construction	• appropriate erosion and sediment control monitoring	• polices in place to ensure that erosion and sediment control techniques used during construction.

Climate Hazard	Infrastructure Impacted	Consequence Category	Risk Rating	Impact	Remedial Engineering Actions Addressed in Preliminary Design Phase	Remedial Engineering Actions Outstanding for Detailed Design Phase	Monitoring Activities	Management Actions
	Upstream & downstream urban landscape buildings and businesses	Economic	High	• local runoff exceeding sewer capacity, flooding roads and urban landscape • road flooding (major system) due to over-capacity sewer system resulting in flooding of surrounding urban landscape • damage to private property	• new stormwater retention cells in boulevards provides additional runoff storage capacity and quality treatment	• revision of stormwater design standards to account for future climate changes • design major system to remove water quickly and limit damage	• monitoring for signs of erosion/weathering due to frequent flooding	• sponsor or cost-share programs to flood-proof buildings within flood-prone areas
Riverine Flooding	Sidewalk, Cycle Track, Waterfront Trail, Etobicoke Creek Bridge, Creek Culverts, Surface, Transit Stations, storm sewer, catch basins, underground utilities, maintenance holes, upstream and downstream urban landscape roadways and boulevards	People	High	• riverine flooding cascading into flooding of boulevard • flooding of creeks, overtopping culverts, inundating road and neighbourhood • potential for roadway and boulevard to convey riverine floodwaters to urban landscape, affecting buildings, roadways, boulevards, pedestrians and cyclists	• No existing issues with flooding at roadway crossings under 100-year storm • proposed culvert modifications designed to accommodate future intensity-duration-frequency for larger returns; based on the larger of the 100-year or Regional storm (City of Mississauga's design standards for arterial road) • new stormwater bioretention cells in boulevards provides additional runoff storage capacity and quality treatment	• Maintain and implement preliminary design stormwater management recommendations	•	•
	Bridges and culverts, Transit stops, upstream and downstream urban landscape,	Economic	High	• erosion damage to bridges and culverts and channel features during high flood events • potential for roadway and boulevard to convey riverine floodwaters to urban landscape, affecting building and businesses		• Implement damage-resilient design techniques for crossings and natural channel features	•	• regular updates to flood hazard mapping • mitigation of upstream contributors to riverine flooding • sponsor or cost-share programs to flood-proof buildings within flood-prone areas
Ice, Snow and Freezing Rain	Sidewalk, Bus Shelter, waterfront trail, Etobicoke Creek Bridge, surface, transit, signals, intersections, trees, power, utility poles, maintenance and construction	People	High	• ice and falling ice safety hazard • freezing rain, ice and snow result in slip hazards and vehicle collision hazards • reduced preparedness for ice and snow in the future may result in disrupted transit service • freezing rain could result in potential power outages, which could cause delays in operations and services; power lines may be damaged by freezing rain; brief (hours) service disruption • reduced maintenance capacity for ice and snow in the future, may result in longer service disruptions • difficult working conditions for staff • risks to construction crews	• Not addressed in preliminary design.	• N/A	• Monitor for ice build-up on above ground infrastructure that could fall. • City maintenance plan for sidewalks, bus stops, and specific trails includes a commitment to clear and salt within set timeframes (within 12 hrs, 24hrs, or 24hrs+ after snowfall), depending on quantity of snowfall	• revisit future climate trends on a regular basis. • maintain sufficient winter maintenance capacity as needed to meet future climate needs. • Maintenance (clearing and removal) of snow and ice

Climate Hazard	Infrastructure Impacted	Consequence Category	Risk Rating	Impact	Remedial Engineering Actions Addressed in Preliminary Design Phase	Remedial Engineering Actions Outstanding for Detailed Design Phase	Monitoring Activities	Management Actions
Drought	Trees Landscape design around stations (trees, public spaces improvements)	Economic	High	• increased maintenance requirements (e.g., watering) • replacement of vegetation if/when needed	• Tree plantings provided in dedicated soil cells per City standards, enabling retention of rainwater to support plantings • City watering of plants on as-needed basis	• plant drought resilient trees and green infrastructure	• monitor health of vegetation growth and resiliency	
		Environment	High	• stress on vegetation leading to potential die-off		• plant drought resilient trees and green infrastructure	• monitoring weather for drought conditions and trees for stress	• increased watering
Winds		People	High	• blowing objects can create safety hazards to pedestrians • falling signs, tree branches, poles, could become safety hazard • hazard to corridor users if aboveground electrical equipment damaged during high winds • high winds risky for maintenance staff and construction workers	• Not addressed in preliminary design.	• aboveground infrastructure (signage, lights, bus shelter) should be resistant to high winds	• inspect trees for broken branches • inspect signage and lighting for damage or weakness	• debris clearing • replacement/rejuvenation of aging signage and lighting

2.4 Mitigation Recommendations

The greatest risks identified through the risk assessment process relate to extreme heat, extreme rainfall, riverine flooding, and wind, as these have the greatest potential for injury or loss of life. Economic risks are generally only high for those infrastructure and climate interactions that may result in flooding.

High temperatures can impact corridor users' and maintenance and construction workers' health and reduce ridership. High temperatures can also increase weathering of infrastructure components (e.g., surface cracking). Arizona State University (Elzomor 2017) completed a study on heat exposure and transit use and identified mitigation measures including urban cover (grass, shrub, tree), urban fabric (cool pavement, green pavement, green wall), and urban metabolism (green roof, solar panel, and water fountain). While these measures may mitigate heat impacts to transit and corridor users, maintenance and implementation costs of these various options should be considered. Mitigation alternatives relating to high temperatures may not be needed at the time of initial construction; however, the City may consider a routine revision of its climate projections and have plans in place to implement these mitigations in the future. The preliminary design includes street tree plantings to provide shade for pedestrians/cyclists, air conditioning on buses, and passenger shelters at all bus stops in corridor (enhanced shelters at BRT stops).

The risk assessment identifies the need for the planting green infrastructure that is resilient to heat, drought, and pests. Longer periods of drought (over 4 weeks) have historically occurred every 3 years in Ontario, while shorter periods (10 to 20 days) occur every year (Gabriel and Kreutzwiser 1993). With decreased summer precipitation and increased temperatures, drought may be realized more frequently, resulting in stress to green infrastructure. The reduction in the number of cold days may result in less pest die off (e.g., Emerald Ash Borer) and more infestation and plant die off as a result. Increased monitoring and watering and the application of insecticides may help mitigate these impacts. However, selecting more resilient trees may reduce the increased maintenance and replacement costs. The Master Plan already recommends mitigations that trees be spaced 8 m apart and within groupings of six or less of the same species to minimize the spread of disease and pests(City of Mississauga & HDR Inc. 2019). The preliminary design notes that trees will be planted in dedicated soil cells per City standards, enabling retention of rainwater to support plantings and that the City will water on an as-needed basis.

The risk of freeze-thaw impacts, mainly pertains to any utilities above the frost depth and the roadway, sidewalks, and trail surfaces. The projected decreasing frequency of freeze-thaw cycles indicate the current standards for minimum cover should still be appropriate in the future if the current future projections are realized. Maintenance relating to freeze-thaw impacts on infrastructure should decrease in the future, however they may increase in the short-term as milder winters are realized until a shortening of the winter season is more realized. Mitigation options are not presented, as the risks are not considered higher than those experienced elsewhere in the City. However, the City's monitoring programs may be oriented at routine monitoring of infrastructure to identify weathering or maintenance trends that are greater than anticipated requirements.

While winter precipitation is projected to increase, warming winters suggest less may fall as snow and the period for freezing rain may shorten with the winter season. Increased volume of winter precipitation can have impact as there may be less infiltration on frozen ground. As the occurrence of snow and ice continue to decrease under a warming future, so too may the preparedness and the capability of the City to respond (maintenance staffing, salt reserves). While the frequency may decrease, the City may still experience events of significant magnitude. The mitigations for ice, snow and freezing rain are more related to monitoring and management and are less specific to the infrastructure design. Falling ice from overhead infrastructure can pose a safety risk and should be monitored and cleared. Ice and snow on sidewalks and roads should be cleared to improve accessibility and safety. The City should continue to revisit its projections of future climate and any changes to its maintenance capacity should only be made when these changes will not introduce greater risk to motorists, cyclists, and pedestrians.

The climate risk assessment identified potential risks relating to intense rainfall and stormwater or overland flooding. In response, the preliminary stormwater management system is designed to accommodate runoff from the larger of the 100 year or Regional storm (City of Mississauga's design standards for arterial road). The cycle track and sidewalk set back from roadway, with dedicated roadway crossings (separate cyclist and pedestrian crossings) at intersections. Finally, stop bars will set back from crosswalks at BRT stops to provide increased visibility for pedestrians crossing Lakeshore Road.

The natural environmental constraints mapping included in the Master Plan indicates that a large section of the corridor is within the regulatory floodplain. The Master Plan identifies potential structure modifications required to widen the watercourse crossings at Etobicoke Creek, Serson Creek, and Applewood Creek. According to the preliminary design study, there are no existing issues with flooding at roadway crossings under 100-year storm. The preliminary design proposes culvert modifications designed to accommodate future intensity duration frequency for larger returns; based on the larger of the 100 year or Regional storm (City of Mississauga's design standards for arterial road). Finally, new stormwater bioretention cells in boulevards provides additional runoff storage capacity and quality treatment.

Storm and sanitary sewers are susceptible to inflow and infiltration (I&I). Groundwater recharge and groundwater levels may increase seasonally in the future as increased winter and spring precipitation are projected. Reduced periods of frozen ground can result in more infiltration during the winter months and is an important consideration for I&I under climate change. The increased frequency of extreme short-duration rainfall events can also impact I&I.

The capacity, age, and location relative to groundwater levels of existing stormwater infrastructure within the corridor should be reviewed prior construction as the greatest opportunity to reduce flooding and to prevent I&I impacts to the infrastructure within the corridor are to upgrade and replace the existing sewers to accommodate future changing IDF and increased groundwater levels. The return on investment of repairing existing systems is low and thus the best opportunity to reduce I&I impacts is during construction of new projects. The benefits of reducing I&I flow include pumping cost savings (reduced conveyance costs); reduced treatment costs and hydraulic benefits (longer service life);

and reduced health risks, property damage and environmental effects (Robinson et al. 2019). Mitigation actions may be needed for construction where sewer inverts are located below the groundwater table.

Wind gusts can pose a safety hazard to pedestrians and maintenance staff and construction workers as blowing objects and falling infrastructure can become a safety hazard. Tree branches can start to break off under gale winds (62 to 74 km/hour) and slight structural damage can occur under strong gale winds (75 to 88 km/hour). Due to the proximity of Lake Ontario, the project area is susceptible to higher winds due to lake affect. To mitigate the safety risk, aboveground infrastructure should be resistant to high winds. Monitoring for damage and weakness in infrastructure can allow for replacement and repair to prevent hazards and loss of infrastructure during future high wind events. Debris clean up may be required following storms.

PART 2: SUSTAINABILITY INITIATIVES

1 INTRODUCTION

In this section the broader sustainability initiatives at various spatial scales/jurisdictions: Municipal, Regional, and Conservation Authorities, are reviewed, highlighting key areas where the BRT project could contribute to advancing their respective environmental and social outcomes.

Municipal initiatives include:

- *Our Future Mississauga, Strategic Plan* (City of Mississauga 2009)
- *Living Green Master Plan* (City of Mississauga 2012a)
- *Green Development Standards, Going Green in Mississauga* (City of Mississauga 2012b)
- *Invasive Species Management Plan and Implementation Strategy* (City of Mississauga 2021a)
- *Cycling Master Plan* (City of Mississauga 2018)
- *Climate Change Action Plan* (City of Mississauga 2019a)
- *Mississauga Transportation Master Plan* (City of Mississauga 2019b)
- *Mississauga Official Plan* (City of Mississauga 2021b)

External initiatives include:

- Credit Valley Conservation's (2019) *Climate Change Strategy, Protecting Today for Resilience Tomorrow, 2019-2023*
- Region of Peel's (2019) *Climate Change Master Plan: Lead, Influence, Transform 2020-2030*

These reports cover a wide range of issues pertaining to Sustainability, and even within the context of environmental and social matters, the scope is extensive. Many reports also reference other strategies and plans, that were developed previously or are considered complementary to their goals and objectives. Even though the BRT project may not be directly related to all of these strategies and plans, they may be indirectly consistent with them.

In applying a sustainability lens on the BRT project, the following common themes emerge:

- Actions to reduce GHG emissions, directed at Climate Change mitigation; and
- Reducing vulnerability of infrastructure assets to the physical impacts of climate change.

By extension, the interface between the BRT project and sustainability issues also includes the interrelationship between the transit line and the surrounding environment, such as the upstream and downstream ecosystems, and the connectivity and access to people, neighbourhoods, and communities that is served. The project per se will help reduce GHG emissions by supporting public transit and active commuting, and will reduce vulnerability of the City's infrastructure assets by being designed and constructed to be more climate resilient. Further benefits can be achieved that go beyond the 2 km section that was assessed, depending upon the measures that are adopted into the final design, the impact of the longer transportation corridor, and how the corridor design helps people, ecosystems, and communities interact.

The discussion addresses each report in chronological sequence of when it was published, noting that in 2017 the City of Mississauga became a signatory to the Global Covenant of Mayors for Climate and Energy, when they joined an international coalition of over 9,000 cities and governments with a long-term vision of advancing voluntary action to combat climate change and create resilient and low-carbon communities. No attempt is made to evaluate and prioritize the strength of the linkages between the BRT project and the broader City initiatives, including differentiating between their role and contribution towards improving environmental and social outcomes. Part 3 summarises how the preliminary design is helping to meet the City's sustainability goals and mitigation measures.

2 MUNICIPAL INITIATIVES

2.1 Mississauga's Strategic Plan (2009)

The plan outlines five key pillars for change, of which three directly apply to the BRT project:

- Move: developing a transit-oriented city, whereby people can get around without an automobile, and transit will be a desirable choice that connects people to destinations;
- Connect: completing our neighbourhoods, whereby communities are connected and residents can engage in active transportation; and
- Green: living green, so that the city co-exists in harmony with its ecosystems, where forests and valleys are protected, and future generations enjoy a clean, healthy lifestyle.

Within each of these strategic pillars for change are a number of strategic goals, that also apply to the BRT project, such as (i) build a reliable and convenient system, by making transit that is frequent, safe, reliable and convenient; (ii) build and maintain infrastructure, that is delivered in a sustainable way; provide mobility choices, such as walking, cycling, and use transit in all seasons; and (iv) promote a green culture, that leads to a change in behaviour to support a more sustainable approach to the environment, minimize our impact on the environment, and contribute to reversing climate change.

2.2 Living Green Master Plan (2012)

The Living Green Master Plan (City of Mississauga 2012a) is linked to the Strategic Plan (City of Mississauga 2009), thereby supports the Move, Connect and Green pillars for change. Of note, this plan promotes the positive long-term impact on the environment by modifying people's behaviours in respect to the way that the City moves people and goods. The Federally funded BRT project supports the plans goal to maximize investment in the expansion of public transit, and for the regional transit system to be funded by higher groups of government.

2.3 Green Development Standards (2012)

The Green Development Standards (City of Mississauga 2012b) indirectly applies to the BRT project as it promotes design that enhances local sustainability and is resilient to flooding. Stormwater retention through Low Impact Development measures and supporting pedestrian and cycling comfort are also indirectly addressed.

2.4 Invasive Species Management Plan and Implementation Strategy (2021)

There does not appear to be any direct relationship between the BRT project and invasive species, insofar as any plantings of vegetation in areas adjacent to the transit corridor should only include indigenous species.

2.5 Cycling Master Plan (2018)

The dedicated cycling lanes in the BRT project supports the Cycling Master Plan (City of Mississauga 2018) vision of cycling that is a way of life in the City of Mississauga, and is made more comfortable, convenient and fun. It addresses the goal of improving safety for cycling, building a connected, convenient and comfortable bicycle network, and reducing the exposure of cyclists to traffic stress and conflict.

2.6 Climate Change Action Plan (2019)

The Climate Change Action Plan (City of Mississauga 2019a) has a vision for Mississauga to become a low carbon and resilient community, and to achieve this vision by meeting the following two goals:

- through mitigation, reduce GHG emissions 80% by 2050, with the long-term goal of becoming a net zero community

- through adaptation, increase resilience and the capacity of the city to withstand and respond to future climate change events by taking action on the highest climate-related risks

Transportation is a major contribution to the City's carbon footprint, and the pathway towards becoming net-zero includes shifting our modes of travel towards lower-emission modes of transportation, such as transit and cycling. We note however that the overall contribution of mode shifting will be influenced by the fuel source for public transit and privately owned vehicles. Nonetheless the BRT project should help increase and improve cycling infrastructure by 2030. In addition, if the next stage of the project involves evaluating flood mitigation alternatives to reduce flood damages, the combined work would contribute to the Climate Change Action Plan's goal to make resilience a cornerstone of infrastructure management and planning by 2030. This applies particularly to Action #12: continue to enhance flood resilience and stormwater management in the context of changing climate conditions.

2.7 Mississauga's Transportation Master Plan (2019)

The Transportation Master Plan (City of Mississauga 2019b) will further the aims of the Strategic Plan and is therefore consistent with the three key pillars of move, connect and green. In addition, the plan outlines six goals and actions that extend to 2041, notably Safety, Integration, Connectivity, and Resilience. In the latter case the Plan seeks to minimize the effects of a changing climate and severe weather events on all parts of the transportation system, through appropriate infrastructure design and operational practices. Further, among their goals and indicators the BRT project helps address the following:

- safety: deaths and serious injuries from transportation,- consistent with the City's Vision Zero approach
- integration: sustainable mode share
- connectivity: travel to jobs
- health: percentage of short trips done by active transportation

2.8 Official Plan (2021)

The proposed new Official Plan (City of Mississauga 2021b) Vision Statement makes direct reference to climate change mitigation and resiliency measures (*Italics added*):

- Mississauga will support a dynamic economy, *expand housing and transportation choices*, protect heritage and environmental features, *increase resilience to climate change*, cultivate inviting public spaces and prioritize design excellence.

The BRT project can also be linked to various themes outlined in the Official Plan review. This includes transportation-related policies that produce better travel options, such as creating a transportation with convenient alternatives to the car; complete streets, where a transportation network is crated that promotes shared and safe spaces among all road users, including pedestrians and cyclists; health options, that includes increasing the use of walking, cycling and transit to support healthy communities; and policy considerations, noting that the plan has a target to have 50% of all trips by sustainable modes by 2041. These policies are also articulated through the Environment, where the City supports healthy, active and resilient communities through Transit and active transportation mode options, in addition to climate resilient development. From a Policy perspective the BRT project with proposed improvements in flood mitigation falls within the natural environment and its role in climate change resilience and stormwater management.

3 EXTERNAL INITIATIVES

3.1 Credit Valley Conservation (2019) Climate Change Strategy: Protecting Today for Resilience Tomorrow 2019-2023

Credit Valley Conservation's Climate Change Strategy (CVC 2019) over 5 years recognizes that addressing climate change successfully required cooperation across agencies and jurisdictions. Three key areas of collaboration are directly or indirectly linked to the BRT project. From a mitigation perspective the strategy identifies support for low carbon communities, while from an adaptation perspective the strategy identifies flood resiliency whereby enhanced ecological resilience can be achieved by restoring and protecting aquatic, terrestrial and wetland habitat. A third key area of cooperation also applies to adaptation through the support for green natural infrastructure, which can play an important role in the adaptive management process. Its applicability to the BRT project is more indirect, insofar as there are limited opportunities to consider natural infrastructure in the design of the transit corridor, but how it is connected to the surrounding area could involve the enhancement of green infrastructure.

The application of Climate Lens guidance to the BRT project also has applicability as an example where climate science is being used to inform decisions and actions that reduce risk from the impacts of climate change. As such the process to assess the project through a climate lens illustrates how the City of Mississauga is meeting Goals 1 and 2 that build climate resiliency:

- Goal 1: Lead Science to Guide Management
  - Apply science to inform decisions/actions that reduce risk from the impacts of climate change, and use this knowledge to guide adaptive management
- Goal 2: Protect Life and Livelihoods
  - Use science to inform and adapt, policy and programming to ensure resiliency in a changing climate, and include real-time monitoring, prediction and warning systems

3.2 Region of Peel (2019) Climate Change Master Plan: Lead, Influence, Transform 2020-2030

In 2017 Regional Council endorsed a Climate Change Statement of Commitment to ensure concrete action is taken to mitigate and adapt to the effects of climate change. This Statement committed the Region of Peel to develop a climate change master plan, effectively updating and expanding their previous plan published in 2011. The Climate Change Master Plan (Region of Peel 2019) is comprised of 20 actions and 66 activities, and the primary outcomes are to reduce emissions and be prepared which reflect the imperative to mitigate and adapt to the effects of climate change. At a high level the Federally funded BRT project helps the Region of Peel achieve all five of their primary and supporting outcomes (Table 21).

TABLE 21 Climate Change Master Plan Outcomes

Outcomes	Description
Primary	
Reduce Emissions	Corporate GHG emissions are reduced by 45% by 2030, relative to 2010 levels
Be Prepared	A safe, secure and connected community is provided by ensuring Regional services and assets are more resilient to extreme weather events and future climate conditions
Supporting	
Build Capacity	Climate change is considered in all decision-making through organization wide climate literacy, planning, and accountability.
Invest	Innovative and sustainable approaches are used to finance action on climate change
Monitor and Report	Progress on addressing Regionally funded climate change work is consistently reported, available, and widely understood

Source: Table 1.1 Climate Change Master Plan (2019)

Although the BRT project itself that was subject to the Climate Lens Guidance will only have a marginal impact on reducing GHG emissions Reduce GHG Emissions across the corridor's 60-year lifecycle, we can expect that the contribution by the corridor itself would be relatively greater by 2030. We note that the electrification of the bus and automobile fleet will not likely happen until well into the next decade, so the contribution of mode shifting to lower emitting public transit and cycling will help the Region achieve its 45% GHG emission reduction target relative to 2010 levels by 2030.

Of their 20 actions aimed at reducing emissions and preparing for climate change, the following four actions have specific relevance to the BRT project, to which it will contribute to social and environmental outcomes:

- Action 9: Support sustainable transportation for commuting - when applied to mode shifting the sustainable transportation strategy envisions that 50% of peak trips will be made by sustainable transportation by 2040.

- Action 13: Identify and Manage Risks to Infrastructure - this will be achieved by developing and implementing climate resilience technical design and performance criteria for infrastructure.

- Action 14: Protect and Increase Green Infrastructure Throughout Peel - depending upon the final design of the transportation corridor and its stormwater management system, the project has the potential to illustrate how to implement green infrastructure elements of the future Storm Servicing Master Plan for Regional Road Infrastructure.

- Action 15: Enhance Standards, Guidelines, and Planning Activities that Pursue Resilient Urban Design and Development - the purpose of this action is to ensure that new infrastructure is planned and built to withstand a range of climate hazards. This includes activities to map and maintain up-to-date data on hazards, vulnerabilities and risks; and in partnership with local conservation authorities and municipalities, align guidelines, standards and tools to further support community flood and heat resiliency planning.

PART 3: SUMMARY

Part 3 summarises how the preliminary design is helping to meet the MECP's expectations in relation the City's sustainability goals and mitigation measures described in Part 2. Rather than summarize the design to meet specific strategic goals for the City, Table 22 is designed to address any of the relevant strategic planning goals identified in Part 2.

TABLE 22 City of Mississauga Sustainability Goals and Mitigation Measures

Strategic Planning Document	Sustainability Strategy Goal	Project Component / Environmental Feature	Measures to Mitigate Effects of the Transit Project on Climate Change	Measures to Mitigate Effects of Climate Change on the Transit Project	Additional Measures to Promote Sustainability	Outcomes
City of Mississauga's Strategic Plan (2009)	**Move**: developing a transit-oriented city, whereby people can get around without an automobile, and transit will be a desirable choice that connects people to destinations; **Connect**: completing our neighbourhoods, whereby communities are connected and residents can engage in active transportation	• Transit lanes • Bicycle lanes	The dedicated transit lanes and bike lanes are expected to result in a decrease in automobile usage and increase in bus and bike usage. GHG emission will reduce due to increased public transit capacity and bike travel accessibility.			Since vehicle fossil fuel consumption is the largest source of GHGs for Lakeshore Road, improvements in public transit and bike travel accessibility result in a reduction of GHG emissions.
	Green: living green, so that the city co-exists in harmony with its ecosystems, where forests and valleys are protected, and future generations enjoy a clean, healthy lifestyle.	• Green infrastructure • Waterfront trail • Creek crossings	The project impact on carbon sinks is relatively small as the Lakeshore corridor is already highly urbanized.	Climate resilient trees will be selected to withstand drought and road salt. Adequate spacing will ensure long-term canopy development. Species will be varied to minimize the spread of disease and pests.		Ecological resilience will be incorporated into the final project wherever technically or economically practical.
	Build a reliable and convenient system, by making transit that is frequent, safe, reliable and convenient; Build and maintain infrastructure, that is delivered in a sustainable way;	• Transit lanes • Bicycle lanes • Waterfront trail • Watercourse crossings • Stormwater infrastructure • Intersections • Bus • Green infrastructure	Reliable and convenient transit will encourage transit usage and reduce vehicle usage.	Intersection safety design considers poor weather conditions		This project contributes to the goal of having a reliable, convenient and sustainable transit system for the City.
	Provide mobility choices, such as walking, cycling, and use transit in all seasons;			Design and maintenance to consider extreme weather to encourage usability in all seasons.		This project provides for multiple choices of transportation.
	Promote a green culture, that leads to a change in behaviour to support a more sustainable approach to the environment, minimize our impact on the environment, and contribute to reversing climate change	• Transit lanes • Bicycle lanes • Waterfront trail •	Reliable and convenient transit will encourage transit usage and reduce vehicle usage. The dedicated bike lanes will encourage more bike usage. GHG emission will reduce due to increased public transit capacity and bike travel accessibility.			Expand transportation choice using lower carbon-emitting options and provide for friendly pedestrian and cycling alternatives. Green boulevards and enhances bus shelters help cultivate inviting public spaces

Strategic Planning Document	Sustainability Strategy Goal	Project Component / Environmental Feature	Measures to Mitigate Effects of the Transit Project on Climate Change	Measures to Mitigate Effects of Climate Change on the Transit Project	Additional Measures to Promote Sustainability	Outcomes
Living Green Master Plan (2012)	Promotes the positive long-term impact on the environment by modifying people's behaviours in respect to the way that the City moves people and goods	• Transit lanes • Bicycle lanes • Waterfront trail	Reliable and convenient transit will encourage transit usage and reduce vehicle usage. The dedicated bike lanes will encourage more bike usage. GHG emission will reduce due to increased public transit capacity and bike travel accessibility.			The Federally funded BRT project maximizes investment in the expansion of public transit, and for the regional transit system to be funded by higher groups of government.
Green Development Standards (2012)	The Green Development Standards indirectly applies to the BRT project as it promotes design that enhances local sustainability and is resilient to flooding. Stormwater retention through Low Impact Development measures and supporting pedestrian and cycling comfort are also indirectly addressed.	• Stormwater infrastructure • pedestrian and cycling infrastructure		new stormwater retention cells in boulevards provides additional runoff storage capacity and quality treatment Street tree plantings throughout, wherever possible, to provide shade for pedestrians/cyclists		
Cycling Master Plan (2018)	The four goals of the Cycling Master plan are to improve safety for cycling, build a connected, convenient and comfortable bicycle network, increase cycling trips in Mississauga, and reduce the exposure of cyclists to traffic stress and conflict. Cycling will become a way of life in the City of Mississauga.	• Bike lanes	The dedicated bike lanes will encourage more bike usage. GHG emission will reduce due to increased public transit capacity and bike travel accessibility.			The dedicated cycling lanes in the BRT project supports the Cycling Master Plan vision of cycling that is a way of life in the City of Mississauga, and is made more comfortable, convenient and fun. It addresses the goal of improving safety for cycling, building a connected, convenient and comfortable bicycle network, and reducing the exposure of cyclists to traffic stress and conflict.
City of Mississauga's Climate Change Action Plan (2019)	The Climate Change Action Plan has a vision for Mississauga to become a low carbon and resilient community	• All parts of the project	Transportation is a major contribution to the City's carbon footprint, and the pathway towards becoming net-zero includes shifting our modes of travel towards lower-emission modes of transportation, such as transit and cycling. We note however that the overall contribution of mode shifting will be influenced by the fuel source for public transit and privately owned vehicles. Nonetheless the BRT project should help increase and improve cycling infrastructure by 2030	If the next stage of the project involves evaluating flood mitigation alternatives to reduce flood damages, the combined work would contribute to the Climate Change Action Plan's goal to make resilience a cornerstone of infrastructure management and planning by 2030. This applies particularly to Action #12: continue to enhance flood resilience and stormwater management in the context of changing climate conditions		This project contributes to the City's vision for becoming a low carbon and resilient community.

Strategic Planning Document	Sustainability Strategy Goal	Project Component / Environmental Feature	Measures to Mitigate Effects of the Transit Project on Climate Change	Measures to Mitigate Effects of Climate Change on the Transit Project	Additional Measures to Promote Sustainability	Outcomes
Mississauga Transportation Master Plan (2019)	Minimize the effects of a changing climate and severe weather events on all parts of the transportation system, through appropriate infrastructure design and operational practices	• All parts of the project		Consideration for extreme temperatures and rainfall addressed in the preliminary design stage: drought resilient tree plantings for shade, A/C on busses, passenger shelters at all stops, stormwater management systems. Mitigations for extreme wind and winter precipitation will be addressed through detailed design		The planning and design of this project has considered the effects of a changing climate and severe weather through the Climate Lens as well as the TPAP stages.
City of Mississauga's Official Plan (2021)	Mississauga will support a dynamic economy, *expand housing and transportation choices*, protect heritage and environmental features, *increase resilience to climate change*, cultivate inviting public spaces and prioritize design excellence.	• All parts of the project	The dedicated transit lanes and bike lanes are expected to result in a decrease in automobile usage and increase in bus and bike usage. GHG emission will reduce due to increased public transit capacity and bike travel accessibility.	Consideration for extreme temperatures and rainfall addressed in the preliminary design stage: drought resilient tree plantings for shade, A/C on busses, passenger shelters at all stops, resilient stormwater management. Mitigations for extreme wind and winter precipitation will be addressed through detailed design.	Expand transportation choices Green boulevards and enhances bus shelters help cultivate inviting public spaces	This project represents an important step in offering new transportation choices, enhancing local environmental features, and increasing resilience to climate change.

CONCLUSIONS

This Climate and Sustainability Report supports the TPAP process associated with the Lakeshore BRT project, following the MECP guide incorporating climate change within the environmental assessment process (MOECC 2017).

As described in this report, GHG emissions were quantified for the existing infrastructure (baseline scenario), construction, and the project. The GHGs quantified include carbon dioxide, methane, and nitrous oxide from the combustion of diesel fuel, gasoline, and from offsite electricity production. Construction of the project will result in approximately 12,481 tonnes of carbon dioxide equivalent emissions. Once built, the project is estimated to result in ongoing reductions of GHG emissions, based primarily on lower vehicle fuel use relative to the baseline scenario. Cumulatively, the GHG emissions are estimated to be reduced by 968 tonnes of carbon dioxide equivalent emissions over the 60-year lifetime of the project as compared to the baseline scenario.

The project impact on carbon sinks is relatively small compared to GHG emissions as the area as the area is already highly urbanized and road widening is offset with wide boulevards and tree planting.

This report summarizes the results of a climate risk assessment originally completed by Matrix (2021) to assess the impact of climate hazards on key project infrastructure components. The risk assessment was undertaken following the PIEVC Protocol (ICLR 2016). The risk assessment focuses on future climate conditions for the 2051-2080 period using an ensemble of climate models under the high-emissions representative concentration pathway (RCP 8.5). The greatest risks identified through the risk assessment process relate to extreme heat, extreme rainfall, riverine flooding, and wind as these have the greatest potential for injury or loss of life.

This report recommends mitigations to reduce the potential impacts of high-risk climate-infrastructure interactions. The preliminary design mitigates several high climate risks, including:

- Effects of extreme high temperatures on people. Mitigations include street plantings/shade, air conditioning on busses, and passenger shelters

- Effects of extreme high temperatures/drought on environment. Mitigations include tree plantings in dedicated soil cells

- Effects of extreme rainfall and flooding on people. Mitigations include stormwater management systems design, culvert design to future climate design standards, cycle track and sidewalk set-backs, and increased safety and visibility for pedestrian crossings.

- Effects of extreme rainfall and flooding on infrastructure, public services, and private property. Mitigations include additional runoff storage capacity in boulevard stormwater retention cells, culvert modifications.

Additional mitigation measures are identified for high risks interactions including remedial engineering actions outstanding for detailed design, and future monitoring actions and management actions.

This report identifies several sustainability initiatives that may be relevant to the completion of this project. The Lakeshore BRT project could contribute to advancing some of the environmental and social outcomes identified by these initiatives. These relevant initiatives include *Our Future Mississauga, Strategic Plan* (City of Mississauga 2009), *Living Green Master Plan* (City of Mississauga 2012a), *Green Development Standards, Going Green in Mississauga* (City of Mississauga 2012b), I*nvasive Species Management Plan and Implementation Strategy* (City of Mississauga 2021a), *Cycling Master Plan* (City of Mississauga 2018), *Climate Change Action Plan* (City of Mississauga 2019a), *Mississauga Transportation Master Plan* (City of Mississauga 2019b), *Mississauga Official Plan* (City of Mississauga 2021b). External sustainability initiatives considered include *Climate Change Strategy: Protecting Today for Resilience Tomorrow 2019-2023* (CVC 2019) and *Climate Change Master Plan: Lead, Influence, Transform 2020-2030* (Region of Peel 2019).

The preliminary design addresses several of the goals associated with the above sustainability objectives. The preliminary design of infrastructure components mitigates the effects of climate change by mitigating the high climate-infrastructure risks impacts to people, the environment, infrastructure, access to public services, and impacts to private property. The effects of the transit project on climate are mitigated as the dedicated transit lanes and bike lanes are expected to result in a decrease in automobile usage and increase in bus and bike usage. GHG emission will reduce due to increased public transit capacity and bike travel accessibility.

REFERENCES

Auld H. et al. 2016. *Climate Trends and Future Projections in the Region of Peel*. Prepared for Region of Peel. Ontario Climate Consortium. pp. 103. Toronto, Ontario. 2016.

Cheng C.S. et al. 2012. "Possible Impacts of Climate Change on Wind Gusts under Downscaled Future Climate Conditions over Ontario, Canada." *Journal of Climate 25*: 3390–3408. May 2012.

City of Mississauga. 2021a. *Invasive Species Management Plan & Implementation Strategy*. Mississauga, Ontario. February 18, 2021.

City of Mississauga. 2021b. *Mississauga Official Plan*. Mississauga, Ontario. October 21, 2021. https://www.mississauga.ca/projects-and-strategies/strategies-and-plans/mississauga-official-plan/

City of Mississauga. 2019a. *Climate Change Action Plan*. Mississauga, Ontario. 2019.

City of Mississauga. 2019b. *Mississauga Transportation Master Plan*. Mississauga, Ontario. May 2019.

City of Mississauga. 2018. *Cycling Master Plan*. Mississauga, Ontario. 2018.

City of Mississauga. 2013. *Mississauga, Ontario, LED Streetlight Scale-up*. Case Study No. 3. Mississauga, Ontario. March 30, 2013.

City of Mississauga. 2012a. *Living Green Master Plan*. Prepared for CompanyName. Mississauga, Ontario. January 2012.

City of Mississauga. 2012b. *Green Development Standards, Going Green in Mississauga*. Mississauga, Ontario. October 2012.

City of Mississauga. 2009. *Our Future Mississauga, Strategic Plan*. Mississauga, Ontario. April 2009.

City of Mississauga & HDR Inc. 2019. "Lakeshore Road Transportation Master Plan and Implementation Strategy - DRAFT Final Report." Mississauga, Ontario. May 2019.

Credit Valley Conservation (CVC). 2019. *Climate Change Strategy, Protecing Today for Resilience Tomorrow, 2019-2023*. 2019.

Credit Valley Conservation (CVC). 2014. *Hydrology & Hydraulics, Adapting to New Weather Realities*. Presentation to Technical Committee of Lake Ontario Integrated Sub watershed Study. March 24, 2014.

Elzomor, M. (Ed.). 2017. *Heat Exposure and Transit Use: Travel Behavior and Infrastructure*. A Collaborative Research Project between Arizona State University's Urban Infrastructure Anatomy & Sustainable Development and Construction Materials & Methods Classes. Report No. ASU-SSEBE-CESEM-2017-CPR-001. May 29, 2017.

Environment and Climate Change Canada (ECCC). 2020. *National Inventory Report, 1990-2018: Greenhouse Gas Sources and Sinks in Canada*. Canada's Submission to the United Nations Framework Convention on Climate Change. 2020. http://www.publications.gc.ca/site/eng/9.506002/publication.html

Gabriel A.O. and R.D. Kreutzwiser. 1993. "Drought hazard in Ontario: a review of impacts, 1960-1989, and management implications." *Canadian Water Resources Journal 18* (*2*): 117–132. 1993.

Global Carbon Project. 2016. *Global Carbon Budget 2016*. Presentation; PowerPoint version 1.0. November 14, 2016.

Government of Canada (GoC). 2019. *Global Warming Potentials*. Ottawa, Ontario. February 18, 2019. https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/quantification-guidance/global-warming-potentials.html

Inflation Tool. 2020. *Inflation calculator - US Dollar*. Accessed September 2020. https://www.inflationtool.com/us-dollar

Infrastructure Canada (Infrastructure Canada). 2019. *Climate Lens General Guidance*. Version 1.2. September 6, 2019.

Institute for Catastrophic Loss Reduction (ICLR). 2016. *PIEVC Engineering Protocol for Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate, Vulnerability Assessment Module*. Version VA - 10.11. Toronto, Ontario. June 2016.

Matrix Solutions Inc. (Matrix). 2021. *Climate Lens Assessment, City of Mississauga Lakeshore Bus Rapid Transit, Lakeshore Corridor Segment 7*. Version 2.0. Prepared for HDR Inc.,. Guelph, Ontario. January 2021.

Natural Resources Canada (NRCan). 2020a. *Life Cycle Assessment Reporting Template*. Accessed in August 2020. 2020.

Natural Resources Canada (NRCan). 2020b. *2020 Fuel Consumption Guide*. 2020.

Ontario Ministry of Municipal Affairs and Housing (MMAH). 2020. *Provincial Policy Statement, 2020*. Issued under Section 3 of the Planning Act. Queen's Printer for Ontario, 2020. Toronto, Ontario. May 1, 2020.

Ontario Ministry of the Environment and Climate Change (MOECC). 2017. *Considering Climate Change in the Environmental Assessment Process*. Toronto, Ontario. 2017. https://www.ontario.ca/page/considering-climate-change-environmental-assessment-process

Prairie Climate Centre. 2020. *Climate Atlas Version 2*. Accessed July 2019. https://climateatlas.ca/

Regional Municipality of Peel (Region of Peel). 2019. *Climate Change Master Plan, Lead, Influence, Transform, 2020-2030*. 2019.

Robinson B. et al. 2019. *Reducing the Risk of Inflow and Infiltration (I/I) in New Sewer Construction, A National Foundational Document for the Development of a National Standard of Canada*. Published by Institute for Catastrophic Loss Reduction, ICLR research paper series – number 64. Toronto, Ontario. November 2019.

Union of Concerned Scientists (UCS). 2018. *Electric vs. Diesel vs. Natural Gas: Which Bus is Best for the Climate?*. July 19, 2018. https://blog.ucsusa.org/jimmy-odea/electric-vs-diesel-vs-natural-gas-which-bus-is-best-for-the-climate#:~:text=Fuel%20efficiencies%20used%20in%20this,a%2090%20percent%20charging%20efficiency.

United States Environmental Protection Agency (US EPA). 2009. *Potential for Reducing Greenhouse Gas Emissions in the Construction Sector*. Washington, DC, USA. February 2009.

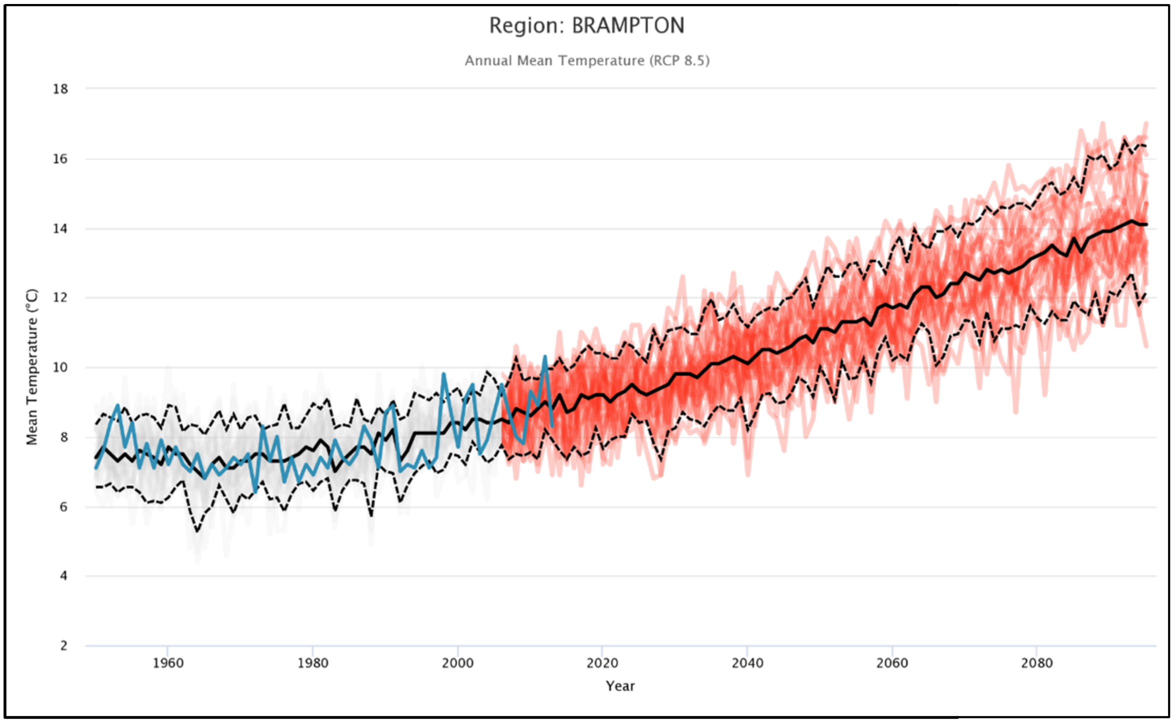
Wang H. et al. 2019. "Quantifying greenhouse gas emission of asphalt pavement preservation at construction and use stages using life-cycle assessment." *International Journal of Sustainable Transportation 14* (*1*): 25–34. January 11, 2019.

Western University. 2018. *IDF_CC Tool 4.0 - Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change – Version 4.0*. 2018. https://www.idf-cc-uwo.ca/home.aspx

World Resources Institute (WRI). 2014. *Global Protocol for Community-scale Greenhouse Gas Emission Inventories*. An Accounting and Reporting Standard for Cities. 2014. https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf

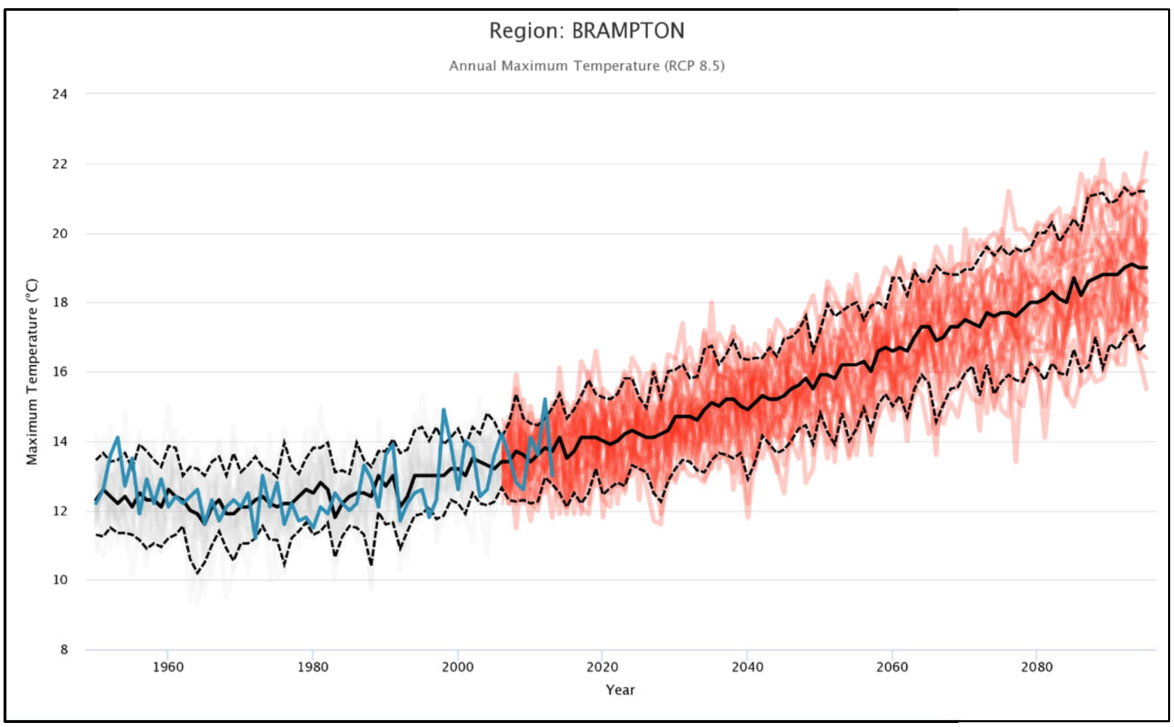
XE.com Inc. 2020. *XE: Convert USD/CAD. United States Dollar to Canadian Dollar*. Accessed September 2020.

APPENDIX A
Climate Profile



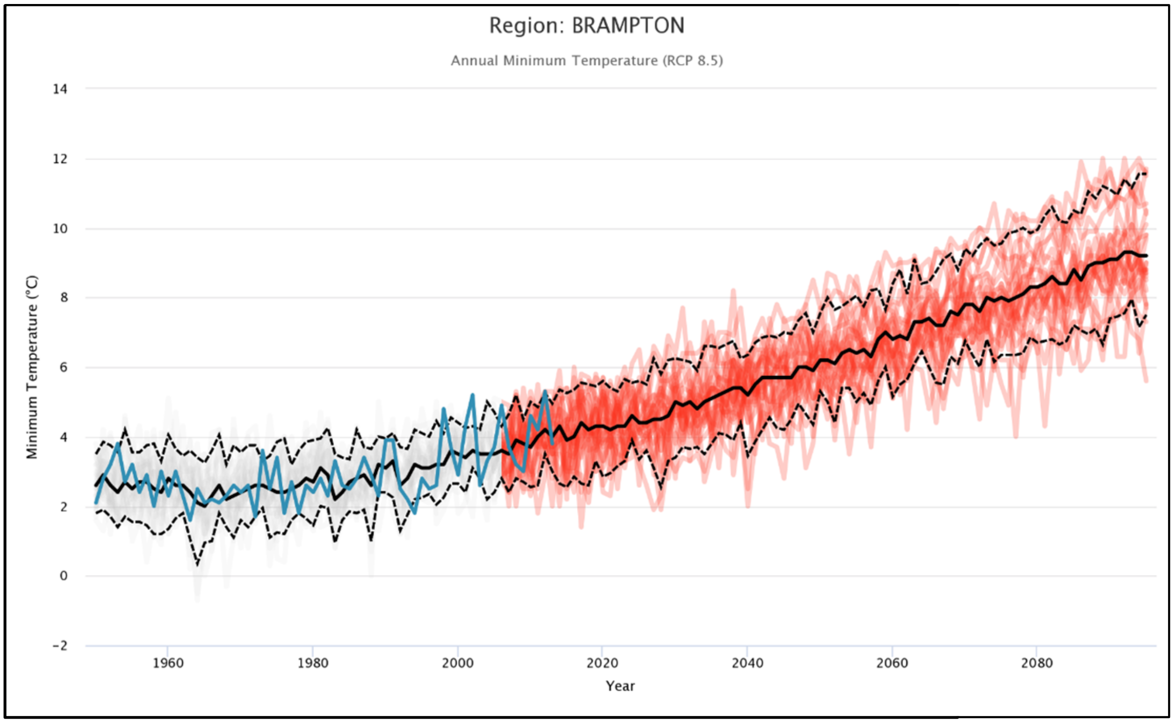
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

1. **Temperature -** Annual Mean Temperature



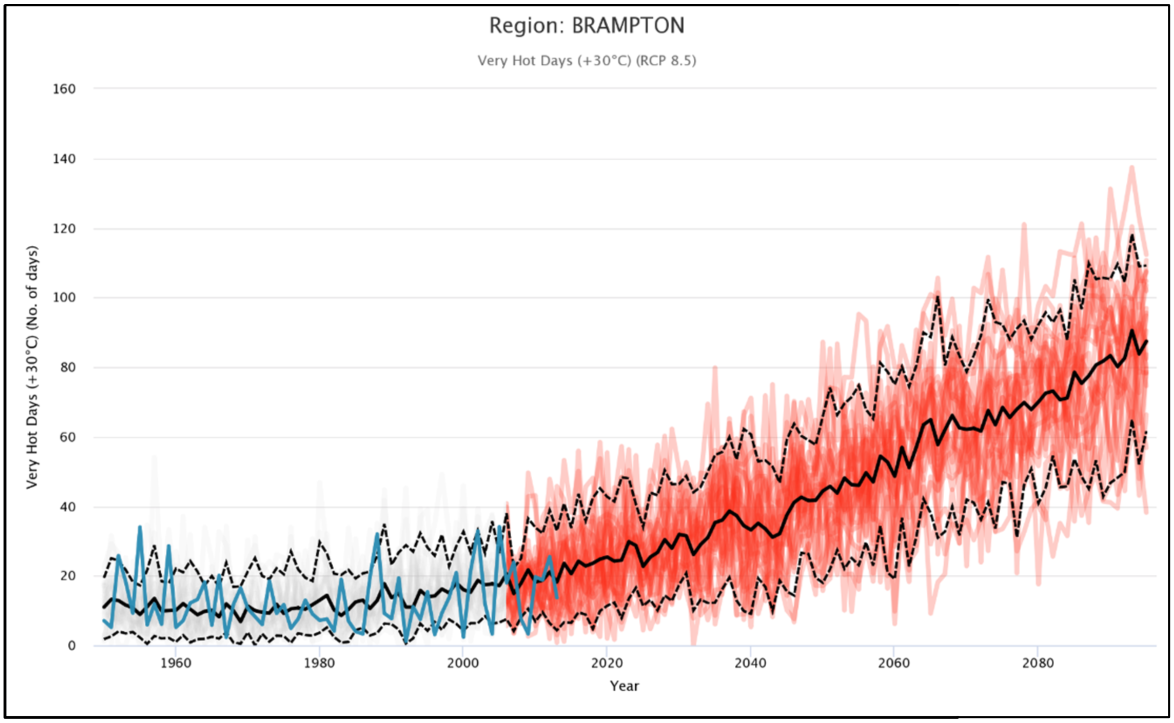
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

2. **Temperature -** Annual Max Temperature



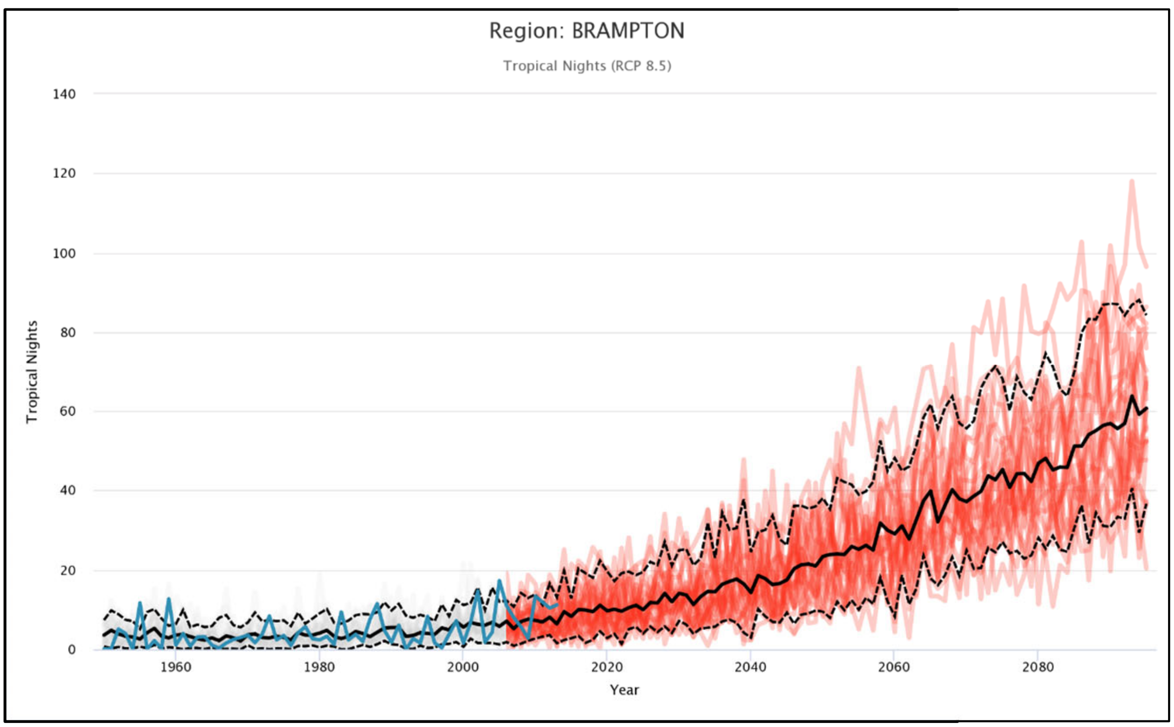
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

3. **Temperature -** Annual Minimum Temperature



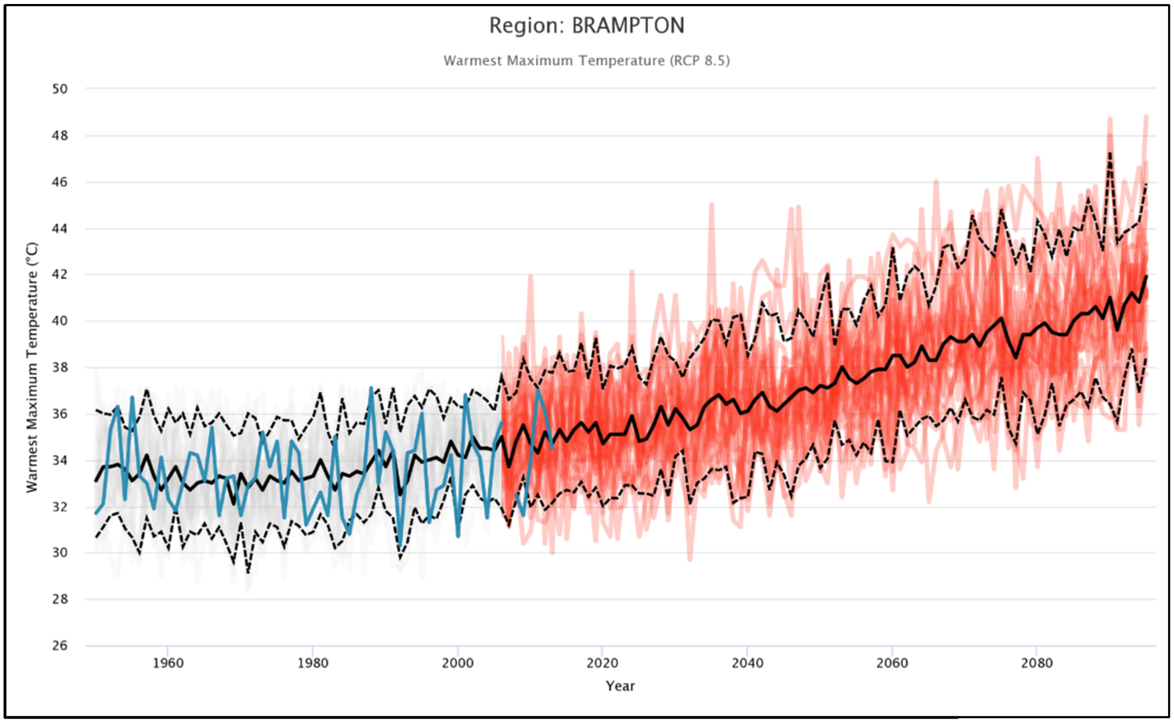
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

1. **Hot Weather -** Very Hot Days (+30°C)



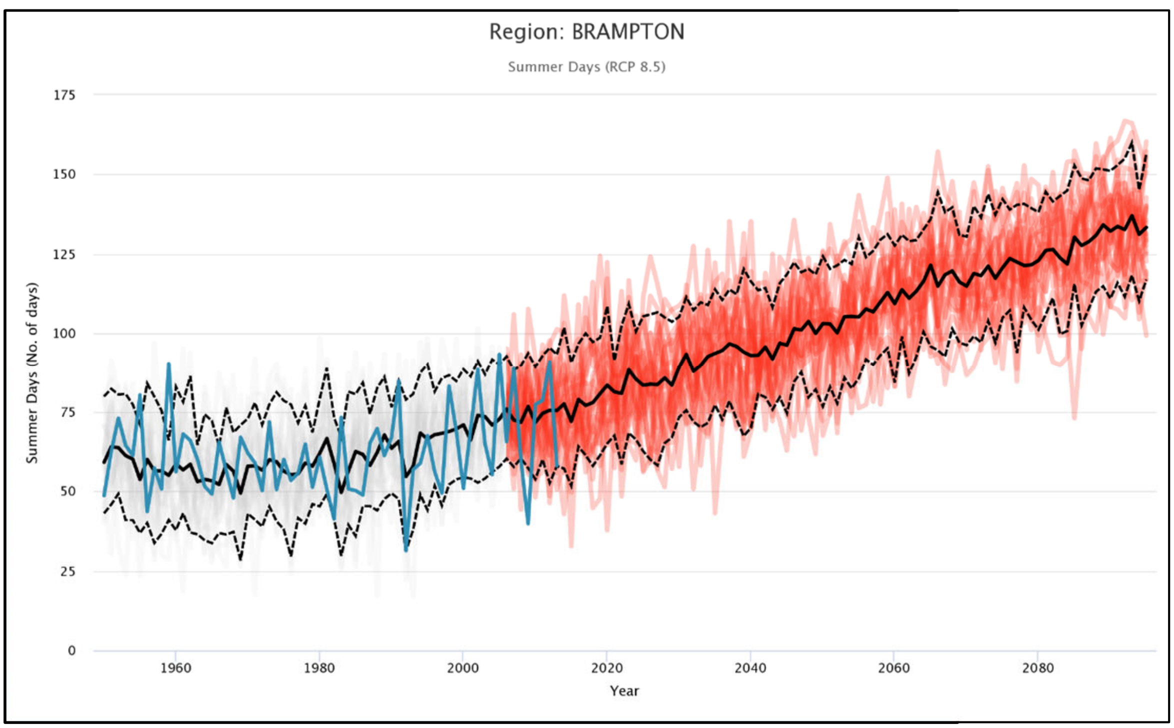
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

2. **Hot Weather -** Tropical Nights



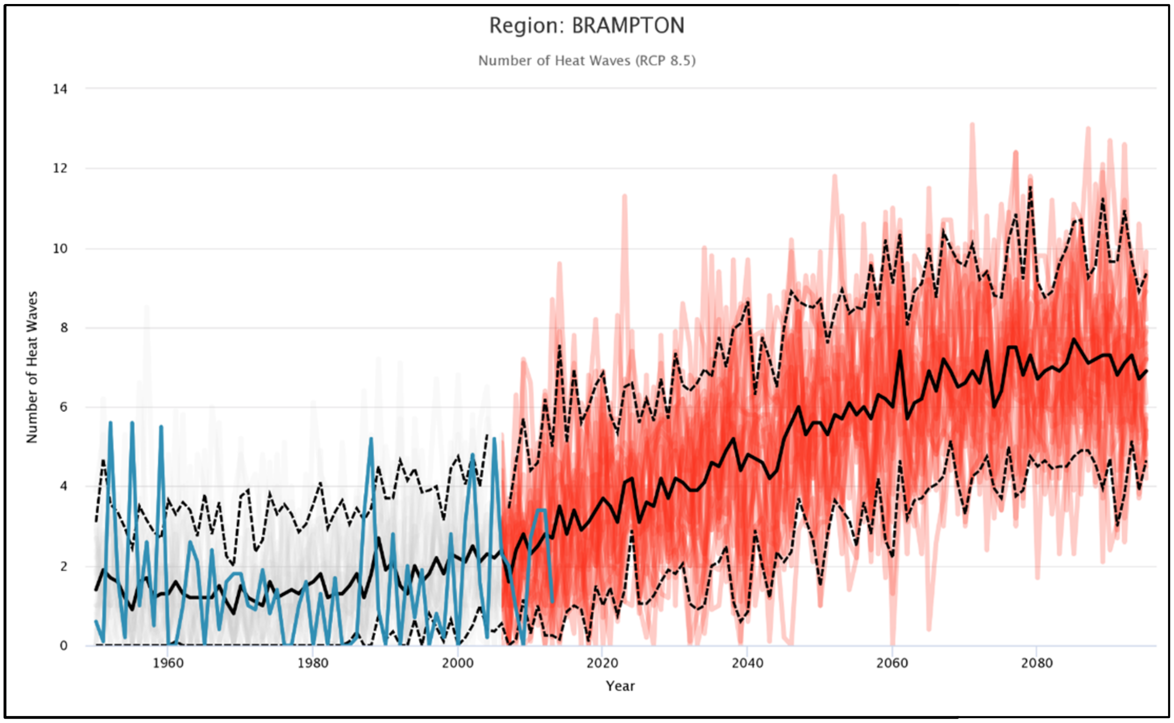
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

3. **Hot Weather -** Warmest Max Temperature



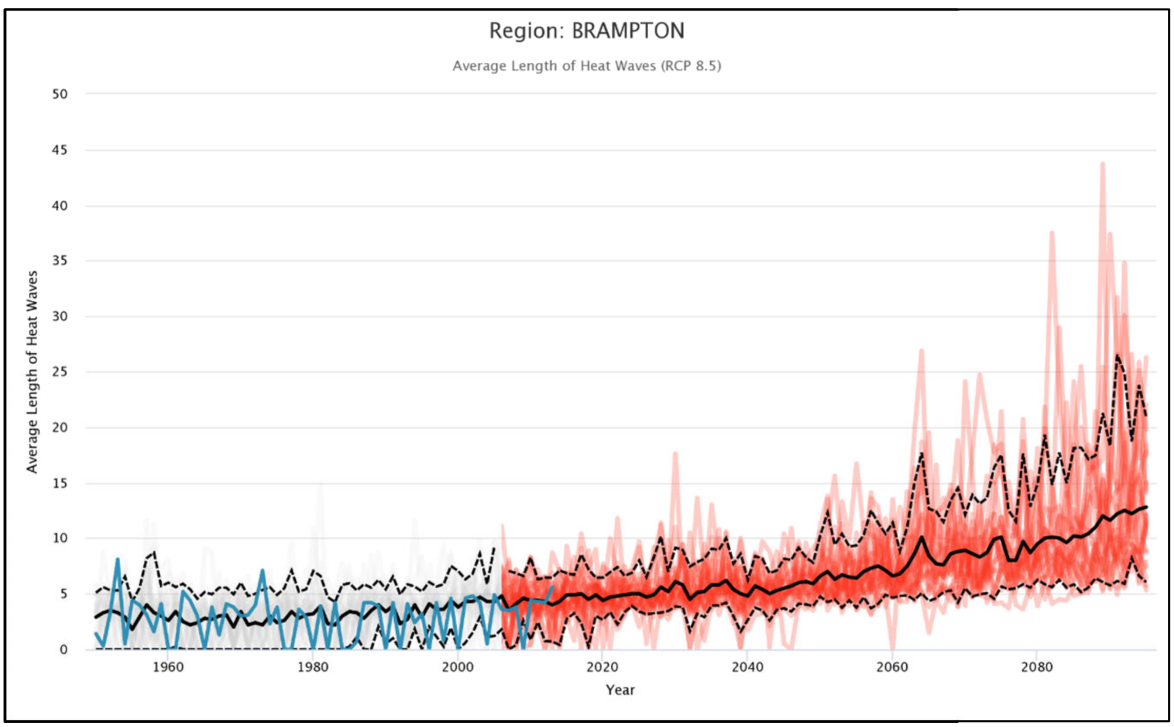
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

4. **Hot Weather -** Summer Days



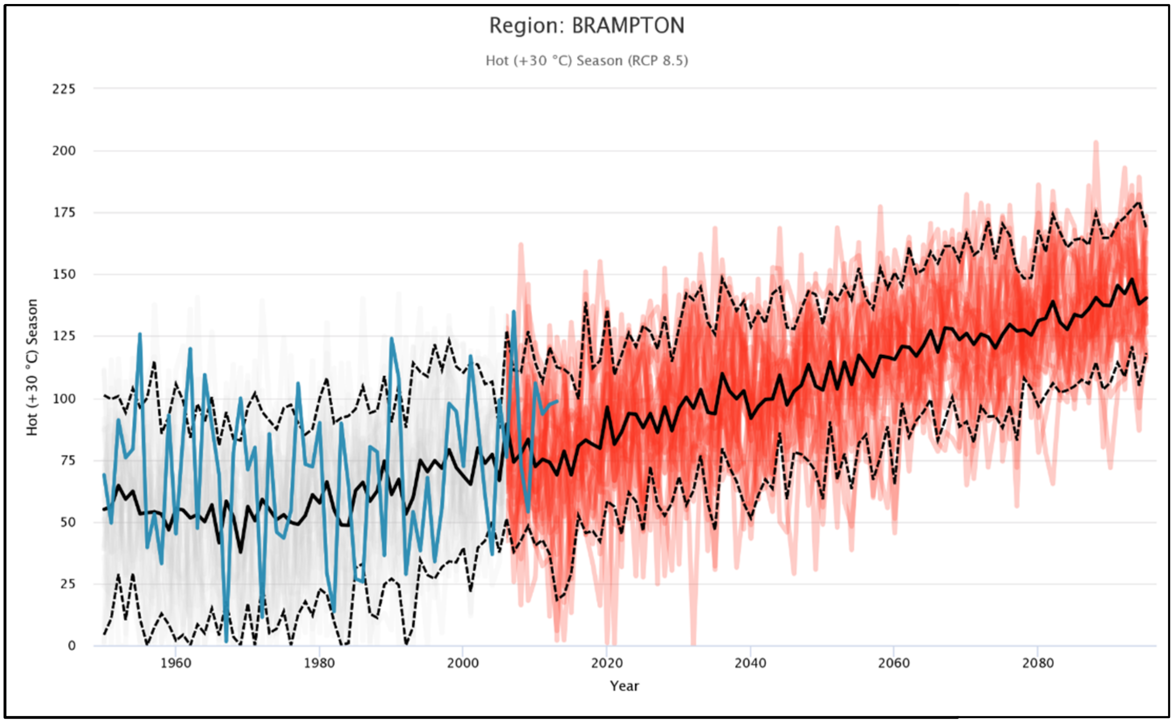
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

5. **Hot Weather -** Number of Heat Waves



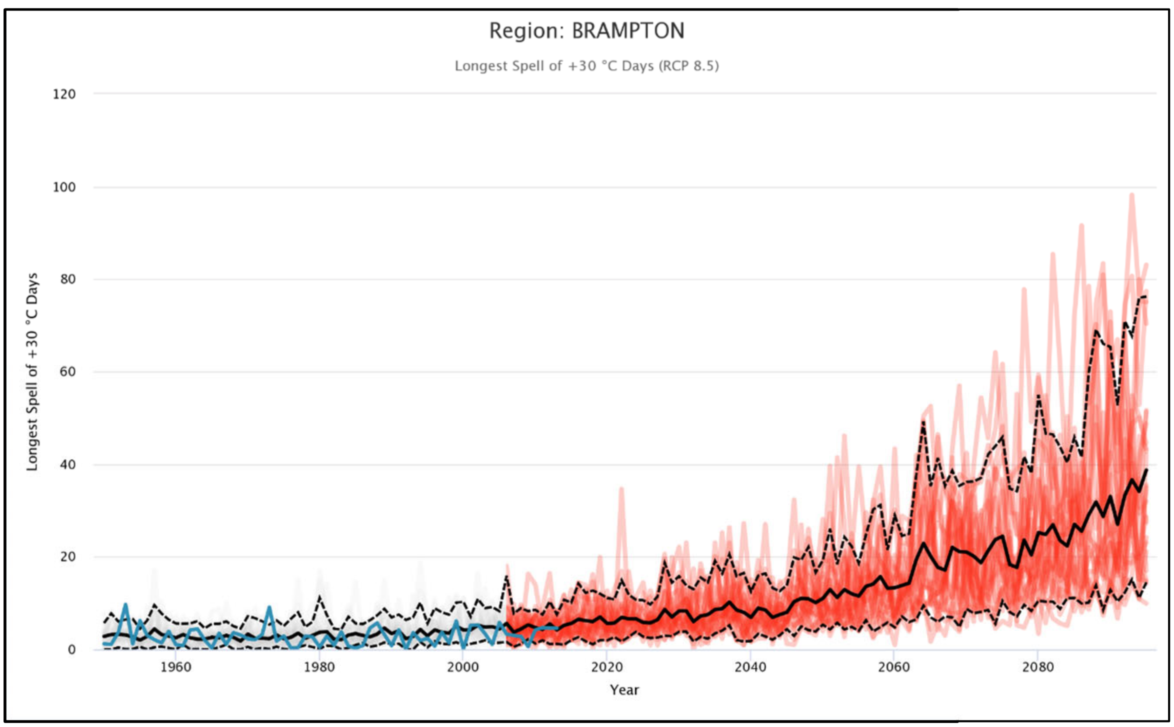
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

6. **Hot Weather -** Avg Length of Heat Waves



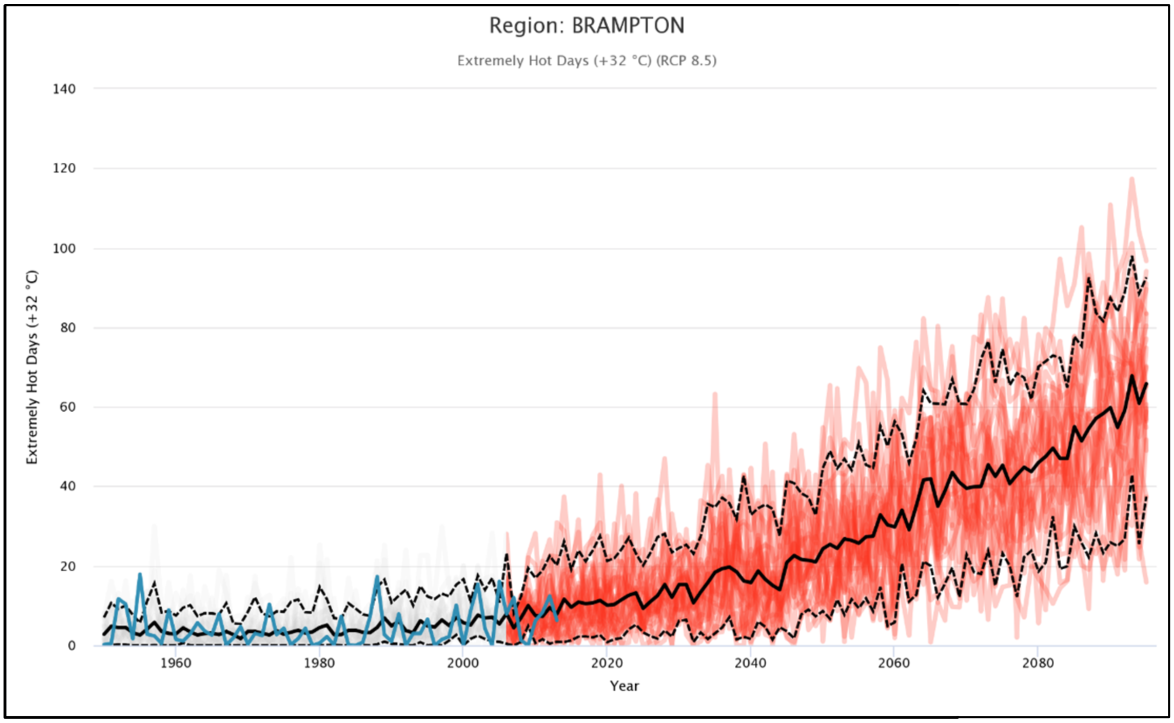
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

7. **Hot Weather -** Hot (+30°C) Season



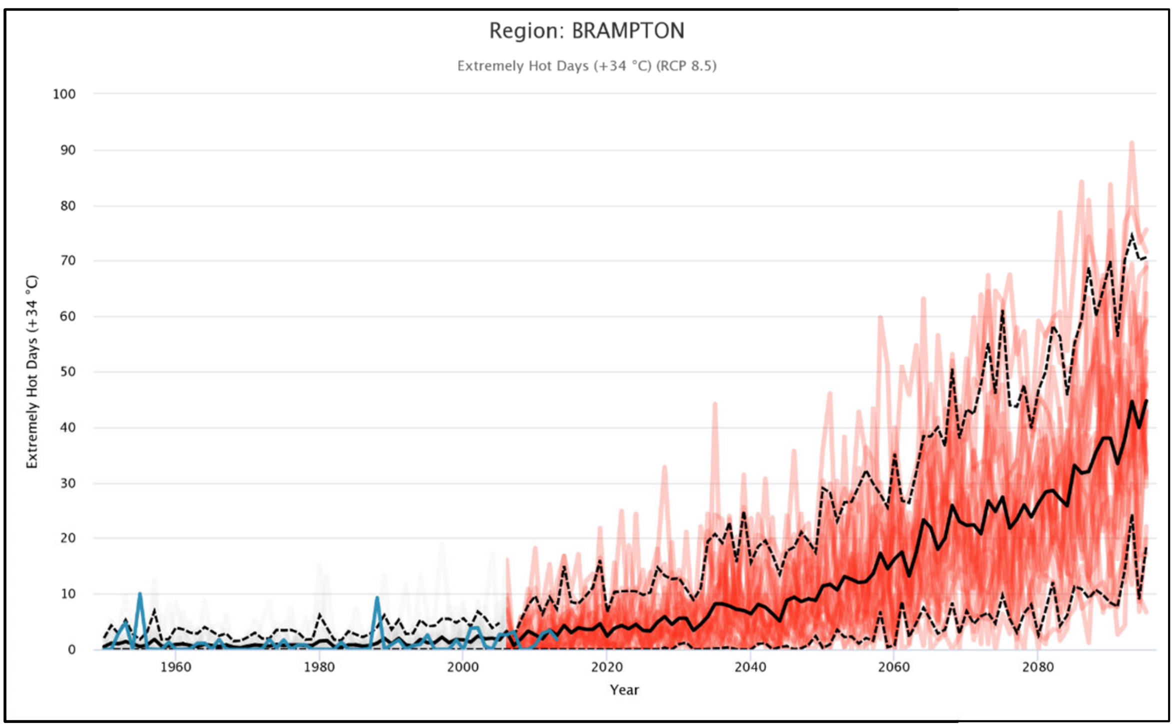
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

8. **Hot Weather -** Longest Spell of +30°C Days



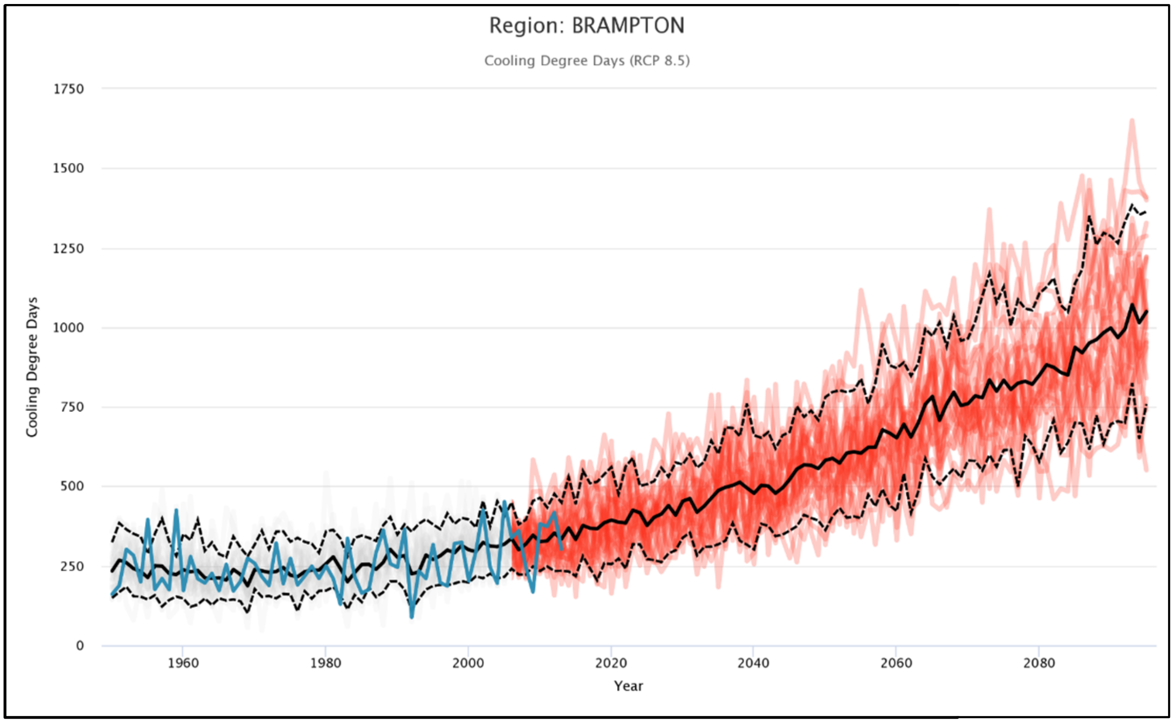
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

9. **Hot Weather -** Extremely Hot Days (+32°C)



Climate Atlas RCP 8.5 Brampton/ Mississauga Region

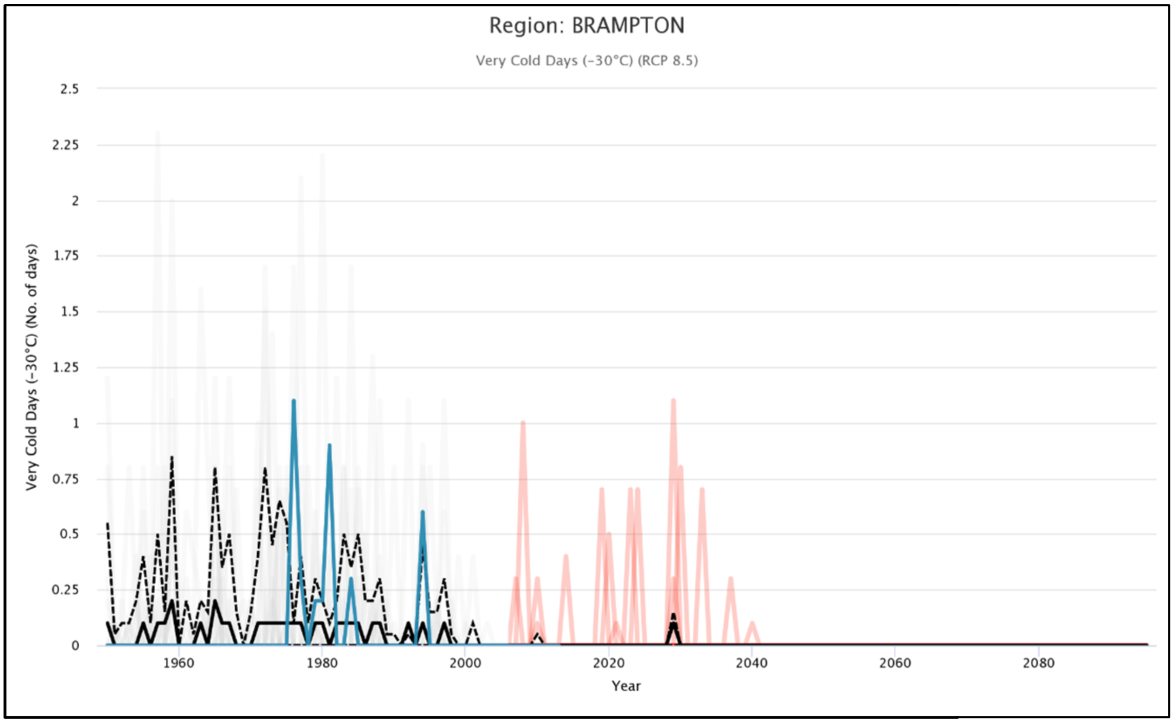
10. **Hot Weather -** Extremely Hot Days (+34°C)



Climate Atlas RCP 8.5 Brampton/ Mississauga Region

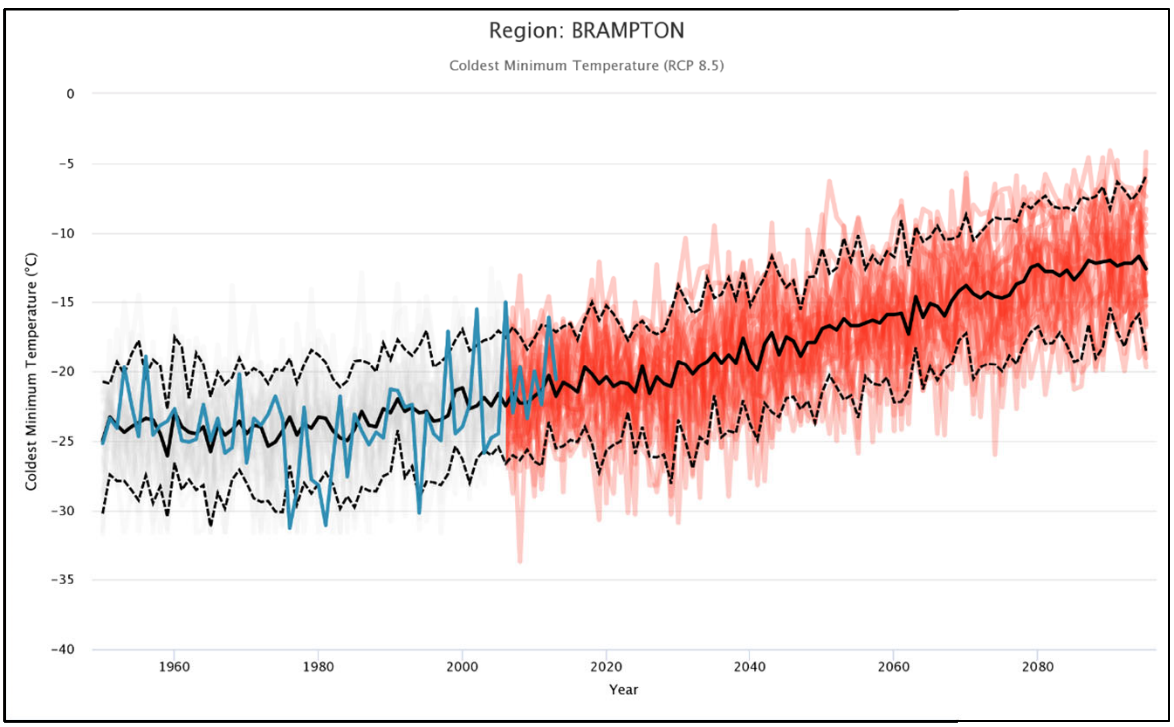
11. Hot Weather - Cooling Deg Days

Climate Atlas RCP 8.5 Brampton/ Mississauga Region



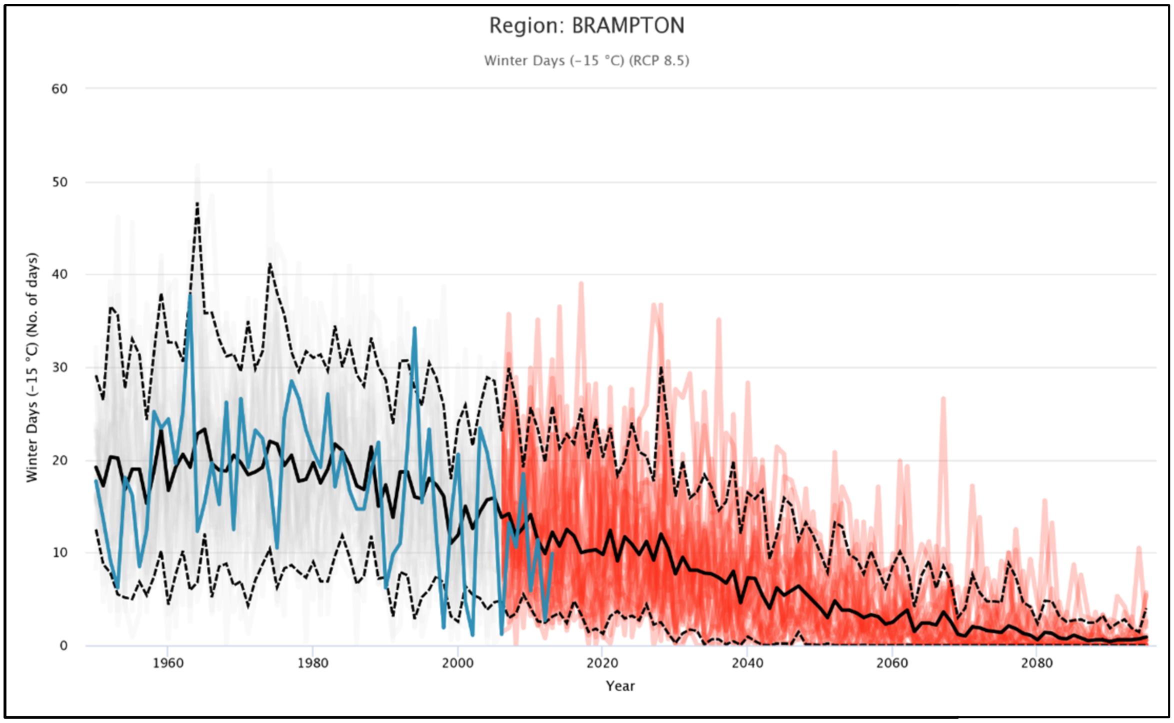
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

1. **Cold Weather** - Very Cold Days (-30°C)



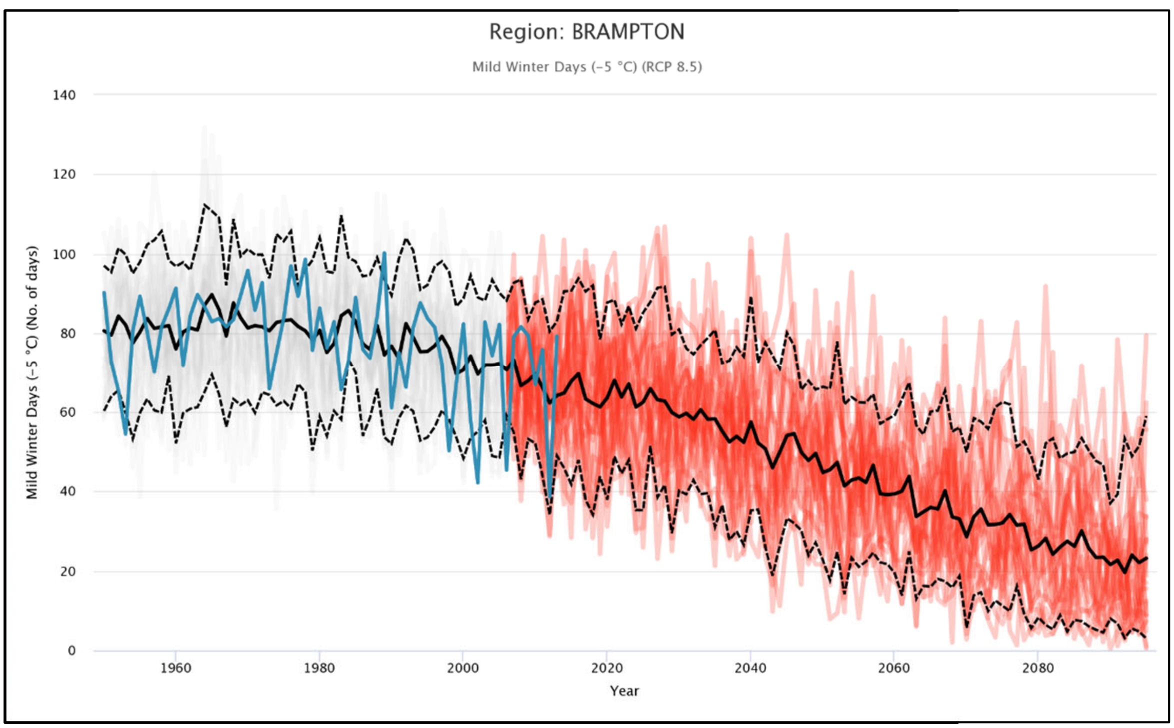
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

2. **Cold Weather -** Coldest Min Temperature



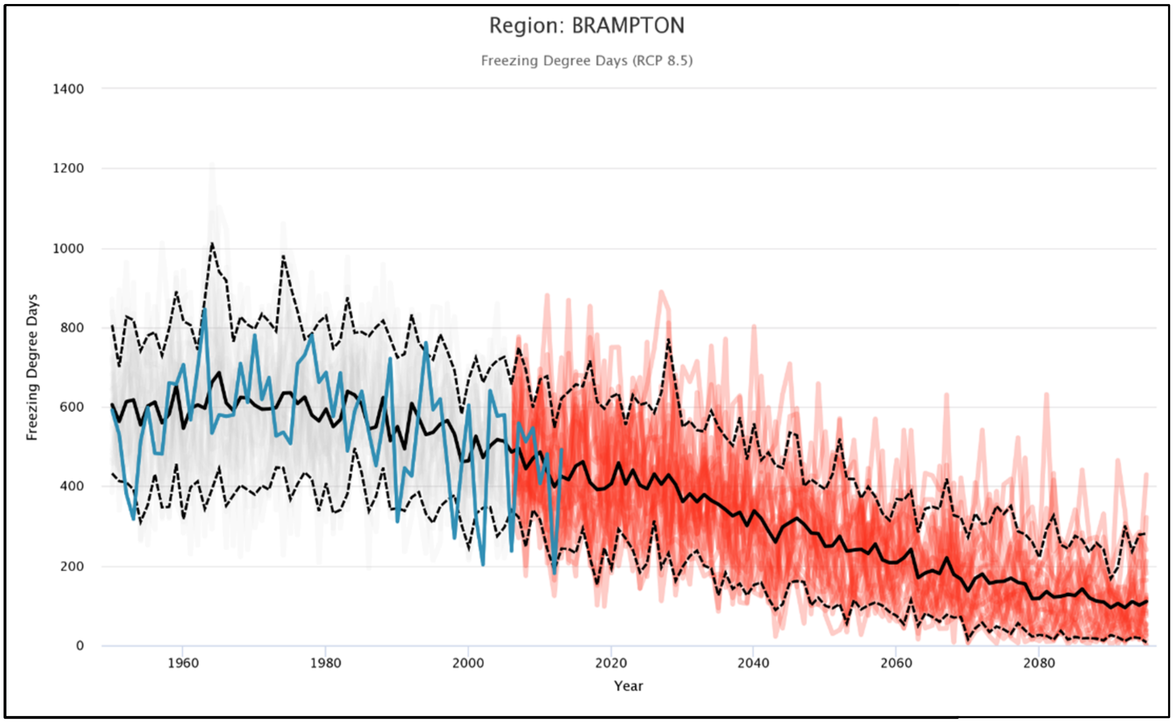
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

3. **Cold Weather -** Winter Days (-15°C)



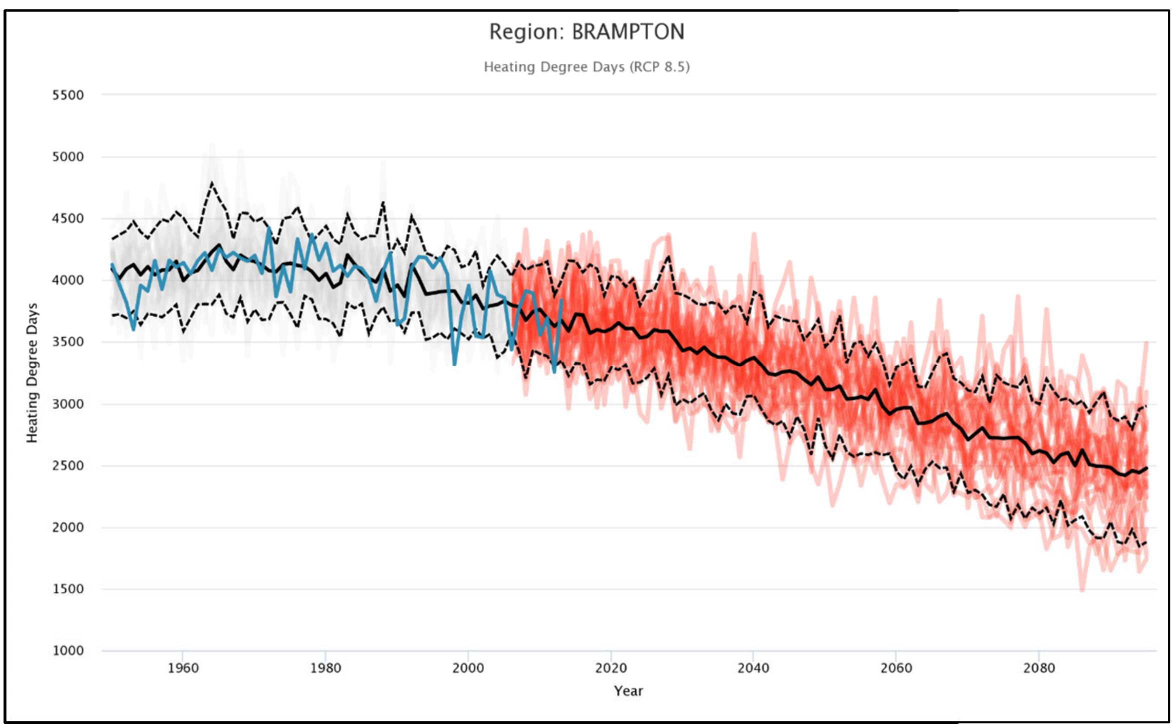
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

4. **Cold Weather -** Mild Winter Days (-5°C)



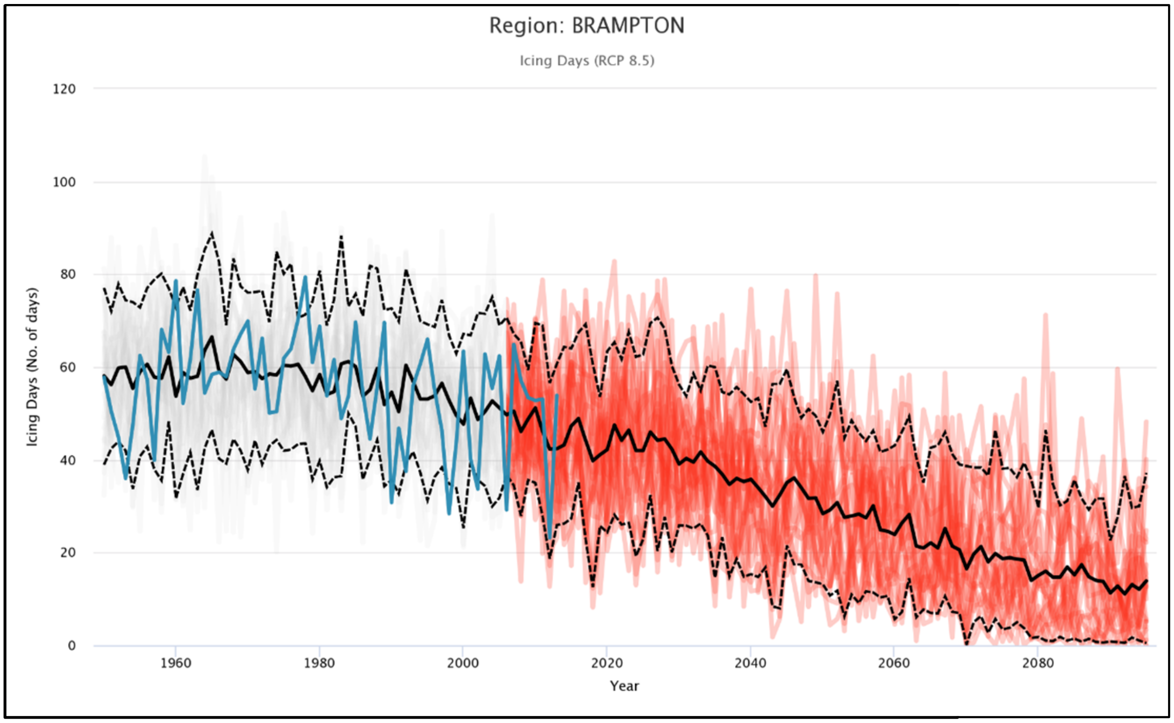
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

5. **Cold Weather -** Freezing Degree Days



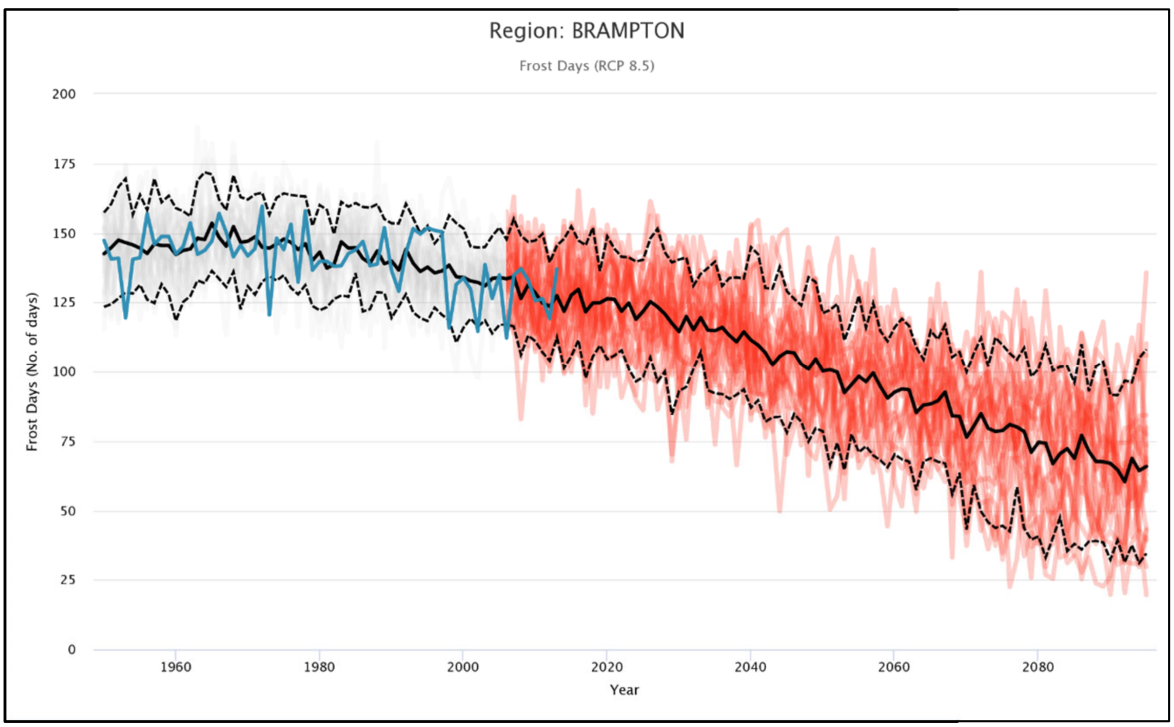
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

6. **Cold Weather -** Heating Degree Days



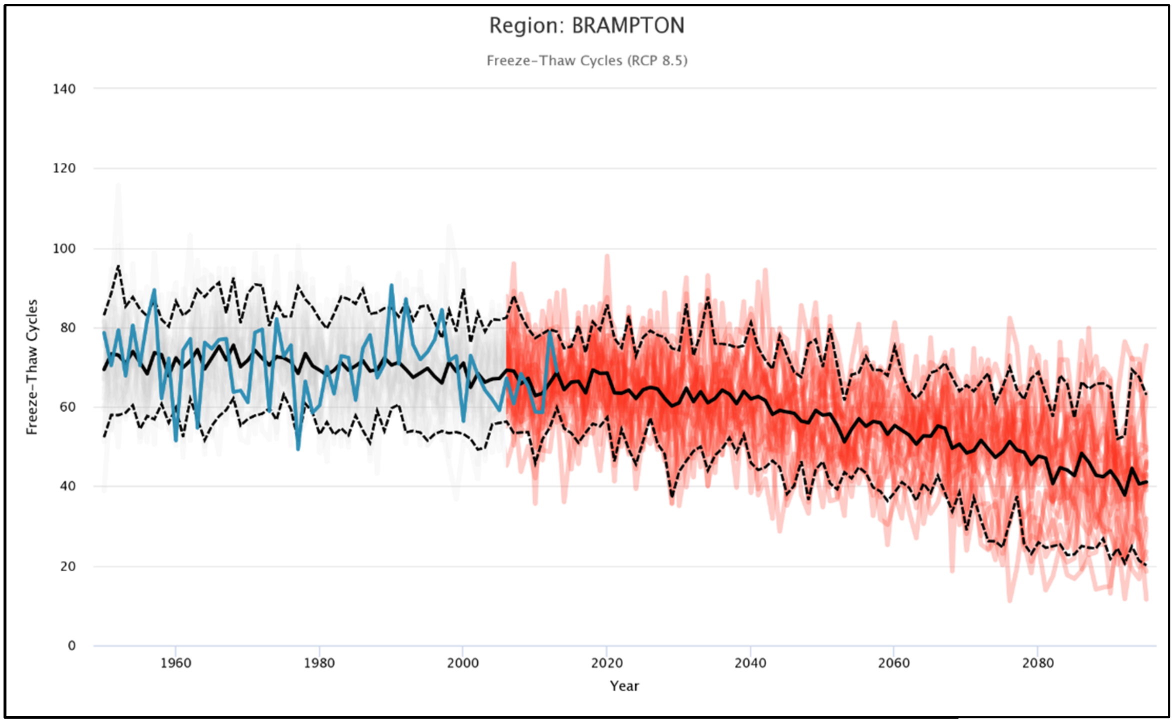
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

7. Cold Weather - Icing Days (Days Tmax<0°C)



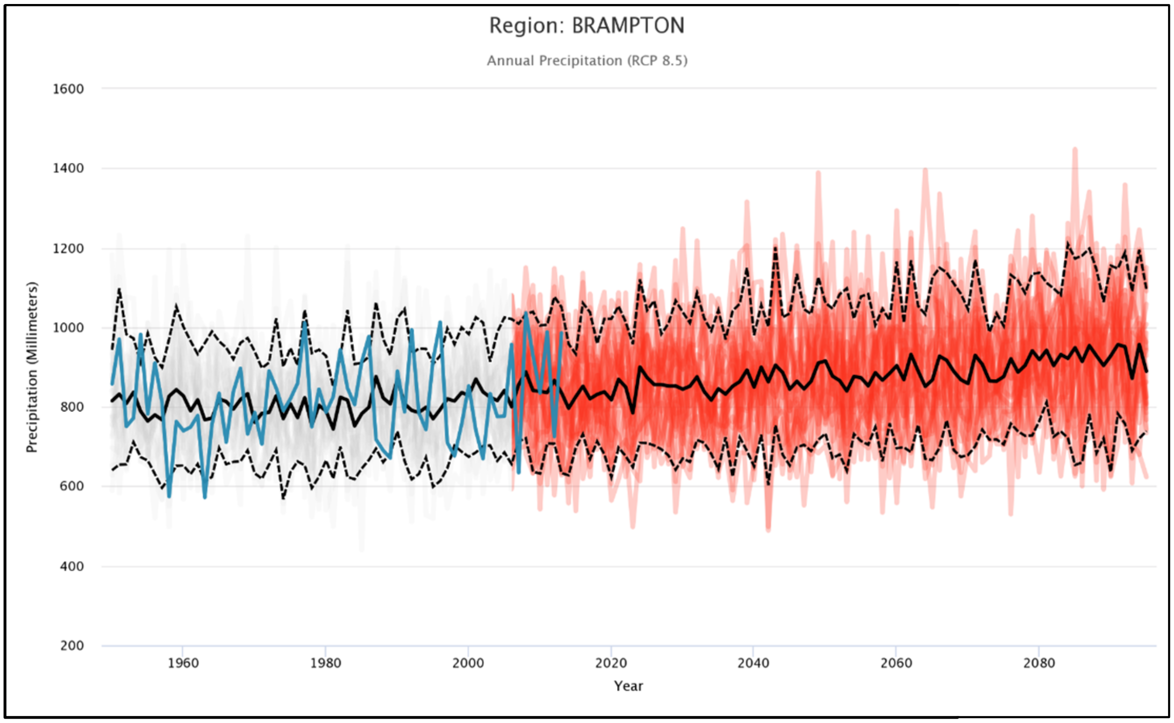
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

8. Cold Weather - Frost Days



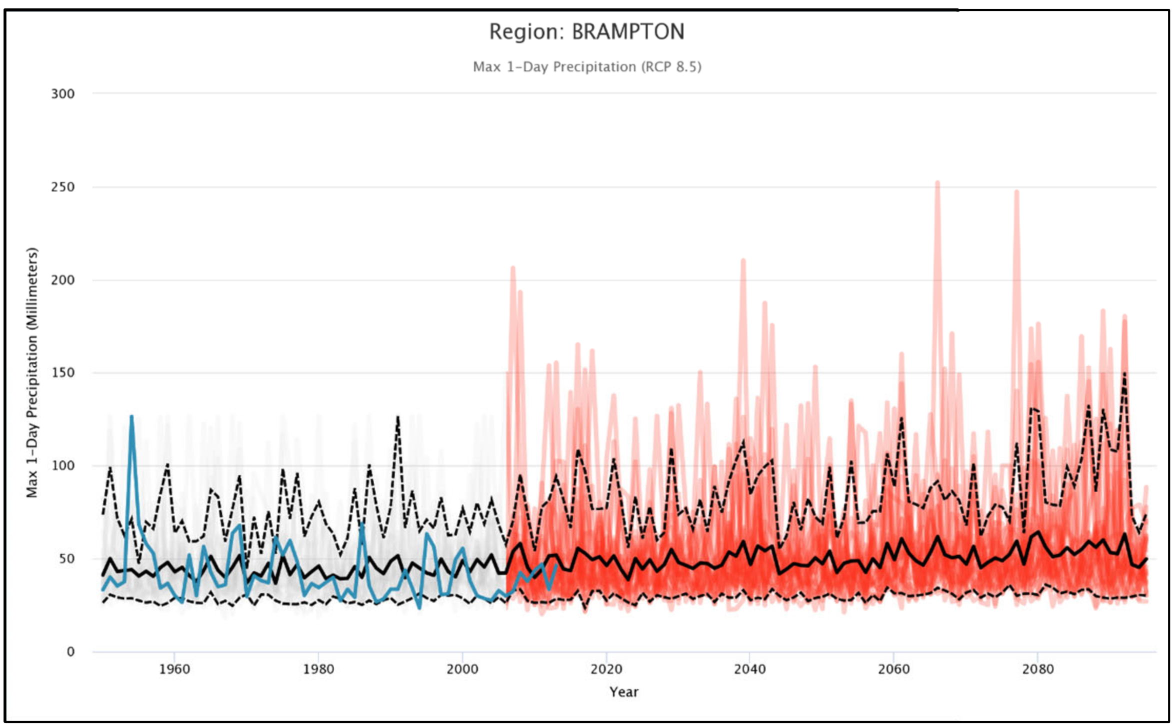
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

10. Cold Weather - Freeze-Thaw Cycles



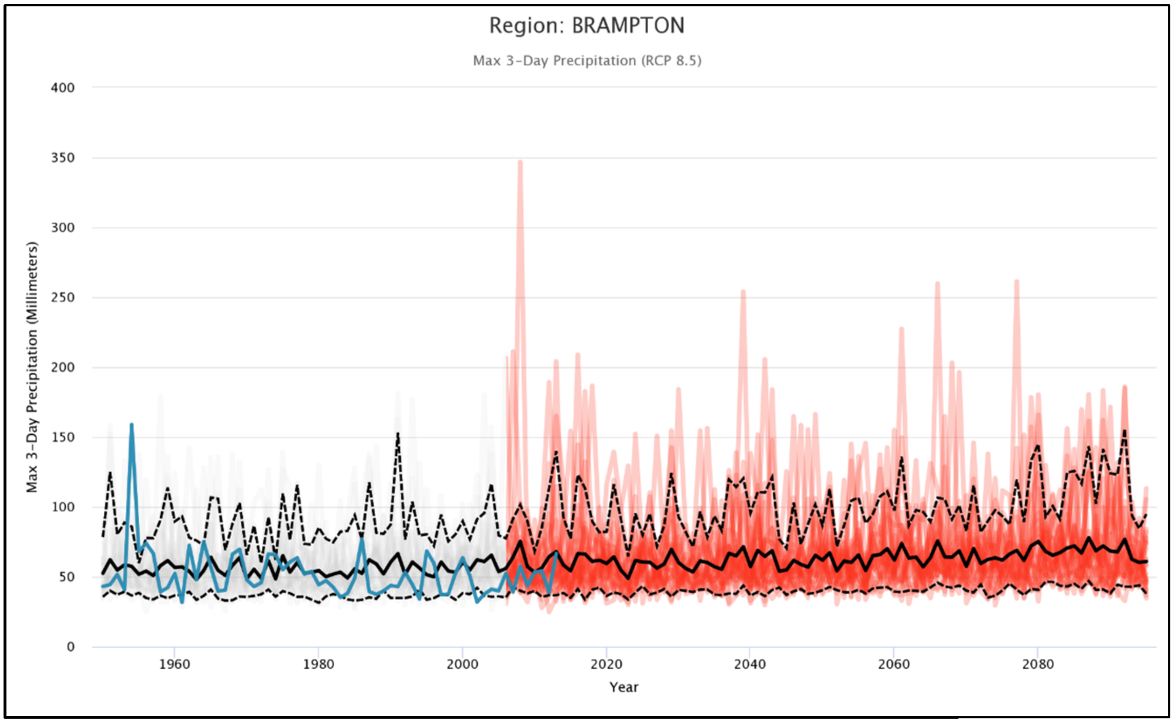
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

1. **Precipitation -** Average Annual Precipitation



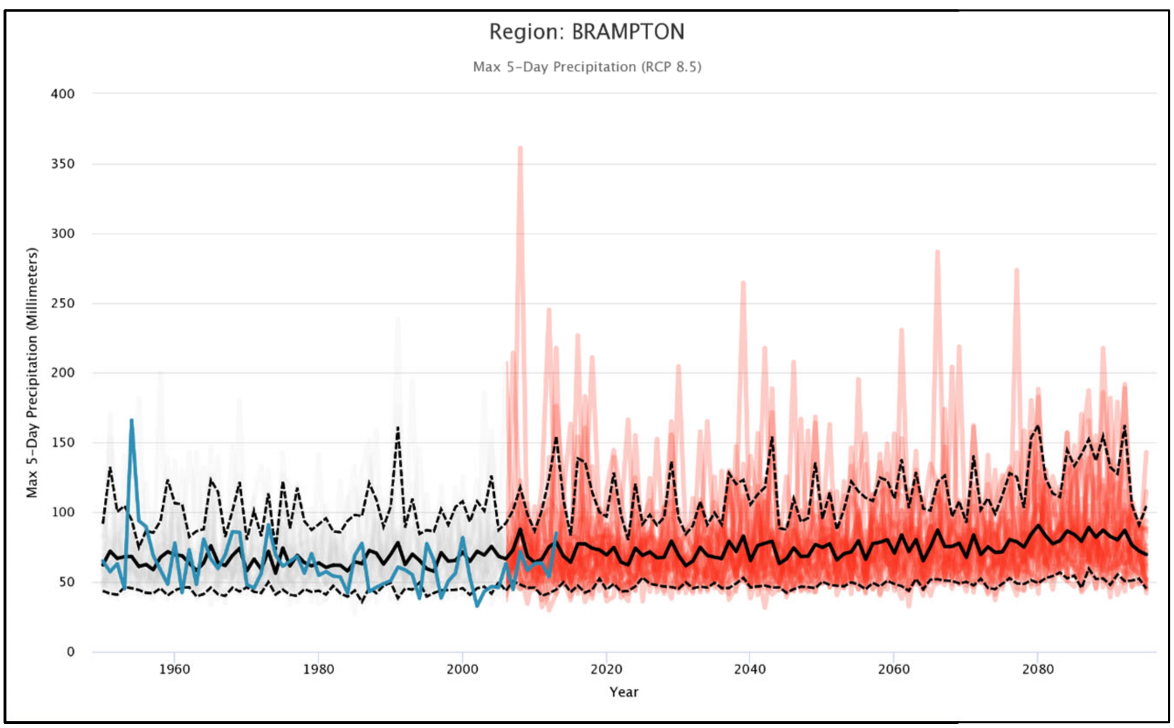
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

2. **Precipitation -** Max 1-Day Precipitation



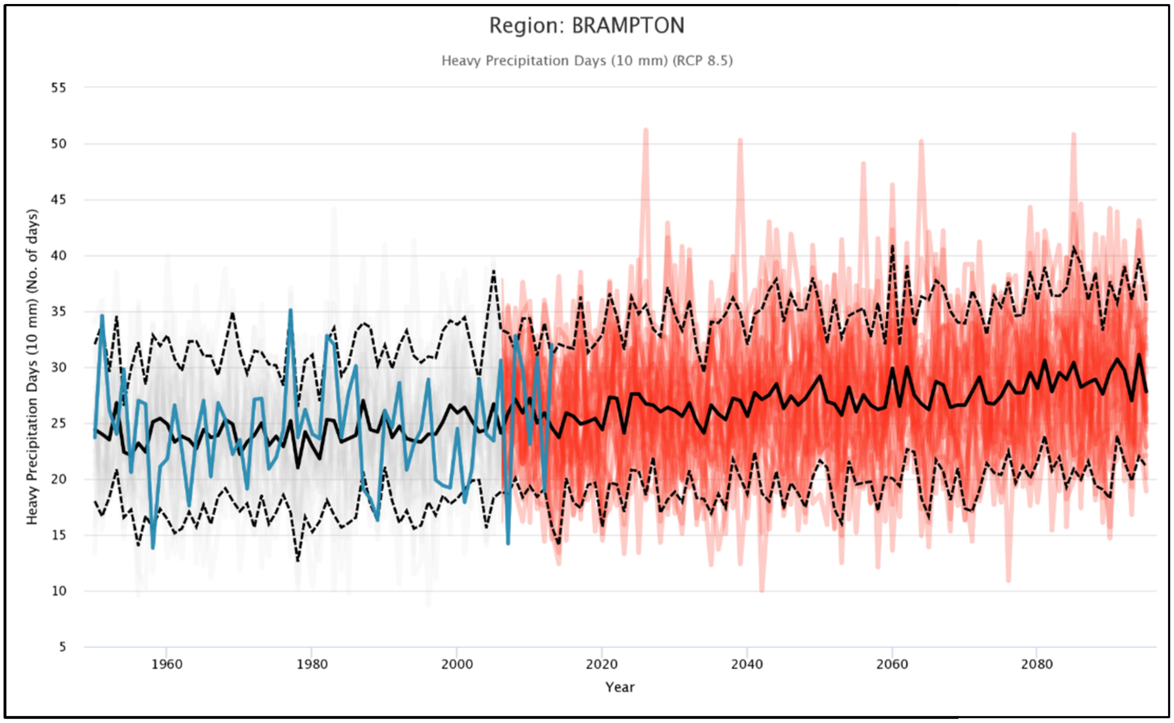
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

1. **Precipitation -** Max 3-Day Precipitation



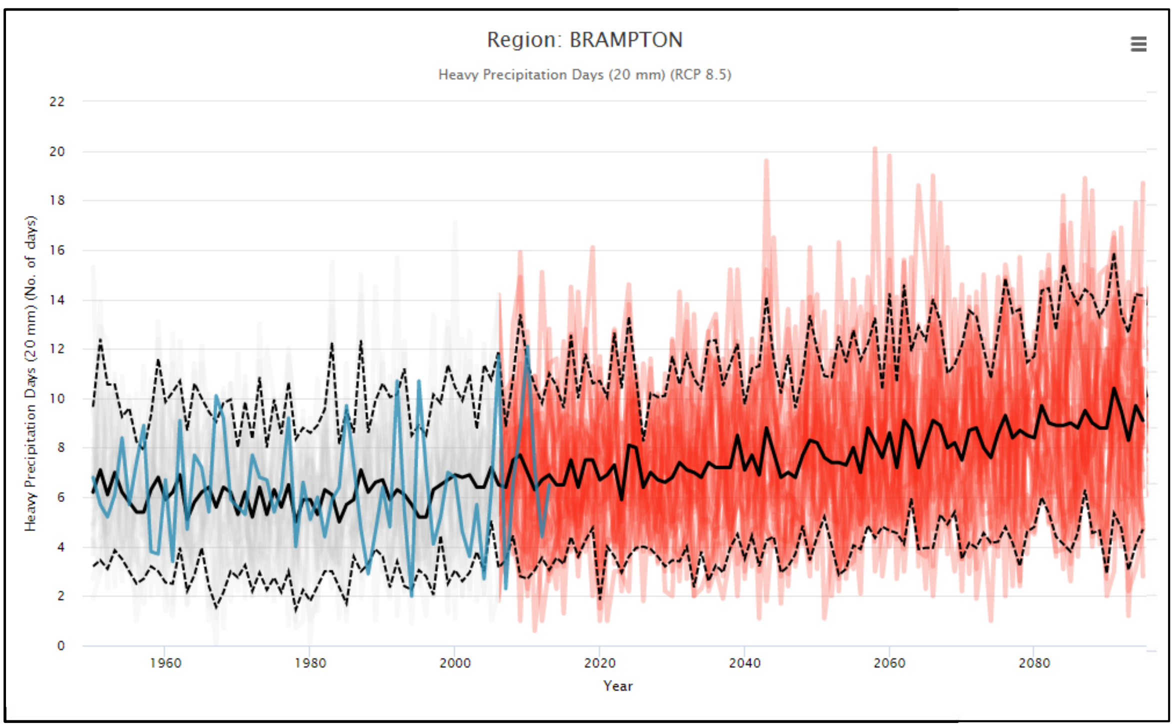
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

2. **Precipitation -** Max 5-Day Precipitation



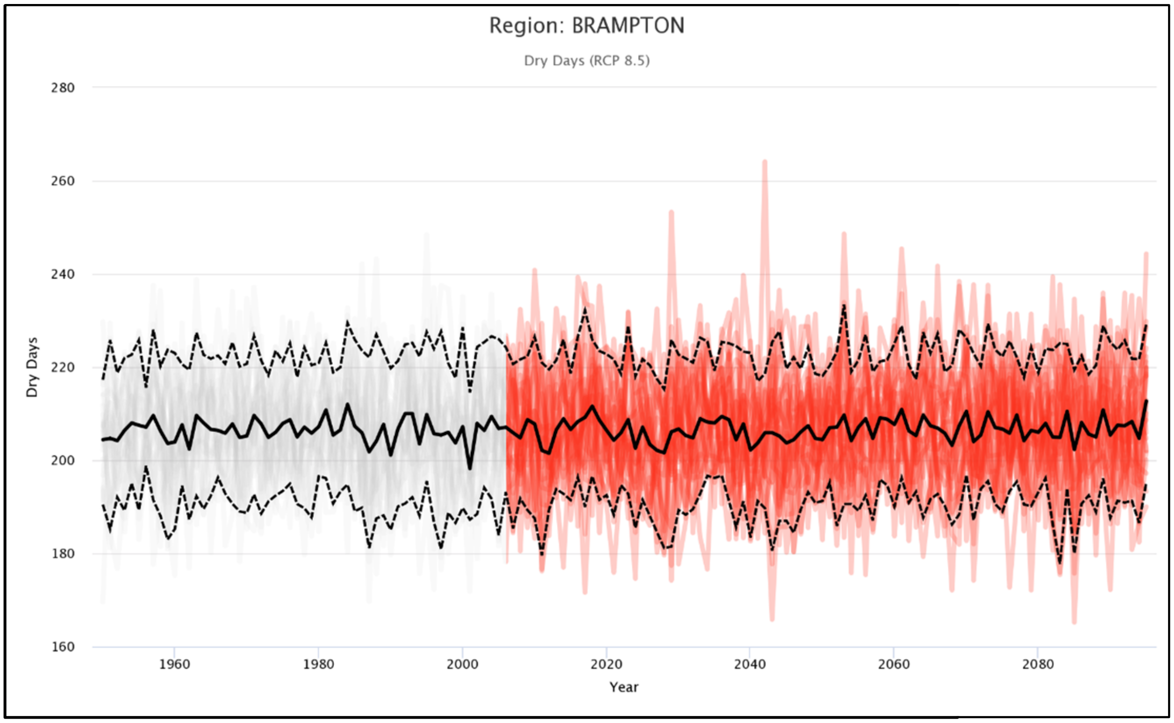
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

1. **Precipitation -** Heavy Precipitation Days (>10mm)



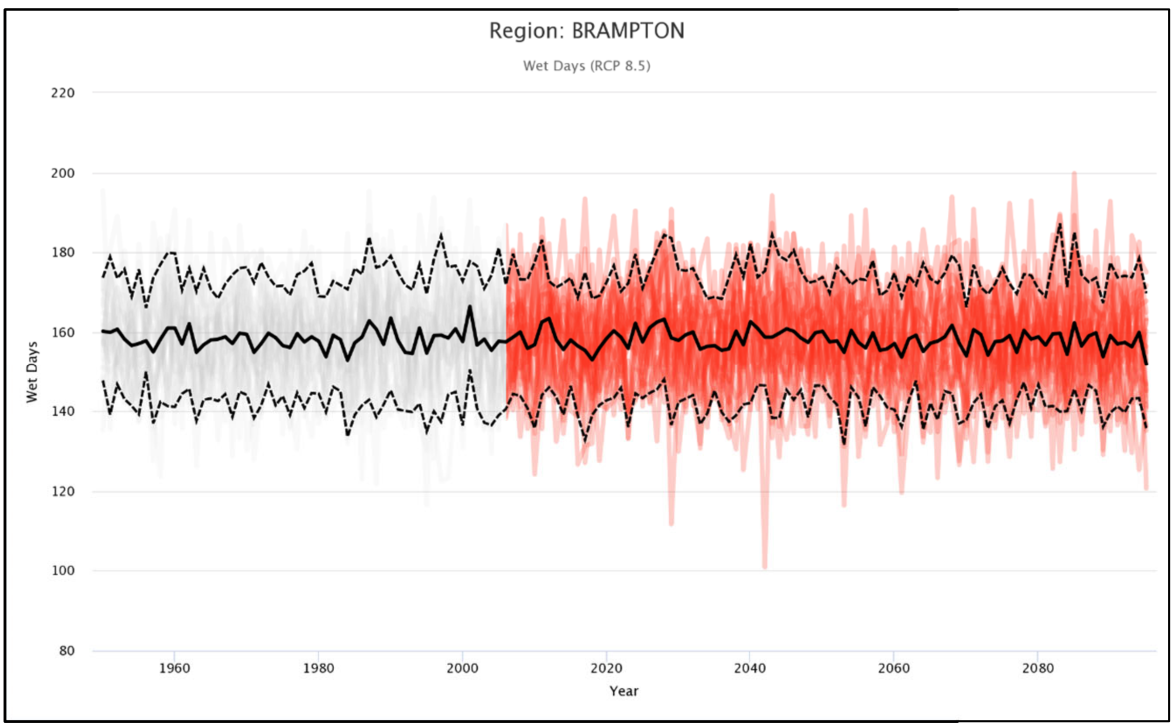
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

2. **Precipitation -** Heavy Precipitation Days (>20mm)



Climate Atlas RCP 8.5 Brampton/ Mississauga Region

1. **Precipitation -** Dry Days



Climate Atlas RCP 8.5 Brampton/ Mississauga Region

2. **Precipitation -** Wet Days

IDF-CC

1. **Precipitation -** IDF Curve for TORONTO INTL A 6158731 (1950-2017)

Storm Duration	Return Period						
	2	5	10	20	25	50	100
5 min	8.36	11.2	13.0	14.8	15.3	17.1	18.8
10 min	12.3	16.5	19.2	21.6	22.3	24.5	26.7
15 min	15.3	20.6	23.8	26.8	27.7	30.3	32.8
30 min	20.1	27.6	32.3	36.6	38.0	42.0	45.9
1 h	23.1	32.0	38.1	44.1	46.0	52.0	58.1
2 h	26.3	36.9	45.0	53.5	56.4	65.9	76.4
6 h	33.7	46.7	57.7	70.5	75.1	91.1	110
12 h	38.7	51.8	63.9	78.9	84.5	105	131
24 h	44.0	58.5	71.6	87.9	93.9	116	143

2. **Precipitation -** Projected IDF Curve for TORONTO INTL A 6158731 (2051-2080)

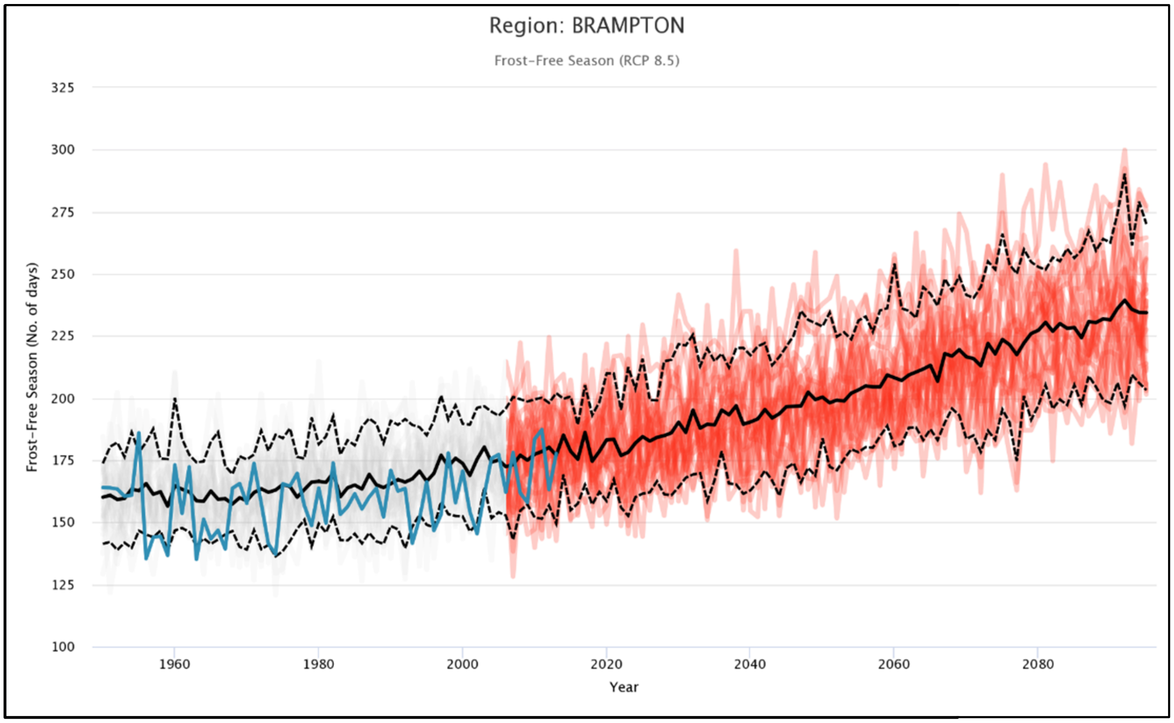
Storm Duration	Return Period						
	2	5	10	20	25	50	100
5 min	9.68	13.0	15.3	17.4	18.1	20.3	22.8
10 min	14.3	19.2	22.5	25.5	26.4	29.3	32.6
15 min	17.7	24.0	28.1	31.7	32.7	36.2	40.1
30 min	23.3	32.1	38.0	43.3	45.0	50.2	56.1
1 h	26.7	37.3	44.9	51.9	54.3	61.9	70.5
2 h	30.5	43.2	53.0	62.6	66.0	78.9	91.9
6 h	39.0	54.7	68.0	81.6	86.8	106	133
12 h	44.8	60.2	75.3	91.0	96.6	118	151
24 h	51.0	67.9	84.4	101	107	131	166

IDF-CC

3. Precipitation - Projected Changes in Extreme Rainfall (mm) at Pearson Airport

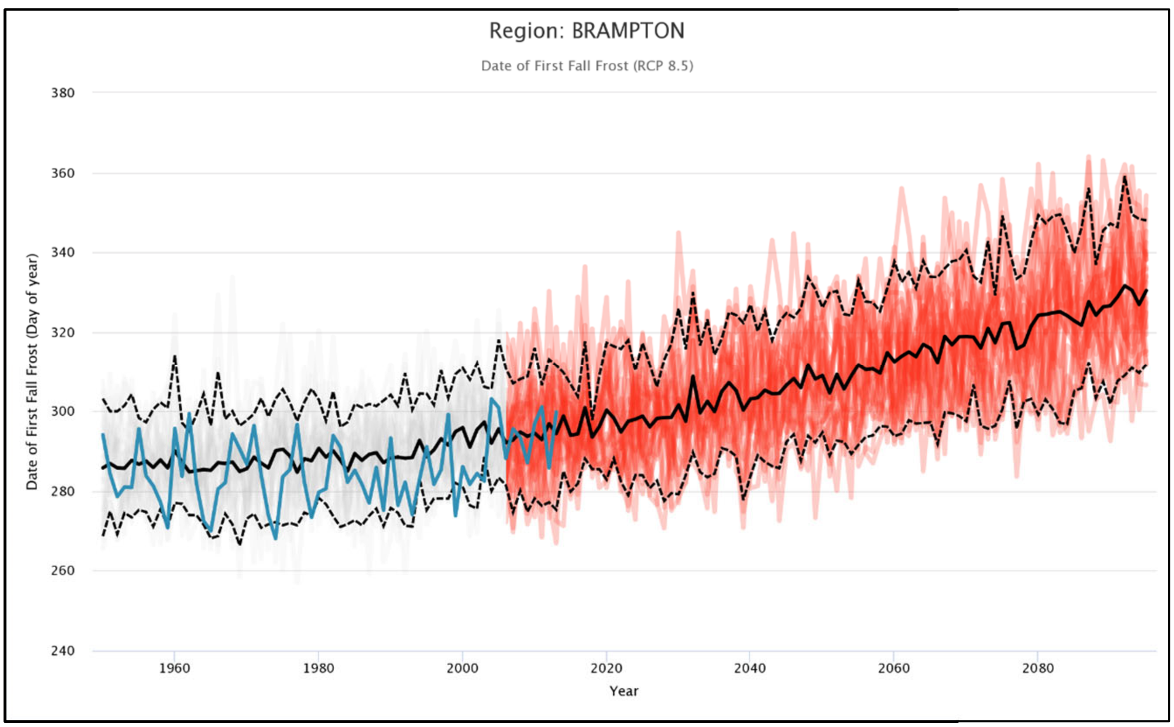
Storm Duration	Return Period						
	2	5	10	20	25	50	100
5 min	16%	17%	18%	18%	18%	19%	22%
10 min	16%	16%	18%	18%	18%	19%	22%
15 min	16%	16%	18%	18%	18%	20%	22%
30 min	16%	16%	18%	18%	18%	20%	22%
1 h	16%	17%	18%	18%	18%	19%	21%
2 h	16%	17%	18%	17%	17%	20%	20%
6 h	16%	17%	18%	16%	16%	16%	21%
12 h	16%	16%	18%	15%	14%	13%	15%
24 h	16%	16%	18%	15%	14%	13%	16%

2. Add photograph caption here



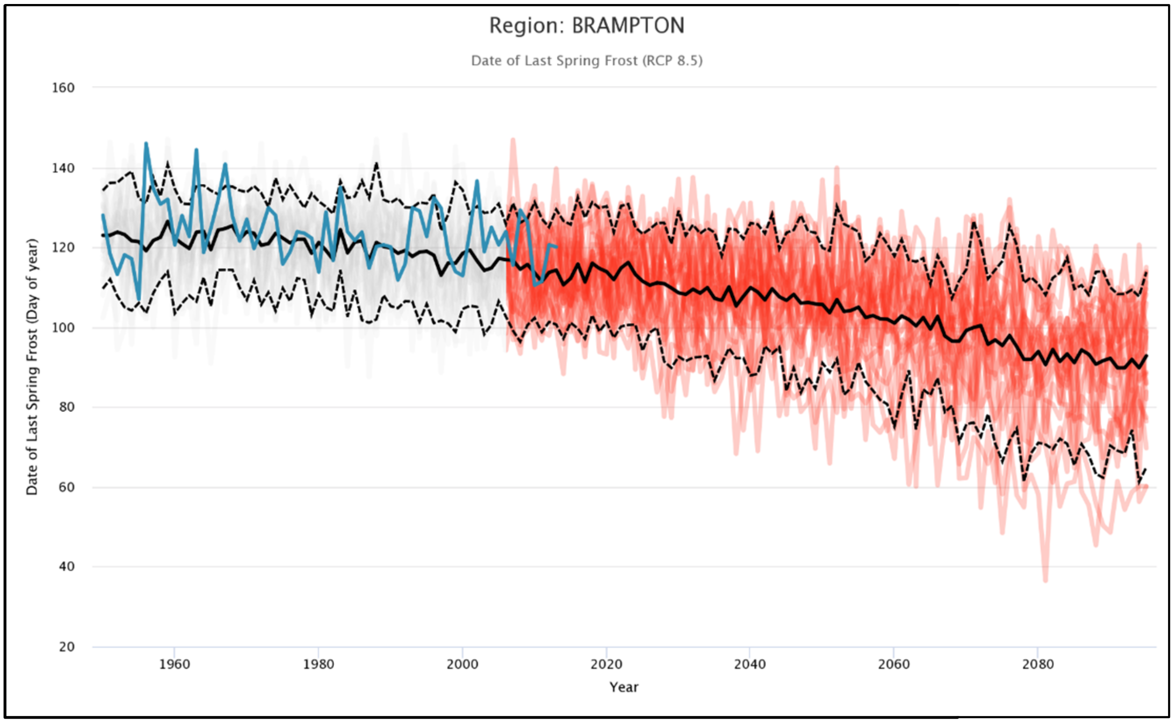
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

1. **Agriculture -** Frost Free Season



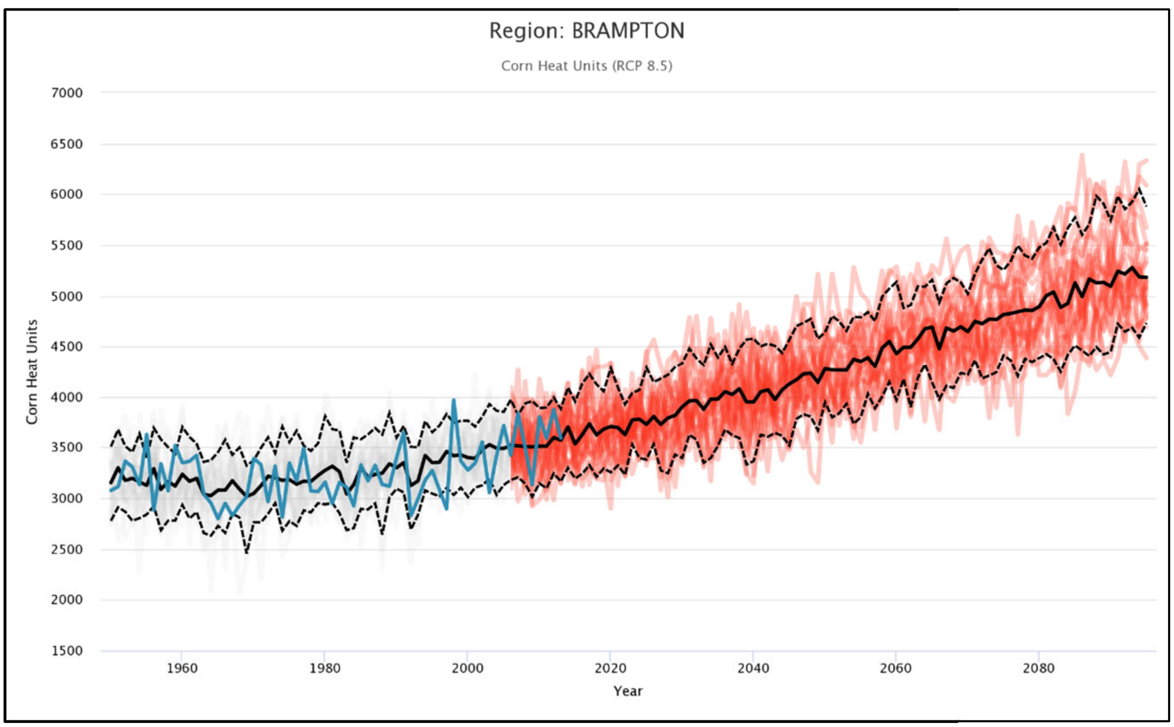
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

2. **Agriculture -** Date of First Fall Frost



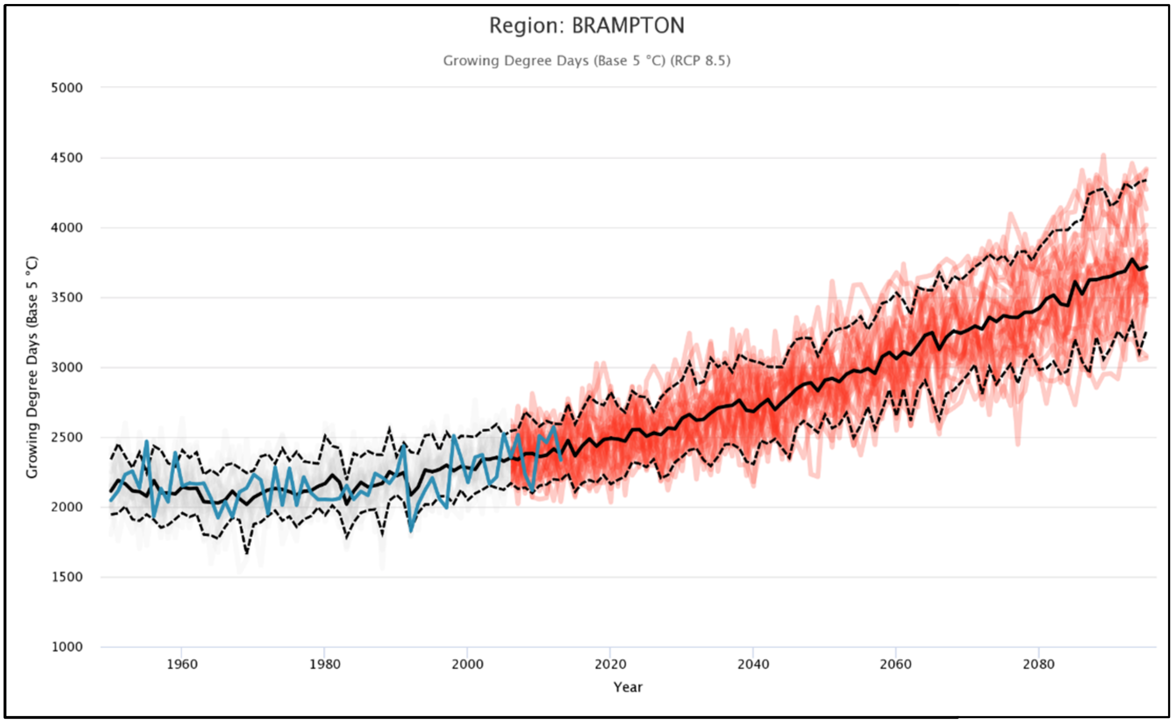
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

3. **Agriculture -** Date of Last Spring Frost



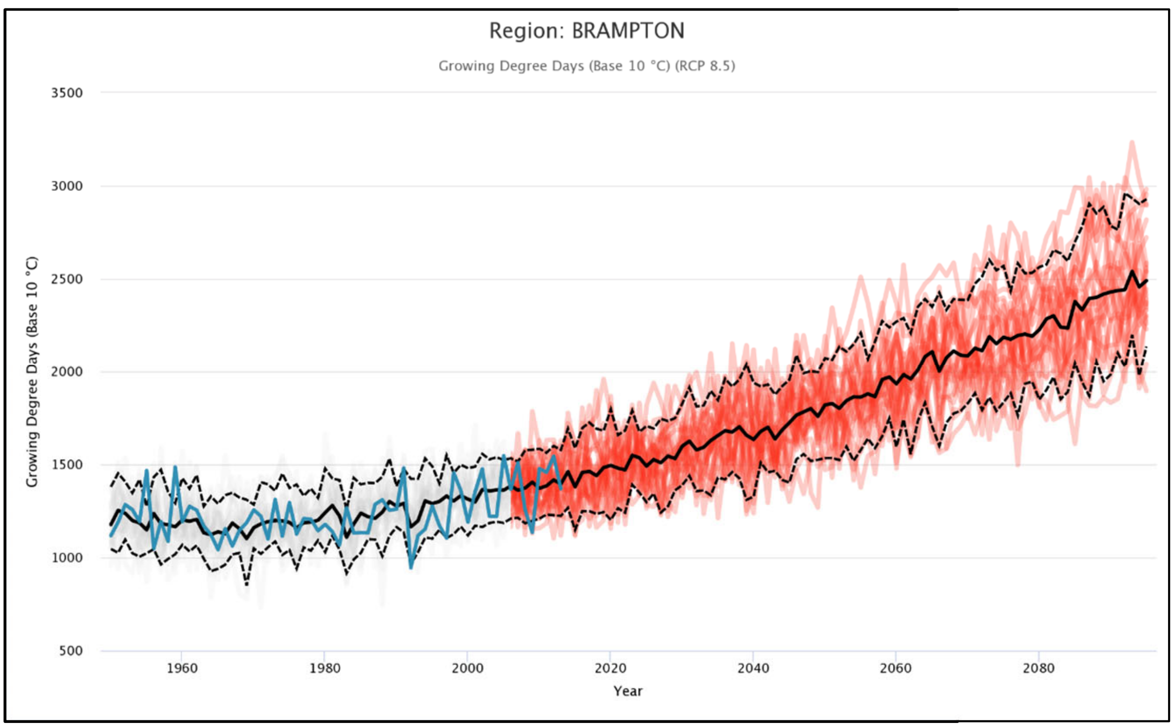
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

4. **Agriculture -** Corn Heat Units



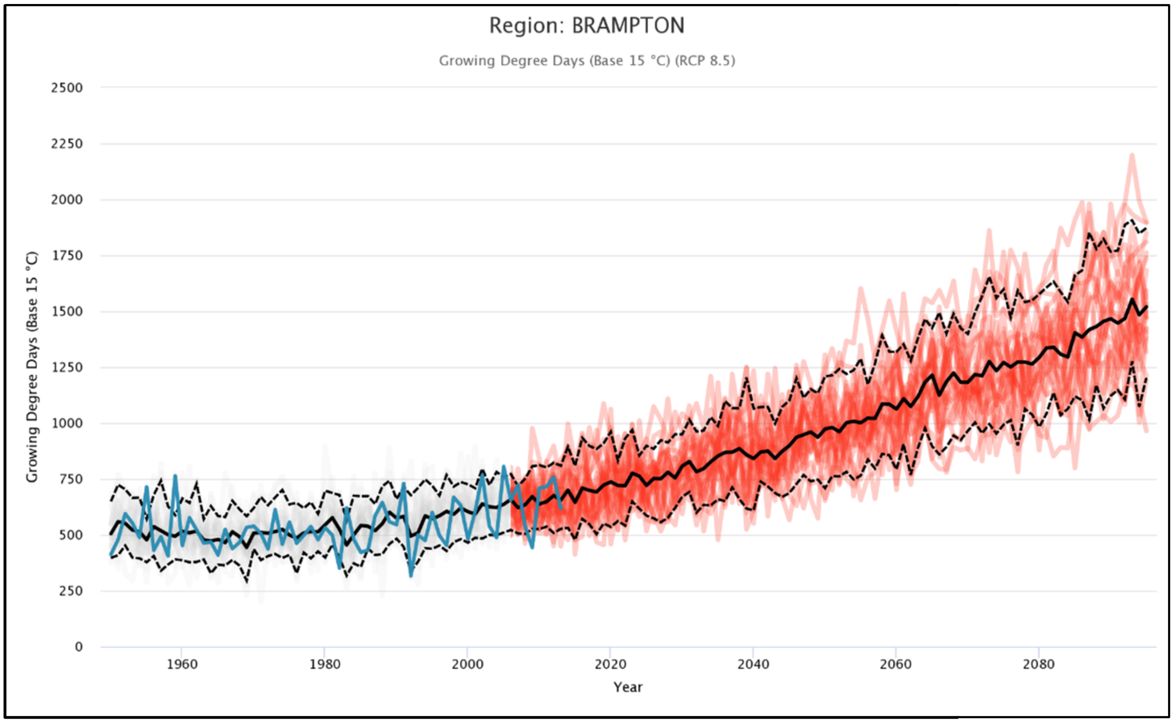
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

5. Agriculture - Growing Degree Day (Base 5)



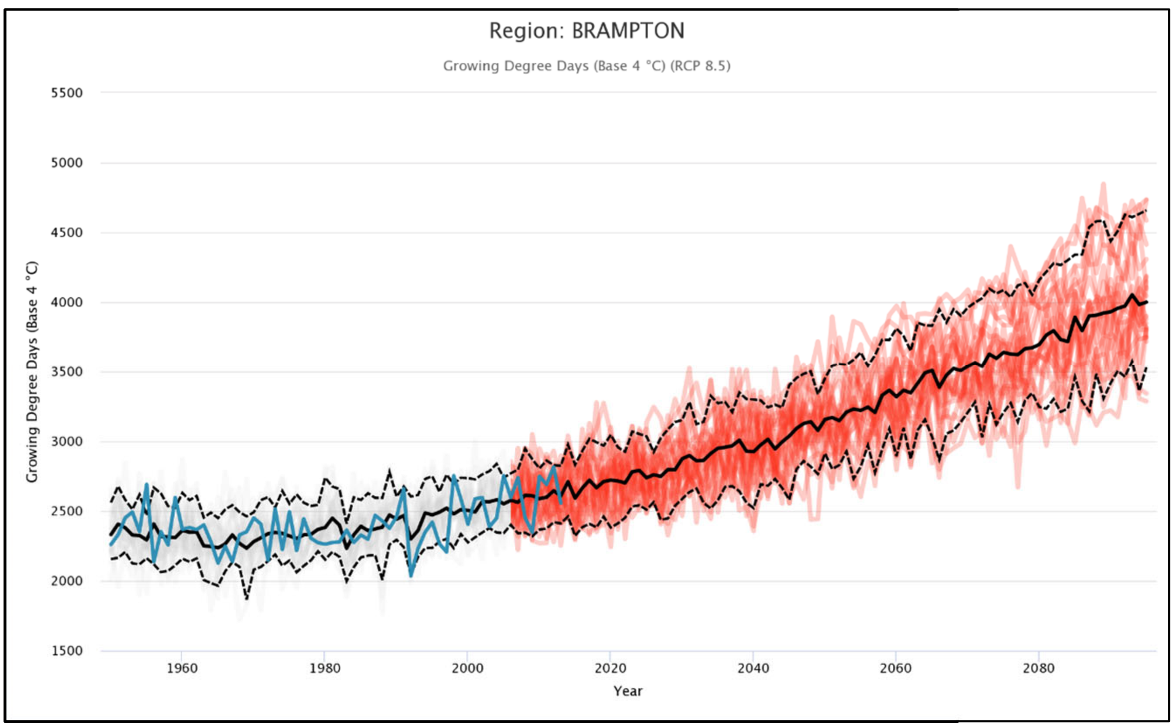
Climate Atlas RCP 8.5 Brampton/ Mississauga Region

6. Agriculture - Growing Degree Day (Base 10)



Climate Atlas RCP 8.5 Brampton/ Mississauga Region

7. Agriculture - Growing Degree Day (Base 15)



Climate Atlas RCP 8.5 Brampton/ Mississauga Region

8. Agriculture - Growing Degree Day (Base 4)

APPENDIX B
Risk Assessment

Infrastructure Components			1 Extreme High Temperatures — Extreme Heat (Days > 30 C)										
			Climate Interaction		Consequence and Risk								
					People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Boulevard	Sidewalk	Y	5	4	20	Health risks to pedestrians	2	10	Expansion and cracking of surface			
		Street Lighting	N										
		Cycle Track	Y	5	4	20	Health risks to cyclists	2	10	Expansion and cracking of surface			
		Bus Shelter	Y	5	4	20	Health risks to transit users	2	10	Heating effects on bus shelter materials			
		Waterfront Trail	Y	5	4	20	Health risks to trail users	2	10	Expansion and cracking of surface			
	Bridges and Culverts	Etobicoke Creek Bridge	Y	5				2	10	Expansion and cracking of surface and structural materials			
		Creek Culverts	Y	5				2	10	Expansion and cracking of road surface above culvert			
	Green Infrastructure	Trees	Y	5				2	10	Increased maintenance requirements/operational impact (e.g. watering)	3	15	Stress on trees and other vegetation
		Landscape design around stations (trees, public spaces improvements)	Y	5				2	10	Increased maintenance requirements/operational impact (e.g. watering)	3	15	Stress on trees and other vegetation
	Roadway	Curb	N										
		Signage	N										
		Sub-Base	Y	5				2	10	Expansion of subbase and subsequent weathering of surface			
		Surface (Transit, auto lanes)	Y	5				2	10	Expansion and cracking of surface			
		Transit Stations/Stops	N										
		Signals (Traffic, pedestrian, cycling)	N										
		Intersections	N										
	Sanitary Infrastructure	Sanitary Sewers	N										
		Pump Stations & Wet Wells	N										
		Maintenance Holes	N										
		Flow & Level Monitors	N										
		Flow Control Structures	N										
	Stormwater Infrastructure	Storm Sewer	N										
		Storm Sewer Outfalls	N										
		Catch Basins	N										
		Pump Stations & Wet Wells	N										
		Maintenance Holes	N										
		Flow & Level Monitors	N										
		Flow Control Structures	N										

Infrastructure Components			2 Decrease in Cold Temperatures — No Winter days below -30 C (kill temperature for EAB)										
			Climate Interaction		Consequence and Risk								
					People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Boulevard	Sidewalk	N										
		Street Lighting	N										
		Cycle Track	N										
		Bus Shelter	N										
		Waterfront Trail	N										
	Bridges and Culverts	Etobicoke Creek Bridge	N										
		Creek Culverts	N										
	Green Infrastructure	Trees	Y	5							4	20	Stress on trees due to less pest/insect die-off
		Landscape design around stations (trees, public spaces improvements)	Y	5							4	20	Stress on trees due to less pest/insect die-off
	Roadway	Curb	N										
		Signage	N										
		Sub-Base	N										
		Surface (Transit, auto lanes)	N										
		Transit Stations/Stops	N										
		Signals (Traffic, pedestrian, cycling)	N										
		Intersections	N										
	Sanitary Infrastructure	Sanitary Sewers	N										
		Pump Stations & Wet Wells	N										
		Maintenance Holes	N										
		Flow & Level Monitors	N										
		Flow Control Structures	N										
	Stormwater Infrastructure	Storm Sewer	N										
		Storm Sewer Outfalls	N										
		Catch Basins	N										
		Pump Stations & Wet Wells	N										
		Maintenance Holes	N										
		Flow & Level Monitors	N										
		Flow Control Structures	N										

Infrastructure Components			1 Extreme High Temperatures: Extreme Heat (Days > 30 C) — Climate Interaction		Consequence and Risk: People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Utilities	Water Distribution Infrastructure	N										
		Electrical - Transformers	Y	5	4	20	If power is lost, safety impact to people.	2	10	More heat waves may reduce the life of transformers leading to failure (overheating)			
		Electrical - Above Ground Distribution	N										
		Utility Poles	N										
		Maintenance Holes	N										
		Other Underground Utilities (e.g., gas, telecom)	N										
Indirect	Operations	Maintenance (cleaning, snow removal)	Y	5	4	20	Health risks to maintenance staff						
		Construction	Y	5	4	20	Health risks to construction crews	1	5	Heat waves may limit construction activities resulting in schedule issues			
	Upstream and Downstream	Creeks	N										
		Downstream Connected Storm Sewers	N										
		Urban Landscape - Buildings	N										
		Urban Landscape - Business and Commerce	N										
		Urban Landscape - Roadways	N										
		Urban Landscape - Boulevards	N										
		Waterfront Trail	N										
		Park	N										
		Lakeview Water Treatment Plant	N										
		Lakeview Wastewater Treatment Plant	N										

Infrastructure Components			2 Decrease in Cold Temperatures: No Winter days below -30 C (kill temperature for EAB) — Climate Interaction		Consequence and Risk: People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Utilities	Water Distribution Infrastructure	N										
		Electrical - Transformers	N										
		Electrical - Above Ground Distribution	N										
		Utility Poles	N										
		Maintenance Holes	N										
		Other Underground Utilities (e.g., gas, telecom)	N										
Indirect	Operations	Maintenance (cleaning, snow removal)	N										
		Construction	N										
	Upstream and Downstream	Creeks	N										
		Downstream Connected Storm Sewers	N										
		Urban Landscape - Buildings	N										
		Urban Landscape - Business and Commerce	N										
		Urban Landscape - Roadways	N										
		Urban Landscape - Boulevards	N										
		Waterfront Trail	N										
		Park	N										
		Lakeview Water Treatment Plant	N										
		Lakeview Wastewater Treatment Plant	N										

Infrastructure Components			3												4											
			Extreme Rainfall												Flooding											
			10-yr Event (return period for storm sewer design). Intensities above 10yr IDF may flood roadway												Riverine Flooding (50 yr event or greater)											
			Climate Interaction		Consequence and Risk										Climate Interaction		Consequence and Risk									
					People			Economic			Environment						People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational		Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Boulevard	Sidewalk	Y	4	4	16	Flash-flooding of sidewalk. Reduced visibility of pedestrians during intense rainfall events	1	4	Potential economic impacts/infrastructure damage					Y	2	5	10	Riverine flooding cascading into flooding of boulevard						
		Street Lighting	N												N										
		Cycle Track	Y	4	4	16	Flash-flooding of cycle track. Reduced visibility of cyclists during intense rainfall events	1	4	Potential economic impacts/infrastructure damage					Y	2	5	10	Riverine flooding cascading into flooding of boulevard						
		Bus Shelter	N												N										
		Waterfront Trail	Y	4	4	16	Flash-flooding of trail. Reduced visibility of cyclists and pedestrians during intense rainfall events	2	8	Erosion of waterfront trail/shoulder materials may require repairs					Y	2	5	10	Riverine flooding cascading into flooding of boulevard	3	6	erosion and channelizing for soil and gravel components of the trail			
	Bridges and Culverts	Etobicoke Creek Bridge	Y	4	4	16	Flash flooding of bridge and nearby roadway. Reduced visibility and dangerous driving conditions	2	8	Potential economic impacts/infrastructure damage					Y	2	5	10	Flooding of creeks, overtopping culverts, inundating road and neighbourhood	5	10	Erosion damage to bridges during high flood events. May result in complete loss of bridge or significant damage upstream or downstream.			
		Creek Culverts	Y	4	4	16	Flash flooding of roadway and landscape when culverts are over capacity.	2	8	Potential economic impacts/infrastructure damage					Y	2	5	10	Flooding of creeks, overtopping culverts, inundating road and neighbourhood	5	10	Erosion damage to culverts and channel features during high flood events. Potentially significant damage to culvert and surrounding infrastructure.			
	Green Infrastructure	Trees	N												N										
		Landscape design around stations (trees, public spaces improvements)	N												N										
	Roadway	Curb	N												N										
		Signage	N												N										
		Sub-Base	N												N										
		Surface (Transit, auto lanes)	Y	4	5	20	Intense rainfall causing local flooding of road. Dangerous driving conditions.	2	8	Increased storm activity resulting in localized weathering/erosion					Y	2	5	10	Riverine flooding onto Roadway. Safety risk to users.						
		Transit Stations/Stops	Y	4	5	20	Intense rainfall causing local flooding of road. Reduced visibility of signage, transit, and pedestrians during high rainfall events								Y	2	5	10	Riverine flooding onto Roadway. Safety risk to users.	4	8	Damage to transit stations during flood events.			
		Signals (Traffic, pedestrian, cycling)	Y	4	5	20	Reduced visibility of signals and signage during high rainfall events								N										
		Intersections	Y	4	5	20	Intense rainfall causing local visibility problems at intersections and interaction with transit/cyclists/ pedestrians	1	4	Economic impact as a result of potential damage (e.g. traffic redirection etc)					N										
	Sanitary Infrastructure	Sanitary Sewers	Y	4				1	4	Stormwater infiltration into sanitary sewers, excess flow to treatment plant	2	8	There could be an environment impact here if infiltration leads to the lake		Y	2				1	2	Stormwater infiltration into sanitary sewers, excess flow to treatment plant			
		Pump Stations & Wet Wells	Y	4				2	8	Flooding of stations and wet wells, leading to increased maintenance					Y	2				2	4	Flooding of stations and wet wells, leading to increased maintenance			
		Maintenance Holes	Y	4				1	4	Stormwater infiltration into sanitary sewers, excess flow to treatment plant					Y	2				1	2	Stormwater infiltration into sanitary sewers, excess flow to treatment plant			
		Flow & Level Monitors	Y	4				1	4	Flooding of system leading to increased maintenance					Y	2				1	2	Flooding of system leading to increased maintenance			
		Flow Control Structures	N												N										
	Stormwater Infrastructure	Storm Sewer	Y	4				2	8	Local runoff exceeding design storm system capacity (all components). Increased weathering of components.					Y	2				4	8	Riverine flood may surcharge the stormsewer, resulting in additional flooding to businesses			
		Storm Sewer Outfalls	Y	4				2	8		2	8	Potential impacts to water quality from increased urban runoff		Y	2							2	4	Potential impacts to water quality
		Catch Basins	Y	4				2	8						N										
		Pump Stations & Wet Wells	Y	4				2	8						N										
		Maintenance Holes	Y	4				2	8						N										
		Flow & Level Monitors	Y	4				2	8						N										
		Flow Control Structures	Y	4				2	8						N										

3 — Extreme Rainfall

10-yr Event (return period for storm sewer design). Intensities above 10yr IDF may flood roadway

Infrastructure Components			Climate Interaction		Consequence and Risk								
					People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Utilities	Water Distribution Infrastructure	N										
		Electrical - Transformers	Y	4	3	12	Potential power outages due to heavy rain may cause delays in operations and services due to water getting into conduit/ access	2	8	Increased maintenance to address power outages and damage			
		Electrical - Above Ground Distribution	N										
		Utility Poles	N										
		Maintenance Holes	Y	4				2	8	Flooding of utilities resulting in increased maintenance			
		Other Underground Utilities (e.g., gas, telecom)	Y	4				2	8	Flooding of utilities resulting in increased maintenance			
Indirect	Operations	Maintenance (cleaning, snow removal)	Y	4	4	16	Health and safety effects on winter maintenance personnel dealing with wet/cold conditions. Heavy rainfall may cause delays and reduced service reliability	2	8	Additional winter maintenance due to winter rain events. Additional maintenance due to impacts of flash flooding.	2	8	Increased precipitation to higher stormwater flows to receiving surface water. Increased maintenc may be requuired to reduce WQ impacts.
		Construction	Y	4	4	16	increased safety risks during construction due to heavy rainfall	2	8	Increased frequency of precipitation resulting in construction delays	3	12	Increased precipitation leading to erosion and sediment impacts to surface water
	Upstream and Downstream	Creeks	Y	4				2	8	Impacts to receiving creeks from over-capacity storm water system. Could result in larger downstream erosion mitigation requirements			Impacts to receiving creeks from urban runoff and debris
		Downstream Connected Storm Sewers	Y	4				2	8	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Increased weathering of infrastructure.			
		Urban Landscape - Buildings	Y	4	2	8	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Short term reduced access.	4	16	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Damage to private properties from potential .			
		Urban Landscape - Business and Commerce	Y	4	2	8	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Short term reduced access.	4	16	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Damage to private businesses from flooding.			
		Urban Landscape - Roadways	Y	4	4	16	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Road flooding (major system) due to over-capacity sewer system resulting in flooding of surrounding urban landscape. Increased safety risk to users.	2	8	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Road flooding (major system) due to over-capacity sewer system resulting in flooding of surrounding urban landscape. Increased maintenance and Increased weathering of infrastructure.			
		Urban Landscape - Boulevards	Y	4	4	16	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Increased safety risk, reduced access.	2	8	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Increased maintenance and Increased weathering of infrastructure.			
		Waterfront Trail	Y	4	1	4	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Increased safety risk, reduced access.	2	8	Local runoff exceeding sewer capacity, flooding roads and urban landscape			
		Park	Y	4	1	4	Local runoff exceeding sewer capacity, flooding roads and urban landscape. Increased safety risk, reduced access.	2	8	Local runoff exceeding sewer capacity, flooding roads and urban landscape.			
		Lakeview Water Treatment Plant	N										
		Lakeview Wastewater Treatment Plant	N										

4 — Flooding

Riverine Flooding (50 yr event or greater)

Infrastructure Components			Climate Interaction		Consequence and Risk								
					People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Utilities	Water Distribution Infrastructure	N										
		Electrical - Transformers	Y	2	2	4	Flooding events may affect transformers, impacting electronic service in the area	2	4	Maintenance and repairs following flood damage			
		Electrical - Above Ground Distribution	N										
		Utility Poles	N										
		Maintenance Holes	Y	2				2	4	Flooding of utilities resulting in increased maintenance			
		Other Underground Utilities (e.g., gas, telecom)	Y	2				2	4	Flooding of utilities resulting in increased maintenance			
Indirect	Operations	Maintenance (cleaning, snow removal)	Y	2	4	8	Safety risks to maintenance crews should flooding occur	2	4	Increased maintenance (repairs and cleanup)			
		Construction	Y	2	4	8	Safety risks to construction crews should flooding occur	2	4	Risk to construction schedule and equipment damage			
	Upstream and Downstream	Creeks	Y	2				3	6	Riverine flooding related to the crossings can lead to erosion of creeks			
		Downstream Connected Storm Sewers	Y	2				2	4	Riverine backup at outfall could back-up stormwater upstream resulting potentially minor consequences.			
		Urban Landscape - Buildings	Y	2				4	8	Potential for roadway and boulevard to convey riverine floodwaters to urban landscape, with flood damage to buildings and businesses			
		Urban Landscape - Business and Commerce	Y	2				4	8				
		Urban Landscape - Roadways	Y	2	5	10	Potential for major system to convey riverine floodwater into urban landscape with safety risks for motorists, pedestrians, residents, cyclists	3	6	Potential for roadway and boulevard to convey riverine floodwaters to urban landscape, affecting roadways, boulevards, pedestrians and cyclists. Increased maintenance and Increased weathering of infrastructure. Erosion and channelizing for soil and gravel components of the trail			
		Urban Landscape - Boulevards	Y	2	5	10		3	6				
		Waterfront Trail	Y	2	5	10		3	6				
		Park	Y	2	5	10		3	6				
		Lakeview Water Treatment Plant	N										
		Lakeview Wastewater Treatment Plant	N										

			5												6										
			Ice and Snow												Freeze Thaw										
Infrastructure Components			Climate Interaction		Consequence and Risk										Climate Interaction		Consequence and Risk								
					People			Economic			Environment						People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational		Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Boulevard	Sidewalk	Y	3	4	12	Freezing rain may cause ramps and platforms to become slippery, which could result in slips and falls. Snow on sidewalks impede accessibility if not cleared.				3	9	Salt usage on adjacent environmental features		Y	3				2	6	Weathering from freeze thaw.			
Project	Boulevard	Street Lighting	N												N										
Project	Boulevard	Cycle Track	N												Y	3				2	6	Weathering from freeze thaw.			
Project	Boulevard	Bus Shelter	Y	3	4	12	Freezing rain could cause ice to build up and fall from bus shelters roofs, which may result in injuries								N										
Project	Boulevard	Waterfront Trail	Y	3	4	12	Snow and ice on trail impede accessibility if not cleared.								Y	3				2	6	Weathering from freeze thaw.			
Project	Bridges and Culverts	Etobicoke Creek Bridge	Y	3	4	12	Ice can build up easiest on bridges, resulting in safety risks								Y	3				2	6	Weathering from freeze thaw.			
Project	Bridges and Culverts	Creek Culverts	N												Y	3				2	6	Weathering from freeze thaw.			
Project	Green Infrastructure	Trees	Y	3	4	12	Ice/snow build up could injur people	2	6	Maintenance and operations (e.g. clearing/removal of ice)	3	9	Freezing rain could damage trees and frail vegetation		N										
Project	Green Infrastructure	Landscape design around stations (trees, public spaces improvements)	Y	3	4	12	Ice/snow build up could injur people				3	9	Freezing rain could damage trees and frail vegetation		N										
Project	Roadway	Curb	N												Y	3				2	6	Weathering from freeze thaw.			
Project	Roadway	Signage	N												N										
Project	Roadway	Sub-Base	N												Y	3				2	6	Weathering from freeze thaw.			
Project	Roadway	Surface (Transit, auto lanes)	Y	3	4	12	Reduced preparedness for ice and snow in the future may result in disrupted service. Freezing rain may cause road to become slippery.	2	6	Econonmic impact from removal. Potential liability from slips/falls low due to insurance					Y	3				2	6	Weathering from freeze thaw.			
Project	Roadway	Transit Stations/Stops	Y	3	4	12	Freezing rain may cause ramps and platforms to become slippery, which could result in slips and falls	2	6	Econonmic impact from removal. Potential liability from slips/falls low due to insurance					N										
Project	Roadway	Signals (Traffic, pedestrian, cycling)	Y	3	4	12	Ice and snow can reduce visibility of signals, increasing risk.								N										
Project	Roadway	Intersections	Y	3	4	12	Freezing rain may cause intersections to become slippery, which could result in slips and falls when crossing. Additional vehicle risk is also present in slippery intersections	2	6	Econonmic impact from removal. Potential liability from slips/falls low due to insurance					N										
Project	Sanitary Infrastructure	Sanitary Sewers	N												N										
Project	Sanitary Infrastructure	Pump Stations & Wet Wells	N												N										
Project	Sanitary Infrastructure	Maintenance Holes	N												N										
Project	Sanitary Infrastructure	Flow & Level Monitors	N												N										
Project	Sanitary Infrastructure	Flow Control Structures	N												N										
Project	Stormwater Infrastructure	Storm Sewer	Y	3				1	3	Increased I&Ipotential from melt					Y	3				2	6	Weathering from freeze thaw.			
Project	Stormwater Infrastructure	Storm Sewer Outfalls	Y	3				1	3	Increased I&Ipotential from melt	3	9	Water quality impacts from salt usage		N										
Project	Stormwater Infrastructure	Catch Basins	Y	3				1	3	Blocked CBs with ice and snow reduces function					Y	3				2	6	Weathering from freeze thaw.			
Project	Stormwater Infrastructure	Pump Stations & Wet Wells	N												N										
Project	Stormwater Infrastructure	Maintenance Holes	N												N										
Project	Stormwater Infrastructure	Flow & Level Monitors	N												N										
Project	Stormwater Infrastructure	Flow Control Structures	N												N										

			5											6										
			Ice and Snow											Freeze Thaw										
Infrastructure Components			Climate Interaction		Consequence and Risk									Climate Interaction		Consequence and Risk								
					People			Economic			Environment					People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational	Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Utilities	Water Distribution Infrastructure	N											N										
		Electrical - Transformers	Y	3	4	12	Freezing rain could result in potential power outages, which could cause delays in operations and services. Power lines may be damaged by freezing rain. Brief (hours) service disruption.	2	6					N										
		Electrical - Above Ground Distribution	Y	3	4	12	Freezing rain could result in potential power outages, which could cause delays in operations and services. Power lines may be damaged by freezing rain. Brief (hours) service disruption.	2	6	Ice accumulation damaging power grid, service disruption.				N										
		Utility Poles	Y	3	4	12	Falling ice.	2	6					N										
		Maintenance Holes	N											Y	3				2	6	Weathering from freeze thaw.			
		Other Underground Utilities (e.g., gas, telecom)	N											Y	3				2	6	Weathering from freeze thaw.			
Indirect	Operations	Maintenance (cleaning, snow removal)	Y	3	4	12	Reduced maintenance capacity for ice and snow in the future, may result in longer service disruptions. During winter, rain and snow could cause an accumulation of slush on sidewalks, which may result in falls and slips as well as difficult working conditions for staff	2	6	Maintenance needs for future ice and snow events may fall outside budgeted amounts.	3	9	Salt usage impacts to adjacent environmental features, groundwater	N										
		Construction	Y	3	4	12	Snow and ice events present risks to construction crews	2	6	Snow and ice events may result in schedule delays on construction projects.				N										
	Upstream and Downstream	Creeks	N											N										
		Downstream Connected Storm Sewers	N											N										
		Urban Landscape - Buildings	N											N										
		Urban Landscape - Business and Commerce	N											N										
		Urban Landscape - Roadways	N											N										
		Urban Landscape - Boulevards	N											N										
		Waterfront Trail	N											N										
		Park	N											N										
		Lakeview Water Treatment Plant	N											N										
		Lakeview Wastewater Treatment Plant	N											N										

Infrastructure Components			7										
			High Groundwater										
			Warmer winters and spring, higher precipitation.										
			Climate Interaction		Consequence and Risk								
					People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Boulevard	Sidewalk	N										
Project	Boulevard	Street Lighting	N										
Project	Boulevard	Cycle Track	N										
Project	Boulevard	Bus Shelter	N										
Project	Boulevard	Waterfront Trail	N										
Project	Bridges and Culverts	Etobicoke Creek Bridge	N										
Project	Bridges and Culverts	Creek Culverts	N										
Project	Green Infrastructure	Trees	N										
Project	Green Infrastructure	Landscape design around stations (trees, public spaces improvements)	N										
Project	Roadway	Curb	N										
Project	Roadway	Signage	N										
Project	Roadway	Sub-Base	n										
Project	Roadway	Surface (Transit, auto lanes)	n										
Project	Roadway	Transit Stations/Stops	N										
Project	Roadway	Signals (Traffic, pedestrian, cycling)	N										
Project	Roadway	Intersections	N										
Project	Sanitary Infrastructure	Sanitary Sewers	Y	2				1	2	Infiltration into sewers and preferential pathways			
Project	Sanitary Infrastructure	Pump Stations & Wet Wells	Y	2				1	2	Infiltration into sewers and preferential pathways			
Project	Sanitary Infrastructure	Maintenance Holes	Y	2				1	2	Infiltration into sewers and preferential pathways			
Project	Sanitary Infrastructure	Flow & Level Monitors	N										
Project	Sanitary Infrastructure	Flow Control Structures	N										
Project	Stormwater Infrastructure	Storm Sewer	Y	2				1	2	Infiltration into sewers and preferential pathways			
Project	Stormwater Infrastructure	Storm Sewer Outfalls	N										
Project	Stormwater Infrastructure	Catch Basins	N										
Project	Stormwater Infrastructure	Pump Stations & Wet Wells	N										
Project	Stormwater Infrastructure	Maintenance Holes	N										
Project	Stormwater Infrastructure	Flow & Level Monitors	N										
Project	Stormwater Infrastructure	Flow Control Structures	N										

Infrastructure Components			8										
			Winds										
			Gale Winds (beufort scale)										
			Climate Interaction		Consequence and Risk								
					People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Boulevard	Sidewalk	Y	4	4	16	Blowing objects can create safety hazards to pedestrians						
Project	Boulevard	Street Lighting	Y	4	4	16	Street light can create safety hazard if blown down during high winds	2	8	May need repair or replacement if damaged			
Project	Boulevard	Cycle Track	N										
Project	Boulevard	Bus Shelter	Y	4	4	16	Damage to bus shelter presents safety risks to transit users	2	8	Possible damage to structure under high winds from flying debris			
Project	Boulevard	Waterfront Trail	N										
Project	Bridges and Culverts	Etobicoke Creek Bridge	N										
Project	Bridges and Culverts	Creek Culverts	N										
Project	Green Infrastructure	Trees	Y	4	4	16	Falling branches and trees create safety hazard to pedestrians	2	8	Tree maintenance, debris clean-up of downed branches	2	8	potential loss of trees during extreme winds (>90km/hr)
Project	Green Infrastructure	Landscape design around stations (trees, public spaces improvements)	Y	4	4	16	Falling branches and trees create safety hazard to pedestrians	2	8	Tree maintenance, debris clean-up of downed branches	2	8	potential loss of trees during extreme winds (>90km/hr)
Project	Roadway	Curb	N										
Project	Roadway	Signage	Y	4	4	16	Potential to become a safety hazard if signage disconnected	2	8	May need repair or replacement if damaged			
Project	Roadway	Sub-Base	N										
Project	Roadway	Surface (Transit, auto lanes)	N										
Project	Roadway	Transit Stations/Stops	Y	4	4	16	Blowing objects can create a safety hazard to pedestrians	1	4	Economic impact if there is any impact to bus service (loss bus fares)			
Project	Roadway	Signals (Traffic, pedestrian, cycling)	Y	4	4	16	Hazard to corridor users if signals damaged	2	8	May need repair or replacement if damaged			
Project	Roadway	Intersections	N										
Project	Sanitary Infrastructure	Sanitary Sewers	N										
Project	Sanitary Infrastructure	Pump Stations & Wet Wells	N										
Project	Sanitary Infrastructure	Maintenance Holes	N										
Project	Sanitary Infrastructure	Flow & Level Monitors	N										
Project	Sanitary Infrastructure	Flow Control Structures	N										
Project	Stormwater Infrastructure	Storm Sewer	N										
Project	Stormwater Infrastructure	Storm Sewer Outfalls	N										
Project	Stormwater Infrastructure	Catch Basins	N										
Project	Stormwater Infrastructure	Pump Stations & Wet Wells	N										
Project	Stormwater Infrastructure	Maintenance Holes	N										
Project	Stormwater Infrastructure	Flow & Level Monitors	N										
Project	Stormwater Infrastructure	Flow Control Structures	N										

Infrastructure Components			7 – High Groundwater Warmer winters and spring, higher precipitation. Climate Interaction		Consequence and Risk – People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Utilities	Water Distribution Infrastructure	N										
		Electrical - Transformers	N										
		Electrical - Above Ground Distribution	N										
		Utility Poles	N										
		Maintenance Holes	N										
		Other Underground Utilities (e.g., gas, telecom)	Y	2				1	2	Infiltration into sewers and preferential pathways			
Indirect	Operations	Maintenance (cleaning, snow removal)	N										
		Construction	N										
	Upstream and Downstream	Creeks	N										
		Downstream Connected Storm Sewers	N										
		Urban Landscape - Buildings	N										
		Urban Landscape - Business and Commerce	N										
		Urban Landscape - Roadways	N										
		Urban Landscape - Boulevards	N										
		Waterfront Trail	N										
		Park	N										
		Lakeview Water Treatment Plant	N										
		Lakeview Wastewater Treatment Plant	N										

Infrastructure Components			8 – Winds Gale Winds (beufort scale) Climate Interaction		Consequence and Risk – People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Utilities	Water Distribution Infrastructure	N										
		Electrical - Transformers	Y	4	4	16	Hazard to corridor users if above ground electrical equipment damaged during high winds	2	8	May need repair or replacement if damaged			
		Electrical - Above Ground Distribution	Y	4	4	16	Hazard to corridor users if above ground electrical equipment damaged during high winds	2	8	May need repair or replacement if damaged			
		Utility Poles	Y	4	4	16	Hazard to corridor users if fall due to high winds	2	8	May need repair or replacement if damaged			
		Maintenance Holes	N										
		Other Underground Utilities (e.g., gas, telecom)	N										
Indirect	Operations	Maintenance (cleaning, snow removal)	Y	4	4	16	High winds risky for maintenance staff	1	4	Effort for debris removal following high wind events. Damage to maintenance equipment			
		Construction	Y	4	4	16	High winds risky for construction staff	1	4	Damage to construction equipment and site materials			
	Upstream and Downstream	Creeks	N										
		Downstream Connected Storm Sewers	N										
		Urban Landscape - Buildings	N										
		Urban Landscape - Business and Commerce	N										
		Urban Landscape - Roadways	N										
		Urban Landscape - Boulevards	N										
		Waterfront Trail	N										
		Park	N										
		Lakeview Water Treatment Plant	N										
		Lakeview Wastewater Treatment Plant	N										

Infrastructure Components			Climate Interaction		Consequence and Risk								
			9 Drought – Dry days and summer precipitation										
					People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Boulevard	Sidewalk	N										
		Street Lighting	N										
		Cycle Track	N										
		Bus Shelter	N										
		Waterfront Trail	N										
	Bridges and Culverts	Etobicoke Creek Bridge	N										
		Creek Culverts	N										
	Green Infrastructure	Trees	Y	4				3	12	Increased maintenance requirements/operational impact (e.g. watering).	3	12	Stress on trees. Drought could cause reduce soil quality.
		Landscape design around stations (trees, public spaces improvements)	Y	4				3	12	Increased maintenance requirements/operational impact (e.g. watering). Drought could cause reduce soil quality, increased maintenance of landscaping around stations.	3	12	Stress on vegetation. Drought could cause reduce soil quality, resulting in loss of vegetation.
	Roadway	Curb	N										
		Signage	N										
		Sub-Base	N										
		Surface (Transit, auto lanes)	N										
		Transit Stations/Stops	N										
		Signals (Traffic, pedestrian, cycling)	N										
		Intersections	N										
	Sanitary Infrastructure	Sanitary Sewers	N										
		Pump Stations & Wet Wells	N										
		Maintenance Holes	N										
		Flow & Level Monitors	N										
		Flow Control Structures	N										
	Stormwater Infrastructure	Storm Sewer	N										
		Storm Sewer Outfalls	N										
		Catch Basins	N										
		Pump Stations & Wet Wells	N										
		Maintenance Holes	N										
		Flow & Level Monitors	N										
		Flow Control Structures	N										

Infrastructure Components			9 Drought: Dry days and summer precipitation										
			Climate Interaction		Consequence and Risk								
					People			Economic			Environment		
			Y/N	P	S	R	Rational	S	R	Rational	S	R	Rational
Project	Utilities	Water Distribution Infrastructure	N										
		Electrical - Transformers	N										
		Electrical - Above Ground Distribution	N										
		Utility Poles	N										
		Maintenance Holes	N										
		Other Underground Utilities (e.g., gas, telecom)	N										
Indirect	Operations	Maintenance (cleaning, snow removal)	N										
		Construction	N										
	Upstream and Downstream	Creeks	N										
		Downstream Connected Storm Sewers	N										
		Urban Landscape - Buildings	N										
		Urban Landscape - Business and Commerce	N										
		Urban Landscape - Roadways	N										
		Urban Landscape - Boulevards	N										
		Waterfront Trail	N										
		Park	N										
		Lakeview Water Treatment Plant	N										
		Lakeview Wastewater Treatment Plant	N										