EICS-03-21- APPENDIX A CLIMATE PROJECTIONS FOR BURLINGTON REGION.DOCX

Prepared by: City of Burlington, Town of Oakville and ICLEI Canada
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Glossary

The definitions below have been taken from the Intergovernmental Panel on Climate Change (IPCC)[i] and Natural Resources Canada[ii] unless otherwise cited.

Baseline - A climatological baseline is a reference period, typically three decades (or 30 years), that is used to compare fluctuations of climate between one period and another. Baselines can also be called references, reference periods or climate normal.

Burlington Region – The geographic area identified as '030M05' in Government of Canada's National Topographic System which includes the City of Burlington and most of the Town of Oakville. All grid squares in the Climate Atlas of Canada are usually named after cities, towns or landmarks within the area, to make it easier to identify where a grid square is located – in this case Burlington Region. All the data associated with each grid is the average of all the climate model grid points (which are 10 km x 10 km) within the grid square.[iii]

Climate Atlas of Canada – First launched in April 2018 and created by the Prairie Climate Centre at the University of Winnipeg with financial support from Environment and Climate Change Canada, Health Canada and others. It is an innovative climate science and communications tool that allows users to visualize and interact with climate data as well as the human stories about climate change and climate action on the landscape from coast to coast to coast.[iv]

Version 2 was released on July 10, 2019. Twenty-four different global climate models are used along with advanced statistical techniques that preserve daily patterns in the global models to downscale temperature and precipitation data to smaller geographical grids, as identified by the Government of Canada's National Topographic System, for two emission scenarios (RCP4.5 and RCP8.5).[v] Climate Atlas of Canada is often referred to as Climate Atlas in this report.

Climate Change - Changes in long-term weather patterns caused by natural phenomena and human activities that alter the chemical composition of the atmosphere through the build-up of greenhouse gases which trap heat and reflect it back to the earth's surface, also known as the greenhouse effect.

Climate Model – Models of varying complexity are used to represent the climate system. They are used as a research tool to study and simulate the climate and for operational purposes, including monthly, seasonal and interannual climate predictions. They are a numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes and accounting for some of its known properties. The data presented in this report is based on global climate models (GCMs).

Climate Projections - The simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models.

Coupled Model Intercomparison Project (CMIP) - A climate modelling activity from the World Climate Research Programme coordinates and archives climate model simulations based on shared model inputs by modelling groups from around the world. The CMIP3 multimodel data set includes projections using Special Report on Emissions Scenarios (SRES) as used in the IPCC Fourth Assessment Report (AR4). The CMIP5 data set includes projections using the Representative Concentration Pathways (RCPs) as identified in the IPCC Fifth Assessment Report (AR5).

Emissions Scenarios - A simplified representation of future climate based on comprehensive scientific analyses of the potential consequences of anthropogenic climate change. It is meant to be a plausible representation of the future emission amounts based on a coherent and consistent set of assumptions about driving forces (such as demographic and socioeconomic development and technological change) and their key relationships.

Ensemble Approach - A system that runs multiple climate models at once, to represent the uncertainty associated with the modelling process. Research has shown that this provides a more accurate projection of annual and seasonal temperatures and precipitation than a single model would on its own. The Climate Atlas uses the mean or average of the 24 climate models.

Greenhouse Gas (GHG) - Those gaseous constituents of the atmosphere, both created by natural and human activity, that absorb and emit radiation at specific wavelengths within the spectrum of thermal (heat) infrared radiation, emitted by the Earth's surface, the atmosphere itself, and by clouds. Water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and chlorofluorocarbons (CFCs) are the six primary greenhouse gases in the Earth's atmosphere in order of abundance. In addition, there are a number of entirely human-made GHGs in the atmosphere.

Intergovernmental Panel on Climate Change (IPCC) - Created in 1988 by the World Meteorological Organization and the United Nations Environment Programme, the objective of the IPCC is to provide governments at all levels with scientific information that they can use to develop climate policies. The IPCC currently has 195 members. Thousands of people from all over the world contribute to the work of the IPCC. [vi]

Radiative forcing - The change in the value of the net radiative flux (i.e. the incoming flux minus the outgoing flux represented as W/m^2) at the top of the atmosphere in response to some perturbation, in this case, the presence of greenhouse gases.

Representative Concentration Pathway (RCP) - Four greenhouse gas concentration trajectories were adopted by the IPCC for its Fifth Assessment Report (AR5)[vii] in 2014 to simulate how climate might change in response to different levels of human activity. It supersedes Special Report on Emissions Scenarios (SRES) projections published in 2000.[viii] RCPs usually refer to the portion of the concentration pathway extending up to the year 2100.

RCP4.5 - Moderate projected GHG concentrations, resulting from substantial climate change mitigation measures. It represents an increase of 4.5 W/m^2 in radiative forcing to the climate system. Climate Atlas of Canada and this report consider this pathway to be the 'Low Carbon Scenario.'

RCP8.5 - Highest projected GHG concentrations, resulting from business-as-usual emissions. It represents an increase of 8.5 W/m^2 in radiative forcing to the climate system. Climate Atlas of Canada and this report consider this pathway to be the 'High Carbon Scenario.'

Special Report on Emissions Scenarios (SRES) – SRES refers to the scenarios described in the IPCC SRES.[ix] These scenarios are grouped into four scenario families (A1, A2, B1 and B2) that explore alternative development pathways, covering a wide range of demographic, economic and technological driving forces and resulting GHG emissions. These scenarios were used in the Fourth Assessment Report (AR4) in 2007.[x]

1.0 Introduction

The purpose of this report is to summarize climate projections for Burlington Region. It presents how local climate has and is projected to change from the baseline timeframe of 1976-2005 until predominantly 2080 for the climate variables listed in Table 1. This report is a necessary first step towards the development of a climate adaptation plan. It will be used to apply a climate lens to corporate and community master plans and programs to reduce vulnerability and increase resiliency.

For consistency, this report uses terminology as identified in the Climate Atlas of Canada including the term Burlington Region which encompasses both the City of Burlington and the Town of Oakville as shown in Figure 1.

Burlington Region

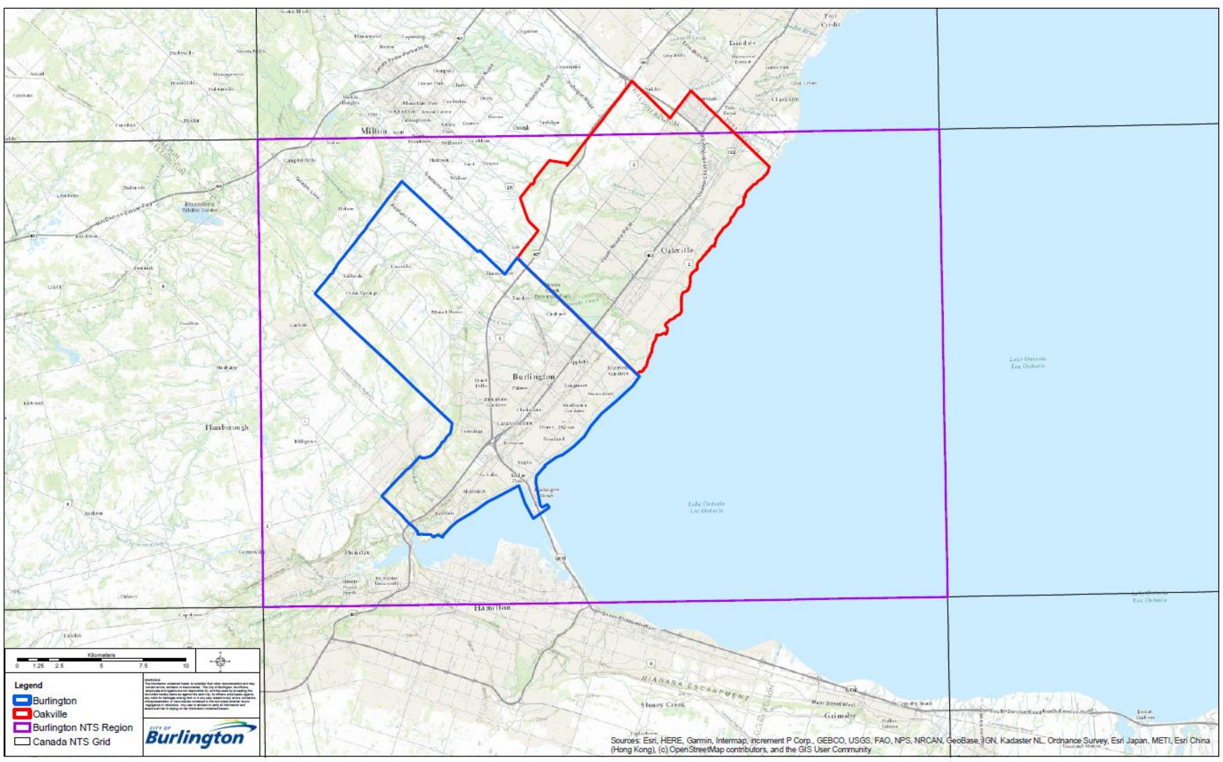


Figure 1: Map of Burlington Region

2.0 Climate Variables

The broad range of climate variables impacting Burlington Region are listed and defined in Table 1. Definitions within the Temperature, Hot Weather, Cold Weather, Precipitation and Agriculture categories were taken from the Climate Atlas of Canada (climateatlas.ca), including the name and description of the climate variables.[xi] Definitions for the variables within the Extreme Weather and Lake Ontario categories are taken from references sourced within sections 5.6 and 5.7 below.

Table 1: Summary of Climate Variables

Category	Climate Variable	Description	Unit
Temperature	Mean Temperature	The average temperature of the day.	ºC
	Minimum Temperature	The lowest temperature of the day.	ºC
	Maximum Temperature	The highest temperature of the day.	ºC
Hot Weather	Warmest Maximum Temperature	The highest temperature of the year.	ºC
	Number of Heat Waves	The total number of heat waves per year. A heat wave occurs when at least three days in a row reach or exceed 30°C.	# of Heat Waves
	Average Length of Heat Waves	The average length of a heat wave. A heat wave occurs when at least three days in a row reach or exceed 30°C so this number will always be three or greater.	Days
	Longest Spell of +30ºC Days	The maximum number of days in a row with temperatures 30°C or higher.	Days
	Hot (+30ºC) Season	Number of days per year when 30°C temperatures can be expected.	Days
	Very Hot Days (+30ºC)	A day when the temperature rises to at least 30°C.	Days
	Extremely Hot Days (+32ºC)	A day when the temperature rises to at least 32°C.	Days
	Extremely Hot Days (+34ºC)	A day when the temperature rises to at least 34°C.	Days
	Tropical Nights	The lowest temperature of the day does not go below 20°C.	Nights
	Cooling Degree Days (CDD)	Annual sum of the number of degrees Celsius that each day's mean temperature is above 18°C. It is a measurement designed to quantify the demand for energy needed to cool buildings.	# of ºC
Cold Weather	Freeze-Thaw Cycles	Number of days when the air temperature fluctuates between freezing and non-freezing temperatures.	Days
	Frost Days	A day when the coldest or minimum temperature is lower than 0°C.	Days
	Icing Days	A day when the maximum temperature is at or below 0°C.	Days

Category	Climate Variable	Description	Unit
	Coldest Minimum Temperature	The very coldest temperature of the year.	^{o}C
	Heating Degree Days (HDD)	Annual sum of the number of degrees Celsius that each day's mean temperature is below 18°C. It is a measurement designed to quantify the demand for energy needed to heat a building.	# of ^{o}C
	Freezing Degree Days (FDD)	Annual sum of the number of degrees Celsius that each day's mean temperature is below $0^{o}C$.	# of ^{o}C
	Mild Winter Days ($-5^{o}C$)	A day when the temperature drops to at least -5°C.	Days
	Winter Days ($-15^{o}C$)	A day when the temperature drops to at least -15°C.	Days
Precipitation	Precipitation	The total amount of rain, drizzle, snow, sleet, etc. Frozen precipitation is measured according to its liquid equivalent: 10 cm of snow is usually about 10 mm of precipitation.	mm
	Heavy Precipitation Days (10 mm)	A day on which at least a total of 10 mm of rain or frozen precipitation falls.	Days
	Heavy Precipitation Days (20 mm)	A day on which at least a total of 20 mm of rain or frozen precipitation falls.	Days
	Wet Days	The number of days in a year with at least 0.2 mm of rain/snow.	Days
	Dry Days	The number of days in a year with less than 0.2 mm of rain/snow.	Days
	Max 1-day Precipitation (mm)	The amount the precipitation that falls on the wettest day of the year.	mm
	Max 5-day Precipitation (mm)	The wettest consecutive five-day period.	mm
Agriculture	Frost-Free Season	The approximate length of the growing season (from the last spring frost to the first fall frost), during which there are no freezing temperatures to kill or damage plants.	Days
	Date of First Fall Frost	The first date in the fall or late summer when the daily minimum temperature is at or less than $0^{o}C$. This date marks the	Date

Category	Climate Variable	Description	Unit
		approximate end of the growing season for frost-sensitive crops and plants.	
	Date of Last Spring Frost	The spring date after which there are no daily minimum temperatures at or less than 0ºC. This marks the approximate beginning of the growing season for frost-sensitive crops and plants.	Date
	Corn Heat Units (CHU)	A temperature-based index of growing-season heat to estimate whether the climate is warm enough but not too hot to grow corn.	# of ºC
	Growing Degree Days (GDD) (Base 5ºC)	Annual sum of the number of degrees Celsius that each day's mean temperature is above 5ºC. Generally, 5°C GDDs are used for assessing the growth of canola and forage crops.	# of ºC
	Growing Degree Days (Base 10ºC)	Annual sum of the number of degrees Celsius that each day's mean temperature is above 10°C. Generally, 10°C GDDs are used for assessing the growth of corn and beans.	# of ºC
	Growing Degree Days (Base 15ºC)	Annual sum of the number of degrees Celsius that each day's mean temperature is above 15ºC. Generally, 15°C GDDs are used to assess the growth and development of insects and pests.	# of ºC
Extreme Weather	Freezing Rain Events	Average percentage change in the number of annual freezing rain events.	%
	Wind Gusts	A relationship between the peak gust speed and mean wind speed.	km/h
	Rainfall Intensity-Duration-Frequency (IDF)	The annual maximum rainfall intensity for specific durations. Common durations are: 5-min, 10-min, 15-min, 30-min, 1-hr, 2-hr, 6-hr, 12-hr, and 24-hr.	mm/h
Lake Ontario	Lake Levels	Annual changes in lake water levels as compared to an average.	m
	Lake Temperature	Change in water temperatures, predominantly summer surface water temperatures.	ºC
	Ice Cover	Trend in ice coverage relative to a baseline.	Days/year

3.0 Climate Change Modelling and Downscaling

Unless otherwise stated, the data presented in this report is based on global climate models (GCMs) and emission scenarios defined by the Intergovernmental Panel on Climate Change (IPCC), drawing from the Fifth Assessment Report (AR5) publications.

Many different methods exist to construct climate change scenarios. However, GCMs are the most conclusive tools available for simulating responses to increasing greenhouse gas (GHG) concentrations, as they are based on mathematical representations of atmosphere, ocean, ice cap, and land surface processes.[xii] Wherever possible, the data presented in this report uses an ensemble approach, which refers to a system that runs multiple climate models at once. Research has shown that this provides a more accurate projection of annual and seasonal temperatures and precipitation than a single model would on its own.

GCMs use grid cells often larger than 100 kilometres. To better understand local impacts and vulnerabilities, climate data is often needed at a smaller resolution. To get finer resolution data, climate modellers use dynamic or statistically downscaling methods. Dynamically downscaled models, also known as regional climate models (RCMs), simulate the climate of a smaller region (grid cells are usually 10 to 50 kilometres in size) and rely on information provided by GCMs. Statistically downscaled models use statistical relationships between local climate variables (such as precipitation) and large-scale variables (such as atmospheric pressure). The relationship is then applied to projections from GCMs to simulate local climate.[xiii] The climate model data presented in the Climate Atlas used a statistically downscaled method - specifically the Bias-Correction/Constructed Analogues with Quantile mapping reordering, Version 2 (BCCAQv2) method which preserved daily patterns in the global climate models.[xiv] This work was done by the Pacific Climate Impacts Consortium.

4.0 Emissions Scenarios

Emissions scenarios are based on models developed by a series of international climate modeling centers. Each emission scenario presents a different possible future based on socioeconomic storylines used by analysts to make projections about future GHGs and to assess future vulnerability to climate change. Producing scenarios requires estimates of future population levels, economic activity, the structure of governance, social values, and patterns of technological change.

4.1 Representative Concentration Pathway Scenarios

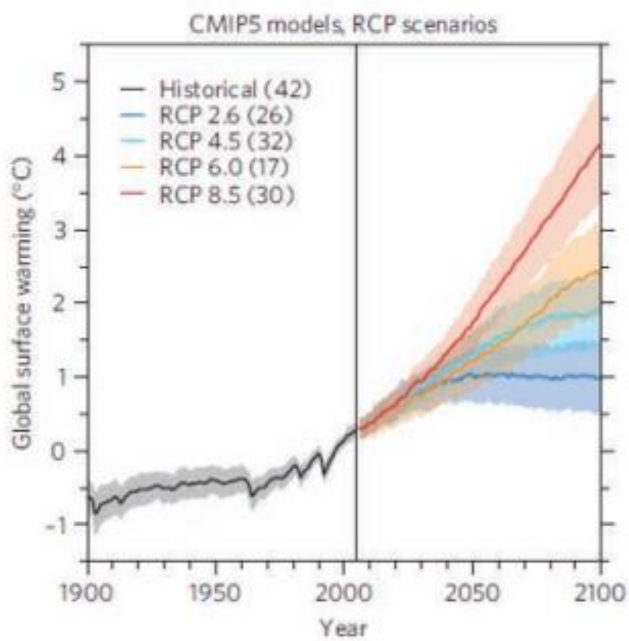
Representative Concentration Pathways (RCPs) are the newest set of climate change scenarios that provide the basis for the IPCC Fifth Assessment Report (AR5).[xv] The new RCPs have replaced the Special Report on Emissions Scenarios (SRES) to be more consistent with new data, new models, and updated climate research from around the world. The RCPs contain information regarding emission concentrations and land-use trajectories and are meant to be representative of the current literature on emissions and concentration of GHGs. The premise is that every radiative forcing pathway can result from a diverse range of socioeconomic and technological development scenarios.[xvi] RCPs are identified by their approximate total radiative forcing in the year 2100 relative to 1750, and are labeled as RCP2.6, 4.5, 6.0 and 8.5. These four RCPs include one mitigation scenario leading to a very low forcing level (RCP2.6), two stabilization scenarios (RCP4.5 and RCP6.0), and one scenario with continued rising GHG concentrations (RCP8.5).[xvii] The RCPs also consider the presence of 21st century climate policies, as compared with the no-climate policy assumption of the SRES in the Third and Fourth Assessment Reports.[xviii]

For this report, projections will use RCP4.5 representing a moderate increase in projected GHG concentrations and RCP8.5 representing the highest projected GHG concentration, as that data is publicly available for many climate indicators. RCP8.5 is referred to as a 'business as usual' pathway, representing a future where regular economic growth continues with emissions continuing to increase. Table 2 provides a description of each RCP scenario, while Figure 2 illustrates the projected global warming associated with the four scenarios.[xix]

Table 2: IPCC Fifth Assessment Report Climate Change Scenario Characteristics

Scenario	Description	Pathway	CO_2 equivalent (ppm)	Temp anomaly (°C)
RCP2.6	Lowest projected GHG concentrations, resulting from dramatic climate change mitigation measures implemented globally. It represents an increase to 3.0 W/m^2 mid-century and a decline to 2.6 W/m^2 in radiative forcing to the climate system by 2100.	Peak and decline	~490	1.5
RCP4.5	Moderate projected GHG concentrations, resulting from substantial climate change mitigation measures. It represents an increase of 4.5 W/m^2 in radiative forcing to the climate system. The Climate Atlas refers to this scenario as the 'Low Emissions Scenario.'	Stabilizing without overshoot	~650	2.4
RCP6.0	Moderate projected GHG concentrations, resulting from some climate change mitigation measures. It represents an	Stabilizing without overshoot	~850	3.0

Scenario	Description	Pathway	CO_2 equivalent (ppm)	Temp anomaly (°C)
	increase of 6.0 W/m^2 in radiative forcing to the climate system.			
RCP8.5	Highest projected GHG concentrations, resulting from business-as-usual emissions. It represents an increase of 8.5 W/m^2 in radiative forcing to the climate system. The Climate Atlas refers to this scenario as the 'High Emissions Scenario.'	Rising	~1370	4.9



Note that the number of models used is given in brackets and the shading (coloured envelopes) represents all model results.

Figure 2: Global Temperature Change Relative to 1986-2005 for the RCP Scenarios Run by Coupled Model Intercomparison Project (CMIP5)

4.2 Time Periods

Climatic projections are typically provided within time periods of 30 years. Additionally, a consistent baseline period is established so that projections can be accurately compared with historical trends. In this report, the time periods of 2021-2050 (immediate future) and 2051-2080 (near future) are used most frequently as well as 1976-2005 for the baseline (recent past). Many climate variables are also divided into seasonal timeframes, defined below in Table 3.

Table 3: Seasonal Timeframes

Season	Months
Winter	December, January, February
Spring	March, April, May
Summer	June, July, August
Fall	September, October, November

4.3 Uncertainty

While it is not possible to anticipate future climatic changes with absolute certainty, climate change scenarios help to create plausible representations of future climate conditions. These conditions are based on assumptions of future atmospheric composition and on an understanding of the effects of increased atmospheric concentrations of GHGs, particulates, and other pollutants. Uncertainty is factored into climate change scenarios, models, and data, and reflects the complex reality of environmental change and the evolving relationship between humans and the planet.

The Climate Atlas identified some important limitations with specific climate variables.

1. Precipitation is more difficult to model than temperature. However, longer-term averages of monthly, seasonal and annual precipitation totals are produced with greater confidence than point- or time-specific precipitation projections.
2. Heavy Precipitation Days are likely underestimated for frequency and intensity as climate models likely don't capture the intense, localized events such as thunderstorms. However, there is greater confidence in longer-term averages of monthly, seasonal and annual precipitation totals.
3. Daily Mean Temperature is often calculated taking the average of 24 individual hourly measurements made in a day. However, since only daily maximum and daily minimum temperatures were available, the Climate Atlas uses the averages of those.
4. Date of First Fall Frost, Last Spring Frost and Frost-Free Season are calculated using standard weather station observations, which are usually at 1.2 m above the ground. Since ground level temperature can be colder than surface air temperature (1.2 m), the length of the Frost-Free Season presented is likely longer than the actual length of the season at ground level.[xx]

5.0 Local Climate Trends and Projections

The Climate Atlas presents data related to climate change for Burlington Region under five different categories: Temperature, Hot Weather, Cold Weather, Precipitation and Agriculture. Within each category, multiple climate variables are presented under a low and high emissions scenario for different time periods compared to the baseline. Appendix A provides a summary of local climate variables and trends in the five climatic categories under a high emissions scenario.

Two additional categories – Extreme Weather and Lake Ontario – are also included in the section below with information based on other sources and referenced accordingly.

5.1 Temperature

All temperature variables for Burlington Region are projected to experience warming for RCP4.5 and RCP8.5. Documenting general trends in temperature change can be helpful for understanding the future distribution of ecological communities including invasive species migration and vector-borne diseases, temperature-related morbidity (disease) and mortality (death), cooling and heating requirements for buildings, and much more.[xxi]

5.1.1 Mean Temperature

Mean Temperature shows the average temperature in an area over a given period. As shown in Table 4 below, the baseline seasonal Mean Temperature over Burlington Region was 6.8°, 20.3°, 10.5° and -3.4˚C for spring, summer, fall and winter respectively. This gives a year-round average temperature of 8.6˚C for 1976-2005. According to RCP8.5, Burlington Region could experience an increase of 4.2˚C in average annual temperature and 4.7˚C in average winter temperature in the near future (2051-2080).

Table 4: Mean Temperature for Burlington Region – RCP4.5 and 8.5

Emissions Scenario	Period	Baseline 1976-2005 (°C)	2021-2050 (°C)			2051-2080 (°C)		
			Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	Spring	6.8	6.5	8.6	10.5	7.4	9.4	11.7
	Summer	20.3	20.6	22.1	23.6	21.3	23.2	25.1
	Fall	10.5	10.8	12.4	14.0	11.5	13.3	15.0
	Winter	-3.4	-3.8	-1.2	1.3	-2.7	0.0	2.6
	Annual	8.6	9.3	10.5	11.8	10.0	11.5	13.1
RCP8.5	Spring	6.8	6.5	8.6	10.8	8.4	10.6	12.9
	Summer	20.3	21	22.4	24	22.8	24.6	26.5
	Fall	10.5	11	12.7	14.3	12.8	14.6	16.3
	Winter	-3.4	-3.5	-1	1.6	-1.3	1.3	4
	Annual	8.6	9.4	10.7	12	11.4	12.8	14.4

5.1.2 Maximum and Minimum Temperature

Maximum and Minimum Temperature trends show the average high temperature and the average low temperature for a given period.

In terms of Minimum Temperature, Table 5 shows the baseline Minimum Temperature across each season at 2.0°, 14.9°, 6.1° and -7.0°C for spring, summer, fall and winter respectively. Seasonal Minimum Temperature is projected to increase substantially under RCP8.5, with an increase of 3.6°C in spring, 4.0°C in summer, 3.9°C in fall and 5.2°C in winter by 2051-2080.

The increases in average Minimum Temperature in the summer and winter months are particularly noteworthy. With the summer Minimum Temperature rising from an average of 14.9°C to 18.9°C, this could result in an increase of Tropical Nights which are described below. In addition, with average winter Minimum Temperature rising from an average of -7.0°C to -1.8°C, this could result in less snow and more mixed precipitation.

Table 5: Minimum Temperature for Burlington Region – RCP4.5 and 8.5

Emissions Scenario	Period	Baseline 1976-2005 (˚C)	2021-2050 (˚C)			2051-2080 (˚C)		
			Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	Spring	2.0	1.9	3.7	5.3	2.7	4.5	6.6
	Summer	14.9	15.2	16.5	17.8	15.8	17.5	19.3
	Fall	6.1	6.3	7.8	9.3	7.1	8.6	10.2
	Winter	-7.0	-7.4	-4.6	-2.0	-6.1	-3.3	-0.5
	Annual	4.0	4.7	5.9	7.1	5.5	6.9	8.4
RCP8.5	Spring	2.0	1.9	3.8	5.8	3.7	5.6	7.8
	Summer	14.9	15.6	16.8	18.2	17.4	18.9	20.6
	Fall	6.1	6.6	8.1	9.6	8.3	10.0	11.5
	Winter	-7.0	-7.1	-4.4	-1.6	-4.6	-1.8	0.9
	Annual	4.0	4.9	6.1	7.3	6.9	8.2	9.7

In terms of Maximum Temperature, Table 6 shows seasonal average baseline temperature for Burlington Region at 11.6°, 25.7°, 14.9° and 0.3˚C for spring, summer, fall and winter respectively. Similar to Mean and Minimum Temperature, Burlington Region will experience an increase in seasonal Maximum Temperature. Average summer Maximum Temperature is projected to reach over 30˚C with average winter Maximum Temperature increasing to 4.4˚C by 2051-2080 according to RCP8.5.

Table 6: Maximum Temperature for Burlington Region – RCP4.5 and 8.5

Emissions Scenario	Period	Baseline 1976-2005 (˚C)	2021-2050 (˚C)			2051-2080 (˚C)		
			Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	Spring	11.6	11.1	13.5	15.8	11.8	14.4	17.0
	Summer	25.7	25.9	27.7	29.5	26.6	28.9	31.0
	Fall	14.9	15.1	17.1	19.0	15.8	17.9	19.8
	Winter	0.3	-0.2	2.2	4.6	0.7	3.3	5.9
	Annual	13.2	13.7	15.2	16.6	14.4	16.1	17.8
RCP8.5	Spring	11.6	11.1	13.5	16.0	12.9	15.4	18.0
	Summer	25.7	26.3	28.0	29.8	28.1	30.3	32.5
	Fall	14.9	15.3	17.2	19.1	17.3	19.3	21.3
	Winter	0.3	-0.1	2.3	4.9	1.8	4.4	7.2
	Annual	13.2	13.9	15.3	16.7	15.7	17.4	19.1

Average annual Minimum and Maximum Temperatures are projected to experience a similar increase as an annual Mean Temperature, as shown for the RCP8.5 scenario for Burlington Region in Figure 3.

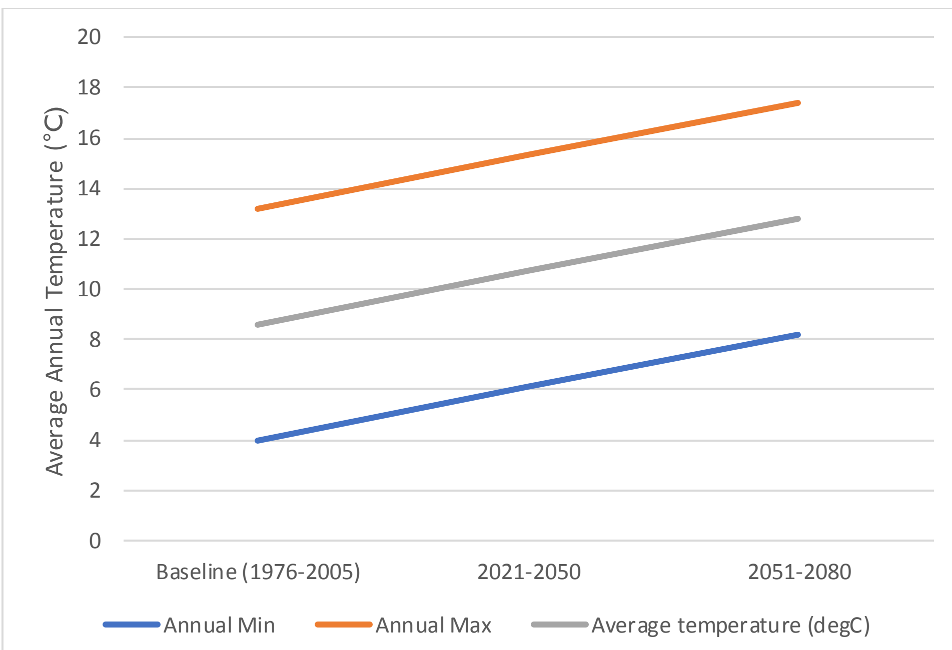


Figure 3: Annual Temperature for Burlington Region - RCP8.5

In addition to the average Maximum Temperature, the Warmest Maximum Temperature in a given year is also expected to increase (i.e. the single, hottest day of the year). For Burlington Region, the baseline average Warmest Maximum Temperature was 34.2°C. According to RCP8.5, the average Warmest Maximum Temperature will increase to 36.5°C in the immediate future (2021-2050), and to 39°C in the near future (2051-2080). These temperatures do not factor in additional warming due to the humidex which could make it feel 5 to 10°C warmer.

5.2 Hot Weather

Historically Canada was a winter peaking climate where more energy was used in the winter to heat homes. In recent years, this has shifted resulting in increased energy use in the summer to cool homes. Hot weather presents new heat related risks, such as heat exhaustion and heat stroke, and limits outdoor exposure and activities. It also impacts whether plants and animals thrive, increases the risk of drought, and can lead to more thunderstorms increasing the risks of flash flooding, lightning and hail.[xxii]

5.2.1 Very Hot Days, Extremely Hot Days and Hot Season

The Climate Atlas presents the number of days where the daily maximum temperature results in a Very Hot Day exceeding 30°C or Extremely Hot Days of 32°C and 34°C for Burlington Region as seen in Table 7.

Days where the daily maximum temperatures exceed 30°C, 32°C and 34°C present the greatest threats to community health due to heat-related illnesses. Specific groups, such as those who work outside, infants and young children, older adults (over the age of 65), those with chronic medical conditions, people experiencing homelessness, people planning outdoor sports or activities, and those with limited mobility may be more adversely affected.[xxiii] Moreover, higher summer temperatures increase electricity demand for cooling possibly leading to electricity reliability issues during heat waves.

The baseline average number of Very Hot Days when the maximum temperature was greater than or equal to 30°C was 16 days for Burlington Region. This is expected to increase to an average of 61 days in the 2051-2080 period under the RCP8.5 scenario as shown in Table 7. This means there will be over two to five times more days above 30°C by 2080 in the study region.

The number of Extremely Hot Days will also increase significantly under both a low and high emissions scenario. Burlington Region experienced six days of Extremely Hot Days (32°C) in the baseline period. This is expected to increase over six-fold to an average of 39 days by 2051-2080 under RCP8.5. Extremely Hot Days (34°C) could increase from almost 2 days to over 21 days on average, an almost 13-fold increase.

Table 7: Very Hot and Extremely Hot Days (30, 32 and 34°C) for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Variable	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
			Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	30°C or more	16.0	14.5	32.9	53.1	20.8	44.2	67.2
	32°C or more	6.0	4.0	16.6	32.8	7.4	25.2	45.7
	34°C or more	1.7	0.4	6.8	17.3	1.3	12.1	27.8
RCP8.5	30°C or more	16.0	17.1	35.5	54.7	36.2	60.9	85.3
	32°C or more	6.0	5.2	18.3	34.2	17.4	38.8	61.2
	34°C or more	1.7	0.7	7.8	18.6	5.7	21.6	40.3

In addition to an overall increase in Very Hot and Extremely Hot Days, Burlington Region is also expected to see an increase in the Warmest Maximum Temperature – i.e. the temperature of the hottest day of the year. In the baseline period, Burlington Region's average Warmest Maximum Temperature was 34.2°C increasing to 36.5°C in 2021-2050 and expected to reach 39.0°C in 2051-2080 for RCP8.5.

While the number of Very Hot Days with temperatures at or above 30°C is expected to increase overall, the length of the Hot Season (the number of days from the first day of the year with temperatures at or above 30°C to the last day of the year with temperatures at or above 30°C)[xxiv] is also expected to increase. Table 8 outlines the length of the Hot Season for Burlington Region. The baseline average length of the Hot Season was 70.5 days. By 2051-2080, Burlington Region can expect an increase to 123.7 days according to RCP8.5 – almost double the length of the Hot Season previously.

Table 8: Length of the Hot Season (30°C) for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	70.5	63.4	99.9	134.2	76.1	109.8	141.9
RCP8.5	70.5	68.7	102.0	134.9	90.1	123.7	156.4

5.2.2 Heat Waves and Tropical Nights

Heat Waves are defined as prolonged periods of extremely hot weather, which may be accompanied by high humidity. The Climate Atlas defines a Heat Wave as three days in a row where temperatures reach or exceed 30°C. Heat waves are location-specific; a heat wave is usually measured relative to the usual weather in the area and relative to normal temperatures for the season. Temperatures that people from a hotter climate consider normal can be termed a heat wave in a cooler area. Thus, understanding shifts in local climate can help inform particular strategies to mitigate population exposure in ways that are appropriate with local norms and behaviours. High, persistent temperatures not only impact human health as previously noted but also increase the risk of drought, which can severely impact food production. High temperatures can also lead to more intense and frequent extreme weather events including thunderstorms, risks of flash flooding, lightning, hail and perhaps even tornadoes.[xxv]

Halton Region, which includes the City of Burlington and the towns of Oakville, Halton Hills and Milton, issues a heat warning when Environment and Climate Change Canada forecasts:

- Two consecutive days with the temperature 31°C or higher during the day and 20°C or higher overnight, or
- Two consecutive days with a humidex of 40°C or higher.

In addition, an extended heat warning is issued when forecasting:

- Three consecutive days with the temperature 31°C or higher during the day and 20°C or higher overnight, or
- Three consecutive days with a humidex of 40°C or higher.[xxvi]

Though the parameters slightly differ between the Climate Atlas and Halton Region, the data presented in the Climate Atlas can still illustrate the degree in which Heat Wave events will become more frequent and prolonged in Burlington Region.

The Climate Atlas considers two variables for Heat Waves – the annual Average Length of Heat Waves, and the annual Number of Heat Waves. The annual Number of Heat Wave events measures the average number of times per year where the temperature reaches or exceeds 30°C for at least three days in a row. The baseline Number of Heat Waves for Burlington Region was 2.1, as presented in Table 9 and Figure 4. In the 2051-2080 period according to RCP8.5, Burlington Region can expect to experience almost seven Heat Wave events per year. This is over triple the current number of occurrences.

Table 9: Annual Number of Heat Waves for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (#)	2021-2050 (#)			2051-2080 (#)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	2.1	1.7	4.5	7.4	2.6	5.7	8.7
RCP8.5	2.1	2.0	4.8	7.5	4.1	6.7	9.5

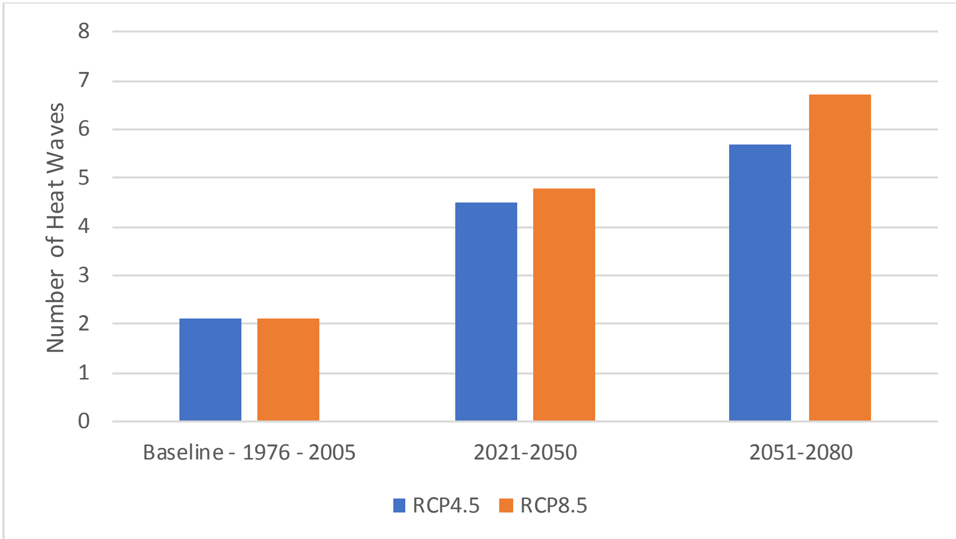


Figure 4: Annual Number of Heat Waves for Burlington Region - RCP4.5 and 8.5

With regards to the Average Length of Heat Waves (in days), Burlington Region experienced an average of 3.7 days of heat wave conditions in the baseline period as displayed in Table 10. In the 2051-2080 period, according to RCP8.5, Burlington Region can expect to see an average heat wave event occurring for 8.1 days – over double the current length.

Table 10: Annual Average Length of Heat Waves for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	3.7	3.3	5.2	7.4	3.9	6.2	9.3
RCP8.5	3.7	3.6	5.5	8.0	4.9	8.1	12.9

Overall, Heat Wave events are projected to occur more frequently and for longer periods of time. While Table 10 outlines the annual Average Length of Heat Wave events, Table 11 outlines the Longest Spell of +30°C Days. The baseline average Longest Spell of +30°C Days for Burlington Region was 3.9. By 2051-2080 according to RCP8.5, Burlington Region could experience 18.2 consecutive days where temperatures exceed 30°C. This could result in an Extended Heat Warning for Burlington Region for almost two and a half weeks.

Table 11: Longest Spell of +30°C Days for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	3.9	2.9	7.5	13.9	4.2	10.8	19.6
RCP8.5	3.9	3.3	8.4	15.7	6.8	18.2	34.2

Traditional patterns of hot weather during the day which then cool off at night can often be enough to mitigate exposure to extreme temperatures.[xxvii] However, during periods of extended heat, many people are at risk from suffering heat exhaustion or heat stroke when experiencing prolonged exposure during hot summer days if nighttime temperatures fail to drop below 20°C (Tropical Nights).[xxviii] There is an increasing trend of nighttime temperatures warming faster than daytime temperatures, especially in places which typically experienced cooler overnight low temperatures. [xxix]

Table 12 and Figure 5 show that the baseline average number of Tropical Nights for Burlington Region was 8.1. In 2051-2080, according to RCP8.5, Burlington could experience 36.7 more Tropical Nights on average representing a fivefold increase and about one-and-a-half months of Tropical Nights.

Table 12: Annual Tropical Nights for Burlington Region – RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Nights)	2021-2050 (Nights)			2051-2080 (Nights)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	8.1	8.2	19.3	32.6	12.4	28.2	48.5
RCP8.5	8.1	10.8	22.4	36.6	26.2	44.8	66.0

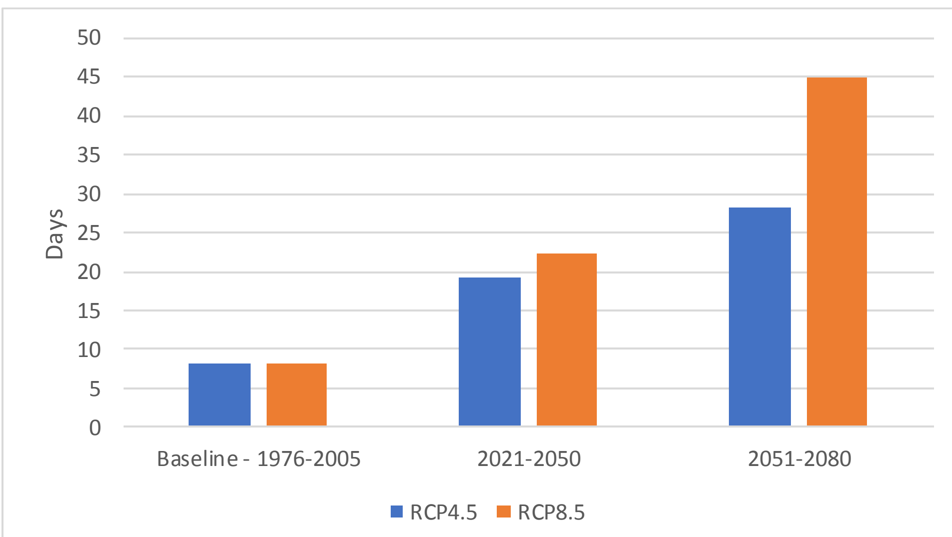


Figure 5: Annual Tropical Nights for Burlington Region - RCP4.5 and 8.5

5.2.3 Cooling Degree Days

Cooling Degree Days (CDD) is an indicator of energy consumption due to air conditioner use during the summer. It is a simple calculation of the number of degrees Celsius that each day's mean temperature is above 18°C. If a location shows an increase in projected CDD values, this implies that it will experience hotter or longer summers requiring more energy (and thus money) to cool buildings for comfort and safety.[xxx] This will have significant impacts for those who do not have access to air conditioning in their homes or apartments.

CDDs are projected to increase significantly in Burlington Region, more than doubling across the region in the 2051-2080 period according to RCP8.5 as shown below.

Table 13: Cooling Degree Days for Burlington Region – RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (# of °C)	2021-2050 (# of °C)			2051-2080 (# of °C)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	315.7	345.9	499.5	658.0	421.3	616.9	837.1
RCP8.5	315.7	383.5	535.1	693.2	580.1	797.0	1033

5.3 Cold Weather

Cold Weather is an important aspect of life in Canada, as many places are well adapted to very cold winters. Overall, the frequency and severity of cold days are decreasing across Canada including in Burlington Region, while the number of hot days is increasing.

It should be noted that the artic is warming much faster than the rest of the world. Researchers are seeing more evidence that the melting arctic ice could be impacting the jet stream, a column of air in the upper atmosphere that helps drive weather systems. A warmer Arctic Ocean radiates more heat to the atmosphere in winter, creating less of a temperature contrast between the Arctic air and the atmosphere in regions further south.[xxxi] Usually the jet stream is relatively straight from west to east with few dips. However, when the jet stream weakens and becomes more unstable, it has larger dips which push cold arctic air further south (polar vortex) or warm air from the south further north.[xxxii] This can not only result in more heat or drought conditions but also more extreme cold spells with extreme precipitation lingering for longer than normal.[xxxiii]

It is important to know how our winters will change in the future, because just like hot temperatures cold temperatures affect health and safety, determine what plants and animals can live in the area, limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use.[xxxiv]

5.3.1 Mild Winter Days and Winter Days

A Mild Winter Day is a day when the temperature drops to at least -5°C. Mild Winter Days indicate how much a location experiences moderately cold temperatures. This variable can be important for certain tourism or recreational industries within Burlington Region. For example, ski slope operators generally require temperatures below -5°C to make artificial snow[xxxv] and temperatures between -7°C to -17°C are recommended for outdoor skating rinks.[xxxvi] The baseline number of Mild Winter Days was 66.6. By 2051-2080 according to RCP8.5, that number could decrease to an average of 27.3 days as shown in Table 14. This means transitioning from over two months of Mild Winter Days to less than one month.

Table 14: Mild Winter Days (-5°C) for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	66.6	26.6	47.5	67.5	16.3	37.6	60.7
RCP8.5	66.6	25.4	46.3	67.2	9.2	27.3	48.3

Winter Days, defined as a day where the temperature drops to at least -15°C, are also projected to decrease across Burlington Region. Table 15 shows that by the end of the century, there could be an average of one day a year where average temperatures dip below -15°C.

Table 15: Winter Days (-15°C) for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	11.2	0.3	4.6	11.2	0.0	2.3	7.1
RCP8.5	11.2	0.3	4.0	10.4	0.0	0.9	3.3

In addition to an overall decrease in Winter Days and Mild Winter Days, Burlington Region is also expected to see a decrease in the Coldest Minimum Temperature – i.e. the temperature of the coldest day of the year. In the baseline period, Burlington Region's average Coldest Minimum Temperature was -20.8°C. According to RCP8.5, Burlington's average coldest temperature will increase to -16.9°C in 2021-2050, and -13.0°C in 2051-2080.

5.3.2 Frost Days and Icing Days

Other variables of cold temperatures are Frost Days and Icing Days. Both are good indictors of the length and severity of the winter season and can help to understand freeze and thaw patterns throughout the region, and document risks relating to morbidity and mortality from traffic accidents, damage to roads and infrastructure, facility closures and more.

A Frost Day is a day with frost potential – meaning the minimum temperature is below 0°C. Frost days are predicted to decrease an average of 52 days by the 2080s in RCP8.5 as shown in Table 16.

Table 16: Frost Days for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	126.0	80.2	102.2	122.4	64.3	90.0	113.9
RCP8.5	126.0	77.7	100.1	123.3	47.3	74.0	97.7

Similarly, the number of Icing Days are projected to decrease as shown in Table 17 and Figure 6. Icing Days are the total number of days when the daily maximum temperature is at or below 0°C. A reduction in days below 0°C could have an impact on the survival and spread of blacklegged ticks, which carry the bacteria that causes Lyme disease, as ticks can be active in temperatures above 4°C.[xxxvii] While deer ticks are most active in spring and fall, warmer winters could extend their window of activity.

Table 17: Icing Days for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	48.0	14.8	32.2	49.3	9.0	25.1	44.8
RCP8.5	48.0	15.2	31.8	49.7	4.4	17.5	34.6

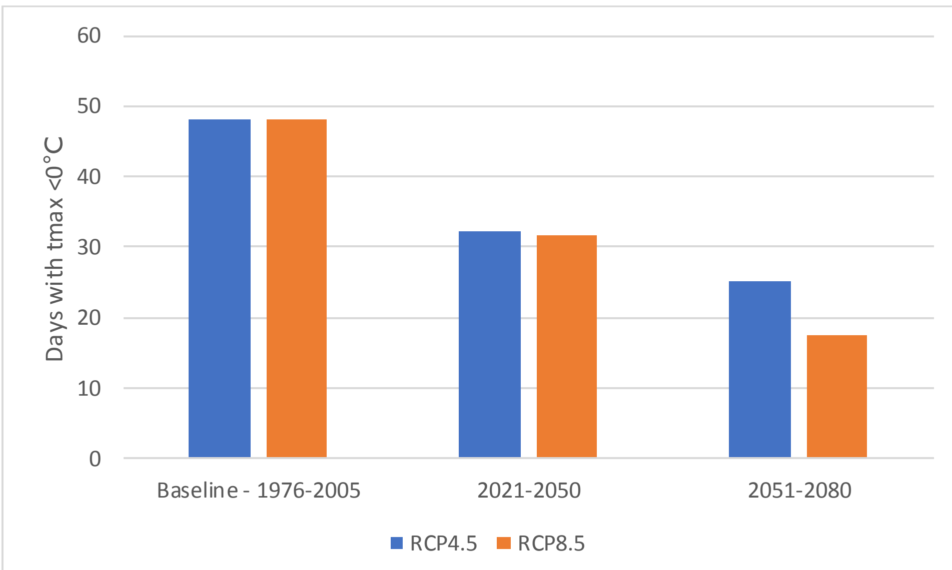


Figure 6: Icing Days for Burlington Region - RCP4.5 and 8.5

5.3.3 Freeze-Thaw Cycles

Freeze-Thaw Cycles are the number of days when the air temperature fluctuates between freezing and non-freezing temperatures. Under these conditions, it is likely that some water at the surface was both liquid and ice at some point during the 24-hour period.[xxxviii]

Freeze-Thaw Cycles can have major impacts on infrastructure. Water expands when it freezes, so the freezing, melting and refreezing of water can over time cause significant damage to roadways, sidewalks, underground pipes and other outdoor structures. Potholes that form during the spring, or during mid-winter melts, are good examples of the damage caused by this process.[xxxix]

Freeze-Thaw Cycles are projected to decrease slightly this century – from 63.3 days in the baseline, to 54.7 days in the immediate future, to 44.5 days in the near future according to RCP8.5 as shown in Table 18 and Figure 7. This is likely due to the fact that overall, the days are getting warmer, and Burlington Region is likely to experience a decrease in the number of days that reach a minimum temperature at or below -1°C.

Table 18: Freeze-Thaw Cycles for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	63.3	43.0	56.2	69.5	38.1	51.5	65.2
RCP8.5	63.3	41.2	54.7	68.7	28.5	44.5	59.8

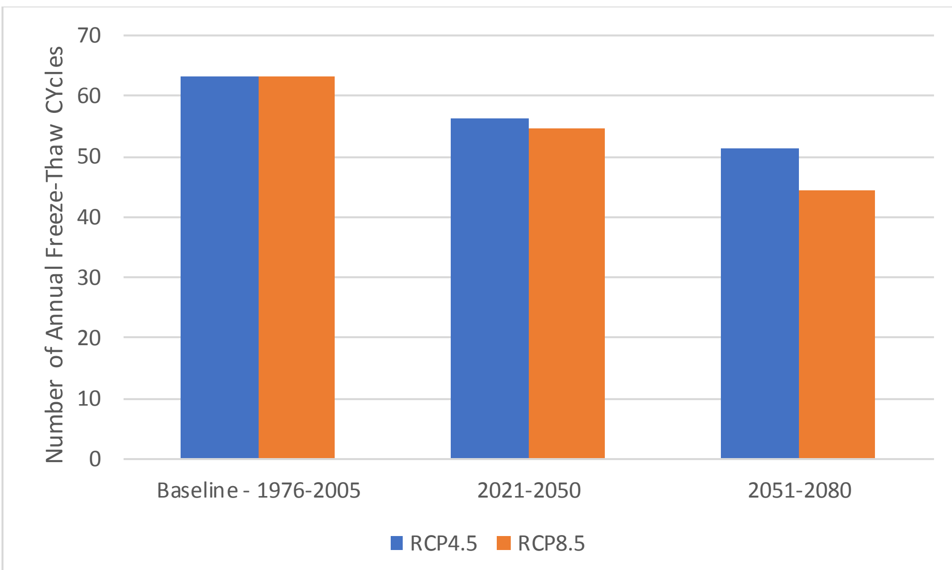


Figure 7: Freeze-Thaw Cycles for Burlington Region - RCP4.5 and 8.5

5.3.4 Heating Degree Days and Freezing Degree Days

Similar to Cooling Degree Days (CDD), Heating Degree Days (HDD) are equal to the number of degrees Celsius a given day's mean temperature is below 18°C. For example, if the daily mean temperature is 12°C, the HDD value for that day is equal to 6°C. If the daily mean temperature is above 18°C, the HDD value for that day is set to zero.[xl]

Heating Degree Days are a measure of how much heating is required in a year. An average temperature below 18°C is when heating is required to maintain a comfortable temperature inside buildings. A place that gets many days with average temperatures below 18°C will require more energy (and thus money) to heat buildings for comfort and safety.[xli]

As shown in the figure below, HDD are expected to decrease, implying that Burlington Region will be experiencing less severe cold events in the future. This could mean a reduction in heating costs and GHG emissions for heating during the winter months.

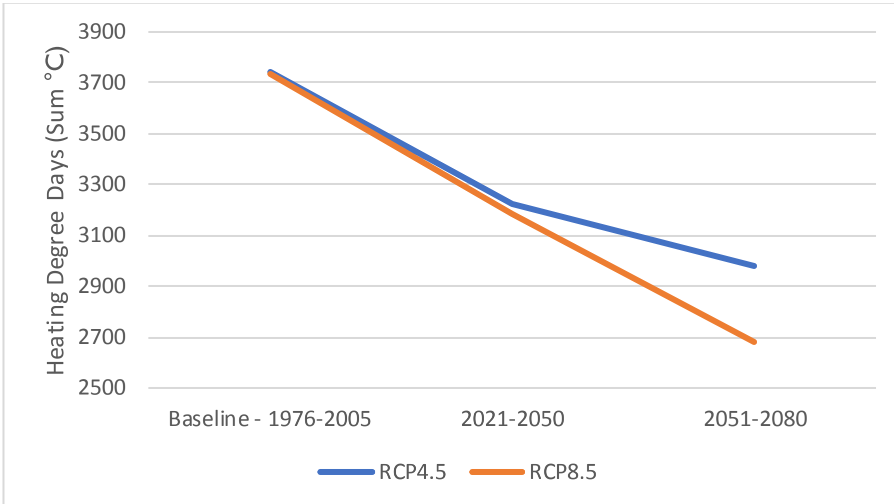


Figure 8: Heating Degree Days for Burlington Region - RCP4.5 and 8.5

Similarly, Freezing Degree Days (FDD) begin to accumulate when the daily mean temperature drops below freezing: if a day's mean temperature is -21°C, for example, it increases the annual FDD value by 21. Days when the mean temperature is 0°C or warmer do not contribute to the annual sum. High FDD values are associated with relatively cold conditions: places with high FDD values likely get many days with temperatures significantly below freezing. If projections show a decrease in FDDs, then that location is likely to experience shorter or less severe winters.[xlii]

Areas with high FDD indicate higher levels of snow and ice accumulation, which is an important consideration for snow clearance and removal.[xliii] These areas would also likely require larger amounts of energy for heating buildings and homes.

As shown in the figure below, FDD are expected to decrease significantly until 2080 which implies that Burlington will experience less days where the temperature is significantly below freezing.

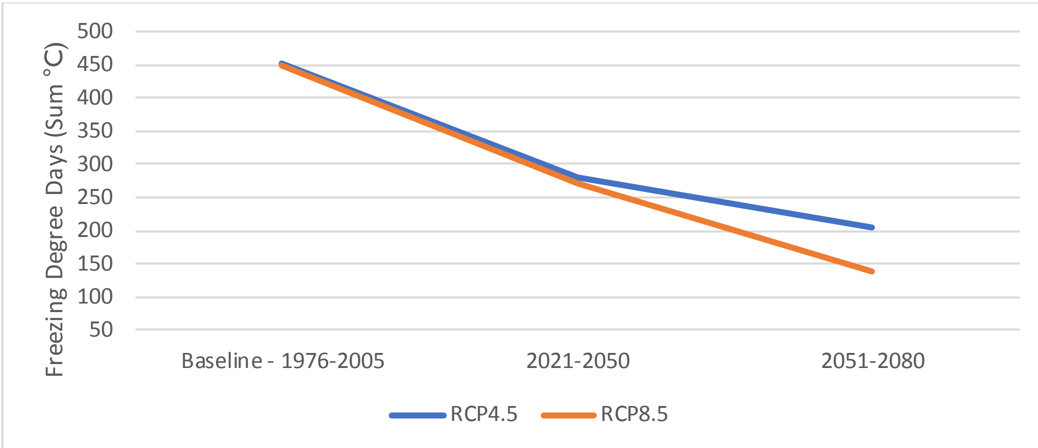


Figure 9: Freezing Degree Days for Burlington Region - RCP4.5 and 8.5

5.4 Precipitation

Precipitation patterns are critical for many important issues including water availability, crop production, electricity generation, wildfire suppression, snow accumulation, seasonal and flash-flooding, and short- and long-term drought risk.[xliv] They are also important drivers of migration and breeding for amphibians and some fish species. A local example is the annual migration of Jefferson Salamanders which is triggered by spring rainfall.

In this section, projections of precipitation accumulation as well as extreme precipitation variables are presented. Freezing rain and Intensity-Duration Frequency (IDF) curves are presented in the Extreme Weather Events section.

5.4.1 Mean Precipitation

The average Annual Precipitation is projected to slightly increase over the coming decades. For Burlington Region, this increase will be from a baseline of 811 mm to approximately 864 mm in the 2021-2050 period, and to 889 mm by the 2051-2080 period under the RCP8.5 scenario as shown below.

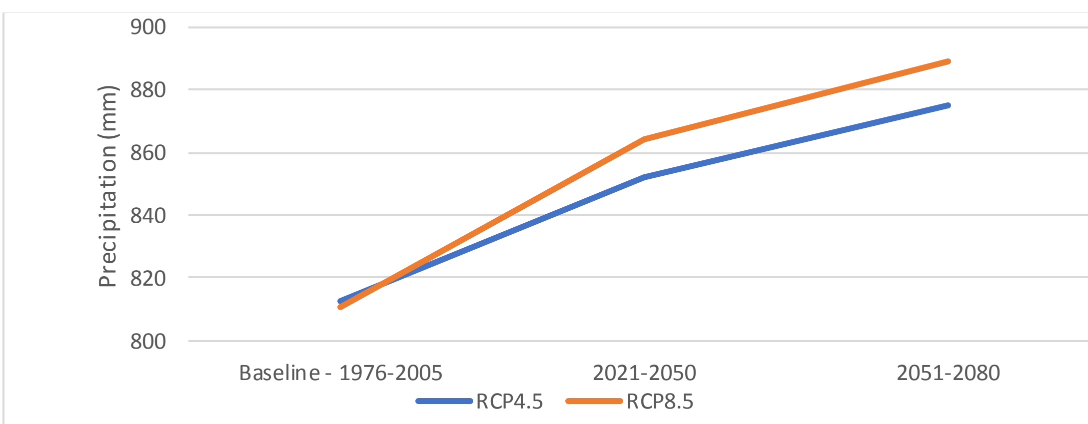


Figure 10: Annual Precipitation for Burlington Region - RCP4.5 and 8.5

On a seasonal basis, spring, winter and fall precipitation accumulations are projected to increase by 2051-2080 with spring and winter experiencing the greatest increases while summer precipitation will remain relatively consistent. Table 19 presents the Annual and Seasonal Precipitation projections for Burlington Region under RCP4.5 and 8.5. Figure 11 presents the Seasonal Precipitation projections under RCP8.5.

Table 19: Annual and Seasonal Precipitation for Burlington Region – RCP4.5 and 8.5

Emissions Scenario	Period	Baseline 1976-2005 (mm)	2021-2050 (mm)			2051-2080 (mm)		
			Low	Mean	High	Low	Mean	High
RCP4.5	Spring	210	148	225	310	155	232	318
	Summer	208	128	211	309	122	211	314
	Fall	213	136	220	319	141	229	329
	Winter	181	127	197	273	133	204	278
	Annual	811	686	852	1025	691	875	1071
RCP8.5	Spring	210	154	232	321	164	245	337
	Summer	208	123	210	306	120	207	311
	Fall	213	137	222	319	135	223	325
	Winter	181	132	200	276	141	214	296
	Annual	811	688	864	1045	714	889	1080

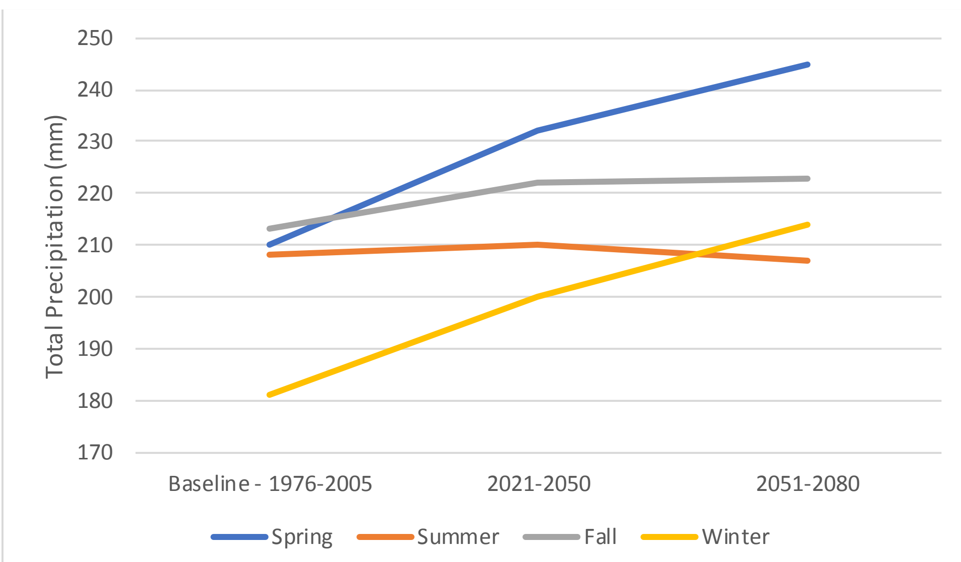


Figure 11: Seasonal Precipitation for Burlington Region - RCP8.5

5.4.2 Dry Days and Wet Days

Two indicators that measure the frequency of rain events are the number of Wet Days and the number of Dry Days. The number of Wet Days measures the number of days in a year with more than 0.2 mm of rain/snow, while the number of dry days measure the number of days with less than 0.2 mm of rain/snow which is consistent with the Meteorological Service of Canada.[xlv]

Table 20 and Table 21 depict the number of annual projected Wet Days and Dry Days for Burlington Region, respectively. The tables show very little change in terms of the number of Dry Days and Wet Days for Burlington Region overall.

Table 20: Number of Annual Wet Days for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	154.2	137.6	154.3	170.1	137.9	154.4	171.1
RCP8.5	154.2	138.5	155.2	171.5	137.8	153.7	169.3

Table 21: Number of Annual Dry Days for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	210.4	194.3	210.3	227.2	193.7	210.2	226.7
RCP8.5	210.4	193.2	209.5	226.1	195.5	210.9	227.0

5.4.3 Heavy Precipitation

The projections of several extreme precipitation variables, with the exception of freezing rain and IDF curves, are presented in this section.

Heavy Precipitation Days are days on which at least a total of 10 mm or 20 mm of rain or frozen precipitation falls. Frozen precipitation is measured according to its liquid equivalent: 10 cm of snow is usually about 10 mm of precipitation.[xlvi] As stated in section 4.3 of this report, Heavy Precipitation Days are likely underestimated for frequency and intensity as climate models likely don't capture the intense, localized events such as thunderstorms.

Max 1-Day Precipitation and Max-5 Day Precipitation indicate the amount of precipitation that falls on the wettest day of the year, and the five wettest days of the year respectively. The Max 1-Day Precipitation amount could be the result of a short but intense precipitation event such as a storm or because a moderate amount of snow/rain falls continuously all day, rather than all at once.[xlvii]

Table 22 and Table 23 respectively show the projected Heavy Precipitation Days (both 10 mm and 20 mm) and the Max 1-Day and 5-Day Precipitation for Burlington Region.

Table 22: Heavy Precipitation Days for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Variable	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
			Low	Mean	High	Low	Mean	High
RCP4.5	Heavy Precipitation Day (10 mm)	24.8	19.0	26.6	34.5	19.5	27.4	36.0
RCP8.5		24.8	19.4	27.1	35.2	20.2	27.8	35.5
RCP4.5	Heavy Precipitation Day (20 mm)	6.1	3.6	7.1	11.0	4.0	7.8	12.1
RCP8.5		6.1	3.7	7.3	11.1	4.2	8.2	12.2

Across Burlington Region, Heavy Precipitation Days (10 mm) are expected to increase by approximately three days and Heavy Precipitation Days (20 mm) are expected to increase by two days. Max 1-Day and 5-Day events are also expected to increase. While the greatest increase in precipitation is projected to be for Max 5-Day events (from 64 mm to 73 mm), the greatest impact will be felt with Max 1-Day events (from 42 mm to 48 mm) as more rain will fall in less time by 2051-2080 for RCP8.5.

Table 23: Maximum 1-Day and 5-Day Precipitation for Burlington Region- RCP4.5 and 8.5

Emissions Scenario	Variable	Baseline 1976-2005 (mm)	2021-2050 (mm)			2051-2080 (mm)		
			Low	Mean	High	Low	Mean	High
RCP4.5	Max 1-Day Precipitation	42	29	45	72	29	46	71
RCP8.5		42	29	45	71	31	48	75
RCP4.5	Max 5-Day Precipitation	64	47	69	104	47	71	103
RCP8.5		64	46	68	98	49	73	107

Changes in the above extreme precipitation variables are visually presented in Figures 12 and 13 for Burlington Region under RCP8.5.

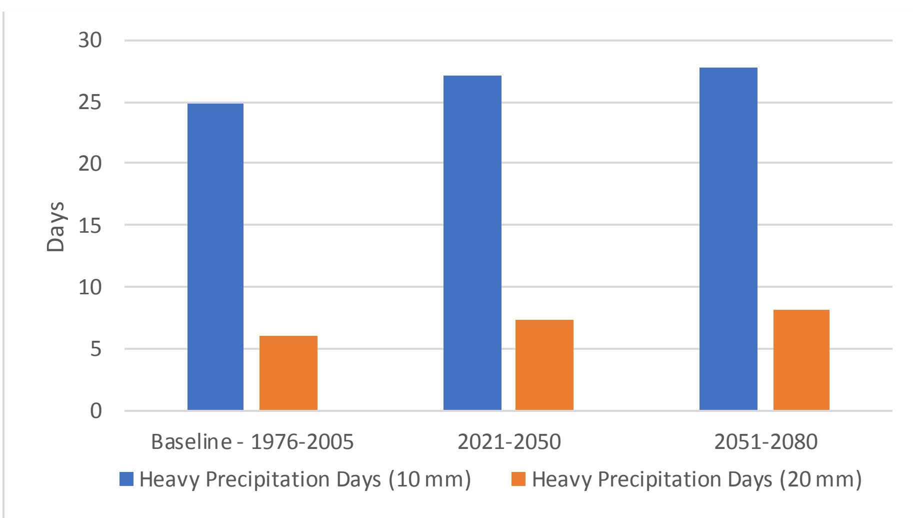


Figure 12: Heavy Precipitation Days for Burlington Region - RCP8.5

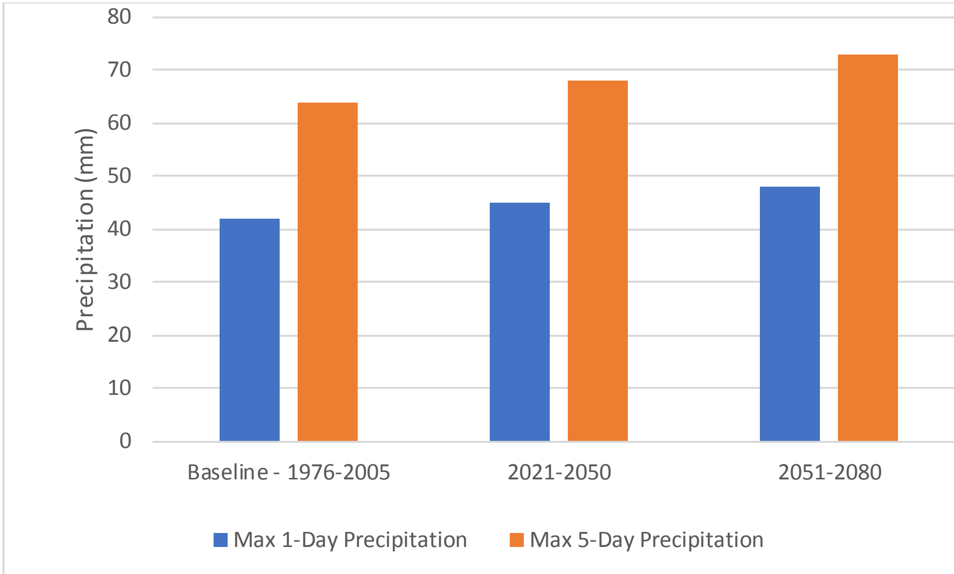


Figure 13: Max 1-Day and 5-Day Precipitation for Burlington Region - RCP8.5

It's important to understand projections for heavy rainfall events, as they can create many challenges. In cities and towns, heavy rainfalls can overwhelm storm drains and cause flash flooding. They can also cause problems in rural areas by drowning crops, eroding topsoil, and damaging roads.[xlviii]

5.5 Agriculture

Climate change creates both risks and opportunities for Ontario agriculture. Changes in seasonal temperatures, precipitation events, the length of growing seasons, and the timing of extreme heat and cold days all determine the types of crops that can be grown now and in the future.[xlix] Managing for increased agricultural productivity and working to reduce risks under climate change will require careful consideration of changing weather and climate conditions, as well as key landscape and soil characteristics, crop suitability, farm management options, and policy and program support.[l]

5.5.1 Frost Variables

Changes in the length and timing of the frost-free season affect plant and animal life, but also our social, psychological, and physical experience of the changing seasons.[li]

The Frost-Free Season is the approximate length of the growing season, during which there are no freezing temperatures to kill or damage plants.[lii] Table 24 and Figure 14 depict that the length of the frost-free season is expected to increase, from a baseline of 184 days per year, to 227.9 days per year in 2051-2080 according to RCP8.5 for Burlington Region. This lengthening of the frost-free seasons means plants and crops have a longer window to grow and mature.[liii]

Table 24: Length of Frost-Free Season for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (Days)	2021-2050 (Days)			2051-2080 (Days)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	184.0	179.9	203.1	227.5	184.0	210.8	236.8
RCP8.5	184.0	180.7	205.4	232.1	200.1	227.9	257.3

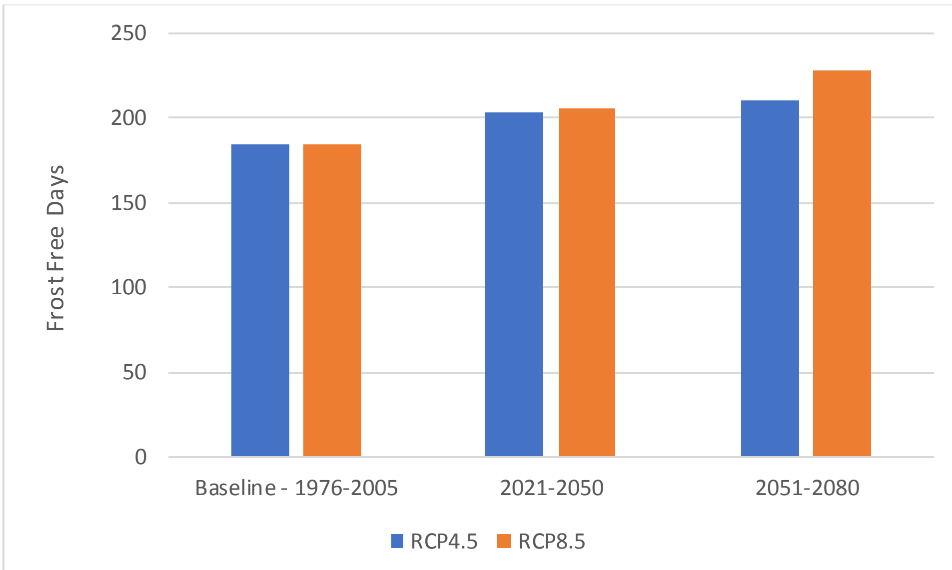


Figure 14: Length of Frost-Free Season for Burlington Region - RCP4.5 and 8.5

Not only is the overall Frost-Free Season becoming longer, the dates of first and last frosts of the year are also changing. The arrival of frost marks the end of the growing season and announces the imminent return of winter. Projections for Burlington Region indicate a later Date of First Fall Frost, meaning the seasonal transition from warmer to colder weather is happening later in the year.

Table 25 outlines the expected changes to Date of First Fall Frost and Date of Last Spring Frost for Burlington Region. According to RCP8.5, the Date of First Fall Frost could shift from a baseline of October 26th to potentially November 20th in the 2051-2080 period. Similarly, the Date of Last Spring Frost is expected to occur earlier – a change from a baseline of April 22nd to April 3rd by the 2051-2080 period according to RCP8.5.

As stated in section 4.3 of this report, Date of First Fall Frost, Last Spring Frost and Frost-Free Season are calculated using standard weather station observations, which are usually at 1.2m above the ground. Since the ground level temperature can be colder than the surface air temperature at 1.2m, the length of the Frost-Free Season presented is likely longer than the actual length of the season at ground level.

Table 25: Date of First and Last Frost for Burlington Region - RCP 4.5 and 8.5

Emissions Scenario	Variable	Baseline 1976-2005	2021-2050			2051-2080		
			Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	Date of First Fall Frost	Oct. 26	Oct. 20	Nov. 6	Nov. 22	Oct. 23	Nov. 11	Nov. 29
RCP8.5		Oct. 26	Oct 21	Nov. 7	Nov. 26	Oct. 31	Nov. 20	Dec. 10
RCP4.5	Date of Last Spring Frost	Apr. 22	Mar. 29	Apr. 13	Apr. 28	Mar. 25	Apr. 11	Apr. 27
RCP8.5		Apr. 22	Mar. 28	Apr. 13	Apr. 27	Mar. 13	Apr. 3	Apr. 20

5.5.2 Corn Heat Units

Corn Heat Units (CHU) is a temperature-based index often used by farmers and agricultural researchers to estimate whether the climate is warm enough to grow corn. One of the common climate variables used to assess the viability of growing a crop in a region is average annual CHUs. The CHUs expected in a region's growing season are used to assess whether corn, or a particular variety of corn, is likely to fully mature in that region.[liv] Generally, at least 2200 CHUs are required to mature most varieties of corn.[lv] Table 26 outlines the annual projected CHUs for Burlington Region.

Table 26: Corn Heat Units for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Baseline 1976-2005 (# of °C)	2021-2050 (# of °C)			2051-2080 (# of °C)		
		Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	3495	3639	4078	4492	3874	4375	4845
RCP8.5	3495	3725	4166	4596	4333	4815	5323

Overall, CHUs are projected to increase from a baseline of 3495 to 4815 by the 2051-2080 period under RCP8.5.

5.5.3 Growing Degree Days

Growing Degree Days (GDD) provide an index of the amount of heat available for the growth and maturation of plants and insects. Different base temperatures (5°, 10° and 15°C) are used to capture results for organisms that demand different amounts of heat.

GDDs accumulate whenever the daily mean temperature is above a specified threshold temperature. Generally, 5°C GDDs are used for assessing the growth of canola and forage crops; 10°C GDDs are more appropriate for assessing the growth of corn and beans; and 15°C GDDs are used to assess the growth and development of insects and pests.[lvi] Table 27 outlines the GDDs for Burlington Region across 5°, 10°, and 15°C thresholds respectively.

Table 27: Growing Degree Days for Burlington Region - RCP4.5 and 8.5

Emissions Scenario	Variable	Baseline 1976-2005 (# of °C)	2021-2050 (# of °C)			2051-2080 (# of °C)		
			Low	**Mean**	**High**	**Low**	**Mean**	**High**
RCP4.5	Growing Degree Days (Base 5°C)	2333	2448	2757	3040	2622	2990	3344
RCP8.5		2333	2523	2816	3108	2950	3333	3733
RCP4.5	Growing Degree Days (Base 10°C)	1353	1435	1685	1916	1569	1872	2166
RCP8.5		1353	1497	1737	1974	1834	2149	2469
RCP4.5	Growing Degree Days (Base 15°C)	626.5	676.9	869.7	1059	773.5	1015	1269
RCP8.5		626.5	725.7	912.8	1103	976.9	1232	1503

All GDDs are expected to increase across all emission scenarios and time periods. This indicates that there will be more days per year that meet these temperature thresholds. While these present some opportunities for agriculture (i.e. longer growing seasons), it also could signal an increase in the survival of pests and other invasive species due to warmer temperatures in the winter months.

5.6 Extreme Weather Events

Canada has seen more frequent and intense extreme events over the last 50-60 years than ever before. These events come in the form of extreme heat days, more instances of extreme precipitation and flooding, wind storms, and ice storms. In Canada, models show return periods, or the estimated interval of time between occurrences, of extreme events in the future will be shorter.[lvii]

5.6.1 Rainfall Intensity-Duration-Frequency

Extreme and heavy rain events are expected to become more intense and more frequent.[lviii] As Southern Ontario is the most intensely urbanized area of the province, the magnitude and costs associated with flooding is significantly higher than elsewhere in the province.

Stormwater management systems depend on Intensity–Duration–Frequency (IDF) curves as a standard design tool, where rainfall intensity (mm/h), duration (how many hours it rained at that intensity) and frequency (how often that level of a rainstorm repeats itself) are stated.[lix] However, due to climate change, the extreme precipitation data represented by IDF curves will be subject to change over time.

5.6.1.1 City of Burlington

The City of Burlington used Western University's "Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change – version 4.0" (www.idf-cc-uwo.ca).

Existing gauged data from Environment Canada stations (in this case the Royal Botanical Gardens station for the years between 1962 and 2016) is integrated with predictions obtained from Global Climate Models (GCMs) to assess the impacts of climate change on IDF curves. GCMs developed for IPCC Assessment Report (AR5) are used to provide future climate scenarios to the year 2100 for the various RCPs (RCP2.6, 4.5 and 8.5).[lx]

Using Western University's tool, the 5-year and 100-year event data showed a percentage increase ranging from eight to 16 percent for the three emission scenarios from Burlington's 1999 IDF curves. Based on this data, the City of Burlington used a 15 percent increase to apply to the City's 1999 IDF curves to update and generate Burlington's new official 2020 IDF curves. These IDF curves were approved and adopted by Burlington City Council in June 2020 as part of the new Stormwater Management Design Guidelines and are being used for all new developments and redevelopments in Burlington.[lxi]

Table 28 and Figure 15 outline the historical IDF curves for the City of Burlington using gauged data from the Royal Botanical Gardens station, while Table 29 and Figure 16 outline Burlington's 2020 IDF curves currently in use.

Table 28: Historical Precipitation Intensity Rates (mm/h) for City of Burlington (1962-2016)

Duration	T (years)					
	2	**5**	**10**	**25**	**50**	**100**
5 min	97.39	124.71	141.56	161.54	175.48	188.60
10 min	68.93	88.20	100.98	117.15	129.16	141.11
15 min	54.86	70.10	81.28	96.82	109.44	122.97
30 min	35.81	45.73	52.37	60.84	67.19	73.55
1 h	22.25	27.83	31.02	34.58	36.90	38.98
2 h	13.80	17.72	20.17	23.12	25.21	27.19
6 h	5.69	7.81	9.44	11.79	13.8	15.98
12 h	3.36	4.51	5.44	6.88	8.16	9.65
24 h	1.99	2.56	3.04	3.77	4.42	5.19

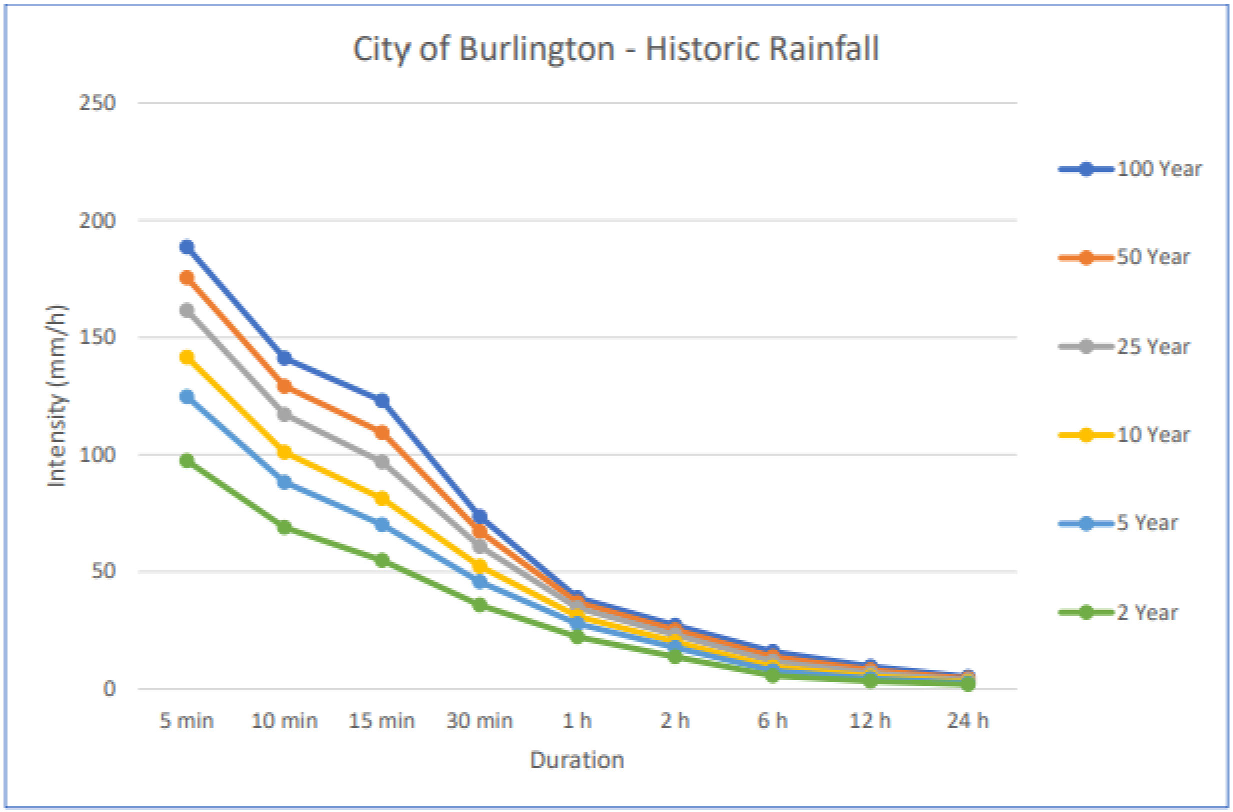


Figure 15: Historical IDF Curve for the City of Burlington (1962-2016)

Table 29: City of Burlington 2020 IDF curve (mm/h)

Duration	T (years)					
	2	**5**	**10**	**25**	**50**	**100**
5 min	105.00	138.10	158.48	184.39	203.26	222.16
10 min	78.39	101.31	116.31	135.38	149.30	163.18
15 min	63.41	81.32	93.39	108.73	119.94	131.09
30 min	41.64	53.03	60.93	70.98	78.35	85.63
1 h	25.96	33.05	37.99	44.29	48.91	53.46
2 h	15.67	20.05	23.07	26.91	29.74	32.50
6 h	6.82	8.84	10.18	11.89	13.16	14.38
12 h	4.00	5.23	6.03	7.05	7.80	8.53
24 h	2.34	3.09	3.56	4.17	4.62	5.05

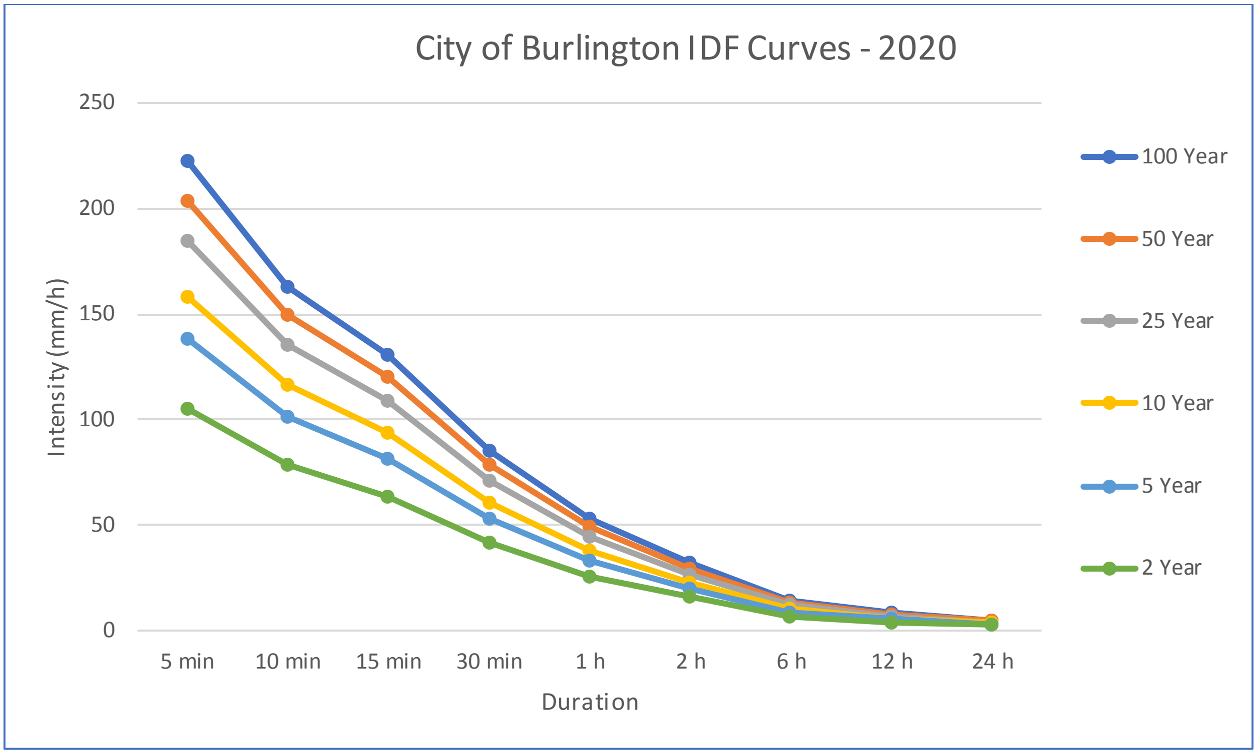


Figure 16: City of Burlington 2020 IDF curve

5.6.1.2 Town of Oakville

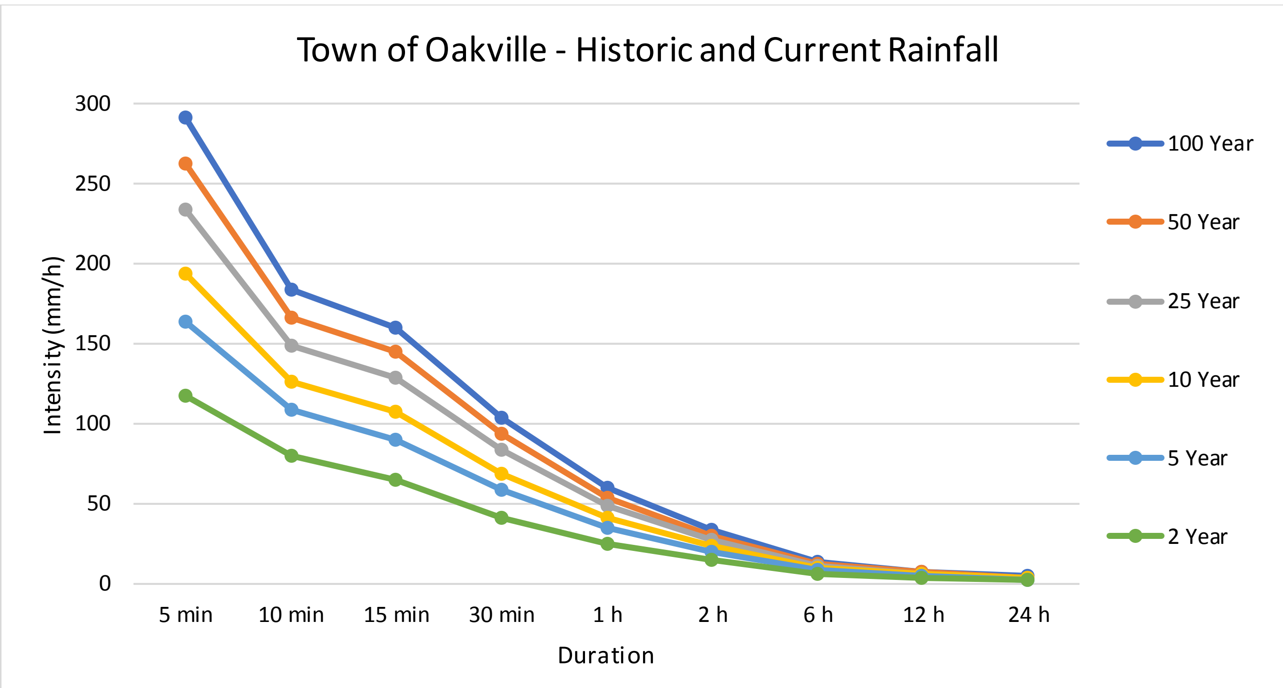
The Town of Oakville defines its rainfall standard in the Development Engineering Procedures and Guidelines Manual.[lxii] It is noted in this manual, that there is no satisfactory meteorological data for Oakville, therefore it will be using the data available from the Toronto Bloor Street station, or Toronto City Station (Gauge ID 6158355). This station has continuous rainfall data from 1940 to 2007 more than any other in closer proximity.[lxiii]

The Town of Oakville's historic IDF curves were developed in 2011 but also serve as the town's current IDF curves. It was realized through the development of the 2019 Stormwater Master Plan that the 2011 IDF values were sufficiently conservative when compared to various IDF relationships developed using many scenarios and several climate tools. The current IDF values were found to provide sufficient resilience to the projected increases in extreme precipitation events.[lxiv] Table 30 and Figure 17 depict the rainfall IDF values that shall be used for all frequencies from 1:2 years to 1:100 years.[lxv]

Table 30: Historic and Current Precipitation Intensity Rates for the Town of Oakville (1946-2007)

Duration	T (years)					
	2	**5**	**10**	**25**	**50**	**100**
5 min	117	164	194	233	262	291
10 min	80	108	126	149	166	183
15 min	65	90	107	129	145	160
30 min	41	58	69	83	93	103
1 h	25	35	41	48	54	60
2 h	15	20	23	27	30	33
6 h	6.1	8.1	9.4	11	12	13
12 h	3.6	4.6	5.3	6.2	6.8	7.5
24 h	2	2.5	2.9	3.4	3.7	4.1

Figure 17: Historic and Current IDF Curve for the Town of Oakville (1946-2007)



Appendices B and C outline the projected IDF curves under RCP4.5 and RCP8.5 for the City of Burlington and Town of Oakville which are included in Burlington Region. Overall, the curves indicate that the intensity of rainfall events are expected to increase. Increases in the intensity of rainfall events as a result of climate change are a major threat to infrastructure systems, especially stormwater infrastructure systems and the transportation systems they protect. Higher rainfall intensities lead to more severe storms, with expected increases in damages related to residential, street, and flash flooding.

5.6.2 Freezing Rain

Although rare in occurrence, Freezing Rain events have the potential to negatively impact personal safety, infrastructure, transportation, trees and utilities incurring substantial response and recovery costs.[lxvi]

A study conducted by the Meteorological Service of Canada branch of Environment Canada observed the possible impacts of climate change on Freezing Rain using downscaled future climate scenarios. This report was published in 2007 and applies the SRES climate scenarios from the IPCC AR4 report.[lxvii] This study focused on four regions in south-central Canada, with the Southern Ontario region specifically focused on the Windsor to Toronto corridor which includes Burlington Region. The six months that Freezing Rain occurs in Canada, were divided into two categories, the three warmer months (November, March and April) and the three colder months (December, January and February).

For the Southern Ontario region Freezing Rain events are projected to decrease from the baseline (1958-2001) in the warmer months by 10 and 15 percent by 2050 and 2080 respectively and increase in the colder months by 40 percent in 2050 and up to 45 percent in 2080.[lxviii] The report concludes that as temperatures increase, more Freezing Rain events are projected to occur across south-central Canada. This increase is more substantial in the short term and as you move south to north and southwest to northeast across the entire study area.

5.6.3 Wind Gusts

High wind speeds and wind gusts, that are not classified as tornadoes, are an important climate variable to consider as they cause considerable damage to properties, infrastructure and trees. They often impact electrical power distribution and transmission lines due to downed trees and poles.[lxix] A 2012 study led by Environment Canada researchers observed the possible impacts of climate change on future Daily and Hourly Wind Gust events in the Province of Ontario. The study area was divided into four regions with Region 1 covering Burlington Region. This study used SRES scenarios from the IPCC Fourth Assessment Report (AR4) where A2 represents a high emissions scenario and B1 represents a low emissions scenario.[lxx]

The authors included some specific wind speeds for the study as they were pre-identified thresholds. For example, 28 km/h is the minimum value to record wind gust observations; 40 km/h related to wind turbines; and 70 and 90 km/h triggered Environment Canada wind gust warnings.[lxxi]

Overall, the study found that Ontario will experience more Wind Gust events (both hourly and daily) by the end of the century. Under the A2 high emissions scenario for the area which includes Burlington Region, annual mean frequency of Hourly Wind Gust events will increase by 15 percent (greater than 28 km/h), 21 percent (greater than 40 km/h) and 19 percent (greater than 70 km/h) by the end of the century. While future Hourly Wind Gust events (90 km/h) are projected to increase from 1.4 hours from the baseline period of 1994-2007 to 2.4 hours by

2046-65 for the high emissions scenario representing a 70 percent increase, the authors of the study stated that it would be inappropriate to attribute a percentage change to 80 and 90 km/h events as they are less frequent. Daily Wind Gusts are also predicted to increase by six, 11 and 22 percent for the same wind categories by the end of the century as shown in Table 31.[lxxii]

Table 31: Percentage Increase in the Frequency of Future Daily and Hourly Wind Gust Events from Current Conditions – A2 scenario

Wind Gust Event (km/h)	Daily wind gust (% increase)		Hourly Wind Gust (% increase)	
	2046-2065	**2081-2100**	**2046-2065**	**2081-2100**
28 or more	4	6	8	15
40 or more	7	11	13	21
70 or more	14	22	17	19

5.7 Lake Ontario

About 11 million people live in Lake Ontario's watershed with nine million in Canada and two million in America. Lake Ontario is the smallest of the five Great Lakes by shoreline, the second smallest by volume and the third deepest. Combined the Great Lakes account for 21 percent of the world's freshwater by volume. Their size (244 000 km^2) influences local climate producing a moderating lake breeze especially in the summer and fall and lake effect precipitation, which is further influenced in the winter by the presence and degree of lake ice.[lxxiii]

5.7.1 Lake Levels

Water levels in the Great Lakes have fluctuated considerably over multi-decadal time scales, rising over the past several years following a period of record low levels. The changes in Lake Ontario water levels result from fluctuations in surface water temperatures, and precipitation. Over the past several decades, monitoring indicates that Lake Ontario has experienced a 3.5 percent increase in over-lake precipitation and a 9.8 percent increase in overland runoff.[lxxiv]

The Department of Fisheries and Oceans Canada uses the 1985 International Great Lakes Data (IGLD) collected from six gauging stations located on Lake Ontario at Port Weller, Toronto, Cobourg, Kingston, Rochester and Oswego. Figure 18 compares the average annual water levels from 2009-2019 to that of the baseline, 1976-2005.[lxxv]

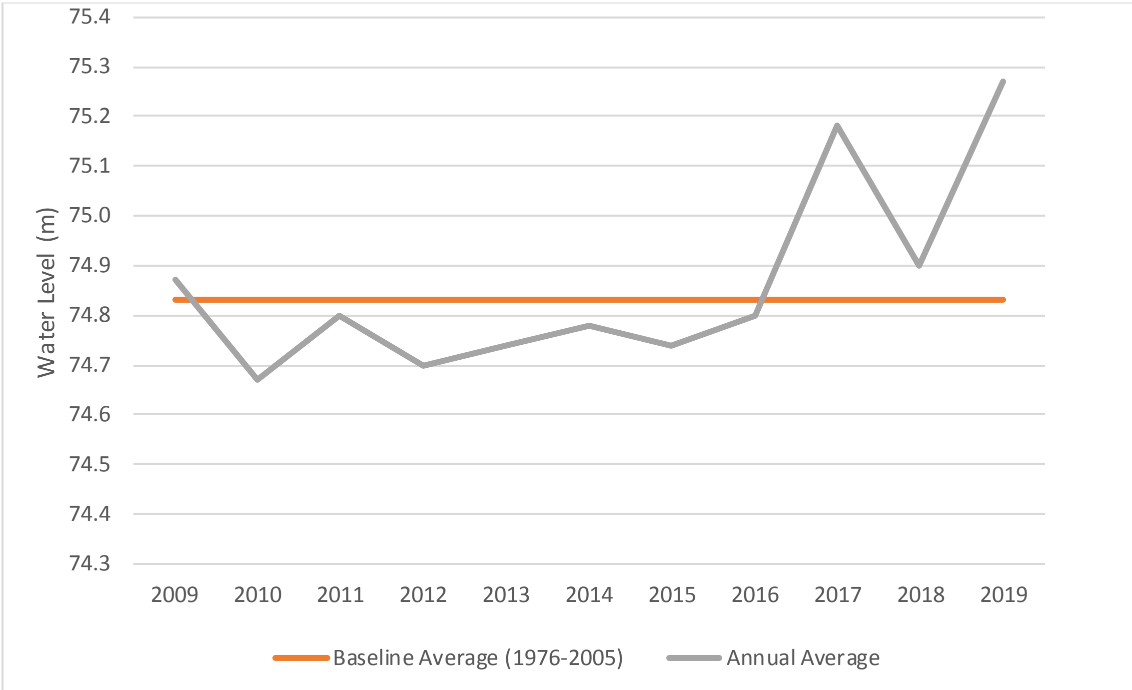


Figure 18: Annual Water Levels (2009-2019) Compared to the Baseline

In 2017 and 2019, Lake Ontario experienced extremely high-water levels due to record-breaking precipitation events in the basin. Burlington Region experienced extensive shoreline flooding, that was intensified by easterly winds, damaging infrastructure and natural areas such as lakeside parks, trails, beaches and harbours. Figure 19 shows the monthly average water levels in 2017 and 2019 compared to the baseline years of 1976-2005.[lxxvi]

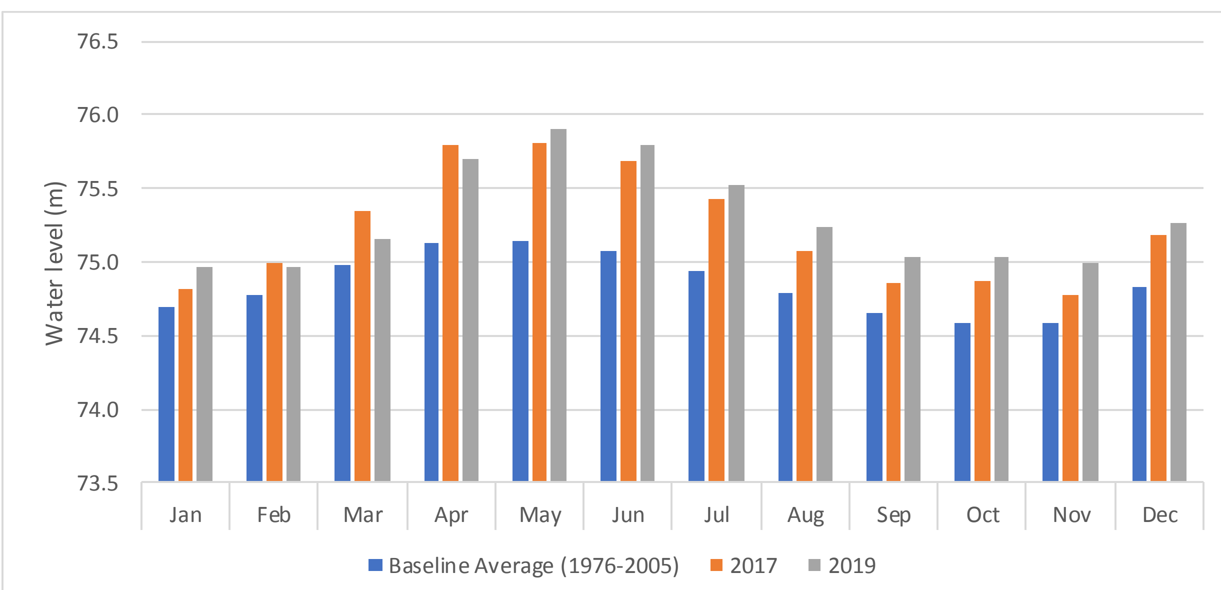


Figure 19: Baseline Water Levels Compared to the Record-Breaking Lake Levels of 2017 and 2019

Several studies indicate that climate change is already impacting the Great Lakes water levels causing shoreline flooding and erosion when lake levels are high and power transmission and ship navigation issues when levels are low. The projected increase in annual temperatures, precipitation and extreme weather events resulting from climate change will continue to impact the Great Lakes basin.[lxxvii] Lake level modelling conducted in 2011 foresees a central tendency toward small drops in lake levels to the end of the 21st century, with a considerable probability of small rises which is in contrast to the large drops projected using the older methodology.[lxxviii]

5.7.2 Lake Temperature

Climate change alters the exchange of heat between the atmosphere and the Great Lakes impacting overall lake temperature, ice cover duration and the seasonal mixing of lake water.[lxxix]

Between 1970 and 2009, annual mean surface air and water temperatures increased (1.43°C and 1.26°C respectively) in Lake Ontario. Seasonally, surface water temperature increased at a faster rate than air temperature in spring and summer whereas air temperature increased at a faster rate than water temperature in fall and winter.[lxxx] Research using fine-scale (versus lake or basin scale) trends also show a significant warming trend in summer surface water temperatures around the eastern regions of Lake Ontario from 1994 to 2013 as shown in Figure 20.[lxxxi]

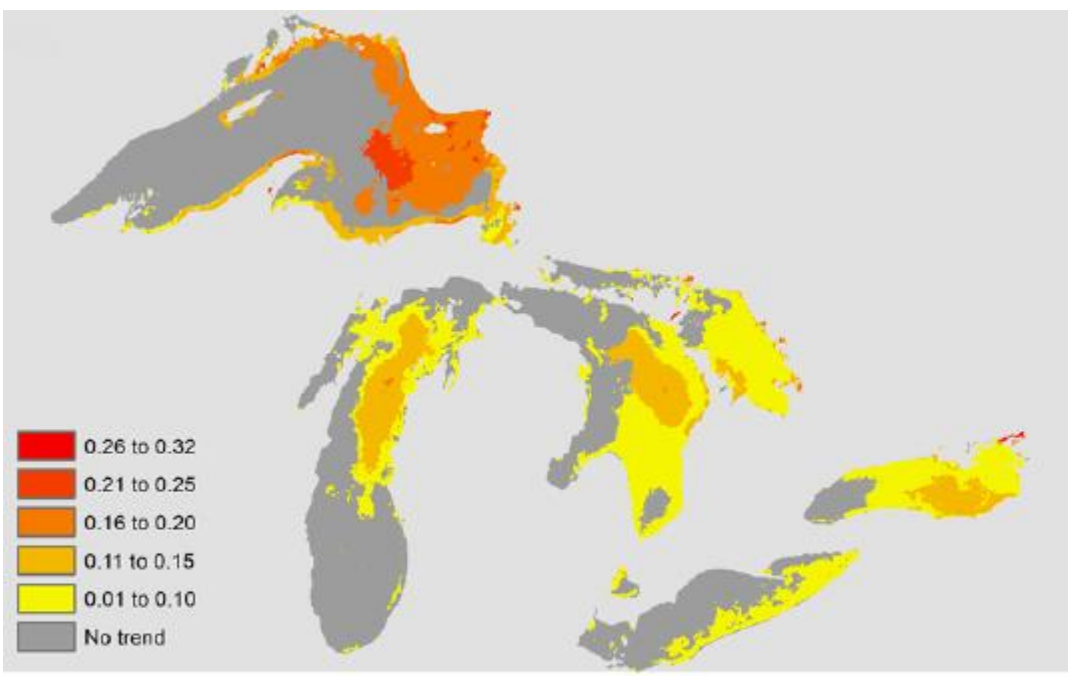


Figure 20: Summer Surface Water Temperature (°C/year) (1994-2013)

Lakes in our climate tend to have defined layers with different water temperatures throughout the water column. Mixing of these layers tends to occur twice each year; in the spring and in the fall when lake surface temperature rises or falls to 4°C. Seasonal mixing of lake water is occurring earlier in the spring and later in the fall.[lxxxii] This could be contributing to a summer thermal stratification season (the last occurrence of a 4°C lake surface temperature in spring and the first occurrence of 4°C in fall)[lxxxiii] in Lake Ontario that was lengthened by about 12 days between 1970 and 2009.[lxxxiv] Notwithstanding the above section on wind gusts (greater than 28 km/hr), surface wind speed has declined about 2.88 to 4.75 km/h over Lake Ontario over four decades.[lxxxv] Since Lake Ontario does not have as much ice cover as other Great Lakes, wind speed could have a greater influence than ice cover on lake surface temperature as lower summer wind speed will result in warmer surface water.[lxxxvi]

5.7.3 Ice Cover

Various studies show a decrease in ice cover on the Great Lakes. Figure 21 shows the decreasing trend in yearly maximum ice coverage in the Great Lakes from 1973 to 2018. [lxxxvii]

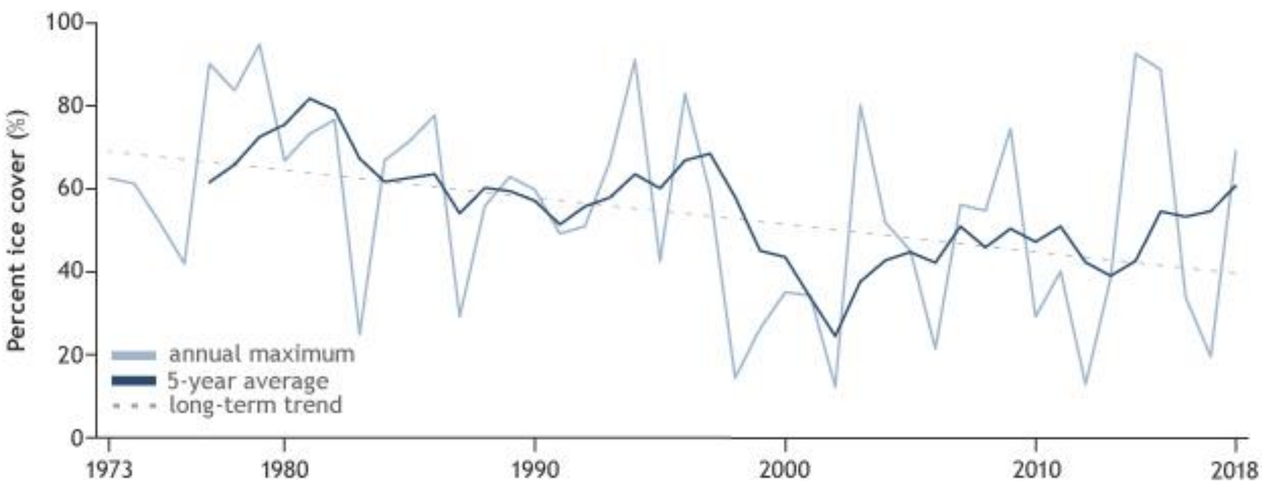


Figure 21: Time Series of Yearly Maximum Ice Cover in the Great Lakes (1973-2018)

As seen in Figure 22, the greatest decline in seasonal ice cover duration occurs in the northern and eastern Great Lakes especially along the shorelines.[lxxxviii]

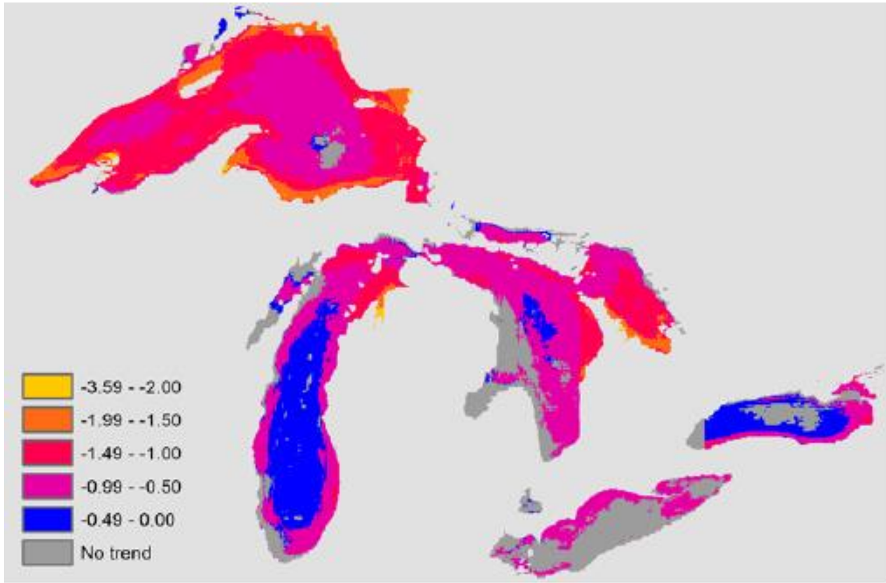


Figure 22: Seasonal Ice Cover Duration (days/year) (1973-2013)

A study of Great Lakes ice cover between 1973 and 2010 found a significant overall decrease in ice cover of 71 percent with Lake Ontario experiencing the most loss at 88 percent.[lxxxix] Between 1970 and 2009, Lake Ontario's surface air temperature warmed four times faster than air temperature in winter perhaps contributing to the decline.[xc]

Another study examined the ice coverage of Lake Ontario for the past, present and future under four categories: very light, light, moderate and heavy. There was a decline of heavy ice seasons for Lake Ontario from six per decade (1840s to 1870s – the most distant climate normal) to one per decade (1980s to 2000s – the most recent climate normal). The same study projected future ice coverage using GCMs for both RCP4.5 and 8.5. Under both scenarios, heavy ice seasons will no longer occur as early as the 2050s with very light ice seasons going from 10 percent in the baseline period (1981-2010) to 73 (RCP4.5) or 100 (RCP8.5) percent by the 2080s as seen in Figure 23.[xci]

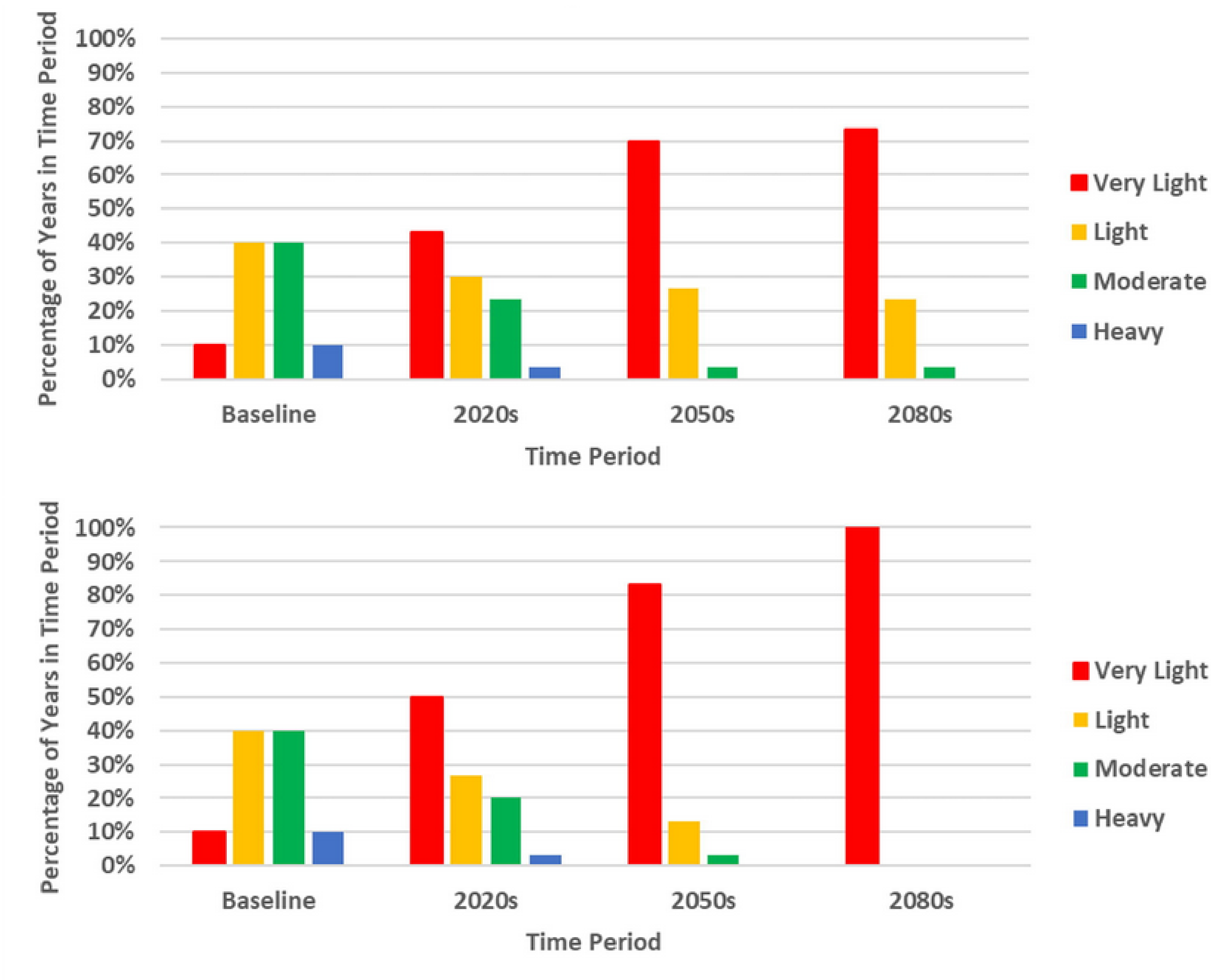


Figure 23: Projected Ice Conditions for Lake Ontario (2011-2100), based on RCP4.5 (top) and RCP8.5 (bottom), including the Baseline Time-Period for Context

6.0 Conclusion

The information provided in this report provides how and to what degree climate change is projected to affect Burlington Region. Increases to annual temperatures, precipitation and extreme events can have major impacts with tremendous ecological, infrastructural, economic and sociological effects for the community. The information in this report will be used to inform proactive adaptation planning across the community and corporation, and may be integrated into asset management practices, emergency management planning, outreach and communications, as well as other climate adaptation programs.

APPENDICES

Appendix A: Summary of Local Climate Variables and Trends

The content in this appendix shows:

- Mean data for climate variables under the categories of Temperature, Hot Weather, Cold Weather, Precipitation and Agriculture under a high emissions scenario (RCP8.5), and
- The trend between the baseline period of 1976-2005 and the near future (2051-2080).

Tables A1: Temperature Climate Variables and Trends – RCP8.5

Period	Annual Mean Temp (°C)	Spring Mean Temp (°C)	Summer Mean Temp (°C)	Fall Mean Temp (°C)	Winter Mean Temp (°C)
1976-2005	8.6	6.8	20.3	10.5	-3.4
2021-2050	10.7	8.6	22.4	12.7	-1.0
2051-2080	12.8	10.6	24.6	14.6	1.3
Trend	↑4.2°C	↑3.8°C	↑4.3°C	↑4.1°C	↑4.7°C

Period	Annual Min. Temp (°C)	Spring Min. Temp (°C)	Summer Min. Temp (°C)	Fall Min. Temp (°C)	Winter Min. Temp (°C)
1976-2005	4.0	2.0	14.9	6.1	-7.0
2021-2050	6.1	3.8	16.8	8.1	-4.4
2051-2080	8.2	5.6	18.9	10.0	-1.8
Trend	↑4.2°C	↑3.6°C	↑4°C	↑3.9°C	↑5.2°C

Period	Annual Max. Temp (°C)	Spring Max. Temp (°C)	Summer Max. Temp (°C)	Fall Max. Temp (°C)	Winter Max. Temp (°C)
1976-2005	13.2	11.6	25.7	14.9	0.3
2021-2050	15.3	13.5	28.0	17.2	2.3
2051-2080	17.4	15.4	30.3	19.3	4.4
Trend	↑4.2°C	↑3.9°C	↑4.6°C	↑4.4°C	↑4.2°C

Tables A2: Hot Weather Climate Variables and Trends – RCP8.5

Period	Very Hot Days (30°C or more) (Days)	Extremely Hot Days (32°C or more) (Days)	Extremely Hot Days (34°C or more) (Days)	Length of Hot Season (30°C) (Days)	Cooling Degree Days (# of °C above 18°C)
1976-2005	16	6	1.7	70.5	315.7
2021-2050	35.5	18.3	7.8	102	535.1
2051-2080	60.9	38.8	21.6	123.7	797
Trend	↑44.9	↑32.8	↑19.8	↑53.3	↑481.4

Period	Annual # of Heat Waves (#)	Length of Heat Waves (Days)	Longest Spell of 30°C Days (Days)	Annual # of Tropical Nights (>20°C) (Nights)	Average warmest max temp (°C)
1976-2005	2.1	3.7	3.9	8.1	34.2
2021-2050	4.8	5.5	8.4	22.4	36.5
2051-2080	6.7	8.1	18.2	44.8	39.0
Trend	↑4.6	↑4.4	↑14.3	↑36.7	↑4.8

Tables A3: Cold Weather Climate Variables and Trends – RCP8.5

Period	Mild Winter Days (-5°C or less) (Days)	Winter Days (-15°C or less) (Days)	Frost Days (Min. Temp < 0°C) (Days)	Icing Days (Max Temp = or < 0°C) (Days)	Freeze-Thaw Cycles (Days)
1976-2005	66.6	11.2	126	48	63.3
2021-2050	46.3	4	100.1	31.8	54.7
2051-2080	27.3	0.9	74	17.5	44.5
Trend	↓39.3	↓10.2	↓52	↓30.5	↓18.8

Period	Heating Degree Days (# of °C below 18 °C)	Freezing Degree Days (# of °C above 0 °C)	Average Coldest minimum temperature (°C)
1976-2005	3739	450.6	-20.8
2021-2050	3185	271.0	-16.9
2051-2080	2680	138.5	-13.0
Trend	↓1059.4	↓312.1	↑7.8

Tables A4: Precipitation Climate Variables and Trends – RCP8.5

Period	Annual (mm)	Spring (mm)	Summer (mm)	Fall (mm)	Winter (mm)
1976-2005	811	210	208	213	181
2021-2050	864	232	210	222	200
2051-2080	889	245	207	223	214
Trend	↑10%	↑17%	↔ 0%	↑5%	↑18%

Period	Dry Days (mm)	Wet Days (mm)	Heavy Precip. Days (10 mm)	Heavy Precip. Days (20 mm)	Max 1-Day (mm)	Max 5-Day (mm)
1976-2005	210.4	154.2	24.8	6.1	42	64
2021-2050	209.5	155.2	27.1	7.3	45	68
2051-2080	210.9	153.7	27.8	8.2	48	73
Trend	↔	↔	↑3 days	↑2.1 days	↑16%	↑15%

Tables A5: Agriculture Climate Variables and Trends – RCP8.5

Period	Frost-Free Season (Days)	Date of Last Spring Frost	Date of First Fall Frost
1976-2005	184	Apr. 22	Oct. 26
2021-2050	205.4	Apr. 13	Nov. 7
2051-2080	227.9	Apr. 3	Nov. 20
Trend	↑43.9 (longer)	↓18.8 (earlier)	↑ 25 (later)

Period	Corn Heat Units (# of °C)	Growing Degree Days Base of 5°C (# of °C)	Growing Degree Days Base of 10°C (# of °C)	Growing Degree Days Base of 15°C (# of °C)
1976-2005	3495	2333	1353	626.5
2021-2050	4166	2816	1737	912.8
2051-2080	4815	3333	2149	1232
Trend	↑1320	↑1001	↑797	↑605.0

Appendix B: Rainfall IDF Curves for the City of Burlington

The following were generated by the City of Burlington using Western University's Computerized Tool for the Development of Intensity-Duration-Frequency (IDF) Curves under Climate Change – version 4.0 (www.idf-cc-uwo.ca) using RCP4.5 and 8.5 for the periods of 2021-2050 and 2051-2080 to be consistent with the years used in the Climate Atlas of Canada. Precipitation data from existing Environment Canada stations (Royal Botanical Gardens in Burlington) is integrated with predictions obtained from Global Climate Models developed for IPCC Assessment Report (AR5) to assess the impacts of climate change on IDF curves.[xcii]

Rainfall Intensity Rates - RCP4.5 (2021-2050)

Table B1: Rainfall Intensity Rates (mm/h) for the City of Burlington – RCP4.5 (2021-2050)

Duration	T (years)					
	2	**5**	**10**	**25**	**50**	**100**
5 min	104.97	135.39	155.41	179.42	196.41	210.04
10 min	74.17	95.48	110.26	128.23	140.8	153.56
15 min	58.9	75.58	88.26	105.19	119.77	135.31
30 min	38.52	49.48	57.16	66.56	73.2	80.22
1 h	23.98	30.27	34.06	38.57	41.58	43.88
2 h	14.87	19.23	22.26	25.65	28.16	30.19
6 h	6.09	8.42	10.21	12.76	14.91	17.34
12 h	3.6	4.85	5.87	7.38	8.67	10.25
24 h	2.13	2.76	3.28	4.05	4.71	5.52

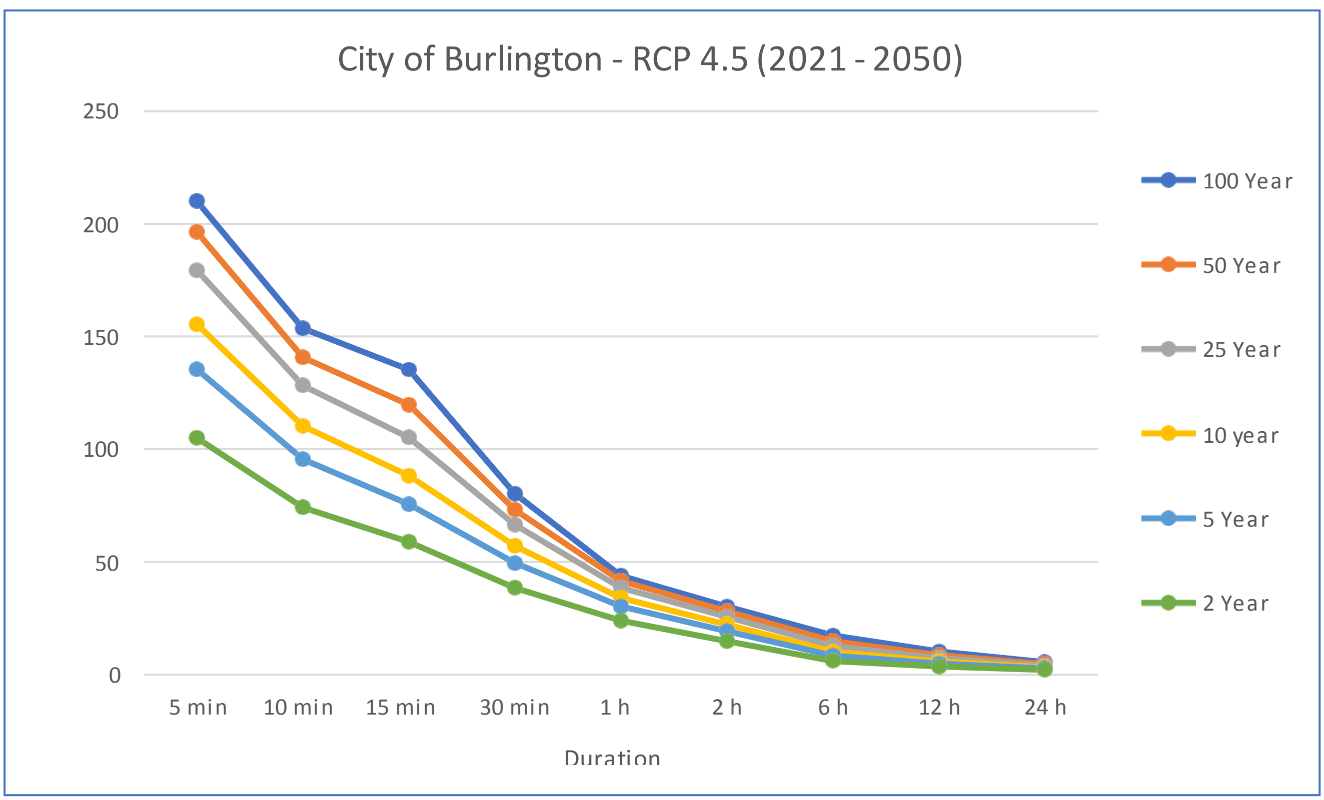


Figure B1: Rainfall Intensity Rates (mm/h) for City of Burlington – RCP4.5 (2021-2050)

Rainfall Intensity Rates - RCP4.5 (2051-2080)

Table B2: Rainfall Intensity Rates (mm/h) for the City of Burlington – RCP4.5 (2051-2080)

Duration	T (years)					
	2	**5**	**10**	**25**	**50**	**100**
5 min	109.14	137.62	156.39	176.41	192.18	207.06
10 min	77.25	97.21	111.17	127.79	141.41	154.18
15 min	61.37	77.28	89.01	105.22	119.42	131.89
30 min	40.13	50.41	57.64	66.36	73.55	80.26
1 h	24.89	30.79	34.39	38.07	40.49	42.77
2 h	15.47	19.54	22.27	25.25	27.61	29.85
6 h	6.35	8.59	10.25	12.78	14.93	16.76
12 h	3.75	4.96	5.89	7.41	8.68	9.76
24 h	2.22	2.83	3.3	4.06	4.71	5.24

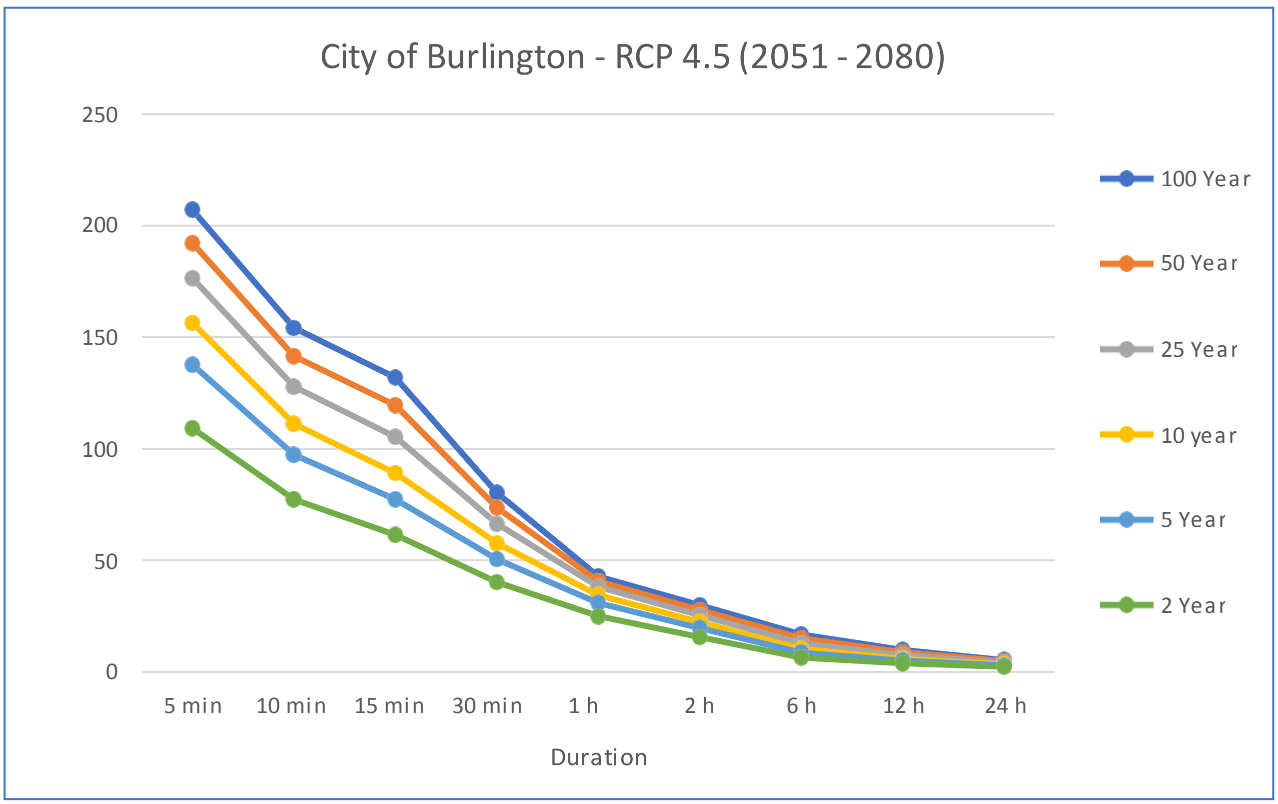


Figure B2: Rainfall Intensity Rates (mm/h) for City of Burlington – RCP4.5 (2051-2080)

Rainfall Intensity Rates - RCP8.5 (2021-2050)

Table B3: Rainfall Intensity Rates (mm/h) for the City of Burlington – RCP8.5 (2021-2050)

Duration	T (years)					
	2	**5**	**10**	**25**	**50**	**100**
5 min	107.63	136.93	154.88	175.55	189.14	199.63
10 min	76.08	96.78	110.27	126.56	137.46	146.42
15 min	60.46	76.85	88.7	103.98	114.27	124.52
30 min	39.53	50.18	57.18	65.68	71.3	76.1
1 h	24.58	30.57	33.98	37.74	39.79	41.79
2 h	15.25	19.45	22.06	25.1	27.18	28.67
6 h	6.24	8.55	10.29	12.52	14.35	16.18
12 h	3.68	4.93	5.91	7.25	8.4	9.6
24 h	2.18	2.81	3.3	3.97	4.56	5.16

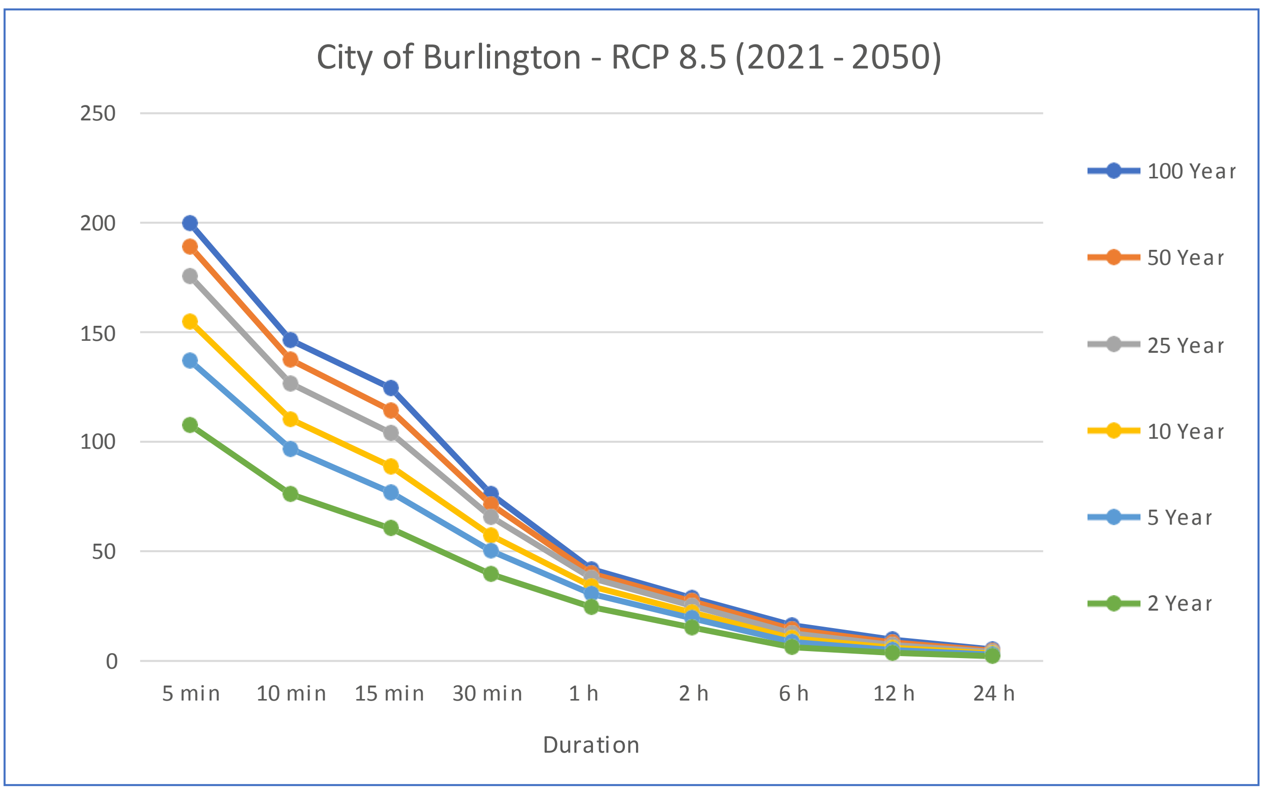


Figure B3: Rainfall Intensity Rates (mm/h) for City of Burlington – RCP8.5 (2051-2080)

Rainfall Intensity Rates - RCP8.5 (2051-2080)

Table B4: Rainfall Intensity Rates (mm/h) for the City of Burlington – RCP8.5 (2051-2080)

Duration	T (years)					
	2	**5**	**10**	**25**	**50**	**100**
5 min	115.03	148.82	171.78	196.72	213.76	229.53
10 min	81.5	105.09	121.03	141.18	151.62	167.68
15 min	64.59	83.34	97.33	115.68	130.02	144.63
30 min	42.35	54.48	62.77	73.27	78.8	87.29
1 h	26.32	33.24	37.19	42.1	44.93	47.43
2 h	16.3	21.14	24.47	28.16	30.7	33.02
6 h	6.7	9.26	11.28	14.15	16.36	18.69
12 h	3.96	5.34	6.49	8.14	9.53	11.11
24 h	2.34	3.04	3.63	4.46	5.17	5.99

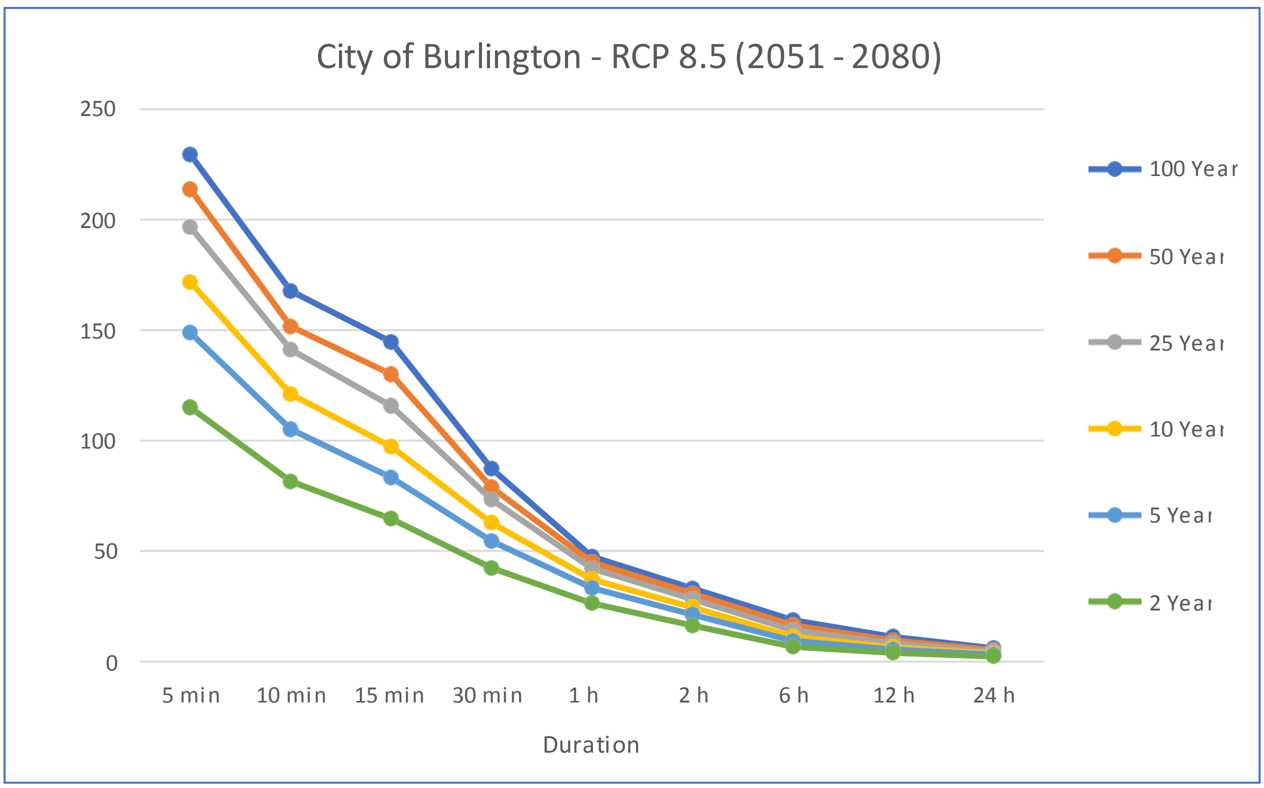


Figure B4: Rainfall Intensity Rates (mm/h) for City of Burlington – RCP8.5 (2051-2080)

Appendix C: Rainfall IDF Curves for the Town of Oakville

The following information was generated by the Town of Oakville using Western University's Computerized Tool for the Development of Intensity-Duration-Frequency (IDF) Curves under Climate Change – version 3.0 (www.idf-cc-uwo.ca). Version 3.0 allows the town to apply the 50+ years of data from Bloor Street Toronto Station to Oakville providing a more comprehensive look at historic and projected trends.

Version 3.0 applied the same two emission scenarios, RCP4.5 & 8.5 but slightly different timeframes. The 2050 and 2080 timeframes selected for assessment represent the five-decade periods of 2015 - 2065 and 2045 - 2095 respectively. These time periods were selected for alignment with the end years of the pre-defined time periods used by the Ontario Climate Change Data Portal (OCCDP). The future rainfall scenarios are compiled from a variety of sources including Environment and Climate Change Canada, University of Western Ontario IDF CC Tool, Ontario Climate Change Data Portal, Ministry of Transportation Ontario Trending Tool.[xciii]

Rainfall Intensity Rates - RCP4.5 (2015-2065)

Table C1: Rainfall Intensity Rates (mm/h) for Town of Oakville

Duration	Return Period (years)					
	2	5	10	25	50	100
5 min	115.9	155	180.8	226.9	262.8	288.3
10 min	80.8	111.6	134.5	177.3	214.1	245.6
15 min	63.2	87.3	105.8	140.3	170	195.3
30 min	41	58	70.8	94	113.4	129.4
1 h	25.5	39	51.3	76.7	102.6	131.1
2 h	15.8	24.7	32.7	48.4	63.7	79.6
6 h	6.8	10.6	14.2	21.7	29.3	35.6
12 h	3.9	5.8	7.5	11.1	14.7	17.8
24 h	2.3	3.3	4.1	5.8	7.4	8.9

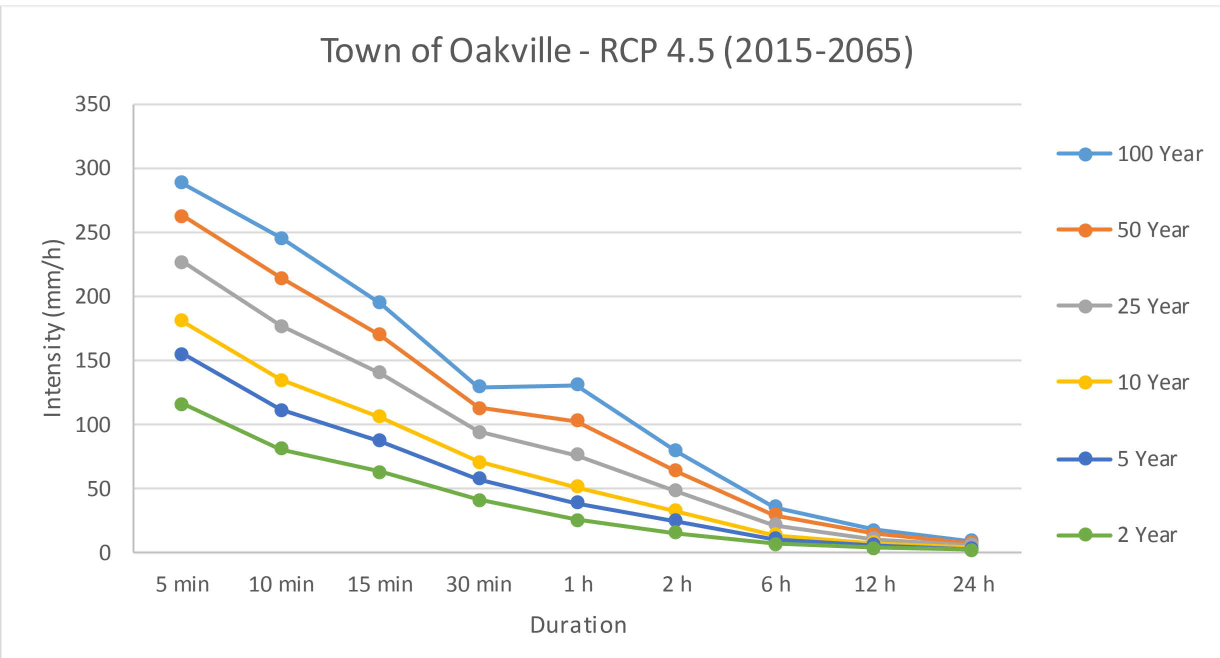


Figure C1: Rainfall Intensity Rates for Town of Oakville

Rainfall Intensity Rates - RCP4.5 (2045-2095)

Table C2: Rainfall intensity Rates (mm/h) for Town of Oakville

Duration	Return Period (years)					
	2	5	10	25	50	100
5 min	127.3	187.6	221.1	264.6	300.4	333.5
10 min	88.7	135.1	164.5	206.8	244.7	284.1
15 min	69.3	105.7	129.3	163.6	194.3	225.9
30 min	45	70.2	86.5	109.6	129.6	149.7
1 h	28	47.2	62.8	89.5	117.3	151.7
2 h	17.3	30	40	56.5	72.9	92.1
6 h	7.5	12.9	17.4	25.3	33.5	41.2
12 h	4.3	7	9.2	12.9	16.8	20.6
24 h	2.5	4	5.1	6.8	8.4	10.3

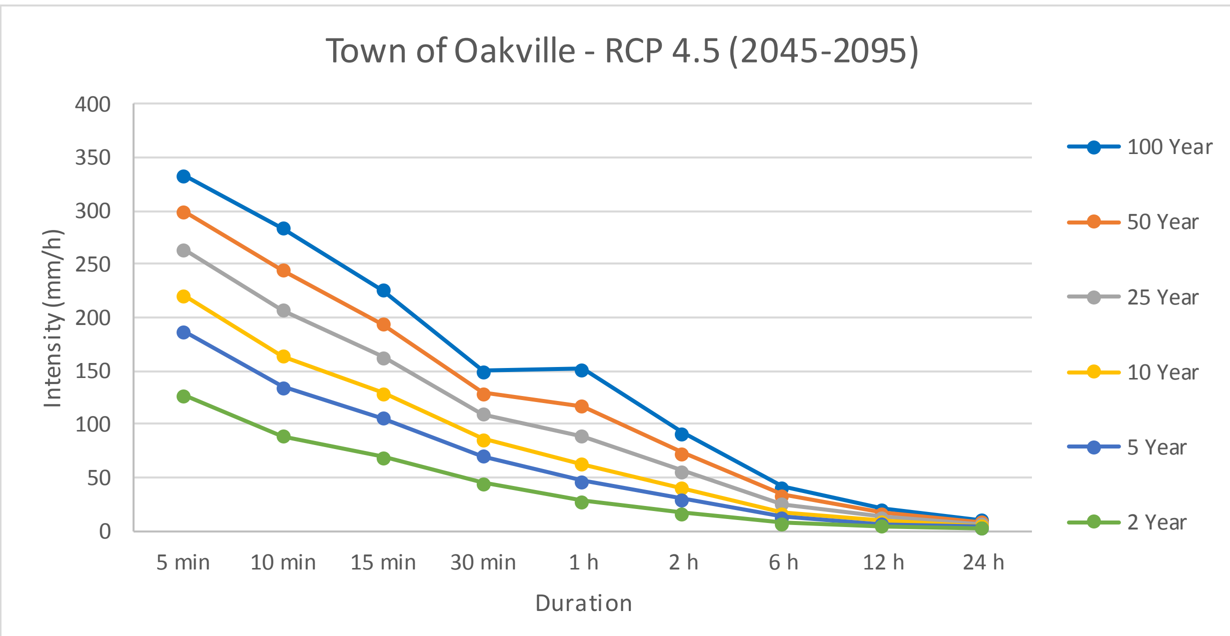


Figure C2: Rainfall Intensity Rates for Town of Oakville

Rainfall Intensity Rates - RCP8.5 (2015-2065)

Table C3: Rainfall Intensity Rates (mm/h) for Town of Oakville

Duration	Return Period (years)					
	2	5	10	25	50	100
5 min	126.2	171.9	201.4	238.4	267.9	288.5
10 min	88	123.8	149.8	186.3	218.2	245.8
15 min	68.8	96.9	117.8	147.4	173.3	195.5
30 min	44.6	64.3	78.8	98.7	115.6	129.5
1 h	27.7	43.3	57.2	80.6	104.6	131.2
2 h	17.2	27.4	36.4	50.9	64.9	79.6
6 h	7.4	11.8	15.8	22.8	29	35.7
12 h	4.2	6.4	8.4	11.6	15	17.8
24 h	2.4	3.6	4.6	6.1	7.5	8.9

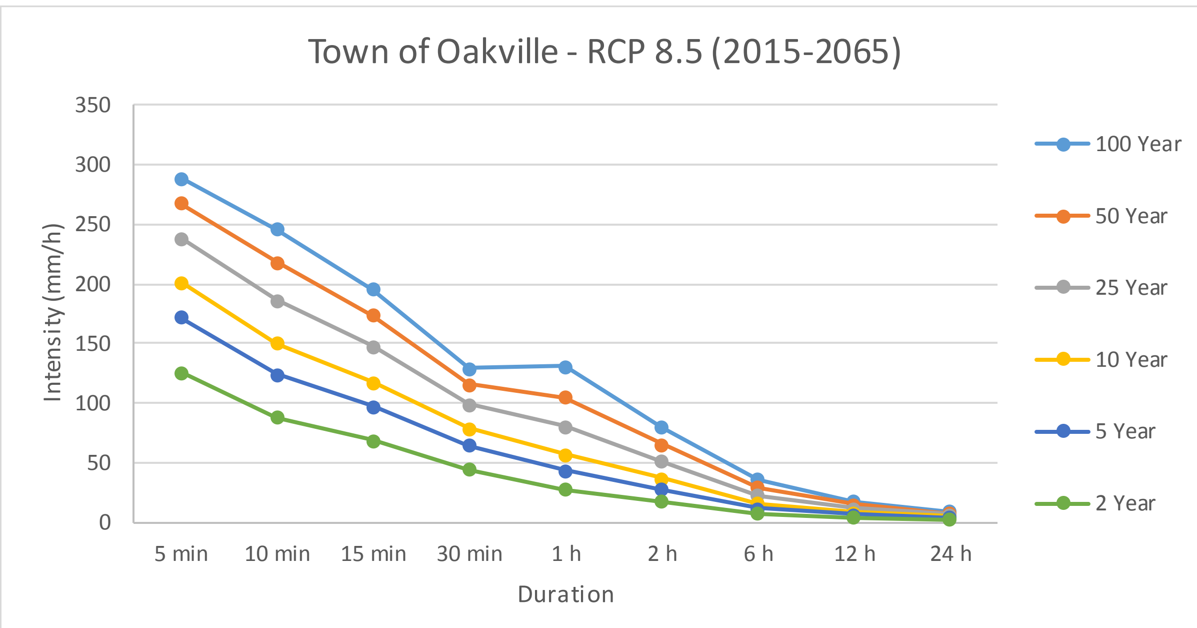


Figure C3: Rainfall Intensity Rates for Town of Oakville

Rainfall Intensity Rates - RCP8.5 (2045-2095)

Table C4: Rainfall Intensity Rates (mm/h) for Town of Oakville

Duration	Return Period (years)					
	2	5	10	25	50	100
5 min	134.7	189.5	236.2	280.1	308.4	344.1
10 min	94	136.4	175.8	219	251.3	293.1
15 min	73.4	106.8	138.1	173.2	199.5	233.1
30 min	47.6	70.9	92.4	116	133.1	154.4
1 h	29.6	47.7	67.1	94.8	120.5	156.6
2 h	18.4	30.3	42.7	59.8	74.8	95
6 h	7.9	13	18.6	26.8	34.4	42.6
12 h	4.5	7.1	9.8	13.7	17.2	21.3
24 h	2.6	4	5.4	7.2	8.7	10.6

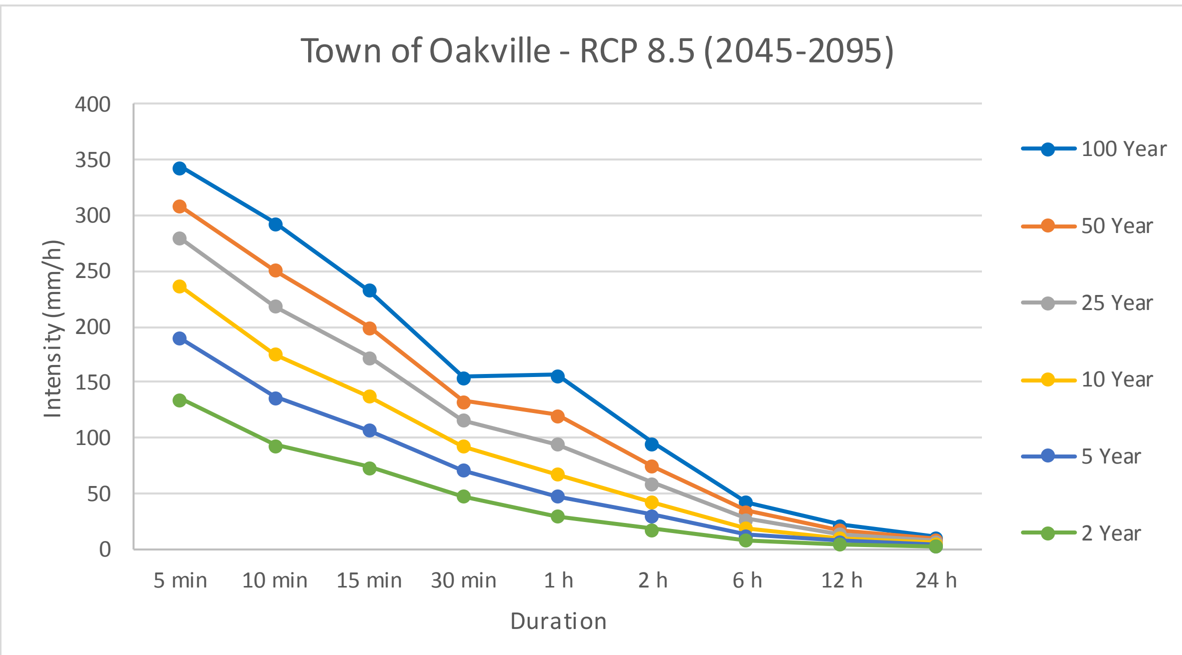


Figure C4: Rainfall Intensity Rates for Town of Oakville

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