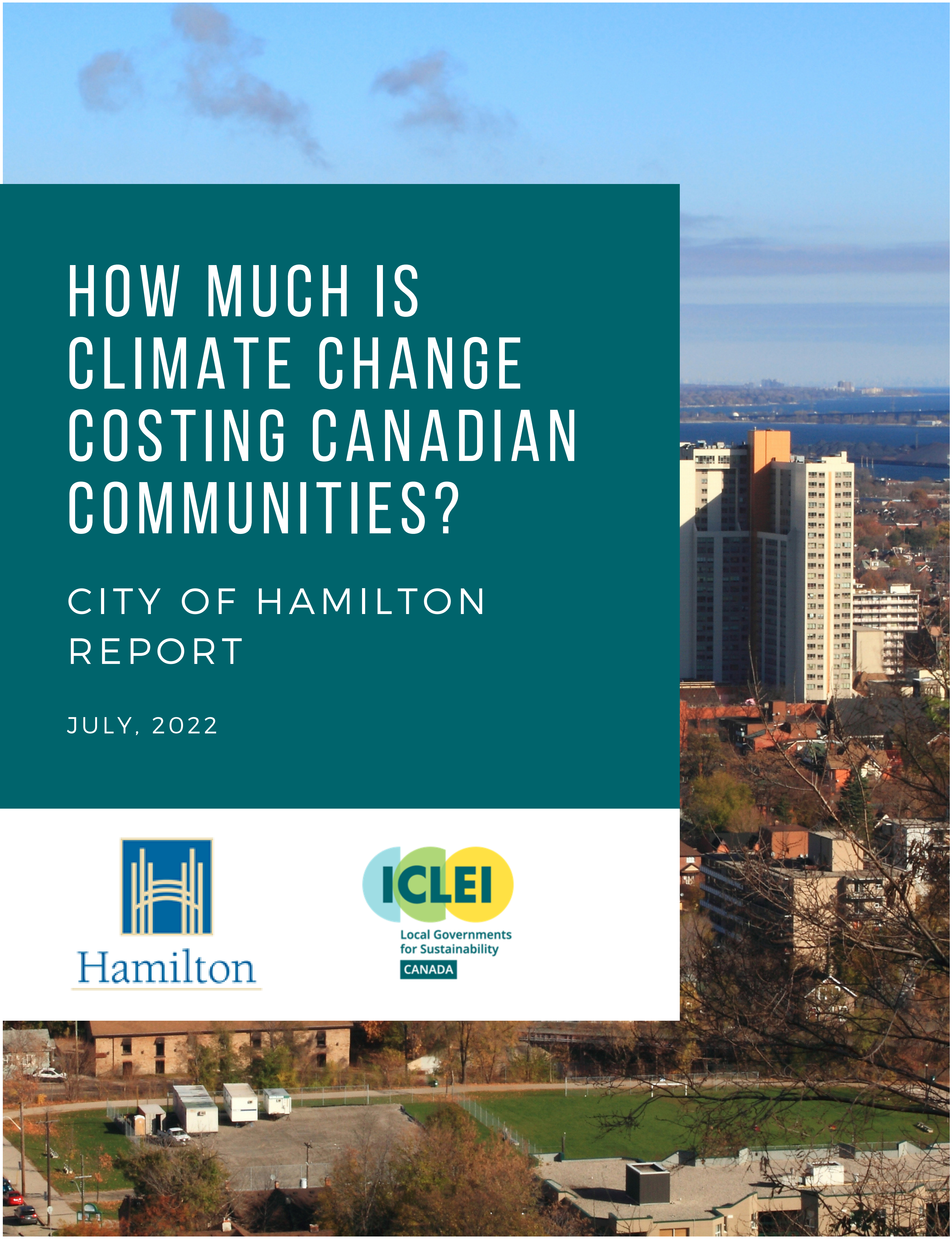

HOW MUCH IS CLIMATE CHANGE COSTING CANADIAN COMMUNITIES?

CITY OF HAMILTON REPORT

JULY, 2022

Hamilton

ICLEI
Local Governments for Sustainability
CANADA

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INTRODUCTION

Climate change impacts in a municipal context

Summary of key climate hazards and impacts facing communities across Canada

The effects of climate change in Canada are already evident, and are projected to worsen in the future, including more frequent extreme heat events, more frequent wildfires, reduced air quality, increased coastal erosion, more frequent extreme precipitation resulting in flooding, and more frequent extreme weather events (e.g., windstorms, ice storms, tornados) (Bush et al., 2022; IPCC, 2021). Consequently, Canadian communities are facing a wide range of direct and indirect costs, with numerous implications for the built, socio-economic and natural systems. Municipalities are facing increased financial costs that include both direct and indirect economic costs (e.g., costs of repairs, increased operations, and maintenance (O & M) expenses, loss of service delivery and business interruption) (Boyd & Markandya, 2021).

National estimates show climate change is now costing Canada billions of dollars every year. Furthermore, as the trend in extreme weather events have increased, so too have the trends in insured and uninsured losses. A growing body of evidence indicates that uninsured losses are often underestimated and may dwarf insured losses (Boyd & Markandya, 2021; IBC & FCM, 2020; Ness et al., 2021; Sawyer et al., 2020).

National Resource Highlight

The Insurance Bureau of Canada (IBC) tracks private insurance payouts for extreme weather events and has seen a jump in the average annual insured losses from $0.4 billion per year, between 1983-2007, to $1.9 billion per year between 2008-2018 (Boyd & Markandya, 2021).

Climate change driven natural disasters have continued to cause significant damage to Canadian communities, with evidence supporting projections that their intensity and frequency are increasing. In fact, eight of the top ten costliest disasters have occurred over the past decade (Figure 1).

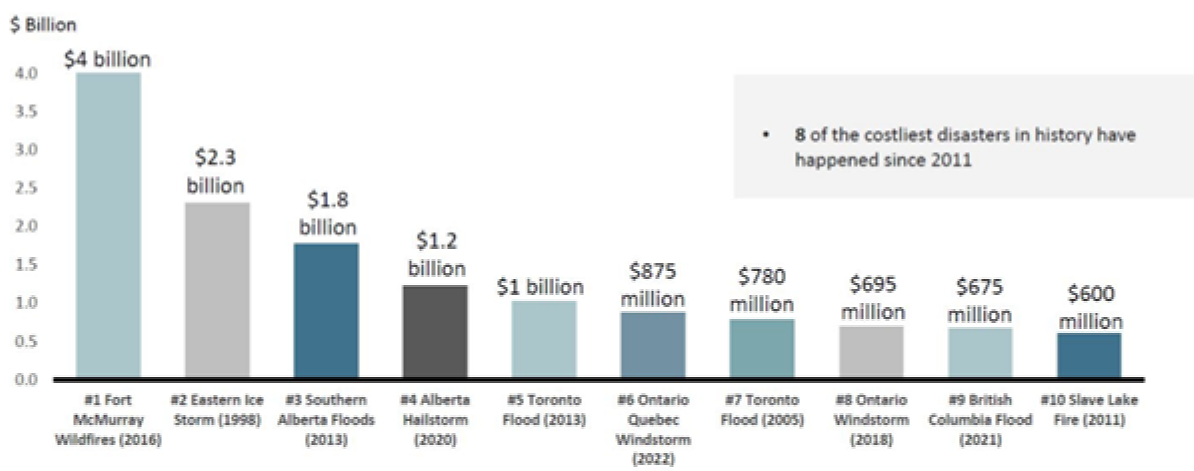

Figure 1: Canada's costliest natural disasters in terms of insurance payouts (in 2021 CAD). Losses exclude loss adjustment expenses (Source: IBC Fact Book 2021, CatQ, Swiss Re, Munich Re & Deloitte).

Table 1 highlights extreme weather events over just the last five years (2016-2021), which have resulted in billions in damages as well unprecedented human and ecological impacts (discussed below).

Table 1: The costliest weather events over the period of 2016-2021.

Date	Location	Weather Event and Cost Estimates
2021	South coast, BC	Multiple atmospheric rivers converged producing record precipitation that led to severe flooding across the region. Early estimates of insured losses are $450 million (IBC, 2021), however, broader estimates suggest billions in damages.
2020	Calgary, AB	Severe hail-storm causing nearly $1.2 billion in damages (IBC, 2020)
2020	Fort MacMurray, AB	Extreme precipitation event that resulted in flooding and $500 million in damages.
2018	Eastern ON and southern QC	Severe thunderstorm which spawned multiple tornados that caused $300 million in damages.
2018	Southern ON and QC	Severe thunderstorms produced hurricane-force gusts that caused over a $1 billion in damages (Government of Canada, 2019)
2017	Southern BC	Widespread and long-lasting wildfires caused an estimated $650 million in damages.
2016	Fort MacMurray, AB	Wildfires caused over $4 billion in insured losses and had a broader economic cost of nearly $11 billion (Alam & Islam, 2017).

Re-Defining costs

Beyond the clear financial costs associated with the damage caused by climate change driven extreme weather events, multiple cascading or indirect costs are not accounted for in these estimates, including municipal service disruption, supply chain disruptions, transportation network interruptions, business interruptions, power outages, food and water shortages, as well as non-market costs.

Linking financial costs to non-market costs

While the financial costs are of paramount importance, non-market costs (the costs to human health and well-being and the natural environment) must also be considered to fully understand the breadth of climate impacts; to allocate public resources for climate adaptation, and to ensure that these resources are directed towards the most efficient actions. It will be important for decision-makers to consider these broader systemic human and environmental costs of climate change as they often have wider spatial and temporal scales than the financial costs (Boyd & Markandya, 2021). Similarly to the financial costs, these non-market costs may be incurred directly and indirectly. It is therefore critical to consider the combined direct and indirect financial and non-market costs of climate change:

Direct costs result from the direct physical impacts of climate change

- Damage to hard infrastructure and buildings (e.g. repair and replacement costs after a flood event)
- Increased wear and tear resulting in increased operations and maintenance costs

- Physical and mental health impacts (e.g. costs for medical treatment after extreme heat event)
- Damage to ecosystems (e.g. damage to tree canopy after a wind storm resulting in loss of ecosystem services)

Indirect costs stem from the direct impacts of climate change

- Flood damage to municipal infrastructure causes disruption/interruption of service delivery. (e.g. water and waste) which in turn results in workers not being able to get to work
- Workers not able to get to work due to damaged transportation networks
- Rising insurance premiums from flooded buildings
- Long-term physical and mental health impacts
- Loss of revenue in businesses who work with directly impacted businesses

impacts to human health and well-being cannot be understated. Extreme heat events are projected to become more common in Canada and are proving to be increasingly dangerous and costly. These climate hazards will have a profound impact on human health and well-being, on our health care systems and specifically on vulnerable populations. Specific groups, such as those who work outside, low-income and racialized populations, infants and young children, older adults (over the age of 65), those with limited mobility and chronic medical conditions, and people experiencing homelessness are particularly at risk (Berry & Schnitter, 2022).

The compounding hazards of extreme heat and higher concentrations of ground level ozone are of particular concern. Ground level ozone, a major component of urban smog, is made more dangerous by interacting with sunlight and warm temperatures. High levels are linked to increased mortality and respiratory illnesses (Berry & Schnitter, 2022; Clarke et al., 2021). Without intervention, as Canadian summers get hotter, including more severe and frequent heat waves, poor air quality is expected to increase.

National Resource Highlight

The Canadian Disaster Database (CDD) provides public data on a wide number of impact metrics from weather related disasters (between 1900-present) including estimated and normalized costs (CAD 2016) deaths, injuries, evacuations and power outages.

The Canadian Institute for Climate Risks projects that by 2080, healthcare costs associated with ground-level ozone could reach $1 Billion per yeaar, while the costs of premature deaths from ground-level ozone could exceed $300 Billion per year under a high-emissions scenario (Clark et al., 2021). The recent 2021 heat dome event in British Columbia is one such example, where a stagnant air mass and solar radiation contributed to very high ground-level ozone concentrations resulting in 619 deaths and many more heat-related physical and mental morbidities (Henderson et al., 2022). Data compiled from the Canadian Disaster Database (CDD, 2022) shows that heat events are responsible for the greatest loss of life in terms of weather-related natural disasters. Figure 2 below shows the top 8 deadliest weather-related natural disasters across Canada between 1900 and 201. Importantly, 3 of the top 5 deadliest heat events have occurred over the past 15 years.

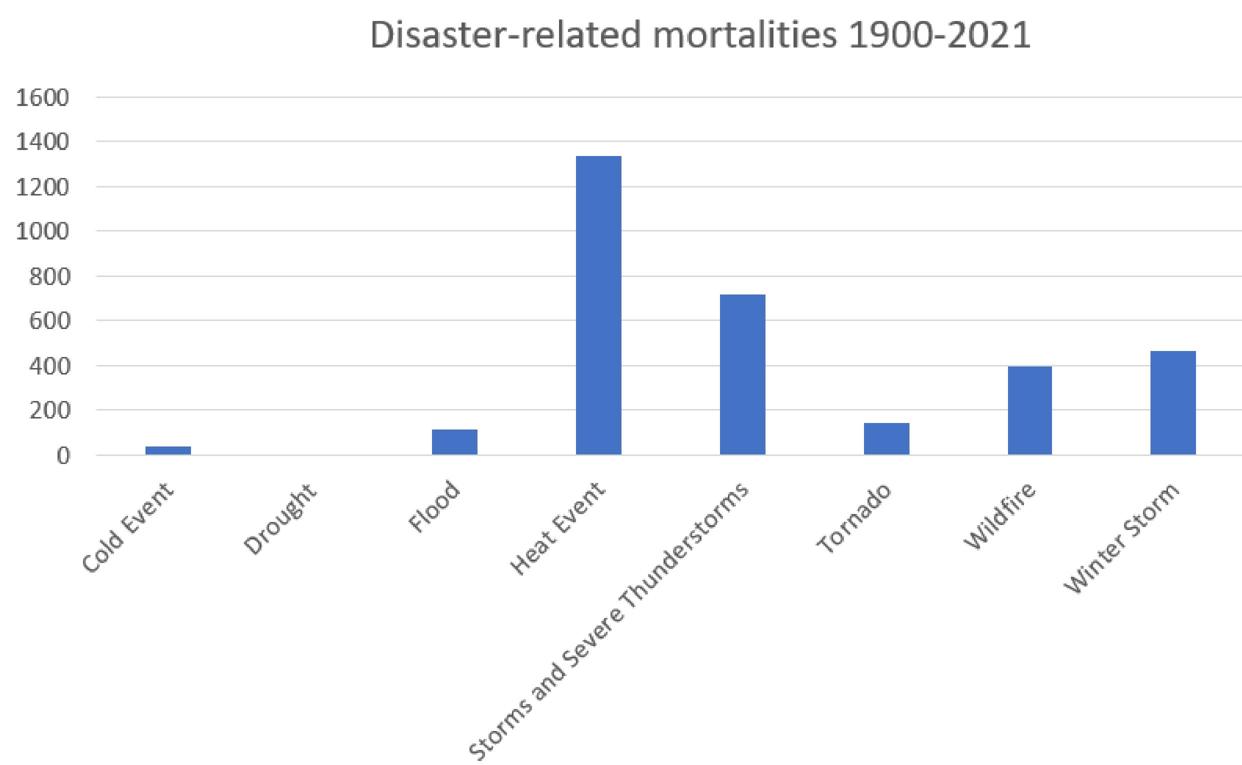

Figure 2: Sum of disaster related mortalities in Canada by category: cold event, drought, flood, heat event, storms and severe thunderstorms, tornados, wildfire, winter storm (Source: CDD, 2022).

About this report

Rationale

The mounting costs of climate change present a serious fiscal and logistical challenge for municipalities whose budgets and capacities are already stretched. Without immediate action, these costs will only increase and threaten to consume funds and resources needed for maintaining and operating critical services and addressing existing and emerging priorities.

While these climate change-driven consequences are happening throughout Canada, municipal governments still lack a complete understanding of the costs (both market and non-market) of climate change. With these costs expected to increase as the climate continues to warm, municipalities need to move rapidly to better understand and prioritize adaptive measures to limit these costs. There is also strong evidence that these will be even greater without rapid decarbonization and adaptive measures that build resilience against mounting risks from climate change.

Further, municipal governments are now responsible for a significantly larger share of infrastructure funding than in the past. To ensure that municipal dollars are efficiently and responsibly allocated, investments in municipal assets and infrastructure must keep the effects of climate change in mind. In making these decisions, the trade-offs and costs of doing nothing must be properly assessed.

National and subnational costing estimates are time sensitive and will change as new information becomes available. They also vary by source and depend on the focus (e.g. economic, insured losses, damages). While this costing data is key to understanding larger trends and scale, local data is key as it can support national figures with on-the-ground real-time reporting.

The goal of this resource is to provide municipal decision makers with guidance on collecting locally-relevant data , and weighing the costs of action vs. inaction. This report will explore the national and provincial/territorial context and examine the costs and impacts of climate change across a number of climate change hazards and sectors.

How to use this report

As municipalities develop their responses to climate change through the Building Adaptive and Resilient Communities (BARC) framework, information on the net costs of inaction (i.e., the net cost reflecting the difference between the costs and any beneficial opportunities arising from climate change) plays a critical role in two areas:

1. The costs of inaction can be used to help document the need and urgency to allocate resources to adaptation planning, including:
    a. the scale and timeframe of climate-related costs;
    b. the distribution of those costs across locations, sectors, population groups, etc.;
2. It can also be used by municipalities and stakeholders as a baseline to inform the prioritization of current and future climate risks and vulnerabilities during the assessment stage.

This report was developed based on the critical risks identified by City of Hamilton staff and key stakeholders through a collaborative risk and vulnerability assessment (VRA) process. The VRA is a key step with the BARC framework and informed the development of the climate change impact adaptation plan. Hamilton's key risks were mapped to national impact statements developed by ICLEI Canada. These impact statements were chosen based on their relevance (high costs, risks and impacts) to Canadian municipalities, the frequency with which they are identified as local impacts by municipalities, and the availability of data from a wide range of sources (local, provincial/territorial, national and academic).

National Impact Statements

1. Increasing frequency of extreme precipitation events leading to overland flooding and damage to buildings and homes.
2. Increasing temperature and precipitation leading to increased replacement and maintenance cost of roads and transportation infrastructure.
3. Increasing frequency of extreme precipitation events leading to overland flooding and loss of local business and public services.
4. Increasing frequency of extreme heat resulting in negative health outcomes, particularly to vulnerable populations, from reduced air-quality and increased heat-stress.

For each of the selected national impact statements, corresponding risks and climate hazards and projections from the City of Hamilton's Climate Science Report and VRA are described. National and subnational costing data is then examined, as well as recent examples of climate change costs incurred by Canadian municipalities. Combined, this information can provide the basis for further exploration by the City of Hamilton to identify local sources of data that can inform decision-making on appropriate allocation of resources to adapt municipal assets, infrastructure and services to reduce risk and build resilience.

RISK 1

Increasing frequency of extreme precipitation events leading to overland flooding and damage to buildings and homes.

What to know about this risk

The annual mean precipitation in Canada has increased since the mid-20th century and is projected to increase further under both low and high emission scenarios (Bush & Lemmen, 2019). Climate change is also expected to increase the intensity, duration and frequency of extreme precipitation events. For example, in Toronto, Edmonton, and Calgary, 100-year flood events are expected to become 6-year events (Ness et al., 2021).

Increasing frequency of extreme precipitation events in Hamilton

Both total annual average precipitation and heavy precipitation events are projected to increase for the City of Hamilton (ICLEI Canada, 2021).

Total precipitation

The total annual average precipitation is projected to increase from a baseline of 844 mm to approximately 898 mm in the 2021-2050 period, and to 923 mm by the 2051-2080 period. Across the City, heavy precipitation days are also expected to increase across the City.

Heavy precipitation

Across the City, heavy precipitation days are expected to increase by approximately 3 days for 10 mm day events, and 2 days for 20 mm day events. Maximum 1-day and 5-day events are also expected to increase across the City, with the greatest increase in 5-day events. For example, Max 5-day events are projected to increase from a baseline of 65 mm to 74 mm by 2051-2080.

The impacts of this risk

The impacts related to this risk are influenced by various local factors and vary from one community to the next.

Local Impacts related to this risk identified in the City of Hamilton's 2021 Risk and Vulnerability Assessment

Several of the impact statements identified in the City's Risk and Vulnerability Assessment are related to the increased risk of either direct or indirect damage to buildings and homes from increasing frequency of extreme precipitation events as listed below.

- Reduced capacity of flood protection measures and water storage caused by an increase in rainfall intensity leading to flooding. (Medium to High Risk)

- Changes in the frequency of extreme rainfall events will result in increased instances of flooding on private and public properties. (Medium to Low Risk)
- Increase rainfall intensity while ground is frozen resulting in sewer system surcharge and flash floods. (Medium to Low Risk)
- Changes in precipitation resulting in decreased functionality of sewers, combined sewers and storm water ponds causing surcharge. (Low Risk)

Past extreme precipitation and flooding events in Hamilton

2009 Red Hill Valley Flood Event

The City of Hamilton experienced unprecedented extent and magnitudes of flooding with only one rain gauge which remained operational after the storm, recorded an astonishing 91 millimeters alone (Sheckenberger, 2010).

April 2017 Dundas Flooding Event

Heavy rain clogged storm drains and swollen the Red Hill Creek in East Hamilton, and Spencer Creek in Dundas, triggering a mudslide and flooding at least eight streets in the community. A nearby plaza owner was quoted saying “This is the worst it's been in 40 years” (Fraser, 2017).

2021 Water/Wastewater Bypasses

Based on its Woodward Wastewater Treatment Plant Bypass and Combined Sewer Overflow Log, the City of Hamilton estimated that 4059.84 million liters of water/wastewater were bypassed in 2021.

Costs related to this risk

Flooding due to extreme precipitation is among the most prevalent and costly climate change hazards affecting Canadian municipalities. Intense precipitation combined with lack of permeable surfaces can quickly overwhelm the capacity of drainage systems and lead to flooding, water infiltration and damage to buildings and homes. In addition, infrastructure damage has cascading impacts through socio-economic and natural systems including reducing economic output, threatening health, well-being, and livelihoods of municipal residents.

Canada has a major deficit in public asset and infrastructure spending, with recent estimates to maintain existing infrastructure at between $110 and $270 billion (Ness et al., 2021). This deficit is compounded by the fact that public assets and infrastructure were not built for a warmer, wetter, and more volatile climate. Maintaining these in a state of good repair will require more money to address accelerated deterioration due to climate change (FAO, 2021).

A recent report by the Financial Accountability Office of Ontario (FAO) found that climate change under the high emissions scenario (RCP 8.5) is projected to add an additional $47 billion in O & M costs to Ontario's municipal building and facilities budgets by the end of the century (FAO, 2021).

Since 2010, flooding has accounted for the costliest extreme weather disaster affecting Canadians in the form of insurable and uninsurable losses and disaster-assistance payouts by federal, provincial, and territorial governments (Moudrak & Feltmate, 2020). Homes and buildings are highly exposed to flood damages. Flood and water related losses have been trending upwards from 1983-2000 baselines with Disaster Financial Assistance Agreements expected to reach $1 billion per year by 2020 (Moudrak & Feltmate., 2020) and costs in annual damages reaching between $1.3 and $12.4 billion by the end of the century (Ness et al., 2021).

As shown in Figure 3, the costs of flooding damage to households located in flood zones will significantly increase under both low and high emission scenarios as can be seen in the data from six major Canadian cities.

Canada's private infrastructure was valued at $6.1 trillion in 2019 with privately-owned homes and buildings making up 85% (or $5.18 trillion) of this number (Moudrak & Feltmate, 2020). As extreme events become more commonplace, homeowners and governments will bear the brunt of these costs. The burden of paying for flood- related damages has already shifted to homeowners as the industry average premium for homeowner insurance has risen by 20-25% over the past five years in Canada (Moudrak & Feltmate, 2020).

Homes at risk of inland flooding will face more damage more often

Flood damages, millions of dollars (2019 CAD)

CMA Name	Province	Households in flood zone	Baseline	Mid-century, low-emissions	Mid-century, high-emissions	End of century, low-emissions	End of century, high-emissions
Toronto	Ontario	146,798	$99	$557	$592	$548	$566
Winnipeg	Manitoba	250,918	$54	$285	$239	$259	$325
Calgary	Alberta	105,441	$37	$193	$195	$193	$234
Mississauga	Ontario	38,341	$24	$162	$166	$157	$165
Edmonton	Alberta	108,171	$35	$131	$108	$129	$144
Ottawa	Ontario	75,514	$44	$114	$92	$109	$114

Figure 3: Canadian Institute for Climate Choices. (2020). Under Water: The Costs of Climate Change for Canada's Infrastructure.

Cost examples from across Canada

2013 Calgary flooding

2013 Calgary flooding is estimated to have cost a combined $5 billion in financial loss and property damage with $409 million in damages to key municipal infrastructure in Calgary alone (City of Calgary, 2021).

The cost of increasing frequency of extreme precipitation events in Hamilton

Damage caused by intense and frequent precipitation in the spring of 2017 cost between $1.8 and $2.5 million (Hamilton Spectator, 2017).

RISK 2

Increased temperature and precipitation leading to increased replacement and maintenance cost of roads and transportation infrastructure.

What to know about this risk

The greatest threats to Canada's transportation structure come in the form of increased annual and extreme temperature, increased precipitation, and freeze-thaw events. Projected changes in temperature, especially +30°C and extended heat wave events, will have a serious effect on roadways and paved surfaces.

As asphalt and pavement are susceptible to increased wear and tear due to high temperatures, freeze thaw events, and erosion from precipitation, understanding how the climate will change is an important first step in assessing the potential future costs of maintenance and replacement.

Extreme temperatures and heat waves

Extreme heat events are extended spells of high temperatures, often described as days over 30°C. As heat events increase in intensity, duration, and frequency they will cause increasing stress on infrastructure and building assets causing damage and increase the rate of degradation. This will result in increased costs of repair, placement, operation and maintenance.

The Climate Atlas of Canada projects a major increase in the number of +30°C days in Ontario, from a baseline average of 3.9 days per year, to 11.8 day by mid-century, and up to 25.5 days by the end of the century. The number of heatwaves and length of heatwaves is also expected to increase substantially. These effects will be acutely experienced in southern Ontario.

Increasing temperatures in Hamilton

As described in the 2021 Climate Science Report Prepared for the City of Hamilton by ICLEI Canada, all temperature indices for the City of Hamilton are projected to experience significant warming under all climate change modeling scenarios. The minimum, average and maximum monthly temperatures will increase, as will the number of extreme heat days, while the number of extreme cold days will decrease.

The City of Hamilton has recently broken late summer temperature records in 2016 and 2018. 2016 also saw 26 heat alert days (where daytime temperatures reached at least 31℃ or at least 40℃ with humidex with nightly temperatures lingering above 20℃) compared to 17 in 2015.

Maximum temperatures

In terms of maximum temperatures, Hamilton will experience an increase in all seasonal maximum temperatures, with average summer maximum temperatures expected to reach over 30˚C in the years 2051-2080 compared to the current baseline of 25.9˚C.

In addition to the average maximum temperatures, the warmest maximum temperature is also expected to increase (i.e. the single, hottest day of the year to 36.4°C in the immediate future (2021-2050), and 38.9°C in the near future (2051-2080) compared to the current baseline average of 34.1°C. . These temperatures do not factor in additional warming due to the humidex which could make it feel 5 to 10°C warmer.

The number of days where the daily maximum temperature exceeds 30°C, 32°C and 34°C will also increase. The baseline average number of days when the maximum temperature was greater than or equal to 30°C was 16.1 days for the City of Hamilton. This is expected to increase to an average of 63.3 days in the 2051-2080 period and means there will be close to four times more days above 30°C by 2080.

Length of the hot season

The length of the hot season, or the days from the first day of the year with tmax ≥ 30°C to the last day with tmax ≥ 30°C, is also expected to increase. The baseline average length of the Hot Season is currently 71.6 days. By 2051-2080, Hamilton can expect an increase to 126.2 days, which is almost double the length of the current hot season.

Heat waves

Heat wave events will become more frequent and prolonged in the City of Hamilton. The annual number of heatwave event baseline numbers for the City of Hamilton is currently 2.1 and is expected to increase to almost 7.0 in the 2051-2080 period, more than triple the current number of occurrences.

With regards to the average length of heat waves (in days), the City of Hamilton's baseline is 3.8 days of heatwave conditions. In the 2051-2080 period, Hamilton can expect to see an average heatwave event occurring for 8.4 days, more than double the current length of heat wave events.

Overall, heatwave events are projected to occur more frequently and for longer periods of time and these changes become more pronounced as time goes on in higher emissions scenarios. The baseline average of consecutive length of 30°C Days for the City of Hamilton is 4.0. By 2051-2080, Hamilton could experience 19.2 consecutive days where temperatures exceed 30°C. This potentially would signify an Extended Heat Warning for the City for more than two and a half weeks.

Increasing frequency of extreme precipitation events in Hamilton

As mentioned in the previous section (RISK 1), total annual average precipitation and heavy precipitation events is projected to increase for the City of Hamilton (ICLEI Canada, 2021).

Total precipitation

The total annual average precipitation is projected to increase from a baseline of 844 mm to approximately 898 mm in the 2021-2050 period, and to 923 mm by the 2051-2080 period. Across the City, heavy precipitation days are also expected to increase across the City.

Heavy precipitation

Across the City, heavy precipitation days are expected to increase by approximately 3 days for 10 mm day events, and 2 days for 20 mm day events. Maximum 1-day and 5-day events are also expected to increase across the City, with the greatest increase in 5-day events. For example, Max 5-day events are projected to increase from a baseline of 65 mm to 74 mm by 2051-2080.

The impacts of this risk

Roads and rail lines are an integral part of Canada's transportation network that facilitates movement of people, goods and services across the country and within municipalities. As the climate continues to warm, increasing intensity and frequency of climate hazards will expedite the degradation of this critical infrastructure.

The sensitivity of paved surfaces and transportation infrastructure is mainly affected by three factors: age, composition, and design (City of Windsor, 2019). The average lifespan of roadways varies by province but generally local, collector, and arterial roads have a lifespan of anywhere from 20 to 35 years (Statistics Canada, 2020); however, high temperatures can significantly reduce this lifespan. Table 2 shows some of the impacts that extreme heat has on road infrastructure (City of Windsor, 2019).

In addition to the impacts of high temperatures and heat waves, increased precipitation and other extreme weather events such as ice storms and wind storms can also lead to damage and reduced transportation infrastructure lifespan. This can include blockages from snow, the damage or destruction of roads and railways from washouts, and dangerous travel conditions. Extreme weather like hail, freezing rain and high winds can also damage traffic and rail signals.

Changing winter precipitation patterns and freeze-thaw cycles will further deteriorate roads, pavement (including sidewalks), and increase the risk of injury or death from accidents and slips on icy surfaces.

The result of these climate-driven hazards will be ever increasing disruption of supply chains, disruption and delay of services, reduced economic output, increased risk of toxic spills, and increased risk of injury and death from transportation accidents.

Table 2:Impacts on various types of infrastructure due to high temperatures (City of Windsor, 2019).

Highways, Roads	Bridges	Buildings
• Pavement softening causing rutting • Increased flushing and bleeding of older pavement • Reduction in maximum loads that can be safely transported • Buckling of roads and sidewalks • Shortened life expectancy of highways, roads and rail	• Cracking of bridge decks due to limits of expansion joints being exceeded • Drier conditions can affect the life cycle of bridges and culverts	• Building damage has been observed when clay soils dry out • Premature weathering • Increased indoor air temperature and reliance on cooling systems

Impacts related to this risk identified in the City of Hamilton's 2021 Risk and Vulnerability Assessment

The following impact statements identified in the City's Risk and Vulnerability Assessment are related to the need for increased maintenance and replacement of roads and transportation infrastructure due to increased temperature and precipitation:

- Changes in precipitation resulting in erosion of natural systems such as waterbanks leading to washout of bridges and roadways. (Medium Risk)
- Increased depth of frost penetration due to extreme cold temperature leading to greater frost heaving and damages to built infrastructure (e.g. gas pipes, building foundation, roadways, sidewalks). (Medium to Low Risk)
- Increased damage to and breakdowns of power lines and transportation systems as a result of more severe heat waves. (Medium to Low Risk)
- Increased demand on roadways and transit due to fewer people walking, running or cycling in extreme heat. (Very Low Risk)

Overarching risks associated with increased heat and precipitation events in Hamilton are also acknowledged in the following impact statements:

- Increased instances of heat-related issues due to extreme heat. (Medium Risk)
- Increased instances of safety-related issues due to hazardous outdoor conditions caused by increasing rainfall intensity. (Low Risk)

It is worth noting that the City of Hamilton identified several additional risks that are indirectly related but can impact the need for increased maintenance and replacement of roads and transportation infrastructure:

- Increased freeze-thaw cycles during the winter months leading to hazardous roads, pathways and sidewalks conditions. (Medium to Low Risk)

- Changes in precipitation leading to more hazardous roads, pathways and sidewalks conditions, especially on frozen ground (e.g. black ice). (Medium to Low Risk)
- Increase in snow storm intensity leading to more hazardous roads, pathways and sidewalks conditions. (Medium to Low Risk)
- Increased freeze-thaw cycles during the winter months damaging public infrastructure (e.g. roads, sidewalks, buildings, bridges, sewer system). (Low Risk)

Past extreme heat and precipitation events that have affected transportation infrastructure in Hamilton

May 2017 High Water Levels

Extremely high water levels in Lake Ontario combined with recent rainfall events continued to cause damage along Hamilton's shoreline, requiring the City to start emergency repairs along the Breezeway Trail and on the Waterfront Trail (City of Hamilton, 2017).

2017 Slope Instability Work

Hamilton's escarpment is slowly eroding to the southwest towards the City of London. According to the General Manager of Public Works, slope instability on the Claremont access cost the City of Hamilton about $1.3 M with further work planned for the Sherman access and Fifty Road access are estimated at $2.5 M each (Cain, S, 2017).

2018 July Extreme Heat Event

Metrolinx issued warnings to riders across the Greater Toronto and Hamilton Area to expect delays as temperatures reached a sweltering 35°C and 36°C over the weekend. Spokesperson for Metrolinx was quoted saying "[...] Slower orders having to be issued amid the risk of rails buckling or warping amid the extreme heat."

2019 Flood Event

Flooding caused the City of Hamilton and Hamilton Conservation Authority to close sections of the Hamilton Harbour Waterfront Trail and Lake Ontario Waterfront Trail (City of Hamilton, 2019).

2019 Rain and Wind Storm

The City of Hamilton closed Highway 8 in Dundas due to significant erosion in October of 2018. The City had to deploy numerous crews to clean up damage from a rain and wind storm that hit Hamilton and the area on Tuesday afternoon (Mitchell, 2019).

2022 Slope Instability Work

The City of Hamilton closed Sydenham Road in February 2022 due to erosion and slope stability concerns along the escarpment access. To safely address an urgent erosion and slope stability concern along the Sydenham Road escarpment access, the City of Hamilton will close the Sydenham escarpment access this week to immediately conduct required repairs (City of Hamilton, 2022).

Costs related to this risk

Increased temperatures and precipitation are expected to reduce the reliability of transportation services and increase the time of both freight services and the cost of lost time and economic opportunity. Temperature increase will lead to greater surface degradation, increased roughness, and thermal cracking and rutting resulting in increased maintenance and repair costs, as well as decreased levels of service delivery and economic losses.

Maintenance and replacement

Statistics Canada (2021) estimates Canada's 2.8 million kilometers of roads already cost federal, provincial, territorial, Indigenous, and municipal governments approximately $20.2 billion per year to maintain. This cost is expected to reach $300 billion over the coming decade (Ness et al., 2021) and is likely to further increase as summers become longer and hotter, and as precipitation events become more frequent and extreme.

Temperature-related damage is projected to be the costliest of climate impacts on transportation infrastructure, accounting for 87% of expected costs (Ness et al., 2021). At the municipal level, projections indicate that climate change-induced damage to road maintenance and repairs could cost an additional $3.1 billion annually by 2050 (CICC, 2021).

Economic losses

Economic losses associated with congested and roadways, transportation system interruptions, and supply chain issues are also expected to increase. In 2017 alone, $2.2 trillion worth of goods were moved on Canadian roads (Ness et al., 2021). Estimated annual costs of road delay across Canada are expected to reach nearly $2 billion by the end of the century if no adaptation measures are implemented, compared to $250 million where proactive adaptation measures are taken (Ness et al., 2021). Poor road conditions also cost Canadian drivers an average of $3 billion per year in higher vehicle operating costs, while traffic congestion in Toronto and Hamilton is estimated to cost $11 billion in lost time and economic opportunity (Ness et al., 2021).

Other costs

Increased maintenance and replacement costs may also result in increased taxes and shipping costs, transport delays and disruptions, increased road and travel related accidents, risk of injury and death.

Cost examples from across Canada

2013 Toronto flood

In 2013, a summer storm produced 126 mm in precipitation and caused flash-flooding throughout the Greater Toronto area. The flooding closed multiple transportation corridors, caused wide-spread property damage, and disrupted power causing over $940 million in insured property damage (CDD, n.d.).

2021 extreme heat event in British Columbia

British Columbia experienced an unprecedented heat dome event in 2021 with record-breaking temperatures throughout much of the province. Peak temperatures in the town of Lytton reached 49.6°C and set a national record for Canada. The extreme heat caused power grids to fail, roads and pavement to buckle, and rail lines to deform.

RISK 3

Increasing frequency of extreme precipitation events leading to overland flooding and loss of local business and public services.

What to know about this risk

As mentioned for RISK 1, the annual mean precipitation in Canada has increased since the mid-20th century and is projected to increase further under both low and high emission scenarios (Bush & Lemmen, 2019). Climate change is also expected to increase the intensity, duration and frequency of extreme precipitation events. For example, in Toronto, Edmonton, and Calgary, 100-year flood events are expected to become 6-year events (Ness et al., 2021).

Increasing frequency of extreme precipitation events in Hamilton

As mentioned in the previous section (RISK 1), total annual average precipitation and heavy precipitation events is projected to increase for the City of Hamilton (ICLEI Canada, 2021).

Total precipitation

The total annual average precipitation is projected to increase from a baseline of 844 mm to approximately 898 mm in the 2021-2050 period, and to 923 mm by the 2051-2080 period. Across the City, heavy precipitation days are also expected to increase.

Heavy precipitation

Heavy precipitation days are expected to increase by approximately 3 days for 10 mm day events, and 2 days for 20 mm day events. Maximum 1-day and 5-day events are also expected to increase, with the greatest increase in 5-day events. For example, Max 5-day events are projected to increase from a baseline of 65 mm to 74 mm by 2051-2080.

The impacts of this risk

As mentioned in RISK 1, the impacts related to this risk are influenced by various local factors and vary from one community to the next.

Local Impacts related to this risk identified in the City of Hamilton's 2021 Risk and Vulnerability Assessment

Several of the impact statements identified in the City's Risk and Vulnerability Assessment are related to the loss of local business and public services from increasing frequency of extreme precipitation events as listed below.

- Changes in the frequency of extreme rainfall events will result in increased instances of flooding on private and public properties. (Medium to Low Risk)

It is worth noting that the City of Hamilton identified several additional risks related to increased extreme precipitation events that although indirectly related, can lead to the loss of local business and public services:

- Reduced capacity of flood protection measures and water storage caused by an increase in rainfall intensity leading to flooding. (Medium to High Risk)
- Increase rainfall intensity while ground is frozen resulting in sewer system surcharge and flash floods. (Medium to Low Risk)
- Changes in precipitation resulting in increased flooding and increased need for evacuation of impacted citizens. (Medium to Low Risk)
- Changes in precipitation resulting in decreased functionality of sewers, combined sewers and storm water ponds causing surcharge. (Low Risk)

Costs related to this risk

The impacts of climate change such as overland flooding routinely disrupt businesses and public services including health care services. While the exact costs related to service loss and disruptions are not yet fully understood, recent reports suggest that the related direct and indirect costs will continue to grow (Sawyer et al., 2020). These include costs related to transportation delays, loss of business income, loss of business value, business disruptions, labout productivity losses, and reduced economic growth due to flooding (Sawyer et al., 2020).

Service disruptions

The cost of public service disruption related to flooding will also increase. Direct flood damage to healthcare facilities as well as related electrical and water service outages can disrupt medical supply chains and critical public health services while demands for such services are at their highest (Clark et al., 2021). Over 5,000 healthcare centers are at risk of flooding across Canada including 1,072 in Alberta and 1,440 in Ontario alone (Clark et al., 2021). A similar proportion of other critical public services such as police and fire stations are also at risk of flooding (Clark et al., 2021).

Other indirect costs

The impacts of business loss of public service disruption on physical and mental health, quality of life, loss of spiritually and culturally important lands, and destruction of ecosystems are more difficult to measure but represent important costs (Sawyer et al., 2020). For example, current productivity loss estimates associated with depression and anxiety combined could increase from the current $51 bilion per year cost (Clark et al., 2021).

Cost examples from across Canada

2013 Alberta Floods

14% of Alberta's workforce was unable to work for over two-weeks during the 2013 floods which is the equivalent of 5.1 million hours of lost work and $601 million of lost economic output (Sawyer et al., 2020).

2019 Floods in New Brunswick, Quebec, and Ontario

Spring flooding in 2019 affected 3,800 businesses across New Brunswick, Quebec, and Ontario, most of which were small businesses that are more vulnerable to business disruption (Sawyer et al., 2020).

RISK 4

Increasing frequency of extreme heat resulting in negative health outcomes, particularly to vulnerable populations, from reduced air-quality and increased heat-stress.

What to know about this risk

Climate projections show increased extreme heat events in communities across Canada
Climate projections show increased extreme heat events in communities across Canada
throughout the rest of this century. The number of days when the maximum temperature climbs over 30°C has already increased by about one to three days annually from 1948 to 2016.

As mentioned for RISK 2, the Climate Atlas of Canada projects a major increase in the number of +30°C days in Ontario, from a baseline average of 3.9 days per year, to 11.8 days by mid-century, and up to 25.5 days by the end of the century. The number and length of heatwaves is also expected to increase substantially. These effects will be acutely experienced in southern Ontario.

Increasing temperatures in Hamilton

As mentioned for RISK 2, all temperature indices for the City of Hamilton are projected to experience significant warming under all climate change modeling scenarios (ICLEI Canada, 2021). The minimum, average and maximum monthly temperatures will increase, as will the number of extreme heat days, while the number of extreme cold days will decrease.

The City of Hamilton has recently broken late summer temperature records in 2016 and 2018. 2016 also saw 26 heat alert days (where daytime temperatures reached at least 31℃ or at least 40℃ with humidex with nightly temperatures lingering above 20℃) compared to 17 in 2015.

Maximum temperatures

In terms of maximum temperatures, Hamilton will experience an increase in all seasonal maximum temperatures, with average summer maximum temperatures expected to reach over 30˚C in the years 2051-2080 compared to the current baseline of 25.9˚C.

In addition to an increase in the average maximum temperatures, the warmest maximum temperature is also expected to increase (i.e. the single, hottest day of the year) to 36.4°C in the immediate future (2021-2050), and 38.9°C in the near future (2051-2080) compared to the current baseline average of 34.1°C. These temperatures do not factor in additional warming due to the humidex which could make it feel 5 to 10°C warmer. This can cause heat-related illnesses in not only vulnerable populations but also healthy, young adults.

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. Examples of these include heat cramps, heat edema, heat exhaustion, or heat stroke. 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.

The number of days where the daily maximum temperature exceeds 30°C, 32°C and 34°C will also increase. The baseline average number of days when the maximum temperature was greater than or equal to 30°C was 16.1 days; this is expected to increase to an average of 63.3 days in the 2051-2080 period and means there will be close to four times more days above 30°C by 2080.

Length of the hot season

The length of the hot season, or the days from the first day of the year with tmax ≥ 30°C to the last day with tmax ≥ 30°C, is also expected to increase. The baseline average length of the Hot Season is currently 71.6 days. By 2051-2080, Hamilton can expect an increase to 126.2 days, which is almost double the length of the current hot season.

Heat waves

Heat waves are defined as prolonged periods of excessively hot weather, which may be accompanied by high humidity. Extreme temperatures sustained over several days will have significant impacts on the health of individuals in the City of Hamilton. Heat illnesses can manifest quickly, and lead to long-term health problems and even death. Overexposure to extreme heat is especially dangerous for children and elderly adults, and those who work outside or are physically active outdoors.

Heat wave events will become more frequent and prolonged. The baseline annual number of heatwaves is 2.1; this is expected to increase to almost 7.0 in the 2051-2080 period, more than triple the current number of occurrences.

The baseline length of heat alerts is 3.8 days. In the 2051-2080 period, Hamilton can expect to see this increase to 8.4 days, more than double the current length.

Overall, heat alerts are projected to occur more frequently and for longer periods of time and these changes will become more pronounced in higher emissions scenarios.

The baseline average of consecutive 30°C Days is 4.0. By 2051-2080, Hamilton could experience 19.2 consecutive days where temperatures exceed 30°C.

Tropical nights

Traditional patterns of hot days and cooler nights can often be enough to mitigate heat exposure impacts. However, during heat alerts, local populations may experience prolonged exposure to heat due to tropical nights (where temperatures do not drop below 20C). This increases the risk of heat exhaustion or heat stroke For the City of Hamilton, the baseline average number of tropical nights is 6.4 per year. Hamilton could experience 33.4 more tropical nights on average by 2080, more than a fivefold increase.

The impacts of this risk

While climate change can affect all Canadians, the distribution and degree of the health-related impacts are uneven. Recent studies have highlighted the interplay between these complex interconnected socio-economic and health factors that increase vulnerability and exposure to climate hazards (Heaviside et al., 2017; Vargo et al., 2016).

Many of the climate hazards occur in the areas where the most vulnerable populations (including seniors, children, racialized populations, low-income individuals, individuals with chronic health conditions, and First Nations, Inuit, and Métis peoples) live (Heaviside et al., 2017; Vargo et al., 2016). Moreover, many of the current strategies to reduce these health impacts are not feasible in areas that need it most, and favour areas that already benefit from the greatest adaptive capacity.

Also, when climate-related emergencies and disasters strike, health facilities and services are affected. In some cases, climate-related events force health care centres and hospitals in Canada to close temporarily, evacuate patients, and/or cancel operations and other services. But it is precisely during these disasters that Canadians need emergency services, and health care disruptions can have major effects on health and well-being.

Even if health facilities and services remain operational during a climate-related disaster, they can be pushed beyond their capacity to respond because of injuries, illnesses, and patient transfers due to the disaster. Combined effects of climate change that overlap and interact could lead to cascading effects on several health outcomes simultaneously.

Local Impacts related to this risk identified in the City of Hamilton's 2021 Risk and Vulnerability Assessment

Several of the impact statements identified in the City's Risk and Vulnerability Assessment are related to negative health outcomes from reduced air-quality and increased heat-stress caused by extreme heat as listed below:

- Dryer, hotter and longer summers may affect the health and safety of local vulnerable populations. (Medium Risk)
- More frequent and intense heatwaves will increase instances of heat-related health and safety issues, particularly for households without access to reliable air-conditioning and the homeless. (Medium Risk)

Overarching risks associated with increased heat events in Hamilton is also acknowledged in the following impact statement:

- Increased instances of heat-related issues due to extreme heat. (Medium Risk)

It is worth noting that the City of Hamilton identified several additional risks related to reduced extreme heat that, although indirectly related, can lead to negative health outcomes:

- Rising summer temperatures and extreme heat will increase energy demand for air conditioning, causing a financial burden for low-income households. (Medium Risk)

- Rising summer temperature and extreme heat leading to greater demand for air conditioning and electricity generating more NOx emissions that contribute to smog. (Medium to Low Risk)

Higher than average lung cancer and chronic obsructive pulmonary disease in Hamilton means extreme heat events could impact more of Hamilton's population.

In 2018 the City of Hamilton Public Health Services released the Health Check: Assessing the local burden of disease in the City of Hamilton report. The report concluded that Lung Cancer and Chronic Obstructive Pulmonary Disease (COPD) are within the top three most burdening health outcomes in Hamilton and are higher than provincial averages (City of Hamilton, 2018).

Increased temperature and extreme heat events worsen air pollution and exacerbate symptoms and risks with people who experience respiratory or cardiovascular illnesses such as lung cancer and COPD which means that Hamilton's population is at greater risk for this climate change impact compared to other populations across Ontario.

Costs related to this risk

The recent Health Canada (Berry & Schnitter, 2022) report on the Health of Canadians in a Changing Climate, highlights the growing body of research that attributes increasing physical and mental health costs of climate change hazards including heat waves. The connection between climate change and negative health outcomes can be both direct through loss of life, injury and increased cases of mental health disorders (e.g. PTSD, climate-anxiety) or indirect through a range of social, environmental, cultural, and economic pathways that have effects on health (Berry & Schnitter, 2022).

Cost to healthcare services

Under future climate conditions, climate-related negative health outcomes are expected to increase, increasing health costs and putting further strain on healthcare systems. In Quebec, estimates of health expenditures attributed to climate change (e.g., increased vector-borne diseases, extreme heat events and aeroallergens) is estimated at just under $1 billion over 50 years through 2065 (in 2012 dollars) (Boyd & Markandya, 2021).

Costs of mental health borne by Canadian health systems are expected to increase in the absence of adaptation measures (Berry & Schnitter, 2022). Climate change increases the risks of mental health impacts, can worsen existing mental illness such as psychosis, and trigger new-onset mental illness such as post-traumatic stress disorder. Climate change can also increase mental health stressors such as grief, worry, anxiety, and vicarious trauma. Some medications, including those for schizophrenia, increase heat sensitivity and the likelihood of negative health outcomes during extreme heat events (Government of Canada, 2011).

Extreme heat can also increase hospitalization for cardiovascular problems and pregnancy complications, including premature birth, early delivery, miscarriage, and congenital abnormalities such as neural tube defects.

Costs from losses in labour and productivity

Productivity costs are related to the lost productivity caused when people are unable to work and participate in other work-related activities because of environmental conditions, illness, or premature death. Reduced output, interruption of services, and loss of employment can all result from heat stress and other climate-related factors. Temperature stress can affect workers (Henderson et al., 2022) either through direct physical or psychological discomfort and/or through reduced task productivity by altering the amount of effort exerted overtime compared to the return on that effort resulting in a loss of economic output (Henderson et al., 2022). Overall, impacts to labor productivity could affect economic growth and incomes at a national scale (Clark et al., 2021).

Under a high emissions scenario, the Canadian Institute for Climate Risk (Clark et al., 2021), projects that drop in annual labour productivity could cost up to $5.4 billion dollars by mid-century, and $14.8 billion by end of century, with much of those losses experienced in Ontario and Quebec. This amounts to 128 million hours, or 62 000 full time workers, in lost productivity annually across the country.

Cost examples from across Canada

2021 extreme heat event in British Columbia

British Columbia experienced an unprecedented heat dome event in 2021 with record-breaking temperatures throughout much of the province. This included peak temperatures of 49.6°C in Lytton, setting a national record for Canada. The deaths of 619 British Columbians were attributed to this event (Report to the Chief Coroner of British Columbia. ,2022).

Research suggests that the risk of death was associated with socio-economic characteristics including deprivation, less access and proximity to green infrastructure, older age, and sex (Henderson et al., 2022). Municipal decision-makers must account for the uneven distribution of impacts as they consider the allocation of funds to address these impacts. For example, focusing efforts on highly deprived neighborhoods with low access to air conditioning and greenspace. (Henderson et al., 2022).

2010 and 2018 extreme heat events in Quebec

It is estimated that recent extreme heat events in Quebec have led to a significant number of deaths. 291 people died in the 2010 extreme heat event, and 86 died in the 2018 extreme heat event.

RECOMMENDATIONS

Next steps for the City of Hamilton

In order for the City of Hamilton to better understand its own specific costs related to climate change, it is important for the City to investigate potential data sources listed in Appendix A to better understand the costs associated with the risks presented in this report.

City Staff currently in Public Health Services - Healthy Environment's Division are currently investigating data sources across City Departments to begin gathering local costs associated with the Climate Risk Statements outlined within this report. This data collection process can be complicated, especially where data may not be tracked properly. In this case it will require the collective buy-in from top decision-makers at the City of Hamilton to prioritize this type of data collection and storage in order to properly assess the climate change impacts and costs specifically for Hamilton.

APPENDIX A

Sample data sources for local climate change impacts and costs

Risk 1: Increasing frequency of extreme precipitation events leading to overland flooding and damage to buildings and homes.

Type	Data	Notes
Climate data	Local IDF Curves, local precipitation data (total/mean precip, intensity rate, max/min precip)	IDF data selected according to project and relevent return periods (should also apply scaling to adjust for climate change)
Climate Data	Flood plain mapping by regional bodies	Can be obtained from local conservation authorities
Event based data	Historical records of extreme precipitation events	Going back a minimum of 10 years
Event based data	Historical records of 311 calls to report flooding of buildings and homes	Going back a minimum of 10 years
Event based data	Flood mapping (i.e. reported flooding locations)	Going back a minimum of 10 years
Departmental data	Major expense records incurred by multiple departments in their response and cleanup to flooding	Going back a minimum of 10 years

Type	Data	Notes
	events. (e.g. operational costs for response and clean-ups of flooding events such as contract services, salaries, landfill fees, etc.)	
Event based data	Municipal subsidy program applications (e.g. number of applications from homeowners applying after flooding events)	Going back a minimum of 10 years
Event based data	Historical records of costs incurred by municipal-run social housing and shelters as a result of flooding	Going back a minimum of 10 years
Climate and Event based	Models of municipal sewer system maps combinded with IDF for different return periods and different climate projections to estimate the number of flooded properties for both current and future flood events	Can also apply Insurance Bureau of Canada estimates to determine costs (e.g. Insurance Bureau of Canada estimates the average home basement repair costs approx. $43K)
National / provincial and territorial data	Counts of disaster-assistance payouts	Local data
Event based insurance data	Records of claims following flooding events	Can be obtained from Insurance Bureau of Canada data
Community outreach / engagement data	Survey data from homeowners costs, type of flood damage, timing of flood impacts, sources of finances to repair damage	Can work with community partners to carry out outreach/engagement

Risk 2: Increasing temperature and precipitation leading to increased replacement and maintenance cost of roads and transportation infrastructure.

Type	Data	Notes
Climate Data	IDF Curves adjusted to return period and accounting for climate change (can be used as proxies for 20yr, 50yr, 100yr flooding events)	IDF data selected according to project and relevent return periods (should also apply scaling to adjust for climate change)
Climate Data	Both current and future temperature and precipication data (Temperature extremes, precipitation averages and totals, etc.)	Visit [ClimateData.ca]() for more information
Climate / Event Data	Records of local heat warnings (e.g. from heat alert system)	Local data
Event based data / Departmental Data	Historic records of extreme heat and precipitation events and associated costs for road and transport system repair and maintenance (this should include costs of repair and maintenance of transportation fleet)	Going back a minimum of 10 years
Departmental Data	Analysis of road and transportation infrastructure life cycle	
National Data	Costs to transportation infrastructure as a result of precipitation and heat damage (e.g. thermal cracking, rutting,	More information from the Canadian Institute for Climate Choices

Type	Data	Notes
	increased roughness, degredation, increased maintenance and repair costs, damage to bridges, decreased service delivery)	
National Data	Transportation of goods	More information from Statistics Canada
Provincial Data	Data collected for the ssset management planning for municipal infrastructure regulation (O. Reg. 588/17)	

Risk 3: Increasing frequency of extreme precipitation events leading to overland flooding and loss of local business and public services.

Type	Data	Notes
Climate data	Local IDF Curves, Local precipitation data (total/mean precip, intensity rate, max/min precip)	Selected according project and relevent return periods. Should also apply scaling to adjust for climate change
Climate Data	Flood plain mapping by regional bodies	Can be obtained from local conservation authorities
Climate data / event based data	River and lake level records	More information from ClimateData.ca and Climate Atlas, National Ocieanic and Atmospheric Administration Great Lake climate change projections
Climate data / event based data	Records of flood warnings issued by local or regional bodies	Going back a minimum of 10 years
Event based data	Records of high river and lake level records and associated costs to businesses and public services (beaches, recreation, parks)	
Event based data	Historical records of extreme precipitation events	Going back a minimum of 10 years
Event based data	Historical records of reports of flooding of local businesses and public buildings	Going back a minimum of 10 years

Type	Data	Notes
Event based data	Flood mapping (i.e. reported flooding locations)	Going back a minimum of 10 years
Event based data	Flood mapping of current and future at-risk / vulnerable businesses and public services under climate change	Can be obtained from the Climate Atlas
Event based data	Estimates of costs of flooding to businesses and public services under current and future climate change projections.	Can combine flood mapping with Insurance Bureau of Canada cost estimates
Departmental data	Major expense records incurred by multiple departments in their response and cleanup to flooding events. (e.g. operational costs for response and clean-ups of flooding events including contract services, salaries, landfill fees, etc.)	Going back a minimum of 10 years
Departmental data	Records of service disruptions and closures associated with flooding events (e.g. libraries, transit, recreation centres/facilities/parks etc.) and records of lost revenue from service disruptions/closures	Going back a minimum of 10 years
Event based data	Historical records of costs incurred by municipal-run public services (e.g. libraries, recreation centres, parks, transit, social housing) as a result of flooding events	Going back a minimum of 10 years

Type	Data	Notes
Climate and Event based	Models of municipal sewer system maps combinded with IDF for different return periods and different climate projections to estimate the number of flooded businesses and public services (e.g. libraries, recreation centres, parks, transit, social housing) for both current and future flood events	
National / provincial and territorial data	Counts of disaster-assistance payouts	Local data
Event based insurance data	Records of claims following flooding events	Can be obtained from the Insurance Bureau of Canada

Risk 4: Increasing frequency of extreme heat resulting in negative health outcomes, particularly to vulnerable populations, from reduced air-quality and increased heat-stress.

Type	Data	Notes
Climate Data	Current and future projections of exteme heat (# of extreme heat days, mean maximum temp, # of heat waves, avg length of heat waves, evening/night time temperatures)	Visit ClimateData.ca for more information
Event based data	Local counts of extreme heat warning (heat alerts) including number of heat warnings, extended heat warnings (duration)	Going back a minimum of 10 years
Event based data	Local count of air quality statements, smog advisories, number of days with Air Quality Health Index Moderate-High	
Departmental Data	Increased demand on cooling infrastructure (e.g. shade spaces, cooling centres and social housing)	
Departmental Data	Decreased enrollment and revenue from municipal outdoor programs	
Departmental Data	Records of heat stress and air quality related health leave and absenteeism for municipal staff, in particular those vulnerable/exposed to heat (e.g.	

Type	Data	Notes
	outdoor workers, age, pre-existing health conditions)	
Departmental Data	Increased operational, maintenance and repair costs from increased use of air conditioning in municipal buildings, cooling centres and transport fleets	
Departmental Data	Records of cooling centre and municipal pool use including costs for maintenance, energy use and chemical use	
Health Risk and Vulnerability Assessment Data (National, Provincial and Local)	National Health Vulnerability assessment for increasing heat events; Ontario Climate Change and Health Vulnerability Assessment toolkit and data; Local Risk and Vulnerability assessment that includes health outcomes (particularly to vulnerable populations)	More information from Health Canada and the Province of Ontario
National Data / Provincial Data	Climate change driven negative health outcomes (e.g. increased mortality, increased hospital visits as a result of increasing extreme heat)	More information from Health Canada
National Data	Health Costs of Climate Change related to poor air quality and extreme heat stress	

Type	Data	Notes
National Data	Economic costs of pre-mature deaths, illness and absenteeism related to extreme heat and poor air quality	More information from the National Round Table on the Environmenta and Economy

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