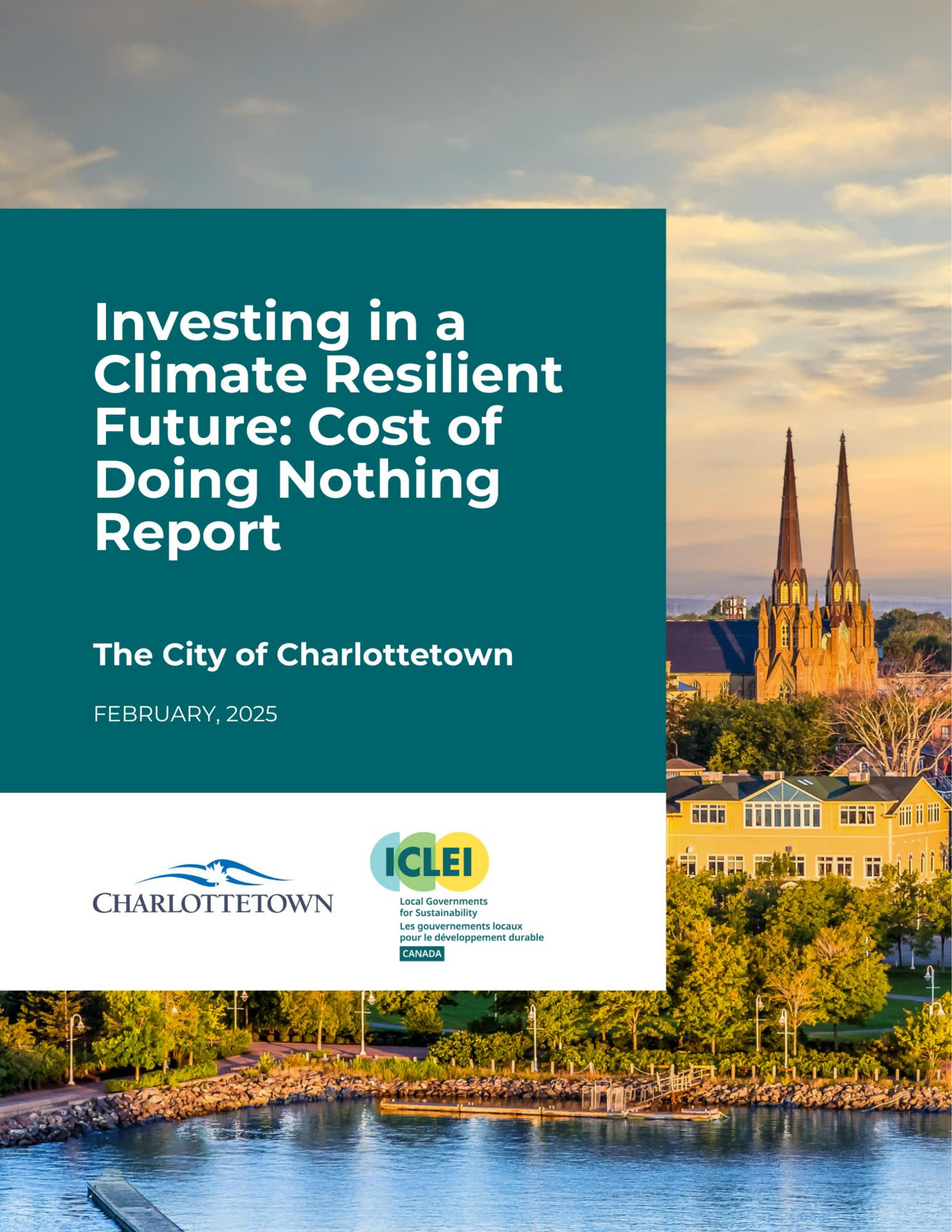

Investing in a Climate Resilient Future: Cost of Doing Nothing Report

The City of Charlottetown

FEBRUARY, 2025

CHARLOTTETOWN

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Local Governments for Sustainability
Les gouvernements locaux pour le développement durable
CANADA

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We also extend our appreciation to the City of Charlottetown staff who generously contributed their time and resources to help identify locally relevant data that informed key sections of this report. Their support in providing local context, data insights, and technical input was invaluable in ensuring that this report accurately reflects Charlottetown's climate risks and challenges.

EXECUTIVE SUMMARY

As the City of Charlottetown navigates the increasing impacts of climate change, understanding the financial, environmental, and social ramifications of inaction now and into the future is critical. This report serves as a guide for decision-makers, situating climate data within national and provincial contexts while highlighting the costs and impacts of climate hazards.

The financial costs of climate-related events are substantial and growing. Extreme weather and precipitation significantly affect Charlottetown's natural ecosystems and infrastructure. Extreme storm events, which are common in PEI, routinely cause infrastructure damage, overland flooding, and service disruption, presenting challenges for stormwater management systems, essential services, and increasing maintenance costs. Additionally, the city's natural asset infrastructure is at risk, with potential losses dwarfing the costs of conserving existing green spaces.

The increasing frequency of extreme heat events is a growing concern. Historically, Charlottetown has averaged one day per year with temperatures exceeding 30°C, but projections indicate a rise to an average of 14 such days annually by 2041-2070 under high emissions scenarios. This will heighten water demand, strain cooling resources, and place additional pressure on City operations.

Sea level rise in Canada has consistently required expensive investments and in 2021, annual damages from coastal and inland flooding were estimated at $1.3 billion. Charlottetown has already witnessed long-term sea level rise, and the province could expect to see annual coastal flooding losses (including damage to infrastructure, disruptions to coastal ecosystems, and other associated impacts) reach $5 million to $55 million by 2050, highlighting the direct impact on the City's financial resources.

Beyond infrastructure, climate impacts are significantly degrading Charlottetown’s natural systems. The loss of natural assets like trees and coasts impairs ecosystem services crucial for temperature regulation and biodiversity, with replacement and restoration costs being significantly higher than those of built or grey infrastructure assets.

Health and safety remain significant concerns for the City, particularly in light of recent climate events. Extreme weather, flooding, and heat waves have wideranging short- and long-term health impacts, including increased hospitalizations, reduced worker productivity, disruptions to essential services, and damage to critical health infrastructure. The financial burden on healthcare systems is expected to rise sharply, requiring immediate intervention to enhance resilience in emergency services and cooling and reception centres.

As the City of Charlottetown continues to develop its Climate Action Plan, the insights gained from this report underscore the necessity of proactive adaptation measures to reduce or avoid the impacts of climate change. This report highlights that while the cost of adaptation is significant, the cost of inaction or "the cost of doing nothing" is far greater. Every dollar invested in proactive climate resilience measures yields substantial savings by preventing future damages and economic disruptions. Around the world, communities that delay action are facing skyrocketing costs for climate-related recovery. Through strategic planning and action, Charlottetown can safeguard its future, ensuring a resilient and thriving community in the face of a rapidly evolving climate landscape.

INTRODUCTION

Climate change is already costing Canadian municipalities billions of dollars each year, and these costs are projected to increase sharply without proactive adaptation. Extreme weather, rising temperatures, and shifting climate patterns threaten infrastructure, public health, and economic stability, placing immense strain on local budgets and essential services.

For Charlottetown, the financial risks are particularly urgent. As a coastal city with aging infrastructure and an economy linked to tourism, climate hazards – such as sea level rise, flooding, and extreme heat – could result in escalating damage and long-term disruptions. The cost of inaction will not only impact municipal assets and operations, but also residents, visitors, businesses, and vulnerable populations.

Purpose of this Report

This report supports the City of Charlottetown's Climate Action Plan by providing decision-makers with locally relevant data to assess the true costs of inaction versus the benefits of proactive adaptation. It:

- Frames Charlottetown-specific climate data (where available) within a provincial and national context.
- Examines the financial, economic, and social implications of climate change across key hazards and sectors.
- Outlines how inaction could lead to escalating costs for infrastructure, public services, health systems, and economic productivity.

Developed in collaboration with ICLEI Canada, this report draws on ICLEI's expertise in helping local governments address climate change impacts by providing technical support, resources, and capacity-building tools to advance climate resilience and sustainability.

The Growing Financial Burden of Climate Change

Municipalities across Canada are experiencing rising financial losses from climate-related disasters, with seven of the ten costliest events occurring in the last decade (Figure 1). However, insured losses capture only part of the impact: many climate-related damages are uninsured, and absorbed by businesses, residents, and municipal governments (IBC & FCM, 2020).

Recent extreme weather events in Canada provide clear evidence of escalating financial risks. These disasters, ranging from billion-dollar wildfires to catastrophic floods, are becoming more frequent and severe. The table below highlights Canada's most costly disasters in recent years, illustrating the scale of financial strain on municipalities, businesses and residents.

Year	Total loss ($ billion)	Notable severe weather events
2024	8.55	Calgary hailstorm, Jasper wildfire, remnants of Hurricane Debby, Greater Toronto Area (GTA) floods
2016	6.20	Fort McMurray, Alta., fire
2013	4.03	Alberta floods, Greater Toronto Area floods and ice storm
2022	3.61	Hurricane Fiona, Montreal storm
2023	3.61	Nova Scotia floods, B.C. wildfires
1998	2.94	Quebec ice storm
2021	2.56	Calgary hailstorm, B.C. floods and wildfires
2020	2.52	Fort McMurray flood, Calgary hailstorm
2018	2.49	Ontario and Quebec rainstorms and windstorms
2011	2.05	Slave Lake, Alta., fire and windstorm

Figure 1: Canada's Top 10 Highest Insured Severe-Weather Loss Years on Record (loss and adjusted expenses in 2023 dollars) (IBC, 2025, as cited in Mayer, 2025).

The financial burden of climate change is projected to skyrocket in the coming decades:

- **By 2050, Canada could face a total of approximately $140 billion (CAD)** in economic losses due to climate impacts (GHD, 2022).
- **By the end of the century, climate-related costs may reach $865 billion annually** under a high-emissions scenario (RCP8.5) (Sawyer et al., 2022).

For Charlottetown, these figures are more than just national statistics; they are a warning sign. With increasing extreme weather, sea level rise, and heat waves intensifying across Atlantic Canada, local governments must prepare for substantial financial and social consequences.

The Cost of Inaction vs. Adaptation

While climate adaptation requires investment, the cost of doing nothing is far greater. Climate-related damages can be measured in two ways:

- **Market costs**: Direct financial losses such as repairing flooded roads, rebuilding damaged buildings, and funding emergency response. These costs appear in municipal budgets immediately and can be quantified in dollars.
- **Non-market costs**: Harder to measure but equally significant, including mental health impacts from climate anxiety, loss of recreational spaces due to flooding, and increased hospital visits for heat-related illnesses. These costs don’t come with an immediate price tag, but they strain public services and quality of life over time.

Consider an extreme heatwave in Charlottetown:

Visible market costs include higher electricity demand, increased hospital visits, and road damage from heat stress. But the non-market costs are just as damaging - seniors struggling without air conditioning, outdoor workers suffering from heat stress, and families avoiding outdoor events and activities. These costs may not appear on a balance sheet but directly impact health, safety, and livability.

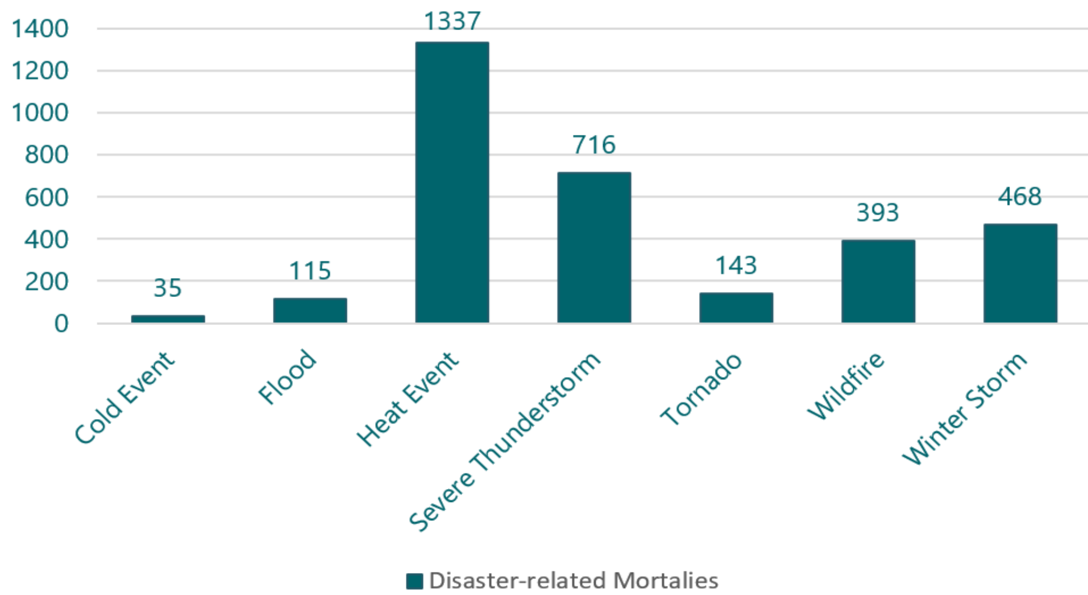


Figure 2: Sum of disaster-related mortalities in Canada by category: cold event, drought, flood, heat event, storms and severe thunderstorms, tornados, wildfire, winter storm (Source: CDD, 2022).

Extreme heat is one of the deadliest climate-related hazards in Canada, with heat events responsible for more disaster-related deaths than any other natural hazard (Figure 2).

Unequal Burden of Inaction

Climate change disproportionately affects vulnerable populations, including low-income residents, seniors, racialized populations, outdoor workers, people with chronic illnesses, children, and many more. These groups face higher health risks, fewer resources to recover from disasters, and greater exposure to climate hazards. For example:

- **Seniors and people with chronic illnesses:** Higher vulnerability to extreme heat, cold, and healthcare disruptions during severe storms.
- **Low-income households:** Limited ability to afford home retrofits, flood protection, or post-disaster repairs.
- **Outdoor workers and temporary labourers:** Increased risk of heat stress, hazardous conditions during storms, and exposure to wildfire smoke.
- **Flood-prone communities:** Greater risk of property damage and displacement due to rising sea levels and extreme precipitation.
- **Rural and isolated areas:** Fewer emergency services, longer disaster recovery times, and limited access to cooling and warming centres.

Without adaptation, these disparities will worsen. Targeted adaptation efforts- such as strengthening flood protection, expanding cooling and warming centres, increasing urban tree canopy, and designing climate-resilient affordable housing- are essential to protecting all Charlottetown residents.

Adaptation as a Cost-Saving Strategy

Investing in adaptation now is not just a choice - it is a necessity that will save Charlottetown millions in the long run. Every dollar spent on proactive measures translates into significant cost savings by preventing destructive and expensive climate-related damages. Strengthening infrastructure, enhancing emergency preparedness, and embedding climate resilience into urban planning will not only protect critical assets but also safeguard public health, reduce economic disruptions, and shield the most vulnerable residents from harm. Without decisive action, the financial burden of inaction will escalate, straining municipal budgets, displacing communities, and threatening the city’s long-term viability. Adaptation isn’t just about resilience- it's about securing Charlottetown’s future prosperity, by keeping the city economically strong and livable for all its residents.

HOW TO READ THIS REPORT

Charlottetown is already experiencing the effects of a changing climate, and these risks are expected to intensify in the coming decades. More frequent and severe extreme weather events, prolonged heat waves, and rising sea levels threaten municipal infrastructure, public health, natural systems, and economic stability.

This section outlines a selected subset of the high-risk climate impacts from Charlottetown's Vulnerability and Risk Assessment that will be explored further in this report.

How These High-Risk Climate Impacts Were Identified

Through the City of Charlottetown's Climate Action Plan, a Vulnerability and Risk Assessment process was undertaken to prioritize the most pressing climate risks affecting municipal infrastructure, services, residents, and visitors. The highest-risk impacts were carried forward into the planning phase, where adaptation actions were developed.

This report does not cover all climate impacts identified in the Climate Action Plan. Instead, it focuses on a select group of high-risk impacts to analyze the financial consequences of inaction.

While the primary focus is on the cost of inaction, this report also serves as a foundation for further data collection, helping to guide future investments in adaptation measures to safeguard Charlottetown's assets, infrastructure, and people.

How This Report is Structured: Climate Hazards and Relevant Localized Impacts

Each chapter examines the following high-risk climate impacts drawn from City's Vulnerability and Risk Assessment:

Chapter 1: Extreme Weather and Precipitation

- **Impact 23:** Increased frequency and intensity of precipitation events causing increased flooding, resulting in damage of private assets and infrastructure (i.e. homes, riverside and coastal homes, businesses, property, products/inventory, reduced long-term property value, etc.).
- **Impact 37:** Increased frequency/intensity of extreme weather and precipitation events (especially freezing rain) leading to increased damage to City-owned assets (e.g., fleet) and infrastructure (e.g. storm water management infrastructure, sports fields, trees, buildings, signs, streetlights,

roads, etc.) resulting in increased maintenance requirements (e.g. snow plowing, road salt, etc.), transportation and operation disruptions (traffic accidents, ice delays, snow days), resilient redevelopment of assets and infrastructure, and increased insurance claims.

- **Impact 38:** Increased frequency/intensity of extreme weather events (especially freezing rain) leading to increased damage of private assets and infrastructure (e.g. vehicles, homes, businesses, inventory/goods, etc.).
- **Impact 29:** Increased extreme weather events will create unsafe road and travel conditions, resulting in disruptions to all transportation (active, vehicular, including bridge and ferry closures), local business, emergency services, and other essential services (i.e. food systems, medical care/hospitals, airports, etc.).
- **Impact 41:** Increased frequency and intensity of extreme weather events and precipitation events resulting in more damage to natural systems, leading to damage to wildlife habitat and a decreased ability for natural systems to provide ecosystem services (i.e. reduced shading from extreme heat, landscapes vulnerable to flooding, depleted recharge abilities, reduced air quality from tree decline, decreased spawning due to altered stream structure, etc.)
- **Impact 42:** Increase in the frequency and/or intensity of windstorms and other extreme weather events could lead to damage and/or toppling of/loss of trees and subsequent reduced tree cover.

Chapter 2: Sea Level Rise and Storm Surge Events

- **Impact 39:** Increase in sea level rise and surge events causing increase in coastal erosion and damage to infrastructure and natural assets, resulting in increased economic costs, the prevention of coastal building and managed retreat, and risk to public health and safety.

Chapter 3: Extreme Heat

- **Impact 4:** Increase in the frequency/duration of hot days (>30 °C) causing heatwaves and reduced air quality, leading to health and safety risks (e.g. heat stress, mental health issues, domestic violence/violent altercations, cardiovascular disorders, food-borne/water-borne illnesses, etc.) especially to vulnerable populations (e.g. outdoor workers, seniors, women, children, those with chronic health conditions, temporary foreign workers, those without air conditioning, etc.)

CHAPTER 1: EXTREME WEATHER AND PRECIPITATION

WHAT TO KNOW ABOUT THESE HAZARDS

Precipitation

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 instance, Intensity-duration-frequency (IDF) curves used to predict heavy rainfall under changing climate conditions show that 100-year flood events in cities like Toronto, Edmonton, and Calgary could become as frequent as six-year events (Ness et al., 2021).

As Canada's climate continues to warm, shoulder seasons will lengthen, and winters will become milder. Precipitation is projected to increase across all seasons, with the most significant rises expected in winter and spring by the century's end. This will likely result in more frequent freezing rain and wet snow events, especially in maritime and southern regions.

Winter Precipitation

Cold weather is a defining feature of life in Canada. While colder regions are well-adapted to extreme cold, shifting winter precipitation patterns are becoming a growing concern. Although the frequency and severity of cold days are decreasing nationwide, milder winters combined with increased precipitation are expected to lead to more frequent freezing rain and ice storms. However, projecting future patterns of freezing precipitation remains challenging due to the complex interplay between warmer temperatures, increased precipitation, and shorter cold seasons.

PEI-Specific Trends

Compared to national trends, projections for Prince Edward Island (PEI) indicate less dramatic changes in precipitation. While overall precipitation is expected to increase across Atlantic Canada, PEI's total annual precipitation is projected to decrease by 6% by the 2040s, relative to the 1981–2010 baseline (City of Charlottetown, 2023). This decrease may result in drier, more drought-prone conditions by mid-century. However, models suggest that average annual precipitation will increase beyond current baselines from 2041-2070, introducing uncertainty and the potential for unpredictable consequences in the region (City of Charlottetown, 2023).

Extreme weather events (i.e. ice storms, wind storms, thunderstorms, freezing rain, tornadoes, etc.)

Over the past 50 years, extreme weather events in Canada have occurred at an unprecedented rate, with an increasing frequency expected as the climate continues to warm. For this report, the events considered under the umbrella of *extreme weather events* include ice storms, windstorms, thunderstorms, freezing rain, and tornadoes. Climate models indicate shorter return periods—meaning the time between occurrences—of extreme weather events in the future (Bush & Lemmen, 2019).

While current climate models cannot predict the exact timing of these events, considerable research shows that the probability of extreme weather has increased twelve-fold due to human-driven climate change (Zhang et al., 2019).

As illustrated in earlier sections (Figure 1), some of the costliest weather events—such as flooding, wildfires, and hailstorms – have resulted in billions of dollars in damages or losses. In PEI, precipitation events are expected to become less frequent but more severe as the climate changes.

Future Projections for Precipitation and Extreme Weather in Charlottetown

Total precipitation

The total annual average precipitation is projected to increase from a baseline of 1085 mm to approximately 1192 mm between 2041 and 2070, using both SSP2-4.5 and SSP5-8.5 scenarios.

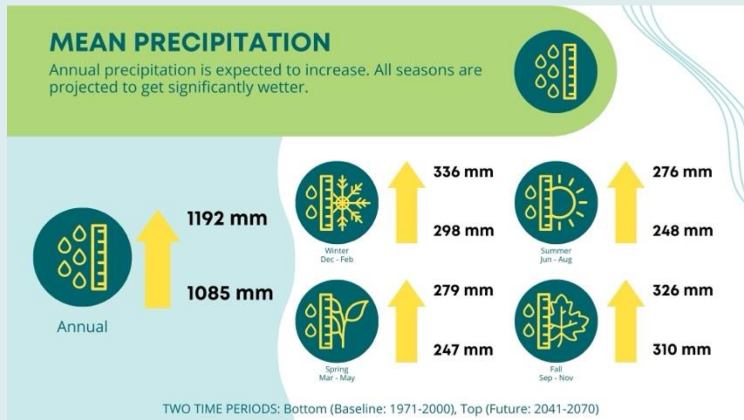


Figure 3: Infographic from the City of Charlottetown Climate Science Report on projected annual and seasonal mean precipitation (present to 2070).

Heavy Precipitation and Intensity-Duration and Frequency of Precipitation Events

Across the city, heavy precipitation days are expected to increase by approximately four days for 10 mm day events, and three days for 20 mm day events.

Maximum one-day and five-day events are also expected to increase across the city, with the greatest increase in five-day events. Specifically, max five-day events are projected to increase from a baseline of 126 mm to 142 mm by 2041-2070.

The Intensity-Duration-Frequency (IDF) analysis for the city underscores a significant trend toward more intense and frequent rainfall events. While longer, more frequent rainfall events (e.g. a typical rainy day) will bring slightly higher amounts of rain, the intensity of rainfall during more infrequent, extreme storms (i.e. one in 20, 25, 50, 100-year storms) is projected to increase by the 2040s to the 2070s.

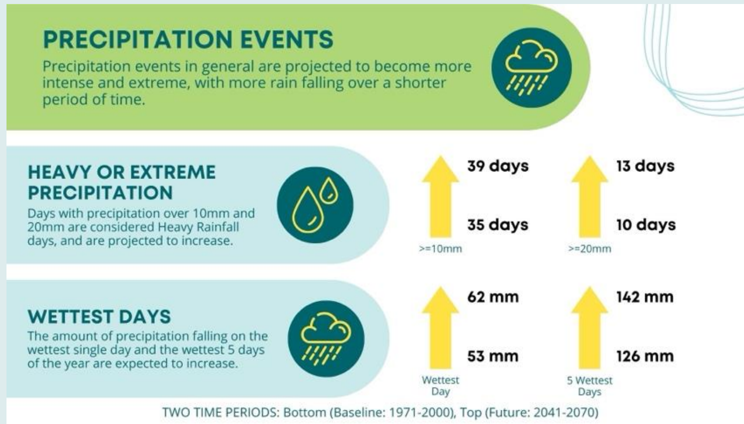


Figure 4: Infographic from the City of Charlottetown Climate Science Report on projected heavy rainfall days and precipitation events (present to 2070).

Visualizing Flooding Risks

Flood maps (e.g., 1:10-year inland flooding scenarios) provide critical insights into current and future flooding risks. These maps highlight areas of economic vulnerability, including key tourism zones, businesses, and other critical infrastructure in downtown areas. Below are the following:

- Current Conditions Map: Illustrates existing inland flooding risks for a 1:10-year event.
- Future Conditions Map: Projects expanded inland flooding risks for a 1:10-year event due to climate change, highlighting areas of increased vulnerability.

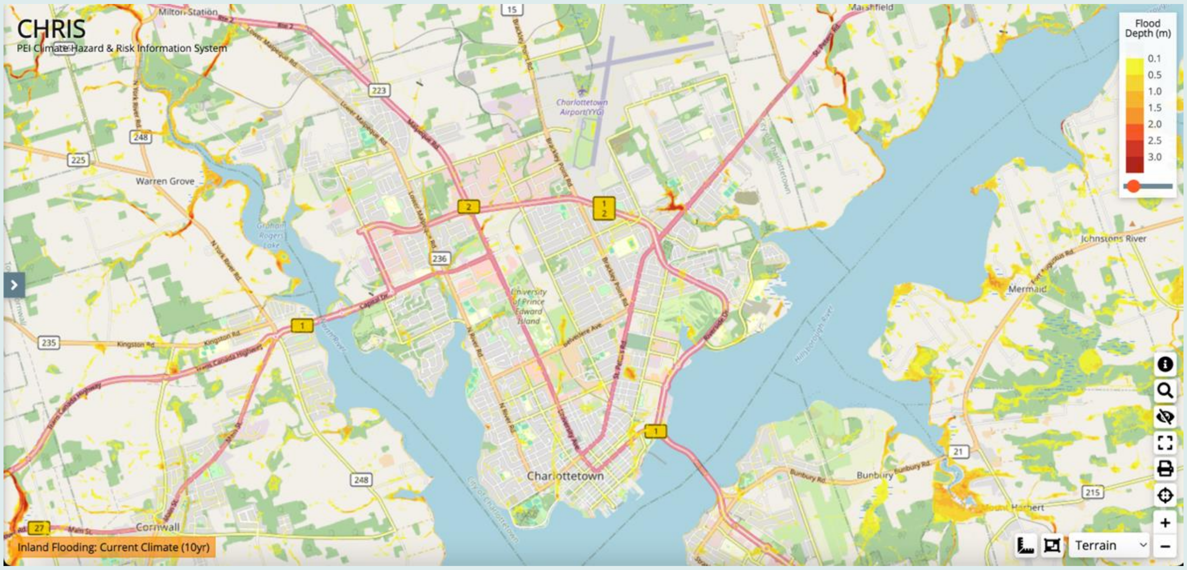


Figure 5: Current Conditions 1:10 year inland flooding map

Figure 6: Current Conditions 1:10 year flooding event, zoom into downtown to show potential economic impacts on tourism, businesses, etc. Extreme flooding outlined in red.

Hail and Thunderstorms

While localized data related to hail projections are largely unavailable and year-to-year variability of hail events can be high, recent studies suggest that the frequency of hailstorms is linked to the increased frequency of severe thunderstorms under future climate projections (Etkin, 2018).

Snapshot of past significant precipitation and extreme weather events in Charlottetown and PEI

To understand the costs of past events, this report uses CatIQ[i] (Canadian Catastrophic Loss Index Provider and Analysis Company) to understand the insured losses of past events in Charlottetown. Through its online subscription-based application, CatIQ combines comprehensive insured loss and exposure indices, as well as other related information.

SIGNIFICANT FLOODING EVENTS

2023 Cold Snap and Flooding

In February 2023, Eastern Canada experienced a sudden drop in temperatures to a low of -20°C. Multiple buildings sustained significant damage due to flooding, burst pipes, or collapsed roofs such as the PEI Supreme Court in Charlottetown, Walmart in Summerside, and Colville Manor in Souris. Evacuations were issued for several low-rise apartments and a townhouse unit in Charlottetown due to burst pipes and flooding damages, which amounted to approximately $1,875,000 in insured losses across PEI according to CatIQ.[ii]

2022 Eastern Canada Bomb Cyclone

A low-pressure system passing through the Maritimes during December 2022, caused powerful winds and blizzards to topple trees and power lines and facilitated coastal flooding. In Charlottetown, winds reached up to 101 km/h and caused 9,000 PEI utility customers to lose power. Cost estimates from CatIQ amount to $725,000 of insured losses within PEI.[iii]

2022 Late Winter Storm

In February 2022, an intense weather system arrived from the west and caused widespread flooding, damages, and power outages across Atlantic Canada due to locally heavy rain, warm temperatures, and snowmelt. Between 10- and 35-mm wind gusts across PEI were reported, peaking in Charlottetown at 85 km/h. At least 120 utility customers were reported without power during the storm, and insured losses for PEI were estimated by CatIQ to be almost $750,000.[iv]

2019 Windstorm

In January 2019 a low-pressure system brought significant levels of snowfall, rain, and strong winds to Atlantic Canada, resulting in flooding in many regions.

A warm front brought record-breaking, double-digit temperatures within PEI, facilitating flooding and causing significant damages. It was estimated by CatIQ that insured losses cost PEI $271,000.[v]

2018 Winter Flooding

In January 2018, a low-pressure system brought unusually warm temperatures and heavy rain to PEI that caused rivers to overflow, basement seepage, and road wash outs. Flooding was reported in Bloomfield Provincial Park, Glenwood, due to the Big Pierre Jacques River water level rising by 2 m, and O'Leary. More than 20,000 utility customers were reported without power. Insured losses were reported at $34,000 by CatIQ.[vi]

2016 Remnants of Hurricane Matthew

In October 2016, PEI was hit with the remnants of a low-pressure system that formed due to the former Hurricane Matthew. Significant rain and hurricane-strength winds caused extensive flooding damage, with up to 73 mm of rain measured in Charlottetown. CatIQ estimates insured losses for PEI amount to approximately $549,000.[vii]

SIGNIFICANT EXTREME WEATHER EVENTS (I.E. ICE STORMS, WINDSTORMS, THUNDERSTORMS, FREEZING RAIN, TORNADOES, ETC.)

2023 Windstorm

In December 2023, Atlantic Canada was hit with heavy rain, snow and strong winds due to an atmospheric river-fueled storm. Although PEI did not receive much rain, wind gusts of up to 90km/h swept through the province and caused power outages for approximately 5,800 utility customers. The majority of these power outages occurred within Charlottetown. Strong winds caused a wind turbine near Hunter River to be bent in half, and flooding was reported in Brackley Beach, Rustico, Savage Harbour, and Malpeque. According to CatIQ estimates, costs from this event amounted to $151,000 in PEI. [viii]

2022 Hurricane Fiona

Hurricane Fiona touched down in the Maritimes as a Category-2 hurricane strength post-tropical storm on September 24th, 2022. As one of the strongest storms in Canadian history, it caused extensive damage to natural and built infrastructure and severe impacts across PEI. Peak wind gusts and rainfall in

Charlottetown reached 131 km/h and 80 mm, respectively, causing roofs to be torn off multiple buildings. Across the island, trees and power lines were uprooted, resulting in 82,000 utility customers, or 95% of the island, without power for up to 21 days in some cases.[ix] The City of Charlottetown estimates that municipal expenses related to Hurricane Fiona amounted to $4,865,248 (The City of Charlottetown, personal communication, November 2024). CatIQ estimates that the hurricane caused over $315 million in insured losses throughout PEI, and a total of over $862 million across Atlantic Canada and Quebec. [x]

Proceeding Hurricane Fiona, many of the City's parks sustained tree damage and resulted in the closure of several trails for safety reasons. The removal of such hazardous trees was estimated by the City to cost $237,120, with further significant costs to remove stumps and conduct replacement plantings. Additionally, some City facilities, such as ballfields, sustained damage due to fallen light posts and forced the early closure of fields leading to lost revenue. The cost of the replacement of lights at Central 1 Ballfield due to damage from Hurricane Fiona was approximately $410,000 (The City of Charlottetown, personal communication, November 2024).

2019 Rain and Windstorm

Significant rainfall and damaging winds were brought upon PEI during October and November 2019. Unusually high temperatures rose into the teens and even exceeded 20° in some parts of Atlantic Canada, and wind gusts rose to a maximum of 91 km/h in Charlottetown. There were at least 800 reports of lost power in PEI, and insured losses for PEI were estimated at $147,000.[xi]

2019 Post-Tropical Cyclone Dorian

The remnants of Hurricane Dorian tracked through Atlantic Canada from September 7 to 8, 2019, causing wind gusts throughout PEI up to 120 km/h and rainfall up to 135 mm. The hurricane-strength post-tropical storm downed trees and power lines across the province and damaged structures, crop fields, and docked boats. 75% of the province's homes and businesses were left without power, approximately 62,000 utility customers, some of which were left without power for eight days. The City of Charlottetown estimates that municipal expenses related to Hurricane Dorian amount to $268,642 (The City of

Charlottetown, personal communication, November 2024). CatIQ estimates insured losses for PEI at $21.4 million out of a grand total of $156.7 million.[xii]

2014 Remnants of Hurricane Arthur

In July of 2014, the post-tropical storm, formerly Hurricane Arthur, passed through Atlantic Canada, causing power outages, and extensive damage to properties and automobiles. During the storm's peak, 1,500 utility customers were without power in PEI, and boats not only sustained extensive damage but were even sunk and lost to sea in some cases. CatIQ estimates that insured losses amount to over $900,000 in PEI.[xiii]

IMPACTS ON INFRASTRUCTURE

Relevant Localized Impacts

The following localized impacts identified through the vulnerability and risk assessment highlight the urgency of addressing infrastructure vulnerabilities:

Impact 23: Increased frequency and intensity of precipitation events causing increased flooding, resulting in damage of private assets and infrastructure (i.e. homes, riverside and coastal homes, businesses, property, products/inventory, reduced long-term property value, etc.).

Impact 37: Increased frequency/intensity of extreme weather and precipitation events (especially freezing rain) leading to increased damage to City-owned assets (e.g., fleet) and infrastructure (e.g. SWM infrastructure, sports fields, trees, buildings, signs, streetlights, roads, etc.) resulting in increased maintenance requirements (e.g. snow plowing, road salt, etc.), transportation and operation disruptions (traffic accidents, ice delays, snow days), resilient redevelopment of assets and infrastructure, and increased insurance claims.

Impact 38: Increased frequency/intensity of extreme weather events (especially freezing rain) leading to increased damage of private assets and infrastructure (e.g. vehicles, homes, businesses, inventory/goods, etc.).

Direct Impact: Buildings and Homes

Flooding from extreme precipitation is one of the most prevalent and costly climate hazards facing Canadian municipalities. Intense precipitation, combined with insufficient permeable surfaces, often overwhelms drainage systems, leading to water infiltration and significant damage to buildings and homes.

An analysis done by Pang et al. shows that all 98 Census Subdivisions in PEI are vulnerable to flooding hazards (Pang et al., 2024).

In PEI, flooding risks are particularly severe due to heavy rain, storm surges, and coastal flooding. Many homes on the island are vulnerable to water infiltration, particularly in basement windows and foundations (Government of Prince Edward Island, 2024b).

Coastal flooding is compounded by heavy rainfall, extreme storms, and storm surge events which produce overland flooding in tandem, especially along the north shore. Recent events, including Post-Tropical Storm Dorian (2019), the remnants of Hurricane Ida (2021), and Post-Tropical Hurricane Fiona (2022), have caused extensive flooding, damaging infrastructure, private and public properties, agriculture, and tourism, and disrupted economic activities across PEI.

Flood risk projections for PEI's 98 census subdivisions and 85,900 buildings (Pang et al., 2024) are as follows:

- Current climate scenario:
  - 3,389 buildings impacted by a 10-year flood.
  - 4,279 buildings impacted by a 100-year flood.
- Future climate scenario:
  - 6,154 buildings impacted by a 10-year flood—**1.5 times more** than the current 100-year flood impact.

The increasing frequency and severity of flooding events underscore the urgent need for proactive measures to protect buildings, homes, and critical infrastructure across PEI.

Direct Impact: Transportation Infrastructure

Transportation infrastructure, including roads, is critical for the movement of people, goods, and services. However, as climate hazards increase in intensity and frequency, the degradation of these systems is expected to accelerate.

Climate Hazards Affecting Transportation:

- Heat and Freeze-Thaw Cycles: High temperatures and freeze-thaw events exacerbate wear and tear on asphalt and pavement, reducing their lifespan.
- Erosion and Extreme Precipitation: Increased rainfall can cause erosion, road washouts, and damage to culverts, while extreme weather events like ice storms and windstorms contribute to infrastructure degradation.
- Blockages and Damages: Snow blockages, road washouts, and damage to traffic signals caused by hail, freezing rain, and high winds create dangerous travel conditions and disrupt transportation networks.

Indirect Impacts

The full economic costs of service losses and disruptions due to extreme weather events are not yet fully understood, but recent reports indicate that these direct and indirect costs will continue to rise. These costs include transportation delays, loss of business income and value, business disruptions, labour productivity losses, and reduced economic growth due to flooding (Sawyer et al., 2020).

Business Impacts

Research by GHD (2022) identifies flooding caused by extreme precipitation as the most disruptive and costly hazard for businesses. The manufacturing, distribution, and consumer goods retail sectors are particularly vulnerable. Flooding can directly damage buildings, inventory, and machinery, leading to increased maintenance, replacement costs, and disruptions. These challenges can result in:

- Higher taxes and shipping costs.
- Transport delays and disruptions.
- Increased road and travel-related accidents.
- Elevated risks of injury and fatalities.

Transportation and Supply Chain Disruptions

Changing winter precipitation patterns and freeze-thaw cycles further deteriorate transportation infrastructure, including roads and sidewalks, increasing risks of accidents and injuries. These hazards disrupt supply chains, delay services, reduce economic output, and increase the likelihood of toxic spills and accidents.

As demonstrated by Hurricanes Ian and Fiona, widespread flooding and extreme storms can cause cascading disruptions to supply chains and trade (Israelson, 2022). These events damage critical transport infrastructure such as roads, ports, harbours, and marinas, leading to compounding delays in shipping.

After Hurricane Fiona, grocery prices, transportation costs, building materials, labour, and shipping container prices rose by up to **60%** in the immediate aftermath, as entire industries temporarily shut down to recover and rebuild (Lord, 2022; Globe Content Studio, 2023).

The economic toll of these disruptions to costal supply chains and trade caused by events like Hurricane Fiona is estimated to range between $4–$17 billion annually (Public Safety Canada, 2024b).

By 2050, damages to Canadian buildings could increase fivefold, with a tenfold increase projected by 2100 as rainfall intensifies and sea levels rise. Average annual costs could reach $13.6 billion (Public Safety Canada, 2024b).

Local Recovery Efforts

Eastern Canada, including PEI, faces severe challenges during and after extreme weather events. Grocers sourcing food from Eastern Canada may pass on higher costs to consumers as businesses recover. In PEI, Hurricane Fiona highlighted the immense costs of recovery, as access to PEI was restricted, and rebuilding efforts were expensive.

In the aftermath of Fiona, the federal government collaborated with fisheries, harbour authorities, and the PEI government to repair critical infrastructure such as small craft harbours and to remove storm-generated waste from the ocean. The federal government invested $100 million in recovery efforts, which included repairing harbours and recovering lost fishing gear (Fisheries and Oceans Canada, 2022a). The agricultural sector also suffered significant damage to barns, storage facilities, and crops. To address urgent financial needs, the federal and provincial governments increased interim payments under the AgriStability program from 50% to 75% (Agriculture and Agri-Food Canada, 2022).

IMPACTS ON CRITICAL AND ESSENTIAL SERVICES

Relevant Localized Impact

The following localized impact, identified through the vulnerability and risk assessment, highlights the urgency of addressing disruptions to community services and infrastructure:

Impact 29: Increased extreme weather events will create unsafe road and travel conditions, resulting in disruptions to all transportation (active, vehicular, including bridge and ferry closures), local business, emergency services, and other essential services (i.e. food systems, medical care/hospitals, airports, etc.).

Direct Impact: Disruptions to Critical and Essential Services

Climate change impacts, such as overland flooding, routinely disrupt critical services that communities depend on, including:

Public Transit

Flood events increasingly force transit agencies to reroute or suspend services in flooded areas, leading to delays, reduced service levels, and reliance on contingency routes that often fail to meet demand.

Emergency and Healthcare Services

Flooding, power outages, and extreme weather events disrupt health services by damaging facilities, cutting off medical supply chains, and forcing temporary closures and patient evacuations. These challenges occur at times of heightened demand, exacerbating their impact. Even when health facilities remain operational during disasters, they are often pushed beyond capacity due to increased injuries, illnesses, and patient transfers. The cascading effects of extreme weather can worsen multiple health outcomes simultaneously.

Research shows that over 5,000 healthcare centres across Canada are at risk of flooding, with a similar proportion of other critical public services—such as police and fire stations—also at risk (Clark et al., 2021).

Utilities and Telecommunications

The utilities sector, including electricity and telecommunications systems, are particularly vulnerable to extreme weather events, including windstorms/high winds, snowstorms, tornadoes, freezing rain, thunderstorms, and hailstorms. These hazards lead to:

- Damage to transmission lines, transformers, and telecommunications towers.
- Increased power demand and more frequent outages.
- Cascading failures across interconnected infrastructure systems.

Over the past 100 years, severe weather events in Canada have caused more than 15 million power outages and over 800 deaths, second only to extreme heat in climate-linked fatalities (CDD, 2022).

As illustrated in Figure 7, severe weather events in PEI have caused widespread power outages over the past decade, impacting between 800 and 82,000 utility customers per event. These disruptions highlight the growing strain on utilities, demonstrating the urgent need for infrastructure resilience in the face of escalating vulnerability.

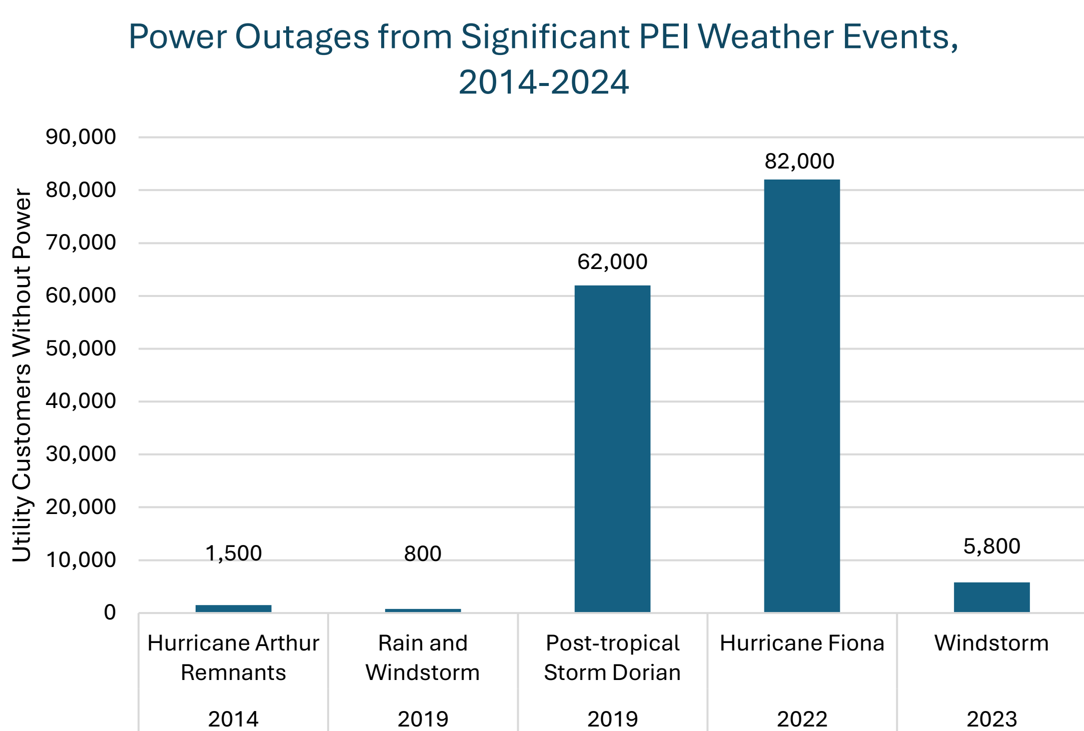


Figure 7: Power outages from significant PEI weather events over the last decade[xiv].

PEI-Specific Challenges and Recovery Efforts

In PEI, ferries and the Confederation Bridge serve as primary transportation routes for goods and materials. Extreme weather events have historically shut down both, sometimes for several days, and although they can recover relatively quickly with minimal damage, this closure can result in cascading supply chain issues (Israelson, 2022). For example, Hurricane Fiona caused devastating and widespread damage to industries critical to Atlantic Canada, such as shellfish farming and fish harvesting. It resulted in the loss of crops, seeds, and fishing gear (ghost gear), along with the destruction of infrastructure and extensive clean up requirements.

In response, the Atlantic Canada Opportunities Agency (ACOA) allocated $40 million over two years to support the shellfish sector (ACOA, 2023). Additionally, the Government of Canada directed $28.4 million from the Hurricane Fiona Recovery Fund ($300 million) to the Ghost Gear Fund, aimed at retrieving lost fishing gear and preventing future losses. Another $1.5 million will be provided for post-storm ghost gear cleanup projects, supporting 11 partners (Fisheries and Oceans Canada, 2022b).

Economic Implications – Infrastructure and Critical Services

Road Maintenance and Transportation Costs

Statistics Canada estimates that maintaining Canada's 2.8 million kilometres of roads already costs all orders of government approximately **$20.2 billion annually**, a figure projected to reach **$300 billion over the next decade** as climate-related hazards escalate (Ness et al., 2021).

- Economic losses from congested roadways, transportation interruptions, and supply chain issues are expected to grow.
- In 2017, $2.2 trillion worth of goods were transported on Canadian roads (Ness et al., 2021). Without adaptation measures, annual road delays could cost nearly **$2 billion by the end of the century**, compared to $250 million with proactive adaptation efforts.
- Poor road conditions already cost Canadian drivers an average of **$3 billion annually** in increased vehicle operating costs (Ness et al., 2021).

Flooding Costs

Flooding is the costliest climate-related hazard in Canada, with insurable and uninsurable losses steadily increasing. As shown in Figure 8, flooding in PEI has caused millions in damages over the past decade, with insured losses ranging from $34,000 to $1.875 million per event.

- Since 2010, flooding has accounted for the highest financial losses from extreme weather disasters, impacting Canadians through disaster-assistance payouts and recovery costs (Moudrak & Feltmate, 2020).
- Disaster Financial Assistance Arrangements (DFAA) payouts were expected to reach **$1 billion annually by 2020**, with projected damages from water-related events estimated at **$1.3–$12.4 billion annually** by the end of the century (Ness et al., 2021).
- Rising insurance premiums and coverage limitations are increasingly shifting the financial burden of recovery onto municipalities, homeowners, and businesses. The average homeowner insurance premium in Canada rose by **20–25% from 2015-2019** (Moudrak & Feltmate, 2020).

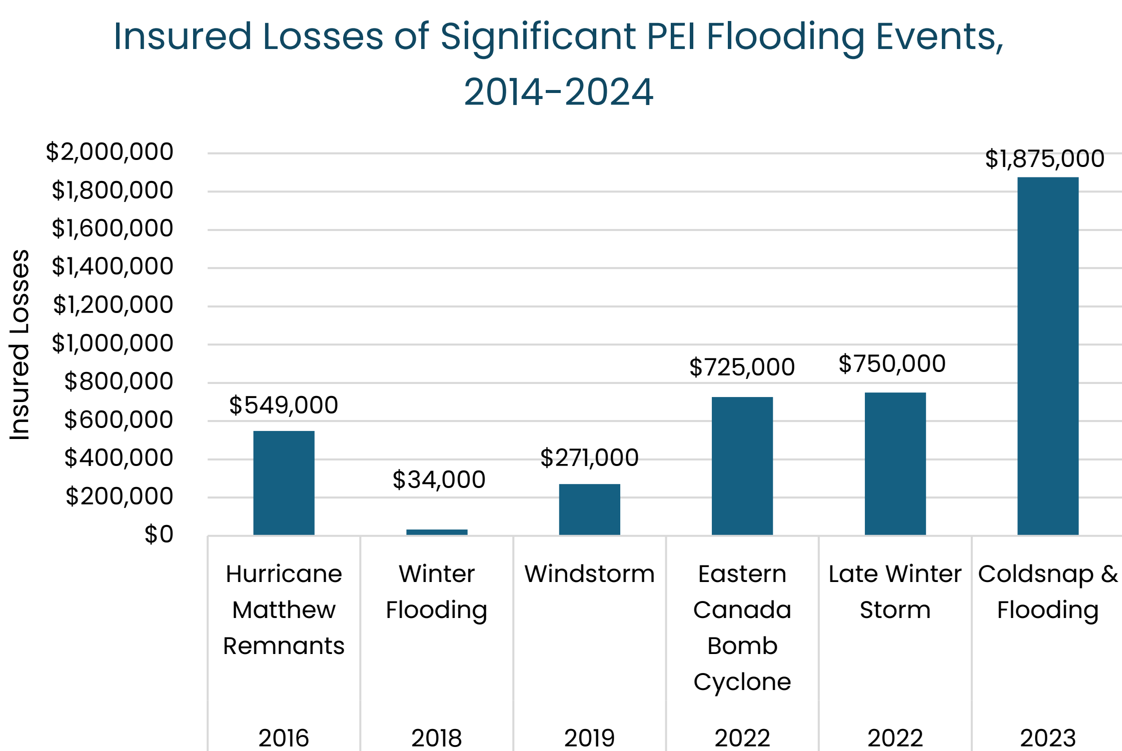


Figure 8: Insured losses of significant flooding events in PEI over the last decade[xv].

As illustrated in Figure 9, the financial burden on households located in flood zones is also projected to increase significantly under both low- and high-emission scenarios by mid-century and the end of the century. For example:

- Households in Toronto's flood zones currently incur baseline damages of **$99 million annually**, which could rise to **$566 million under high-emission scenarios** by the end of the century.

- Winnipeg is expected to see annual damages increase from **$54 million to $325 million** under similar conditions.

The data emphasizes the critical need for proactive adaptation measures to mitigate damages and financial losses across both urban and rural communities.

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 9: Projected Changes in Household Flood Damage Costs Across Canadian Communities Under Different Emissions Scenarios. Flood damages, millions of dollars (2019 CAD) (Ness et al., 2021).

Insurance Claims and Trends

The Insurance Bureau of Canada (IBC) reports a dramatic rise in property and casualty insurance claims due to extreme weather:

- From 1983 to 2008, annual payouts averaged **$405 million**. In the following decade, payouts exceeded **$1 billion annually** for 11 out of 12 years before 2020, with water-related damages accounting for over half of these costs (Moudrak & Feltmate, 2020).
- Extreme weather events in 2021 alone caused over **$2 billion in insured losses**, ranking sixth among Canada's top 10 loss years on record (IBC, 2022). Additionally, it is estimated that insured losses only encapsulate a fraction of the true cost of these events.

The IBC reports that 2024 was the most expensive year on record for insurance payouts, with insurers paying out $8.55 billion, more than $2 billion above the previous record set in 2016. This surge in payouts, driven by a series of devastating weather-related disasters, has led insurers to warn that home insurance rates are likely to rise significantly in 2025 (IBC, 2025, as cited in Mayer, 2025).

Charlottetown and PEI-Specific Financial Impacts

PEI has experienced significant financial impacts from extreme weather:

- Hurricane Fiona (2022): Expenses for Charlottetown totaled $4,865,248.59, with insurance covering infrastructure damage and the Province covering 75% of remaining costs. However, this does not include additional costs to the municipality, such as tree replacements, which were absorbed by the municipality.
- Hurricane Dorian (2019): Expenses for Charlottetown totalled **$268,642.06**, though reimbursement details remain unclear (The City of Charlottetown, personal communication, November 2024).
- A 2003 freezing rain event resulted in **$1.8 million in damages** (See Table 1 below).
- DFAA Allocations (2023): The federal government allocated **$659,449** under the Disaster Financial Assistance Arrangements (DFAA) program to compensate for damages from severe weather events in 2011 and 2013 (Public Safety Canada, 2024a).

PEI-Specific Recovery Efforts

- The Climate Challenge Fund, established by the PEI government in 2020, **provides $1 million annually** to support innovative climate change adaptation solutions (Government of Prince Edward Island, 2024d).
- The Agriculture Resiliency Program has **invested over $1.3 million** to prepare farmers for extreme weather events, including improving and retrofitting existing infrastructure through the Extreme Weather Preparedness Sub-Program (Government of Prince Edward Island, 2024c).
- In 2022, local businesses and communities were allocated **$300 million over two years** from the Hurricane Fiona Recovery Fund to support long-term recovery. Furthermore, **$9 million of that fund** was allocated to upgrade comfort and emergency centres affected by Fiona. (Atlantic Canada Opportunities Agency, 2024a; Atlantic Canada Opportunities Agency, 2024b).

Other Notable Canadian Case Studies

While PEI faces unique challenges, lessons can be drawn from other parts of Canada. Looking at freezing rain specifically, Table 1 below provides a summary of the fatalities, financial costs and impacts on utilities of these rain events over a 20-year period between 2001-2021 (CDD, 2022).

Table 1: Fatalities, financial costs and power outages caused by freezing rain events between 2001-2021 (CDD, 2022).

Location	Year	Fatalities	Financial costs	Power outages
Western Canada	2021	–	$155 million	212,000 without power
Eastern Canada	2019	–	$39 million in damages	57,000 without power
Southern Ontario	2016	–	$27 million in damages	300,000 without power
Southern Ontario	2013-14	2	$262 million in damages	2.4 million without power
Prince Edward Island	2008	–	$1.5 million in repair costs incurred by utilities	95% of PEI without power
Russell, Ontario	2006	0	–	Entire town lost power and issued state of emergency
Prince Edward Island	2003	0	$1.8 million in damages	–
Quebec	2001	6	$143 million	–

Given these events, municipalities must consider strengthening engineering standards for critical infrastructure to improve adaptive capacity. For example, a recent study showed that power lines aligned west to east, perpendicular to the strongest winds, are most susceptible to the consequences of icing and accretion within both current and future climate projections (Tropea & Stewart, 2021). Investments in proactive adaptation measures will help mitigate long-term risks to people, property, and communities.

Building the Case for Investment

The increasing frequency and intensity of extreme weather and heavy precipitation pose significant risks to critical services and infrastructure. Proactive adaptation is not optional - it is essential for reducing long-term costs, safeguarding public safety, and ensuring the continuity of essential services in the face of escalating climate threats.

Adaptation measures - such as upgrading stormwater systems, reinforcing transportation networks, and integrating resilient engineering practices - are not just expenses; they are strategic investments in economic stability and community well-being. By strengthening infrastructure, Charlottetown can reduce the direct costs of damages while ensuring continuity in essential services such as public transit, emergency response, healthcare, and utilities.

These investments also safeguard important supply chains, enhance the reliability of transportation networks, and protect vulnerable populations from cascading failures during extreme weather events. As municipalities grapple with rising insurance premiums and shrinking federal disaster assistance, the financial case for adaptation grows even stronger.

By prioritizing resilience-building now, Charlottetown can avoid exponentially higher recovery costs in the future and ensure critical services and infrastructure remain functional in a changing climate.

IMPACTS ON NATURAL SYSTEMS

Relevant Localized Impacts

The following localized impacts, identified through the risk assessment, highlight the vulnerabilities of natural systems to extreme weather events:

Impact 41: Increased frequency and intensity of extreme weather events and precipitation events resulting in more damage to natural systems, leading to damage to wildlife habitat and a decreased ability for natural systems to provide ecosystem services (i.e. reduced shading from extreme heat, landscape vulnerable to flooding, depleted recharge abilities, reduced air quality from tree decline, decreased spawning due to altered stream structure, etc.)

Impact 42: Increase in the frequency and/or intensity of windstorms and other extreme weather events could lead to damage and/or toppling of/loss of trees and subsequent reduced tree cover.

Direct Impact: Natural Assets

Natural asset infrastructure refers to both naturally occurring and enhanced naturally occurring assets (**green infrastructure assets**) and human-made assets designed or engineered to mimic the functions and processes of natural assets (**grey assets**). These systems are critical to maintaining ecological balance and delivering essential **ecosystem services**, which broadly refer to benefits humans derive from the natural environment.

Examples of Natural Asset Infrastructure:

- Blue Spaces: Aquifers, streams, wetlands, ponds, and lakes.
- Green Spaces: Parks, forests, street trees, cemeteries, and gardens.
- Engineered Natural Assets: Green roofs, artificial swales, rain gardens, and stormwater retention ponds.

These assets deliver services at a fraction of the cost of hard infrastructure, often providing equivalent or superior benefits. Key **ecosystem services** include water filtration, pollination, carbon sequestration, stormwater management, air purification, urban cooling, and recreation. Natural assets also reduce risks such as urban heat islands, soil erosion, flooding, and drought while supporting biodiversity.

However, climate change is increasingly compromising these essential functions. The rising frequency and intensity of extreme weather events significantly disrupt Charlottetown's natural systems and their ability to provide ecosystem services:

- Loss of Wildlife Habitat: Intense rainfall and flooding displace species, alter stream structures, and degrade habitats.
- Water Quality Degradation: Accelerated sediment runoff from increased water flow degrades aquatic ecosystems and diminishes water filtration services.
- Reduced Tree Canopy: Windstorms and freezing rain events cause tree loss, reducing air quality, urban cooling, and biodiversity.
- Diminished Ecosystem Services: Damage to wetlands, forests, and other natural systems weakens their ability to manage stormwater, sequester carbon, and mitigate flooding.

The compounded effect of these disturbances extends to the loss of ecosystem services such as water filtration, flood mitigation, and the provision of recreational spaces. These challenges highlight the urgent need for resilient ecological management and targeted restoration strategies to sustain biodiversity and ecosystem functionality in Charlottetown as the climate continues to change.

Local example

In 2022, Hurricane Fiona caused extensive damage to natural systems throughout PEI, impacting approximately 24,300 hectares, or 9.4% of the island's forest area, with 70% or more of the trees in these areas being blown down (Government of Prince Edward Island, 2024). Many of PEI's 16,000 private woodlot owners reported significant losses, damages, and clean-up costs that affected past and future investments in wood and wood products (Government of Prince Edward Island, n.d.). Notably, over 51 km^2 of coastal land was lost due to the erosion and over 11 km^2 of sand dunes was lost (Pang et al., 2024), affecting marine life in the tidal zone, affecting species such as shellfish, sea worms and aquatic plants (CBC News, 2022).

Economic Implications – Natural Systems

Quantifying the financial impacts of climate threats on natural asset infrastructure is essential for informed decision-making, prioritizing adaptation strategies, and strengthening community resilience. Unlike built infrastructure, natural assets, such as wetlands and forests, take significantly longer to recover from disturbances. However, their value often increases over time, contrary to built assets, making them a critical component of climate adaptation strategies (City of Calgary, 2021b).

Evaluating the costs of extreme weather events on municipal natural assets requires a comprehensive approach. This includes:

- Valuing both the financial and intrinsic benefits of natural assets.
- Calculating the costs associated with ecosystem service losses due to climate-induced damage.
- Accounting for expenses related to restoration and replacement.

By considering both the tangible and intangible contributions of natural systems, this holistic approach underscores the vital role of natural assets in building long-term climate resilience.

Valuation Studies of Natural Asset Infrastructure

Recent studies highlight the economic importance of protecting and enhancing natural assets. Table 2 provides examples of valuation studies conducted by municipalities across Canada:

Table 2: Examples of valuation studies for various ecosystem services.

Location	**Service**	**Value**
City of Edmonton, AB	Urban forest services	$2.7 billion (MNAI, 2022)
City of Calgary, AB	Ecosystem services (includes recreation, amenity and enjoyment, habitat, water retention, urban heat reduction, and carbon storage services)	$2.5 billion per year, $6.9 billion total replacement value (City of Calgary, 2021b)
City of Toronto, ON	Ravine ecosystem services (includes recreation, physical health, mental health, air	$822 million per year (MNAI, 2022)

	quality, carbon sequestration, food provision, aesthetic appreciation, and habitat services)	
City of Saskatoon, SK	Aquatic, grass, forest, and shrubland services	$48.2 million per year (City of Saskatoon, 2020)
Town of Aurora, ON	Natural asset services	$7.4 million per year (Town of Aurora, 2013)

In 2021, Calgary conducted a detailed valuation of its natural assets, as shown in Table 3 below. The study provides an excellent model for establishing baseline values to assess the consequences of climate change.

Table 3: Natural asset valuation conducted by the City of Calgary (City of Calgary, 2021b).

Service	**Value**
Recreation	$899 million annually
Amenity and enjoyment	$50 million annually
Habitat	$33.7 million annually
Water retention	$1.2 billion annually
Urban heat reduction	$381 million annually
Carbon storage	$1.8-7.6 million

Saskatoon's Natural Capital Asset Valuation Pilot Project

The City of Saskatoon's Natural Capital Asset Valuation (NCAV) Pilot Project underscores the cost-saving potential of protecting natural environments (City of Saskatoon, 2020):

- Carbon Sequestration: Wetlands and grasslands store **82,904 tonnes of CO_2**, in soils in one area, with an additional **54,081 tonnes of CO_2** stored in biomass and soils in adjacent wetlands, grassland and forests/shrubland.
- Total Value: The total annual value of ecosystem services for Saskatoon's natural areas is estimated at **$48.2 million**, demonstrating the economic benefits of preserving these systems.

Building the Case for Investment

Understanding the baseline value of natural assets and the ecosystem services they provide is crucial for effective decision-making. This knowledge enables municipalities to quantify the full financial impact of climatic events on natural systems, highlighting the urgent need to restore damaged ecosystems to preserve their long-term benefits. In this context, it is essential to differentiate between the services provided by grey infrastructure and green infrastructure. While grey infrastructure, such as roads, bridges, and stormwater drains, is designed to deliver specific functions, such as water management or transportation, it can only provide the ecosystem services it was explicitly engineered to support.

In contrast, green infrastructure has the capacity to deliver a multitude of ecosystem services. Beyond water management, green infrastructure can improve air quality, support biodiversity, reduce urban heat islands, enhance recreational spaces, and even store carbon. For instance, a wetland not only manages floodwaters but also provides habitat for wildlife, purifies water, and offers carbon sequestration, all of which contribute to community resilience and sustainability. Recognizing these broader benefits strengthens the case for protecting, enhancing, and managing natural assets as a cost-effective adaptation strategy, ensuring their continued contribution to both immediate and long-term environmental and social well-being.

The City of Charlottetown is taking initial steps to create a natural asset inventory, a critical foundation for understanding the value of these assets and their role in climate adaptation and community resilience. However, to fully leverage the benefits of natural infrastructure, further investment is needed. A key next step for Charlottetown is to conduct an economic valuation study, similar to those undertaken by other municipalities referenced previously in this section, to quantify the financial benefits that natural assets provide, such as flood mitigation, carbon storage, and reduced strain on grey infrastructure. By putting a dollar value on these essential services, the City can make a stronger case for integrating natural asset management into long-term planning and budgeting. This data-driven approach would support cost-effective decision-making, helping to prioritize conservation and restoration efforts while reducing reliance on expensive engineered solutions.

CHAPTER 2: SEA LEVEL RISE AND STORM SURGE EVENTS

WHAT TO KNOW ABOUT THIS HAZARD

Understanding Sea Level Rise

Sea level rise refers to the increasing average sea levels relative to coastal land, primarily driven by global temperature rise due to climate change. This rise in temperature melts ice sheets in locations such as Antarctica, the Arctic, and Greenland, adding significant amounts of water to our oceans. Concurrently, increasing air temperatures warm ocean waters and cause them to expand, further contributing to sea level rise (Parnham et al., 2023).

However, sea levels do not rise uniformly. They vary due to temporal, atmospheric, and oceanographic factors, including:

- El Niño and La Niña Southern Oscillation events, which influence extreme water levels, temperature shifts, and storm surge flooding.
- Regional variations in salinity, land water storage, and ocean currents can amplify or mitigate local sea level rise.
- Coastal subsidence (land sinking) and glacial isostatic adjustment, which particularly affect Atlantic Canada can compound sea level rise.

Between 1901 and 1990, the global mean sea level (GMSL) increased by an average of 1.4 mm per year, but this rose to 3.6 mm per year between 2006 and 2015, a trend expected to continue. Figure 10 illustrates global sea level rise projections under different emission scenarios, showing potential increases of 0.61 to 1.10 meters by 2100 under high-emission pathways (RCP8.5) (Oppenheimer et al., 2019).

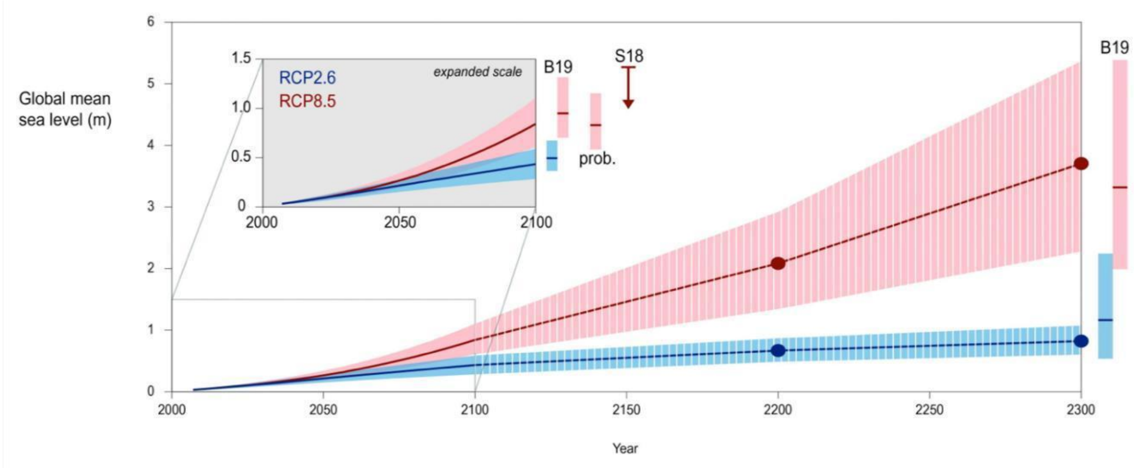


Figure 10: Global Mean Sea Level Rise Under Different Emissions Scenarios (including RCP8.5 - a high-emissions scenario) (Oppenheimer et al., 2019).

Regional and Local Trends

In Atlantic Canada, sea level rise is compounded by land subsidence. Projections indicate:

- 30–35 cm increase by 2050 and 75–80 cm increase by 2100 (Parnham et al., 2023).
- Some models suggest up to 160 cm of sea level rise by 2100 (see Figure 11 below)(Wade and CLIMAtlantic, 2022b).

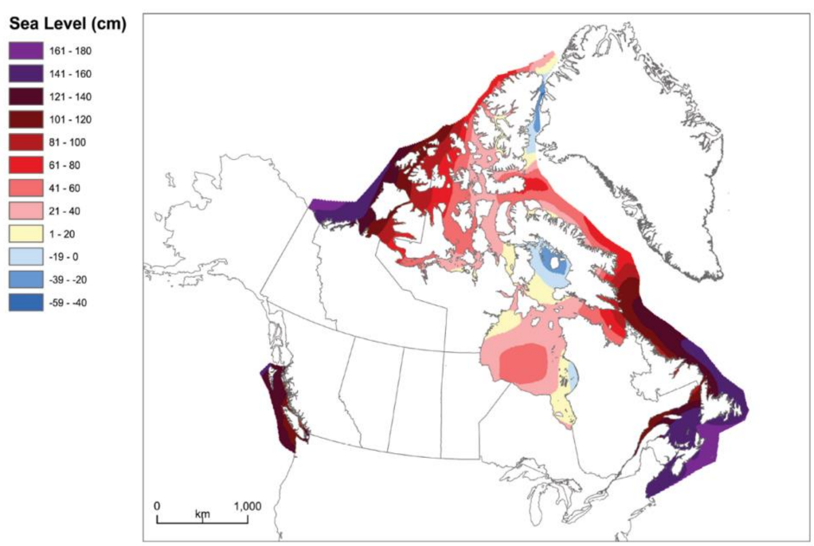


Figure 11: Projected Relative Sea-Level Rise in Canada by 2100. (Wade and CLIMAtlantic, 2022b).

As shown in Figure 14 below, Charlottetown has already experienced significant long-term sea level rise.

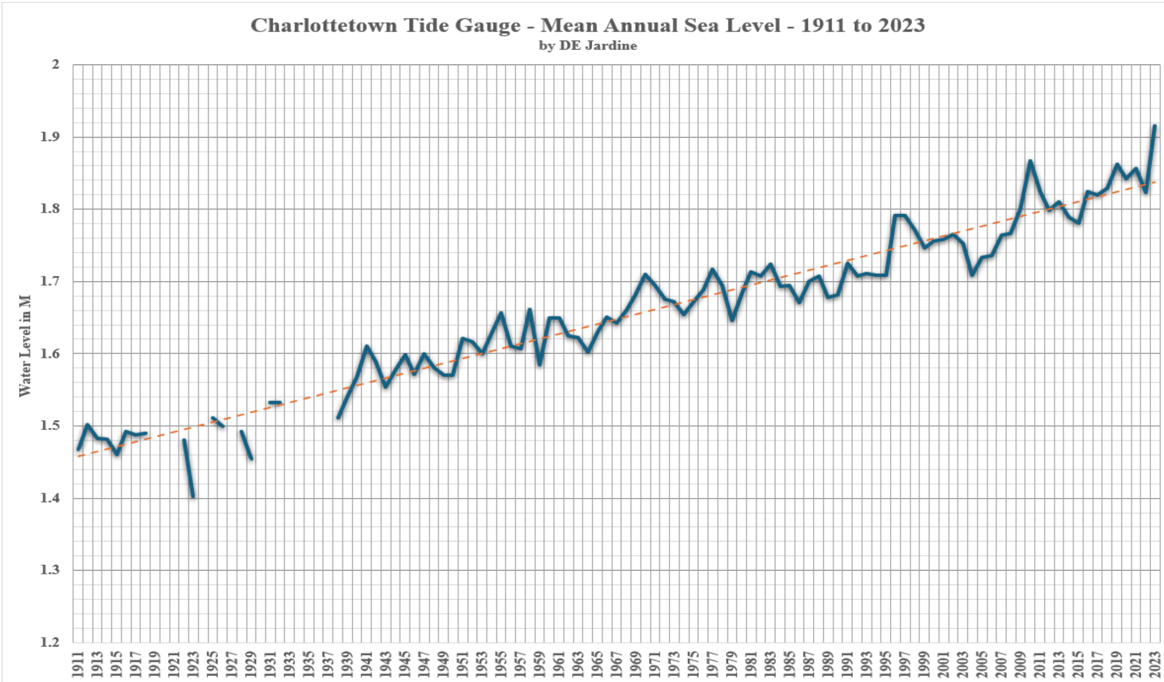


Figure 12: Charlottetown Tide Gauge - Mean Annual Sea-Level Rise (1911 - 2023) (The City of Charlottetown, personal communication, November 2024).

Tide gauge records from Charlottetown Harbour indicate an increase of approximately 0.32 meters per century (1911–2008)(Arnold and Fenech, 2017). Given these trends, the city must prepare for higher water events reaching +1 to 2 meters in the next 50 to 100 years, increasing the risk of coastal flooding in low-lying areas, such as Victoria Park (The City of Charlottetown, personal communication, November 2024).

Storm Surges and Extreme Sea Level Events

Beyond gradual sea level rise, extreme sea level (ESL) events, driven by tides, storm surges, and wave action, will become more frequent. The combination of these events will increase the historically 100-year storm surge events into annual occurrences, by mid-century (Oppenheimer et al, 2019).

- Storm surges occur when extreme weather, such as hurricanes or extratropical storms, generate high winds and low atmospheric pressure, pushing seawater onto land. Forecasting tools, such as Dalcoast (Dalhousie

University Coastal Ocean Prediction System), used by Environment Canada, help predict storm surge levels in Atlantic Canada. These models simulate coastal water movements under storm conditions, aiding in flood risk assessments and emergency preparedness. (The City of Charlottetown, personal communication, November 2024)

- With its shallow waters and extensive sandbars, the Northumberland Strait is particularly vulnerable to large surges (The City of Charlottetown, personal communication, November 2024).

Figure 14 shows that storm surges of up to 1.7 metres above predicted high tide have already been recorded in Charlottetown.

By the 2080s, climate models project an increase in storm intensity in the North Atlantic, meaning more frequent and severe tropical cyclones. This will significantly increase storm surge risks for PEI (The City of Charlottetown, personal communication, November 2024).

2050 Sea Level Rise and Storm Surge, Hazard Map

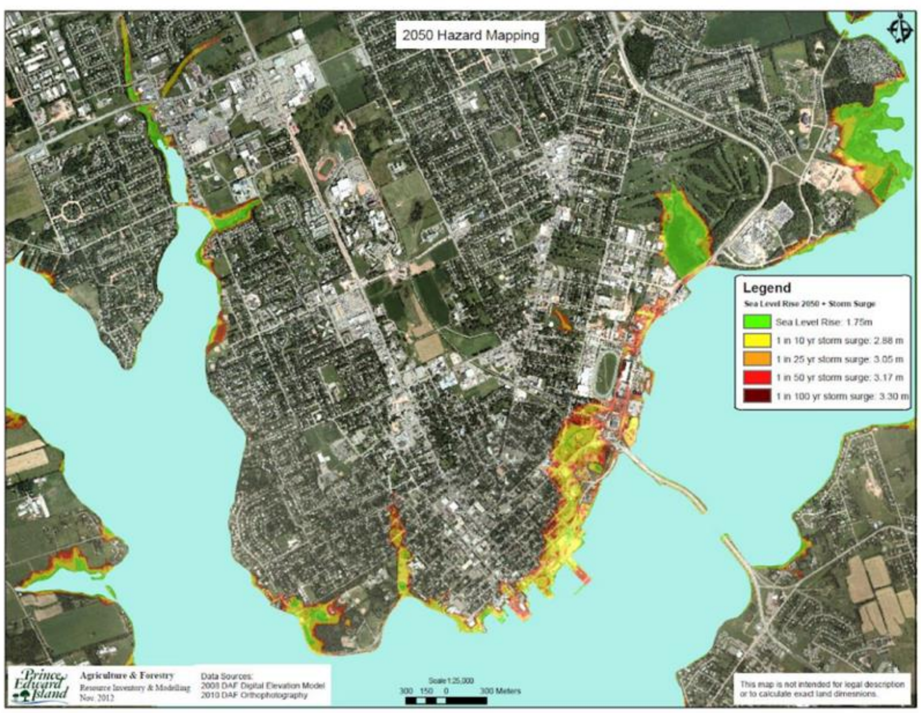
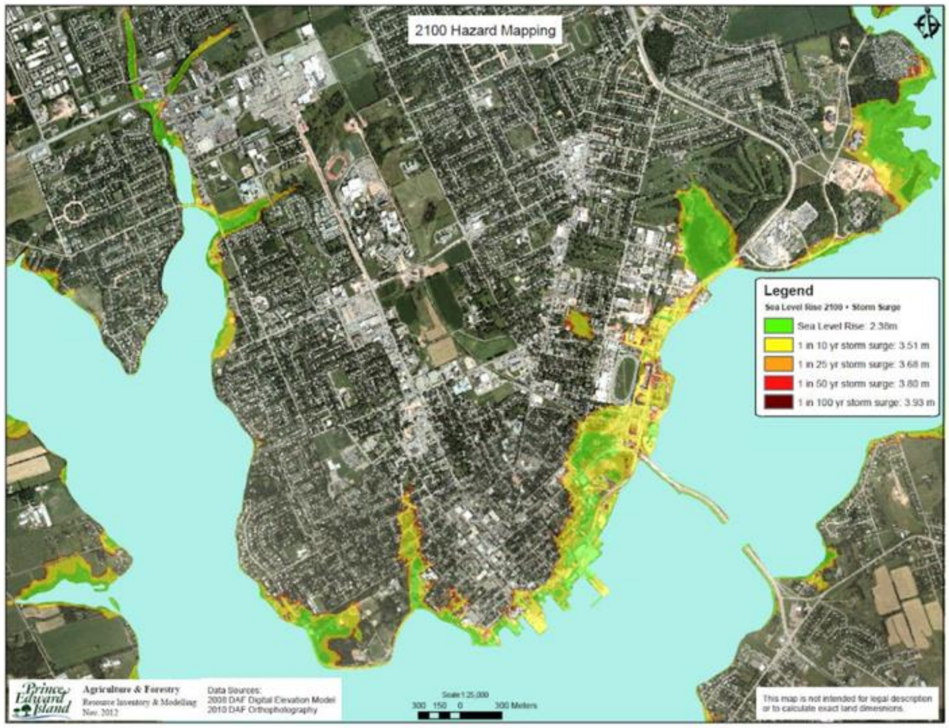


Figure 13: Projected Sea Level Rise and Storm Surge Hazard Mapping for Charlottetown in 2050, highlighting areas at risk of inundation (Oldfield & Bunker, 2019).

2100 Sea Level Rise and Storm Surge, Hazard Map



Source: Climate Change Secretariat, PEI

Figure 14: Projected Sea Level Rise and Storm Surge Hazard Mapping for Charlottetown in 2100, highlighting areas at risk of inundation (Oldfield & Bunker, 2019).

Coastal Flooding and Erosion Risks

Coastal flooding, triggered by storm surges, poses significant risks to coastal properties, infrastructure, and communities.

Currently:

- PEI’s coastal floodplain covers approximately 194 km² (~3% of the province’s total land area).
- Under a worst-case scenario for 2100, where the Greenland Ice Sheet significantly melts, coastal hazard zones could expand to 7% of the province’s land area. These areas would face increased flooding risks during storm surge events, with further expansion if sea level rise exceeds 0.65m, as some projections predict (Parnham et al., 2023).

Coastal erosion is another major consequence of rising sea levels, extreme weather, and storm surges. Stronger storms, larger surges, and reduced protective winter sea ice will accelerate shoreline loss, threatening coastal infrastructure (e.g., roads, buildings, utilities), coastal ecosystems and habitats, and public health and safety (Government of Prince Edward Island, 2024a).

Figure 15: Charlottetown Yacht Club Storm Surge, December 6, 2010 (The City of Charlottetown, November 2024).

Snapshot significant sea level rise and storm surge events in Charlottetown/PEI

To understand the costs of past events, this report uses CatIQ[xvi] to understand the insured losses of past events in Charlottetown.

Charlottetown has experienced multiple significant sea level rise and storm surge events, leading to coastal flooding, infrastructure damage, and shoreline erosion. This section highlights key historical events and their impacts.

2023 Hillsborough River High Water Event

This storm surge and high-water event on January 27, 2023, left storm and plant debris alongside the Confederation Trail in Glenroy (Figure 18). The Charlottetown Tide Gauge DFO station recorded a peak water level of 3.58m at 3:00 AM, making it the 12th highest water level recorded since 1911 (The City of Charlottetown, personal communication, November 2024).

Figure 16: Photo by John TeRaa at Confederation Trail, Glenroy, May 4, 2023.

2022 Hurricane Fiona Storm Surge

The post-tropical storm that hit PEI in September 2022, caused extensive damage due to high winds, large waves, and storm surge. Waves as high as 16 metres and storm surge lashed the north shore of the island along the Gulf of St. Lawrence. Damage to structures was largely concentrated along the Northumberland Strait. The surge shifted houses off their foundations in Stanley Bridge, Rustico, Covehead, and Tracadie and damaged them extensively. Significant portions of PEI's beaches were eroded along the north coast.[xvii]

For a more detailed breakdown of the financial costs and damage of this event, please refer to the Extreme Weather and Precipitation chapter.

2022 Eastern Canada Bomb Cyclone

In December 2022, a powerful low-pressure system brought with it strong winds and blizzard-like conditions. The event caused power outages, toppled trees and coastal flooding.[xviii]

For a more detailed breakdown of the financial costs and damage of this event, please refer to the Extreme Weather and Precipitation chapter.

2003 Hurricane Juan Storm Surge

When Hurricane Juan hit the Charlottetown area in 2003, the tide was low so coastal flooding was not a critical factor although wave action did some damage at Peake's Quay, Charlottetown Yacht Club, and other exposed areas along the Charlottetown waterfront.[xix]

1911 to 2000 Historical Storm Surges

Several storm surge events recorded between 1911 and 2000 provide insight into Charlottetown's vulnerability to extreme water levels:

- The largest storm surges recorded were 1.43 m (December 19, 1963) and 1.41 m (March 12, 1991). These two events occurred during low tide, preventing flooding of historical waterfront properties (The City of Charlottetown, personal communication, November 2024).
- However, six smaller storm surges between 1911–2000 coincided with high tide, resulting in coastal flooding. The maximum recorded water level from these events was 3.6 m or more above chart datum.
- Given the historic sea level rise rate of 3.2 mm/year since 1911, these past events would cause more severe flooding to the historical waterfront if they occurred today.[xx]

IMPACTS ON INFRASTRUCTURE AND NATURAL SYSTEMS

Relevant Localized Impact

The following localized impact identified through the vulnerability and risk assessment highlights the urgency of addressing infrastructure and natural systems vulnerabilities:

Impact 39: Increase in sea level rise and surge events causing increase in coastal erosion and damage to infrastructure and natural assets, resulting in increased economic costs, the prevention of coastal building and managed retreat, and risk to public health and safety.

Coastal regions in Canada are already experiencing significant impacts due to climate change. Rising sea levels, warming air and water temperatures, stronger storms, and reduced sea ice are some of the key environmental shifts affecting coastal communities (Lane et al., 2013). These impacts vary based on coastal geography, exposure to wind and waves, natural and built protections (e.g., beaches, dunes, seawalls, breakwaters), and proximity of infrastructure to hazardous areas (Simpson et al., 2012).

While some opportunities may emerge from climate shifts, the risks far outweigh them – particularly for infrastructure, transportation systems, and natural environments (Lemmen et al., 2016). Charlottetown is particularly vulnerable due to its low-lying geography and reliance on coastal infrastructure. Key risks include coastal erosion, flooding of homes and buildings, damage to transportation networks, and saltwater intrusion into groundwater supplies.

Direct Impact: Built Infrastructure

Sea level rise poses an increasing long-term threat to coastal communities, homes, and public infrastructure. As sea levels rise, storm surges reach further inland, increasing flood risks, eroding coastal foundations, and in extreme cases, permanently submerging low-lying areas (Oppenheimer et al., 2020).

Key Risks Include:

- More frequent flooding: High tides and storm surges will flood homes, roads, and essential services more often.
- Permanent loss of land: As shorelines continue to erode, some areas may require the relocation of buildings and infrastructure to safer locations, a process known as coastal retreat.
- Structural damage: Coastal buildings, highways, marinas, and port facilities will experience accelerated wear and damage.
- Increased infrastructure costs: Maintenance and repair costs for roads, seawalls, and drainage systems will escalate. (Oppenheimer et al., 2020)

Figure 17 below highlights the Atlantic coastal communities most at risk of sea level rise by 2100, including Charlottetown, which faces an estimated 152 cm of sea level rise.

Region	Community examples	SLR estimates to 2100[b]	Population[c]	Population density (people/km^2)
Acadian Peninsula / Chaleur Region (NB)	Gloucester County (Beresford, Bathurst, Le Goulet, Shippagan, Sainte-Marie-Saint-Raphael, Bas Caraquet, Maisonnette)	148 cm	78,256	16.5
Northumberland Strait (NB/PEI)	Shediac (NB)	146 cm	7535	117.7
	Pointe-du-Chêne (NB)	146 cm	767	333.3
	Summerside (PEI)	146 cm	16,001	567.2
	Borden-Carleton (PEI)	146 cm	1600	60.9
	Victoria (PEI)	148 cm	226	59.0
	Charlottetown (PEI)	152 cm	38,809	42.2
Chignecto Isthmus (NB/NS)	Amherst (NS)	148 cm	9404	2.8
	Sackville (NB)	148 cm	6099	82.5
Atlantic Coast (NS)	Lunenburg County (Lunenburg, Mahone Bay)	157 cm	48,599	16.7
	Halifax County	164 cm	440,072	80.3
	Richmond County (Cape Breton)	175 cm	8914	7.2
Gulf of St. Lawrence	Souris (PEI)	157 cm	1079	299.0

Figure 17: Atlantic Coastal Communities Most Exposed to Sea Level Rise (Wade and CLIMAtlantic, 2022b).

Charlottetown is among the communities most vulnerable to sea level rise in Atlantic Canada. Approximately 600,000 people in the Atlantic region live within 20 km of the coastline, with those at sea level at greatest risk of storm surges and flooding, and those on cliffs more exposed to erosion (Wade and CLIMAtlantic, 2022b).

By 2100, Canada could lose 6,400 to 14,400 km of sandy beach coastline due to coastal erosion permanently altering natural landscapes and putting thousands of structures at risk.

According to David Stonham (2016) more than 2,000 buildings in PEI are currently at risk of flooding during a storm surge. This number will rise as sea levels increase. The table below illustrates the number of buildings that will be vulnerable to different levels of storm surge (Stonham, 2016).

According to the University of Prince Edward Island's Climate lab, within PEI alone, erosion threatens 1,000+ homes, 450 outbuildings, and 17 historic lighthouses (The Canadian Press, 2024).

Table 4: Number of Buildings Vulnerable in PEI During Storm Surge Events (including current metrics at 0m and scenarios predicted during 1, 2, and 3 m storm surge events).

Storm Surge Sea Level Rise (metres)	Number of buildings vulnerable
0	2,215
1	3,510
2	4,623
3	5,634

Projected Flooding in Charlottetown

Within Charlottetown, Climate Hazard and Risk Information System (CHRIS) data provides flood risk projections for 2050 and 2100, identifying the total land area and structures at risk as sea levels rise.

Table 5: Projected Flood Zones and At-Risk Structures in Charlottetown (The City of Charlottetown, personal communication, November 2024).

Year	Flood Zone Area (ha)	Municipal Structures at Risk	Total Structures at Risk
2020	107.175	22	213
2050	130.95	27	320
2100	195.51	36	553

As seen above, by 2050, flooding will threaten 130.95 hectares of land in Charlottetown, with 320 total structures at risk. By 2100, this increases to 195.51 hectares, impacting 553 structures, including 36 municipally owned buildings (The City of Charlottetown, personal communication, November 2024).

These numbers illustrate the growing urgency for adaptation measures, including coastal defenses, flood-resistant infrastructure, and land-use planning to prevent catastrophic losses.

Direct Impact: Natural Systems

Coastal ecosystems, spanning both terrestrial and marine environments, play a critical role in maintaining ecological balance. They provide essential habitats for biodiversity, support fishing, shellfish harvesting, and tourism, and buffer inland areas from severe weather events such as storms and waves. Features such as wetlands, dunes, barrier islands, and estuaries help stabilize coastlines by absorbing wave energy and facilitating nutrient exchange between land and sea (Savard et al., 2016).

However, climate change and sea level rise are rapidly altering these environments, causing habitat loss, saltwater intrusion, and accelerated erosion.

Coastal Squeeze and Habitat Loss

As sea levels rise, coastal ecosystems must migrate inland to maintain their functions. However, in many areas, human development (e.g., roads, buildings, seawalls) and natural barriers prevent this migration. This phenomenon, known as coastal squeeze, reduces available habitat and weakens natural coastal defenses (Savard et al., 2016).

- Salt marshes, dunes, and beaches are particularly vulnerable to displacement.
- In areas where sediment supply cannot keep up with sea level rise, wetlands and intertidal zones may be permanently submerged.
- Loss of these ecosystems results in reduced storm buffering, flood mitigation, and wildlife habitats. (CLIMAtlantic, 2024)

Saltwater Intrusion and Groundwater Contamination

Saltwater intrusion is an increasing concern for coastal freshwater resources. As seawater advances inland, it contaminates groundwater supplies, affecting drinking water sources. This is particularly concerning for PEI, where many residents rely on wells and groundwater (Savard et al., 2016). Higher salinity disrupts coastal plant and animal life, particularly in salt marshes and forests. Certain plant species cannot tolerate rising salinity, leading to shifts in ecosystem composition (Atkinson et al, 2016).

Coastal Dune Erosion and Instability

Coastal dunes act as natural seawalls, absorbing storm surge energy and protecting inland areas. However, sea level rise, storm surges, and reduced winter sea ice are accelerating dune erosion across PEI.

- Dunes along PEI's north shore have taken nearly a century to recover from past storm damage.
- Some regions, like Tracadie Bay, remain unable to redevelop dunes, leaving shorelines exposed.
- Increased erosion limits dunes' ability to regenerate, reducing their long-term protective function (Atkinson et al, 2016).

Coastal Erosion and Landward Retreat

Soft and erodible coastlines, including sandy beaches and salt marshes, are particularly vulnerable to wave action and storm surges. These areas naturally retreat inland, but in some locations, erosion rates are outpacing natural recovery.

- Sandy shorelines often re-establish after storms, but bluffs and cliffs cannot regenerate, leading to permanent land loss.
- Increased wave energy and storm intensity accelerate erosion, reducing available sediment to replenish beaches and dunes.

The table below details observed coastal retreat rates in PEI, highlighting areas experiencing significant erosion.

Table 6: Coastal Retreat Rates in PEI (Savard et al., 2016).

Location	Retreat Rate	Time Period	Reference
Prince Edward Island — Sandstone and till, entire island	0.28 m/year (average)	1968–2010	(Webster, 2012)
Prince Edward Island — Till bluffs, Gulf of St. Lawrence coast	Up to 2.24 m/year	1935–1990	(Forbes and Manson, 2002)
Prince Edward Island — Till bluffs, Northumberland Strait coast	0.74 m/year (average)	1935–2000	(O'Carroll, 2010a)

In addition, the anticipated effects of sea level rise and storm pattern changes on Atlantic coastal areas are summarized in Figure 18 below (Savard et al., 2016).

Coastal feature	Impacts
Beaches	Large-scale morphological adjustments to absorb the wave energy, including: ▪ overwash and erosion ▪ potential formation of new beaches down-drift of erosion areas ▪ landward migration of barrier beaches
Salt marshes	More frequent tidal flooding Sedimentation and possible landward migration at a rate equal to sea-level rise, depending on sediment and organic matter supply Increased margin-edge erosion (van Proosdij et al., 2006) Changes in carbon storage (Chmura, 2011)
Fresh-water marshes	Gradually become salt marshes or migrate inland
Estuaries and tidal rivers	Increased tidal volume and exchange Further penetration of saltwater
Unconsolidated cliffs	Accelerated erosion
Species and ecosystems	Modification of coastal habitats Threatened viability from changes in numerous factors, including water temperature, salinity, sea-ice patterns, runoff and water quality

Figure 18: Anticipated Coastal Effects of sea level rise in Atlantic Canada (Savard et al., 2016).

Coastal ecosystems provide essential protection and economic benefits, but they face growing threats from sea level rise, erosion, and saltwater intrusion. Without adaptation strategies such as coastal restoration, managed retreat, and infrastructure modifications, these vital systems will continue to degrade, increasing risks for both natural and human communities.

Indirect Impacts

Sea level rise has far-reaching implications beyond direct damage to coastal infrastructure. It poses serious risks to public health, essential services, housing stability, and local economies, with disproportionate effects on vulnerable communities.

Public Health Risks

As flooding and storm surges become more frequent and severe, health risks escalate:

- Injuries, drownings, and waterborne illnesses increase in low-lying and high-risk coastal areas.
- Mold growth and indoor air quality decline as homes suffer repeated flood damage (Wade and CLIMAtlantic, 2022a).
- Saltwater intrusion into groundwater threatens freshwater resources, particularly in regions dependent on wells for drinking water (Wade and CLIMAtlantic, 2022).
- Compromised wastewater infrastructure can lead to the spread of pathogens and contaminants.
- Mental health challenges, including anxiety and depression, stemming from uncertainty, property loss, and forced relocation (Wade and CLIMAtlantic, 2022a).

These health impacts are amplified in communities with pre-existing socio-economic disparities, where access to healthcare and adaptation measures is often limited.

Economic and Social Disruptions

The effects of rising seas extend beyond infrastructure and health to economic stability, employment, and community well-being (Wade and CLIMAtlantic, 2022a). These include those such as:

- Loss of livelihoods in tourism, fisheries, and coastal industries due to erosion, flooding, and property damage.
- Housing displacement as storm surges and high-water levels encroach further inland, rendering some areas uninhabitable.

Managed Retreat as an Adaptation Strategy

As coastal flooding becomes more severe, managed retreat is gaining attention as a proactive strategy. This approach involves relocating, abandoning, or restricting development in high-risk areas to reduce long-term financial, environmental, and social losses. Key methods include (Parnham, 2023):

- Building restrictions and setbacks to prevent new developments in flood-prone zones.
- Government-led buyouts of at-risk properties to prevent repeat flood damages.
- Land-use planning and zoning regulations that discourage construction in hazard-prone areas.

One example is a 2018 buyout program in Grand Forks, British Columbia, where the municipal, provincial, and federal governments collaborated to permanently relocate properties after a 1-in-200-year flood. A cost-benefit analysis of the program showed a 3.4:1 return on investment, reinforcing that proactive adaptation can be financially advantageous (O'Toole, 2024).

Case Study: Financial Benefits of Adapting to Sea Level Rise in Quebec and Atlantic Canada[xxi]

To better understand the financial implications of sea level rise adaptation, the federal government conducted a cost-benefit analysis (CBA) of adaptation measures at 11 case study sites across Quebec and Atlantic Canada. The study included two locations in PEI: North Cape Coastal Drive and Provincial Park and Tracadie Small Craft Harbour and Road.

The study aimed to assess whether adaptation actions would reduce future climate-related economic damages from coastal flooding and erosion compared to a "without project" scenario in which no additional adaptation measures were implemented.

The analysis assessed the costs of adaptation actions (such as planned retreat, elevating buildings, and shoreline protection) against the projected economic damage costs if no action was taken over a 50-year period (2015–2064). This "without project" scenario assumed no additional adaptation or socioeconomic shifts, providing a baseline comparison for understanding the financial risks of inaction.

Key Findings:

- In 59% of cases (27 out of 46 coastal segments analyzed), adaptation resulted in net economic gains, meaning the long-term benefits of intervention outweighed the costs.
- The most effective strategies varied by location but often involved a combination of engineering solutions (e.g., breakwaters, flood barriers) and preventative strategies (e.g., zoning restrictions, property buyouts), rather than relying solely on seawalls.
- The study reinforced that locally tailored, proactive adaptation is both necessary and financially sound, as delaying action significantly increases long-term costs.
- The choice of adaptation strategy was highly site-specific, demonstrating that there is no single best approach—success depends on local environmental, economic, and social factors.

For a detailed breakdown of this case study, please refer to *Costs and Benefits of Climate Change Impacts and Adaptation; Chapter 6 in Canada in a Changing Climate*: *National Issues Report* by Boyd and Markandya (2016).

Economic Implications – Infrastructure and Natural Systems

Flooding is the leading cause of loss and damage to homes, buildings, and infrastructure in Canada. With climate change increasing both sea levels and rainfall intensity, 100-year rainfall events are expected to become 25- to 10-year events, or sooner, leading to a significant rise in flood damages (Ness et al., 2021).

In 2021, annual damages from coastal and inland flooding were estimated at $1.3 billion. By mid-century, damages from flooding could increase fivefold, and by 2100, costs could reach $13.6 billion annually (Ness et al., 2021).

Without adaptation, growing financial risks will place significant pressure on already strained infrastructure budgets, diverting resources away from critical needs such as housing, transportation, and food and water security (Ness et al., 2021).

Rising Costs Without Adaptation

Between 2005 and 2014, flood-related costs across Canada, spanning government, insurance, and private sector expenses, exceeded $12 billion. Without intervention, these costs are expected to increase significantly. A study in Halifax estimated that annual flood-related losses could triple by the end of the century under a high-emissions scenario (Ness et al., 2021).

For coastal flooding specifically, high-end projections estimate that:

- Annual damages could reach $750 million in a low-emissions scenario.
- Annual damages could exceed $1.2 billion in a high-emissions scenario, a 12- to 20-fold increase over current levels.
- Cumulative losses from coastal flooding from 2011 to 2100 could reach $380 billion (in 2008 dollars) (Boyd and Markandya, 2021).

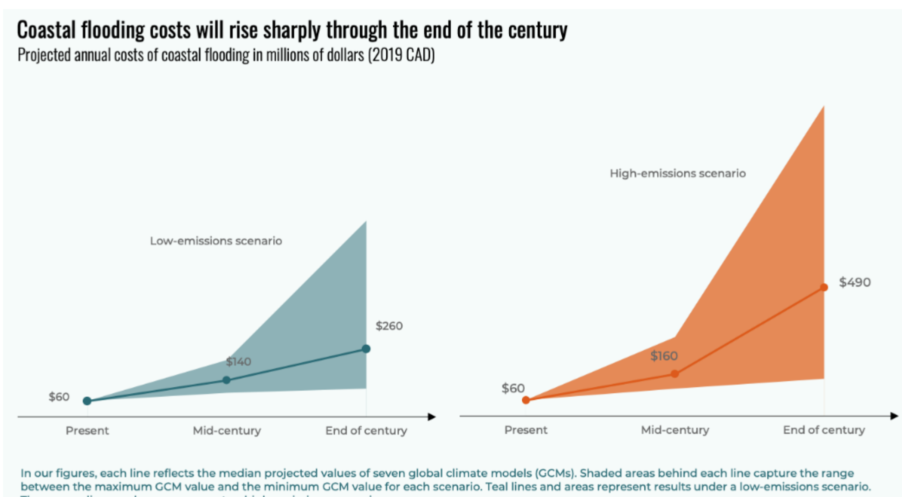


Figure 19: Projected Coastal Flooding Costs by 2100 (Ness et al., 2021).

Figure 19 illustrates the projected increase in annual coastal flooding costs, demonstrating how flood-related damages will rise sharply through mid-century and beyond under both low- and high-emissions scenarios.

Within Canada, some projections suggest that flood-related losses from coastal properties could consume half of annual GDP growth by 2050 (Ness et al., 2021).

In PEI alone, annual coastal flooding losses attributable to climate change are projected to reach $5 million by 2050 in a low-emissions scenario and $55 million by 2050 in a high-emissions scenario (Boyd and Markandya, 2021).

Infrastructure and Insurance Risks

Infrastructure owned by individuals and businesses will also bear increasing costs. Annual flood-related damages to private property are expected to rise by $4.5 to $5.5 billion within 30 years, nearly four times today's costs (Ness et al., 2021).

However, many Canadians remain unaware of their exposure. Nearly 45% of homeowners believe their insurance covers flood damage, while in reality, only 10-15% have sufficient coverage.

Models by Ness et al. (2021) project:

- 950,000 mapped buildings (8% of total) in Canada are in a 100-year flood risk zone
- 550,000 buildings (5%) are in a 20-year flood risk zone

Building the Case for Investment

As sea levels rise, some coastal areas may face permanent inundation, leading to irreversible property devaluation. Taking proactive action, such as restricting development in high-risk areas and relocating existing structures, could reduce annual coastal flooding costs by up to $1 billion or cut damages by 90% by 2100 (Ness et al., 2021).

Unlike many jurisdictions where government flood maps are over 20 years out of date and fail to account for projected climate change impacts, PEI has a significant advantage with access to the Coastal Hazard Risk Information System (CHRIS) platform. CHRIS provides high-resolution, up-to-date flood risk data, including projections for sea-level rise, storm surge impacts, and coastal erosion. This advanced resource equips policymakers, businesses, and residents with the information needed to make strategic, evidence-based investments in climate adaptation.

By leveraging and building upon this data, Charlottetown has the opportunity to take a leadership role in coastal resilience, prioritizing investments in proactive adaptation measures that can prevent costly future damages. Figure 20 highlights the substantial cost savings that can be achieved through such measures, demonstrating how flood-related losses can be significantly reduced through strategies like development restrictions, elevation, and coastal protection (Ness et al., 2021). Investing now in evidence-driven solutions will ensure protection of valuable coastal assets and reduce long-term financial burdens on the municipality and property owners.

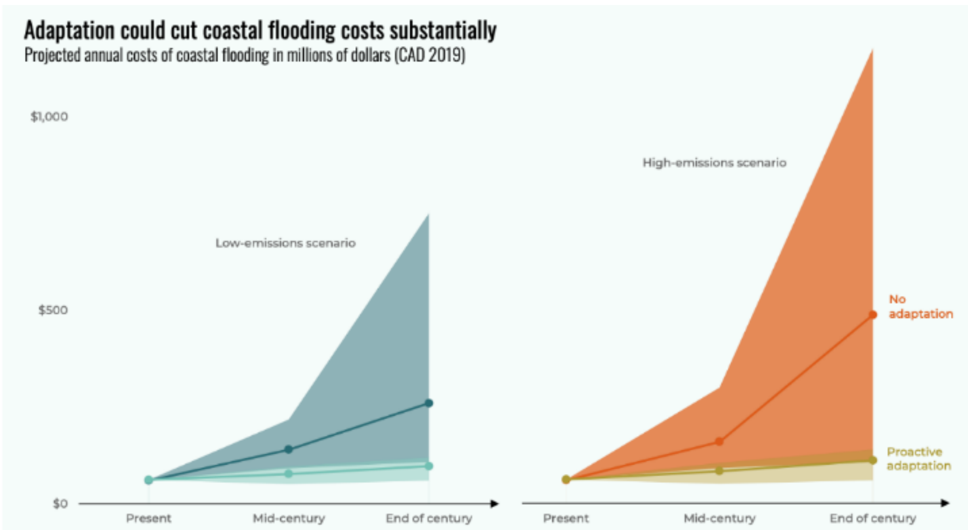


Figure 20: Cost Reduction Through Adaptation (Ness et al., 2021).

CHAPTER 3: EXTREME HEAT

WHAT TO KNOW ABOUT THIS HAZARD

Climate change is driving significant temperature increases across Canada, with Atlantic Canada already experiencing warming over the past 50 years. If emissions continue at current rates, PEI's annual average temperature is projected to rise by 4.2°C by the end of the century (City of Charlottetown, 2023). Downscaled climate models suggest incremental increases of 0.7°C by the 2020s, 1.6°C by the 2050s, and 2.4°C by the 2080s. These changes will have profound effects on PEI's environment, economy, and society (Arnold and Fenech, 2017).

Extreme heat events – defined as extended spells of high temperatures, often described as days over 30°C – are expected to increase in frequency, severity, and duration, particularly under high-emission scenarios. Extreme heat is the most well-documented climate hazard linked to negative health outcomes and increased mortality, though thresholds and duration vary across the country (Gosselin et al., 2022).

Temperature extremes in PEI will shift significantly. Defined by Arnold and Fenech (2017) as days above 27.5°C, the average number of extreme heat days is expected to rise from eight per year to 16 in the 2020s, 22 in the 2050s, and 35 in the 2080s. Meanwhile, extreme cold days (below -20°C) will decline from six per year to five in the 2020s, four in the 2050s, and three in the 2080s (Arnold & Fenech, 2017).

Future Projections for Extreme Heat in Charlottetown

Temperature Extremes

The baseline average number of days when the maximum temperature (TMax) was greater than or equal to 30°C was one day for Charlottetown. This is expected to increase to an average of 14 days, with a possible range in any given year of seven to 29 days under the SSP5-8.5 scenario, as shown in Figure 23.

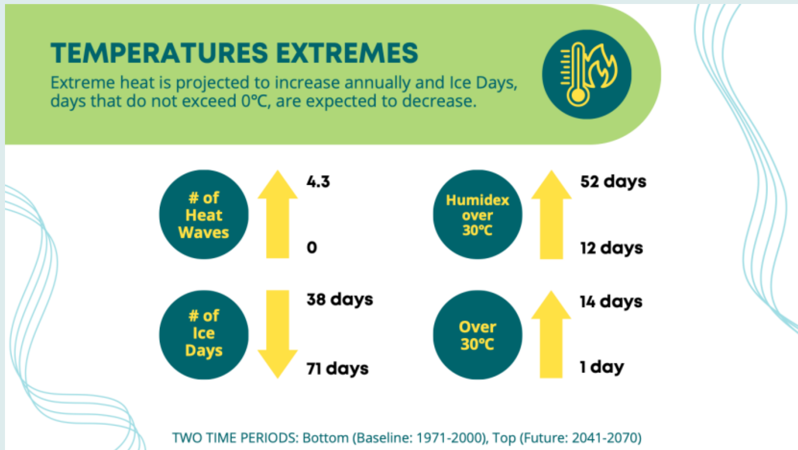


Figure 21: Infographic from the City of Charlottetown Climate Science Report on projected temperature extremes (present to 2080).

Heat Waves

The Government of Prince Edward Island defines a heat wave as “two or more days in a row with daytime highs expected to reach 28°C or warmer and nighttime falling to 18°C or warmer; or two or more days in a row of humidex values expected to reach 36°C or higher.”[xxii] The baseline number of heat waves for Charlottetown is 0. In the 2041-2070 period according to SSP5-8.5, Charlottetown can expect to experience 4.3 heat wave events per year.

With regards to the average length of heat waves (in days), Charlottetown experienced an average of 0.1 days of heat wave conditions in the baseline period. In the 2041-2070 period, Charlottetown can expect an average heat wave event length occurring for 20.3 days.

Overall, heat waves will occur more frequently and last longer, leading to more extreme heat events in the City (Figure 23).

Snapshot of past significant extreme heat events in Charlottetown and PEI

To understand the costs of past events, this report uses CatIQ[xxiii] to understand the insured losses of past events in Charlottetown.

SIGNIFICANT EXTREME HEAT EVENTS

September 2024 Heat Wave

On September 17-18, temperatures peaked into the high 20s, with a humidex in the low 30s. Charlottetown measured a peak daytime high of 27.1°C[xxiv], creating unbearably hot conditions in many schools, many of which lack formal policies for heat operations or closures.[xxv]

July 2024 Back-to-Back Heat Waves

PEI endured two consecutive heat waves in July, beginning with daytime highs of 28–29°C on July 8, followed by three days of lingering heat around 26°C, with humidex values climbing into the high 30s. Just days later, a second wave brought temperatures over on 29°C on July 14–15, with a humidex of 36°C. Residents were advised to remain prudent and take all precautions to guard against heat exhaustion and heat stroke.[xxvi]

June 2024 Heat Wave

From June 18–20, hot and humid conditions gripped PEI, with regional temperatures averaging 26.1°C, which is 10.6°C above normal. On June 20, Charlottetown set a new heat record at 32°C, surpassing the 2001 record of 28.5°C[xxvii]. Humidex values in some areas pushed past 40°C, breaking past records.[xxviii] This prompted. the PEI Home and School Federation to call for updated school policies on heat-related closures. Some classrooms reportedly reached 36°C in some schools.[xxix]

July 2022 Five-Day Heat Wave

A five-day heat wave swept across PEI beginning July 22, with three consecutive days surpassing 30°C and humidex levels nearing 40°C. On July 24, temperatures at Charlottetown Airport hit 30.9°C, breaking previous records. Even after the peak, heat lingered at 26°C through July 26[xxx], forcing some businesses to close.[xxxi] Pride PEI's annual parade, held at the height of the heat wave, took place under the full noon-hour sun, putting participants at risk of heat-related illness. [xxxii]

August 2021 Heat Warning

A heat warning was issued August 12-14, with temperatures ranging from 27–30°C and a humidex of 34 to 37°C.[xxxiii] Temperatures reached 30°C on August 14, disrupting Old Home Week operations. Extreme temperatures forced organizers to cancel petting zoo activities and horse wagon rides to protect animal welfare.[xxxiv]

June 2021 Heat Wave

PEI saw temperatures surge to 30°C on June 6, with a humidex of 37°C, followed by 29.9°C and a humidex of 38°C on June 8. [xxxv] [xxxvi] With many schools lacking air conditioning, overheated classrooms prompted the PEI Teachers' Federation to endorse school closures in the future under such conditions. In neighbouring towns, it was reported that students at Montague Intermediate School jumped off the bridge into the Montague River to keep cool.[xxxvii]

July 2019 Heat Wave

A four-day heat wave struck PEI starting July 28, with temperatures peaking at 30.3°C, breaking the 1949 record of 30°C. [xxxviii] Humidex values climbed into the mid-30s, and nighttime lows never dropped below 18°C, offering little relief. [xxxix] Without air conditioning, indoor temperatures soared to 35°C, forcing residents and workers to rely on shade, fans, and water to cope with the extreme heat.[xl]

August 2018 Seventeen Day Hot Spell

From July 23–August 8, PEI endured its longest heat streak since 1967, with heat warnings in place for all but one day.[xli] Maximum temperatures averaged 27.7°C, with Charlottetown Airport hitting 29.9°C on August 1. Overnight lows hovered around 19.2°C, offering minimal relief.[xlii] Humidex values remained in the mid-to-high 30s[xliii], occasionally surpassing 40°C. [xliv]

July 2018 Heat Warning

A heat warning was issued July 8, with daytime highs of 29°C and humidex values over 30°C. Nighttime lows stayed above 18°C, and warm temperatures persisted until a cold front brought relief two days later.[xlv] Combined with another heat spell in late July, this month was confirmed as the warmest July since 1940.[xlvi]

IMPACTS ON HEALTH AND SAFETY

Relevant Localized Impact

The following localized impacts identified through the vulnerability and risk assessment highlight the urgency of addressing infrastructure vulnerabilities:

Impact 4: Increase in the frequency/duration of hot days (>30 °C) causing heatwaves and reduced air quality, leading to health and safety risks (e.g. heat stress, mental health issues, domestic violence/violent altercations, cardiovascular disorders, food-borne/water-borne illnesses, etc.) especially to vulnerable populations (e.g. outdoor workers, seniors, women, children, those with chronic health conditions, temporary foreign workers, those without AC, etc.)

Direct Impact: Health and Safety

As extreme heat events become more frequent and prolonged, the risks to physical and mental health will intensify. Prolonged exposure to extreme heat is linked to increased hospitalizations, reduced worker productivity, and disruptions to essential services. The impacts are particularly severe for vulnerable populations who face barriers to cooling, medical care, and safe indoor environments. Addressing these risks requires both immediate interventions and long-term adaptation strategies to protect community well-being.

Physical Health

Traditionally, cooler nights have helped mitigate daytime heat, but tropical nights (i.e. when temperatures remain above 18°C, as defined by ClimateData.ca (n.d.)) are becoming more frequent, prolonging heat exposure. The increasing intensity, duration, and frequency of heat events can have immediate and long-term health consequences, including heat exhaustion, heat stroke, and even fatalities (The Lancet, 2021).

Globally, heat-related deaths reached 356,000 in 2019, making extreme heat one of the most lethal climate hazards (The Lancet, 2021).

Canada has already experienced deadly heatwaves:

- Quebec (2010 and 2018): 291 and 86 deaths, respectively.
- British Columbia (2021 Heat Dome): 619 deaths, with socio-economic factors such as lack of green space, older age, and sex influencing mortality rates (British Columbia Coroner Service, 2022; Henderson et al., 2022).

Extreme heat also exacerbates air pollution, aggravating conditions for those with respiratory and cardiovascular diseases, and can lead to an increase in admissions for cardiovascular issues and pregnancy complications.

Vector-Borne Diseases

As temperatures rise and seasonal patterns shift, ticks and mosquitoes are expanding their range, increasing the risk of vector-borne diseases such as Lyme disease and West Nile virus. Milder winters and longer shoulder seasons allow these disease-carrying species to persist in new areas, extend their activity periods, and increase transmission risks (Alberta Health, 2019).

- Ticks, particularly deer ticks (*Ixodes scapularis*), thrive in temperatures above 4°C and are already expanding northward into southwestern, south-central, and southeastern Canada. Warmer conditions enable ticks to remain active earlier in the spring, later into the fall, and even during winter warm spells, increasing Lyme disease transmission risks.
- Mosquitoes benefit from wetter conditions and prolonged warm seasons, raising concerns over West Nile virus, Eastern Equine Encephalitis, Jamestown Canyon virus, and snowshoe hare virus. Standing water and high humidity create ideal breeding conditions, extending the period when humans and animals are exposed to these diseases.
- Fewer ice days (when temperatures stay at or below 0°C) disrupt natural population controls, allowing more ticks to survive winter and prolonging transmission seasons for Lyme disease and other infections (Alberta Health, 2019).

Canada is already experiencing a rapid rise in Lyme infections linked to climate change. Vulnerable groups, including immunocompromised individuals, seniors, children, and marginalized populations, face heightened risks. The increasing burden of vector-borne diseases is expected to strain healthcare systems, disrupt workplaces due to rising worker absenteeism, and create financial pressures on governments, health services, and employers (Public Health Agency of Canada, 2023).

Mental Health

Extreme heat not only strains physical health but also has profound effects on mental well-being and social behavior. Climate change is compounding mental health risks, exacerbating existing conditions such as anxiety, post-traumatic stress disorder, and climate-related distress. The Canadian healthcare system is already facing increasing mental health costs, and without adequate adaptation, this burden is expected to grow (Berry & Schnitter, 2022).

Higher temperatures have been linked to increased aggression and interpersonal violence, including domestic violence. Research shows that a one standard deviation increase in temperature can lead to a 4% rise in interpersonal violence and a 14% increase in group violence (Psychiatric Times, 2023).

Expanding community support systems, improving access to mental health resources, and ensuring heat adaptation measures can help reduce these growing risks.

Economic Implications – Health and The Workforce

Extreme heat events have far-reaching economic consequences, affecting public health, workforce productivity, and infrastructure resilience. The rising frequency and intensity of heatwaves will increase costs for healthcare systems, disrupt business operations, and reduce economic output—placing significant financial strain on local governments, businesses, and workers.

Without adaptation, the financial burden of heat-related illness and infrastructure disruptions will continue to rise. The Health of Canadians in a Changing Climate report (Berry & Schnitter, 2022) highlights the growing economic toll of climate-related health impacts, particularly from extreme heat events. As heatwaves become more frequent and severe, their financial costs will escalate across healthcare, labour productivity, and municipal budgets.

The Climate Risk Institute projects that, under low- and high-emissions scenarios, annual national health-related expenditures due to climate change will reach:

- **$3.0 billion – $3.9 billion** by mid-century, and
- **$5.2 billion – $8.5 billion** by the end of the century (CICC, 2021).

Case Study: The 2021 Heat Dome in British Columbia

The 2021 heat dome in British Columbia provides a stark example of how extreme heat strains healthcare systems (Beugin et al., 2023). Based on the Figure below:

- 530 additional hospital admissions, costing an estimated **$8 million** in healthcare expenses.
- 619 excess deaths, with emergency response and immediate healthcare costs reaching **$4 million** ($7,028 per person)

During this event, hospital admissions surged for dehydration, acute kidney failure, diabetic complications, neurocognitive disorders, pneumonia, and heatstroke—all linked to extreme heat exposure. Heatstroke alone saw a **16,876% increase**, emphasizing the deadly nature of extreme temperatures.

Illness	Per cent change from baseline (number of excess hospitalizations for B.C.)	Average acute bed length of stay (days)	Average cost of hospitalization per patient
Dehydration	136% increase (88)	3.8	$4,892
Acute kidney failure	45% increase (147)	6.4	$9,183
Diabetic ketoacidosis with coma	285% increase (4)	5.3	$5,739
Neurocognitive disorders*[11]	33% increase (94)	12.7	$14,513
Pneumonia	25% increase (40)	6.0	$8,718
Hepatorenal syndrome	170% increase (5)	7.9	$10,458
Heatstroke	16,876% increase (511)	5.8	$10,317

Figure 22: Illnesses requiring hospitalization that increased during the heat wave (Beugin et al., 2023).

Labour Productivity Losses

Extreme heat reduces workforce efficiency, leading to increased errors, slower output, and higher absenteeism. Workers in outdoor, construction, manufacturing, and agricultural sectors are especially vulnerable, facing greater risks of heat stress, dehydration, and fatigue. High temperatures also impair cognitive function and decision-making abilities, leading to productivity losses even in indoor settings without adequate cooling. These workforce disruptions translate into significant financial losses.

Projections by the Climate Risk Institute (Clark et al., 2021) show that by mid-century, Canada is projected to **lose $5.4 billion** in annual productivity due to heat stress, with this figure reaching **$14.8 billion** by the end of the century – equivalent to **128 million lost work hours** or 62,000 full-time jobs annually.

These productivity declines affect businesses, government revenues, and workers themselves, leading to reduced economic output, lower wages, and increased operational costs. As extreme heat events become more frequent, both public and private sectors will face rising adaptation costs to maintain workforce efficiency and economic stability.

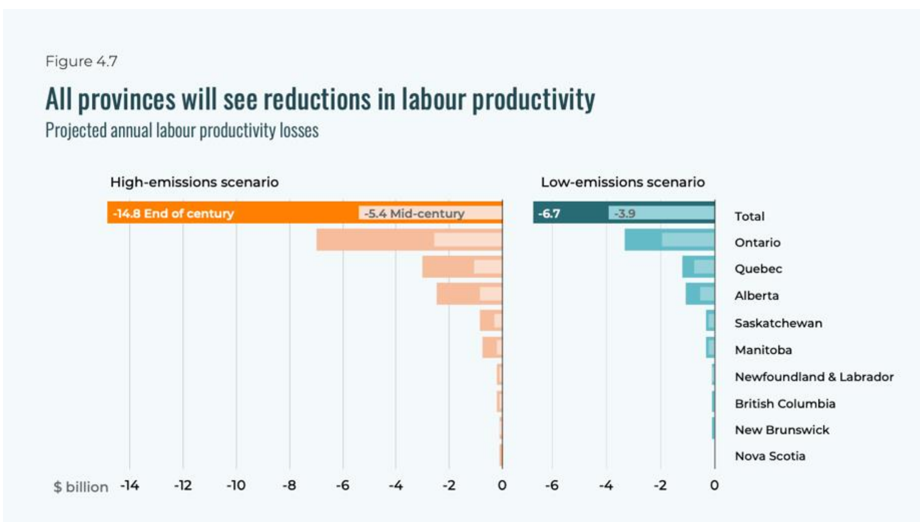


Figure 23: Provincial labour productivity reductions in low- and high-emissions scenarios. (CICC, 2021)

Costs of Vector-Borne Diseases

Quantifying the economic toll of vector-borne and emerging infectious diseases is complex, but the costs include emergency care, hospitalizations, laboratory testing, physician time, and administrative expenses. Research by Shing et al. (2019) shows:

- West Nile Virus can cost an average of **$13,648 per patient** over a year.
- Lyme disease costs **$832 per patient**, though indirect costs from missed work, prolonged illness, and complications drive up overall economic impacts.

Beyond direct healthcare costs, wider socio-economic losses include workforce absenteeism, reduced productivity, extended illness, and premature mortality. As tick and mosquito populations expand due to climate change, these financial pressures on healthcare systems and employers will only grow.

The Case for Investment

As Charlottetown faces the growing impacts of climate change, the financial, social, and environmental costs of inaction are becoming increasingly evident. Extreme weather, flooding, heatwaves, and the degradation of natural systems are already straining the city's infrastructure, public health, and essential services. The findings from this report make a compelling case for investing in proactive adaptation measures, as the "cost of doing nothing" is far greater than the cost of taking action. By investing in resilient infrastructure, restoring natural assets, and enhancing emergency preparedness, Charlottetown can prevent future damage, safeguard public health, and reduce economic disruptions.

These insights directly will feed into the City's Climate Action Plan and will help shape future planning, development, and engagement efforts in Charlottetown. By prioritizing climate resilience and strategic adaptation, the City can ensure a sustainable, thriving future that minimizes risks and maximizes long-term benefits. Investing now will protect Charlottetown's built and natural environment, securing its prosperity in the face of a rapidly changing climate.

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