Prince Edward Island (PEI) Climate Change Risk Assessment

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FINAL

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Glossary

- **Adaptive capacity:** Inherent traits of the system or individual assets, institutions, populations, or species in question that make it more or less susceptible to impacts from the climate risk event, including actions the Government of PEI or other stakeholders are already taking to address risk.
- **Climate driver:** Fundamental changes in climate that create climate hazards.
- **Climate hazard:** A potentially damaging event or phenomenon, resulting from climate drivers, that would consequently result in major impacts to the province, such as loss of life or injury, environmental degradation, infrastructure damage, or social and economic disruptions [15].
- **Climate hazard scenario:** For a given climate hazard, a plausible set of specific circumstances such as location affected, time frame, and severity of hazard, to facilitate evaluation of likelihood and consequences.
- **Consequence:** A measure of the severity of impacts from a climate hazard scenario.
- **Consequence category:** The dimensions on which consequence are evaluated (e.g., health, economy, environment, social stability, infrastructure)
- **Discrete climate hazard:** A climate hazard related to an individual extreme event (e.g., storm) or disaster that occurs over a relatively short period of time (e.g., days or weeks).
- **Likelihood:** The probability or expected frequency a climate hazard scenario is expected to occur.
- **Ongoing climate hazard:** A climate hazard related to a phenomena or gradual change in climate that occurs over many years (e.g., sea level rise).
- **Risk:** The chance that a hazard will cause harm. Risk is a function of the likelihood of an adverse impact occurring and the severity of its consequences [15].

Executive Summary

Climate change presents a great challenge to the current way of life on Prince Edward Island (PEI), affecting communities, the environment, and the economy. The Province of PEI has already taken steps to understand and prepare for climate challenges through efforts such as the *Climate Change Action Plan 2018–2023*[1] and the *PEI Climate Change Adaptation Recommendations Report,*[2] which was commissioned by the Province and produced by the University of Prince Edward Island (UPEI). To build on the current understanding of social, environmental, health, economic, and cultural impacts that may be induced or exacerbated by climate change and identify priorities for adaptation planning, the Province commissioned a Climate Change Risk Assessment (CCRA) in 2020.

The CCRA will serve as a tool to identify and better understand risks, set priorities for adaptation planning, and inform decision making across the province. The process for developing the CCRA involved working with federal, provincial, and municipal stakeholders, as well as subject matter experts in external agencies, to identify and select climate hazards, estimate their likelihood, define consequence categories, and analyze climate risk. A parallel effort was undertaken with First Nations communities drawing on information collected from interviews and existing studies.

Figure 1 outlines the major components of the CCRA process.

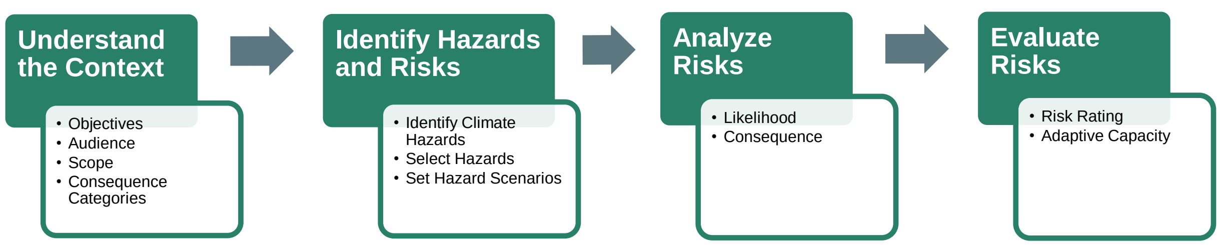

Figure 1. Climate Change Risk Assessment process.

Two major products emerged from the CCRA:[3]

1) A **CCRA framework**, which provides a consistent, repeatable, and scalable approach that can be customized for any jurisdiction or sector within PEI to analyze climate hazards for multiple climate-related risks. The Province can use the framework to periodically repeat the CCRA in future years as the climate changes, scientific understanding improves, and socioeconomic conditions evolve. Stakeholders across PEI can adapt the framework for their own assessments of climate risk. This framework is now integrated into this report as the CCRA methodology.
2) A **CCRA for PEI** that identifies and ranks current and future risks related to seven priority climate hazards. The CCRA also includes: information on climate risks to Indigenous

[1] Government of Prince Edward Island. 2019. PEI Climate Change Action Plan. https://www.princeedwardisland.ca/en/information/environment-water-and-climate-change/climate-change-action-plan-2018-2023
[2] University of Prince Edward Island Climate Research Lab. 2017. Climate Change Adaptation Recommendations Report. https://projects.upei.ca/climate/2017/12/07/pei-climate-change-adaptation-recommendations-report-now-available/
[3] The project team also provided the Province with a "reference library" of the literature and articles used for the CCRA.

communities on PEI based on interviews and reviews of existing studies; and ratings for adaptive capacity in specific sectors, populations, and ecosystems.

Key Findings

The CCRA includes analysis of the risk of specific scenarios in PEI for seven priority climate hazards by 2050. Key findings are summarized below for each hazard. Note that in addition to ratings for overall risk, the CCRA estimated likelihoods for each hazard (currently and in 2050) and consequences to categories of concern, including health, the economy, the environment, social stability, and infrastructure.

Climate Hazards and Scenarios Analyzed in the CCRA

- **Coastal erosion:** Acceleration of the historic rate of erosion
- **Post-tropical storm**: Multi-day post-tropical storm with heavy rain, storm surge, and wind making landfall in Queens County
- **Heat wave**: Three consecutive days with temperatures over 29°C
- **Heavy precipitation and flooding**: 100 mm rain event in 24 hours
- **Severe ice storm/freezing rain**: Multi-day severe ice storm/freezing rain event in winter
- **Earlier, warmer springs**: Earlier arrival of spring temperatures by two weeks affecting key species
- **Seasonal drought**: Months-long severe summer drought affecting the entire Province

- **Coastal erosion** poses the greatest level of risk to PEI by 2050. Due to the Island's socioeconomic and socio-cultural reliance on the coast, nearly all Islanders are likely to be directly or indirectly affected by coastal erosion in the future. Key consequences of unmitigated future coastal erosion include:
    - Potential for long-term or permanent damage to Island infrastructure, especially transportation and wastewater infrastructure.
    - Widespread moderate mental health impacts, particularly as result of loss of sense of place.
    - Risk to endangered and at-risk species (e.g., piping plover) and unique natural environments (e.g., mobile parabolic sand dunes).
    - Impacts to the tourism and recreation industry, including narrowed beaches and restricted access to parks, historic landmarks, golf courses, and other resources.
    - Inundation or erosion of socio-cultural coastal communities and properties, including Lennox Island where the risk could increase if a breach of Hog Island occurs.
- **Post-tropical storm** frequency on PEI is unlikely to change drastically by 2050; however, the consequences of a post-tropical storm event could continue to be quite severe: power outages are likely; key infrastructure such as the Confederation Bridge and Charlottetown Harbour have potential to be disrupted; aquaculture operations can be damaged or disrupted at certain times of year; and coastline stability and hydrology may be permanently altered, among other impacts. Critical access bridges and roads to some communities, including the causeway to Lennox Island First Nation, may also be impacted.
- **Heat waves** with temperatures above 29°C for three consecutive days are expected to occur significantly more frequently by 2050. The health risk—including potential mortality—to vulnerable populations such as seniors, infants, outdoor workers, and those with limited or no access to air conditioning would increase as a result. Extreme heat events may also cause

power outages and impacts to infrastructure and can affect heat-intolerant species of plants and animals.

- **Heavy precipitation and inland flooding** events can lead to impacts such as infrastructure damage, agricultural crop contamination and damage, unsafe driving conditions and injury, road washouts and closures. Heavy rain events are projected to become more frequent and intense over time: a rain event that has a 4% chance of occurring annually now, could have a 10% chance of occurring annually by mid-century.
- **Severe ice storms and freezing rain** events on PEI can lead to significant potential loss of life and injury, power outages and infrastructural damage (particularly to electric transmission and distribution infrastructure), damaged or downed trees, and limitations on ground and air travel due to unsafe conditions. The present-day risk of these events is high but is projected to decline by 2050 because the ratio of precipitation falling as rain rather than snow or ice is expected to increase as average temperature rises.
- **Earlier, warmer springs** could create potential opportunities by 2050, such as increased lobster population, extended growing season for existing and new crops, extended spring tourism season, and expansion of suitable habitat for flora and fauna. However, lobster are sensitive to water temperatures and may experience a decline once optimal conditions are surpassed beyond 2050. Other potential impacts include infrastructure damage from changes in freeze/thaw cycles and an increase in the prevalence of pests, diseases, and invasive species. The current risk associated with earlier, warmer springs is low, and is estimated to rise to medium by 2050.
- **Seasonal droughts** are not expected to become more likely by 2050 compared to today, but their impacts to agriculture (and related impacts to mental health) on PEI are worth attention, especially considering the significant consequences PEI farmers have already experienced from recent droughts.

The project team developed risk ratings for the seven identified climate hazards based on their estimated likelihood and consequences (see Figure 2). Likelihood ratings were informed by consultations with the Canadian Centre for Climate Services to identify the best available climate indicator for each hazard and consequence ratings were informed by a combination of desktop review and engagement with experts across PEI. The consequence ratings encompass the individual scores for nine consequence categories shown in the top row of Figure 3. Consequence categories are the dimensions on which consequence are evaluated (e.g., health, economy, environment, social stability, infrastructure)

Using input from agency staff and stakeholders, the project team also assessed

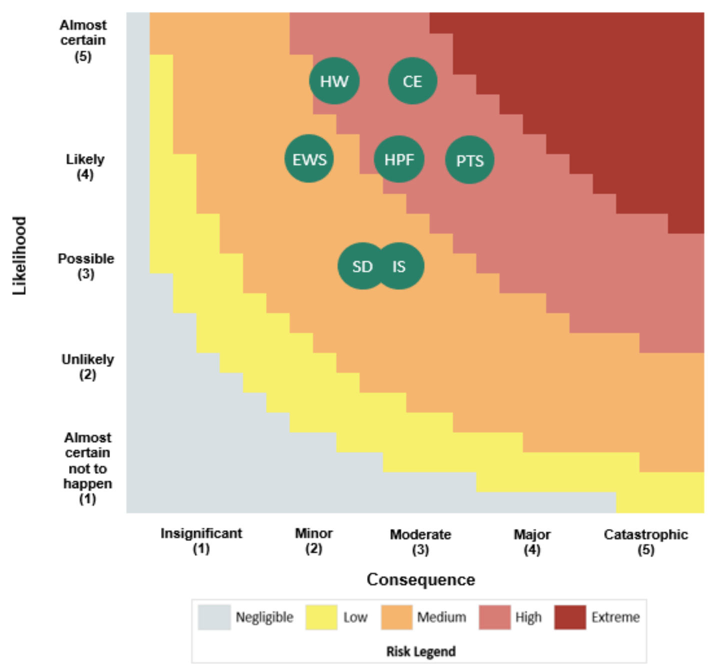

Figure 2. Overall risk rating matrix. Hazard legend: CE = coastal erosion | PTS = post-tropical storm | HW = heat wave | HPF = heavy precipitation/flooding | IS = ice storm/freezing rain | EWS = earlier/warmer spring | SD = seasonal drought

the adaptive capacity of specific sectors, populations, and ecosystems per consequence category to identify where the Province has the greatest opportunities to reduce climate risks.

Hazard	Consequence Category									
	Health			Economy			Environment	Social Stability	Infrastructure	Overall Risk Rating
	Potential loss of life	Potential Morbidity, injury, disease, or hospitalization	Mental health	Tourism and recreation	Agriculture, fisheries, aquaculture	Other industries				
Coastal Erosion	5	5	15	15	10	15	20	15	20	**15.3**
Post-tropical storm	12	12	8	12	16	8	16	12	20	**14.1**
Heat wave	15	20	10	5	15	5	10	10	15	**11.7**
Heavy precipitation and flooding	8	12	8	8	16	8	12	8	16	**11.2**
Severe ice storm/freezing rain	12	12	6	3	6	9	9	6	15	**9.2**
Earlier, warmer springs	4	4	4	8	12	4	16	4	12	**8.8**
Seasonal drought	3	6	12	3	12	3	9	9	6	**7.4**

Risk Score (low end inclusive)	Rating
0 – 3	Negligible
3 – 5	Low
5 – 11	Medium
11 – 18	High
18+	Extreme

Figure 3. Risk scores for consequence categories in the PEI CCRA.

Conclusions and Next Steps

The CCRA revealed important risks posed by climate change, which will require a coordinated, cross-sectoral response. Risks are interconnected and will not affect all people on PEI equally. Climate change may also present opportunities for PEI, which should be considered alongside the negative impacts. Further, climate risks PEI faces through 2050 are not fixed; the results of the risk assessment process are likely to change as hazards are revisited, research progresses, and adaptation strategies are implemented.

ICF recommends the Province builds on the understanding gained through the CCRA to:

- Expand on the CCRA to gain a better understanding of the risks facing PEI;
- Develop a province-wide adaptation plan and/or coordinated sector-specific adaptation plans;
- Consider how best to integrate the CCRA findings into decision-making and investment planning.

1. Introduction

With more than 1,100 kilometres of coastline and an economy driven in large part by agriculture, fisheries, and tourism, Canada's smallest and most densely populated province faces significant risks from climate change. PEI is already experiencing some of these effects, such as rising temperatures and sea levels, increases in coastal erosion, and impacts to lobster and other shellfish related to warming and increasingly acidic ocean waters.

Scientists expect climate change and its impacts to intensify and accelerate over the course of this century, with growing risks to PEI's inhabitants, economy, infrastructure, and environment. For example:

- Extreme heat events, which are projected to increase with climate change, pose risks to **public health**, especially to vulnerable populations such as older adults (ages 64 and older), infants, and low-income households. PEI's population of older adults has been rising faster than any other age group in the province [16], suggesting that more people could be in harm's way as the climate warms. Other types of extreme events, such as severe storms or floods, could hamper access to health care and emergency services.
- Although PEI's **economy** is diverse, changes in temperature, precipitation, extreme events, and ocean acidity could adversely affect some key economic drivers such as agriculture (including potato farming), fisheries, and tourism. Impacts such as coastal erosion could also have negative consequences for the PEI real estate market, insurance industry, and private homeowners.
- Some of the impacts of climate change could disrupt **daily life and livelihoods** on PEI, create challenges for community and cultural institutions, and affect residents' sense of place. Specific impacts could range from disruptions to the daily workplace commute, damage to sites of cultural importance, or, in more extreme cases, displacement from place of residence.
- Climate change will have a range of impacts on PEI's **natural environment**, including wetlands, forests, beaches, conservation areas, vulnerable species, and biodiversity.
- Roads, bridges; water, wastewater, and stormwater systems; recreational facilities; and other built **infrastructure** could be damaged or disrupted by changes in climate and extreme weather events on PEI.
- Climate change poses further risks to **Lennox Island and Abegweit First Nations**. In addition to damage to coastal residences and impacts to community infrastructure, their sacred grounds, medicinal plant sites and traditional hunting and fishing areas are also at risk.

The COVID-19 pandemic revealed important vulnerabilities and dependencies for PEI's economy and population (see textbox), especially in the tourism industry but also in fisheries and other sectors. However, it also highlighted PEI's resilience and ability to adapt to an uncertain and evolving situation. The pandemic has created an opportunity to reflect on and apply lessons learned on how to prepare for and respond to future disruptions like climate change. For example, understanding the impacts of physical isolation could be instructive if access to communities is compromised by coastal erosion or a post-tropical storm. The pandemic also highlighted certain economic sectors that may be more vulnerable to supply chain impacts and subsets of the population that may have more difficulty accessing critical services during an event. The effects of climate change are likely to be disruptive and evolving force for PEI's population, economy, and environment, and will interact with other existing and emerging stressors in the years ahead.

In light of these concerns, the Government of PEI, in conjunction with various stakeholders and the consulting firm ICF (the project team), has undertaken a Climate Change Risk Assessment (CCRA) to identify and better understand key social, environmental, health, economic, and cultural risks that may be induced or exacerbated by climate change. The CCRA provides the foundation for future strategies to reduce PEI's exposure to climate risk through adaptation and resilience-building measures.

What Did the COVID-19 Pandemic Reveal About Climate Change Risks on PEI?

Several of the impacts that occurred during the COVID-19 pandemic could also occur due to climate-related events or changes, including:

- Supply chain challenges
- Food insecurity
- Reduced access to critical off-island services
- Significant disruption to tourism industry
- Isolation and anxiety
- Healthcare access challenges
- Limited emergency response capacity
- Differential impacts to vulnerable populations

1.1. What is Risk?

In simplest terms, risk is the possibility that something bad will happen. The words "possibility" and "bad" stand in for the key components of risk: probability and consequences. Risk must be evaluated in terms of both of these components: if an event has zero chance of occurring, the risk is zero even if the consequences of that event would be enormous. Similarly, an event with a high probability of occurring but only minor consequences would be considered a low-risk event.

1.2. What is a Climate Change Risk Assessment?

Risk assessments are used to identify, evaluate, and rank risks, with a goal of informing prioritization and decision making. Analysts evaluate and rank risks based on their likelihood and consequences. In a stable environment where nothing changes, this can be a straightforward exercise since historical data on past events can be used to calculate probabilities and consequences with a high degree of confidence. The world is dynamic and changing, however, which makes assessing future risks difficult. It is especially challenging to understand future risks associated with

Figure 4. North Cape of Prince Edward Island [7].

climate change, due to uncertainties in climate models, emissions scenarios, and future demographic and economic conditions.

For these reasons, climate change risk assessments usually develop qualitative—rather than quantitative—scores and rankings for risk. Probabilities are estimated based on the best available current science, with a range of uncertainty, and consequences are estimated based on expert judgment and past experience with similar events. Typically, climate change risk assessments analyze a set of specific representative hazard scenarios, such as a storm of a specified magnitude and area, or a flood with a specified return period, to make it possible to estimate probability and consequences. The specific hazard scenarios are selected based on priority risks of concern.

In 2020–2021, the Government of PEI engaged the consulting firm ICF to conduct a CCRA. This CCRA is intended to equip provincial government staff and decision makers with a better understanding of climate-related risks and opportunities to adapt to the impacts of climate change. Its specific objectives are to:

- Improve understanding of climate change risks across sectors and identify knowledge gaps
- Inform risk mitigation (i.e., adaptation and resilience) priorities
- Form a foundation for future risk assessments, through which decreases in risk and increases in resilience can be evaluated
- Develop a risk assessment process that is repeatable and scalable so adaptation progress can be measured, and the process can be replicated by other jurisdictions, such as local governments

The risk assessment process included engagement with Mi'kmaq communities on PEI to receive Indigenous perspectives and gather information through interviews, a workshop, and review of their existing climate risk studies and adaptation planning documents.

Additionally, the project team engaged representatives across sectors, including federal, provincial, and municipal government stakeholders, and subject matter experts from external agencies through surveys and workshops.

The scope of the assessment spans the entire province of PEI, major provincial government interests, and seven priority climate-related hazards that could affect those interests. The assessment focused on near-term risks to PEI through 2050. While the CCRA is focused on evaluating the potential harms or negative consequences that could occur as a result of climate changes, potential positive impacts or opportunities that could arise as a result of climate changes are also noted where possible.

2. Climate Change Risk Assessment Methodology

The CCRA ultimately evaluated the likelihood that a climate hazard scenario will occur and the magnitude of its consequences, in order to understand relative risks across hazards and consequence categories, and to inform adaptation priorities.

Throughout the CCRA process, the project team engaged representatives across sectors, including federal, provincial, and municipal government stakeholders, and subject matter experts from external agencies, to guide the CCRA. The project team also engaged with the Mi'kmaq communities in PEI to ensure a thorough understanding of the unique risks to Indigenous communities and to foster improved coordination with First Nations toward increased resilience. Due to the COVID-19 pandemic, all engagement was conducted virtually.[4]

The CCRA followed the basic steps outlined in Figure 5 below, including understanding the context, identifying and selecting the climate hazards for further analysis, analyzing risk through likelihood and consequences ratings, and evaluating risks and adaptive capacity. This process is consistent with the International Organization for Standardization (ISO) 31000 Risk Management standard [17] and ISO 14090 Adaptation to Climate Change [18].

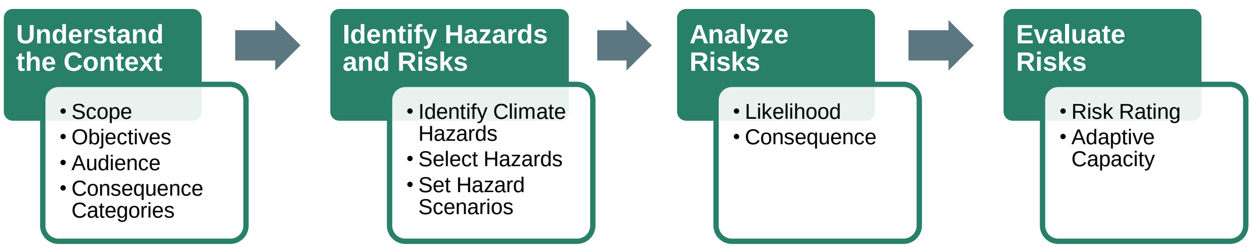

Figure 5. Climate change risk assessment process.

2.1. Step 1 – Understand the Context

The critical first step of the CCRA was to establish and clearly articulate the context, including the scope, objectives, and intended audience. This ensured that all parties involved understood the scope of the project and had a shared understanding to drive the subsequent analysis.

[4] For a complete list of contributors to the development and execution of the CCRA, see the Acknowledgements.

2.1.1 Scope

The box at right summarizes the **scope** of the CCRA that emerged from this process. The timeframe of the assessment focused on risks to PEI through 2050. Longer term risks past 2050 were evaluated qualitatively where possible, to account for uncertainty in projections.

2.1.2 Objectives and audience

The **objective** of the PEI CCRA was to equip the Province with a better understanding and assessment of climate-related risks and opportunities for adaptation responses. Specific objectives included:

- Improve understanding of climate change risks across sectors
- Understand implications of climate change for all people in the province
- Identify key knowledge gaps and under-studied risk areas
- Inform risk mitigation (i.e., adaptation) priorities for the province
- Inform risk management decisions across provincial government departments

The primary intended **audience** for the risk assessment is provincial decision makers and staff across provincial departments. In addition, the risk assessment framework and results may be useful to First Nations, municipal governments, health authority, industry groups, and the general public.

CCRA Scope

Geography and Resolution:

- PEI, province-wide

Climate Hazards:

- Coastal Erosion
- Post-Tropical Storm
- Heat Wave
- Heavy Precipitation and Inland Flooding
- Severe Ice Storm/Freezing Rain
- Earlier, Warmer Springs
- Seasonal Drought

One scenario per climate hazard

Consequence Categories/ Focus Areas:

- Health
  - Loss of life
  - Morbidity, injury, disease, or hospitalization
  - Mental health
- Economy
  - Tourism and recreation
  - Agriculture, fisheries, and aquaculture
  - Other industries (e.g., manufacturing)
- Environment
- Social Stability
- Infrastructure

Time Frame: Through 2050

2.1.3 Consequence categories

Another important step of context-setting was to articulate focus areas for the CCRA. Focus areas are the dimensions on which consequence are evaluated. The Province has conducted prior studies exploring climate-related risks to infrastructure and coastal communities. Thus, the CCRA places particular emphasis on other under-studied areas including the people of the province and the potential risks to social, economic, environmental, and cultural life in PEI.

The project team selected the following nine consequences, which are each linked to important policy objectives centred on maintaining healthy communities, economic stability, environmental preservation, social stability, and continuity of infrastructure services for all people in PEI. The nine consequences are grouped into five categories to capture the wide range of provincial government objectives:

- **Health** – measure of impacts to public health and safety, specifically:
    - Loss of life
    - Morbidity, injury, disease, or hospitalization
    - Mental health (e.g., sense of place or identity, anxiety)
- **Economy** – measure of impacts to economic activity and employment, broken out into:
    - Tourism and recreation
    - Agriculture, Fisheries, and Aquaculture
    - Other industries
- **Environment** – measure of impacts to the natural environment such as wetlands, forests, beaches, conservation areas, vulnerable species, and biodiversity
- **Social stability** – measure of disruption to daily life, livelihoods, community/cultural institutions, sense of place
- **Infrastructure** – measure of impact/disruption to roads, bridges, water, wastewater, stormwater, recreational facilities, and other built infrastructure

2.1.4 Risks to Indigenous communities

Lennox Island First Nation and Abegweit First Nation have shown great leadership in understanding the risks and vulnerabilities their communities face from a changing climate. Climate change poses unique risks to First Nations due to their close ties to the land. Sea level rise, coastal erosion and increased storm surges pose a risk to coastal residences, community infrastructure, sacred grounds, medicinal plant sites and traditional hunting and fishing areas in communities such as Lennox Island First Nation.

The Indigenous communities on PEI have been keenly aware of the challenges posed by climate change and have engaged in extensive research through the Mi’kmaq Confederacy of Prince Edward Island (MCPEI) and the University of Prince Edward Island (UPEI) Climate Research Lab. MCPEI provided the project team with a number of resources that were used to inform the risk assessment, including: historic and projected meteorological and fire risk data, coastline change and sea level rise analyses, climate hazard cost-benefit analyses and adaptation planning information, and vulnerability studies specific to the Mi’kmaq communities.

The risk assessment project also included engagement with the Mi’kmaq communities on PEI to ensure a thorough understanding of these risks and to foster improved coordination with First Nations toward increased resilience. Leaders from the Mi’kmaq community shared numerous existing climate risk studies and adaptation planning documents completed by MCPEI for the project team to review. The project team also hosted a virtual workshop with citizens, staff, and leadership of Lennox Island First Nation and members of the UPEI School of Climate Change and Adaptation to discuss their preferred approach to being involved in the CCRA. This workshop led to an offer to contribute key questions to research already underway by Julie Pellissier-Lush, Community Consultant for MCPEI, who was conducting one-on-one interviews with citizens of Abegweit First Nation and Lennox Island First Nation. The interviews yielded Indigenous perspectives on climate-related risks to Mi’kmaq communities in PEI.

Structural racism and the effects of colonialism continue to reverberate across communities, creating compounding inequities in how climate change impacts are experienced and addressed. The willingness of the Mi’kmaq to share their perspectives and knowledge into the development of the

CCRA is deeply appreciated and it is hoped that this will help to ensure that avenues for meaningful collaborations and partnerships on mitigation and adaptive actions will continue into the future. Information gathered through Indigenous engagement has been incorporated into the final CCRA report (both within individual hazard sections and in a standalone chapter on Indigenous perspectives on impacts) and provided to participating communities. Information from MCPEI studies, cost-benefit analyses, and other MCPEI resources were particularly useful to inform the mental health consequences of the coastal erosion hazard and the environment, social stability, and infrastructure consequences of the post-tropical storm hazard.

2.2. Step 2 – Identify Hazards and Risks

The next critical step in the CCRA was to determine which specific climate hazards to evaluate.

The CCRA evaluated the risks of seven climate hazard scenarios. Each scenario represents one permutation of that hazard and is used to illustrate the types of consequences associated with the hazard. The likelihood and consequence ratings are specific to these scenarios.

The seven climate hazards and scenarios analyzed in the CCRA are summarized in Table 1. Appendix B details the process for arriving at this set of hazards and scenarios.

Table 1. Climate hazard scenarios

Climate Hazard	Scenario
Severe ice storm/freezing rain	Multi-day severe ice storm/freezing rain event in winter
Post-tropical storm	Multi-day post-tropical storm with heavy rain, storm surge, and wind; landfall in Queens County
Heavy precipitation and flooding	100mm of rain in 24 hours
Seasonal drought	Months-long severe summer drought affecting the entire province
Coastal erosion	Acceleration of the historic rate of erosion
Heat wave	Three consecutive days with temperatures above 29°C
Earlier, warmer springs	Earlier arrival of spring temperatures by two weeks affecting key species

2.3. Step 3 – Analyze Risks

Risk is a function of the likelihood of a hazard scenario occurring, and the consequences of that hazard scenario. The CCRA applied a consistent likelihood and consequence rating rubric to each of the hazard scenarios, as described below, based on a combination of quantitative data analysis and qualitative expert opinion.

2.3.1 Rate likelihood

The CCRA rated the likelihood of each hazard scenario on a scale of 1 to 5 to represent the degree of certainty that the scenario will occur in a given timeframe; in this case, by 2050.

Climate hazards can be either discrete (e.g., heat wave) or ongoing (e.g., sea level rise). Evaluating the likelihood of these hazards is fundamentally different:

- **Discrete climate hazards:** Likelihood is measured by the expected frequency of the hazard in a given time period.
- **Ongoing climate hazards:** Likelihood is measured by the probability that a critical threshold–a defined tipping point at which significant impacts occur–is exceeded by a given time period.

The likelihood rating scale in Table 2 provides the rubric for evaluating the likelihood of discrete and ongoing climate hazards. The CCRA evaluated likelihood for both a baseline time period and future time period (2050) to capture how the likelihood of the climate hazard scenarios changes over time. The specific baseline time period varies slightly by hazard, depending on available data, but is roughly aligned with the most recent historical data available (see the climate hazard profiles in Appendix A: Risk Assessment Details).

Table 2. CCRA likelihood rating scale for discrete and ongoing climate hazards

Likelihood	Rating	Criteria for Discrete Climate Hazards	Criteria for Ongoing Climate Hazards
Almost certain	5	Event is expected to happen about once every two years or more frequently (i.e., annual chance ≥ 50%*).	Event is almost certain to cross critical threshold.
Likely	4	Event is expected to happen about once every 3-10 years (i.e., 10% ≤ annual chance < 50%).	Event is expected to cross critical threshold. It would be surprising if this did not happen.
Possible	3	Event is expected to happen about once every 11-50 years (i.e., 2% ≤ annual chance < 10%).	Event is just as likely to cross critical threshold as not.
Unlikely	2	Event is expected to happen about once every 51-100 years (i.e., 1% ≤ annual chance < 2%).	Event is not anticipated to cross critical threshold.
Rare	1	Event is expected to happen less than about once every 100 years (i.e., annual chance <1%).	Event is almost certain not to cross critical threshold.

*Annual chance is the probability that an event will occur in a given year

Likelihood ratings were based on the best available climate science. For each climate hazard scenario, the project team climate scientists coordinated with the Canadian Centre for Climate Services to identify the best available climate indicator for each hazard. In most cases, data on baseline and future projections came from the climatedata.ca portal, though the project team also drew on additional research and studies as appropriate. For the two ongoing hazards (coastal erosion and earlier, warmer springs), the project team used existing research to identify a critical threshold from which to measure change in likelihood over time. Details on the sources used to assess likelihood for each hazard can be found in the risk assessment details in Appendix A.

2.3.2 Rate consequences

Each consequence category was rated on a 1 to 5 scale (from Insignificant to Catastrophic) based on provincial-scale impacts through the 2050 time period. The metrics to define each category are intended to ensure consistency and comparability across climate hazard scenarios. The project team held a virtual workshop with stakeholders to vet and refine the consequence rating scale; the final scale is shown in Table 3.

In addition to an overall consequence rating for each category and hazard, the CCRA includes findings, where available on the variable distribution of these consequences, which can inform risk management strategies. For example:

- Are these impacts evenly distributed across the population?
- Are these impacts evenly distributed geographically?

Each consequence rating was based on evidence compiled from a combination of desktop review and expert engagement, prioritizing peer-reviewed and grey literature, but also supplemented with news stories documenting past events and their impacts as appropriate. The project team compiled an initial evidence base and draft consequence ratings, and then held a second virtual workshop to vet the draft ratings and gather additional evidence from experts across the province.

Table 3. CCRA consequence rating scale

	Health			Economy			Environment	Social stability	Infrastructure
	Potential loss of life	Potential morbidity, injury, disease, or hospitalization	Mental health	Tourism and recreation	Agriculture, fisheries, aquaculture	Other industries			
Catastrophic – 5	100+ people	1,000+ people affected	Widespread, severe mental health impacts (e.g., loss of home, identity, or sense of place) lasting years	Severe disruption to multiple seasons or employment Over $100 million in potential losses	Severe, disruption to multiple industries and employment lasting months to years Over $100 million in potential losses	Severe, long-term disruption to multiple industries and employment Over $100 million in potential losses	Irreversible damage to a significant natural asset	Severe months-long disruption to daily life, livelihoods, and community/cultural institutions	Months-long disruption in infrastructure services Widespread disruption to critical infrastructure system
Major – 4	10-100 people	100-1,000 people affected	Widespread, severe, short-term mental health impacts (e.g., loss of home, identity, or sense of place) lasting weeks to months	Severe disruption to one season or employment $10 million to $100 million in potential losses	Moderate, disruption to multiple industries and employment; or severe impacts to one industry lasting months to years $10 million to $100 million in potential losses	Moderate, long-term disruption to multiple industries and employment; or severe long-term impacts to one industry $10 million to $100 million in potential losses	Widespread damage to a natural asset Recovery would take years to decades	Severe, days-to-weeks-long disruption to daily life, livelihoods, and community/cultural institutions	Weeks-long disruption in infrastructure services Disruption to multiple critical infrastructure assets
Moderate – 3	2-10 people	10-100 people affected	Widespread, moderate, mental health impacts (e.g., loss of home, identity, or sense of place) lasting years	Moderate disruption to multiple seasons or employment; or severe weeks-long disruption to one season $1 million to $10 million in potential losses	Severe, weeks- to months-long disruption to multiple industries and employment; or moderate impacts to one industry lasting months to years	Severe, weeks- to months-long disruption to multiple industries and employment; or moderate long-term impacts to one industry	Localized, significant damage to a natural asset Recovery would take years to decades	Moderate, months-long disruption to daily life, livelihoods, and community/cultural institutions	Days-long disruption in infrastructure services Localized disruption to a singular critical infrastructure asset

					$1 million to $10 million in potential losses	$1 million to $10 million in potential losses			
Minor – 2	Low potential for multiple loss of life	<10 people affected	Widespread, moderate, mental health impacts (e.g., feelings of fear and anxiety) lasting weeks to months	Moderate disruption to one season or employment $100,000 to $1 million in potential losses	Moderate, weeks- to months-long disruption to multiple industries and employment; or severe short-term impacts to one industry $100,000 to $1 million in potential losses	Moderate, weeks- to months-long disruption to multiple industries and employment; or severe short-term impacts to one industry $100,000 to $1 million in potential losses	Localized, moderate damage to a natural asset Recovery would take months to years	Moderate, days-to-weeks-long disruption to daily life, livelihoods, and community/cultural institutions	Hours-long disruption in infrastructure services
Insignificant – 1	Extremely low potential for loss of life	Extremely low possibility for morbidity, injury, disease, or hospitalizations	Minimal expected mental health impacts	Insignificant disruption to sector and employment Less than $100,000 in potential losses	Insignificant disruption to industries and employment Less than $100,000 in potential losses	Insignificant disruption to industries and employment Less than $100,000 in potential losses	Minimal damage Recovery would take days to months	Minimal disruption to daily life, livelihoods, and community/cultural institutions	Temporary nuisance

2.4. Step 4 – Evaluate Risks

2.4.1 Rate risk

Finally, the CCRA combined the likelihood and consequence ratings for each climate hazard scenario to evaluate overall risk.

The five consequence category ratings were averaged to create an overall consequence score, then multiplied by the likelihood score to compute a total risk score, as shown in the formula below.

Risk = Likelihood × Overall Consequences

where

Overall Consequences = Average (Health, Economy, Environment, Social Stability, Infrastructure Consequence Scores)

The health and economy consequence scores represent the average scores across their sub-consequence categories.

Table 4 and Table 5 provide the final risk rating matrix and for the corresponding score-to-rating rubric.

Table 4. PEI climate change risk rating matrix

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	High
Unlikely	Negligible	Low	Medium	Medium	Medium
Rare	Negligible	Negligible	Low	Low	Medium

Table 5. Risk rating rubric

Risk Score (low end inclusive)	Rating
0 – 3	Negligible
3 – 5	Low
5 – 11	Medium
11 – 18	High
18+	Extreme

2.4.2 Rate confidence

Recognizing that the availability and quality of data sources for evaluating climate hazard scenarios varies, the CCRA also includes a confidence rating for each likelihood and consequence rating. The confidence rating indicates the strength, consistency, and makeup of the knowledge base used to inform the likelihood and consequence ratings. The confidence rating guidelines in Table 6 are adapted from the *UK Climate Change Risk Assessment* [19] and *Framework for Yukon-wide Assessment of Risk from Climate Change [20]*. Evidence for the CCRA was primarily gathered through desk research and engagement with agency staff and stakeholders, Indigenous communities, and subject matter experts.

Table 6. Confidence rating scale

High confidence	Medium confidence	Low confidence
Multiple sources of independent evidence based on reliable analysis and methods, with widespread agreement	Several sources of high-quality independent evidence, with some degree of agreement	Varying amounts and quality of evidence and/or little agreement between experts; or assessment made only using expert judgment

2.4.3 Consider adaptive capacity

Adaptive capacity refers to the inherent traits of the system or individual assets, institutions, populations, or species in question that make it more or less susceptible to impacts from the climate risk, including actions the government or other stakeholders are already taking to address risk (e.g., emergency preparedness planning, designing infrastructure with climate change in mind, professional development and training programs, etc.). Considering adaptive capacity to sectors, populations, and ecosystems within each consequence category is important for identifying where PEI has the greatest needs and opportunities to reduce risks.

As a starting point for assessing adaptive capacity, identifying adaptation priorities, and measuring progress over time, the CCRA includes an initial Adaptive Capacity Assessment Matrix for PEI. Table 7 provides an abbreviated version of the matrix (for the full matrix, see Appendix C). The matrix is derived from the concept of a capability maturity model, which was first developed for software development and optimization [21], but has since been modified and applied to a variety of industries and analyses, including climate analyses.

The Adaptive Capacity Assessment Matrix provides a five-point scale for measuring the strength of each adaptive capacity factor by consequence category. The adaptive capacity factors included in the matrix were identified through a combination of literature review and coordination with workshop participants throughout the CCRA process. This assessment matrix could continue to be developed over time as PEI continues implementing adaptation strategies and developing and tracking measures to track its resilience performance. This process is consistent with ISO 14090 guidance to assess organizational capacity to adapt to climate change (e.g., financial, human, and technical resources), engage key decision-makers, and track progress over time [18].

Table 7. Abbreviated Adaptative Capacity Assessment Matrix (with one adaptive capacity factor example per consequence category)

Consequence Category	Adaptive Capacity Factor	Low (1) *Couldn't be worse*	(2)	(3)	(4)	High (5) *Couldn't be better*
Health	Access to basic needs and services (e.g., affordable housing, employment, education)	No access to basic needs and services				All residents have access to basic needs and quality services
Economy	Diversity of economic sectors	Economy heavily reliant on one sector or product				Highly diversified economy
Environment	Ecosystem health	Declining health and prevalence of ecosystems and species				Thriving coastal and species
Social Stability	Strength of faith-based, informal networks or other community institutions	Weak or nonexistent networks and community institutions				Strong and robust networks and community institutions
Infrastructure	Level of transportation network resiliency	Network susceptible to disruptions during common events				Network designed or hardened to withstand extreme risk aversion conditions

To identify adaptation priorities and measure progress over time, workshop participants filled out a survey to rate current adaptive capacity on five-point scale per adaptive capacity factor within each consequence category.

The adaptive capacity findings help identify priority climate risks and consequence categories where the government should focus adaptation efforts and next steps. For example, if a particular hazard has high consequence ratings and low adaptive capacity ratings for health, building the capacity of low scoring health factors could be a priority for adaptation to lower overall health risks from that hazard. Adaptive capacity factors scoring in the bottom half of the range (scoring less than 3) may provide the greatest opportunities for improvement.

2.5. Assumptions, Limitations, and Other Considerations

The CCRA provides a high-level characterization of climate risks and its many dimensions to allow provincial decision makers to assess adaptation priorities and needs. For example, this method helps to identify key hazards and consequence categories that may be most affected by climate change over time, or where current capacity to respond to these impacts is limited.

The CCRA is not intended to be a precise measurement of risk and therefore may not capture every element of risk. Critical assumptions and considerations to keep in mind in interpreting the risk assessment results include:

- **The seven climate hazard scenarios are illustrative, and not comprehensive of how climate change could affect PEI**. Each climate hazard scenario represents just one permutation of how a climate hazard could affect PEI at a fixed severity. More and less severe versions of each scenario are possible, as are additional hazards. Each scenario is intended to illustrate the types of events and consequences climate change could cause or exacerbate.
- **Each climate hazard scenario was assessed independently of the other hazards.** However, many of the hazards are interconnected and could occur simultaneously or in succession which could increase the severity of the potential consequences (e.g., experiencing a post-tropical storm shortly after a heavy precipitation event could exacerbate flooding due to saturated soils and strain emergency response resources). Compound events could be included as additional hazards in a future assessment.
- **Coastal flooding and storm surge are acknowledged as posing a significant threat now and in the future for Prince Edward Island.** However, these hazards were being addressed through an independent yet parallel coastal hazard assessment and were therefore omitted as a standalone climate hazard scenario in this risk assessment. Future work will include efforts to integrate the results of both initiatives.
- **Consequences and risks are assessed at the provincial scale.** However, many of these hazard scenarios could also be significant for individual communities or subsectors of the province. Where possible, differential impacts to certain populations or subsectors are documented in the risk assessment hazard profiles, though these are not individually assessed or comprehensive of all potential impacts.

- **Factors such as economic, social, cultural, political, and demographic trends may change over time and influence climate-related risk.** For the risk rating process, population levels and density are assumed consistent with the 2016 Census [14] (see box for current data). The population is likely to grow and age over the next 30 years, which could increase risks to the population, particularly impacts related to health, social stability, and infrastructure.
- **The CCRA focused on evaluating negative consequences of the hazards. This does not mean all climate change impacts will necessarily be negative.** The emphasis on evaluating where climate change has potential to cause harm is intended to identify areas where the Province may need to take action to mitigate these consequences. The CCRA does also note potential ways that climate change could create some positive impacts or opportunities in PEI if managed appropriately where they arose during the research process.
- **The risk ratings assume no management or new adaptation actions.** In reality, of course, PEI has an opportunity to manage climate risks and capitalize on opportunities.
- **Some climate hazards have a more robust evidence base than others.** Where information was not available, the project team relied on expert judgment gathered through interviews and workshops. The confidence ratings and descriptions throughout the CCRA (as defined in Section 2.4.2 and contained in the risk assessment details in Appendix A) reflect the robustness of the evidence base and note remaining knowledge gaps.

Population Assumptions

The risk analysis assumed the following information based on the trends of the 2016 Census to evaluate risk:

- PEI had a population of approximately 143,000 and a population density of 25.1 persons per square kilometer [4].
- 60.1% of the population (about 86,000 people) lives in one of two census agglomerations (core area with a population over 10,000); 39.9% of the population (about 57,000 people) live outside of these areas [4].
- City and town centres with populations greater than 5,000 people include [4]:
    - Charlottetown: 36,094
    - Summerside: 14,829
    - Stratford: 9,706
    - Cornwall: 5,348
- PEI had about 59,500 private dwellings occupied usual by residents [4].
- PEI's population increased 2.3% from 2006 to 2011 and 1.9% from 2011-2016 [4].
- About 65% of the population is in 15-64 age range; 20% of the population is 65 and above years old [14].

3. Risk Assessment Results by Hazard

This chapter provides a brief synopsis of the risk assessment results for each hazard, including the overall risk ratings and information on the breakdown of potential consequences of each hazard. Detailed risk profiles for each hazard containing the full evidence base and rationale for the ratings are provided in Appendix A.

The CCRA includes analysis of the relative likelihood of seven climate hazards and their relative consequences across a range of critical categories of concern (e.g., health, economy, environment, social stability, infrastructure), illustrating how climate change could affect PEI by 2050.

Table 8 presents the overall risk ratings by hazard, based on the likelihood rating and the average consequence rating across the nine consequence categories for 2050 risk (the current risk rating is provided for context of how future risks may differ than those PEI is accustomed to today). Coastal erosion and post-tropical storm emerged as the climate hazards with the highest associated risk by 2050.

Table 8. Overall risk assessment results

Climate Hazard	Scenario	Current Risk Rating (Score)	2050 Risk Rating (Score)
Coastal erosion	Acceleration of the historic rate of erosion	Medium (9.2)	High (15.3)
Post-tropical storm	Multi-day post-tropical storm with heavy rain, storm surge, and wind making landfall in Queens County	High (14.1)	High (14.1)
Heat wave	Three consecutive days with temperatures over 29°C	Medium (7.0)	High (11.7)
Heavy precipitation and flooding	100 mm rain event in 24 hours	Medium (8.4)	High (11.2)
Severe ice storm/freezing rain	Multi-day severe ice storm/freezing rain event in winter	High (12.3)	Medium (9.2)
Earlier, warmer springs	Earlier onset of spring temperatures by two weeks affecting key species	Low (4.4)	Medium (8.8)
Seasonal drought	Months-long severe summer drought affecting the entire province	Medium (7.4)	Medium (7.4)

Coastal erosion poses the greatest overall risk to PEI by mid-century. Due to the Island's socioeconomic and socio-cultural reliance on the coast, most Islanders are likely to be impacted by the effects of coastal erosion in the future, including those who do not live directly on the coast. The high likelihood of accelerating coastal erosion by 2050 results in this hazard holding the highest level of risk.

Post-tropical storms also pose a high risk by 2050. While projections indicate that the frequency of post-tropical storms (as defined in the scenario analyzed) could increase by 2050, they are unlikely to occur more than once every two years, Even without a significant change in future likelihood, the consequences of these events still have potential to be quite severe: power outages are likely, key infrastructure such as the Confederation Bridge, and Charlottetown Harbour have potential to be disrupted, aquaculture operations can be damaged or disrupted at certain times of year, and coastline stability and hydrology may be permanently altered, among other impacts. Critical access bridges and roads to communities, including the causeway to Lennox Island First Nation, may also be impacted.

Heat waves are expected to occur more frequently by 2050, and the risk to vulnerable populations (seniors, infants, low-income earners, those with limited or no access to air conditioning) and heat-intolerant species would increase as a result.

Heavy precipitation and inland flooding events pose similar risks to post-tropical storms but are less likely to cause as extensive damage as a post-tropical storm that is also accompanied by high winds and storm surge. Heavy rainfall can lead to runoff and flooding, which in turn can damage stormwater, transportation, and other infrastructure; cause unsafe driving conditions; reduce groundwater recharge; contaminate waterways; and damage crops, among other impacts.

Severe ice storms and freezing rain are likely decreasing as temperatures warm and more precipitation falls as rain. However, there may be increased variability in weather patterns in the short-term, and these events can be extremely disruptive when they occur, causing unsafe driving conditions and leading to closures in schools and other services. Ice storms can also cause downed trees and prolonged power outages, with associated health and economic consequences.

Earlier, warmer springs could create opportunities by mid-century, such as increased lobster population, extended growing season for existing and new crops, extended spring tourism season, and expansion of suitable habitat for flora and fauna. However, lobster are sensitive to water temperatures and may experience a decline once optimal conditions are surpassed beyond 2050.

Drought events were found unlikely to occur more frequently by 2050 compared to today, however the impacts of droughts to agriculture and mental health on PEI are worth attention, especially considering the significant consequences PEI farmers have already experienced from recent droughts.

Figure 6 provides additional insight into how the risks from each hazard break down across consequence categories. The hazards are presented from left to right by descending 2050 risk score (indicated by the black dot). The size of the colour bar corresponds to the severity of the consequence rating per category. Not all hazards with the highest overall consequences have the highest risks. For example, severe ice storm/freezing rain has high potential consequences, but moderate overall risk once likelihood is factored in. This figure also shows how the hazards affect different consequence categories. For example, four of the seven hazards have at least moderate consequences to human health (the green bars), and all hazards affect infrastructure. On the other hand, post-tropical storms, heavy precipitation, and seasonal drought stand out as affecting agriculture, fisheries, and aquaculture more than other hazards.

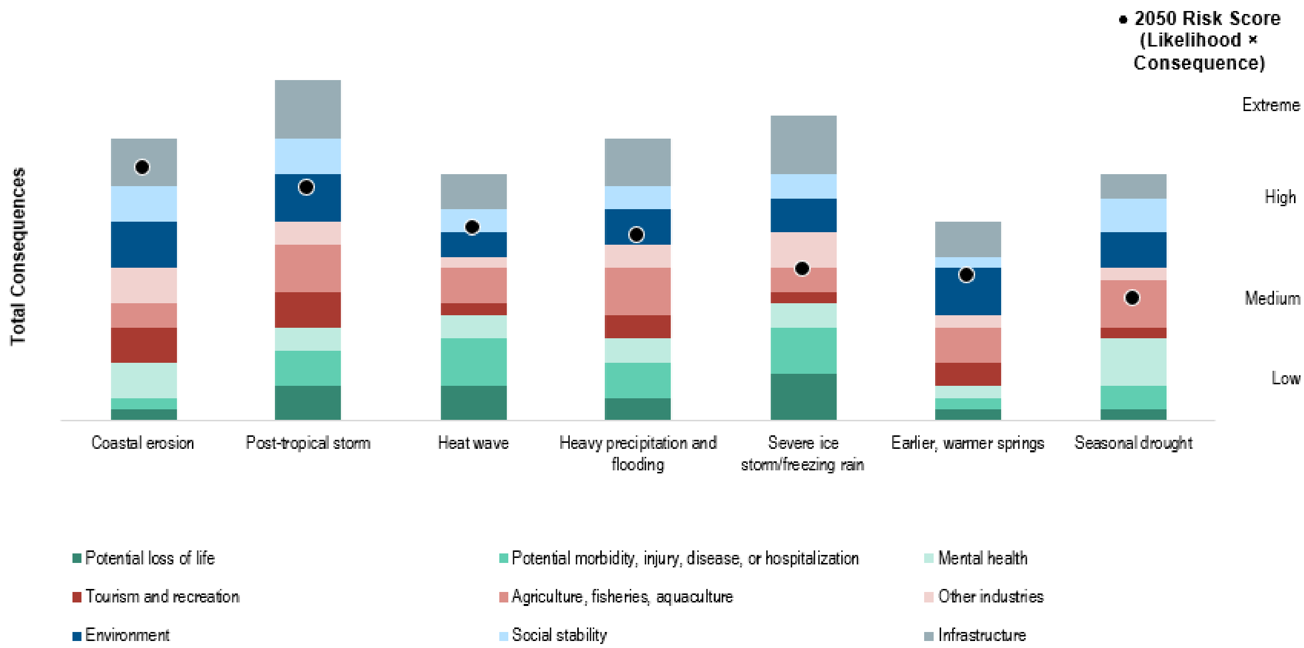

Figure 6. Total consequences by risk and hazard.

Figure 7 presents the overall risk for each hazard across consequence categories, which can be used to identify priorities for PEI adaptation planning. The values represent the product of the 2050 likelihood rating and the individual consequence score (see Appendix A for detailed scoring). Coastal erosion and severe storm have high risks across nearly all consequence categories, leading to their high overall risk scores. As illustrated, infrastructure holds the highest risk scores of any consequence category, with all hazards at high risk or greater, except seasonal drought. This is followed by agriculture, fisheries, aquaculture, and the environment, which both have medium or higher risks across all hazards. The hazard and consequence pairs with the greatest risks (e.g., coastal erosion and environment and infrastructure, post tropical storm and infrastructure, as well as heat wave and potential morbidity, injury, disease, or hospitalization) should be a primary focus for future adaptation strategies.

Hazard	Consequence Category									
	Health			Economy			Environment	Social Stability	Infrastructure	Overall Risk Rating
	Potential loss of life	Potential Morbidity, injury, disease, or hospitalization	Mental health	Tourism and recreation	Agriculture, fisheries, aquaculture	Other industries				
Coastal Erosion	5	5	15	15	10	15	20	15	20	**15.3**
Post-tropical storm	12	12	8	12	16	8	16	12	20	**14.1**
Heat wave	15	20	10	5	15	5	10	10	15	**11.7**
Heavy precipitation and flooding	8	12	8	8	16	8	12	8	16	**11.2**
Severe ice storm/freezing rain	12	12	6	3	6	9	9	6	15	**9.2**
Earlier, warmer springs	4	4	4	8	12	4	16	4	12	**8.8**
Seasonal drought	3	6	12	3	12	3	9	9	6	**7.4**

Risk Score (low end inclusive)	Rating
0 – 3	Negligible
3 – 5	Low
5 – 11	Medium
11 – 18	High
18+	Extreme

Figure 7. Risk scores for consequence categories in the PEI CCRA.

3.1. Coastal Erosion

Scenario: Acceleration of the Historic rate of erosion

Coastal erosion is a natural process that has always occurred on PEI. Evidence indicates that rates of erosion have been increasing in recent years. Importantly, the impacts will depend on how much acceleration occurs and where it is being experienced. Different segments of the coastline will experience these impacts differently. Accelerating coastal erosion on PEI could lead to consequences such as: infrastructure damage; disruption to the natural environment; mental health impacts; and impacts to iconic or economically important Island resources, such as beaches or lighthouses.

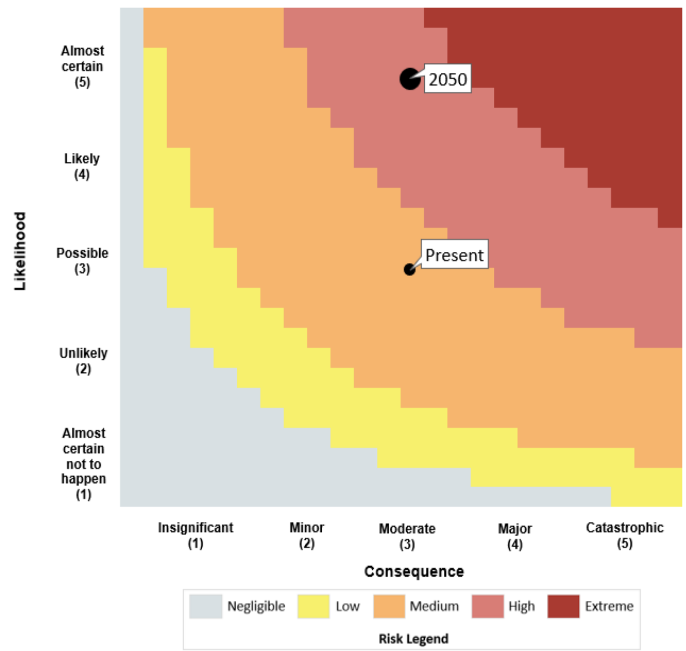

Figure 8. Risk matrix: coastal erosion.

Overall, the present-day risk of coastal erosion is medium, scoring 9.2 out of 25. The 2050 risk rating increases to high, scoring 15.3 out of 25. Figure 8 and Figure 9 summarize the present and future risk, as well as the breakdown of potential consequences. The overall consequence score is 3.1 out of 5, giving this scenario the second highest consequence rating out of the hazards considered (behind post-tropical storms and tied with severe ice storm/freezing rain).

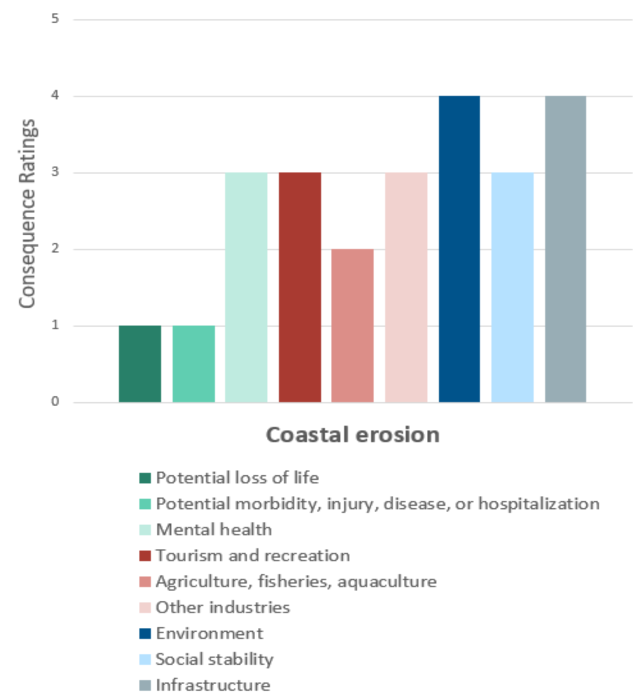

Figure 9. Consequence summary for coastal erosion.

This scenario presents potential consequences of damage to built infrastructure and the natural environment along vulnerable areas of the coast. Damage to those areas then has cascading consequences across all areas of PEI economy and society, such as effects on tourism amenities, private property, sense of place and mental health.

Additionally, it is likely to be unfeasible to protect all at-risk assets, which could lead to difficult decisions as to which are most valuable. Accelerated coastal erosion will likely have varying degrees of consequence to different parts of the Island, and the Lennox Island First Nation is at risk for erosion-related impacts, including to infrastructure, mental health, social stability, sacred grounds, medicinal plant sites, and traditional hunting and fishing areas. Erosion to Hog Island (the barrier island that provides protection to Lennox Island) may exacerbate this erosion risk [22].

Table 9 summarizes these consequences, and additional detail is provided in Section 8.1.

Table 9. Risk assessment summary for accelerated coastal erosion

COASTAL EROSION: Acceleration of the Historic Rate of Erosion			
Likelihood			
Timeframe	**Rating**	**Justification***	**Confidence**
Current	3	On average, the historic rate of erosion of PEI's coastline between 1968 and 2010, was 28 cm each year.	Medium
2050	5	Climate change causes the drivers of coastal erosion (severe storms, storm surge, sea level rise, reduction of sea ice, etc.) to increase in frequency/intensity, therefore coastal erosion is very likely to accelerate across PEI.	Medium
Beyond 2050	Projections for coastal erosion this far into the future are less certain, yet rates will likely continue to accelerate as the drivers of coastal erosion increase in frequency/intensity.		
Consequences			
Category	**Rating**	**Justification**	**Confidence**
Health: Loss of life	1	This scenario has very low potential for loss of life due to its ongoing nature.	High
Health: Morbidity	1	This scenario has very low potential for loss of life due to its ongoing nature.	High
Health: Mental health	3	Widespread loss of sense of place may be realized due to changing landscape and loss of cultural resources, especially for First Nation communities. More acute impacts are likely for those who could be displaced, lose land in their community, or face additional stress from financial impacts of coastal erosion, although the gradual nature of coastal erosion may lessen the severity of impact.	Medium
Economy: Tourism and recreation	3	Effects include less available beach to use for recreation, restricted access to certain parts of parks, and restricted access to coastal roads. Some tourist amenities such as golf courses, small businesses and cultural landmarks may also be at risk.	Low
Economy: Agriculture, fisheries, and aquaculture	2	Agricultural lands nearest to the shoreline may be at risk of losing farmland and suffering from saltwater intrusion, and aquaculture operations can face disruption from changing water flow dynamics, although disruptions are unlikely to be severe.	Medium
Economy: Other industries	3	The PEI real estate market, insurance industry, and private homeowners may face consequences such as declining property value. Local PEI businesses near the shore, or reliant on beach tourism may also be at risk.	Low
Environment	4	Local shoreline biodiversity has potential to see serious disruption, including rare and at-risk species such as the bank swallow and species of cultural significance such as sweetgrass. Coastal armouring and other structural attempts to reduce erosion may have substantial negative environmental impact.	High
Social stability	3	Moderate disruptions may be realized as a result of loss of sense of place, or loss of cultural resources such as beach access, lighthouses, or near shore gathering places. Mi'kmaq communities may be particularly vulnerable to these impacts.	Low

Infrastructure	4	Transportation and wastewater infrastructure may be at particular risk to coastal erosion. Without employing mitigation tactics, infrastructure impacts may be long-term or permanent.	Medium
Potential Opportunities			
• The visibility of coastal erosion damage on PEI provides an opportunity to teach students and the general public about the reality of climate change in an experiential and meaningful manner. • The episodic nature (particularly following storm events) provides an opportunity to observe dramatic permanent changes, while many other climate impacts are incrementable and less immediately perceptible. • Erosion of coastal sandstone cliffs on PEI is a natural ongoing process that supports maintaining PEI's iconic sandy beaches and sand dunes and can occasionally result in new natural areas. For example, the Gulf Shore Parkway, a popular scenic road within the National Park, was decommissioned, leaving sand dunes to undergo natural changes and resulting in the restoration of a saltmarsh and the restoration of a trail and boardwalk. While people initially resisted this change, the altered landscape is now a destination for locals and visitors [23].			
Overall Risk	**Current**	**Medium (9.2)**	
	2050	**High (15.3)**	

*References and additional supporting information for all content in this table are included in the risk assessment details in the appendix.

3.2. Post-tropical Storm

Scenario: Multi-day post-tropical storm with heavy rain, storm surge, and wind; landfall in Queens County

The assessment focused on a multi-day post-tropical storm with heavy rain, storm surge, and wind making landfall in Queens County. A storm with these conditions can lead to consequences such as infrastructure damage; disruption to the natural environment, including forest cover, coastline stability and hydrology; and damage to crops.

Overall, the present-day risk of a post-tropical storm scenario is **high**, scoring 14.1 out of 25. The 2050 risk rating remains **high**, with the same score of 14.1 out of 25. Figure 10 and Figure 11 summarize the present and future risk, as well as the breakdown of potential consequences. The overall consequence score is 3.5 out of 5, giving this scenario the highest consequence rating out of the hazards considered.

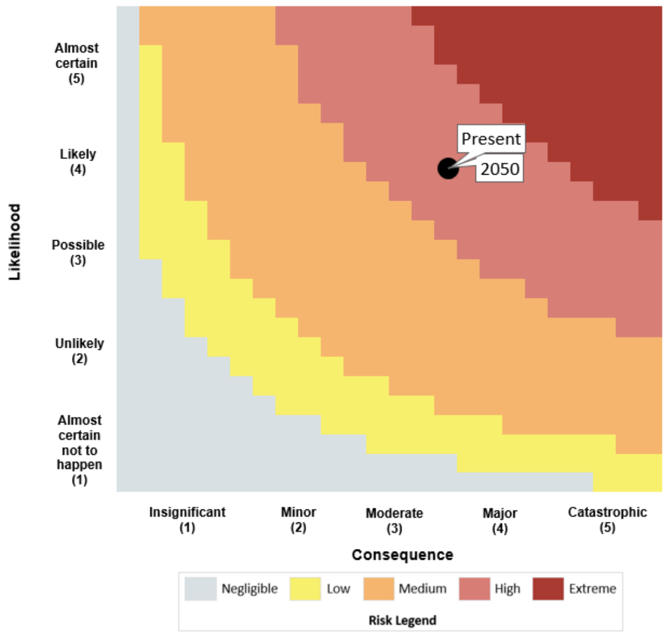

Figure 10. Risk matrix: post-tropical storm.

Compounding impacts of multiple post-tropical storms in one hurricane season hold potential to increase consequence, especially in the economy, environment, and infrastructure categories, although, the ratings in this assessment assume a single post-tropical storm event. Additionally, severity and type of damage will be dependent on the intensity and the track of the storm. For example, a Category 2 hurricane making landfall on an urban area is likely to have more severe impacts than a post-tropical storm where the most intense bands miss populated areas. The ratings below are based on a post-tropical storm defined as a multi-day storm with heavy rain, storm surge, and wind making landfall in Queens County, which would have island-wide impacts.

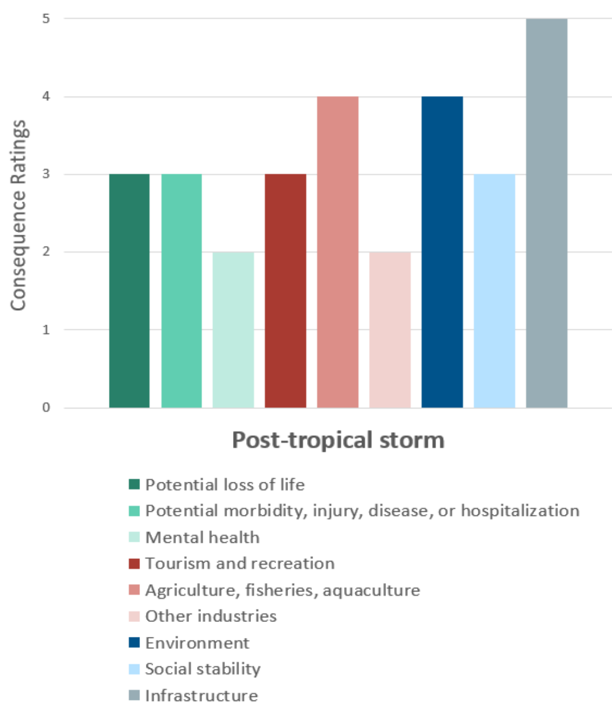

Figure 11. Consequence summary for post-tropical storm.

There are several areas on PEI that may face particularly severe impacts as a result of extreme events due to limited access, difficulties during evacuation, or lack of preparedness. These include Panmure Island and, North Rustico and many private lanes with multiple cottages [24]. Post-tropical storms may also undermine or damage the bridge to Lennox Island, which could isolate the community and impair access to emergency services and supplies. The land base of the bridge is low-lying and floods regularly during storm surge events, with water typically receding within 6-12 hrs. Additionally, the north shore of the province is more likely to face significant impact from storm surge because the tidal range is smaller.

Table 10 summarizes the risk assessment results, and additional detail is provided in Section 8.2.

Table 10. Risk assessment summary for post-tropical storm hazard

POST-TROPICAL STORM: Multi-day Post-tropical Storm with Heavy Rain, Storm Surge, and Wind; Landfall in Queens County			
Likelihood			
Timeframe	**Rating**	**Justification***	**Confidence**
Current	4	From 1900-1949 severe storms (average sustained wind speed of 63 kilometres per hour or greater) occurred equivalent to a 12% annual chance on PEI. From 1950-1999, and from 2000-2019 the equivalent annual chance was 22% and 20%, respectively. This suggests severe storms are likely to occur about once every 3-10 years on PEI.	High
2050	4	Severe storms will likely increase in frequency, but storms as defined in this scenario (multi-day post-tropical storms with heavy rain, storm surge, landfall in Queens County), are unlikely to occur more than once every two years, thus the future likelihood rating does not increase.	Medium
Beyond 2050	Projections for severe storms this far into the future are less certain, although further increases in severity and frequency of severe storms is expected.		
Consequences			
Category	**Rating**	**Justification**	**Confidence**
Health: Loss of life	3	Post-tropical storm events have historically caused limited loss of life. However, there is potential for multiple loss of life (e.g., 2-10 people), particularly if warning time is limited, or access to medical and emergency care is impaired.	Medium
Health: Morbidity	3	Historically, there are few reported instances of serious injury, disease, or hospitalization. PEI's low potential for hurricanes more powerful than Category 2 also lessens the probability of injury. Still, hazards such as fast-moving floodwaters, debris, and falling trees create potential for injury and power outages can result in health impacts or lack of access to medical care.	Medium
Health: Mental health	2	Populations may experience increased stress and anxiety and loss of sense of place. More severe impacts are likely for those who are displaced, experience damages to personal property, or suffer from extended power outages.	Low
Economy: Tourism and recreation	3	Specific sites, such as campgrounds and parks, may face severe, weeks-long disruptions. Road closures, power outages, cancelled events, limited access to attractions, and park closures may disrupt tourists' itineraries or cause tourists to cancel trips altogether.	Low
Economy: Agriculture, fisheries, and aquaculture	4	There is potential for moderate disruption to multiple industries and isolated severe disruption to the shellfish industries and crops that are particularly sensitive to wind damage (e.g., fruits and vegetables). Disruptions may last as long as a few days to a season and in rare instances can last multiple seasons.	Medium

Economy: Other industries	2	Days to weeks-long disruption to PEI's industries such as manufacturing and shipping is possible, mostly due to power outages, road/bridge closures, or ferry closures.	Low
Environment	4	Natural assets such as freshwater fisheries and biodiversity may take months to years to recover from a post-tropical storm. Forest cover may be dramatically impacted, taking decades to fully recover. Coastline stability and hydrology may be severely disrupted, causing irreversible damage.	High
Social stability	3	Road/bridge closures, destroyed property, extended power outages, damaged or flooded homes, and school closures can result in moderate to severe disruption to daily life. Financial stress, break in routine, and feelings of hopelessness may also occur for periods of weeks to months depending on time required to recover and rebuild.	Medium
Infrastructure	5	Impacts include washed out roads, damage to utility infrastructure, damage to water drainage or wastewater treatment sites, and driving/travelling restriction, among others. Disruptions can last for days to months, depending on the severity of the event and period of time required for redesign and reconstruction of damaged infrastructure.	High
Potential Opportunities			
None identified.			
Overall Risk	**Current**	**High (14.1)**	
	2050	**High (14.1)**	

*References and additional supporting information for all content in this table are included in the risk assessment details in the appendix.

3.3. Heat Wave

Scenario: Three consecutive days with temperatures above 29°C

To evaluate risks of a heat wave, the assessment focused on a specific scenario of three consecutive days with temperatures over 29°C, a threshold at which Environment Canada issues heat advisories. This scenario can lead to consequences such as physical health impacts, with some potential for loss of life, as well as damage to infrastructure, including potential power outages.

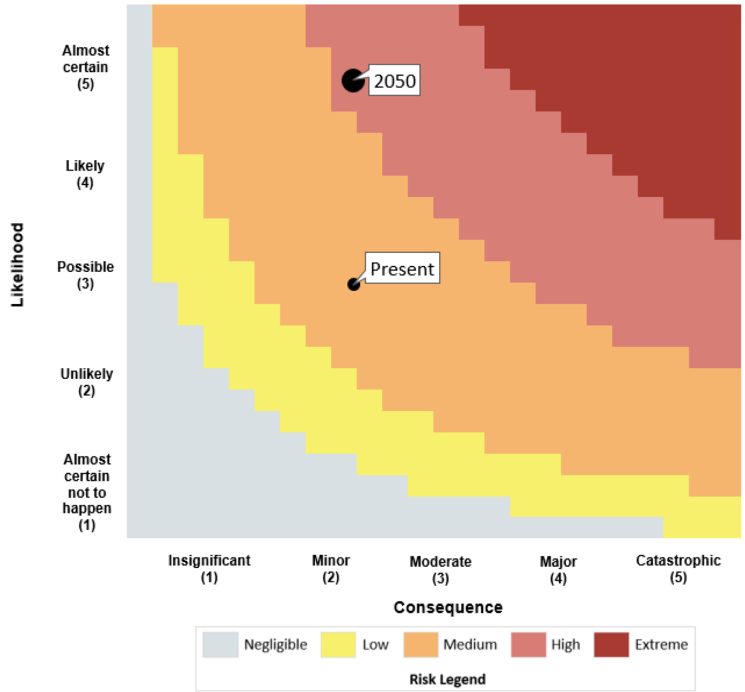

Figure 12. Risk matrix: heat wave.

Overall, the present-day risk of a heat wave scenario is **medium**, scoring 7.0 out of 25. The 2050 risk rating increases to **high**, reaching 11.7 out of 25 (see likelihood section for explanation). Figure 12 and Figure 13 summarize the present and future risk, as well as the breakdown of potential consequences. The overall consequence score is 2.3 out of 5, giving this scenario the second lowest consequence rating out of the hazards considered.

The ratings in this assessment assume a single heat wave event occurring in isolation, but compounding impacts of a heat wave with drought, or multiple heat wave events in one season hold potential to increase consequences. Additionally, the amount or duration by which temperatures exceed 29°C can influence the severity and type of damage. Risks are greatest for older adults, infants and young children, people with chronic illnesses, people who work or exercise in the heat, people experiencing homelessness, and low-income earners.

Table 11 summarizes the risk assessment results, and additional detail is provided in Section 8.3.

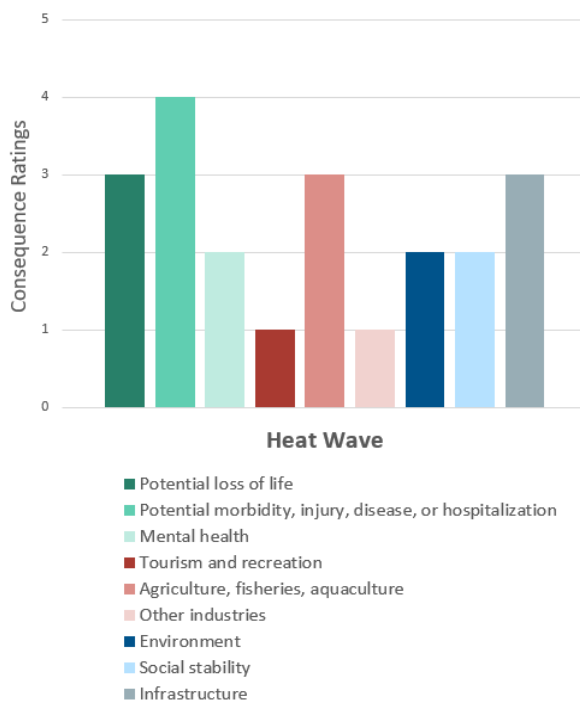

Figure 13. Consequence summary for heat wave.

Table 11. Risk assessment summary for heat wave hazard

HEAT WAVE: Three Consecutive Days with Temperatures above 29°C			
Likelihood			
Timeframe	**Rating**	**Justification***	**Confidence**
Current	3	On average heat waves of 3+ days over 29°C currently have a 5% chance of occurring each year (0.05 times per year) in the 1980-2020 time period.	High
2050	5	Based on modelled data, heat waves of 3+ consecutive days over 29°C are projected to occur 1.7 times per year by mid-century (averaging over the 2041-2060 period).	High
Beyond 2050	Heat waves are expected to continue to increase in frequency beyond 2050.		
Consequences			
Category	**Rating**	**Justification**	**Confidence**
Health: Loss of life	3	There is some potential for loss of life on PEI as a result of heat wave events. Risk of death is higher for vulnerable populations (e.g., seniors, infants, low-income) and for individuals suffering from heat-related health conditions who are left untreated.	Medium
Health: Morbidity, injury, disease, or hospitalization	4	Physical health disruptions can range from minor (heat rash or heat cramps) to life threatening (severe dehydration or nervous system damage). Vulnerable populations (seniors, infants, those with limited access to air conditioning, people working outdoors etc.) are at higher risk.	Medium
Health: Mental health	2	There is potential for widespread moderate mental health impacts such as increased anxiety and discomfort as a result of heat wave events.	Low
Economy: Tourism and recreation	1	Small-scale, short-term disruptions, such as disinclination or inability for tourists to experience outdoor attractions are possible.	Low
Economy: Agriculture, fisheries, and aquaculture	3	Agriculture may face moderate disruption, as heat stress may affect poultry, livestock, worker productivity, and potato yield.	Medium
Economy: Other industries	1	Restaurants, and other businesses unable to control the climate of their place of business may face disruption during the course of heat wave events. Effects are likely to be short-term and insignificant.	Low
Environment	2	Localized and moderate disruption is possible as water quality can suffer while amphibians, trees, and species with low heat tolerance may face increased thermal stress.	Medium
Social stability	2	Short-term negative consequences, such as higher crime rates, increased incidence of domestic violence, and lower productivity are possible. Disruptions are mostly likely to be experienced by populations more likely to face social isolation, such as the elderly.	Low
Infrastructure	3	Moderate disruption is possible. Consequences include increased strain on electric utilities, potential blackouts, and damage to	Medium

		transportation infrastructure. Workers may face increased risk of occupational safety and health risk.	
Potential Opportunities			
• Increased opportunities for tourism operations that provide water-based or cooling activities, such as beaches or water parks and increased opportunities for facilities that offer air conditioning.			
Overall Risk	**Current**	**Medium (7.0)**	
	2050	**High (11.7)**	

*References and additional supporting information for all content in this table are included in the risk assessment details in the appendix.

3.4. Heavy Precipitation and Inland Flooding

Scenario: 100 mm rain event in 24 hours

The heavy precipitation and inland flooding scenario focused on an event of 100 mm or more of rain falling in 24-hours. An event of this magnitude currently has a 4 percent chance of occurring in any year. Such an event can lead to runoff and flooding, which in turn can damage stormwater, transportation, and other infrastructure; cause unsafe driving conditions; reduce groundwater recharge; contaminate waterways; and damage crops, among other impacts.

Overall, the present-day risk of this heavy precipitation and flooding scenario is medium, scoring 8.4 out of 25, and the 2050 risk rating increases to **high,** scoring 11.2 out of 25. Figure 14 and Figure 15 summarize the present and future risk, and the breakdown of potential consequences, respectively.

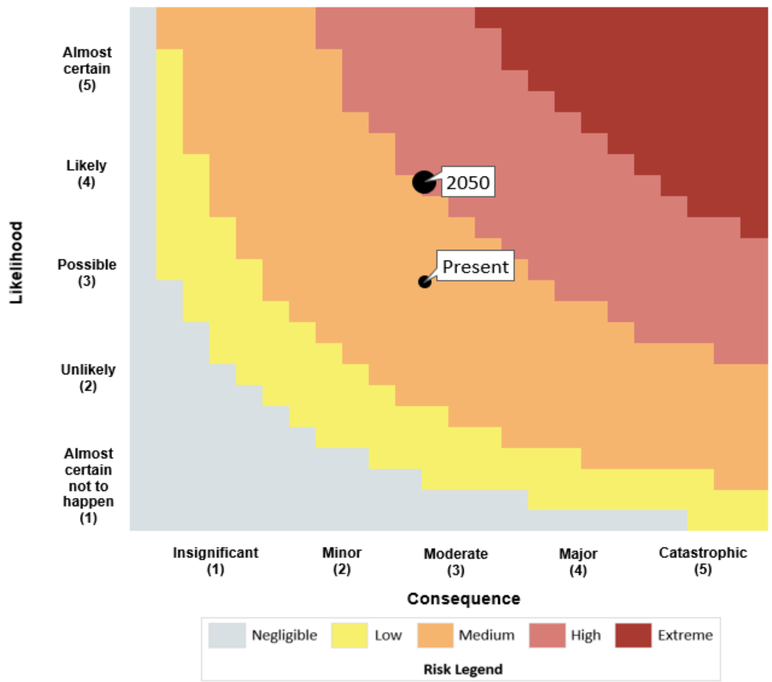

Figure 14. Risk matrix: heavy precipitation and inland flooding.

The severity and type of damage that occurs will depend upon the time of year that the flood event occurs and the rate at which rainfall occurs over the 24-hour period. For example, storms in the summer months would be more likely to cause significant access issues versus early spring or late winter storms and two hours of intense rainfall is more likely to lead to infrastructure damage such as culvert washouts and road damage, while resources and infrastructure may be more resilient in response to lighter but more consistent rain events. Compounding impacts of multiple floods also have the potential to increase consequences, although the ratings in this assessment assume a single heavy precipitation event occurring in isolation.

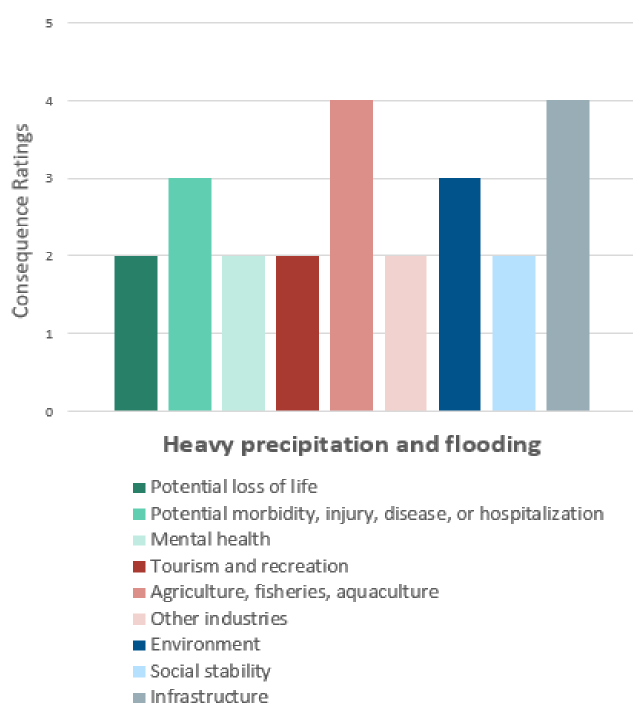

Figure 15. Consequence summary for heavy precipitation and inland flooding.

The greatest impacts may be experienced by those whose livelihoods rely on low-lying agricultural lands or freshwater fisheries/aquaculture. Additionally, those industries that require consistent access to transportation would be more impacted during road closures resulting from flooding.

Table 12 summarizes the risk assessment results, and additional detail is provided in Section 8.4.

Table 12. Risk assessment summary for heavy precipitation and inland flooding hazard

HEAVY PRECIPITATION AND FLOODING: 100 mm Rain Event in 24 Hours			
Likelihood			
Timeframe	**Rating**	**Justification***	**Confidence**
Current	3	A rain event with approximately 100 mm of precipitation within 24 hours, has a 4% chance of occurring in any year, otherwise known as a 1-in-25 year event.	High
2050	4	Heavy rain events are projected to become more frequent and intense, such that a rain event that has a 4% annual chance of occurring now could have an approximately a 10% chance of occurring in any year by mid-century.	Low
Beyond 2050	Extreme precipitation events are expected to continue to increase in frequency and intensity beyond 2050.		
Consequences			
Category	**Rating**	**Justification**	**Confidence**
Health: Loss of life	2	This scenario has low potential for multiple losses of life, although loss of life could occur if access to medical and emergency care is impaired.	Low
Health: Morbidity	3	Flash flooding and/or agriculture contamination could pose health risks to PEI communities. It also may cause difficulties during evacuation due to lack of access to transportation routes.	Low
Health: Mental health	2	Widespread moderate mental health impacts are expected with some isolated severe impacts, especially those subject to or experiencing displacement, flood damage, evacuation, and utility disruption.	Medium
Economy: Tourism and recreation	2	Road closures may limit access to tourist sites or disrupt tourist itineraries, but disruptions are expected to be minimal and short-term.	Low
Economy: Agriculture, fisheries, and aquaculture	4	Freshwater fish kills resulting from pesticide runoff and shellfish fisheries damage in the form of erosion, silt formation, and/or equipment damage are possible under this scenario. There is also potential for washouts and damage to agricultural crops, such as potatoes.	Medium
Economy: Other industries	2	Days- to weeks-long disruption can occur to PEI's other industries including manufacturing and shipping, mostly due to road closures or ferry/marine shipping centre closures.	Low
Environment	3	The majority of PEI's natural environment is likely to be resilient to this flooding scenario, although specific species such as freshwater fish and shellfish can experience stress or damage from contamination and lower water quality.	Low
Social stability	2	Negative community-wide social stability impacts are possible as a result of disruption to daily life and financial stress.	Low
Infrastructure	4	Road washouts, damage to utility/water supply infrastructure, and driving/travelling restrictions could potentially last days to weeks.	Medium

Potential Opportunities			
None identified.			
Overall Risk	**Current**	**Medium (8.4)**	
	2050	**High (11.2)**	

*References and additional supporting information for all content in this table are included in the risk assessment details in the appendix.

3.5. Severe Ice Storm/Freezing Rain

Scenario: Multi-day severe ice storm/freezing rain event in winter

This scenario considers an ice storm with effects (e.g., ice on vegetation and infrastructure) lasting several days or more. These storms occur when temperatures are freezing or below freezing; they may involve snow but are defined by the presence of ice and/or freezing rain.

Severe ice storms and freezing rain events on PEI can lead to consequences such as: significant potential loss of life and injury; power outages and infrastructural damage (particularly to electric transmission and distribution infrastructure); damaged or downed trees; and limitations on ground and air travel due to unsafe conditions.

Overall, the present-day risk of this severe ice storm/freezing rain scenario is **high**, scoring 12.3 out of 25, while the 2050 risk rating becomes **medium**, with the score decreasing to 9.2 out of 25. Figure 16 and Figure 17 summarize the risk assessment results for this scenario. The overall consequence score is 3.1 out of 5, giving this scenario the second highest consequence rating out of the hazards considered (behind post-tropical storm and tied with coastal erosion).

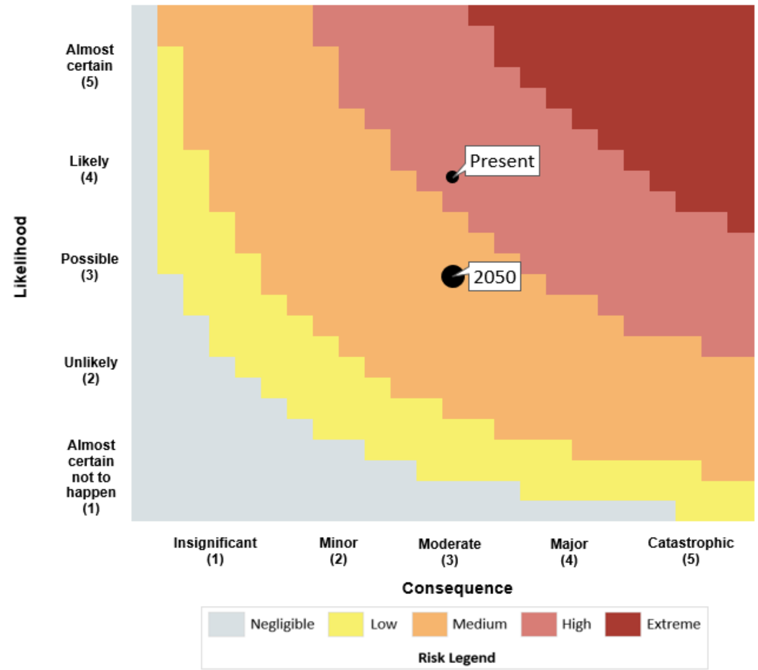

Figure 16. Risk matrix: severe ice storm/freezing rain.

The potential for loss of life and morbidity is relatively high, with a consequence score of 4, as ice storms have previously resulted in death and injury. Infrastructure faces the highest consequence rating for ice storms (5), as the most frequent and impactful consequence of ice storms has been prolonged, widespread power outages (i.e., loss of critical infrastructure) and road closures. Power outages and limited transportation options have further health, social, and economic consequences, worsening the longer they last.

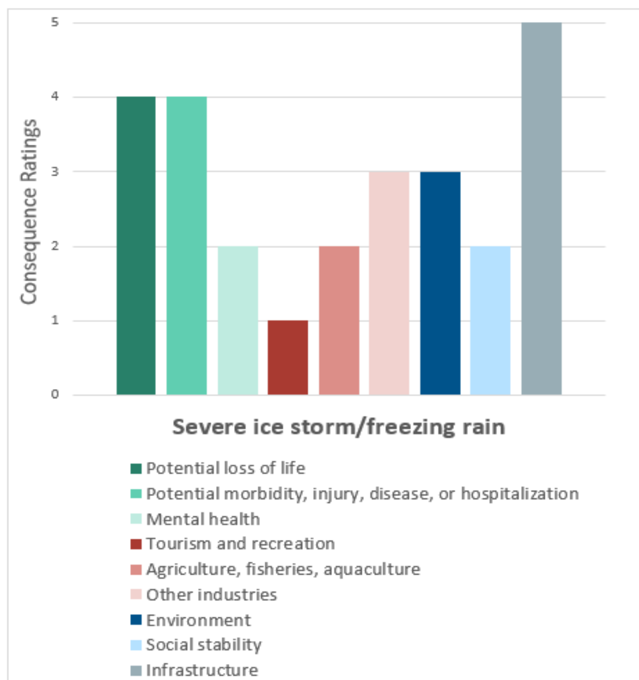

Figure 17. Consequence summary for ice storms/freezing rain events.

Not all people or sectors will be affected equally. For example:

- People with limited access to backup fuel sources (e.g., a wood stove, battery-powered lights and radios, generators, heaters) are more likely to experience negative health impacts during a prolonged power outage. Generators can be costly and low-income families may have less access to backup power as a result [24].
- Residents dependent on mobility devices may be more susceptible to falls and injuries in icy conditions.
- Families and caregivers due to school cancellations and subsequent childcare concerns.
- People experiencing homelessness may be more susceptible to physical and mental health impacts due to exposure to the elements and lack of healthcare access.
- Workers in service and essential industries who must go to work despite hazardous road conditions will be more exposed to safety risks.
- Residents living on private roads in more remote or rural areas may be without critical services for longer or have difficulty accessing resources until roads are cleared.

There are also several areas on PEI that may pose challenges during extreme events due to limited access, difficulties during evacuation, or lack of preparedness. These include Panmure Island and North Rustico ports [24]. Furthermore, citizens of Lennox Island may also be vulnerable to a severe ice storm or freezing rain event, especially if the Lennox Island Causeway is damaged or too icy for safe travel. Consequences may include lack of access during a health emergency, difficulty transporting food, fuel, and other goods and services, as well as interrupted communication.

Table 13 summarizes these consequences, and additional detail is provided in Section 0.

Table 13. Risk assessment summary for severe ice storm/freezing rain

SEVERE ICE STORM/FREEZING RAIN: Multi-Day Ice Storm/Freezing Rain Event in Winter			
Likelihood			
Timeframe	**Rating**	**Justification***	**Confidence**
Current	4	From 1950 to 2005, Charlottetown has experienced an average of about 68 ice days per year. From 1950 to 2005, Charlottetown experienced an average of 154 frost days per year. In addition, over the past century, PEI has experienced ice storms approximately every 5 to 10 years.	High
2050	3	The number of ice days and frost days are projected to decrease 41% and 27% respectively by mid-century compared to the historical average as is ice accretion thickness, while the amount of total annual precipitation is projected to increase. As temperatures warm, the ratio of precipitation falling as rain rather than snow or ice is expected to increase. These are proxy metrics and do not perfectly capture the unique conditions of ice storms and freezing rain events.	Low
Beyond 2050	Beyond 2050, temperatures are projected to increase and the number of annual ice days and frost days as well as ice accretion thickness are projected to decrease. There is less consensus on precipitation projections, though the general trend toward more precipitation than the historical average is expected. As these are imperfect proxy metrics, there is high uncertainty in future projections beyond 2050.		
Consequences			

Category	Rating	Justification	Confidence
Health: Loss of life	4	There are a variety of ways that ice storms can be fatal for as many as 10-100 people, including freezing/hypothermia, being struck by falling trees/poles, vehicle accidents, overexertion while trying to deal with the onslaught of wet snow and ice, and carbon monoxide poisoning due to improper use of generators and heaters during power outages.	Medium
Health: Morbidity	4	Ice storms present opportunities for as many as 100-1,000 injuries and other health hazards, including slipping or crashing due to icy roads, being struck by falling branches, dangerous driving conditions, hypothermia, and health impacts due to extensive power outages.	Medium
Health: Mental health	2	Temporary displacement due to hazardous conditions and loss of heating and electricity can result in short-term feelings of fear, anxiety, and stress which can pose disruptions to normal life.	Low
Economy: Tourism and recreation	1	Ice storms generally impact tourism and recreation by temporarily limiting travel and creating unsafe conditions for outdoor recreation. The ice storm scenario considered in the CCRA would only cause disruptions in one season (winter).	Low
Economy: Agriculture, fisheries, and aquaculture	2	Extreme cold and ice conditions can negatively affect livestock, perennial crops, and forage crops. Although winter is the offseason for fisheries, there may be temporary disruptions to aquaculture as well.	Low
Economy: Other industries	3	Power outages, structural damage to critical infrastructure, and hazardous road conditions could negatively affect the majority of PEI's service industries. Outages and infrastructure repairs could cause severe days to months-long disruptions, especially if persistent dangerous weather conditions make it more difficult to perform repairs.	Low
Environment	3	The most prominent impact to the environment is damage to trees (which can then damage critical infrastructure). Ice damage to trees includes broken branches, bending of the trunk or crown, or total loss of the tree from the weight of the ice	Medium
Social stability	2	Social stability is impacted by loss of electricity and the closing of businesses, schools, and government offices. Such disruptions – particularly outages – can last for days to weeks.	Low
Infrastructure	5	Transportation, energy, and communication infrastructure are all vulnerable to damage or disruption. The most prevalent and expected impact of past events is loss of electricity – which has lasted for days to even months and has widespread ripple effects on other consequence categories such as health, economy, and social stability.	High
Potential Opportunities			
When repairing and rebuilding after ice storm damage, there is the opportunity to "build back better" and incorporate resilient design.			
Overall Risk	**Current**	**High (12.3)**	
	2050	**Medium (9.2)**	

*References and additional supporting information for all content in this table are included in the risk assessment details in the appendix.

3.6. Earlier, Warmer Springs

Scenario: Earlier arrival of spring temperatures by two weeks affecting key species

The earlier onset of warm spring temperatures is an ongoing climate hazard that will happen gradually due to increasing temperatures and reduced sea ice coverage. This gradual shift may also be punctuated by short-term warm spells and variability in temperature.

Earlier arrival of spring temperatures could result in mainly positive consequences by mid-century for PEI including: a temporary increase in lobster population; an extended growing season for existing and new crops; an extended spring tourism season; and expansion of suitable habitat for flora and fauna. This gradual shift, however, will necessitate some change and action in order to take advantage of new opportunities (e.g., modifications to planting and harvesting). Negative consequences could also include infrastructure damage from a change in freeze/thaw cycles and an increase in the prevalence of pests, diseases, and invasive species.

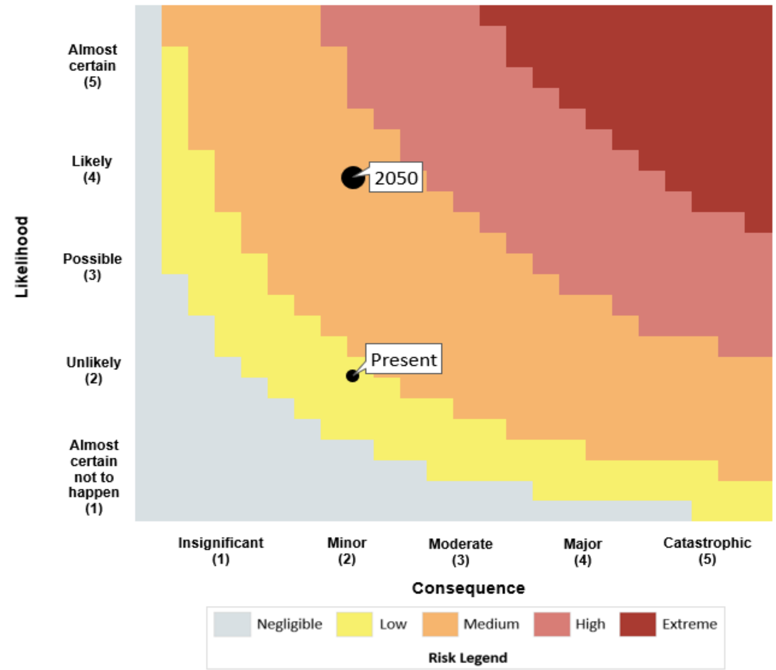

Figure 18. Risk matrix: earlier, warmer springs.

Overall, the present-day risk of earlier, springs is **low**, scoring 4.4 out of 25, while the 2050 risk rating is **medium**, scoring 8.8 out of 25. Figure 18 and Figure 19 summarize the risk assessment results for this scenario. The overall consequence score is 2.2 out of 5, giving this scenario the lowest consequence rating out of the hazards considered.

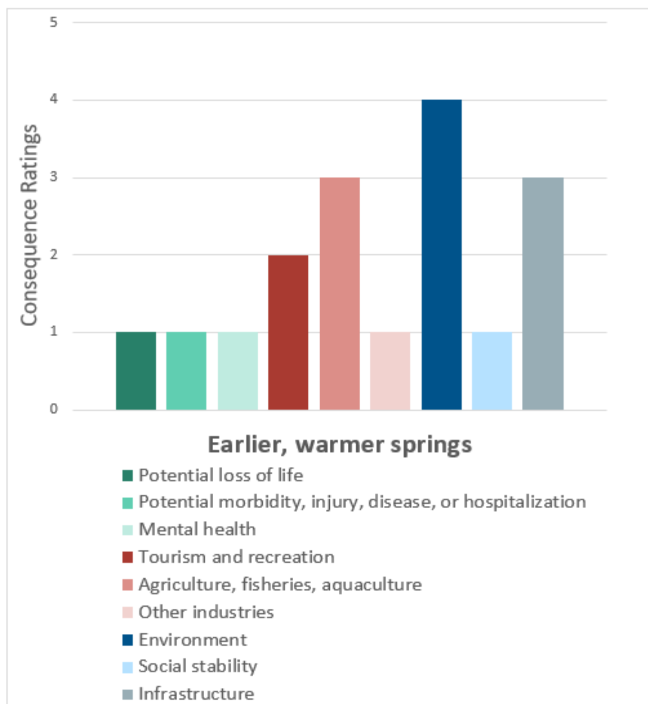

Figure 19. Consequence summary for earlier, warmer springs.

While many of the consequences of earlier, warmer springs are positive by mid-century, some may shift to negative consequences by end of century as critical temperature thresholds are surpassed. This is especially true for lobster. Losses from warmer sea temperatures are already being observed at lower latitudes. Additionally, shifts in seasonality could have disproportionate impacts on Indigenous communities and farmers, whose way of life may be more closely tied to the land compared to other communities and farmers.

Table 14 summarizes these consequences, and additional detail is provided in Section 8.6.

Table 14. Risk assessment summary for earlier, warmer springs

EARLIER, WARMER SPRINGS: Earlier Arrival of Spring Temperatures Affecting Key Species			
Likelihood			
Timeframe	**Rating**	**Justification***	**Confidence**
Current	2	Mean monthly temperatures have historically risen above 0°C between March and April.	Medium
2050	4	Above freezing temperatures are projected to begin between February and March. This indicates a shift in the arrival of warm temperatures by at least two weeks and monthly temperatures will continue to be warmer than the historic average.	Medium
Beyond 2050	Monthly temperatures will continue to warm. While mid-century projections could largely result in positive consequences or opportunities, late-century temperatures may lead to more negative consequences as critical thresholds are crossed for specific species (e.g., lobster)		
Consequences			
Category	**Rating**	**Justification**	**Confidence**
Health: Loss of life	1	No expected loss of life. Rather, warmer temperatures could contribute to a decrease in cold-related mortality.	High
Health: Morbidity	1	Earlier arrival of spring temperatures is not expected to directly cause morbidity, injury, disease, or hospitalization. However, a longer growing season could lengthen the allergy season and support disease-transmitting insects.	Medium
Health: Mental health	1	Positive mental health impacts are expected from an increase in the lobster industry such as reduced stress and a strengthened sense of pride and place. Seasonal affective disorder could also be alleviated sooner.	Low
Economy: Tourism and recreation	2	The winter tourism and recreation season is expected to decrease while the spring tourism season could expand. There could also be an increase in the need for and duration of seasonal employment services.	Low
Economy: Agriculture, fisheries, and aquaculture	3	Agriculture and fisheries industries are expected to have an earlier and extended growing and harvest season. Lobster is expected to become more prevalent around PEI and experience a shift in the start of the spring lobster season.	Medium
Economy: Other industries	1	Shifts in economic activities (e.g., agriculture and aquaculture harvesting, construction) could shift or expand processing and shipping activities as well as seasonal employment needs.	Low
Environment	4	Many species will experience a shift in the onset of spring and related biological responses to warmer temperatures. This shift is also expected to extend growing seasons and suitable habitat ranges. Negative impacts could include phenological mismatch between key species and increased prevalence of pests, disease, and invasive species.	Low
Social stability	1	Positive impacts to culture and limited or else positive impacts to daily life.	Low
Infrastructure	3	As freeze/thaw cycles change in response to earlier, warmer temperatures, roads may become more susceptible to frost heaving	Low

		and potholes. Lower energy demand for heat could represent a positive impact.	
Potential Opportunities			
• Temporary expansion of the lobster industry as optimal conditions continue to shift northward. • Extension of growing season for agriculture and potential to grow new crops. • Lower energy demand for heat. • Extended season for active transportation and outdoor recreational activities.			
Overall Risk	**Current**	**Low (4.4)**	
	2050	**Medium (8.8)**	

*References and additional supporting information for all content in this table are included in the risk assessment details in the appendix.

3.7. Seasonal Drought

Scenario: Months-long severe summer drought affecting the entire province

A months-long severe summer drought (-3.0 to -3.9 on the Palmer Drought Severity Index[5]) affecting the entirety of PEI can lead to consequences such as agricultural damage, mental health disruptions, and weakened social stability. The agricultural industry and the industries that rely on the agriculture industry are particularly vulnerable. While the future likelihood of severe seasonal drought on PEI is difficult to ascertain, climate models for North America indicated that evaporation and surface drying are expected to increase, leading to more frequent drought events, especially in the summer [210]. In PEI, total precipitation has decreased over the past 50 years—a trend that is expected to continue in the short term.

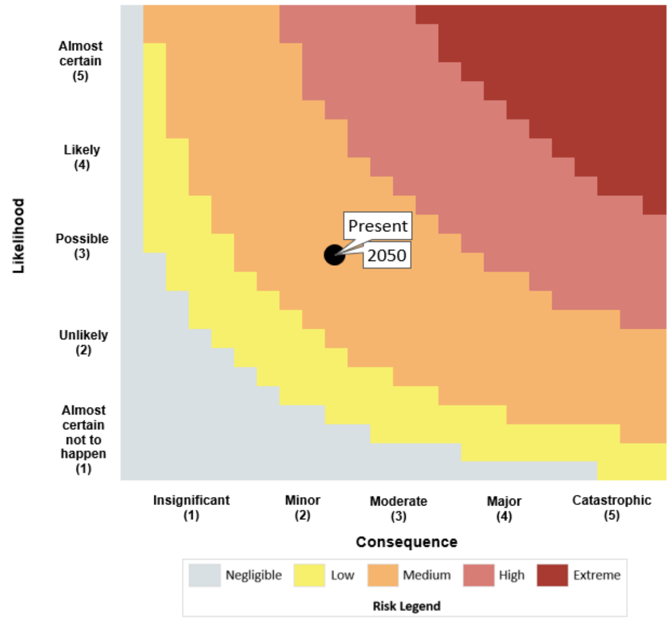

Figure 20. Risk matrix: seasonal drought.

Overall, the present-day risk of a seasonal drought scenario is **medium**, scoring 7.4 out of 25, while the 2050 risk rating remains **medium**, with the same score. Figure 20 and Figure 24Figure 13 summarize the present and future risk, as well as the breakdown of potential consequences. While the current and future overall consequences of a seasonal drought event on PEI are rated as moderate, drought could have more severe consequences for particularly vulnerable industries and populations. For example, low-income individuals and agricultural communities may be particularly vulnerable to drought impacts, especially if drought influences the price or availability of produce or seasonal employment opportunities. Additionally, this analysis considers only a single drought event. Multiple drought events over many years may be cause for more serious and permanent consequences.

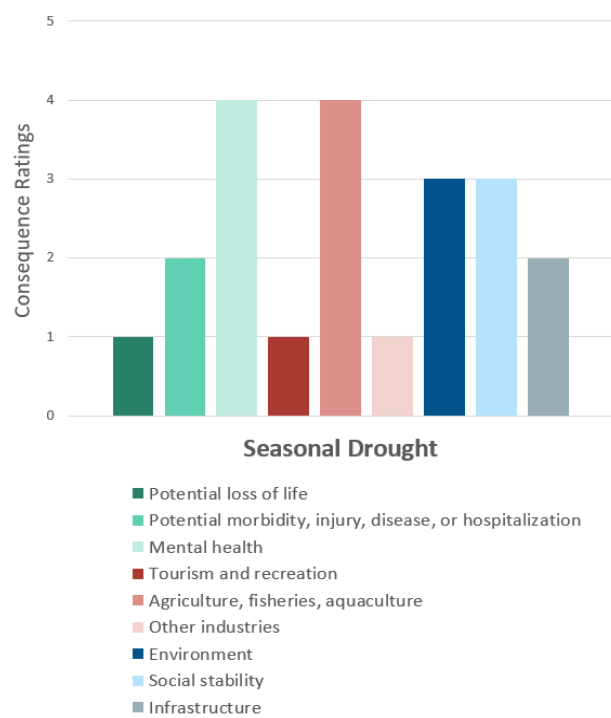

Figure 24. Consequence summary for seasonal drought.

Table 15 summarizes the risk assessment results, and additional detail is provided in Section 8.7.

[5] A standardized index that uses temperature and precipitation data to determine a -10 (dry) to +10 (wet) rating.

Table 15. Risk assessment summary for seasonal drought

SEASONAL DROUGHT: Months-Long Summer Drought Affecting the Entire Province			
Likelihood			
Timeframe	**Rating**	**Justification***	**Confidence**
Current	3	According to the Canadian Drought Monitor, severe drought (-3.0 to -3.9 on the Palmer Drought Severity Index) occurs once every 10-20 years.	High
2050	3	Future likelihood of severe seasonal drought on PEI is difficult to ascertain. Preliminary projections indicated PEI is to experience a decrease from the current levels of precipitation by 6% on average through 2040s. However, these changes may not necessarily indicate greater likelihood of drought on PEI.	Low
Beyond 2050	Longer-term drought projections are even more uncertain. Over time, models show total annual precipitation returning to today's normal by the 2080s (2071-2100), though total annual precipitation is not a direct measure of drought [25].		
Consequences			
Category	**Rating**	**Justification**	**Confidence**
Health: Loss of life	1	There is virtually no potential for a months-long seasonal drought resulting in loss of life on PEI.	Low
Health: Morbidity	2	There is potential for the possibility of an increase in rates of injury and infectious diseases; however, there is no past evidence of droughts resulting in these impacts on PEI. Second and third order impacts of effects of droughts, such as wildfire and decreased air quality may also result in health effects.	Medium
Health: Mental health	4	Serious disruption to individual wellbeing is possible, especially for those whose occupations rely on agriculture. Because agriculture is a critical industry on PEI, there is potential for widespread mental health impacts.	Medium
Economy: Tourism and recreation	1	The tourism and recreation industry on PEI is unlikely to be dramatically affected by drought events. Golf courses, gardens, and some agriculture-related tourist attractions (e.g., flowering potato crops, gardens at heritage sites) may face slight impacts, but they will likely be short-term.	Low
Economy: Agriculture, fisheries, and aquaculture	4	Potatoes are the most vulnerable and economically impactful crop on PEI that are likely to face effects, although other water-sensitive crops may face impacts as well.	High
Economy: Other industries	1	There is little evidence suggesting other industries will face consequences of drought on PEI.	Low
Environment	3	Coastal wetlands and streamflow may be vulnerable to impacts. A single drought event can cause short-term impacts, although irreversible damages could occur if seasonal drought events occur repeatedly over many years.	Medium
Social stability	3	Moderate disruptions are possible, mostly as a result of damages to the agriculture industry. Those directly reliant on agriculture are most	Low

		vulnerable with some cascading moderate disruption possible for other residents, in areas such as jobs and food security.	
Infrastructure	2	Small, short-term disruptions are possible. Specific areas of concern include irrigation infrastructure, as well as energy system stress if drought affects off-province hydroelectric sources of power.	Low
Potential Opportunities			
None identified.			
Overall Risk	**Current**	**Medium (7.4)**	
	2050	**Medium (7.4)**	

*References and additional supporting information for all content in this table are included in the risk assessment details in the appendix.

4. Indigenous Perspectives on Climate Risks

Following a workshop with Indigenous leaders, the CCRA project team was invited to contribute key questions to research already underway by Julie Pellissier-Lush, Community Consultant for MCPEI. Ms. Pellissier-Lush was conducting one-on-one interviews with citizens of Abegweit First Nation and Lennox Island First Nation to capture Indigenous perspectives for a separate project, and she generously gathered additional information on climate-related risks to Indigenous communities on PEI for the CCRA.

A total of 30 people took part in the interviews in early 2021. Of these, 14 people were citizens of Abegweit First Nation and 16 people were citizens of Lennox Island First Nation. One-third of the people interviewed (10 out of 30) lived on reserve. The people who took part in the interviews represented a cross-section of ages and included three people between the ages of 16 to 19, 10 people between the ages of 19 to 35, nine people between the ages of 35 to 50, and eight people over the age of 50.

During the interviews, each person was asked the following questions:

1. What are the effects from climate change to you personally and in your community?
2. What things could be done to reduce the harm to your community from climate change?
3. What actions have you or your community taken to date to reducing greenhouse gases within your home or community? (note: this question does not pertain directly to the CCRA but is relevant for continued coordination between the Province and Indigenous communities with respect to future climate change planning).

For each question, the answer that was provided by each interviewee was transcribed without accompanying personal information that could be used to identify the individual.

Following the interviews, the transcripts were reviewed and analyzed in relation to the seven climate hazard scenarios within the scope of the CCRA. Other climate change related information gathered during the interviews was also summarized.

The findings of the interviews are presented below and in Table 16 .This information has also been incorporated into the hazard-by-hazard risk assessment profiles.

Question 1: What are the effects from climate change to you personally and in your community?

- Thirteen citizens indicated that warmer winter temperatures are resulting in less snow. This affects the ability of community members to participate in winter activities (e.g., skating, skiing) as well as their mental and physical health and wellbeing. This also negatively affects farmers.

- Five citizens indicated that they have observed an increase in rapid fluctuations in temperature (e.g., between warm weather, rain, cold weather and snow events), which is affecting their personal health and wellbeing (e.g., by causing migraine headaches).

- Two citizens indicated that rapid fluctuations in temperature are affecting the livelihood of their community members by making hunting and fishing less accessible, and also having an effect on their lobster fishing season. In addition, it is affecting plant growth which can affect natural medicines.

- Two citizens indicated that they are more concerned about climate change mitigation and personal or government actions to protect the environment for the benefit of future generations (e.g., recycling more, idling vehicles less, keeping water clean and safe, heat pumps to lessen fossil fuel use, reducing deforestation).

- One citizen indicated that summers are not as hot as they used to be.

"[Climate change] is affecting my personal life in such ways where it is hard to adjust to my surroundings… it is throwing my balance off. … it is making hunting and fishing less accessible due to temperature fluctuations and increased water temperatures, and it is killing our fishing industry. In the summer it is causing our crops to dry out… we lose our products we've made for winter which then leads to us having to buy from the grocery story, and it is so expensive to buy healthy food in the stores now." –Indigenous interviewee

"Climate change where I live has impacted ecosystem diversity. The displacement of certain animals from urban areas has created an explosion in the local bird population, creating infrastructure problems and creating a greater risk to indicator species native to the area." –Indigenous interviewee

Question 2: What things could be done to reduce the harm to your community from climate change?

- Interviewees overwhelmingly indicated a need to both mitigate climate change (i.e., reduce greenhouse gas emissions) and adapt to changes already occurring. Twenty-five citizens identified actions that could be taken individually or as a community to mitigate climate change by reducing carbon footprints and protecting the environment, which would benefit their community. These included investing in eco technology for the community, more renewable energy installations (e.g., solar, wind) in the community, reducing the use of non-renewable energy such as oil and gas (e.g., by installing heat pumps), practicing energy conservation (e.g., turning off and unplugging electronic devices when not in use, changing to energy efficient lightbulbs, using energy efficient appliances), reducing food waste, avoiding the use of plastic and non-biodegradable or compostable products, picking up plastic waste and other litter, educating the community about climate change, growing more organic foods, reducing pollution, planting more trees and reducing deforestation, buying local, recycling, carpooling, changing to electric cars, driving less and biking, walking, skateboarding/longboarding or using transit/buses more often.

- Six citizens indicated that a lack of financial resources to do many of these things is a barrier for people in their community, and that additional funding is needed for energy projects (e.g., solar panels), training, and education about climate change and recycling, as well as for the provision of resources needed for community members (e.g., recycling bags). Jurisdictional boundaries can also be a barrier, as in the case of a hedgerow program for erosion that cannot be accessed on reserve because it is a provincial program.

Question 3: What actions have you or your community taken to date to reducing greenhouse gases within your home or community?

- All 30 citizens identified actions that they have taken individually or as a community to reduce greenhouse gases and protect the environment. These included installing green developments and renewable energy (e.g., solar panels at the Abegweit Fish Hatchery), reducing the use of non-renewable energy such as oil and gas (e.g., by installing heat pumps, converting houses from oil to electric heating), practising energy conservation (e.g., turning off and unplugging electronic devices when not in use, changing to energy efficient lightbulbs, using energy efficient appliances, turning the heat down, running the washer and dryer less often), reducing personal consumption and food waste, composting, growing their own food, conserving water, reducing packaging waste and using reusable dishes, picking up plastic waste and other litter, recycling and reusing things when possible, plantings trees, better forest management, re-naturalization and protection of natural areas, assisting stream life and fisheries (e.g., by letting spawning salmon and trout back into streams), less burning of household garbage in the back yard, energy efficiency audits, creating housing that is energy efficient, installing metals roofs because they last longer, conserving water, carpooling, switching to electric vehicles, regular vehicle maintenance, educating others, driving less and walking, biking or taking the bus more often.

Overall, coastal erosion was most frequently identified as an effect of climate change, as well as a risk that could be addressed through actions to reduce harm. Another common theme in the interviews was a strong desire to act at individual and community levels to prevent climate change and protect the environment.

Table 16. Summary of information gathered in relation to the seven climate hazard scenarios assessed for the CCRA

Climate Hazards	What are the effects from climate change to you personally and in your community?	What things could be done to reduce the harm to your community from climate change?
Coastal erosion ***Accelerating coastal erosion can lead to consequences such as infrastructure damage; disruption to the natural environment, mental health impacts, and impacts to iconic or economically important Island resources, such as beaches or lighthouses.***	• Seventeen citizens indicated that coastal erosion is affecting their community. Much of their land and shoreline has been receding, and this is occurring at an increasing rate (previously 1-1.5 feet/year, recently 5 to 8 feet/year). The sand dunes in the bridge area and close to the Pow Wow grounds are starting to erode. They are losing Lennox Island, Rocky Point and parts of PEI to coastal erosion and rising water levels. Citizens are concerned that Lennox Island will be completely under water in the future. Less ice and snow on land and water in the winter increases vulnerability to fall and winter storms, causing erosion. This is negatively affecting aquaculture (e.g., mussel farming, hatcheries). • One citizen indicated that more saltwater getting onto land is causing ecosystems to be overgrown, including areas that have been used for harvesting in the woods and on the shores of Lennox Island.	• Eight citizens indicated that active steps could be taken to manage erosion including more reinforcement, rock barriers or walls, or planting trees around the cliffs to protect the shorelines from erosion. Afterward, fill could be brought in to raise low-lying area. Perforated pipe could be installed to help with water drainage and runoff.
Post-tropical storm ***Post-tropical storm with heavy rain, storm surge, and wind can lead to consequences such as infrastructure damage; disruption to the natural environment, including forest cover, coastline stability and hydrology; and damage to crops that may last as long as a full season.***	• Five citizens indicated that they are concerned about more frequent and stronger hurricanes or stronger storm surges. Bigger hurricanes are damaging trees and their land, and storm surges are causing coastal erosion. Severe storms could shut down the province.	• One citizen indicated that hurricane awareness and readiness would reduce harm. • One citizen indicated that having a generator in a building for all community members to come to during a time of need would reduce harm. The building would have beds and a kitchen. Designated people could be available to drive people to this Centre in time of need. Scotchfort may have something similar (no beds, restricted time, unsure if generator) but Rocky Point and Morell do not. In times of

		need, the reserves are easily forgotten about and they need something like this too. • One citizen indicated that a shelter for fishing boats, the lifeline of many of their community members, would help to shield them from the worsening winds being felt each year.
Heat wave ***Heat waves can lead to consequences such as physical health disruption, with some potential for loss of life as well as damage to infrastructure, including potential power outages.***	• Four citizens indicated that summers are warmer and longer. This can cause the cancellation of outdoor community events due to extreme heat. • One citizen indicated that increased humidity has caused an increase in respiratory health issues in the community, which is exacerbated by a lack of housing. • One citizen indicated that summers are not as hot as they used to be.	• One citizen indicated that having a generator in a building for all community members to come to during a time of need would reduce harm. The building would have beds and a kitchen. Designated people could be available to drive people to this Centre in time of need. Scotchfort may have something similar (no beds, restricted time, unsure if generator) but Rocky Point and Morell do not. In times of need, the reserves are easily forgotten about and they need something like this too.
Heavy precipitation and flooding ***Heavy rainfall can lead to inland flooding with consequences such as infrastructure damage, agricultural crop contamination and damage, unsafe driving conditions and injury, road washouts and closures, among others.***	• Two citizens indicated that heavy rains are carrying pesticides into rivers and streams, which is killing off fish and contaminating shellfish and all other species of marine life. • One citizen indicated that there has been a lot of flooding in the low areas of the community. • One citizen indicated that extreme rain can cause the cancellation of outdoor community events. • One citizen indicated climate change is making their driveway muddy and not possible to drive on in the spring.	• One citizen indicated that having a generator in a building for all community members to come to during a time of need would reduce harm. The building would have beds and a kitchen. Designated people could be available to drive people to this Centre in time of need. Scotchfort may have something similar (no beds, restricted time, unsure if generator) but Rocky Point and Morell do not. In times of need, the reserves are easily forgotten about and they need something like this too.
Severe ice storm/freezing rain ***Severe ice storms and freezing rain events can lead to consequences such as potential loss of life and injury, infrastructural damage***	• One citizen indicated that heavy snow fall affects driving conditions and winter accessibility. This affects Elders, making it harder to ensure they are properly taken care of because it is hard to travel to them.	• One citizen indicated that having a generator in a building for all community members to come to during a time of need would reduce harm. The building would have beds and a kitchen. Designated people could be available to drive people to this Centre in time of need.

(particularly to electric transmission and distribution infrastructure, resulting in outages), damaged or downed trees, and limitations on ground and air travel due to unsafe conditions.		Scotchfort may have something similar (no beds, restricted time, unsure if generator) but Rocky Point and Morell do not. In times of need, the reserves are easily forgotten about and they need something like this too.
Earlier, warmer springs ***Earlier arrival of spring temperatures could result in mainly positive consequences by mid-century including a temporary increase in lobster population, an extended growing season for existing and potentially new crops, an extended spring tourism season, and expansion of suitable habitat for flora and fauna. This gradual shift, however, will necessitate some change and action in order to take advantage of new opportunities. Negative consequences could also include infrastructure damage from a change in freeze/thaw cycles and an increase in the prevalence of pests, diseases, and invasive species.***	• Five citizens indicated that climate change is affecting species distributions, including wildlife and harvesting. Insects are becoming less abundant. Invasive species are becoming more abundant. Climate change has impacted ecosystem diversity, including displacement of certain animals from urban areas and an explosion in local bird populations, which creates infrastructure problems and a greater risk to indicator species native to the area. Bird behaviours and the timing of their migration are changing. Pests and rodents are becoming more of an issue. Sharks and other species are travelling farther north. Climate change has affected eel distribution. Climate change can affect plant growth which can affect natural medicines. • Two citizens indicated that increases in water temperatures and less ice formation in the Strait are negatively affecting their fishing industry. • One citizen indicated that climate change has brought lobster into the bay more as the overall Malpeque Bay has warmed each year.	• One citizen indicated that the reintroduction of foxes, owls and frogs would boost ecosystem diversity while creating a sustainable solution to dealing with the overabundance of ducks, seagulls, and other birds in the area. These birds are predators of indicator species living in the area such as frogs.
Seasonal drought ***A months-long severe summer drought can lead to consequences such as agricultural damage, mental health disruptions, and***	• One citizen indicated that summer droughts are causing crops to dry out, resulting in less produce availability in the winter. This has adverse health implications because store-bought produce is expensive.	

weakened social stability. The agricultural industry and the industries that rely on it are particularly vulnerable.	• One citizen indicated that climate change will affect the Island's biggest revenue, potatoes.	

5. Adaptive Capacity

The CCRA results indicate the potential risks to PEI if no action is taken to avoid or otherwise reduce the impacts of the climate hazards included in the assessment. They do not account for the adaptive capacity of PEI and its different consequence categories of concern (e.g., health, economy, environment, social stability, infrastructure).

Adaptive capacity refers to the inherent traits of the system or individual assets, institutions, populations, or species in question that make it more or less susceptible to impacts from the climate hazard, including actions the government or other stakeholders are already taking to address risk (e.g., emergency preparedness planning, designing infrastructure with climate change in mind, professional development and training programs, etc.).

Pairing the risk ratings with an understanding of existing and potential adaptive capacity indicates where PEI has the greatest opportunities to reduce risk. It can help distinguish, for example, between two high-risk sectors where one has inherently high adaptive capacity and the other is more limited; even though both sectors must adapt, it is likely more critical and urgent to focus adaptation resources on the latter.

Measuring adaptive capacity is also a way for the Province to track its progress over time and to identify nuances in how resilient certain populations, ecosystems, or sectors are to climate risks. While the Province may have limited control over many of the inherent risks it faces from climate change, such as those risks related to location, geology, and climate, Islanders can take action to boost PEI's adaptive capacity and reduce its risk.

To identify adaptation priorities and measure progress over time, workshop participants rated each adaptive capacity factor (described previously in Section 2.4.3), by consequence category. The results are shown in Figure 25 and discussed further below. Each consequence category has some factors with relatively high adaptive capacity, but also areas for potential improvement.

The ratings represent PEI's inherent and immutable adaptive capacity factors as well as the influence of current actions to increase the Province's adaptive capacity.[6] These ratings can be revisited over time as more adaptation actions are implemented across PEI.

[6] The geographic location of workshop participants may be a potential limitation of the adaptive capacity findings. It is assumed that most participants lived in urban areas.

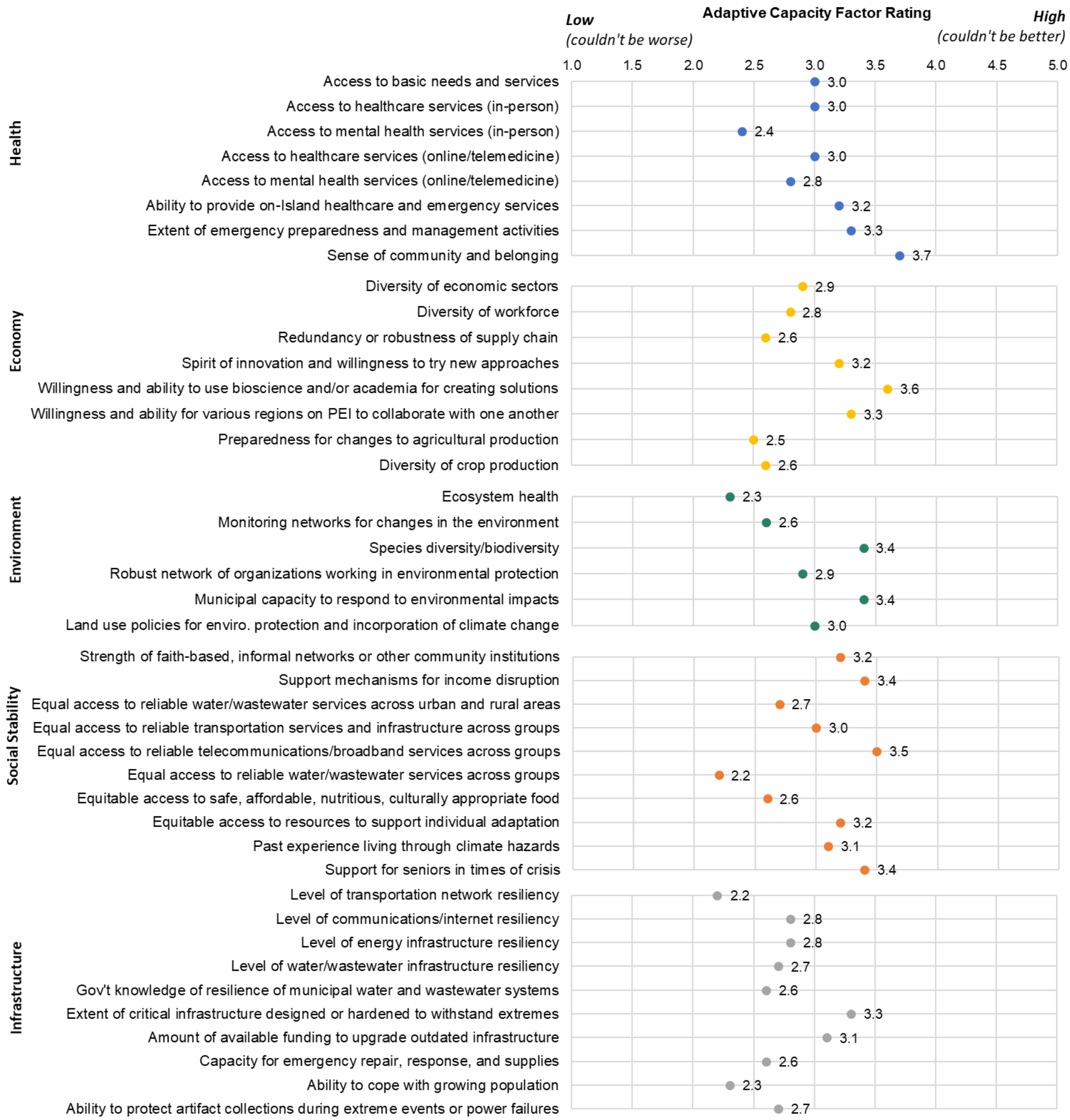

Figure 25. Adaptive capacity assessment matrix ratings based on workshop participant input.

The sections below summarize the key risks per consequence category as well as the adaptive capacity findings per consequence category. For a complete list of findings on the adaptive capacity factors, see Appendix C, which includes:

- details on the current status of each adaptive capacity factor according to workshop participants,
- additional research findings on the adaptive capacity factors,
- example existing adaptive actions in place to reduce risks, and
- additional adaptive capacity factors for consideration in future assessments, as suggested by workshop participants and survey respondents.

5.1. Health

5.1.1 Risk assessment findings

Nearly all the climate hazards analyzed pose risks to physical health and safety. Heat waves pose the greatest risk to health; while ice storms and freezing rain events have the most significant consequence in terms of potential number of fatalities and injuries. In the instance of heat waves, the health risk — including potential mortality— is highest for vulnerable populations such as seniors, infants, outdoor workers, and those with limited or no access to air conditioning. Extreme heat events may also cause power outages and impacts to infrastructure, which may have ripple effects on health. Potential loss of life and injury during ice storms and freezing rain events results from both hazardous conditions during the storm and the risk of hypothermia and other impacts in the event of extended power outages, especially in rural or isolated areas.

Climate hazards can also create profound, though uncertain risks to mental health as climate changes affect individuals' livelihoods or sense of place. The most severe impacts are likely for those who could be displaced, lose land in their community, or face additional stress from financial impacts of coastal erosion, as well as those whose occupations rely on agriculture.

5.1.2 Adaptive capacity findings

The health consequence category has the highest average adaptive capacity rating of all consequence categories analyzed; factors received scores ranging from 2.4 to 3.7. Access to in-person mental health services received the lowest score and provides the greatest opportunity for improvement. The COVID-19 pandemic has been useful for expanding telehealth services. However, there are still health care access issues, particularly for those in rural communities who may have limited internet connections or have to travel farther for in-person care. Another issue is that many specialists are located in neighbouring provinces, which requires travelling outside of PEI to visit (e.g., driving over the Confederation Bridge).

The highest rated factor, sense of community and belonging may serve as a protective factor and coping mechanism for individuals experiencing climate-related physical and mental health impacts. PEI's overall sense of community and belonging is strong, though connections vary by individual and geographic location (e.g., rural vs. urban). Social stability and economic factors can also influence public health and wellbeing.

5.2. Economy

5.2.1 Risk assessment findings

The agriculture, fisheries, and aquaculture sectors are integrally linked to climate and weather. Therefore, climate-related risk is high across nearly all climate hazards included in the CCRA. For example, post-tropical storm events and heavy rain events (which result in heavy runoff) can damage crops and the shellfish industry. Warmer temperatures could also affect worker safety and productivity; poultry, livestock, and potato yields; and fish species with low heat tolerance.

PEI's tourism and recreation sector are most at risk from coastal erosion and post-tropical storms. For example, erosion events—whether gradual or sudden from storms—have potential to narrow beaches, restrict access to certain parts of parks, and put tourist attractions at risk. Other notable potential risks include potential for earlier-season post-tropical storms that could interfere with the tourism season and flood-related impacts to heritage and tourism sites. Earlier, warmer springs may also shorten the winter tourism and recreation season but extend the spring and summer tourism season.

Other industries and overall economic activity are also at risk from climate hazards, which may cause infrastructure service disruptions, such as power outages from severe storms and road closure or supply chain disruptions from flooding and other extreme events.

5.2.2 Adaptive capacity findings

The economic consequence category received relatively high adaptive capacity scores ranging from 2.5 to 3.6. Preparedness for changes to agricultural production received the lowest score and provides the greatest opportunity for improvement, especially since workshop participants noted farmers' general openness to trying new innovations and approaches, such as utilizing precision agriculture technology or exploring carbon markets. Certain climate hazards like earlier, warmer springs may offer opportunities to expand and diversify the agriculture, fisheries, and aquaculture sectors, but PEI will need to position itself to take advantage of these changes. The COVID-19 pandemic has exposed fragility to sectors, such as tourism and recreation, and Islanders noted that similar impacts could be witnessed in the aftermath of a negative climate event.

The highest rated factor, willingness and ability to use bioscience/academia for creating solutions, is emblematic of Islanders attitude and ability to adjust to changing times. Recent research into renewable energy, aquaculture genomics, and agriculture are helping to drive economic innovation on PEI, but it was noted that commercialization of research remains a challenge. Capacity to adapt to a changing economy can influence nearly all other consequence categories, especially health, social stability, and infrastructure.

5.3. Environment

5.3.1 Risk assessment findings

Climate change inherently means environmental change, which could threaten several ecosystems or sensitive species on PEI, such as bank swallows and piping plover. Runoff and flooding associated with heavy rains or post-tropical storms could reduce groundwater recharge and introduce contaminants into water bodies. The CCRA revealed that PEI's forests are fortunately relatively resilient to the climate hazards and scenarios analyzed. Low-lying and coastal areas are most at risk.

5.3.2 Adaptive capacity findings

Environmental adaptive capacity factors also range widely depending on the factor. Sources of relative strength in the environment's adaptive capacity include existing strength of ecosystem diversity and biodiversity and municipal capacity to respond to environmental impacts—both are rated 3.4 out of 5, indicating relatively high ratings compared to other adaptive capacity factors but still with room for improvement.

In many cases, environmental adaptive capacity may depend on the municipality and watershed groups. Capacity to manage environmental impacts can vary across the Island and is a key factor in the Island's ability to manage environmental impacts of climate change. Another key factor is whether land use practices are flexible in response to the realities of climate change.

The lowest rated environmental adaptive capacity factors are overall current ecosystem health and the presence of monitoring networks or systems to track environmental health. This indicates opportunities for PEI to manage environmental risks over time through near-term activities that can improve environmental health, and also establish monitoring process for key indicators (e.g., vulnerable habitats or species) so that PEI can understand changing environmental conditions over time, how those changes may or may not relate to climate change, and make appropriate management decisions.

5.4. Social Stability

5.4.1 Risk assessment findings

Social stability risks are closely linked to human health and economic risks, especially to the extent that those risks are not distributed or managed equitably across areas and identity groups. Low-income households may be most at risk to many of the expected impacts of climate change, including those related to power outages and infrastructure service reliability and food security. First Nations are also particularly well-informed of their vulnerabilities due to their leadership investigating how climate change will impact their coastal communities.

5.4.2 Adaptive capacity findings

Factors influencing social stability and the adaptive capacity of PEI's social fabric also received relatively high ratings. Some of the strongest existing factors are equal access to reliable telecommunications and broadband services across different populations and identity groups, existing support mechanisms for those experiencing temporary or prolonged income disruptions, and existing support networks and mechanisms for seniors and elders in times of crisis. For example, the Healthy School Food Program provides support for low-income families, though it is not always sufficient to meet needs.

The lowest adaptive capacity factor ratings, and thus potential areas with the greatest room for improvement relate to ensuring equal access to reliable infrastructure services across populations and groups, such as transportation and water/wastewater services. For example, residents who rely on private water supplies are particularly vulnerable to power disruptions, and rural areas are currently more likely to have more difficulty recovering power and transportation services after an event.

The COVID-19 pandemic has presented a relevant example or "stress test" to social stability when PEI has been confronted with a significant challenge. PEI can build on lessons learned from the pandemic to enhance social stability.

5.5. Infrastructure

5.5.1 Risk assessment findings

Infrastructure faces the highest risk across hazards of the consequence categories analyzed. Some of the greatest risks include:

- Damage or disruption to coastal infrastructure from erosion or post-tropical storms, particularly transportation, water, and wastewater infrastructure. Higher risk of damage brings potential for added cost of repairs and inability to fund other planned infrastructure needs.
- Power outages from a range of events, including ice storms and post-tropical storms, which in turn have severe economic, social, and health implications, although all public health facilities on PEI do have access to backup power.
- Increased temperatures and likelihood of heat waves could also begin to strain infrastructure by 2050, such as increasing strain on electric utilities and pavement materials.

5.5.2 Adaptive capacity findings

The adaptive capacity of the Island's infrastructure had the lowest average rating of all consequence categories analyzed, with scores ranging from 2.2 to 3.3. Points of weakness include PEI's transportation system resiliency, which may be particularly challenging to address due to the limited direct ingress/egress points to the Island. Islanders also recognized the challenge of adapting to PEI's growing population, which poses specific problems to infrastructure including increased vehicle traffic, greater stress to transportation infrastructure, the expansion of coastal infrastructure that may be vulnerable to coastal erosion, and the need to consider population growth when planning future infrastructure. A key opportunity to improve adaptive capacity on these fronts was noted as increased support for training of engineers and planners.

Relative strong points of adaptive capacity include the extent of critical infrastructure to withstand extremes and the level of funding available to upgrade infrastructure if necessary. Additionally, workshop participants noted existing political will to build and fund infrastructure at higher standards. With these noted strengths, PEI may be well positioned to increase infrastructure adaptive capacity by targeting weaknesses and utilizing funding to address specific vulnerabilities, including those indicated by this analysis.

5.6. Adaptation Priorities

The adaptive capacity findings can help identify priority climate risks and consequence categories where the government should focus adaptation efforts and next steps. Table 17 summarizes the highest scoring climate hazards per consequence category. Six of the nine categories could see major or catastrophic consequences from at least one climate hazard included in the CCRA. The top three climate hazards for overall consequence scores are post-tropical storm, severe ice storm/freezing rain, and coastal erosion.

Table 17. Climate hazards with major or catastrophic consequences

Consequence Category	Hazards with "Major" Consequences	Hazards with "Catastrophic" Consequences
Potential loss of life	Severe ice storm/freezing rain	
Potential morbidity, injury, disease, or hospitalization	Severe ice storm/freezing rain Heat wave	
Mental health	Seasonal drought	
Tourism and recreation		
Agriculture, fisheries, aquaculture	Heavy precipitation and inland flooding Post-tropical storm Seasonal drought	
Other industries		
Environment	Post-tropical storm Coastal erosion Earlier, warmer springs	
Social stability		
Infrastructure	Heavy precipitation and inland flooding Coastal erosion	Severe ice storm/freezing rain Post-tropical storm

Factoring in adaptive capacity helps to prioritize within the list of critical risks (shown in Table 17). Consequence categories or hazards with high risk but also high adaptive capacity would be lower priorities than those with high risk and low adaptive capacity. In general, adaptive capacity factors scoring in the bottom half of the range (less than 3) provide the greatest opportunities for improvement, though these findings would have to be considered alongside other important factors (e.g., impact, reach, population distribution).

Seasonal drought and mental health are an example of an area with high risk and low adaptive capacity. The adaptive capacity assessment ranks access to in-person and telemedicine mental health care as relatively low (scoring below a 3); the mental health-related factors are the lowest rated of all the health adaptive capacity factors. This indicates that improving mental health services should be a priority to raise the adaptative capacity, or ability to cope with the effects of seasonal drought on mental health.

Comparing the findings of the adaptive capacity assessment (Figure 25) to the list of climate hazards with major or catastrophic consequences (Table 17), emerging adaptation priorities include:

- Improving access to mental health services, particularly for those most affected by seasonal drought (e.g., farmers).
- Improving access to healthcare services, particularly for those most vulnerable to severe ice storm/freezing rain or heat waves (e.g., rural communities, the elderly).
- Diversifying PEI's economy and crop production, particularly for agriculture, fisheries, and aquaculture practices and products sensitive to flooding and drought conditions.
- Increasing the redundancy or robustness of the supply chain, particularly to limit disruptions to agriculture, fisheries, and aquaculture during storm events.
- Improving ecosystem health, particularly for coastal ecosystems and key species affected positively or negatively by earlier, warmer springs.
- Improving the resiliency of critical transportation, communication/internet, energy, and water/wastewater infrastructure, particularly to withstand impacts from heavy rain, wind, inland and coastal flooding, coastal erosion, and ice and freezing rain.
- Increasing capacity for emergency repair, response, and supplies, particularly for post-tropical storm, severe ice storm/freezing rain, heavy precipitation and inland flooding, and coastal erosion.

Additional adaptation priorities identified by workshop participants are included in Appendix C.

6. Conclusions

The CCRA revealed important risks posed by climate change to PEI's residents, economy, and environment. Several key findings emerged from the CCRA, irrespective of individual hazard or sector-specific risks:

- **Climate hazards affect PEI across consequence categories**, **and will thus require a coordinated, cross-sectoral response.** While some impacts can be addressed within individual departments, others would benefit from coordinated strategies that can reduce risks in a comprehensive way. The selected hazards and their consequences could bring significant costs to government, in a variety of ways, meriting a case for action to mitigate these risks.
- **Risks across hazards and consequence categories are interconnected.** Impacts to one area of the Island or economy can have extensive ripple effects. For example, power outages (whether caused by ice storms, wind events, or heat waves) can cause a variety of health, social, economic, environmental, and infrastructure impacts.

Example: Cascading Impacts From a Heat Wave

Loss of power during a heat wave can lead to increased risk of heat-related illnesses and temporary closure of schools and businesses due to the reliance on internet and electricity. These impacts may increase stress on caregivers to take care of family members (e.g., children, elderly). An extended power outage can also have ripple effects on the economy, such as lost revenue from inability to operate restaurants and other establishments or spoiled agriculture and aquaculture products if backup power sources are unavailable or fail.

- **The climate change impacts discussed in this assessment will not affect all people on PEI equally.** Factors such as income, health, age, gender, location, housing, Indigeneity, intergovernmental dynamics, access to resources (human, financial, and others) influence specific levels of vulnerability for individuals and groups. The spatial distribution of factors may differ across distinct federal, provincial, municipal, and Indigenous regions. For example, Figure 26 shows the spatial distribution of the elderly population in PEI, which can be more vulnerable to heat-related health conditions. Additionally, the location of some First Nations' communities as well as the distinct socio-cultural values that First Nations people hold result in higher vulnerability to some hazards. These differential impacts and others are highlighted throughout the assessment where possible for specific climate hazards.

Figure 26. Spatial distribution of example vulnerability drivers in PEI by Census District [1].

Understanding differential impacts remains an important topic for further research.

- **While this assessment mainly focused on characterizing negative consequences and risks, climate change may also present opportunities for PEI.** For example, the gradual nature of coastal erosion and shifts toward earlier, warmer springs allows time for PEI to reduce potential risk and build on existing adaptive capacity measures for these hazards, avoiding dramatic consequences. Islanders may also enjoy extended growing and harvest season for many crops among other potential opportunities.
- **The climate risks PEI faces through 2050 are not fixed;** the results of the risk assessment process are likely to change as hazards are revisited, research progresses, and adaptation strategies are implemented. Additionally, the risks discussed here are intended to help develop the understanding of the Island's relative risk for the selected hazards; they do not serve as comprehensive account of all climate risks facing PEI.

7. Next Steps

ICF recommends the Province consider the following three next steps to build on the CCRA findings presented in this report:

1. Expand on the CCRA to gain a better understanding of the risks facing PEI, considering the following future actions:
    a. Undertake additional stakeholder, public engagement, and other approaches to better understand differential impacts, including how Islanders are affected by climate change and what they are most concerned about. Understand how specific factors such as income, health, age, gender, location, housing, Indigeneity, intergovernmental dynamics, access to resources influence specific levels of vulnerability for specific individuals and groups.
    b. Expand the risk assessment to include other climate hazards, such as those considered in Appendix B: Process for Selecting Climate Hazards and Scenarios, which were excluded from the scope of this assessment. The Province should continue to conduct or support research that expands the understanding of how different climate drivers and hazards will impact PEI.
    c. Consider analyzing the cumulative impacts of multiple hazards occurring simultaneously or in succession.
    d. Consider different climate hazard scenarios than those analyzed in this assessment.
    e. Update the risk assessment periodically (ICF recommends every 5 years) with new information on impacts, consequences, and adaptation actions. Prioritize updating likelihood or consequence ratings with low confidence due to data gaps or a reliance on expert knowledge. Specific actions could include:
        i. Track the development of potential government flood insurance programs and update analysis for flood-related hazards.
        ii. Monitor key climate impact indicators. This could include indicators such as bridge closures, school/government office closures, fire hazard index, Environment Canada weather warnings, storm surge warnings, first day of spring activities such as golf, as well as natural indicators such as the first appearance of certain species each spring.
        iii. Incorporate future iterations of coastal erosion mapping.
        iv. Incorporate future research on how climate change affects mental health and social stability. There is currently limited information available on these topics.
        v. Analyze the net effect of climate change. While the CCRA is focused primarily on negative consequences, climate change poses opportunities for PEI as well. The net cost (or benefit) of climate change for PEI is unknown.
        vi. Re-evaluate the risk assessment and adaptive capacity results, particularly after adaptation measures have been implemented to see if risks have been significantly reduced.
    f. Conduct additional research for questions that emerged during the CCRA process for the seven focus climate hazards. Topics include, but may not be limited to:
        i. The prevalence of heat-related health conditions on PEI.
        ii. How warmer temperatures may affect energy demand in PEI.

iii. How warmer temperatures can affect invasive species and what the net effect might be from many ecosystems having more favorable climate conditions but also having to compete with more invasive species.
iv. What the critical temperature threshold is for key species other than lobster (e.g., mussels) and how those species are specifically affected by earlier, warmer springs or other climate hazards covered in the CCRA.
v. The difference in likelihood between shorter more intense rainfall versus longer duration, but less intense events.
vi. How changes in precipitation and snowmelt cycles may affect water and stormwater infrastructure. The frequency and duration of road closures occur due to ice and freezing rain events.
vii. Whether an extended season for outdoor recreation due to earlier, warmer springs could improve the population's health and physical fitness?
viii. The timeframe at which the viability of the winter tourism and recreation sector and associated employment becomes at risk.
ix. Whether there are labour market statistics for current and projected spring, summer, and winter seasonal employment needs to understand whether PEI has the capacity to meet the changing market demands.
x. The proportion of the PEI population that has limited access to backup fuel sources.
xi. Whether there is a correlation between income disparity and access to backup power sources.

g. Expand the Adaptive Capacity Assessment Matrix to include more specific and measurable indicators or metrics for adaptive capacity.

2. Develop a province-wide adaptation plan and/or coordinated sector-specific adaptation plans that identify adaptation priorities and lay out a plan for how to undertake measures to achieve those priorities. Examples of emerging adaptation priorities include but may not be limited to:
    a. Improving access to mental health services, particularly for those most affected by seasonal drought (e.g., farmers).
    b. Improving access to healthcare services, particularly for those most vulnerable to severe ice storm/freezing rain or heat waves (e.g., rural communities, the elderly).
    c. Diversifying PEI's economy and crop production, particularly for agriculture, fisheries, and aquaculture practices and products sensitive to flooding and drought conditions.
    d. Increasing the redundancy or robustness of the supply chain, particularly to limit disruptions to agriculture, fisheries, and aquaculture during storm events.
    e. Improving ecosystem health, particularly for coastal wetland ecosystems and key species affected positively or negatively by earlier, warmer springs.
    f. Improving the resiliency of critical energy, transportation, communication/internet, and water/wastewater infrastructure, particularly to withstand impacts from heavy rain, wind, inland and coastal flooding, coastal erosion, and ice and freezing rain.
    g. Increasing capacity for emergency repair, response, and supplies, particularly for post-tropical storm, severe ice storm/freezing rain, heavy precipitation and inland flooding, and coastal erosion.

h. Identifying next steps for seizing climate opportunities in sectors such as agriculture, aquaculture, and tourism.
i. Increasing risk awareness in decision making across all levels of government (e.g., training and development).
j. Further engaging with Indigenous leaders to discuss adaptation priorities and coordinate next steps for adaptation planning.

3. Integrate CCRA findings into decision making and investment planning. Understanding where climate change considerations could be integrated into existing decision-making processes can help streamline and facilitate climate adaptation planning and investments within individual departments or across the provincial government.

8. Appendix A: Risk Assessment Details

This chapter provides detailed risk profiles for each hazard containing the full evidence base and rationale for the ratings. A more concise synopsis of the risk assessment results for each hazard, including the overall risk ratings can be found in Section 3.

8.1. Coastal Erosion

Scenario: Acceleration of the historic rate of erosion

To evaluate coastal erosion risk, the assessment focused on a specific scenario of the likelihood and consequences of an acceleration of the historic rate of erosion on PEI. For the risk rating process, population levels and density are assumed consistent with the 2016 Census [14]. If the current trend continues, the population growth and aging over the next 30 years, could increase risks to the population, particularly those impacts related to health, social stability, and infrastructure.

This scenario represents the ongoing hazard of accelerated coastal erosion. Historic examples of coastal erosion across the Island are used to inform this scenario and assessment of consequences.

Likelihood

Coastal erosion is not a new phenomenon on PEI. Eighteenth-century maps show striking differences from current conditions, including dune systems and barrier islands that no longer exist [26]. The average rate of coastal erosion on PEI from 1968 to 2010 was 28 cm annually [27]. From 2000 to 2010, however, there was significantly more erosion, with an average annual loss of 40 cm [27]. Erosion rates differ across PEI, with till bluffs and the Gulf of St. Lawrence coast experiencing annual average erosion rates of 74 cm from 1935-1990 [28] and some sites on the Island experiencing as much as 200 cm of erosion in a given year [29]. Determining a "critical threshold" level of coastal erosion, or the point at which significant impact occurs, is difficult since erosion rates can differ dramatically in either direction from one decade to the next. These factors considered, the *long-term* historical rate (1968-2010) of 28 cm per year was used to determine the critical threshold; meaning annual average erosion beyond 28 cm is considered beyond the critical threshold, while annual erosion rates under 28 cm is below the critical threshold. Since the annual average rate of erosion is just about as likely to cross the critical threshold as not, the **current likelihood rating is 3**.

> **Likelihood Rating Drivers**
>
> Type of hazard: Ongoing
>
> Climate driver(s): Sea level rise, change in sea surface temperatures
>
> "Present day": 1968-2010 historical data
>
> Source of 2050 projections: 2000-2010 data and other assessments across literature

Future likelihood of advancing beyond the critical threshold of 28 cm of erosion per year will be dictated by changes in severity and frequency of events that drive coastal erosion, such as severe storms, storm surge, sea level rise, and reduction of sea ice [30]. In fact, wintertime sea ice, which serves as an effective barrier that decreases wave energy along the coastline, has been declining at a rate of 8.3% per decade from 1969-2016 [31]. Considering the 2000-2010 erosion rate of 40 cm/year and because the drivers of coastal erosion are projected to increase in frequency and severity on PEI by 2050 [26, 27], it is almost certain that the critical threshold will be exceeded by 2050. Thus, the **future likelihood rating is 5.**

Confidence: Medium

High quality historical coastal erosion data was available for the years 1968-2010. More current data would improve confidence for the current likelihood rating. Future likelihood was ascertained by examining the most recent historical data available and by investigating the literature for projected changes in frequency and intensity for the drivers of coastal erosion.

Consequences

Health: 1.7 (minor)

Potential loss of life: 1 (insignificant)

Due to the gradual nature and high level of warning inherent to an accelerating coastal erosion scenario on PEI, it is very unlikely that loss of life will be a consequence of this scenario. There is some small potential for loss of life as a result of falling rocks from eroding cliffs, but these events are rare on PEI. However, *events that cause* accelerated coastal erosion, such as severe storms and storm surge, may result in loss of life. Please see the post-tropical storm scenario for consequence analysis related to these events.

Figure 27. Teacup Rock on Thunder Cove Beach [5].

Supporting evidence includes:

- There is no evidence of direct loss of life as a result of coastal erosion on PEI; however, accelerating erosion may cause increased chance of coastal cliff collapse or sea cave collapse which may result in loss of life for individuals standing near cliffs or exploring sea caves. For example, Thunder Cove Beach's popular rock formations and sea caves pose particular risk. In July 2019, a 10-year-old boy was hit by a falling rock while posing for a picture on Thunder Cove Beach resulting in hospitalization [5].

Confidence: High

The lack of any evidence indicating loss of life due to coastal erosion leads to a high level of confidence. Workshop participants unanimously agreed with this low rating.

Potential morbidity, injury, disease, or hospitalization: 1 (insignificant)

Similarly, the potential for injury and hospitalization is low.

See supporting evidence under potential loss of life.

Confidence: High

Injuries due to coastal erosion have been documented, yet it is clear they are infrequent, leading to a high level of confidence.

Mental health: 3 (moderate)

Accelerating coastal erosion has the potential to cause widespread moderate mental health impacts, particularly as a result of loss of sense of place. The most severe impacts are likely for those who could be displaced, lose land in their community, or face additional stress from financial impacts of coastal erosion, although the gradual nature of coastal erosion lessens the severity of impact.

Supporting evidence includes:

- Coastal erosion may diminish sense of place as coastal areas that residents feel a sense of attachment to may be altered or disappear altogether. Since it has been found that there is a strong association between sense of place and mental health this may have negative mental health consequences [32].
    - Some longtime residents remember areas that previously held lobster canneries and are now under water, home foundations that were previously on farmland, but now exist on the beach, and roads that were previously traversable but are now inundated by water [33]. At current rates of erosion, over 1,000 homes are vulnerable to coastal erosion between now and 2090 [30].
    - The north shore of Lennox Island is vulnerable to coastal erosion, while the south shore is classified as a low erosion-risk hazard (0-30cm annual erosion rate). Lennox Island's shorelines are socio-culturally valuable to the Mi'kmaq First Nation community and loss of land may impact mental health [34]. The risk of erosion would increase if a breach of Hog Island occurs [22].
    - Citizens of Lennox Island have expressed concern that their Island will be completely under water in the future [35].
    - A severe storm heightens the risk of a breach on Hog Island, a barrier island which protects Lennox Island from waves, swells, and storms. This would greatly increase the flood and erosion hazards of Lennox Island, resulting in greater risk of mental heath disruption to Lennox Island residents [22]
- Severe coastal erosion in some areas may result in relocation or loss of homes. This may have secondary impacts such as anxiety and depression [25].
    - Lennox Island has been exploring the purchase of new land for relocation purposes, partially as a result of coastal erosion pressure. The process of moving from culturally important land may be particularly stressful [36]. Additionally, the estimated costs of retreat from Lennox Island are significant. Full retreat to a new location is estimated to cost $155-170 million [37].
- There is potential for a loss of cultural resources as a result of coastal erosion, which may result in damaged cultural integrity, further impacting mental health. For example, in 2014 the Cape Bear lighthouse had to be moved back from the side of a cliff to ensure its survival [38]. Seventeen lighthouses are denoted as vulnerable to coastal erosion on PEI over the next 83 years [8].
- Individuals who rely on industries that have potential to be severely impacted by coastal erosion (such as tourism and recreation or infrastructure) may face more severe mental health impacts as a result of additional stress and uncertainty. Future generations of farmers may also feel mental health impacts of coastal erosion as they manage attempting to maintain production while having fewer acres of agricultural land available [39].

Confidence: Medium

Several high-quality independent sources indicate relationships between mental health and loss of property or loss of sense of place. These studies are supported in the PEI context with anecdotal evidence of mental health impact from coastal erosion.

Economy: 2.7 (moderate)

Tourism and recreation: 3 (moderate)

Accelerating coastal erosion has potential to narrow beaches, restrict access to certain parts of parks, and put tourist attractions such as golf courses, and cultural landmarks at risk. Effects are likely to be moderate, but widespread and long-term in the tourism and recreation industry.

- Scenic beaches and coastal cliffs are some of the most popular tourist attractions on PEI and are at high risk from erosion. Beaches naturally shift landward as coastal erosion progresses, but where erosion control structures are in place they prohibit landward migration of the beach, and as a result the beach is narrowed. In such places it would be particularly expensive to restore [40]. Additionally, some buildings that were previously several metres from the shore may now be closer to the water, making maintenance difficult. This can result in damage, as witnessed at the Cedar Dunes boardwalk.
- Beaches where structural attempts to combat cliff or bluff erosion have occurred are littered with debris of failed systems, which negatively affect viewscapes and presents a public safety hazard [39, 41]. Working systems are often expensive to maintain [42] and are not recommended by the Province of PEI as a first alternative to address shoreline stabilization.
- Historic lighthouses, golf courses, and other areas of interest to tourists may be threatened by coastal erosion [38, 43, 44]. It may be unfeasible to protect all at-risk assets, which could lead to difficult decisions as to which are most valuable.
- A 2016 case study indicated that campgrounds at Jacques Cartier Provincial Park are vulnerable to coastal erosion and flooding. It was estimated that the provincial park would be expected to lose 38% of its campsites by 2040 if no adaptation options are implemented [45].

Confidence: Low

The province-wide economic impact to tourism and recreation from coastal erosion is difficult to ascertain. The rating is based on primarily upon the impact erosion is likely to have on coastal tourism and recreation attractions and facilities, and studies describing vulnerability of specific assets on PEI.

Agriculture, fisheries, aquaculture: 2 (minor)

Agriculture, aquaculture, and fisheries on PEI may face moderate disruptions from accelerating coastal erosion.

Supporting evidence includes:

- Coastal erosion may shrink the availability of land that is suitable for agriculture [51]. The removal of coastal vegetation that serves as barriers and buffers against erosion has potential to exacerbate loss of land [46].
- PEI’s near shore agricultural lands may be at risk of shoreline recession causing a reduction of agricultural land and thus reduced yields [47].
- Changes to water flow dynamics in Island bays and estuaries resulting from coastal erosion may impact suitability for aquaculture operations [39].
- Coastal erosion may increase the risks of saltwater intrusion to groundwater which can impact farmers ability to irrigate crops with groundwater [48].
- One citizen of Lennox Island indicated that diminishing shorelines are causing saltwater to be closer to lands not previously on the shore and causing ecosystems to be overgrown, including areas that have been used for harvesting in the woods and on the shores of the Island [35].

Confidence: Medium

Several high-quality sources indicated previous and potential impacts to agriculture, fisheries, and aquaculture, although there was some level of disagreement between anecdotal evidence and the literature or reports on the level of impact these industries are likely to face. Additionally, the confidence rating is medium because of the difficulty in expressing incongruence of impacts to the aquaculture and fisheries industries versus the agriculture industry (i.e., agricultural consequences are more severe than aquaculture or fisheries consequences).

Other Industries: 3 (moderate)

Accelerated coastal erosion has potential to result in negative consequences for the PEI real estate market, insurance industry, and private homeowners. Local PEI businesses near the shore, or reliant on beach tourism may also face negative impacts. Impacts to these industries are likely to not exceed moderate impacts but are long-term.

Figure 28. Photo exhibiting coastal erosion within the last 80 years on PEI [8].

Supporting evidence includes:

- The real estate market may be moderately impacted by accelerating coastal erosion. In the last 20 years, buyers have become more concerned with erosion risk on potential properties, decreasing options for development. Properties near the shore may face particularly harsh impacts of declining property value [49].
    - Risk for potential and current property owners may be exacerbated by the lack of insurance for coastal erosion damages [25].
    - Development permits in provincial jurisdictions use erosion rates to inform the required amount of setback from the shore. If rates are high enough, and the parcel of land does not extend inland far enough to accommodate retreat, vacant lots may be deemed undevelopable [39].
- Insurance rates on PEI are based on historical climate. The increase in damaged property caused by accelerated coastal erosion may therefore pose problems for the insurance sector or could result in growing property insurance premiums for property owners [44].
- Large portions of property owners' land may be eroded as a result of a single storm. There are several anecdotal examples of property owners suffering property loss to erosion [33].
- Residential housing and available land for future housing needs on Lennox Island is threatened by coastal erosion [50].
- UPEI's coastal erosion mapping indicates that at current rates of erosion, over 1,000 homes, over 500 barns and garages, 17 lighthouses, and 150 commercial operations vulnerable to coastal erosion over the next 83 years [8].

Confidence: Low

Impacts to other industries are based on only a few key pieces of evidence, some of which are anecdotal. Potential impacts to insurance and real estate markets have high agreement, but are not based on formal studies.

Environment: 4 (major)

Accelerating coastal erosion has potential to disrupt multiple natural assets on PEI, with particular impacts on local biodiversity. Shoreline birds, such as the piping plover and bank swallows may face severe long-term consequences as erosion degrades habitat and causes increased stress, while less severe impacts may be realized by coastal wetlands and other aquatic habitats.

Supporting evidence includes:

- Most cliffs on PEI are composed of sandstone, which is very susceptible to coastal bank erosion. Species that rely on these cliffs for habitat, such as the threatened bank swallow (*Riparia riparia*), may face habitat degradation impacts [51].
- Despite being discouraged, structural measures are increasingly being installed to protect properties and infrastructure from coastal erosion, resulting in alteration of the shoreline which can impact aquatic habitats by upsetting natural sediment exchanges [25]. The negative environmental implications of hardening the shoreline can be significant.

Figure 29. Erosion at the shoreline of Pointe aux Vieux, 2010. Courtesy of Claude Arsenault.

- The piping plover (*Charadrius melodus*) may face significant risk as a result of accelerating coastal beach erosion. This already endangered bird uses wide, open, sandy beaches as habitat—a type of land that is at risk from not only erosion itself, but also from attempts at mitigating coastal erosion, structural and otherwise. In addition to habitat degradation, accelerating coastal beach erosion may cause increased stress for the piping plover as humans that use the beaches for recreation may be pushed closer to nesting areas as beaches shrink. Piping plovers are very sensitive to human disturbance [52].
- Dune erosion is a significant issue on PEI. Dunes have suffered significant erosion as a result of large storms that result in wash-over. This is partially due to the decline of ice foots during the winter. An ice foot is the pile of ice chunks that stack up on the beach in a continuous line. Ice foots are critical to the environmental health of dunes as it protects them from erosion resulting from storms and waves. They also protect invertebrates in the sand from being washed away. As ice in the gulf becomes less prevalent as a result of changes in climate and warming ocean temperatures, dunes may face even greater erosion risk [53, 54]. A severe storm heightens the risk of a breach on Hog Island, a barrier island which protects Lennox Island from waves, swells, and storms. This would greatly increase the flood and erosion hazards of Lennox Island, resulting in greater risk to the environment on the Island [22]. A similar event has already occurred near Grand Tracadie (see textbox) where a breach of the dunes altered circulation patterns in the harbour. As it stands, the recent breach is now the main area dredged to support the local fisheries and the previous pass has been left to close over [39].

Tracadie Bay

Changes in barrier island spit systems can occur naturally. In 2000 the Tracadie Bay spit system was characterized by a single outlet on the west side of the Bay. In 2010 a breach occurred near the center of the Bay, creating a second outlet, and resulting in the formation of a barrier island (see left photo). This breach resulted in improved circulation of water in the harbor which benefited aquaculture fishers and provided lobster fishers with a favourable outlet from the Bay. In 2020, the outlet on the west side of the Bay closed, leaving the center outlet as the only functioning and dredged outlet from the bay (see right photo) [9]. While changes in barrier islands can sometimes result in positive outcomes, such as the case in Tracadie Bay, shifting erosion patterns can also expose previously protected lands to erosion hazards, such as the case with Lennox Island and the protection it receives from Hog Island. A breach of Hog Island could expose Lennox Island to the open waters of the Gulf of St. Lawrence and result is large-scale changes to the landscape [13].

Figure 30. Grand Tracadie 2010 (left) vs 2020 (right).

- Accelerated coastal erosion combined with sea level rise may cause a phenomenon known as "shoreline squeeze" where development located near the shoreline does not allow for the migration of dunes and saltmarshes as erosion moves the shoreline farther inland. This may have negative consequences for a variety of species that rely on these areas for habitat, such as the Gulf of St. Lawrence Aster [53, 55].

Confidence: High

Multiple high-quality sources of evidence indicated environmental impact to PEI from coastal erosion with agreement. Since coastal erosion has been observed and recorded on PEI for a long period of time, the environmental impacts are well known. However, several stakeholders advocated for a lower consequence rating (of 3), indicating that erosion is a natural process on PEI, and many of the impacts are related to human assumptions of natural stability.

Social Stability: 3 (moderate)

Accelerating coastal erosion has the potential to cause moderate disruptions to community social stability, particularly as a result of loss of sense of place, or loss of cultural resources such as beaches, homes, cottages, archaeological sites, lighthouses, or near shore gathering places. The impacts are likely to be most severe for communities near the coastline.

Supporting evidence includes:

- Coastal erosion may diminish sense of place as coastal areas that residents feel a sense of attachment to may be altered or disappear altogether. Since it has been found that there is a strong association between sense of place and mental health this may have negative mental health consequences on PEI [32]. As locations that hold a sense of place for many Islanders shift and change, community-wide social stability impacts may result.
- There is potential for a loss of cultural resources as a result of coastal erosion, impacting social stability. There are many instances of relocation/decommissioning of coastal assets on PEI. For example, in 2014 the Cape Bear lighthouse was moved from the side of a cliff to ensure its survival [38]. Seventeen lighthouses are denoted as vulnerable to coastal erosion on PEI [8].
- The north shore of Lennox Island is vulnerable to coastal erosion and coastal flooding, while the shore is classified as a low erosion-risk hazard (0-30cm annual erosion rate). Both shores are socio-culturally valuable to the Mi'kmaq First Nation community and the social stability of Mi'kmaq communities in general may be particularly at risk from coastal erosion [34].

Confidence: Low

Limited high-quality information indicating likely impacts to social stability was available. The rating is based mainly upon likely impacts to key social resources and reasonable expected impact the loss of those social resources will have on social stability. Workshop stakeholders were consistent in rating social stability consequences either as a three (moderate, months-long disruptions) or a two (moderate, days-to-weeks-long disruptions).

Infrastructure: 4 (major)

Accelerating coastal erosion can result in the widespread disruption of multiple infrastructure assets on PEI. Transportation and wastewater infrastructure may be at particular risk as many coastal roads and water infrastructure equipment (septic tanks, wastewater treatment ponds, etc.) are within projected areas of erosion vulnerability. Without employing mitigation tactics, infrastructure impacts may be long-term or permanent.

Supporting evidence includes:

- As erosion damages properties and infrastructure near the coast, the cost of maintenance, repair, and adaptation of infrastructure, and equipment may increase [25]. Extensive erosion along the coastline, may require the redesign of coastal highways and bridges, which can take months or years to complete [39, 56].
- Water and wastewater infrastructure located near coastline (e.g., wells and septic systems) may be at risk as a result of accelerating coastal erosion [39].
- Accelerating coastal erosion may increase the risk of saltwater intrusion, which may pose even further risk to water infrastructure, especially if wells and groundwater are contaminated [48].
- According to UPEI's coastal erosion hazard mapping, 126 vehicle bridges, 10 footbridges, 5 settling ponds, and about 50 kilometres of roads totalling $45 million in road infrastructure are at risk over the next 83 years, although some of this infrastructure will be decommissioned by the time it is at risk to coastal erosion [8, 27].
- Armourstone is commonly utilized as a strategy to protect vulnerable infrastructure from the effects of coastal erosion, although it can be an expensive strategy since PEI is distant from a source of armourstone [51].

Confidence: Medium

There was a high level of agreement between anecdotal evidence and reports yet estimates of impact are reliant on only a couple key studies.

8.2. Post-tropical Storm

Scenario: Multi-day post-tropical storm with heavy rain, storm surge, and wind; landfall in Queens County

To evaluate post-tropical storm risk, the assessment focused on a specific scenario of the likelihood and consequences of a multi-day post-tropical storm with heavy rain, storm surge, and wind making landfall in Queens County. A storm with these conditions is likely to have the most severe impacts to the infrastructure and agriculture, fisheries, and aquaculture consequence categories. Specific consequences include large-scale power outages, road damage, wind damage to crops, and loss or damage to aquaculture/fisheries equipment, among others. These impacts are likely to disrupt day-to-day life and have potential to threaten the public safety of residents. The severity of impacts could vary by population density and variation in land use.

This scenario represents one permutation of a post-tropical storm event, used to illustrate the types of consequences associated with this hazard. The consequence ratings are specific to this scenario.

Some examples of multi-day post-tropical storms used to inform this scenario and assessment of consequences include:

- In June 1959, a post-tropical storm referred to as the Escuminac Disaster caused widespread damage to PEI's fisheries industry, and resulted in multiple loss of life of PEI fishers [57].
- In late September 2003, Hurricane Juan made landfall on PEI leaving two-thirds of PEI without power, capsizing boats, and disrupting an election [58, 59].
- In November 2007, Post-tropical Storm Noel resulted in flooding on PEI and caused 10,000 residents on the Island to lose power [60].
- In September 2010, Post-tropical Storm Earl hit eastern and central PEI causing thousands to lose power, restricting travel on Confederation Bridge for high-sided vehicles and motorcycles, and shutting down ferry travel for a day [61].
- In September 2019, Post-tropical Storm Dorian (downgraded to a post-tropical storm by the time it reached PEI) caused millions of dollars in damages, destroying buildings, downing trees, flooding basements, and causing infrastructure damage [62]. Peak storm surges were reported over 1.5 metres above normal tide levels [63].

Likelihood

> **Likelihood Rating Drivers**
>
> Type of hazard: Discrete
>
> Climate driver(s): Change in precipitation patterns, sea level rise, and change in sea surface temperatures
>
> "Present day": 1900-2019 historical data
>
> Source of 2050 projections: Assessments across literature

Current likelihood assessments were built from severe storm data ranging from 1900-2019. From 1900-1949 severe storms (average sustained wind speed of 63 kilometres per hour or greater) occurred equivalent to a 12% annual chance on PEI. From 1950-1999 the equivalent annual chance was 22% and from 2000-2019, the equivalent annual chance was 20% indicating an increase in likelihood since the start of the 20th century [64]. Atlantic Canada in general has a greater annual chance of severe storms than PEI specifically, with Nova Scotia currently experiencing a one in three, or 33% equivalent annual chance of a severe storm [65]. This evidence supports a **current likelihood rating of 4**, as severe storms are likely to occur on PEI approximately once every 3-10 years. Considering this scenario's specific definition (multi-day post-tropical storm with storm surge, heavy rain, and wind making landfall in Queen's county), this event is currently likely to occur closer to once every 10 years, rather than once every 3.

Specific 2050 likelihood of post-tropical storms on PEI is less certain, although there is widespread agreement that Atlantic Canada will see an increase in both storm frequency and severity and that Atlantic coast hurricanes will experience a northward shift [66-68]. Sea level and sea surface temperatures are also expected to increase by 2050, further supporting the notion that severe storms will increase in frequency and intensity [67, 69]. Although severe storms are projected to increase in frequency, post-tropical storms as defined in this scenario, are unlikely to occur more than once every two years, thus the **future likelihood rating remains 4**.

Confidence: Medium

The current likelihood rating is based strictly upon historical data on the rate of severe storm (but not necessarily post-tropical storms) occurrence on PEI. This data is rigorously tracked and reported, providing a high level of confidence to the rating. The future likelihood rating has a lower confidence rating as literature projecting severe storm occurrence lacks either specificity in the level of frequency and intensity that severe storms will increase, or consistency in the margin at which they will increase, thus bringing the overall rating to medium.

Consequences

Health: 2.7 (moderate)

Potential loss of life: 3 (moderate)

Historically, post-tropical storm events have caused limited loss of life on PEI. However, there is potential for multiple loss of life, particularly if warning time is limited, or access to medical and emergency care is impaired. If clean water or power services are unavailable, it could lead to indirect deaths as emergency care would be less available.

Supporting evidence includes:

- The 1959 Escuminac Disaster resulted in multiple loss of life for Canadian fishers, some of which from PEI, in the Northumberland Strait when boats were capsized due to rough seas up to 15 metres. Fishers were not equipped with radio to receive warning of the upcoming storm [57].
- Loss of life risk is lessened on PEI due to the current improbability for a Category 3 storm or greater to impact Atlantic Canada [70].
- Queens County, the location of the storm's landfall under this scenario, is home to some of the province's largest health facilities, including the province's largest emergency medical services base, long-term care homes, and a hospital [41]. Damage or loss of power to these facilities may delay treatment for injuries or endanger the lives of inpatients. The severity of this impact may be compounded if damage occurs at a time when Confederation Bridge or other ingress/egress points are limited or closed for access [41].
- In the U.S., from 1995-2007 165 deaths occurred from as a result of fallen trees caused by thunderstorm winds [71]. Falling trees have caused damage to buildings on PEI in the past [62].
- Other than the Escuminac Disaster, there is no historic evidence of modern severe post-tropical storm-related deaths on PEI specifically, although death has occurred in Atlantic Canada as a result of severe storms, and there is some potential for loss of life for future events on PEI:

    - In 2003, Hurricane Juan resulted in two direct deaths caused by falling trees in the nearby Province of Nova Scotia [72].
    - In 2010, Hurricane Igor resulted in the death of an elderly Newfoundland man who was swept into a river [73].
- Factors that could influence loss of life are the level of warning prior to the flood event and time for evacuation, if necessary [74].

Confidence: Medium

Previous loss of life due to post-tropical storms on PEI is well accounted for. Multiple high-quality non-PEI-specific studies exist that detail potential for loss of life from post-tropical storm events, although PEI-specific studies were not available.

Potential morbidity, injury, disease, or hospitalization: 3 (moderate)

Historically, there are few reported instances of serious injury, disease, or hospitalization due to post-tropical storms on PEI. Additionally, PEI's low potential for hurricanes more powerful than Category 2 lessens the probability of injury. However, post-tropical storm events have potential to expose citizens to hazards such as fast-moving floodwaters, debris, and falling trees. Additionally, loss of services to clean water or power may exacerbate impacts.

Supporting evidence includes:

- As described above, Queens County, the location of the storm's landfall under this scenario, is home to some of the province's largest health facilities [39]. Damage or loss of power to these facilities may delay treatment for injuries or endanger the lives of inpatients. The severity of this impact may be compounded if damage occurs at a time when Confederation Bridge or other ingress/egress points are limited or closed for access.
- Post-tropical storm events can cause negative health consequences such as the interruption of medical care, food insecurity, dehydration (e.g., power outages prevent drinking well pumps from operating); and respiratory stress/illnesses from mould/bacterial growth on water-damaged surfaces that may result from increased in-home vulnerability to flooding [25]. Power outages may lead to carbon monoxide poisoning due to improper use of generators and indoor barbeques [24].
- Falling trees have potential to cause injury or even death in post-tropical storm events. In the U.S.S, from 1995-2007 165 deaths occurred from as a result of fallen trees caused by thunderstorm winds [71]. Falling trees have caused damage to buildings on PEI in the past [62].
- Injury due to automobile accidents may increase during or before a post-tropical storm event [75]. When roads wash out during storm events, drivers may be at increased risk:
    - During evacuation events, people tend to rush to get out of at-risk areas, which may lead to more accidents [75] .
    - High winds, rain, and flooded roads create dangerous driving conditions [75].
    - Traffic lights are more likely to not be functioning [75].
- Precipitation-driven flooding has the potential for contamination and disease of natural resources which may pose a risk for citizens of PEI. For example, in May 2018 the public health office of PEI advised residents not to eat fiddleheads as they were potentially contaminated by floodwaters [76]. Additionally, from 2015-2020 rainfall events on PEI have caused at least 5 shellfish harvesting closures due to potential contamination [77].
- There are several areas on PEI that may pose challenges during extreme events due to limited

access (E.g., Panmure Island), difficulties during evacuation (E.g., North Rustico), or lack of preparedness (E.g., Crystal Beach Campground) [24].

- Prevalence of private lanes with multiple seasonal cottages – many of which are being converted to year round residences – presents a risk due to lack of maintenance and limited year round access [24].
- The Public Health Agency of Canada lists the following negative health outcomes due to flooding: drowning, injuries, diseases spread through water contamination and sewage backup, diseases spread through food contamination, diseases spread by insects, carbon monoxide poisoning, and mental health effects [78].

Confidence: Medium

Previous instances of injury, disease, and hospitalization due to post-tropical storms on PEI are well accounted for. Multiple high-quality non-PEI-specific studies exist that detail causes of and potential for injury, disease, and hospitalization from severe storm events, although PEI-specific studies were not available.

Mental health: 2 (minor)

Post-tropical storm events have the potential to cause widespread moderate and some isolated severe mental health impacts. More severe impacts are likely to be witnessed for those who were displaced or experienced damages to personal property.

Supporting evidence includes:

- Mental health issues commonly reported after severe storm-related flooding events include behavioural problems in children; increased substance use and/or misuse; increased domestic violence; as well as exacerbating, precipitating or provoking people's existing problems with their mental health. Economic problems resulting from severe storm events may cause additional mental health stress. Severity of the storm event and level to exposure to the event are major factors that influence the severity of mental health issues realized as a result of the event [79].
- Specific sectors, such as agriculture, may be particularly affected as farmers often face unique characteristics that may be hazardous to mental health [80].
- Flooding as a result of post-tropical storms can be very stressful for residents and potential exists for stress to continue for significant periods of time after water has receded [79]. Residents may also experience stress due to the financial burden of basement floods originating from heavy rainfall in combination with the loss of submersible pump power [81].
- Forced displacement, relocation, or land loss as a result of severe storms diminishes sense of place which causes further negative consequences for mental health [82]. Severe storm events of the magnitude required to result in displacement, relocation, or significant home damage do not happen frequently on PEI, although under certain circumstances this can occur. Loss of trees (especially old-growth trees) due to severe storms may impact the landscape significantly and further reduce sense of place.
    - In the aftermath of Post-tropical Storm Dorian, first responders evacuated over 30 people from their homes on PEI [83]. Residents of coastal communities in Western PEI were also evacuated in December 2014 after a rainstorm resulted in breached dikes [84].
    - One study found 15-20% of natural disaster victims have symptoms of PTSD [85].
    - In 2019 Woodhall-Melnik and Grogan studied the mental health impacts of the Spring

2018 St. John River Flood. This study indicated that those who experienced residential damage or displacement experienced negative mental health impacts, but both studies also indicated positive community growth resulting from public collaboration in the wake of the disaster [86].

  - In September 2008, 90 mm of rain from Post-tropical Storm Hanna caused flood damage to several residential basements [87].

- Disruptions to utility services may further delay recovery and the ability of evacuated individuals to return home, increasing stress and anxiety. See Infrastructure section for more details.
- Key risk factors that may increase vulnerability to disasters include age, low socioeconomic status, minority ethnic status, previous mental health issues, lack of adequate insurance coverage, and level of social support [88, 89]. Rural communities on PEI tend to be more socially connected than urban communities.
- First Nations and coastal communities have a higher risk for evacuation and longer recovery periods from flood events, which may increase these groups mental health risk relative to the general population [90].

Confidence: Low

Post-tropical or severe storm impacts to mental health are generally well accounted for in the literature, although impacts to specific communities on PEI rely mainly on anecdotal evidence, causing the confidence rating to be low.

Economy: 3 (moderate)

Tourism and recreation: 3 (moderate)

The tourism and recreation industry has potential to be moderately impacted by a post-tropical storm, with some industries (such as campgrounds and park visitation) facing severe, weeks-long consequences. Road closures, limited access to attractions, cancellation of events, and park closures may disrupt tourists' itineraries or cause tourists to cancel trips altogether. Since peak hurricane season for PEI (August-September) coincides closely with peak tourist season on PEI (July-September), post-tropical storms pose risk to the closure of PEI tourist amenities during peak season, exacerbating economic impact of a post-tropical storm. Furthermore, if climate change results in peak hurricane season to be extended into July, then this could further put the tourism industry at risk.

Figure 31. Storm surge driven flooding at Cedar Dunes Park in September 2019. Photo provided by DE Jardine.

Supporting evidence includes:

- PEI National and Provincial parks have suffered drastic damage resulting in significant closures as a result of post-tropical storms in the past. Closures of PEI's popular campgrounds, parks, and trails has potential to impact the Island's tourism sector.
- Beaches and coastal boardwalks may face damages and closures as a result of post-tropical storms [25].

- Post-tropical Storm Dorian caused multi-day and in some cases multi-week closures to the following parks, campgrounds, and trails: PEI National Park, Cedar Dunes Provincial Park, Panmure Island Provincial Park, Cabot Beach Provincial Park, Stanhope Campground, and Confederation Trail [91].
- Popular tourist destinations may be affected by wind damage or storm surge. For example, the Cape Egmont Lighthouse was moved 20 years ago in order to ensure it was not lost to erosion. Its former base lies on the shoreline [92]. Trails at Green Gables Heritage Place were damaged and Cavendish Campground at PEI National Park was closed for the 2020 season after Post-tropical Storm Dorian [93]
- Recreational freshwater fishing is a popular activity for residents of PEI as over 6,000 residents held fishing licences on PEI as of 2015 and two of the three most popular targeted fish species are freshwater fish (brook trout and rainbow trout) [94]. Fish kills as a result of pesticide runoff from flooding have occurred in the past and hold potential to impact recreational freshwater fishing recreation quality [95].
- Golf is an important tourism industry on PEI and although historically there is no evidence of golf courses being inoperable for long periods of time due to severe storms, courses have had to close for periods shorter than a week to clear damage from severe storms [96].
- Since peak hurricane season for PEI (August-September) coincides closely with peak tourist season on PEI (July-September), severe storms pose risk to cause damage or closure of PEI tourist amenities during peak season, exacerbating economic impact of a post-tropical storm. Furthermore, if climate change results in peak hurricane season to be extended into July, then this could further put the tourism industry at risk.
    - In 2014 Post-tropical Storm Arthur caused the Cavendish Beach Music Festival to cancel a night of performances because of “extreme high winds” and resulting restricted access across Confederation Bridge [97]. Cancellation of large-scale summer events may have cascading economic impacts.

Confidence: Low

The consequence rating is based mainly on accounts of effects previous severe storms or post-tropical storms have had on the tourism and recreation industry. Little high-quality independent evidence relevant to the tourism industry on PEI was available.

Agriculture, fisheries, aquaculture: 4 (major)

Historically, agriculture, aquaculture, and fisheries on PEI have faced negative consequences as a result of post-tropical storm events, including negative impacts to crops and the shellfish industry. There is potential for moderate disruption to multiple industries and isolated severe disruption to the shellfish industries and crops that are particularly sensitive to wind damage (e.g., fruits and vegetables). Disruptions may last as long as a few days to a season.

Supporting evidence includes:

- Wind damage from post-tropical storms poses serious risk to crops on PEI. As a result of Post-tropical Storm Dorian, farmers on PEI suffered significant damage and yield loses to corn, wheat, soybean, apple, and potato crops. Strong winds can flatten stems and stalks of crops, damage leaves, disrupt harvest lines creating difficulty at harvest time, as well as damage the crop itself [98].
- Post-tropical storm events and storm surge can cause bank erosion and runoff. Runoff and soil erosion may cause pesticide and nutrients to enter streams, causing issues such as eutrophication and fish kills [25].

- Oysters and mussel fisheries on PEI can be damaged by post-tropical storms as flooding can damage culture equipment and cause erosion and runoff, which may result in heavy silt formation in rivers, smothering oysters and mussels living on the river bottom [99]. Impacts can occasionally last multiple seasons; for example, Post-tropical Storm Dorian caused the loss of mussel spat, which can affect future seasons of mussel growth [39].
- Damage to boats and fisheries equipment may occur during post-tropical storm events. The 1959 Escuminac Disaster caused significant damage to fisheries, including the loss of 5000 lobster traps, damaged or capsized fishing vessels, and broken fishing nets [57].
- Impacts to agricultural infrastructure can result in high repair costs and loss of yields for farmers [39].
- Storm surges can result in lobster and other shellfish kills, although at the current frequency, these events rarely have significant impact on shellfish populations [100].
- A 1995 study demonstrates that hurricanes can cause lobster to move to deeper water or suffer mortality as a result of decreased salinity and temperature. This may affect lobster seasons during the fall on PEI [101].
- The potato industry is valued at over one billion dollars, which includes the value of the crop, direct employment, and the additional services and industries [102, 103]. As PEI’s largest agriculture export, any risk to the potato crop is cause for serious concern to PEI’s agricultural community [104]. The potato crop on PEI has suffered from severe storm events in the recent past; for example, in 2008 Post-tropical Storm Hannah resulted in a significant portion of the potato crop being severely damaged [105] and in 2011 flooding (of uncertain severity) washed out over 100 acres of potato fields [106]. Government aid programs have been utilized in the past to assist farmers with flood damaged potato crops [105].
    - The timing of storms is also important. Damage in early in agricultural cycles may impact seeding and planting (occurring in April-May), which may cause ripple effects later in the season. Storms occurring in the growing season (June to late fall, depending on variety) have potential to cause damage to the crop near harvest time [107].
- Following heavy rainfall on PEI after Post-tropical Storm Dorian, the Canadian Department of Fisheries and Oceans announced the closure of shellfish fisheries inland and within three kilometres of the Island’s coast as they posed a contamination risk [108]. From 2015-2020 rainfall events on PEI have caused at least 5 shellfish harvesting closures [77].
- Increased storm activity may cause a reduction in amount of fish caught by reducing the amount of days fishers are able to take their vessels to fishing sites [25].

Confidence: Medium

Several high-quality sources indicated impacts to PEI agriculture, fisheries, and aquaculture from post-tropical storm events. Accounts from multiple previous storm events provide examples of likely outcomes for future storm events.

Other Industries: 2 (minor)

There is some potential for days to weeks-long disruption to PEI’s industries such as manufacturing and shipping, mostly due to road/bridge closures or ferry/marine shipping centre closures. Historically, these closures have been brief in duration and there is little evidence to suggest that a post-tropical storm on PEI will have long-term and significant impact to these industries. This considered, even short-term closures may result in shipping delays and/or increased freight costs. Additionally, the insurance sector may face particular stress as a result of post-tropical storms.

Supporting evidence includes:

- High wind or post-tropical storm events have caused restrictions for high-sided vehicles or complete closure of Confederation Bridge in the past for hours up to two days in length [109, 110]. Ferries have also been cancelled due to severe storm events [111]. These closures result in limited ingress/egress access to and from the Island and thus have potential to impact industries that rely on consistent supply chains such as grocery stores.
    - As a province where exports are a key driver of the economy ($1.5 billion exported internationally in 2019), closures of the limited ingress/egress infrastructure are likely to have a direct impact to the economy.
- Road damages and washouts, or other impact to transportation infrastructure has potential to cause significant impact on PEI's exports since land transportation constitutes a significant method of transport. The aerospace industry may face particular risk as it is nearly completely reliant on truck transport to bring parts to market. Delays to ship and increased freight costs may also be associated with transportation infrastructure closures.

Figure 32. Boats displaced at Covehad after Hurricane Dorian. Photo Courtesy of Aaraon Ramsay.

- As post-tropical storm frequency increases, it is likely that demand for insurance to protect against damages resulting from storms will also increase. This may be problematic, as the insurance industry is not well-positioned to supply coverage for severe storms occurring at more frequent intervals [25].
- When storm surge occurs, Islanders' properties may be damaged or eroded, with some areas losing as much as one acre over the previous 65 years [92]. As such, personal and commercial real estate value may drop and real estate investment interest has potential to face negative consequences [112, 113].

Confidence: Low

Impacts to other industries are based mostly upon anecdotal evidence, some of which is supported by independent literature or reports. Some impacts to other industries may be missing from this evidence base.

Environment: 4 (major)

Post-tropical storms have potential to moderately disrupt multiple natural assets such as freshwater fisheries and biodiversity resulting in months to years of recovery, as well as severely disrupt coastline stability and hydrology and forest cover, causing irreversible damage or taking years to decades to fully recover. Multiple storms occurring within a short time frame would likely cause compounding effects.

Supporting evidence includes:

- PEI's coast is primarily composed of sandstone, resulting in high susceptibility to erosion as a result of intense storm waves and storm surge events resulting from tropical storms or hurricanes [114].

- Post-tropical storms have significant potential to down trees across PEI, dramatically affecting forest cover in some areas. For example, Post-tropical Storm Dorian downed 80% of trees in the Cavendish area of PEI National Park [115]. When old-growth trees are downed by a storm, impacts take decades to fully recover.
- PEI has observed an average historical loss of 28 centimetres of land a year to erosion, much of which is exacerbated by post-tropical storm events. Some intense storm waves and storm surge events can cause some areas to lose pieces of land as large as 3-5 metres from a single event [92].
- Sedimentation and hydrological changes resulting from severe storms may increase need to dredge channels near PEI to maintain boat access [25]. Dredging can have strong negative biological effects on marine environments [116].
- Barrier islands may be at serious risk as a result of post-tropical storms. If barrier islands are breached, the hydrology of the watersheds behind them may be altered as wetlands lose a line of protection[117]. A post-tropical storm heightens the risk of a breach on Hog Island, a barrier island which protects Lennox Island from waves, swells, and storms. This would greatly increase the flood and erosion hazards of Lennox Island, resulting in greater risk to shorelines and other natural environments on the Island [22].
- Post-tropical storms result in risk for multiple organisms on PEI. These impacts are compounded if storms are severe enough to damage key habitats such as saltwater wetlands. For example, the piping plover, one of PEI's most notable species, is already endangered and faces further negative consequences from severe storm events that could leave less habitat to establish burrows in springs subsequent to storm events [118].
- Agricultural runoff caused by post-tropical storm precipitation can result in serious environment problems on PEI. The Island experienced 51 documented fish kills from 1962-2016 that were proven or suspected to have been caused by pesticide runoff [119]. For example, after a heavy rainstorm in July 2016 more than 300 fish were found dead and pesticides were suspected as a plausible cause [120]. In July 2014 a PEI farmer was fined $72,000 for pesticide runoff resulting in fish kills during 2011-12 [95]. Post-tropical storm events have serious potential to increase the amount of pesticide and herbicide runoff into nearby rivers and streams thereby impacting environmental resources [121]. Salmonid eggs can also be suffocated by sediment and agricultural runoff from post-tropical storm events [25].
    - Runoff resulting from post-tropical storms can also result in favourable growing conditions for invasive or unwanted species. For example, sea lettuce thrives in disturbed conditions created by extreme storms. These conditions compounded with agricultural runoff further stimulate sea lettuce growth, ultimately depriving other aquatic organisms of sufficient oxygen, causing trophic cascades [25]. High levels of runoff can also support the growth of harmful blue-green algae [122].
- Sewage treatment plants at Lennox Island and North Rustico have flooded as a result of storm surge events in the past, posing an environmental hazard [123].
- A post-tropical storm heightens the risk of a breach on Hog Island, a barrier island which protects Lennox Island from waves, swells, and storms. This would greatly increase the flood and erosion hazards of Lennox Island, resulting in greater risk to shorelines and other natural environments on the Island [22].

Confidence: High

Multiple high-quality sources of evidence indicated environmental impact to PEI from post-tropical storms with agreement. Additional pieces of support were provided via consultation with experts and from workshop activities.

Social Stability: 3 (moderate)

Post-tropical storms have the potential to cause negative community-wide social stability impacts. Events such as road closures, destroyed property, damaged or flooded homes, and school closures can result in moderate to severe disruption to daily life depending on the severity of the impact faced by the individual. Financial stress, break in routine, and feelings of hopelessness may also occur for periods of weeks to months depending on time required to recover and rebuild. Severe outcomes are less likely to occur as storms greater than Category 3 are unlikely to occur on PEI [70].

Supporting evidence includes:

- The current level of social stability in a community is an important factor in the social stability after a flood event. A 2012 study found that since individuals tend to rely on community to address disaster related demands, individuals suffer less from post-traumatic stress in populations with high social capital [124].
    - PEI's strong sense of community and familiarity as a small and well-connected province may be beneficial as related to social stability upkeep in the wake of a flooding event, although loss of power and/or internet connection can hinder the ability to connect [39].
- Loss of power due to high winds can result in increased crime rates and damaged communication infrastructure, thereby disrupting social stability [125].
- Victims of flooding and severe events frequently report feeling isolated and depressed. Cleaning up, making repairs, and dealing with insurance claims may result in higher levels of stress, especially if rigorous support systems are not in place. Forced displacement and relocation diminishes sense of place which causes further negative consequences for mental health [82].
    - In the aftermath of Post-tropical Storm Dorian, first responders evacuated over 30 people from their homes on PEI [83].
- Residents of PEI have experienced land loss as a result of post-tropical storms and storm surge, with some areas losing three to five metres of land as a result of one event [92]. Loss of personal property can decrease sense of community and belonging [126].
- Storm damage to iconic tourist locations, sites of cultural importance, and archaeological artifacts may diminish sense of place and thereby impact community social stability [32].
- When public facilities such as schools, recreation centres, etc. are converted to shelters those locations are not available for their usual usage, which can affect social stability [39].
- Potential positive: As the frequency of emergencies and storms increases, people may become more proactive in addressing needs and preparation prior to events [24].
- The Oapus trail, which is the only access road to the ceremonial pow wow grounds on Lennox Island, has potential to be lost or damaged during a storm surge event and has been previously flooded during combined high wind and high tide events [22, 34]. Adaptation actions such as raising the roadbed or relocation may reduce or eliminate risk [34].
- A post-tropical storm heightens the risk of a breach on Hog Island, a barrier island which protects Lennox Island from waves, swells, and storms. This would greatly increase the flood and erosion hazards of Lennox Island, resulting in greater risk to socio-cultural and heritage sites such as the pow wow grounds [22].

Confidence: Medium

Non-location specific high-quality information indicated post-tropical storm events' likely impacts to social stability, some of which was supported by anecdotal evidence. Although a fair amount of anecdotal information was available, there was little agreeance between accounts.

Infrastructure: 5 (catastrophic)

Post-tropical storm events can cause significant disruption to infrastructure services and day-to-day life for citizens of PEI. Disruptions can last for days to months, depending on the severity of the event and time period required for redesign and reconstruction of damaged infrastructure. Impacts include washed out roads, damage to utility infrastructure, power outages, and driving/travelling restriction, among others.

Example: Hurricane Juan

In the early morning of September 29, 2003, Hurricane Juan made landfall on PEI as a category-one hurricane. The storm reached winds of 146km/h at Charlottetown, leaving nearly two thirds of PEI without power, destroying multiple boats at the Charlottetown Yacht Club, and causing extensive tree damage.

Figure 33. Damage from Hurricane Juan. Photo provided by DE Jardine.

Supporting evidence includes:

- Storm surge and extreme storm events can lead to a variety of infrastructure issues such as bridge scour, flight delays, closed roads, and road and culvert washouts, among others [25]. Some examples of storms that have led to these types of damage include Post-tropical Storm Dorian, Post-tropical Storm Hannah, Tropical Storm Earl, and Post-tropical Storm Noel [59-62, 87, 127].
    - In September 2008, PEI experienced 90 mm of rain in one day as a result of Post-tropical Storm Hanna. Multiple streets in Charlottetown were closed due to flooding. Additionally, several culverts, ditches, and storm sewers were overwhelmed due to the storm [87].
    - Highway infrastructure, especially bridges, could take months for redesign, tender, and construction process to complete [39].
- Large-scale power outages have occurred as a result of post-tropical storms on PEI leaving tens of thousands without power. Power outages of over 10,000 households without power occurred during Post-tropical Storm Dorian, Hurricane Juan, Post-tropical Storm Earl, and Post-tropical Storm Noel [59-61, 128]. Power outages can also temporarily close essential services such as grocery stores [24].
- Severe storms that cause disruption to New Brunswick's energy infrastructure are likely to cause disruption on PEI as well since PEI receives approximately 80% of its energy needs from New Brunswick [129].
- North Rustico Harbour has flooded in both 2016 and 2010 as a result of storm surge, effectively shutting down parking lots and road access to some areas [92].

- Flooding may also result in damage to power lines and other utility infrastructure on PEI. Following Post-tropical Storm Dorian, nearly 22,000 utility customers were without power, some for as long as a week [130].
- Restrictions not allowing transit for high-sided vehicles, motorcycles, and vehicles towing trailers may be placed on Confederation Bridge as a result of high winds for hours to days [109, 110]. In extreme cases the bridge may be temporarily closed during a storm [110]. Ferries have also been cancelled due to heavy precipitation events [111]. This results in limited ingress/egress access to and from the Island and thus have potential to impact supply chain lines.
- Storm surge compounded with intense storms may cause damage to power poles, electricity substations, generation plants, and other energy infrastructure located close to the coast on PEI [25]. Closures to transportation infrastructure (namely Confederation Bridge) may disrupt the supply chain for fuel and heating oils [25].
- Winds from post-tropical storms have potential to damage wind turbines as well as disrupt wind farm production if wind speeds exceed maximum designed capacity. High winds may also damage power lines and increase the probability that falling trees damage power lines [131].
- Intense wave action caused by post-tropical storms may result in navigation hazards for boats and ferries [25].
- Increased wave energy as a result of post-tropical storms on PEI could damage wastewater treatment pipes as well as causing risk to coastal septic systems [25].
- Many infrastructure assets on Lennox Island may be at risk as a result of a post-tropical storm event:
    - Damage from a severe storm may result in the Lennox Island Causeway becoming nonoperational. If this occurs, the Community on Lennox Island may be at particular risk since the Causeway is the only access point to the Island. Consequences may include disruption during a health emergency, difficulty transporting food, fuel, and other goods and services, as well as interruptions to communication [123]. The road on the Lennox Island side of the Causeway is also prone to flooding, along with residencies along it and at least one commercial property in the surrounding low-lying area [34].
    - On Lennox Island, 12 buildings are currently at risk of flooding during a 1 in 100-year storm surge event, and 18 are at risk by 2055 [34].
    - A severe storm heightens the risk of a breach on Hog Island, a barrier island which protects Lennox Island from waves, swells, and storms. This would greatly increase the flood and erosion hazards of Lennox Island, resulting in greater risk to infrastructure on the Island [22].

Confidence: High

The impacts to infrastructure from post-tropical storm events on PEI are well documented and well supported by previous storm events. Multiple sources of high-quality evidence were available, which were generally supported by experts form interviews or workshop activities.

8.3. Heat Wave

Scenario: Three consecutive days with temperatures above 29°C

To evaluate risks of a heat wave, the assessment focused on a specific scenario of three consecutive days with temperatures over 29°C, a threshold at which Environment Canada issues heat advisories. A heat wave of this severity is likely to have the greatest consequences to physical health and infrastructure. Specific consequences include potential power outages, increased risk of heat-related illnesses and injuries, and potential for reduced yields for crops such as potatoes. Additionally, the consequence ratings and analysis assume approximately 25% prevalence of air conditioning across PEI (2nd lowest prevalence of all Canadian provinces as of 2017), although air conditioning may become more prevalent in the future for those that are able to afford it and through efficiencyPEI's energy efficient equipment rebate program, which may have already increased prevalence of cooling systems [132, 133].

This scenario represents one permutation of a heat wave event, used to illustrate the types of consequences associated with this hazard. The consequence ratings are specific to this scenario only, meaning secondary and tertiary effects of heat waves (such as increased likelihood of wildfire) are not considered in the consequence ratings. Additionally, heat waves often occur in conjunction with drought events, which may exacerbate impacts; however, the consequence ratings below assume a heat wave scenario in isolation. Impacts of drought events are explored in Section 3.7.

Likelihood

Modelled hindcast climate data indicate that heat waves of at least 3 consecutive days above 29°C have occurred on average, 0.05 times per year, in the period 1980-2020.[7] This translates to a 5% annual chance of occurring, or a **current likelihood rating of 3.**

Projected data for the 2041-2060 time period estimate such heat waves will occur 1.7 times per year on average, by mid-century, which would translate to a **future likelihood rating of 5.** This is consistent with other sources that indicate a likely increase in the frequency of heat waves across North America as well as an increase in overall frequency of extreme hot days (>27.5°C) on PEI [25, 134].

Likelihood Rating Drivers

Type of hazard: Discrete

Climate driver(s): Increase in air temperatures, change in sea surface temperatures

"Present day": Modeled data for 1980-2020

Source of 2050 projections: ClimateData.ca projections for frequency of 3+ consecutive days above 29°C, 2041-2060, RCP 8.5

Confidence: High

Climate model data and literature are consistent in projecting an increase in frequency of extreme hot days and heat waves over time in PEI with higher global greenhouse gas emissions. Note, however, that historical observed heat wave data for PEI was not readily available, so modelled hindcast data was used to evaluate current likelihood as the best available data source. Ideally, historical weather station data could be analyzed across the island to verify historical heat wave frequency.

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[7] Value based on ICF analysis of data from ClimateData.ca. Values are for the PCIC12 multi-model ensemble. To represent the climate of the entire Island, climate projections were pulled from 3 grids, located in the west (near O'Leary), central (near Charlottetown), and east (near Souris) areas of the province. Projected values are under RCP8.5.

Consequences

Health: 3 (moderate)

Potential loss of life: 3 (moderate)

There is some potential for loss of life on PEI as a result of heat wave events. Risk of death is higher for vulnerable populations (such as seniors and infants) and for individuals suffering from heat-related health conditions who are left untreated. High humidity, high overnight temperatures, or sustained temperatures several degrees above the threshold of 29°C would worsen consequences.

Supporting evidence includes:

- High temperatures paired with high humidity and/or high overnight temperatures can increase heat-related health consequences and speed up the onset of these conditions [135].
  - If the air temperature is 29°C with 80% humidity, it will feel like 36°C [136].
  - More mild heat-related health conditions (see next section for more detail) tend to begin at 32°C [136]. Prolonged exposure to extreme heat or temperatures exceeding 54°C tend to evolve into the most severe heat-related health conditions (e.g., heat stroke) or death, if left untreated [136-138].
  - Heat exposure can also be a contributing cause of death for people experiencing cardiovascular diseases, alcohol poisoning, and drug overdoses [137, 138]. Prolonged exposure to extreme heat will affect the nervous system and vital organs like the kidneys, which can trigger or exacerbate existing medical conditions [135].
- Older adults, people living in urban centres, those with a lack of air conditioning or ventilation, socially isolated individuals, and those experiencing physiological factors such as cardiovascular conditions, diabetes, hypertension, etc. are at greater risk of heat-related death [139].
- When workers are exposed to high heat levels, occupational health and safety risk is increased as workers are more likely to develop a heat-related illness and the risk for accident or injuries is increased due to heightened physical strain and mental status changes [139]. Both heat-related illness and workplace accidents can result in loss of life [140].
- As illustrated in Figure 34, emergency medical care is often needed when the core body temperature exceeds 39°C and is fatal when body temperature exceeds 42°C [141].

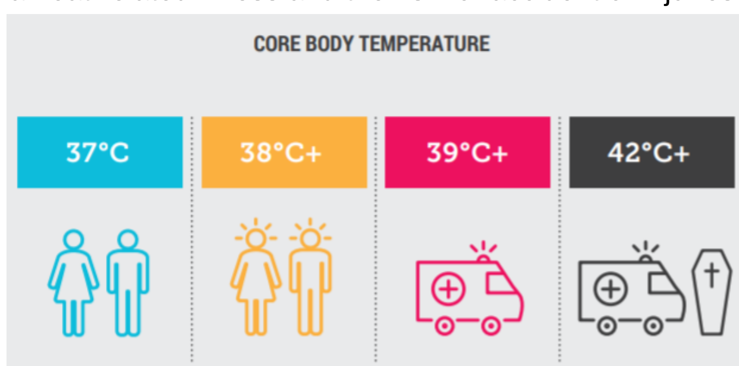

Figure 34. Critical thresholds for core body temperature. Source: Climate Council 2016.

Confidence: Medium

The rating was informed by several government reports indicating potential for loss of life. There was widespread agreement between these sources, although they mostly discussed impacts at temperatures greater than the specific scenario used to define heat wave in this analysis, lowering the rating to medium. A remaining data gap is understanding the prevalence of heat-related deaths on PEI, specifically.

Potential morbidity, injury, disease, or hospitalization: 4 (major)

There is significant potential for morbidity, injury, disease, or hospitalization as a result of heat waves on PEI. Physical health disruptions can range from minor (heat rash or heat cramps) to life threatening (severe dehydration or nervous system damage). Vulnerable populations (seniors, infants, those with limited or no access to air conditioning, those working outdoors, etc.) are at higher risk. Power outages may worsen health impacts.

Supporting evidence includes:

- Exposure to high temperatures can cause conditions like heat exhaustion, dehydration, heat rash, heat stroke, and heat cramps [137]. Prolonged exposure to extreme heat will affect the nervous system and vital organs like the kidneys, which can trigger or exacerbate existing medical conditions [135]. Heat events can also exacerbate respiratory and cardiovascular disease [142].Those who work or exercise outdoors are likely to be more vulnerable to health impacts of heat waves [140].
- Power outages due to excess demands on the electrical grid may worsen health impacts of heat waves by resulting in more limited access to health care, loss of light, increased potential for carbon monoxide poisoning, and decreased levels of food security [143]. The health of those who reside in climate-controlled environments may be particularly vulnerable to power outages during a heat wave.
- High temperatures paired with high humidity and/or high overnight temperatures can increase heat-related health risks and speed up the onset of these conditions [135].
- Underlying health conditions, age, race, access to air conditioning, and living in urban areas can all increase risk to heat-related health conditions [138, 144].
    - Health Canada warns that health risks are greatest for older adults, infants and young children, people with chronic illnesses, people who work or exercise in the heat, people suffering from homelessness, and low-income earners [140].
    - A study of heat waves in 106 U.S. cities found that renal, heat, and respiratory hospitalizations during extreme heat events are more likely among Black, male, and elderly populations. Hospitalization rates were also higher in areas with older housing, lower education, and lower air conditioning use [144].
- When workers are exposed to high heat levels, occupational health and safety risk is increased as workers are more likely to develop a heat-related illness and the risk for accident or injuries is increased due to heightened physical strain and mental status changes [139].
- As of 2017, only 25% of households on PEI had any type of air conditioner [132]. This low prevalence of air conditioning may worsen potential physical health impacts during heat wave events, especially for already vulnerable populations [145].

Confidence: Medium

The rating was informed by several government reports indicating health related impacts of extreme heat. There was widespread agreement between these sources, although they mostly discussed impacts at temperatures greater than the specific scenario used to define heat wave in this analysis, lowering the rating to medium. Additionally, there was no accessible information regarding the prevalence of heat-related diseases on PEI, which would better inform the consequence rating.

Mental health: 2 (minor)

There is potential for widespread moderate mental health impacts such as increased anxiety and discomfort as a result of heat wave events. In severe cases, there may be possibility for more severe mental health disruptions such as suicide, or severe mental illness, although these relationships are less conclusive.

Supporting evidence includes:

- Mood disorders, feelings of anger and frustration, increased anxiety, and increased incidence of domestic violence are all associated with heat stress and discomfort [146, 147]. Feelings of discomfort may be heightened for those without access to air conditioning on the Island.
- Extreme heat is also associated with higher rates of suicide and increased medical/emergency department visits [148].
- Heat can be a contributing cause of death for people suffering from certain mental health conditions that alter risk perception and awareness of dangerous heat conditions. Certain medications to treat mental health can also compromise the body's ability to thermoregulate [138].

Confidence: Low

While high-quality evidence exploring the relationship between heat wave and mental health exist, these sources were unspecific to PEI and generally discussed impacts of extreme heat at temperatures greater than the defined heat wave scenario in this analysis, resulting in a low rating.

Economy: 1.7 (minor)

Tourism and recreation: 1 (insignificant)

Heat waves may result in small-scale short-term disruptions to tourism and recreation on PEI. Islanders and tourists may be disinclined to spend time at outdoor attractions or parks during heat waves and outdoor events may experience decreased attendance and impacts to employees. Consequences are unlikely to persist beyond the course of the heat wave event.

Supporting evidence includes:

- A reduction in visitors to outside attractions resulting from particularly hot temperatures could cause reduced revenue for tourist operations, parks, or other outdoor attractions. PEI may be particularly vulnerable since many of the Island's tourist attractions are outdoors (golf courses, beaches, festivals, etc.). Impacts may worsen if a heat wave coincides with a popular outdoor event, such as the Cavendish Beach Music Festival, potentially lowering access to water (i.e., water is available by purchase only) and increasing health risks [39].
    - Environment Canada recommends avoiding outside activity during heat waves [149].
- When workers are exposed to high heat levels, occupational health and safety risk is increased as workers are more likely to develop a heat-related illness and the risk for accident or injuries is increased due to heightened physical strain and mental status changes [139]. Decreases in worker productivity may also occur. The American Conference of Governmental Industrial Hygienists recommendations to increase rest time at higher temperatures have been adopted in PEI's Occupational Health and Safety Act [150].
- Water-based attractions such as beaches and water parks can be a way to cool down during on hot days and may experience increased visitors during heat events.

Confidence: Low

The relationship between heat waves and the tourism and recreation industry is not well conveyed by multiple high-quality sources of evidence, beyond potential impacts to workers and worker productivity. The rating relied mainly upon anecdotal evidence of heat events on PEI.

Agriculture, fisheries, aquaculture: 3 (moderate)

There is some evidence suggesting fish species with low heat tolerance could face short-term disruption as a result of a heat wave event. Agriculture may face moderate disruption, as heat stress may affect worker productivity, poultry, livestock, and potato yield on PEI.

Supporting evidence includes:

- Extreme heat can lower crop productivity by increasing evaporation which leads to water stress. Crops that rely on rain on PEI, such as wheat, corn, and soybeans may be at particular risk [25].
- Decreases in worker productivity are likely as temperatures above 24-26°C are associated with reduced labour productivity and temperatures above 33-34°C reduce productivity (of moderate intensity work) by 50 percent. Agricultural workers are especially prone to decreased productivity during heat waves because the job occurs outdoors and requires generally high physical effort [151].

Figure 35. Potatoes harvested in Bellevue [3].

- Due to increasing frequency of extreme heat events farmers may need to upgrade or install cooling systems in barns, thereby increasing costs [39].
- If heat waves result in sustained high water temperatures some freshwater fish species that require cool water, such as trout, can face thermal stress or increased vulnerability to predators as they move to cooler, but shallower streams [152].
- Heat waves may result in reduced weight gain and milk production in cattle. Mortalities and heat stress for livestock and poultry may also occur [153].
- Since heat waves coincide with potato growing season on PEI (May to October), potatoes can be vulnerable to heat waves with impacts including reduced yields and physiological defects [153].

Confidence: Medium

Independent sources of evidence indicated generalized impacts of heat waves to agriculture, fisheries, and aquaculture. Some anecdotal PEI-specific impacts indicating agreement with reports/literature were included from workshop events.

Other Industries: 1 (insignificant)

Restaurants, and other businesses unable to control the climate of their place of business may face disruption during the course of heat wave events. However, effects are likely to be short-term and insignificant, unless the heat wave were to lead to widespread power outages.

Supporting evidence includes:

- Heat waves can cause difficulties for employees in the restaurant and food truck industry who may find the heat difficult to endure, especially if working in non-airconditioned locations. Heat waves may also alter food preferences [154].
- Occupational groups that conduct work outside (e.g., farmers and construction workers) are likely to experience decreased productivity and higher risk to occupational safety and health [39, 151].
- As the majority of households on PEI do not have access to air conditioning, heat wave events have historically increased the demand for air conditioning and cooling units beyond the available supply [132, 155]. Businesses that are unable to cool their buildings may be more vulnerable to impacts from a heat wave.
- Heat waves are likely to result in a higher demand and usage of fans, air conditioners, and refrigeration, which increases the strain on the electric grid, which could result in power outages, and reduced efficiency of electrical transmission [156]. Blackouts result in major disruption for businesses, especially those that require cooling.

Confidence: Low

The quality of sources indicating impact to varied from news sources to official reports. Some impacts to other industries may be missing from this evidence base.

Environment: 2 (minor)

The environment on PEI may face localized and moderate disruption as a result of heat waves, but widespread impacts are unlikely as natural resources are largely resilient to high heat events. Water quality, amphibians, trees, and species with low heat tolerance may face increased thermal stress.

Supporting evidence includes:

- Heat waves can result in negative consequences for trees as extreme heat reduces photosynthesis efficiency and growth rate of leaves. Trees may also become more susceptible to disease and wildfire during high heat [157].
- Heat waves can result in negative consequences for wildlife, especially those that rely on damp and wet places such as amphibians. Specific species on PEI that require damp places for habitat include the blue-spotted salamander, the re-backed salamander, and a variety of species of frog [158].
- Heat waves can cause increased incidence of blue-green algae which can harm terrestrial and aquatic wildlife [159]. Eleven cases of blue-green algae have been reported on PEI since 2004 [160].
- Lengthy heat wave events may result in increased water temperatures that may cause undesirable species such as sea lettuce to thrive [39].
- Some species (e.g., bank swallows, salmonoids) may experience increased thermal stress as a result of extreme heat events, which can impact migratory patterns and/or survival [39].

- If heat waves result in sustained high water temperatures some freshwater fish species that require cool water, such as trout, can face thermal stress or increased vulnerability to predators as they move to cooler, but shallower streams [152].

Confidence: Medium

The impact of extreme heat events to the environment on PEI is fairly well expressed in the literature or government reports, although the level of heat required to yield some impacts discussed in the evidence base is higher than the specific scenario.

Social Stability: 2 (minor)

Social stability on PEI may face short-term negative consequences, such as higher crime rates, and lower productivity during a heat wave event. Disruptions are mostly likely to be realized by populations more likely to face social isolation, such as the elderly.

Supporting evidence includes:

- Heat waves may result in higher degrees of social isolation to vulnerable populations (e.g. the elderly) who are encouraged to remain indoors, and may avoid participating in social events or visiting friends and family [156].
- Mood disorders, feelings of anger and frustration, increased anxiety, and increased incidence of domestic violence are all associated with heat stress and discomfort [146, 147]. Feelings of discomfort may be heightened for the majority of Islanders who lack access to air conditioning.
- Heat stress can also affect the ability of children to learn and retain information and adults to be able to work productively [146, 161].
- Evidence suggests that heat waves may contribute to community disruption in the form of higher crime rates, limited access to social spaces, and the isolation of particularly vulnerable groups such as the elderly, who comprise 20% of PEI's population [16, 162].
- Since heat-related health disruptions are likely more prevalent for those who lack air conditioning [145], inequality between those that are able to afford air conditioning and those that cannot may be heightened.
- Dogs are particularly vulnerable to heat waves and historically animal shelters have been closed on PEI due to high temperatures. Centres that lack air conditioning may be at particular risk [163].

Confidence: Low

Generalized effects to social stability are expressed by the literature, however limited evidence of PEI-specific impacts were available, resulting in a low confidence rating.

Infrastructure: 3 (moderate)

Infrastructure on PEI has potential to be moderately disrupted as a result of heat waves. Consequences include increased strain on electric utilities, potential blackouts, and damage to transportation infrastructure.

Supporting evidence includes:

- Heat waves are likely to result in a higher demand and usage of fans, air conditioners, and refrigeration, which increases the strain on the electric grid, which could result in power outages, and reduced efficiency of electrical transmission [156]. Higher demand for electricity may become an increasing challenge as transportation and other sectors become increasingly electricity-dependent. The capacity for power lines to carry electrical current is also reduced

when outside temperatures exceed a certain level and heat can also result in increased sag in power lines [25].
    - Power outages may worsen health impacts of heat waves by resulting in more limited access to health care, loss of light, increased potential for carbon monoxide poisoning, and decreased levels of food security [143]. The health of those who reside in climate-controlled environments may be particularly vulnerable to power outages during a heat wave.
- Heat waves can cause damage to transportation infrastructure including pavement cracking and rutting, increased risk of accidents, and increased maintenance costs [156]. When immediate maintenance for transportation infrastructure is required as a result of a heat wave, workers in the field who are exposed to extreme heat may face health consequences [139]
- Worker productivity is likely to decrease while worker occupational safety and health risk is likely to increase for infrastructure workers who are required to be outside during heat events [139, 151].

Confidence: Medium

Extreme heat impact to infrastructure were discussed in government reports, some of which were PEI-specific. Concern for heat wave effects on energy infrastructure were reiterated during workshop sessions.

8.4. Heavy Precipitation and Inland Flooding

Scenario: 100 mm rain event in 24 hours

To evaluate risk from heavy precipitation and flooding, the assessment focused on the likelihood and consequences of 100 mm of precipitation falling within a 24-hour period, and associated flooding. This scenario is equivalent to today's "1-in-25-year" (or 4 percent annual chance) heavy rain event [164]. Rainfall of this amount is likely to have the most severe impacts to the infrastructure and agriculture, fisheries, and aquaculture consequence categories. Specific consequences include, agricultural crop contamination and damage, unsafe driving conditions and injury, road washouts and closures, among others. Heavy rain events on PEI are most common in late summer and early fall.

Some examples of heavy precipitation and flooding used to inform this scenario and assessment of consequences include:

- In September 2008, PEI experienced 90 mm of rain in one day as a result of Post-tropical Storm Hanna [87].
- In December 2014, PEI experienced a record-setting 156 mm of rainfall over three days [6].
- In March 2013, PEI experienced a "10-year" rainstorm event that flooded homes, damaged roads, washed out culverts, and caused dam overflows [165].
- In June 2011, a rainstorm washed out over 100 acres of potato farms and caused considerable damage to some farmer's crops [106].

The ratings in this scenario represent one permutation of a heavy precipitation and flooding event, occurring in isolation. Heavy precipitation events can occur jointly with post-tropical storm events (see Post-tropical Storms Hanna and Dorian), and while the precipitation and flood-related consequences of these events are taken into account, consequence ratings in this section do not reflect concomitant hazards such as storm surge or wind.

A more severe (and less likely) heavy rain or flooding event would have more severe consequences.

Likelihood

The scenario of 100 mm of rainfall in 24-hours currently has a 4% chance of occurring in any year [164], corresponding to **a present-day likelihood rating of 3**. By mid-century, a 25-year rain event is expected to become a 10-year rain event, which has a 10% chance of occurring in any year. This results in a **future likelihood rating of 4** (i.e., 10% annual chance) as the conservative end of the 25-year precipitation projections were chosen to better illustrate a change in likelihood over time. The increasing trend in the frequency and intensity of extreme precipitation events on PEI is expected to continue beyond 2050.

> **Likelihood Rating Drivers**
>
> Type of hazard: Discrete
>
> Climate driver(s): Change in precipitation patterns
>
> "Present day": 1967-2016
>
> Source of 2050 projections: 2040-2060

Supporting evidence includes:

- Based on data for Charlottetown, the historical 24-hour, 25-year rain event (based on 1967-2016) is expected to become the 10-year rain event by 2050 under RCP 8.5 (Figure 36). That is, the same rainfall scenario is expected to happen more frequently [166].

- Additional support for this trend consistent with the Charlottetown projections includes:
    - Across Canada on average, a 24-hour, 20-year extreme precipitation event is projected to become about a 10-year event under RCP 8.5 by 2050 (see Figure 37).
    - Extreme precipitation in Atlantic Canada is projected to increase even more than the nationwide average [167]; therefore, we estimate a 25-year event on PEI can be expected to become close to a 10-year event by mid-century [167].
    - The 24-hour precipitation amount associated with a 20-year event in Atlantic Canada is expected to increase by 13.7% (25th to 75th percentile range: 7.9% to 19.2%) under RCP 8.5 by mid-century, which is significantly higher than the Canadian average of 8.8% (25th to 75th percentile range: 6.6% to 11.6%) [167].

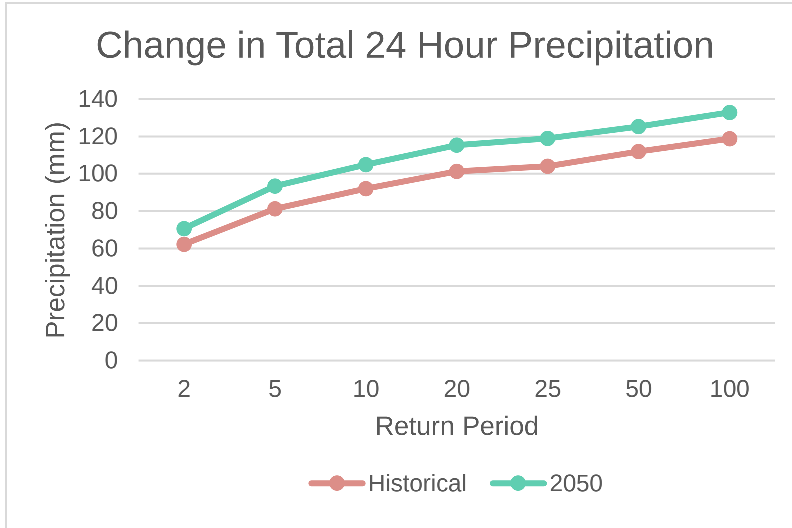

Figure 36. Intensity duration frequency (IDF) curve for 24 hour precipitation in Charlottetown, PEI.

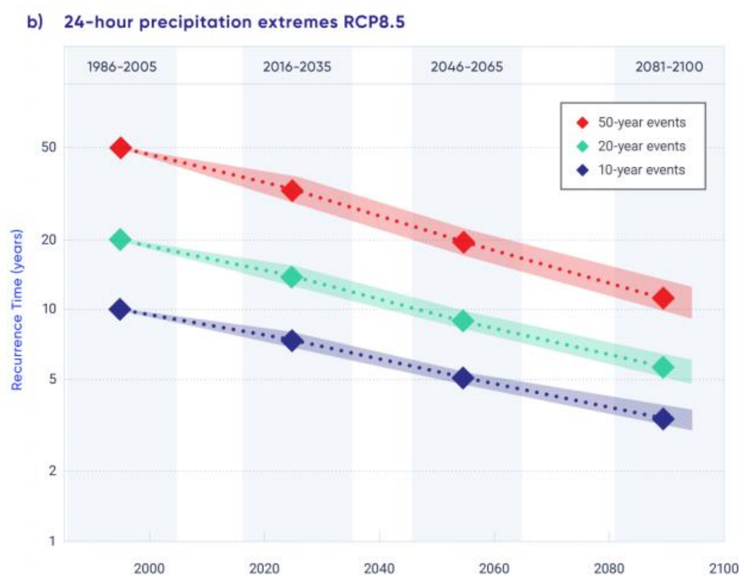

Figure 37. Change in recurrence intervals for 24-hour extreme precipitation events across Canada under RCP 8.5 from Canada's Changing Climate Report.

Confidence: Medium

While the scientific literature shows consensus that 24-hour extreme precipitation will increase in Canada on average and in PEI, there is uncertainty in projecting localized extreme precipitation events.

Consequences

Health: 2.3 (minor)

Potential loss of life: 2 (minor)

Historically, precipitation-driven flooding events have not caused loss of life on PEI. However, there is potential for multiple loss of life, particularly if flooding occurs in more populated areas of the Island or access to medical and emergency care is impaired.

Supporting evidence includes:

- No recorded deaths from inland flooding events similar to this scenario were found on PEI.
- Although there is no historic evidence of precipitation-driven flooding deaths on PEI, there is still a *potential* for loss of life:
    - Heavy precipitation events and flash flooding can cause unsafe driving conditions [39].
    - On average flood waters become unsafe at flow depths of 0.8 to 0.9 metres [168]. However, low-depth, high-velocity floodwaters may be more hazardous to people than high-depth, low-velocity floodwaters [74]. PEI's topography, however, is such that it rarely experiences high-velocity overland flooding events [24].
    - Other factors that could influence loss of life are the level of warning prior to the flood event and time for evacuation, if necessary [74].

Confidence: Low

There are some pieces of evidence that suggest potential for loss of life, primarily from news sources. There is limited PEI-specific evidence of loss of life.

Potential morbidity, injury, disease, or hospitalization: 3 (moderate)

Historically, there are few reported instances of serious injury, disease, or hospitalization due to inland flooding on PEI. However, flooding events have potential to expose citizens to hazards such as fast-moving floodwaters and debris, as well as environmental contamination to PEI's low-lying agricultural lands.

Supporting evidence includes:

- In December 2014 minor injuries were reported after floodwaters caused a bridge to collapse on Boulter Road and a sinkhole developed in Tyne Valley [169]. Occurrences such as these hold potential for injuries as a result of flooding.
- Precipitation-driven flooding has the potential to contaminate natural resources, which may pose a risk for citizens of PEI. For example, in May 2018 the public health office of PEI advised residents not to eat fiddleheads as they were potentially contaminated by floodwaters [76]. Additionally, from 2015-2020 rainfall events on PEI have caused at least 5 shellfish harvesting closures due to potential contamination [77].
- There are several areas on PEI that may pose challenges during extreme events due to limited access (e.g., Panmure Island), difficulties during evacuation (e.g., North Rustico), or lack of preparedness (e.g., Crystal Beach Campground) [24].
- The prevalence of private lanes with multiple seasonal cottages – many of which are being converted to year round residences – presents a risk due to lack of maintenance and limited year round access [24].
- If water damage is not properly cleared from living or working spaces, mould and mildew can build up resulting in health impacts [39].
- Impacts to health infrastructure may be observed, especially if power outages occur. Damage or loss of power to health facilities may delay treatment for injuries or endanger the lives of inpatients [39]. Additionally, heath facilities may be forced to close due to heavy rain events [170].
- The Public Health Agency of Canada lists the following negative health outcomes due to flooding: drowning, injuries, diseases spread through water contamination and sewage backup, diseases spread through food contamination, diseases spread by insects, carbon monoxide poisoning, and mental health effects [78].

Confidence: Low

Impacts of flooding to physical health rely mainly on anecdotal evidence and expert judgment at workshop sessions, causing the confidence rating to be low.

Mental health: 2 (minor)

Heavy precipitation and inland flooding events have the potential to cause widespread moderate and some isolated severe mental health impacts. More severe impacts are likely to be witnessed for those who were displaced or experienced flood damages to personal property.

Supporting evidence includes:

- Victims of flood events frequently report feeling isolated and depressed. Cleaning up, making repairs, and dealing with insurance claims may result in higher levels of stress, especially if rigorous support systems are not in place. Forced displacement and relocation diminishes sense of place which causes further negative consequences for mental health [82]. Flood events of this magnitude do not commonly result in displacement, relocation, or significant home damage, although under certain circumstances this can occur.
    - One study found 15-20% of natural disaster victims have symptoms of PTSD [85].
    - In September 2008, 90 mm of rain from tropical Storm Hanna caused flood damage to several residential basements [87].
- Key risk factors that may increase individuals' vulnerability to disasters include age, low socioeconomic status, minority ethnic status, previous mental health issues, and level of social support [88].
- In 2019 Woodhall-Melnik and Grogan studied the mental health impacts of the Spring 2018 St. John River Flood, in New Brunswick. This study indicated that those who experienced residential damage or displacement experienced negative mental health impacts, but both studies also indicated positive community growth resulting from public collaboration in the wake of the disaster [86].
- Mental health impacts are likely to be more severe for those who have their livelihoods effected, such as farmers or aquaculture workers [39].
- Residents may experience stress due to the financial burden of basement floods originating from heavy rainfall events [81].

Confidence: Medium

Several high quality literature sources document the link between flooding events and mental health impacts. However, PEI-specific information is limited and based primarily on expert judgment.

Economy: 2.7 (moderate)

Tourism and recreation: 2 (minor)

Tourism and recreation can be moderately impacted by a heavy precipitation and flood event. Road closures have limited tourists' access to sites of interest and disrupted tourist itineraries, although impacts are likely to be predominately short-term.

Supporting evidence includes:

- Lack of access to PEI tourist destinations likely poses the largest threat to the tourism and recreation industry as a result of heavy precipitation and flooding.
    - The ingress/egress to the Anne of Green Gables heritage site historically was subject to

    flooding and safety concerns. This site was reconstructed in 2017 to address these issues [42].
    - March 2013 storms caused road washouts that limited access to at least one entrance to PEI National Park. Visitors could still access the park from an alternative location [165].
    - Employees' ability to access tourism or recreation sites may also be hindered, potentially extending the length of destination closure periods [39].
- Heavy rain events are more common in late summer and early fall, coinciding with high cruise ship visitation periods [39].
- Recreational freshwater fishing is a popular activity for residents of PEI as over 6,000 residents held fishing licenses on PEI as of 2015 and two of the three most popular targeted fish species are freshwater fish (brook trout and rainbow trout) [94]. Fish kills as a result of pesticide runoff from inland flooding have occurred in the past and hold potential to impact recreational freshwater fishing recreation quality [95].
- Golf is an important tourism industry on PEI and although historically there is no evidence of golf courses being inoperable for long periods of time due to inland flooding and heavy precipitation, low-lying courses or those with poor drainage may face minor impacts. Additionally, golf courses remain closed during moderate and heavier precipitation events so sustained heavy precipitation may impact the golfing industry regardless of flooding events.

Confidence: Low

There is limited data or literature available on impacts to tourism and recreation. The rating is primarily based on expert judgment.

Agriculture, fisheries, aquaculture: 4 (major)

Historically, agriculture, aquaculture, and fisheries on PEI have faced negative consequences as a result of heavy precipitation and inland flooding including negative impacts to potato crops, lobster fisheries, and shellfish fisheries. There is potential for moderate disruption to multiple industries and isolated severe disruption to the shellfish and/or riverine fishing industries on PEI in the wake of a heavy precipitation and inland flooding event. Disruptions may last as long as a few days to a season.

Supporting evidence includes:

- The potato industry is a significant economic driver on PEI, boosting provincial GDP by over half a billion dollars annually [102, 103]. As PEI's largest agriculture export, any flooding risk to the potato crop is cause for serious concern to PEI's agricultural community [104]. The potato crop on PEI has suffered from flooding events in the recent past; for example, in 2008 Post-tropical Storm Hanna resulted in a significant portion of the potato crop being severely damaged [105] and in 2011 flooding (of uncertain severity) washed out over 100 acres of potato fields [106]. Government aid programs have been utilized in the past to assist farmers with flood damaged potato crops [105].
    - The timing of floods is also important. Flooding early in agricultural cycles may impact seeding and planting, which may cause ripple effects later in the season. Flooding later in the growing season has potential to cause damage to the crop near harvest time [107].
- PEI has implemented successful flood prevention infrastructure (box culverts, storm sewer extensions, alternative watering systems) to protect its agricultural resources against flood damages as well as avoid contamination to streams and rivers from agricultural resources such as cattle [171].

- High waters and strong currents as a result of flooding in New Brunswick can lead to a shortage of lobster bait for PEI fishers. In 2018, PEI lobster fishers struggled to obtain gaspereau (a bait fish commonly utilized by lobster fishers in the area) due to New Brunswick flooding; an event reminiscent of the 2008 bait shortage where significant flooding in New Brunswick caused $23.3 million in overall damages and significant bait shortages [172].
- Oysters and mussel fisheries may be impacted by inland flooding on PEI as storms can damage culture equipment and cause erosion and heavy silt formation in rivers which can smother oysters and mussels living on the river bottom [99].
- Following heavy rainfall the federal Department of Fisheries and Oceans has historically announced the closure of shellfish fisheries at least 5 times from 2015-2020 due to potential contamination risk [77]. Emergency closures of shellfish growing areas could increase as storm frequency increases [25].

Confidence: Medium

Independent sources of evidence indicated generalized impacts of heat waves to agriculture, fisheries, and aquaculture. Some anecdotal PEI-specific impacts indicating agreement with reports/literature were included from workshop events and past news articles.

Other industries: 2 (minor)

Days- to weeks-long disruption can occur to PEI's industries including manufacturing and shipping, mostly due to road closures or ferry/marine shipping centre closures. Historically, these closures have been temporary and there is little evidence to suggest that a long-term and significant impacts will occur. This considered, even short-term closures may result in shipping delays and/or increased freight costs that could affect industries for months.

Supporting evidence includes:

- Road damages and washouts, or other impacts to transportation infrastructure have potential to considerably effect PEI's exports since land transportation constitutes a significant method of transport. Delays to ship and increased freight costs may also be associated with transportation infrastructure closures due to heavy precipitation and flooding.
    - As a province where exports are a key driver of the economy ($1.5 billion exported internationally in 2019 [173]), closures of the limited ingress/egress infrastructure is likely to have a direct impact to the economy.
- According to a workshop participant, the aerospace industry may face particular risk due to its recent impacts from the COVID-19 pandemic and near-total reliance on truck transport to bring parts to market [41].
- Increasing frequency of flooding events could raise insurance rates for homeowners in flood-prone areas on PEI [39]. While a federal flood insurance program does not yet exist, a federal task force was recently created to examine options to protect homeowners who are at high risk of flooding [174].

Confidence: Low

Evidence of impact to other industries came from only a few sources which included news articles, official reports, and expert judgment from workshops.

Environment: 3 (moderate)

The natural environment on PEI is likely to be resilient to heavy precipitation and flooding events, although specific species such as freshwater fish and shellfish can experience stress or damage from contamination and lower water quality. As such, localized significant damage that takes years to recover is possible, although widespread damage is unlikely.

Supporting evidence includes:

- Moderate flooding rarely causes permanent damage to flood-prone ecosystems as they are generally resilient to flooding and able to bounce back to normal conditions quickly [175].
- Agricultural runoff can result in serious environmental problems on PEI. The Island experienced 51 documented fish kills from 1962-2016 that were proven or suspected to have been caused by pesticide runoff [119]. For example, after a heavy rainstorm in July 2016 more than 300 fish were found dead and pesticides were suspected as a plausible cause [120]. In July 2014 a PEI farmer was fined $72,000 for pesticide runoff resulting in fish kills during 2011-12 [95]. Heavy precipitation and inland flooding events have serious potential to increase the amount of pesticide and herbicide runoff into nearby rivers and streams thereby impacting environmental resources [121].
- Low-lying coastal wetlands, bogs, and swamps, where the water table is already high, may increase in size, reducing nearby productive forest area [39].
- Riverine shellfish, particularly oysters and mussels may be impacted by inland flooding on PEI as storms can cause heavy silt formation in rivers which can smother oysters and mussels living on the river bottom [99].
- Flooding can loosen topsoil, thereby damaging microorganism communities that use topsoil for habitat and potentially disrupting soil-based ecosystems [39].

Confidence: Low

There were only a few examples of environmental resource impacts on PEI resulting from heavy precipitation and flooding events, most of which are anecdotal. Little information was available pertaining to specific threatened/endangered species' reaction to flooding events and available information primarily focused on more severe flooding. As a result, the rating relies primarily expert judgment and anecdotal evidence.

Social Stability: 2 (minor)

Heavy precipitation and inland flooding have the potential to cause negative community-wide social stability impacts. Events such as road closures, flooded homes, and school closures can result in moderate to severe disruption to daily life depending on the severity of the impact faced by the individual. Financial stress, break in routine, and feelings of hopelessness may also occur for periods of weeks to months depending on time required to recover and rebuild.

Supporting evidence includes:

- Individuals in communities with strong social stability may be better able to cope with impacts from a flooding

Figure 38. A home in Inverness sits in a pool of water after the December 2014 rainstorm [6].

event. A 2012 study found that since individuals tend to rely on community to address disaster related demands and individuals suffer less from post-traumatic stress in populations with high social capital [124].

  - PEI's strong sense of community and familiarity as a small and well-connected province may be beneficial as related to social stability upkeep in the wake of a flooding event.

- The West-Isle Family of Schools experienced short-term school closures as a result of flooding after the December 2014 rainstorm [176]. Temporary school closures have the potential to diminish community social stability as flood-related school closures result in higher levels of stress for students and increased workloads for teachers and parents. Impacts can be compounding for teachers and students who are dealing with flood-related impacts at home as well [177].
- Fish kills can impact social stability, especially for communities that are culturally tied to fisheries and those that rely on fisheries for the livelihood. Two First Nation citizens indicated concern that heavy rains are carrying pesticides into rivers and streams, which is killing off fish and contaminating shellfish [35].
- Heavy precipitation events can cause the cancellation of outdoor community, cultural, and First Nation events [35].
- Archaeological and built heritage sites of cultural importance could be damaged during flood events, thereby impacting the social stability of groups who value those sites [39].

Confidence: Low

Generalized effects to social stability were expressed by the literature, however limited evidence of PEI-specific impacts were available, resulting in a low confidence rating.

Infrastructure: 4 (major)

Heavy precipitation and inland flooding events can cause significant disruption to infrastructure services and day-to-day life for citizens of PEI. Disruptions can last for days to weeks depending on the severity of flooding and number of locations and people effected. Impacts include washed out roads, damage to utility infrastructure, damage to water drainage or water supply systems, and driving/travelling restriction, among others.

Figure 39. Road damage in West PEI after the December 2014 rainstorm [6].

Supporting evidence includes:

- Heavy precipitation and inland flooding have washed out roads and caused damage to bridges and culverts multiple times on PEI:
  - In September 2008, PEI experienced 90 mm of rain in one day as a result of Post-tropical Storm Hanna. Multiple streets in Charlottetown were closed due to flooding. Additionally, several culverts, ditches, and storm sewers were overwhelmed due to the storm [87].
  - Although more extreme than this hazard's scenario, in December 2014, PEI experienced a record-setting 156 mm of rainfall as recorded at the Foxley River climate station. Flooding from the storm was responsible for an estimated $10 million in damages to

infrastructure across the province. Infrastructure damages included bridge wear, road washouts, and culvert damage [6]. After the event, the federal government provided the PEI Provincial Government with $1.2 million through the Disaster Financial Assistance Arrangements program to upgrade infrastructure and mitigate the impact of future flooding events [178].

    - In March 2013, a “10-year” rainstorm event flooded homes, damaged roads, washed out culverts, and caused dam overflows [165].

- Flooding may also result in damage to power lines and other utility infrastructure on PEI. Following Post-tropical Storm Dorian, nearly 22,000 utility customers were without power, some for as long as a week [130].
- In July 2016, flash flooding caused extensive damage to a Montague Marina boat slip, putting it out of commission and requiring up to $25,000 in repairs [169].
- The Lennox Island Causeway experienced damage during a heavy rainstorm in 2010. The communities on Lennox Island may be at particular risk if the Causeway becomes nonfunctional since it is the only access point to the Island. Consequences may include disruption during a health emergency, difficulty transporting food, fuel, and other goods and services, as well as interrupted communication [123].

Confidence: Medium

The impacts to infrastructure from heavy precipitation and flooding events on PEI are well documented from previous events. Multiple sources of evidence, including reports and news articles, were available, but high-quality peer-reviewed literature was minimal.

8.5. Severe Ice Storm/Freezing Rain

Scenario: Multi-day severe ice storm/freezing rain event in winter

To evaluate severe ice storm/freezing rain risk, the assessment focused on a specific scenario of the likelihood and consequences of a multi-day severe ice storm/freezing rain event in winter. Under this scenario, PEI would experience an ice storm with effects (e.g., ice on vegetation and infrastructure) lasting several days or more. These storms occur when temperatures are freezing or below freezing; they may involve snow but are defined by the presence of ice and/or freezing rain. When these storms occur, ice collects on infrastructure and vegetation leading to closures such as roads, schools, and businesses. Weighed down by ice, trees can also snap and fall into electric transmission and distribution wires, causing widespread outages during the coldest winter months.

This scenario represents one permutation of a severe ice storm/freezing rain event, used to illustrate the types of consequences associated with this hazard. The consequence ratings are specific to this scenario.

Likelihood

While projections are not available for the frequency of severe ice storms or freezing rain events, other climate variables can help us understand the changing likelihood for this hazard, including ice days, frost days, ice accretion thickness, and patterns in total precipitation. Ice and frost days are two available variables that can indicate the frequency in temperature conditions that are conducive to ice storms and freezing rain (i.e., freezing or below freezing temperatures).

> **Likelihood Rating Drivers**
>
> Type of hazard: Discrete
>
> Climate driver(s): Increase in air temperatures, change in precipitation patterns
>
> "Present day": 1950-2005
>
> Source of 2050 projections: ClimateData.ca projections for ice days, frost days, and precipitation variables, 2041-2060
>
> Environment and Climate Change Canada for ice accretion thickness, global mean temperature change scenarios

Ice days are defined as days when the daily maximum temperature does not exceed 0°C. From 1950 to 2005, Charlottetown has experienced an annual average of about 68 ice days per year, though this number has been decreasing over time (the number of ice days in 2005 was seven days less than the number of ice days in 1950) [179]. Frost days are defined as days when daily minimum temperature is less than 0°C and indicates that conditions are below freezing (usually overnight). In the historical period of 1950 to 2005, Charlottetown experienced an average of 154 frost days per year, though the number of annual frost days in 2005 was 4 days less than that of 1950 [180]. This evidence, as well as the frequency of past multi-day severe ice storms and freezing rain events, merits a **current likelihood rating of 4** (e.g., an event approximately once every 3-10 years)**.**

The downward trends in ice days and frost days are projected to continue throughout the 21st century. The average number of ice days per year (in the period 2041-2060) is projected to be 40 (RCP 8.5), which represents a 41% decrease in the number of ice days from the historical to the mid-century average. The number of annual frost days is projected to decrease to a 2041-2060 average of about 113 frost days per year (RCP 8.5) (a 27% decrease from the historical average).

Ice accretion thickness can also provide insights on freezing rain, particularly for how much ice accumulates on exposed surfaces. This variable is affected by freezing rain, which freezes on contact with a sub-freezing surface, surface wind speed, and surface air temperature. Change in ice thickness for multiple global mean temperature change scenarios are projected to decrease in Atlantic Canada relative to the 1986-2016 baseline, particularly under the 2°C and 3°C global warming scenarios [181]. There is high uncertainty and internal model variability in these projections.

In PEI, total precipitation has decreased over the past 50 years [25]. The direction of change for precipitation projections is uncertain. Some sources indicate PEI could experience a 6% decrease from the current levels of precipitation through the 2040s [25], while others indicate that Charlottetown, for example, may experience an 8.6% increase in total annual precipitation for 2041-2060 compared to 1950-2005 [182]. However, given the historic and projected trends of increased temperatures and decreased ice and frost days and ice accretion thickness, it is expected that precipitation will increasingly fall as rain rather than snow and ice. There is some uncertainty – winters are projected to become milder, but precipitation is expected to become more variable. Given this evidence and keeping uncertainty in mind, the **future likelihood rating is reduced to 3.**

Confidence: Low

Assessing the likelihood of severe ice storms and freezing rain is especially challenging due to the limited specific conditions at which these events occur and the variety of influencing atmospheric factors at play. As a result, ice days, frost days, and ice accretion are used as a proxy to understand the directional change in likelihood over time, recognizing there is a high degree of uncertainty in these projections, especially as they relate to severe ice storm and freezing rain. More robust and tailored data is necessary to rate the likelihood of this hazard with high confidence.

Consequences

Health: 3.3 (moderate)

Potential loss of life: 4 (major)

Ice storms have not been fatal on PEI, but do have the potential to be, as demonstrated by ice storm fatalities in other provinces. There are a variety of ways that ice storms can be fatal, including freezing/hypothermia (particularly during prolonged power outages), being struck by falling trees/poles, vehicle accidents, overexertion while trying to deal with the onslaught of wet snow and ice, and carbon monoxide poisoning due to improper use of generators and heaters during power outages.

Supporting evidence includes:

- A January 2017 ice storm in New Brunswick caused two deaths and two hospitalizations from carbon monoxide poisoning [183]. In Ontario, two carbon monoxide poisoning deaths were also attributed to an ice storm in December 2013 [184]. Carbon monoxide poisoning can occur when reliant on improperly ventilated generators and heaters during a power outage.
- During a severe winter storm in southern Ontario with ice pellets and freezing rain in January 1999, 11 people died while shovelling heavy wet snow. Seven people were injured [184].
- In January 1998, a severe ice storm deposited over 85 mm of total water equivalent precipitation in Ottawa and over 100 mm in Montreal. The storm had serious consequences in Canada, including 35 deaths and over 1 million households (over 3 million people) without power. Many of the deaths were attributed to hypothermia [184, 185].

Confidence: Medium

Although there is limited PEI-specific evidence of loss of life, several select events from other provinces document and support the potential for major loss of life from a number of causes.

Potential morbidity, injury, disease, or hospitalization: 4 (major)

Ice storms present many opportunities for injuries and other health hazards, though the research did not return many specific examples of ice storm-related morbidity on PEI. The accumulation of ice during ice storms limits mobility and raises the potential for injuries due to slipping on ice or vehicle crashes. Downed trees are often a result of ice storms; these not only pose a threat to anyone who might be underneath when branches or the full tree falls, but also to those who experience outages when the trees take down power lines. The loss of power can cause health impacts beyond the duration of the storm itself, such as hypothermia, loss of refrigerated medicine, and loss of perishable food. Ice storm-induced power outages are particularly dangerous with respect to hypothermia, since by definition the storms occur during freezing conditions.

Supporting evidence includes:

- Widespread power outages call for heavy labour and long hours in cold, icy conditions; rescue teams and hydro crews worked 16-hour days to restore power due to the 2007-2008 ice storms on PEI. Such exposure to the elements and physically demanding schedule can pose a risk to the health and safety of workers [186].
- During a December 2010 winter storm in Lambton County, Ontario, over 600 people were stranded on roads due to unsafe conditions and had to be rescued and taken to warming centres. Many of these people were trapped in their vehicles for up to six hours (i.e., overnight) and one man died due to exposure to the elements [184].
- The infamous January 1998 ice storm that hit Ontario, Quebec and New Brunswick led to 945 injuries and 17,800 evacuees [184].
- Carbon monoxide exposure can also occur when reliant on improperly ventilated generators and heaters during a power outage. In a January 2017 ice storm in News Brunswick, two people were hospitalized due to carbon monoxide poisoning [183].
- Power outages and hazardous road conditions can temporarily limit emergency services as well as access to food and water if residents do not have supplies at home. These conditions could affect health and safety, especially for a multi-day event [39].
- Heavy ice storms can make driving conditions dangerous, affecting for example, First Nation Elders by making it harder to ensure they are properly taken care of due to difficulties accessing their homes [35].
- Aging critical health care facilities (e.g., community hospitals) may be more susceptible to structural damage and power outages and unable to provide services during an event [39]. Limited access to healthcare may have ripple effects on physical and mental health.

Confidence: Medium

Although there is limited PEI-specific evidence available on physical health impacts, several select events from other provinces document and support the potential for significant morbidity, injury, disease, or hospitalization from a number of causes.

Mental health: 2 (minor)

The mental health impacts from ice storms are likely to be widespread (throughout the area affected by the storm, which has in the past spanned across provinces and the Canada-U.S. border) but moderate. Ice storms generally do not result in a loss of home, identity, or sense of place. However, temporary displacement due to hazardous conditions and loss of heating and electricity can result in short-term feelings of fear, anxiety, and stress as well as disruptions to normal life.

Supporting evidence includes:

- Electricity customers who experienced outages during the January 2021 ice storm on PEI experienced anxiety due to the lack of electricity and subsequent impacts on the ability to stay warm during a cold month, as well as the ability to work from home as the COVID-19 global pandemic continued to force people to stay at home [187].
- The January 1998 ice storm in Ontario, Quebec and New Brunswick caused prolonged outages and other damages that forced millions of Canadian residents into mobile living or other temporary living situations. During the February 2016 storm (which affected Ontario, Quebec, New Brunswick, Nova Scotia, PEI and Newfoundland), about 200 Quebec residents had to be evacuated to escape flooding due to ice breakup. Housing instability is detrimental to mental health [184, 185].
- Power outages and hazardous road conditions could lead to days-long isolation at home. This can put additional stress on parents and caregivers, homeowners or renters who may experience structural damage and need to make repairs or coordinate with insurance, and workers unable to work remotely without power. Isolation can also exacerbate family violence if shelters and safe spaces are unavailable and inaccessible. Women tend to be more likely to experience these impacts [39].

Confidence: Low

There is limited quality data available on mental health impacts from ice storm and freezing rain events. However, there is agreement between sources and expert judgments supporting moderate mental health impacts.

Economy: 2 (minor)

Tourism and recreation: 1 (insignificant)

Ice storms generally impact tourism and recreation by temporarily limiting travel and creating unsafe conditions for outdoor recreation. The ice storm scenario considered in the CCRA would only cause disruptions in one season (winter). The loss of electricity, which is the main impact of ice storms, has an indirect effect across all sectors of the economy.

Supporting evidence includes:

- During the January 1998 ice storm, air and rail travel was discouraged due to the dangerous conditions [185].
- Winter-related travel delays and closures in central Canada can also cause cascading impacts to air travel in PEI such as shutdowns or delays for travellers [24].
- These events can also disrupt heritage and cultural sites' (e.g., PEI Museum and the Heritage Foundation) ability to access and maintain seasonal heritage sites [39].

Confidence: Low

There is limited data or literature available on impacts to tourism and recreation. The rating is primarily based on expert judgment.

Agriculture, fisheries, aquaculture: 2 (minor)

Extreme cold and ice conditions can negatively affect livestock, perennial crops, and forage crops. Although winter is generally the offseason for fisheries, there may be temporary disruptions to ice fishing activities as well. The loss of electricity, which is the main impact of ice storms, has an indirect effect across all sectors of the economy.

Supporting evidence includes:

- The January 1998 ice storm severely affected livestock farmers, who had to share generators to run milk machines and care for newborn and cold-sensitive animals [185].
- Severe ice storms or freezing rain can damage or kill perennial crops as well as forage crops that farmers rely on to feed livestock [39].
- Although winter is the offseason for fisheries, this type of event could affect the ability of mussel and oyster growers to harvest product from ice fishing in a timely manner due to challenges accessing ice fishing locations and hazardous road conditions [39].
- The ripple effects of infrastructure disruptions could include challenges processing, delivering, and storing product. The length of disruption and fragility of the product may lead to losses and food waste [39].

Confidence: Low

There is limited high-quality research available on PEI-specific impacts to agriculture, fisheries, and aquaculture. The rating is based primarily on expert judgment gathered at the workshop.

Other Industries: 3 (moderate)

Power outages, structural damage to critical infrastructure, and hazardous road conditions could negatively affect the majority of PEI's service industries. Transportation, energy, and communication infrastructure is critical to supporting other industries. This is especially relevant for the shipping industry, which relies on access to roads and harbours for successful operations. The loss of electricity, which is the main impact of ice storms, has an indirect effect across all sectors of the economy. Outages and infrastructure repairs could cause days to months-long disruptions, especially if persistent dangerous weather conditions make it more difficult to perform repairs.

Figure 40. Freezing rain on powerlines. Photo provided by DE Jardine.

Supporting evidence includes:

- Power outages, structural damage, and hazardous road conditions could negatively affect the majority of PEI's service industries [39]. For example, hazardous conditions and power outages may temporarily disrupt transportation services and supply chains. This could have ripple effects on the distribution of food, economic goods, and other supplies within PEI as well as with neighbouring provinces.

- In January 2021, an ice storm in PEI caused roughly 7,000 Islanders to lose power for one night due to ice buildup on power lines. Repairs also had to be made to the Lorne Valley substation before power could be restored [187].
- More than 24% of PEI's electricity comes from provincially and privately owned wind energy developments. Wind power can cut out during extreme cold and icy conditions. Wind turbines have minimum operating temperatures and can fail if temperatures are too cold to reach that threshold – such was the case for PJM Interconnection and Midcontinent Independent System Operator wind units in the United States during the January 2014 polar vortex [188]. Icing on wind turbines affects their design, safety, and performance, as well as wind sensors. If too much icing occurs, wind turbines can eventually fault and shutdown, creating a period of downtime that can last for weeks [188]. This would compound the issue of outages caused during ice storms due to damaged transmission and distribution infrastructure.
- Ice storms in New Brunswick have resulted in significant loss of wind energy production as icing on wind turbines can render them inoperable. Although not common, these events in New Brunswick can have cascading impacts to PEI since PEI relies on New Brunswick for approximately 77% of its electrical energy needs [129].

Confidence: Low

The severity and duration of impacts to other industries are challenging to pinpoint given the diversity of industry services. In addition, most impacts are a result of the ripple effects to critical infrastructure damages. There is limited data available on specific impacts to these industries.

Environment: 3 (moderate)

The most prominent impact to the environment from severe ice storms and freezing rain is tree damage (which can then damage critical utility and road infrastructure). Ice damage to trees can include broken branches, bending of the trunk or crown, or total loss of the tree from the weight of the ice [189]. The damage to trees also increases their susceptibiltiy to pathogens.

Figure 41. Freezing rain in Winsloe South. Photo provided by DE Jardine.

Supporting evidence includes:

- The January 2008 ice storm on PEI damaged about three-quarters of the trees in Summerside with felled trees blocking roads [186]. Tree damage is particularly impactful in urban areas, where fallen branches or trees can damage critical utility and road infrastructure [39].
- The January 1998 ice storm brought down millions of trees across Ontario, Quebec and New Brunswick [185].
- Trees were downed during the March 2016 southern Ontario ice storm [184].

- Deciduous forests, which include wet rich hardwood and upland hardwood forest stands, are most susceptible to ice storm and freezing rain events [39], and according to the 2010 State of the Forest report, represent approximately 29% of the forest stands in PEI [190].
- Ice cover can prevent animals from finding food and shelter, which can be particularly harmful when these events last extended periods of time [39].

Confidence: Medium

Tree damage or loss is a common occurrence with severe ice storm and freezing rain events as documented in a few select examples above. There is agreement among literature sources and experts that tree damage is the most prominent impact to the environment, which can also have ripple effects on critical infrastructure damage.

Social Stability: 2 (minor)

Social stability is impacted by loss of electricity and the closing of businesses, schools, and government offices. Such disruptions—particularly power outages—can last for days to weeks.

Supporting evidence includes:

- School closures often result from ice storms, which can cause childcare challenges for families and caregivers. Recent examples of school closures include:
    - According to PEI Public Schools Branch data, over the course of three full school years from 2017-2020 there were 20 full day school closures as a result of weather or related events [191]. School closures can put additional stress on caregivers [39].
- As prolonged outages caused by ice storms left residents without power, makeshift shelters were organized to help PEI residents stay warm during the winter 2007-2008 ice storms [186].
- Power outages and hazardous road conditions can temporarily limit access to medical care, businesses, and schools. It can also limit the ability to obtain critical resources like food, water, and fuel if resident's do not have supplies at home [39].
- Power outages and hazardous road conditions could lead to days-long isolation at home. This can exacerbate family violence if shelters and safe spaces are unavailable and inaccessible [39].

Confidence: Low

There is limited high-quality evidence documenting social stability impacts from ice storms in PEI. The rating is based largely on expert judgment and available news reports.

Infrastructure: 5 (catastrophic)

The most prevalent and expected infrastructure impact is loss of electricity, as any above-ground lines are at risk, and all buildings, from homes to hospitals to businesses, require electricity. Buildings and roads have also incurred infrastructure damage from ice, which in the past has lasted for days to even months.

Supporting evidence includes:

- Transportation, energy, and communication infrastructure are all vulnerable to damage or disruption during severe ice storm and freezing rain events. This has ripple effects on the other consequence categories such as health, economy, and social stability [39].

- Ice storms can create slick and dangerous conditions on roads and bridges, which may lead to delays or closures [192].
- Previous ice storms have caused widespread damage to electric infrastructure.
    - A January 2021 ice storm on PEI left roughly 7,000 electric customers without power overnight [187].
    - Almost 95% of the Island was without power for at least a few hours [193] and 100 electric poles were downed (amounting to $3 million in repairs for PEI's Maritime Electric) over the winter of 2007-2008. A third of residents were without power for multiple days [186].
    - If ice collects on wind turbines they become inoperable, reducing wind-generated power [129].
    - In southern Ontario, outages affected 300,000 people in March 2016 and nearly 2.5 million people in December 2013 [184].
- Aging critical health care facilities (e.g., community hospitals) may be more susceptible to structural damage and power outages and unable to provide services during an event [39].

Confidence: High

Although there is not an abundance of PEI-specific supporting evidence, there is strong agreement among available research and experts that catastrophic infrastructure damage and disruption is of great concern. These impacts also have significant ripple effects on other consequence categories, as documented in the previous sections. Tracking the frequency, duration, and ripple effects of road closures and power outages in PEI specifically due to ice and freezing rain would be useful to understand the severity of impacts.

8.6. Earlier, Warmer Springs

Scenario: Earlier arrival of spring temperatures by two weeks affecting key species

This assessment focused on a specific scenario of earlier onset of spring temperatures causing a seasonal shift for key species and sectors. Warming air temperatures will also increase ocean temperatures so marine impacts to key species like lobster are included.

To focus the assessment of likelihood, a shift in the arrival of above freezing temperatures by two weeks is used as the critical threshold. A critical temperature threshold for lobster is also discussed. Lobster are a culturally and economically significant species that is sensitive to temperature change [194-196]. Lobster landings peak from April to June in PEI and the lobster spring season runs from May to June [194, 197].

Likelihood

The earlier onset of warm spring temperatures is an ongoing climate hazard that will happen gradually. This gradual shift may also be punctuated by short-term warm spells and variability in temperature. To better assess likelihood and consequences, this scenario is focused on a shift in above freezing temperatures by two weeks.

As illustrated in Table 18 and Figure 42, mean monthly temperature historically (1981-2010) rose above 0°C between March and April [198]. By 2050 (2041-2060), above freezing temperatures are projected to begin between February and March under the RCP 8.5 scenario [198]. This indicates a shift in the arrival of warm temperatures by at least two weeks and monthly temperatures will continue to be warmer than the historic average. Therefore, the **current likelihood rating is 2 and the future likelihood rating is 4**. The project team feels reasonably confident that the critical threshold of a two-week shift will be crossed by 2050.

Likelihood Rating Drivers

Type of hazard: Ongoing

Climate driver(s): Increase in air temperatures, Change in sea surface temperatures

"Present day": 1981-2010

Source of 2050 projections: ClimateData.ca projections for mean monthly temperature, 2041-2060, RCP 8.5

Table 18. Mean monthly temperature

	Mean Monthly Temperature (°C)	
	Baseline 1981-2010	Projected 2041-2060 (RCP 8.5)
Jan	-7.0	-3.5
Feb	-6.8	-2.9
Mar	-2.4	0.7
Apr	3.0	5.5
May	9.4	11.8

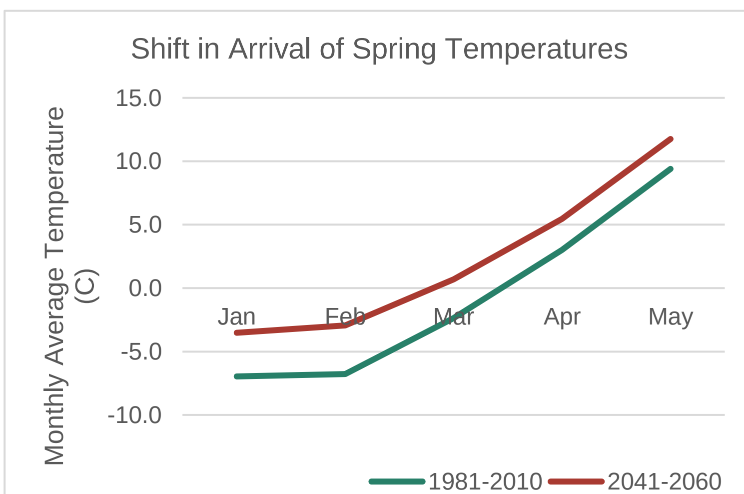

Figure 42. Projected change in mean monthly temperature, Jan-May for the RCP 8.5 scenario.

Whether this shift affects key species, depends on the critical temperature thresholds for the individual species. As an example, lobster has a critical water temperature threshold of 20°C. Lobster prefer water temperatures of 10 to 16°C, but can tolerate a range of 0 to 20°C. When temperatures exceed 20°C, parasites and shell disease are more likely to be prevalent and lobster will move to colder waters if possible [199].

Annual mean sea surface temperature in Atlantic Canada was 13.03°C for 1945 to 2010 and 13.11°C for 1981 to 2010 [200]. The rate of change per decade, based on the 1981 to 2010 data, is estimated at 0.38°C per decade [200]. Assuming this rate remains constant through 2050 (which is a conservative assumption), the project team estimates that in 2050, annual mean sea surface temperature would be around 14.63°C. This is consistent with the projected change in air temperature of around 1.5°C by mid-century described in the bullets below.

Mean sea surface temperature data for spring months is lacking, but the same study has data for August which would be much warmer than March to May. August mean sea surface temperature was 17.49°C for 1981-2010 with a rate of change per decade of 0.65°C [200]. Applying the same calculation, the project team estimates that by 2050, average August sea surface temperature would be around 20.09°C. This is the critical threshold for lobster.

Confidence: Medium

Mean monthly temperature projections assume the RCP 8.5 emissions scenario. The data analyzed firmly support a two-week shift in the arrival of spring temperatures for this scenario, but there is inherent uncertainty in climate projections. In addition, while on average monthly temperatures may shift by two weeks, in reality there may be wide variability from year to year on when PEI begins to experience spring temperatures. Furthermore, the critical threshold component is focused on lobster. To understand impacts to lobster, the best available data is sea surface temperature, but lobster spend most of their lives on the ocean bottom so sea surface temperature data may give a conservative (high) estimate. The critical temperature threshold for lobster is not representative for all species that may be affected by the earlier onset of spring temperatures. Future assessments could focus on other key species such as tuna or blue mussels.

Consequences

Health: 1 (insignificant)

Potential loss of life: 1 (insignificant)

Earlier arrival of spring temperatures is not expected to cause loss of life. If anything, warmer temperatures could contribute to a decrease in cold-related mortality.

Confidence: High

There is no evidence to suggest earlier, warmer springs would result in loss of life. Workshop participants unanimously agreed with this rating.

Potential morbidity, injury, disease, or hospitalization: 1 (insignificant)

Earlier arrival of spring temperatures is not expected to directly cause morbidity, injury, disease, or hospitalization. However, there is evidence that with earlier spring (and thus a longer growing season), allergy season could lengthen and disease-transmitting insects may be more prevalent.

Supporting evidence includes:

- Observations in Canada and the United States have recorded increases in the ragweed pollen season (one of the most common environmental allergens) from 1995 to 2015. In Canada, the season lengthened by 24 to 25 days in Saskatoon and Winnipeg, respectively [201].[8]
- The earlier arrival of spring temperatures could increase the prevalence and survival of disease-transmitting pests (e.g., ticks and Lyme disease) [39].

Confidence: Medium

Although there is evidence that the allergy season may lengthen and there could be higher incidences of disease, limited morbidity, injury, disease, or hospitalization is expected. There is no evidence to suggest more than 10 people could experience morbidity, injury, disease, or hospitalization as a result of earlier, warmer springs. Workshop participants unanimously agreed with this rating. Further research could explore whether an extended season for outdoor recreation may actually have a positive impact on health and physical fitness.

Mental health: 1 (insignificant)

Mainly positive mental health impacts are expected from an earlier onset of spring temperatures. If lobster populations begin to decline beyond 2050 due to warmer ocean temperatures, there may be a shift to negative mental health impacts like stress, anxiety, and loss of sense of place.

Supporting evidence includes:

- Positive projected changes to key species like lobster may reduce stress and bolster sense of place and identify for PEI. The start of the lobster fishing season is a celebration for the community [194].
- The earlier onset of spring temperatures could help alleviate Seasonal Affective Disorder (SAD) sooner. Up to 15% of Canada's population experiences SAD or a milder form of SAD called "winter blues" [202]. In PEI, public libraries have worked on addressing SAD among Islanders by providing light therapy lamps as part of the library catalogue [203]. A spot check on January 7, 2021 showed all 18 lamps were checked out and 26 holds in place for future users [204]. Earlier and warmer springs could be an additional tool for combatting SAD by enhancing moods and getting people outside [39].
- If negative projected changes to key species like lobster prevail (which for lobster is more likely to occur beyond 2050), there could be increased stress and anxiety, as lobster populations decrease or become less palatable for sale.
- The earlier onset of certain biological events (e.g., blooming) may disrupt agricultural cycles and practices. If farmers are unprepared for this shift, there could be increased stress and anxiety [39]. However, changes in growing season length and ability to grow certain crops may also have a positive effect on mental health [39].

Confidence: Low

There is limited quality research available on mental health impacts from earlier, warmer springs. Available evidence suggests a net positive impact, especially for the 2050 timeframe. There is

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[8] An earlier spring would lengthen the allergy season by causing the plants to start producing pollen earlier. However, it should be noted that the lengthening of the ragweed pollen season is due in part to a later fall frost, as this first frost event heralds the end of the pollen season.

uncertainty regarding when the net positive impact may shift to negative as residents associated with the lobster industry in particular are affected by changes in lobster population.

Economy: 2 (minor)

Tourism and recreation: 2 (minor)

The winter tourism and recreation season is expected to decrease while the spring tourism season could expand. There could also be an increase in the need for and duration of spring and summer seasonal employment services.

Supporting evidence includes:

- An earlier onset of warmer temperatures could expand the spring tourism season. Spring attractions include lobster season, the opening of seasonal shops and restaurants, golf, hiking and other outdoor activities [205]. This may also increase the need for and duration of seasonal employment services [39].
- This shift could also shorten the winter tourism and recreation season, which centres around snow. Winter attractions include alpine and cross-country skiing, snowshoeing, snowmobiling, and other recreational activities [206].

Confidence: Low

While a shift in tourism and recreation seasons is expected, the degree to which the gains for the spring season will outweigh or exceed the losses for the winter season by mid-century is unknown. The timeframe at which the viability of the winter tourism and recreation sector and employment is threatened is also unknown, but unlikely to occur by mid-century. More research is needed to understand the extent of positive and negative impacts.

Agriculture, fisheries, aquaculture: 3 (moderate)

The agriculture and fisheries industries are expected to have an earlier and extended growing and harvest season. For example, by mid-century, lobster is expected to become more prevalent around PEI and experience a shift in the start of the spring lobster season. Beyond 2050 as ocean temperatures continue to warm, PEI lobster may begin to experience more significant heat-related impacts like impaired growth, earlier moulting, and shell disease.

Supporting evidence includes:

- For agriculture, warming temperatures are expected to lengthen the growing season by 4 to 8 weeks by end of century, which could increase yields for existing crops such as potatoes and expand opportunity for new crops. Historically, the average start day for the growing season is May 19th. A shift in start date to May 8th is expected by 2050 [207].
    - New crop opportunities could include lentils, dry peas, chickpeas, dry beans [208].
    - Being able to plant and harvest earlier, may allow time to plant winter cover crops, which will also help prevent erosion and nutrient loss [39].
    - Warmer spring temperatures will increase survival of key pollinators like honeybees but will also support survival of pests and diseases [209-211].
    - A shorter winter will lessen the need for feed as livestock can increase grazing outdoors [25].
    - Sensitive crops like fruit trees may begin to bud earlier due to warmer temperatures but then get caught in a cold spell or frost that damages the buds [210].

- The normal start date for spring lobster fishing is April 30th and runs from May to June [197, 212]. Approximately 80% of PEI's lobster harvest occurs in the spring season [197]. The spring season may need to start earlier to adjust to warming temperatures.
- Lobster landings, an indicator of abundance, have been increasing in Atlantic Canada in recent years [213-215]. In PEI, lobster landings have grown to 29.7 million pounds in 2014 compared to 17.6 million pounds in 1997 [215]. Warmer ocean temperatures are expected to support continued growth for PEI's lobster industry through mid-century as lobster populations migrate north toward colder and more habitable waters. The North Shore is already seeing record levels of juvenile lobster in population surveys conducted by the PEI Fisherman's Association [195]. As the industry grows in the near-term, lobster should continue to be sustainably managed to ensure its longevity.
    - Unusually warm temperatures in spring 2012 in the Gulf of Maine led to earlier shell moulting and higher than normal lobster landings in Maine and Atlantic Canada. High supply can also lower the market price per pound[216].
- The eastern oyster has a relatively higher thermal tolerance compared to other commercially important bivalves in PEI (i.e., blue mussels) and is expected to experience faster growth rates as sea surface temperatures increase and as this temperature increase leads to greater temporal synchronization between the oysters' growing period and its food supply [217, 218].
- Warmer ocean temperatures can also negatively affect lobster and other crustaceans:
    - Warmer temperatures and ocean acidification can affect the growth of lobster larvae. Slower respiration rates have been observed in studies replicating future climate conditions [214].
    - Warmer temperatures are correlated with the prevalence of shell disease, a bacterial infection that dissolves a lobster's shell. Severe cases of shell disease can cause blindness and issues moulting. Shell disease is currently not a big issue for Canadian fisheries but has been observed in warm waters around Rhode Island which led to a drop in population. There is concern that shell disease could become more prevalent on the south side of PEI [195, 215].
    - Lobster will begin moulting earlier in the season due to warmer temperatures, which may require a shift in harvesting periods. An earlier moult also makes lobster more susceptible to shell disease, particularly in the summer and fall due to the shell's longer than normal period of exposure [196].
    - Mussels are another important resource on PEI, as the Island industry provides 80 percent of North America's mussels and employs 1,500 people. Because mussels are grown in shallow water that can respond quickly to changes in temperature, they are particularly sensitive to increased temperatures under climate change. There is concern that as temperatures rise, mussel farmers may reach critical temperatures (23-25°C) that could be lethal to mussels and lead to large losses [219-222].
    - Warmer temperatures and ocean acidification can soften and weaken the shell of species like lobster and snow crab, which makes them less marketable [199].
    - Warmer temperatures can support marine invasive species like tunicates and sea lettuce, which can compete with species for nutrients and spaces and create eutrophication conditions [223, 224].
- In interviews, two citizens of First Nations communities indicated that changes in seasons have negatively affected the fishing industry due to increases in water temperature and less ice formation in the straight [35].

Confidence: Medium

The net impact between positive and negative consequences is challenging to distill without additional data and research. Although many of these changes are positive, PEI may need to take actions to fully embrace the potential opportunities and benefits for agriculture, fisheries, and aquaculture.

Other Industries: 1 (insignificant)

Shifts in economic activities (e.g., agriculture and aquaculture harvesting, construction) could shift or expand processing and shipping activities as well as seasonal employment needs.

Supporting evidence includes:

- Shifts in the timing or quantity of agriculture and aquaculture harvests could require a shift or expansion of processing and shipping activities to meet demand [39].
- Spring and summer seasonal employment needs may increase or the duration of seasonal work may expand. For example, with planning the construction season can be extended to adapt to earlier, warmer springs [39].

Confidence: Low

There is limited information available on impacts to other industries, including impacts to winter seasonal employment (e.g., snowplow drivers, ski facilities, etc.), which could be an area for further research. The rating is based on expert judgment.

Environment: 4 (major)

Many species are likely to experience a shift in the onset of spring and related biological responses to warmer temperatures. This shift is also expected to extend growing seasons and suitable habitat ranges. Negative impacts could include phenological mismatch between key species and increased prevalence of pests, disease, and invasive species.

Supporting evidence includes:

- Warmer spring temperatures could expand the growing season and suitable habitat range for some species [167]. The date of the last spring frost is expected to shift.
    - Warmer temperatures will increase the survival and expansion of pests, diseases, and invasive species (e.g., tunicate, sea lettuce) [39, 210, 211].
    - Northern Boreal tree species may not compete as well in a shifting seasonal climate. Southern tree species may become more suitable for PEI's changing climate and outcompete existing species found in PEI's forests [39].
    - PEI may experience positive and negative changes in suitability for certain bird species [39].
- A seasonal shift and phenological mismatch between species is possible as spring temperatures warm affecting insects, pollinators, migratory birds, and many plant species [167].
    - Warmer spring temperatures will increase survival of key pollinators like honeybees. However a shift in the timing of flowering species could disrupt pollinator diets and nutritional value [209, 211].
    - Cold-sensitive species like fruit trees and other flowering plants may begin to bud earlier due to warmer temperatures but then get caught in a cold spell that damages the buds [210].

    - Increasing river temperatures may affect Brook Trout and Atlantic Salmon migration and spawning [41].
    - Warmer spring temperatures may lead to a disconnect between insect emergence events and food supply for migratory birds and breeding wildlife [39].
- Warmer temperatures can affect the spring freshet and the timing of snowmelt, which is critical to aquatic ecosystem health [25, 39].
    - Snowmelt may occur earlier in the year, accelerating the timing of large flow events [39].
- Reduced streamflow due to changes in snowmelt (e.g., less precipitation falling as snow in late winter/early spring) can threaten fish habitat in streams and increase residence times in estuaries, disturbing normal ecological processes [225]. Low streamflow has resulted in fish kills on the Winter River in the past [2].
- In interviews, First Nations members indicated multiple environmental changes including displacement of certain animals from urban areas, explosion in local bird populations, increase in pest and rodents, sharks travelling farther north, changes in eel distribution, and altered plant growth [35].

Confidence: Low

The net impact between positive and negative consequences is challenging to distill without additional data and research. Individual species will be uniquely affected by earlier, warmer springs. Additional research is needed to understand the net impact to the environment and to individual species. For example, a workshop participant noted a knowledge gap for how changes in the seasonality of the hydrologic cycle will affect fish populations.

Social Stability: 1 (insignificant)

Limited or else positive impacts to culture and daily life are expected by mid-century (e.g., lower heating costs). Beyond 2050, PEI may experience cultural loss, especially as lobster declines.

Supporting evidence includes:

- Low-income populations could benefit from lower heating costs and vulnerable homeless populations could benefit from a shorter period of potential exposure to below freezing temperatures [39].
- PEI lobster is a large part of the Island’s culture and sense of pride and community. The first day of the lobster spring season is a celebration for the community [194]. There may be a shift in start of the spring season and therefore the date of the community-wide celebration. There are about 1,200 lobster fishers on PEI, many of which are carrying on family traditions going back many generations [194]. The projected growth and success of PEI’s lobster industry by mid-century is expected to bolster feelings of pride, family, and community across PEI.
- A potential decline in lobster abundance and health beyond 2050, however, could be a significant cultural loss for PEI, including and especially Lennox Island and Abegweit First Nations.

Confidence: Low

There is limited information available on impacts to social stability and uncertainty regarding when future lobster decline may affect the larger community. Another research gap is the social impact from potential decreases in winter activities and winter employment opportunities. This rating is based on expert judgment.

Infrastructure: 3 (moderate)

Roads will be more susceptible to frost heaving and potholes as freeze/thaw cycles change in response to earlier, warmer temperatures. A positive impact is the potential for lower energy demand from heat.

Supporting evidence includes:

- An earlier onset of warm temperatures or more wavering above and below freezing, could affect freeze/thaw cycles and cause significant damage to roads and structures. PEI's geology makes roads more susceptible to frost heaving and potholes. PEI has weight restrictions on certain roads for late winter and spring months to limit these types of impacts, which may need adjustment as temperatures shift [226].
- The earlier onset of spring temperatures has the potential to lower heating demands on the energy system [39].

Confidence: Low

There is limited information available on infrastructure impacts. However, PEI is already susceptible to road damage, which could become more significant as temperatures shift. Priority knowledge gaps include understanding how energy demands may change or how changes in precipitation and snowmelt cycles might after water and stormwater infrastructure.

8.7. Seasonal Drought

Scenario: Months-long severe summer drought affecting the entire province

To evaluate seasonal drought risk, the assessment focused on a specific scenario of the likelihood and consequences of a months-long severe summer drought affecting the entire province. For simplicity in the risk rating process, population levels and density are assumed consistent with the 2016 Census [14]. If the current trend continues, the population is likely to grow and age over the next 30 years, which could increase risks to the population, particularly impacts related to health, social stability, and infrastructure.

This scenario represents one permutation of seasonal drought, used to illustrate the types of consequences associated with this hazard. The consequence ratings are specific to this scenario, meaning secondary and tertiary events resulting from drought (such as higher incidence of wildfires or structural fires) are not considered in the ratings below.

Multiple drought events on PEI were used to inform this scenario including the 2001-2002 Canadian drought as well as the current (2020) drought PEI is experiencing.

Likelihood

Drought on PEI is a fairly common occurrence. According to the Canadian Drought Monitor, moderate drought occurs once every 5-10 years, and severe drought (-3.0 to -3.9 on the Palmer Drought Severity Index)—the focus of this scenario—occurs once every 10-20 years [227]. This translates to a **current likelihood rating of 3**.

> **Likelihood Rating Drivers**
>
> Type of hazard: Discrete
>
> Climate driver(s): Change in precipitation levels
>
> “Present day”: 2002-2020
>
> Source of 2050 projections: Assessments across literature

Future likelihood of severe seasonal drought on PEI is difficult to ascertain. Globally, models predict increases of dryness during the summer and associated increased risk of droughts. In North America specifically, evaporation and surface drying are expected to increase, leading to more frequent drought events, especially in the summer [228]. In PEI, total precipitation has decreased over the past 50 years—a trend that could continue. The direction of change for preliminary projections are uncertain. Some sources indicate PEI could experience a 6% decrease on average from the current levels of precipitation through the 2040s [25]. However, these changes may not necessarily influence drought likelihood on PEI; the Atlantic region of Canada is expected to experience limited changes in the annual climate moisture index over the next 100 years and some projections expect Atlantic Canada to become wetter in the future [229, 230]. This considered, the **future likelihood rating remains a 3.**

Confidence: Low

Current likelihood rating is based on the Palmer Drought Severity Index which states severe droughts occur once every 10-20 years. Future likelihood is based on assessments across literature which have low levels of agreement, resulting in the low confidence rating. As additional data and projections of drought metrics become available over time (e.g., through ClimateData.ca), projected trends in drought may become more clear. In the meantime, the province is advised to plan for continued and potentially increased variability in precipitation patterns. Future studies (such as anticipated research from Dr. Suqi Liu on climate projections and crop adaptation [231]) may fill current data gaps and provide higher resolution predictions of future drought conditions on PEI.

Consequences

Health: 2.3 (minor)

Potential loss of life: 1 (insignificant)

There is virtually no potential for a months-long seasonal drought resulting in loss of life on PEI. Second and third order effects of drought such as wildfire or increase in vector-borne diseases may result in slightly greater potential for loss of life; however, there is no evidence of these events causing loss of life on PEI in the past.

Supporting evidence includes:

- Vector-borne diseases, particularly those that are mosquito-borne, may be more likely to impact residents of PEI during a drought, or during the times when drought is followed by wetter weather (which can provide better breeding conditions for mosquitoes) [232].
- Predicted increased average and extreme temperatures, as well as drier conditions over this century may increase likelihood of future wildfire and structural frequency and severity on PEI [233, 234]. Physical health impacts of wildfire include respiratory, ophthalmic, and cardiovascular illnesses [228].

Confidence: Low

There is little evidence in the literature discussing a relationship between direct loss of life and drought events on PEI.

Potential morbidity, injury, disease, or hospitalization: 2 (minor)

There is some potential for a months-long seasonal drought directly resulting in morbidity, injury, disease, or hospitalization, mostly as a result of increased food and water insecurity as well as increased potential for respiratory health issues. There is potential for the possibility of an increase in rates of injury and infectious diseases; however, there is no past evidence of droughts resulting in these increases on PEI. Second and third order impacts of effects of droughts, such as wildfire and decreased air quality, may have more significant potential to result in morbidity, injury, disease, or hospitalization.

Supporting evidence includes:

- The U.S. Centers for Disease Control and Prevention states that drought can pose both short-term and long-term health implications. Short-term impacts include increases in infectious disease and irritation of the bronchial passages and lungs due to increased dust in the air. Long-term impacts include increase in incidence of chronic diseases such as asthma due to decreased air quality, as well as reduced water availability, which may result in second and third order effects for health and disease [235, 236].
- Vector-borne diseases, particularly those that are mosquito-borne, may be more likely to impact residents of PEI during a drought, or during the times when drought is followed by wetter weather (which can provide better breeding conditions for mosquitoes) [232].
- Drought can increase likelihood that some marginal private wells could experience shortages of water. Drought may also increase the extent of saltwater intrusion on PEI, which may impact coastal freshwater wells on PEI [228].
- Droughts lead to an increased likelihood of wildfires or structural fires, which may hold more significant potential for morbidity, injury, disease, or hospitalization than drought itself does.

Some physical health impacts of wildfire include respiratory, ophthalmic, and cardiovascular illnesses [228].

- Agricultural impacts of drought may cause food security issues across PEI. Community gardens, such as the Goodwill Garden, usually donate 20,000 pounds of produce a year to food security initiatives. During the 2020 drought they able to donate only about 1,000 pounds [237].
- One of the Lennox Island or Abegweit First Nation citizens interviewed indicated that summer droughts are causing crops to dry out, resulting in less produce availability in the winter. This can have adverse health implications because store-bought produce is less affordable [35].

Confidence: Medium

Government reports and literature provided evidence for drought events having potential to cause morbidity, injury, disease, or hospitalization, although only some were PEI-specific. Workshop participants provided some agreement and PEI-specific evidence.

Mental health: 4 (major)

Months-long seasonal drought events on PEI have the potential to seriously disrupt the mental health of residents, especially those whose occupations rely on agriculture. Because PEI as a whole is fairly reliant on agriculture, there is potential for widespread mental health impacts.

Supporting evidence includes:

- Farmers are among the most vulnerable occupations to mental health impacts, with stress, depression, anxiety, and emotional exhaustion occurring at higher incidence rates than in other occupations in Canada [238].
    - Although only 6.7% of the province’s total occupations are directly related to agriculture, the cultural importance of the agricultural industry is worth consideration. As a result, drought impacts to agriculture may not only result in mental health disruptions for farmers and farm workers, but may also extend into the general population of the province, especially if droughts negatively affect the economy [39, 173].
- Those who experience financial impacts as a result of a drought may experience shame and humiliation, leading to depression, anxiety, and suicide. The more severe the drought event, the more likely it is to have a severe impact on the mental health of those affected [239].
- Indigenous communities may be at particular risk for drought-related mental health disruptions due to strong connections with the natural environment [239].
- PEI’s small size, sense of community, and informal support networks that tend to exist within tight-knit rural communities, may be utilized to address mental health issues, but as drought conditions worsen, this support network may deteriorate due to increased pressure on community resources [239].
- Wildfire, which can be a second order effect of drought can cause displacement, loss of property, and destruction of infrastructure, all of which can have negative mental health impacts. In severe cases, post-traumatic stress disorder is a possibility [228].
- Residents with low socioeconomic status may experience greater levels of stress as a result of an increase of food costs which can occur during a drought [228].
- Drought events may lead to the amplification of intra-provincial tensions between different water users, such as tensions between environmental groups and potato farmers over the current ban on using high-capacity wells for irrigation. These competing interests may lead to increased stress levels and decreased social stability across the province [240].

Confidence: Medium

Some government reports and literature provided evidence of mental health impacts from drought events. Expert judgment and workshop discussions provided a high degree of supportive anecdotal, PEI-specific effects of droughts, particularly regarding impact those in the agriculture industry.

Economy: 2 (minor)

Tourism and recreation: 1 (insignificant)

The tourism and recreation industry on PEI is unlikely to be dramatically impacted by drought events. Golf courses, gardens, and some agriculture-related tourist attractions may face slight impacts, but they will likely be short-term.

Supporting evidence includes:

- If extended periods of drought lead to water use restrictions, golf course operators' ability to use irrigation may be disrupted [153]. Golf courses accounted for about 1% of the total annual water usage on PEI as of 2016 [241].
- Some tourist sites that include agricultural features, such as the Orwell Corner Village Historic Site Farm may be impacted by a drought event's effect on crops [41].
- PEI's natural beauty, including gardens at heritage sites and flowering potato crops, may be diminished during drought events, which may decrease tourist satisfaction [41].
- Water restrictions can be placed by municipalities. In extreme drought situations, it is possible that some tourists amenities, although restriction is generally limited to watering of lawns and hosing of hard surfaces [242].
- Drought events may result in cancelled events, such as fireworks celebrations on PEI, or bans on activities such as campfires and bonfires [243].

Confidence: Low

Limited evidence was available in the literature on the relationship between drought and the tourism and recreation industry. This rating relies primarily on expert judgment.

Agriculture, fisheries, aquaculture: 4 (major)

Historically, agriculture has faced severe consequences as a result of drought events. Potatoes are the most vulnerable and economically impactful crop on PEI that are likely to face effects, although other water-sensitive crops such as corn and tomatoes may face impacts as well. In drought events that result in months-long summer water shortages, losses may exceed $50 million.

Supporting evidence includes:

- The potato industry is a significant economic driver on PEI, boosting provincial GDP by over half a billion dollars annually . As PEI's largest agriculture export, any risk to the potato crop is cause for serious concern to PEI's agricultural community [103, 104]. Drought has potential to severely damage the potato industry on PEI as

2020: A Dry Year

2020 was a particularly dry year on PEI, where much of the summer and fall was spent in moderate to severe drought conditions. These conditions were particularly harsh for the agricultural industry – some farmers likened conditions to the 2001 drought (sometimes referred to as "the year of the drought"). Although the quality of potatoes was largely unaffected, production was down by over 25% on some farms [10, 11]. Additionally, dairy production was interrupted as dry conditions affected the availability and quality of feed/fodder for cattle [2, 12].

dry conditions can impact both quality and yield quantity [244]. Severe impacts to yields or quality can result in farmers being forced to break contracts with processors and/or harvest crews that rely on season farm work, multiplying economic impacts.

  - Drought conditions can cause potatoes to be growth stunted, have odd shapes, and have increased vulnerability to diseases.
  - In 2001, sometimes referred to as "the year of the drought," a very severe drought caused potato yield reductions of 40% across the Island. Some areas experienced even greater losses [25].
  - Potato farmers have compared 2020 to 2001 in terms of severity of drought. PEI spent much of the 2020 growing season in "severe drought conditions." Yields were down 20-25% or more in Central PEI, although the quality of potatoes was very good. A 25% reduction in harvest yield across PEI would total more than a $50 million loss [10, 11].

Figure 43. Potato field during the 2016 drought. Photo provided by DE Jardine.

- Crops other than potatoes are likely to face negative consequences from drought as well. Crops grown on PEI that are most sensitive to water shortages include corn, strawberries, cauliflower, and broccoli [104, 245]. Droughts do not necessarily result in water shortages, but shortages can occur when seasonal demand for water exceeds availability [81].
- Droughts can have negative impact for livestock on PEI as dry conditions can decrease the availability of pasture and forage for livestock herds. The 2020 drought caused forage crops for some PEI farmers to be down 40%, which can dramatically increase the price of feed and cause difficulties to store enough feed to support livestock throughout the winter. The 2020 drought has also caused Kelly's Cross Community Pasture to request that farmers remove some of their cattle off of the land for the first time since the creation of the pasture in 1990 [12, 153].
- High cost investments may be necessary to preemptively install irrigation infrastructure in areas that require increased irrigation to manage future drought events [39].
- Agricultural impacts of drought may cause food security issues across PEI. Community gardens, such as the Goodwill Garden, usually donate 20,000 pounds of produce a year to food security initiatives. During the 2020 drought they able to donate only about 1,000 pounds [237].
- Drought can cause negative consequences for freshwater fisheries and aquaculture operations by increasing the likelihood of disease and decreasing the quantity and quality of water in freshwater aquatic ecosystems [39, 228].
- Drought conditions can increase occurrences of forest fires, which have negative consequences on agriculture or silviculture on PEI by damaging crops themselves and changing soil composition [153].

Confidence: High

The extensive evidence in the literature, government reports, and news stories or anecdotes displays a high degree of agreement regarding drought events and impacts to agriculture, fisheries, and aquaculture, both generally and specific to PEI.

Other Industries: 1 (insignificant)

There is little evidence suggesting other industries will face consequences of drought on PEI.

- Water supplies for communities (drinking water and otherwise) may be diminished as a result of a yearlong or wintertime drought. This was realized in some parts of Canada during the 2001 drought [153].
- Island businesses who are exporting drought-affected goods may experience reduced volumes of products available to export [39].

> **Drought-Induced Water Restrictions**
>
> During previous drought events the City of Charlottetown has implemented and enforced temporary restrictions on water usage by closing car washes and prohibiting lawn irrigation [2].

Confidence: Low

Limited published information regarding other industries and drought on PEI was available. This rating relies primarily on expert judgment.

Environment: 3 (moderate)

Seasonal drought has potential to moderately disrupt multiple natural assets on PEI, especially coastal wetlands and streamflow. Impacts of one summer drought event, as this analysis explores, are unlikely to cause serious or irreversible damage to environmental resources on PEI; however, consistent seasonal drought events over many years may be cause for more serious and permanent environmental damage.

Supporting evidence includes:

- Wetland areas on PEI are likely to be diminished as a result of summer seasonal drought. Wetlands already stressed from other causes such as coastal erosion or development pressure are more likely to experience significant effects [246].
- If yearlong or wintertime drought events occur, groundwater resources may recharge at lower-than-normal levels, resulting in a drop in the water table. This may result in reduced streamflow and/or lower water levels in ponds and lakes. Additionally, due to climate change it is possible that seasonal patterns in snowmelt and streamflow will have higher change than the current average. Drought events may further exacerbate the alteration from the norm [247].
    - Reduced streamflow may result in aquatic habitat degradation which may result in lower oxygen concentrations thus negatively impacting freshwater fish and invertebrate growth on PEI [248].
- Shallow-rooting trees, such as spruces, are particularly sensitive to drought and may face disruption as a result of severe drought events [249]. Young trees and saplings are especially vulnerable to damage from drought conditions [39].
- Drought conditions can increase occurrences of forest fires, which have negative consequences on multiple environmental resources on PEI, especially for forest nutrient cycling [246].

Confidence: Medium

Several government reports provided high-quality evidence with agreement regarding impact to PEI's environment from drought. Workshop participants had a high level of agreement.

Social Stability: 3 (moderate)

Months-long seasonal drought events on PEI have the potential to moderately disrupt community social stability. Agriculture is a crucial asset of PEI economy and culture, and therefore drought-related impacts to agriculture could cause severe disruption for those directly reliant on it and cascading moderate disruption for other residents.

Supporting evidence includes:

- There has been considerable debate over a moratorium passed after the 2001 drought that restricts deep-well water extraction for irrigation. Some farmers believe that is it time to consider reversing the moratorium so they can better irrigate their crops, while environmental groups suggest extracting water from the aquifer is risky, considering PEI relies exclusively on groundwater as a freshwater source. The PEI Potato Board has formally requested to lift the moratorium in previous years [250]. Community debates regarding water use and policy may lessen social stability and negatively affect the ability for collaboration and adaptation [39].
- Agricultural impacts of drought may cause food security issues across PEI. Community gardens, such as the Goodwill Garden, usually donate 20,000 pounds of produce a year to food security initiatives. In 2020 they were donating closer to 1,000 pounds [237]. These community gardens may serve as important social resources for PEI and their lack of production may cause social disruption.
- Potatoes and agriculture are inwritten into the culture of PEI, and significant damage to these industries as a result of drought events may have cascading social stability impacts across the Island [103].
- Individuals who rely on agriculture may face more severe mental health impacts as a result of additional stress and uncertainty. If the agricultural industry shifts as a result of increased drought incidence on PEI, Islanders may face social stability impacts.

Confidence: Low

Evidence of potential impacts to social stability were mainly provided via workshop sessions, with some support from agricultural reports. The rating is based primarily on expert judgment.

Infrastructure: 2 (minor)

Infrastructure on PEI has potential to face small, short-term disruptions as a result of a drought event. Specific areas of concern include irrigation infrastructure, as well as energy system stress if drought effects off-province hydroelectric sources of power.

Supporting evidence includes:

- Municipal water supplies for communities may be diminished as a result of year-long or wintertime droughts which have potential to impact groundwater availability [39, 153]. Restrictions may require changes to agricultural irrigation infrastructure [39].
- Costly damage to water-related infrastructure such as septic tanks and wells have been reported in Canada during prior droughts [228].
- Although PEI does not produce its own hydroelectric power, most of the power consumed by PEI is sourced from New Brunswick, where about one-fifth is generated by hydroelectric [251]. That said, the energy that PEI purchases from New Brunswick is sourced from a variety of means so significant disruption is unlikely, unless compounded with other events [39].

Confidence: Low

Evidence regarding impacts to infrastructure from drought events was available from only a few sources. The consequence rating relied heavily on expert judgment.

9. Appendix B: Process for Selecting Climate Hazards and Scenarios

Step 2 of the CCRA process was to determine which specific climate hazards and scenarios to evaluate. This appendix provides background information on how the final set of seven hazards and scenarios was determined.

9.1. Determine climate hazards

Climate hazards are changes or events, resulting from climate drivers that would consequently result in major impacts to the province. Climate hazards are a function of both the climate drivers and their relationship to the consequence categories. The selected hazards are those that are likely to occur in PEI as a result of changing climate conditions and that are expected to affect the key consequence categories identified in Section 2.1.3.

The likelihood and consequences of the selected climate hazards were assessed and scored during the risk assessment process.

9.1.1 Identify climate drivers

An initial step to identifying climate hazards was to identify relevant climate change drivers in PEI. Climate drivers represent the underlying causes of climate hazards. Table 19 summarizes the core set of climate drivers relevant to PEI [25, 167, 252, 253].

Table 19. PEI climate drivers

Climate Drivers
Increase in air temperatures (this relates to warmer average temperatures month-to-month, higher growing and cooling degree-days, a potential increase in associated heat waves, and reduced heating degree-days)
Change in precipitation patterns (including more rain and less snow, more heavy rain events, and a potential increase in drought conditions)
Sea level rise (exacerbating coastal erosion, leading to more frequent flooding, and more severe storm surges)
Change in sea surface temperatures (related to reduced sea ice and changes in marine biospheres)
Ocean acidification (related to changing marine biospheres)

9.1.2 Identify climate hazards

Climate hazards are the specific changes or events, resulting from climate drivers, that would consequently result in major impacts to provincial objectives—and for which the risks will be evaluated.

The initial list of climate hazards relevant to PEI is provided in Table 20. The project team identified these hazards through a crosswalk of the climate drivers and the key consequence categories for the risk assessment, and a review of existing resources, such as a historical list of climate-related storm events on PEI [254], *Canada's Changing Climate Report* [167], PEI's *Climate Change Action Plan* [252, 253], and UPEI's *Climate Change Adaptation Recommendations Report [25]* , PEI's *Climate Change Action Plan* [252, 253], and UPEI's *Climate Change Adaptation Recommendations Report.*

See Figure 44 for a visualization of the crosswalk process and example climate hazards. The figure illustrates how climate hazards serve as a bridge between key consequences and climate drivers. For the sake of simplicity and readability, lines are only shown for two climate hazards (flood and invasive species), but all climate hazards shown could contribute to several key consequences and are the result of several climate drivers.

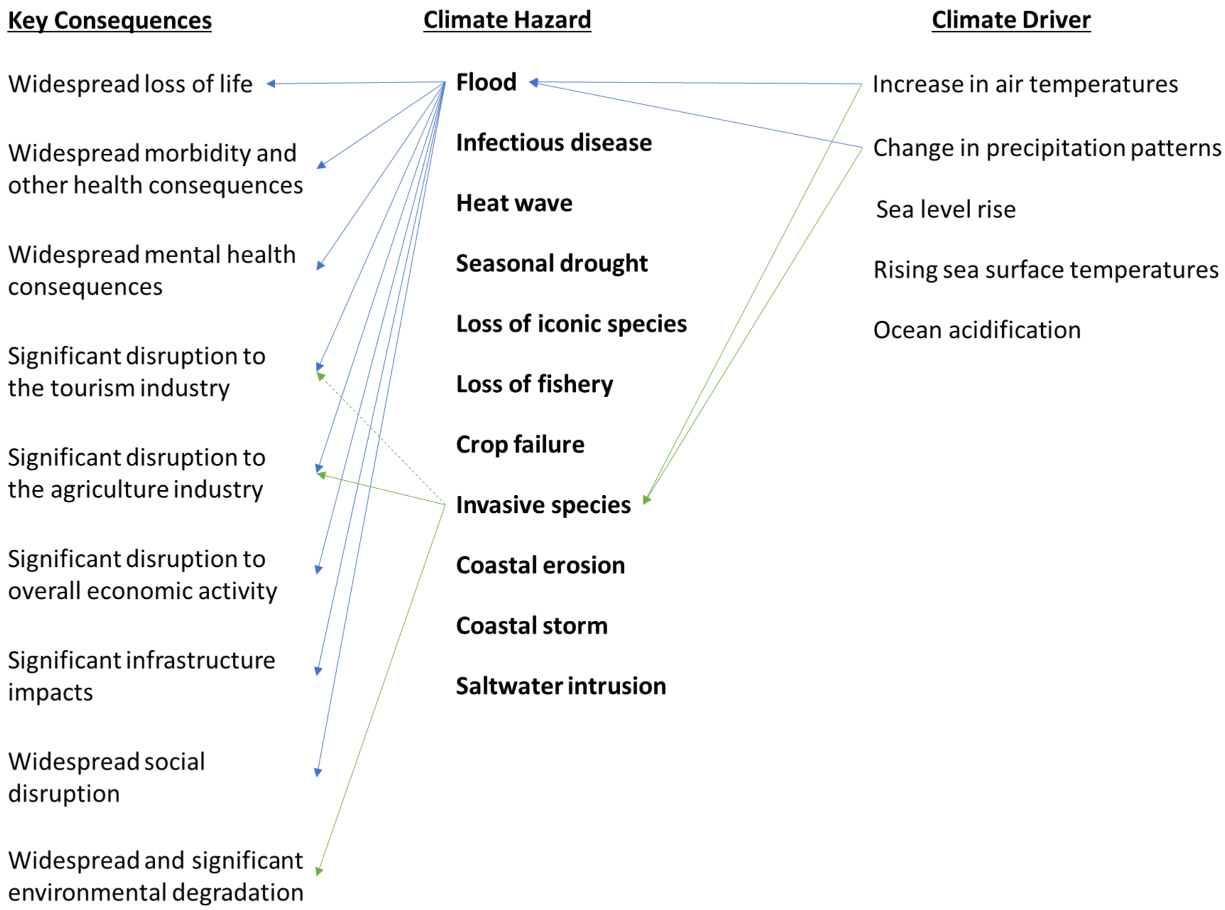

Figure 44. Illustrative crosswalk between key consequences and climate drivers to identify climate hazards.

Climate hazards are either "discrete," (i.e., extreme weather events), or "ongoing" (e.g., increase in temperatures) changes in climate variables. Discrete and ongoing climate hazards can also have compounding effects, and therefore are both important to consider. In many cases, changes in ongoing climate hazards may affect the frequency and severity of discrete climate hazards. In addition, ongoing climate hazards may reach a critical threshold at which a significant discrete impact occurs during the time period of analysis. For example, gradual changes in temperature or precipitation could eventually result in the extirpation (local extinction) of a species or introduction of a new disease vector.

Table 20. Initial list of PEI climate hazards

Climate Hazards	Discrete or Ongoing
Increase in freeze/thaw	Ongoing
A winter with rapid fluctuations in temperature	Discrete
A growing season with rapid fluctuations in temperature	Discrete

Climate Hazards	Discrete or Ongoing
Heat wave	Discrete
Increase in the frequency and intensity of precipitation events	Ongoing
Seasonal drought	Discrete
Severe winter storm	Discrete
Severe ice storm/freezing rain	Discrete
Heavy precipitation and flooding event	Discrete
Severe coastal storm	Discrete
Coastal erosion	Ongoing
Sea level rise	Ongoing
Saltwater intrusion	Ongoing
Warmer sea surface temperatures	Ongoing
Reduced sea ice coverage	Ongoing
Ocean acidification	Ongoing
Loss/decline of specific ecosystem	Ongoing
Loss/decline of an iconic species	Ongoing
Loss/decline of a fishery	Ongoing
Loss/decline of forest resources	Ongoing
Crop failure	Discrete
Increase in invasive species	Ongoing
Emergence or increase in infectious disease	Ongoing

9.1.3 Select climate hazards

To narrow the focus of the CCRA, the project team, informed by workshop participants, selected seven climate hazards for further analysis. Criteria used to select the climate hazards included:

- Hazards should be expected to be relevant within the time frame of the CCRA (2020-2050)
- Hazards should have information available to inform likelihood and consequence assessment
- Hazards should be "provincially significant," and likely to result in catastrophic or major impacts to any of the risk assessment focus areas. For example, a climate change-related event or ongoing change that could result in:
    - Significant loss of life
    - Widespread public health and safety impacts
    - Severe or long-term mental health impacts
    - Severe or long-term disruptions to social services, community institutions, employment, and quality of life and wellbeing

- Significant or irreversible damage to the natural environment
- Severe or long-term disruption to infrastructure services and assets
- Significant long-term economic impacts to the tourism and recreation or agriculture, fisheries, aquaculture, and other industries

The project team circulated a survey and held a virtual workshop with various internal and external stakeholders to gather feedback on the list of climate hazards. Workshop participants refined and narrowed the list and also helped to frame specific scenarios of each of the seven climate hazards to be representative of a significant event or projected changes on PEI. Worth noting, coastal flooding and storm surge were acknowledged as posing a significant threat now and in the future for Prince Edward Island. However, these hazards were being addressed through an independent yet parallel coastal hazard assessment and were therefore omitted as a standalone climate hazard scenario in this risk assessment. Future work will include efforts to integrate the results of both initiatives.

The final selected climate hazards for the CCRA included:

1. Coastal erosion
2. Post-tropical storm
3. Heat wave
4. Heavy precipitation and flooding
5. Severe ice storm/freezing rain
6. Earlier, warmer springs
7. Seasonal drought

9.2. Define climate hazard scenarios

Building on the feedback received at the workshop, the project team defined plausible climate hazard scenarios for each of the seven climate hazards to analyze in the CCRA. The purpose of the scenario is to detail the specifics of one possible permutation of the climate hazard to evaluate likelihood and consequences. Scenario details include defining severity conditions, temporal scale, or the spatial scale of the event. For ongoing climate hazards, it is especially important to define the critical threshold at which significant impacts occur as part of the scenario.

The climate hazard scenarios were defined at the provincial scale for the 2050 timeframe. However, recognizing that risk may vary geographically across the province, the assessment findings identified areas or populations that face disproportionately greater risk, as appropriate.

The seven climate hazard scenarios analyzed in the CCRA are summarized in Table 21.

Table 21. Climate hazard scenarios

Climate Hazard	Scenario
Severe ice storm/freezing rain	Multi-day severe ice storm/freezing rain event in winter

Climate Hazard	Scenario
Post-tropical storm	Multi-day post-tropical storm with heavy rain, storm surge, and wind; landfall in Queens County
Heavy precipitation and flooding	100 mm rain event in 24 hours
Seasonal drought	Months-long severe summer drought affecting the entire province
Coastal erosion	Acceleration of the historic rate of erosion
Heat wave	Three consecutive days with temperatures above 29°C
Earlier, warmer springs	Earlier arrival of spring temperatures by two weeks affecting key species

10. Appendix C: Adaptive Capacity Assessment Details

To assess adaptive capacity, the project team held a workshop with agency staff and stakeholders using the virtual platform Mural. Participants were divided into one of three breakout groups:

- Health
- Environment and social stability
- Economy and infrastructure

Workshop participants responded to the following prompts to develop a list of adaptive capacity factors for their focus area(s):

- What adaptive capacity factors are we missing? In other words, are there other factors that may make the sector more or less susceptible to impacts from climate hazards (what influence ability to adjust to impacts)?
- Vote for your top three factors.
- Describe the current status of each of the top voted adaptive capacity factors.

To capture existing adaptive actions, participants also answered:

- What existing adaptive actions are the Province or others taking to reduce [health; economy; environment; social stability; infrastructure] risks (hazard-specific or cross-cutting)?

Using the findings of the workshop, the project created an Adaptive Capacity Assessment Matrix (Table 22). This matrix includes a number of adaptive capacity factors per consequence category. Workshop participants then filled out a survey to rate each adaptive capacity factor on a 1-5 scale from “couldn’t be worse” to “couldn’t be better.” Ratings were averaged to produce a preliminary score per factor. These ratings can be revisited in the future as PEI takes more adaptive actions.

For each consequence category, the following sections document:

- Details on the current status of each adaptive capacity factor according to workshop participants,
- Additional research findings on the adaptive capacity factors,
- Example existing adaptive actions in place to reduce risks, and
- Additional adaptive capacity factors for consideration in future assessments, as suggested by workshop participants and survey respondents.

Table 22. Adaptive Capacity Assessment Matrix

Consequence Category	Adaptive Capacity Factor	Low (1) *Couldn't be worse*	(2)	(3)	(4)	High (5) *Couldn't be better*
Health	Access to basic needs and services (e.g., affordable housing, employment, education)	No access to basic needs and services				All residents have access to basic needs and quality services
	Access to healthcare services (in-person)	No access to healthcare services				All residents have access to quality healthcare services
	Access to mental health services (in-person)	No access to mental health services				All residents have access to quality mental health services
	Access to healthcare services (online/telemedicine)	No access to healthcare services				All residents have access to quality healthcare services
	Access to mental health services (online/telemedicine)	No access to mental health services				All residents have access to quality mental health services
	Ability to provide on-Island healthcare and emergency services	No access to healthcare and emergency services				All residents have access to quality healthcare and emergency services
	Extent of emergency preparedness and management activities	No emergency preparedness or management activities				Robust emergency preparedness and management activities spanning all hazards
	Sense of community and belonging	No sense of community and belonging				All residents have strong sense of community and belonging
Economy	Diversity of economic sectors	Economy heavily reliant on one sector or product				Highly diversified economy

Consequence Category	Adaptive Capacity Factor	Low (1) *Couldn't be worse*	(2)	(3)	(4)	High (5) *Couldn't be better*
	Diversity of workforce (e.g., whether reliant on one sector, one specialized skill, or a subset of the population)	Workforce heavily reliant on one sector or pool of workers				Highly diversified workforce
	Redundancy or robustness of supply chain	Limited ingress/ egress options for transporting goods and services				Multiple ingress/ egress options for transporting goods and services
	Spirit of innovation and willingness to try new approaches	Lack of support for or interest in innovation				Robust support for and widespread interest in innovation
	Willingness and ability to use bioscience and/or academia for creating solutions	Lack of support for problem solving within biosciences or academic				Robust support for problem solving within biosciences or academic
	Willingness and ability for various regions on PEI to collaborate with one another	Lack of support for or interest in collaboration across regions				Robust regional collaboration and widespread support for further efforts
	Preparedness for changes to agricultural production (e.g., shifting away from potatoes as the primary crop)	No preparedness for or considerations of agricultural changes				Agricultural sector and supporting industries prepared for and driving changes to production
	Diversity of crop production	Crop production relies on single method				Crop production conducted using multiple methods
Environment	Ecosystem health	Declining health and prevalence of ecosystems and species				Thriving coastal and species
	Monitoring networks for changes in the environment (e.g., invasive species)	No existing monitoring networks				Robust monitoring networks covering multiple environmental changes

Consequence Category	Adaptive Capacity Factor	Low (1) *Couldn't be worse*	(2)	(3)	(4)	High (5) *Couldn't be better*
	Species diversity/biodiversity	Declining species diversity/ biodiversity				Thriving and robust species diversity/ biodiversity
	Robust network of organizations working in environmental protection / conservation	No network of environmental protection / conservation organizations				Robust network of environmental protection / conservation organizations
	Municipal capacity to respond to environmental impacts	Limited municipal response capacity				Robust municipal response capacity
	Land use policies for environmental protection and incorporation of climate change	No land use policies in place for environmental protection and climate change response				Significant land use policies in place for environmental protection and climate change response
Social Stability	Strength of faith-based, informal networks or other community institutions	Weak or nonexistent networks and community institutions				Strong and robust networks and community institutions
	Support mechanisms for income disruption	No support mechanisms for income disruption				Robust support mechanisms for income disruption accessible to all residents
	Equal access to reliable water/wastewater services across urban and rural areas	Inequitable allocation of services				Equitable allocation of services
	Equal access to reliable transportation services and infrastructure across different population/identity groups	Inequitable allocation of services and infrastructure				Equitable allocation of services and infrastructure
	Equal access to reliable telecommunications/broadband services across different population/identity groups	Inequitable allocation of services				Equitable allocation of services
	Equal access to reliable water/wastewater services across different population/identity groups	Inequitable allocation of services				Equitable allocation of services

Consequence Category	Adaptive Capacity Factor	Low (1) *Couldn't be worse*	(2)	(3)	(4)	High (5) *Couldn't be better*
	Equitable access to safe, affordable, nutritious, culturally appropriate food in a way that maintains human dignity	Inequitable allocation of food				Equitable allocation of food
	Equitable access to resources (e.g., financial, knowledge) to support individual adaptation or risk management strategies	Inequitable allocation of resources				Equitable allocation of resources
	Past experience living through climate hazards	No experience or comfort level with the hazards				Community is well-versed in necessary preparations
	Support for seniors in times of crisis	No support for seniors during crises				Robust support accessible to all seniors during crises
Infrastructure	Level of transportation network resiliency	Network susceptible to disruptions during common events				Network designed or hardened to withstand extreme risk aversion conditions
	Level of communications/internet resiliency	Network susceptible to disruptions during common events				Network designed or hardened to withstand extreme risk aversion conditions
	Level of energy infrastructure resiliency (e.g., diversity of energy sources and generation locations)	Infrastructure susceptible to disruptions during common events				Infrastructure designed or hardened to withstand extreme risk aversion conditions
	Level of water/wastewater infrastructure resiliency	Infrastructure susceptible to disruptions during common events				Infrastructure designed or hardened to withstand extreme risk aversion conditions
	Government knowledge of resilience of municipal water and wastewater systems to power outages and flooding	No knowledge of susceptibility of potential disruptions to systems				Infrastructure designed or hardened to withstand

Consequence Category	Adaptive Capacity Factor	Low (1) *Couldn't be worse*	(2)	(3)	(4)	High (5) *Couldn't be better*
						extreme risk aversion conditions
	Extent of critical infrastructure designed and hardened to withstand extreme conditions	Critical infrastructure susceptible to disruptions during common events				All critical infrastructure designed or hardened to withstand extreme risk aversion conditions
	Amount of available funding to upgrade outdated infrastructure	Very limited funding and resources available for upgrades				Capacity and supplies to upgrade all outdated infrastructure
	Capacity for emergency repair, response, and supplies	Very limited emergency response capacity and stockpile (e.g., enough for a small event)				Capacity and supplies to cover multiple events occurring simultaneously or back-to-back across the Island
	Ability to cope with growing population	No plans or capability in place to cope with growing population				Robust planning efforts in place to cope with rapidly growing population
	Ability to protect provincial artifact collections during extreme weather events and power failures	Very limited emergency response capacity				Capacity and supplies to cover multiple events occurring simultaneously or back-to-back across the Island

10.1. Health

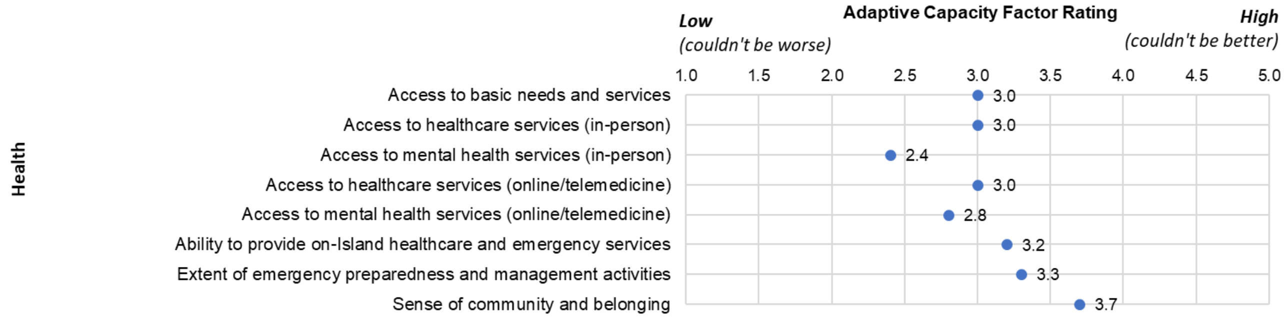

Figure 45. Adaptive capacity factor ratings for health.

The following information gathered from the workshop, survey, and additional desk research supports the health adaptive capacity factor ratings (Figure 45). Survey respondents also provided additional adaptive capacity factors to consider for health.

Current status of each adaptive capacity factor (per workshop participants)

- Ability to Provide Healthcare Services
    - There are many issues with cell phone service and internet connections across the province. Poor conditions of some rural roads making some areas difficult to access. There has been some discussion about increased rural public transportation. The 811 help line is important. When the line is down, information can be shared over social media platforms like Facebook.
    - Health PEI has proven able to largely sustain critical services during storm/severe weather events. Information sharing during events continues to be a challenge within the health system. Access to mental health services and digital care are important. Many in-person appointments could be carried out virtually or via telephone. The list of retired healthcare providers willing to serve in emergencies developed for the pandemic may also be useful in an extreme climate event.
    - PEI health services were able to remain open during the COVID-19 pandemic, with limited (short-term) interruption in elective procedures.
    - There is a lack of specialist doctors on the Island and in Atlantic Canada more broadly. Addiction services and abortion clinics have many barriers to access.
    - There is a shortage of family doctors on PEI, which has led to a long wait list to be assigned a doctor. Additionally, the Summerside Emergency Room has been understaffed, leading to a reduction of hours and transfer of patients to Charlottetown.
    - The Island is moving toward community health hubs where there is a network of healthcare practitioners that can provide a holistic health assessment. Currently there is a one physician/one patient system without any backup options and only a single point of care.
    - There is a need for pop-up health centres.
    - There is an expanded role for Island Emergency Medical Services, pharmacists, and mobile integrated health services.
    - There is a need for home care after surgeries and for seniors.

  - Access to online tools is hampered by both the education/experience level of the potential clients and the technology, particularly in light of an aging population and an increase in new residents, some of whom may face language barriers. Not all Islanders have access to computers or reliable internet for online/telemedicine.
- Rural Community Access/Services
  - Provision of virtual/online services have enhanced access in rural communities, but broadband services are often limited in rural areas. There has been increased focus on expanding high-speed internet in rural areas.
  - Acute care services are mostly located in Charlottetown and Summerside. There is a lack of public transportation in rural areas which limits the ability of residents to access services.
  - Challenges related to failure are often more severe in rural communities.
- Emergency Preparedness and Response:
  - There is a requirement for all municipalities to have an emergency preparedness plan. All government departments contribute to the emergency response, which makes a difference in speed of response and ability to alert residents quickly. The system was tested during Hurricane Dorian. The government needs a plan for how to streamline communication on emergency shelters. Communication is needed with both the centres and with the public. Some federal mitigation supports are available for governments. The Island could benefit from maintaining many of the response resources developed for the COVID-10 pandemic (e.g., compiled list of skillsets).
  - Municipalities in PEI are constrained by limited financial resources and outdated municipal boundaries. One in three municipalities is smaller than five square kilometres in area. In addition, 63 percent of the province is not incorporated. This creates significant challenges for local emergency preparedness [255]. and land use planning.
  - Emergency preparedness and management varies by municipality as this factor is highly dependent on funding and education. For example, with increased drought conditions there may be an increase in wildfire related incidents; however, the local fire department may not have the infrastructure in place, due to cost, and/or personnel educated on wildfires to provide an appropriate emergency response.
  - The H1N1 influenza was a learning experience for emergency management officers. The government has improved processes and applied lessons learned. It has been useful to debrief after events. COVID-19 has strengthened the government's ability to respond to emergencies and provides an opportunity to learn and improve, especially for prolonged and widespread responses.
  - Emergency management officers are working toward a more integrated provincial approach for severe events.
  - Business continuity plans related to power and water loss are important to emergency preparedness and response.
  - The switch to heat pumps has led to a lack of secondary heat sources or backup power.
- Sense of Community
  - Some communities have a stronger base due to the availability of volunteers, but volunteer fatigue is an issue.
  - There is a very organic sense of community that does not necessarily follow official municipal/community boundaries. Much of the sense of community is transferring online.

The community is shifting to include new residents and unhoused populations. Communities do not necessarily share ecological boundaries which means environmental impacts can be felt in other communities. There is a network of watershed groups connecting communities related to environmental and socioeconomic issues.

  - The community is experiencing a shift away from women's institute type organizations, with less interest from younger generations.
  - Shrinking rural areas has led to a decrease in the tax base and the closing of schools. There is also increasing urban pressures on schools, services, and green space. There is a tax incentive to live in areas outside of municipalities.
  - The Town of Stratford is arranging a senior care buddy system to help assist with services such as snow shovelling. Stratford is also encouraging people to check in with their neighbours during the COVID-19 pandemic.
  - Communities come together to help members save buildings threatened by the weight of snow.
  - Sense of belonging may be overestimated, as some feel that insular communities leave people out. COVID-19 has shown that PEI faces major issues in regards to an insider vs. outside mentality that is deeply ingrained and may prevent new residents from feeling welcome. A deep sense of community is also hampered by the lack of diverse government employees and elected officials in PEI. Some residents may not feel represented by elected officials and government employees.
  - There is often high turnout for community events and public forums.
  - There is a misconception that community health and general caring are robust, but it's not possible to generalize a provincial population. Statistics on abuse to women and mental health (e.g., suicides) are poor.

- Social Stability:
  - Overall, social stability factors are high, but need to be fostered.
  - There is an ongoing housing crisis and low community acceptance of social housing models along with resistance to building. There has been a housing boom with many homes purchased by off-Island buyers, which limits the ability of Islanders to purchase homes. There are also many first time buyers. There are considerable growth pressures in the City of Charlottetown. Coastal erosion and managed retreat place pressure on available space. The city must place controls to ensure individuals are not priced out.
  - COVID-19 will have differential impacts on returning to work and income security for vulnerable groups, which may be exacerbated by a climate event. Women and those employed in tourism, service, and creative industries may be particularly affected. There are concerns around a post COVID-19 housing bubble and questions about whether residents will remain.
  - Strengthening the supports for improving socioeconomic status will help increase population level resiliency. There are free recreation and youth addictions programs. Organized sports and city programs (e.g., Jack Frost) are important. There are Employee Assistance Programs. The 211 help line contributes to social stability.
  - There are a variety of models of governance but there is no province-wide incorporation. As a result, residents are either receiving information from a municipality or from the Province depending on place of residence.
  - Airbnb does not contribute to social stability. Rental cost and availability are still not

meeting needs.

    - Hotels should become sheltered during weather events to serve those seeking safety from domestic violence and the unhoused population.
    - There has been increased habitat rehabilitation work to develop more resilient environments (e.g., environmental Non-Governmental Organizations, Watershed Management Fund). The Province is aiming to protect 7% of green space.
    - The School of Climate Change at the University of PEI and the development of a research centre is drawing talent and increasing the capacity on the Island.
- Food Security:
    - Provincial school food programs contribute to food security.
    - There has been a focus on community and home gardens (e.g., food gardens in Charlottetown).
    - The government provided a number of food gift cards at a meaningful time.
- Energy:
    - Solar rebates are important to the energy sector. Backup generators are not universally available. Energy and water audits are available, as are solar rebates, Climate Challenge Grants, and Heat Pump Grants. There are currently Energy Efficiency Rebates, but the rebate amount should be higher.
    - Energy security is impacted by the Island's relationship with New Brunswick, which is the source of 75% of the Island's electricity.
    - Access to warming centres is contingent upon access to transportation.

Additional research findings on adaptive capacity factors

- Ease and ability to access healthcare, both on a regular basis and during emergency events, is a key factor to reduce health risks. Currently:
    - Approximately 82% of PEI residents have a regular health care provider [256]. If healthcare services are needed during a climate-related event, residents with regular health care providers may have greater access to immediate care. Residents with limited access may be more vulnerable to climate-related health impacts.
    - From April 2019 to March 2020, PEI's average ambulance response time ranged from 9:08 minutes to 10:41 minutes. More rural areas of the province have longer response times than urban areas (e.g., up to 15 minutes) [257]. Depending on the location and severity of a discrete climate event (e.g., flooding), response times may be longer.

Example existing adaptive actions to reduce health risks

- **Cross-cutting:** The Farmers Talk program has assisted hundreds of PEI's farmers and their families find help to deal with the mental and emotional stress associated with farming life [258].
- **Cross-cutting:** ECCC Weather PEI sends out alerts for extreme weather, watches, and warnings. It also sends weather reports to the Emergency Management Office which then get distributed to municipalities and local emergency management offices.
- **Cross-cutting:** The newly introduced 211 information is designed to help with navigation [39].
- **Heat:** The town of Stratford has implemented a splashpad facility to cool users and also has at least one park designated as sun safe due to its features that provide protection from the sun [259, 260]. This can also help cool residents during an extreme heat event.

Suggested additional factors (per survey respondents)

Workshop and survey participants also identified potential additional adaptive capacity factors to consider in future assessments:

- Resiliency of health care infrastructure is important. Should health care or supporting infrastructure fail, life and safety would be threatened at institutional environments, hospitals, and long-term care facilities.
- Better public messaging of impending threats and reliable information sources may help to reduce public anxiety over climate change.
- Shifting to a less centralized health care system, including more clinics outside of major urban areas, could help to improve awareness of and access to some services.
- Allowing pharmacists a greater scope of practice (e.g., prescribing antibiotics) might alleviate additional pressures on the health care system.
- A universal nutrition program to ensure all Islanders are receiving adequate nutrition for health would be ideal to mitigate the reduction of nutrients or access to food sources.

10.2. Economy

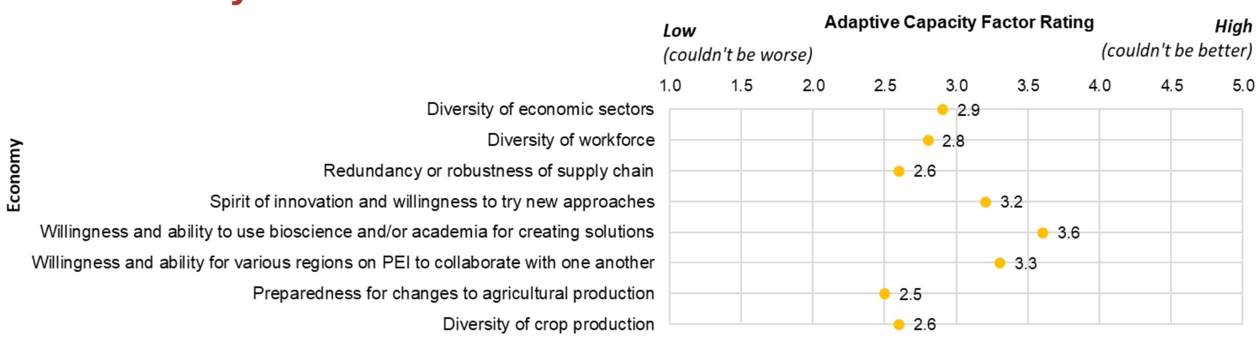

Figure 46. Adaptive capacity factor ratings for economy.

The following information gathered from the workshop, survey, and desk research supports the economy adaptive capacity factor ratings (Figure 46). Survey respondents also provided additional adaptive capacity factors to consider for economy.

Current status of each adaptive capacity factor (per workshop participants)

- Need for Diversification of Sectors:
    - Actions should consider that the population grows by approximately 10,000 people every 5 years. The population growth has allowed the economy to be stable and thrive.
    - PEI has a diverse economy that has allowed economic growth despite some downturns. There are efforts to grow other sectors (e.g., clean technology). There are efforts to diversify the agricultural sector (e.g., Perennial Crop Program).
    - PEI has an entrepreneurial spirit.
    - Currently there is heavy reliance (100%) on wild caught mussel seed, which is vulnerable to high losses from strong wind events. Diversifying seed sources would help to decrease vulnerability.
    - Some farmers are exploring renewable energy projects. The agriculture industry is interested in carbon markets.

    - While climate change studies shown that crop changes are needed to adapt to climate change, there is a resistance to change and a commitment to the potato industry. The agriculture industry is not prepared for climate change. While some initiatives aid in shifting current farming systems to be more sustainable, the potato industry has unwillingness to change and significant influence on farming practices.
- Spirit of Innovation & Willingness to Try New Approaches:
    - PEI and the Atlantic region have rolled out various pilot projects. However, government programming can be slow to support new initiatives and the government needs to be innovative with program development, and collaboration between departments or with other actors is necessary. The private sector is more willing to take diversification risks than the public sector. PEI needs to shed the stereotype of being behind the times. Many feel the Island is heavily invested in the status quo.
    - Farmers are generally open to trying new approaches.
    - Maritime Electric is invested in the status quo. Maritime Electric needs to allow innovation while attempting not to increase electricity prices and considering equity.
    - Working from home has become more acceptable.
    - There is a need to explore untapped tourism opportunities.
    - There are new packaging and storage options for some sectors.
    - The diversity of the workforce is reflective of population diversity. However, significant changes are required to create an inclusive workforce on the Island.
- Ability to Lean on Bioscience/Academia for Solutions:
    - Government programming can change quickly to meet emerging needs. It is important to monitor programs and track change. There are Mussel and Oyster monitoring programs and invasive species monitoring and research programs.
    - The Wind Energy Institute of Canada provides research into renewables. A new engineering school and Climate Lab are in development. There is also new soil health testing and an ongoing genomics program related to breeding mussels to adapt to higher water temperatures. However, commercialization of research remains a challenge.
    - There have been investments in research (e.g., University of PEI School of Sustainable Design Engineering, Canadian Centre for Climate Change and Adaptation).
    - The bioscience sector continues to be innovative and can share best practices with other sectors.
    - There has been international collaboration with like jurisdictions.
    - Existing programming includes Fisheries and Aquaculture Clean Technology Adoption Program; Research, Innovation and Growth Program.
- Crop Rotation Diversity:
    - Rotational crops provide resistance to early frost and build soil health. Farmers are generally interested in crops that build soil health. Efforts in building soil health are generally province-wide and include many stakeholders.
    - Using precision agriculture technology supported by UPEI to enhance agricultural productivity.
    - Shifting seasons have allowed for more cover crop coverage in recent years. Some are

    - using seed mixture as rotation crops.
    - The potato board is testing new crops. Cavendish Farms is performing research on new potato varieties.
    - Increasing the value-added manufacturing in the food sector will help generate increased wealth for the Province.
- Increasingly Diverse Food Production:
    - 50% of PEIs international exports are food products. Major changes in climate change could impact this diverse sector. A diversified international population may help with establishing other food markets. There have been some efforts in researching new crop market opportunities.
    - Canada Smartest Kitchen.
    - Bio Food Tech.
    - There are program developments to encourage on-farm adoption of Best Management Practices. Some farmers have adjusted planting dates due to changes in climate. Some companies have studied variety selection for drought and heat resistance.
    - PEI has worked to diversify its exports with value-added products.

Additional research findings on adaptive capacity factors

- Economic diversification is an important adaptive capacity factor.
    - PEI's economy is currently generally well-diversified, which improves adaptive capacity. The major economic industries on PEI include agriculture, manufacturing, retail trade, fisheries, exports, tourism, construction and investment, public service, and provincial finance [173]. Impacts to those sectors would have the largest overall economic impacts.
    - Potatoes, which are vulnerable to several climate hazards, are the largest commercial crop grown on the Island and the biggest export for the Province [102].
    - Lobster are also a key commercial product. There is a set season and licence limitations for lobster harvesting to ensure sustainable management [197, 212]. The PEI Department of Fisheries and Communities coordinates with the industry to monitor lobster population and health and adjust management practices as necessary [197].
- Supply chain redundancy and resilience is another key factor that can help reduce risk in the event of extreme weather events or other disruptions.
    - PEI has limited direct ingress/egress points for transporting economic goods, which limits the Island's resilience to infrastructure disruptions [261].
    - PEI has limited direct ingress/egress points for transporting economic goods, which limits the Island's resilience to infrastructure disruptions [261].
    - Most goods produced on PEI (e.g., potatoes) are transported via roads and trucks to Nova Scotia or New Brunswick, where it is then further distributed across Canada or internationally through trucks, container ships, or cargo airplanes. PEI's ports and airports move very little cargo. However, the Charlottetown and Summerside ports do move some imports (e.g., fertilizer, aggregate for large infrastructure projects) [110].
    - Charlottetown Port is the largest port for tourism. More than 100 cruise ships pass through the port in a year [110].

Example existing adaptive actions to reduce economic risks

- **Cross-cutting:** The PEI government has recently implemented the Provincial Disaster Financial Assistance Program, which is designed to provide aid to families, businesses, non-profits, and municipal governments in the wake of a disaster [262]. This program is only for uninsured losses from discrete catastrophic or major events like severe storms, floods, or drought. To date it has publicly been offered for Hurricane Juan and Post-tropical Storm Dorian.
- **Flooding:** PEI has implemented successful flood and runoff prevention infrastructure to protect its agricultural resources against flood damages as well as avoid contamination to streams and rivers from agricultural resources such as cattle [171].
- **Flooding:** The agricultural sector is working alongside government and environmental groups to “reduce and eliminate land-use-related fish kills; keep soil on the land and out of waterways; and develop an industry standard code of practice for agricultural cropping [263].”
- **Flooding:** The Anne of Green Gables heritage site was reconstructed in 2017 to address historic flooding issues [42].
- **Flooding:** The Canadian Food Inspection Agency, Environment and Climate Change Canada, and Fisheries and Oceans Canada developed a protocol to institute emergency closures of shellfish growing areas as a result of heavy rainfall or severe storms that may cause contamination [25].
- **Flooding and erosion:** PEI released a Coastal Property Guide which includes best practices of coastal land management—many of which focused on mitigating the impacts of coastal erosion [264].
- **Flooding and heat:** The PEI Department of Agriculture and Fisheries provides an Oyster Monitoring program to oyster growers on the Island [265].
- **Heat and early, warmer springs:** There is an ongoing effort to selectively breed mussels to be more resistant to higher temperatures [219].
- **Drought:** The PEI Crop Insurance Agency provides coverage for damaged crops during periods of extended drought [153].
- **Drought:** Historically, farmers have been able to innovate and diversify in times of drought. These tactics may help reduce risk of farm failure and increase ability to cope with drought [239].
- **Drought:** Ongoing research is underway through the *Comprehensive Study on Crop Adaptation to Climate Change* to strengthen the adaptive capacity of PEI’s agriculture systems to climate change (e.g., improving existing crop varieties, assessing new varieties and new crops, and devising new cropping systems and methods) [231].

Suggested additional factors

Workshop and survey participants did not identify any additional adaptive capacity factors to consider in future assessments.

10.3. Environment

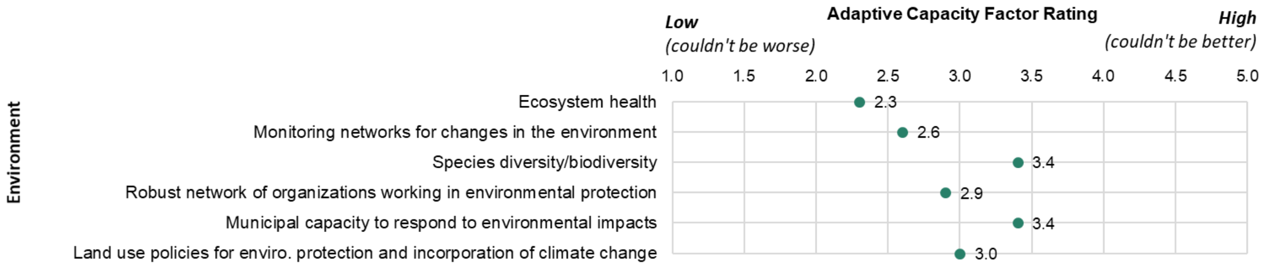

Figure 47. Adaptive capacity factor ratings for environment.

The following information gathered from the workshop, survey, and desk research supports the environment adaptive capacity factor ratings (Figure 47). Survey respondents also provided additional adaptive capacity factors to consider for environment.

Current status of each adaptive capacity factor (per workshop participants)

- Changes in Land and Water Utilization:
    - The Water Act will be implemented in June 2021. This Act will operationalize Water Management Plans. Water Management Plans allow stakeholders in watersheds to work together to determine what changes they need to make to meet environmental goals. These plans present an opportunity to incorporate climate change considerations.
    - Residents dislike planning in rural areas and have been resistant.
    - There may be fewer restrictions for coastal development outside of municipalities, leading to significant developments that may soon be at risk to coastal erosion.
    - The government is replacing washed out culverts with properly sized structures. The Atlantic Canada Water Works Association (ACWWA) and Atlantic Provinces are developing a Guideline Document for water and wastewater systems that consider climate change design standards. W/WW systems. There have been improvements in agricultural planning to incorporate the latest environmental climate knowledge. Transportation engineers have incorporated climate change adjusted weather patterns in design considerations.
    - Increasing monitoring of specific environmental issues allows for long-term assessment of status as climate changes.
    - The plastic bag ban has been effective.
    - The University of PEI Climate Lab shares coastal erosion monitoring/flood risk models with the public. There are also other University research projects related to climate change and adaptation methods/data collection/monitoring.
    - Some areas are using discarded Christmas trees to prevent erosion. Some areas are conducting shoreline stabilization efforts to reduce/mitigate erosion through planting of native shrubs and marram grass. There has been salt marsh restoration to help cope with sea level rise. Coastal Erosion and Flood Risk Assessments are provided for free to anyone.
    - Some locations are planting trees and shrubs to enhance riparian zones.
    - Tree habitat suitability studies have been completed.

- The government is beginning to work with Canadian Forest Service on climate sensitive growth and yield modelling to help accurately predict future forest states.
- New flood map data is being used to inform infrastructure and coastal projects.
- PEI does not yet use conservation design for subdivisions.
- The government is promoting diverse planting programs with private woodlot owners through Forest Management Plan creation.
- There are subsidies for renewable energy on private homes.
- Land use policies are an aid but not robust enough to be adaptive to change. For example, coastal golf courses and private landowners cutting their lawn within a metre of an already diminishing cliff is not allowing for adaptation to erosion. There may be rules surrounding buffer zones, but there does not appear to be adherence to them.
- Monitoring networks for the environmental conditions of concern are fairly robust. (e.g., Surface Water Quality Monitoring, Mussel Monitoring Program, Oyster Monitoring Program).

- Threat of Invasive Species:
  - When invasive species are introduced (e.g., Hemlock woolly adelgid), they can travel quickly and decimate native species, leading to a reduction of habitat and biodiversity. However, there are still many unknowns and monitoring is needed.
  - Southern species can invade as temperature increase. Native species might not be able to compete in changing environments. Some invasive species can destroy threatened habitat (e.g., invasive green crab within native eel grass).
  - The Island Nature Trust (INT) is working on an "Early Detection-Rapid Response" framework managing invasive species. INT runs an invasive insect monitoring program for emerald ash borer and hemlock woolly adelgid. They also conduct environmental education curricula for grade 7 students in some schools.
  - Provincial forestry insect monitoring (non-invasive) program has been set back due to personnel changes.
- Funding:
  - Project based funding limits consistent focus on an issue.
  - Watershed groups struggle with obtaining sufficient funding for their work. Municipalities are having to decide what impacts of climate change they can adapt to based on funding. For example, deciding whether to upgrade sewage systems or build seawalls for adapting to flood risks. Funding is not unlimited, especially in smaller communities.

Additional research findings on adaptive capacity factors

- Different species and ecosystems have different inherent capacity to adapt to environmental change based on their ability to migrate, adopt different feeding habits, etc. Climate change could limit the ability of certain species to thrive on the Island as conditions change. Specific examples of sensitive species and ecosystems include:
  - The endangered piping plover (*Charadrius melodus*) requires PEI’s wide, open, sandy beaches for habitat and cannot tolerate high levels of disturbance from humans, lowering the resilience of this iconic species [52].

- Sand dunes provide vital protection for coastal wetland environments; damage to dunes or damage to the marram grass that holds dunes together would result in negative environmental consequences [53, 266].
- Sand dunes provide vital protection for coastal wetland environments; damage to dunes or damage to the marram grass that holds dunes together would result in negative environmental consequences [53, 266].
- Freshwater aquatic ecosystems that have high reliance on regular streamflow may have low levels of resilience of streamflow were to be altered due to climate events [225].
- Freshwater aquatic ecosystems that have high reliance on regular streamflow may have low levels of resilience of streamflow were to be altered due to climate events [225].
- Lobster have a limited temperature range they can thrive in but are able to shift with changes in ocean temperature. In the near-term, PEI will be an optimal location for lobster, but by end of century, they may migrate farther northward [213-215].

Example existing adaptive actions to reduce environmental risks

- **Cross-cutting:** PEI National Park conducts regular conservation activities such as monitoring freshwater systems for unhealthy conditions, and monitoring and managing endangered species. Specifically, to address storm surge erosion damage, the park conducts restoration and protection activities including the management of dunes by placing discarded Christmas trees near dunes to capture sand, marram grass planting, as well as installing rope and T-bars on beaches [267].
- **Cross-cutting:** Multiple environmental groups, such as the PEI Watershed Alliance has joined the PEI Federation of Agriculture to form the PEI Agri Watershed Partnership, which is focused on watershed stewardship and beneficial management practices on the Island [263].
- **Cross-cutting:** The Prince Edward Island Wildlife Conservation Act was developed to aid in the protection of at-risk species and habitat. This includes species impacted by accelerating coastal erosion [268].
- **Flooding and erosion:** Coastal Impacts Visualization Environment (CLIVE), a interactive 3D tool was developed to allow Islanders to simulate coastal erosion and storm surge. This tool provides projections demonstrating which areas and infrastructure are most at risk on PEI [269]. Research is ongoing.
- **Flooding and erosion:** The PEI Department of Transportation, Infrastructure and Energy installed an inter-tidal reef on the Souris Causeway, which is vulnerable to coastal erosion and flooding. This project will grow the beach, protect the Causeway, and provide habitat for fish and plants [252].
- **Flooding and erosion:** Large rocks were added to the North Rustico shoreline, the sewage treatment plant was moved to higher ground, and the capacity of the area's sewer system was examined to avoid spills, thereby protecting beaches and fisheries. Granite has also been used to strengthen some Islanders' personal properties on the coast, although this may deflect damages to other areas [92].

Suggested additional factors (per survey respondents)

Workshop and survey participants also identified additional adaptive capacity factors to consider in future assessments:

- Enforcement of policies in place for environmental protection
- Promoting species or ecosystem characteristics that will be best suited to future climate

conditions, especially with respect to agriculture, woodlots, and other landscape related fields.

10.4. Social Stability

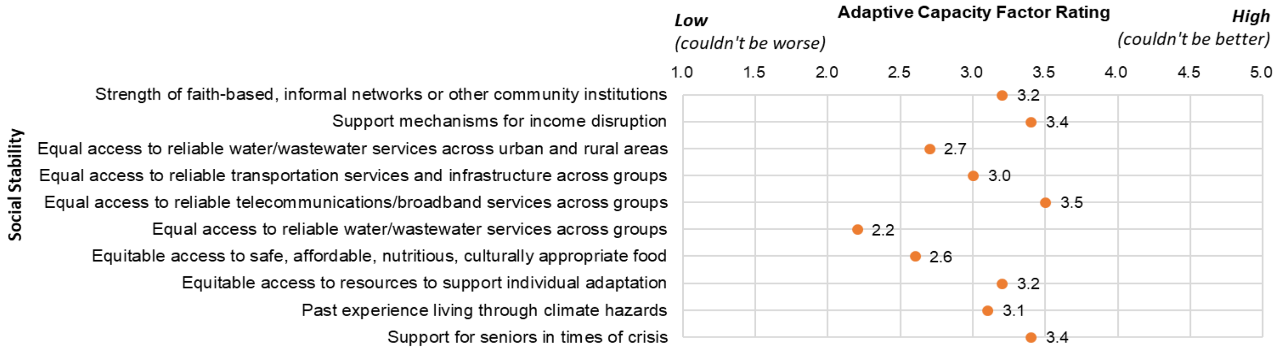

Figure 48. Adaptive capacity factor ratings for social stability.

The following information gathered from the workshop, survey, and desk research supports the social stability adaptive capacity factor ratings (Figure 48). Survey respondents also provided additional adaptive capacity factors to consider for social stability.

Current status of each adaptive capacity factor (per workshop participants)

- Support Mechanisms for Income Disruption:
    - There is a Healthy Food Program that provides support for low-income families. Support for income loss only replaces a portion of income (e.g., half) which is not sufficient.
    - Social Development and Housing has business continuity plans in place to ensure the ability to provide social assistance checks to clients/Islanders in the event of natural disasters, even those that cause a large disruption to power and communications.
- Population Equity:
    - The Archaeology Office has initiated a climate change strategy to survey and document coastal sites affected by coastal erosion and sea level rise. Inland populations are less concerned about erosion.
    - Urban populations are prioritized for snowplowing.
    - Rural populations have fewer options for transportation. Impacts to rural infrastructure may be longer-lived and cause more significant disruptions. Rural internet is so poor in places that residents must travel to access resources. However, rural communities are well prepared for emergencies and have proven plans for power loss, opening warming centres, and other preparedness activities.
    - Over 90% of land area under provincial jurisdiction for road clearing.
    - There is a need to ensure Indigenous communities have support and can access resources.
    - Municipalities in PEI are constrained by limited financial resources and outdated municipal boundaries. One in three municipalities is smaller than five square kilometres in area. In addition, 63 percent of the Province is not incorporated. This creates significant challenges for local emergency preparedness and land use planning [255].

  - There have been significant efforts to provide a continuum of care for persons experiencing homelessness.
  - For clients of Seniors Housing Units in rural areas, backup generators have been purchased for all units, ensuring a heat water will continue to operate even during a multi-day power loss event. These systems worked well during Dorian, with limited failures which were fixed within hours.
  - In the past five years the Province has been hit with multiple emergencies, including a post-tropical storm that caused widespread damage to power and communications infrastructure, several ice storms that have caused power outages, some lasting days, a loss of all power to the region due to power issues in NB/NS and now, a pandemic which has caused widespread job losses in the region. In each case government has been able to ensure the safety and security of Islanders. The government has an all-hazards emergency plan that envisions many different disaster scenarios. Staff from the Office of Public Safety work with all departments to plan for these scenarios, ensuring departments and communities are prepared to work together in the event of a disaster. The government has an agreement with the Canadian Red Cross (CRC) that the CRC staff and volunteers will be available to assist during disaster events, this includes the opening of emergency shelters using CRC resources if required.
  - Emergency Measures is working more closely with the Island Food Banks to ensure vulnerable Islanders have access to food during emergencies. Emergency Measures Organization (EMO) has an all-hazards plan which includes an all of government response during emergencies through department emergency service officers. The government is requiring/supporting municipalities to prepare emergency management plans. Capacity Building funding is available to municipalities.
  - There is an inclusive communities initiative supported by Rural Development. There are also new projects on equity and impacts of climate change funded under CCF this year.
  - Residents who rely on private water supplies are particularly vulnerable to power disruptions (e.g., ability to cook, store food, access running water).
  - Island Food Banks are a valued community partner and are available to provide food to all Islanders, including those who are not traditional clients, in times of emergency. This was done during Hurricane Dorian and again at the beginning of the pandemic.
  - After action reporting from Hurricane Dorian showed that communications for vulnerable communities could be improved during sustained power outages. Improvements are being reviewed and implemented, including improved messaging processes to community shelters/warming stations and for persons experiencing homelessness.
  - Rural areas are more likely to have more difficulty recovering after an event with respect to power and transportation.
- Income Limitations on Sustainability:
  - Sustainable products (e.g., electric vehicles) are often expensive. Lower-income residents may need to choose the most affordable short-term option.
  - Access to nutritious food is not necessarily affordable.

Additional research findings on adaptive capacity factors

- Sense of community and connectivity with neighbours is an important factor in maintaining social stability in times of stress.
  - PEI’s strong sense of community and familiarity as a small and well-connected province

may be beneficial as related to social stability upkeep in the wake of a climate-related event.

Example existing adaptive actions to reduce societal risks

- **Cross-cutting:** During extreme events, the federal and provincial government can activate emergency response teams and set up emergency shelters. For example, during the 2008 ice storm, 10 emergency shelters were set up across the province to provide food, water, and shelter from the cold temperatures [193].
- **Erosion:** The visibility of coastal erosion damage on PEI provides an opportunity to teach students and the general public about the reality of climate change in an experiential and meaningful manner [25].
- **Drought:** Historically, farmers have been able to innovate and diversify in times of drought. These tactics may help reduce risk of food insecurity [239].

Suggested additional factors (per survey respondents)

The Workshop and Survey also identified additional potential adaptive capacity factors to consider, though these have not yet been rated:

- Outreach efforts to seniors.
- A network for enabling those in dire need of emergency water supply, energy, or preservation of frozen foods for families that rely heavily on seasonally harvested food stored in freezer could provide temporary relief.
- Food security could be improved through the addition of community gardens in every community.
- Water waste may be reduced through rainwater recycling programs for irrigation.
- E-bikes.
- Expanding the involvement of the general public in emergency planning or practice from emergency events may replace a sense of anxiety with a sense of confidents and make preparedness a routine consideration.

10.5. Infrastructure

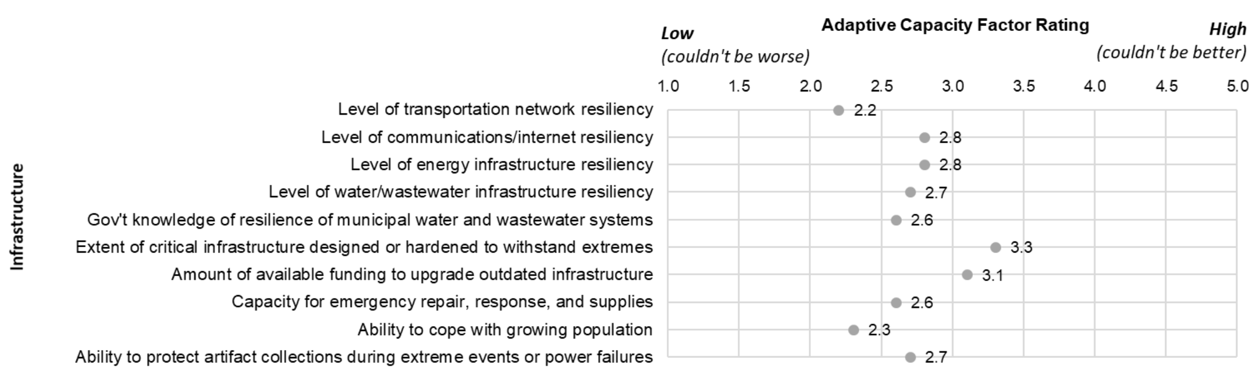

Figure 49. Adaptive capacity factor ratings for infrastructure.

The following information gathered from the workshop, survey, and desk research supports the infrastructure adaptive capacity factor ratings (Figure 49). Survey respondents also provided additional adaptive capacity factors to consider for infrastructure.

Current status of each adaptive capacity factor (per workshop participants)

- Highway Network Resilience:
  - New road designs are considering and seeking to accommodate increased storm water flows, but a lot of the exiting storm water infrastructure is susceptible to climate change impacts. There is a need for additional resilience, especially in coastal areas.
  - Where possible, coastal infrastructure (e.g., bridges, highways) is constructed higher to account for sea level rise. Inland infrastructure is currently designed for the 100-year event with provisions for climate change.
  - Coastal erosion and overland flooding are big items. A good portion of the provinces highway and bridge infrastructure networks were designed and constructed from 1960-1990, without accounting for climate change.
  - The channel to access the Malpeque Harbour has been prone to annual infilling and has incurred significant annual costs associated with dredging.
- Communications and Internet Redundancy:
  - Because technology is rapidly changing, adequate technologies are constantly improving.
  - Current projects should help with the addition of new fibre lines.
  - The government continues to work to address issues with high-speed internet in the rural areas. The ability to provide public transportation in some of the more remote areas will require creativity.
  - StarLink.
- Electricity Diversity:
  - More solar and wind infrastructure could help build in redundancy in the face of power failures, though residential solar systems do not operate during power outages. Energy storage is also needed. Solar and wind power has become more common and the government currently has solar incentives.
  - Mandating clean technology power generation could be an important step. On-Island small modular reactors to provide baseload energy. Moving toward smart metres and load adjusting can help to reduce reliance on power from New Brunswick. Incorporating vehicle to grid incentives may be an important step.
  - Home efficiency incentives are very important and will help with e-heating loads (e.g., increasing insulation, weather stripping).
  - There is continued investment in the on-Island electrical system to increase resilience to extreme weather events.
  - Some areas have completed upgrades to energy monitoring systems and energy diversification (e.g., City of Summerside).
- Electricity Generation During Interconnection Loss:
  - Without generation from wind there is not enough on-Island generation to serve all customers. It will be important to diversity renewable energy (e.g., solar banks), but renewable generation sources cannot supply all of load. There is also a need for a controllable source of electricity generation.
  - There is a need for generator capability at fuel tank farms, grocery stores, gas stations, etc.

    - The government installed a second set of cables connecting our electrical system to New Brunswick.
- Training in Infrastructure Design and Maintenance:
    - Design codes are moving toward inclusion of climate change resilience, while Building Codes already have provisions. The Bridge Code will include provisions in 2025. New wharves are built to accommodate sea level rise and storm surge.
    - There is political will needed to build and fund infrastructure design at higher standards.
    - Adoption of innovative parking lot designs would help relieve storm water systems.
    - There is a need to incorporate climate change considerations and solution-based learning in civil engineering courses.
    - Climate Lens Assessments have been completed for large projects. Climate change has been integrated into Environmental Assessment Technical Reviews.
    - New subdivision developments are considering storm water management with a net zero increase in peak flows off site as a target.
    - Some residences and public buildings have completed coastal hazard assessments.
    - Some farmers are building efficient barns.
    - Financial support is needed to train engineers and planners.
- Population Growth Could Strain Existing Infrastructure
    - PEI has momentum with increasing active transportation infrastructure to help reduce vehicle traffic.
    - Certain communities/municipalities are starting to encourage higher density housing.
    - There is a need to consider impacts on vulnerable populations and a need for a broad government approach to infrastructure management.
    - There is a lack of air travel cargo options.
    - New investments/retrofits must consider population growth.
    - Erosion and sediment control plans are now being provided for new subdivision developments, with the aim to minimize the impact of the development on downstream properties and watersheds.
    - The Province supports a coastal erosion monitoring network. Adaptive measures are being enacted to mitigate against coastal erosion (e.g., Souris Beach inter-tidal reefs). Flood and scour protective measures are being placed on coastal infrastructure.
    - The Province restricts coastal development based on erosion risk but does not have regulations in place to prohibit coastal development based on flood risk.
    - The biggest gap in water and wastewater infrastructure probably lies with private well owners where disruption in power supply can cause serious disruption to daily life. Smaller, privately owned central supply systems without back up power are also a concern, as are larger municipal systems.

Additional research findings on adaptive capacity factors

- Redundancy and strength of infrastructure can be key factors in its ability to withstand or recover from extreme events and other climate stresses.
    - PEI has limited direct ingress/egress points to the Island, which limits the Island’s

resilience to infrastructure disruptions. Critical infrastructure includes Charlottetown Airport (commercial), Summerside Airport (non-commercial), Charlottetown Port, Confederation Bridge, and travelling by ferry [261]. Delays or impacts to any of these major points of entry are a concern.

  - Confederation Bridge, which has been operational since 1997, was built to be resilient to severe storms [110].
  - Charlottetown Airport is the only major airport for passenger, tourism, and business travel. During the COVID-19 pandemic, flights have been reduced to once a day due to low demand [110].

Example existing adaptive actions to reduce infrastructure risks

- **Cross-cutting:** Maritime Electric will consider rising sea levels and storm surges, increased win and ice loading, and higher summer ambient temperatures in the design of future infrastructure [270].
- **Flooding and erosion:** Coastal Impacts Visualization Environment (CLIVE), a web-based interactive 3D tool was developed to allow Islanders to simulate coastal erosion and storm surge. This tool provides projections demonstrating which areas and infrastructure are most at risk on PEI [269]. Research is ongoing.
- **Flooding and erosion:** PEI Energy Corporation is working to monitor the shoreline around energy infrastructure, such as the Island's wind farm, as well as implementing solutions such as sandstone reefs to slow erosion and the impacts of storm surge events [271].
- **Flooding:** Several PEI communities have used the Clean Water and Wastewater Fund to implement flood and stormwater management projects. For example, the City of Summerside used the funding to extend storm sewers, and install new box culverts in areas prone to flooding [272].
- **Flooding:** Following heavy rainfall in 2014, the Province upgraded highway infrastructure sites to increase culvert size and have an adaptation plan for all future infrastructure maintenance and repairs to increase resilience and adapt [24].
- **Extreme cold/ice:** Wind generators in cold climates usually install "cold weather packages" to allow for lower minimum temperature thresholds, though this requires up to 200-300 kW of parasitic power per turbine at conditions below -20°C (which may be an issue if power outages occur due to ice storm damage). Cold weather packages can sometimes include active or passive de-icing or anti-icing systems for blades [188].
- **Ice storms:** For large ice storms, Maritime Electric will proactively notify off-Island crews in case assistance is needed to respond to the storm [273].
- **Freeze/thaw:** PEI has weight restrictions on certain roads for late winter and spring months to limit freeze/thaw damage to roads [226].

Suggested additional factors (per survey respondents)

Workshop and survey participants also identified additional adaptive capacity factors to consider in future assessments:

- It would be useful to have readily available messaging systems to communicate with utility customers about any limitations or instructions regarding services during periods of disruption to power or service.

10.6. Adaptation Priorities

After discussing the draft risk assessment results and adaptive capacity factors, workshop participants also identified adaptation priorities from their own perspectives. Their responses are listed below for additional consideration:

- Increased resiliency for the Island Electrical System. This means adequate on-island controllable generation to go along with renewables and maintaining or increasing the interconnection with other jurisdictions.
- Tax reductions to farmers who adopt organic, sustainable farming practices.
- Emergency housing crisis response. End Airbnb. Make hotels act as shelters during weather events.
- Agriculture - needs to be a coordinated, whole-of-government response with targeted, effective actions.
- Solar energy storage in batteries.
- Consideration of low-income and other vulnerable groups and solutions.
- Governmental response to climate change should have BIPOC employees.
- Need for province-wide land-use planning. Ability to plan and mitigate for these changes.
- Strategic land use to protect sensitive habitats.
- Increased efforts in mitigation/adaptation on coastal erosion and net sea-level rise.
- Housing supports for people who are underhoused.
- Transportation change support.
- Making stewardship a more profitable endeavor for island farmers.
- Accept the results and act on the results.
- Community engagement and knowledge-sharing- also data sharing.
- Limiting developments along sensitive shoreline ecosystems and wetlands (carbon sequestration, water filtration benefits).
- Acquisition of natural assets and championing of nature based solutions.
- Engagement of stakeholders for planning their watersheds.
- Stockpiling of critical supplies to safeguard critical supplies during supply chain interruptions.
- Wrap around healthcare supports for people with complex health concerns.
- Groundwater protection – without healthy water we can't exist.
- Redundancy of energy systems.
- Engagement of stakeholders for planning their watersheds.
- Preservation of groundwater resources.
- Maritime Electric – better incentives to generate/put energy back into the grid.
- Support for those experiencing ecological grief.
- Agriculture and aquaculture crop diversification and/or resilience. Protect what you have and look to new possibilities.
- Grants for individual landowners to reinforce their properties along shoreline.
- Support and seek Indigenous knowledge.
- Ability for individuals to generate own energy.
- Contingency plans for loss of transportation to the mainland.
- Strategic transition of crops/forests with climatic shift.
- Invasive species management and monitoring.

- increased funding to watershed groups for adaptation projects.
- Habitat protection and conservation of habitats including rehabilitation for resiliency.
- Engagement at community level in the Climate Action Plan to increase support.
- Do not allow deep water wells just to save a dying potato industry. Cons outweigh pros.
- Importance of water quality and quantity.
- Decisions based on science and best-practices and land use planning can be used to address some of these issues.
- Programs/initiatives that get people out of the status quo daily practices that don't help us adapt or mitigate climate change.
- E-bikes.
- Re-framing native and acceptance of loss of particular habitats/species.
- Shorten the work week from 5 days to 4 to decease emissions.
- Often community groups (e.g., watershed groups) are the ones who have to bring different government departments/agencies together.
- Reinforcing our forests and natural habitats.
- Build back better....as infrastructure ages and needs replacing...build to a standard that will be ready to handle climate change.
- Identify key forest communities and develop stand specific plans to address potential impacts. Don't be afraid of new management practices.
- Ensuring water/wastewater facilities will keep going and/or bounce back quickly after disruptions caused by climate change impacts.
- Support for mental health, support for individuals who want to do something but don't know where to start.
- Climate gentrification and protection of low-income individuals or those at risk of being priced out.
- Retrofits and expanding of barrier free spaces/public spaces in Charlottetown.
- Importance of diversification in environments, industries, adaptations.
- Support research and monitoring efforts.
- Support for farmers who would like to take a risk (take the jump) to diversify their operation - they may be locked into a contract or don't have the knowledge or capital to start making some changes.
- Redundancy in government funding programs - better collaboration or make a "one-stop shop" for program information?
- Bike lanes!!!
- Better funding formulas to encourage more individual solar power systems as payback is too high currently.
- Increase in rebate programs for homeowners to adapt at the lot level (flooding/energy/food).
- Adoption of LEED and universal design standards for all new construction in PEI.
- Continue to support online/remote working to reduce carbon emissions from personal vehicles.
- Alternative irrigation methods.
- An understanding of the connectiveness of our province and how this can be both an asset and liability.
- Utilizing vertical space for farming.
- Create a Youth Council on Climate Change (youth have great ideas!).

- Keep the moratorium on high capacity wells and support farmers wanting irrigation to diversify crops and support agriculture in a just transition to carbon neutral future.
- Make sure active transportation routes connect communities together.
- Retrofitting of older homes.
- Try microprojects to test ideas - instead of implementing all at once across PEI.
- Willingness to make the big/hard decisions that will allow for our future sustainability but will mean short-term economic loss and changes to lifestyle and way of life.
- Connection of islanders with their green assets and local environments.
- Teach sustainable living from a young age- add to the curriculum.
- COVID has highlighted just how important green space is to islanders.
- Tiny home programs - existing identity and acceptance of small homes in the city opportunity to capitalize and increase urban density/infill.
- Work inclusively and include Indigenous perspective.
- The water use issue, it's been a public debate for a long time already – continued debate and divide on it won't allow for good collaboration on adaptation strategies.
- Municipal capacity varies - many small municipalities cannot provide any services.

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