ADAPTING TO A CHANGING CLIMATE

2023 Current Environmental Issue STUDY RESOURCES

Part B

Adapting to a Changing Climate

Current Environmental Issue Study Resources- Part B

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2023 NCF-Envirothon New Brunswick

Adapting to a Changing Climate

Current Environmental Issue Study Resources- Part B

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4. Explain the concept of climate action co-benefits and how these can impact local communities.

Study Resources

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Climatic and Environmental Changes Affecting Communities in Atlantic Canada

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Abstract: Small rural coastal communities located in Atlantic Canada are vulnerable to the effects of climate and environmental changes. Major storms have impounded the coastline, causing much physical damage and affecting the socioeconomics of these communities that are composed of an aging population. The current study relays findings based on interviews completed in 2011–2012, following the 2010 winter storms in Atlantic Canada. It portrays the physical and social–ecological impacts affecting 10 coastal communities located in the provinces of Québec, New Brunswick, and Prince Edward Island. Semi-structured interviews held in these provinces are the basis for the contributions of this research. The findings reveal physical changes related to coastal erosion from high-wave impacts and storm surge causing flooding of the coastal zone. Also considered are strategies preferred and actually implemented by residents, such as building of protection walls, although undesirable. Due to funding constraints, however, many of these large-scale flood protection projects are not possible without governmental support. Instead, it is suggested that development be controlled and some respondents in this study upheld that relocation be used to alleviate the situation. Finally, more work is required to improve emergency planning. Better concerted short- and long-term responses need to be coordinated by local authorities and higher up in the government in order to ensure the sustainability of these coastal communities.

Keywords: climate change; physical landscapes; impacts; responses; adaptation; sustainability

1. *Introduction*

Adaptation strategies are complex to define because of the types of impacts caused by climate change at the landscape level that can be exacerbated by cross-temporal and -spatial environmental changes. For this reason, a well-rounded adaptation effort is required, particularly where multiple impacts are observed or expected. Along Atlantic Canada shorelines, coastal communities can expect rising sea level, increasing wave movements from storm surges or hurricanes (depending on the season), and high winds, causing erosion, flooding, and saltwater intrusion [1]. Storms, as low-pressure systems, are known to frequently hit the eastern Canadian shoreline and cause damage to coastal communities.

This paper focuses on work performed in Atlantic Canada after a series of storms that occurred in December 2010 and January 2011 to better understand how damage affected communities and what coastline changes were observed and discussed in those communities. This was an opportunity for a multidisciplinary team that included physical geographers to engage in sustainability research and thereby contribute to the environmental sustainability of small rural communities in Canada.

The existing literature suggests that further work is required to understand how to adapt to the potential of accelerated changes, such as sea-level rise, increased storm intensity, diminished winter ice cover, and increasing future coastal erosion hazards [2]. One of the strategies that has been promoted by international organizations, such as the United Nations and its affiliates (e.g., the United Nations Environment Programme or UNEP and the United Nations Development Programme or UNDP) and the International Union for Conservation of Nature (IUCN), is ecosystem-based adaptation to climate change. This approach is based on using biodiversity and natural ecosystems to enhance adaptation at the landscape level [3]. There are natural barriers that can be integrated into physical landscapes to oppose environmental change, such as wetlands and mangroves that can serve as natural reservoirs for floodwaters and for their roles in wave attenuation, making it a critical part of coastline protection [4].

In Atlantic Canada, most of the coastline is susceptible to erosion, except the "granite shores of Nova Scotia [which] are highly resistant to erosion and coastal retreat" ([5], p. 35). Most regions where this study was completed encompassed sedimentary rocks, which are more susceptible to erosion than the granites shores of Nova Scotia. This is particularly true for regions of the province of Prince Edward Island that are mainly composed of brittle soft sandstone [5]. As stated by Atkinson et al. [5], "gravel and mixed sand-gravel beaches and barriers predominate in this region [Atlantic Canada], except in the southern Gulf of St. Lawrence, where sand-rich glacial deposits, derived from soft sedimentary rocks, support the development of extensive sandy barriers with large dunes" (p. 31). Wave action especially during storm surges on these systems can, therefore, greatly accelerate the rate of erosion [5]. The main challenge for these ecosystems have been the increasing frequency of less intense storms (mainly in the summer and fall) that do not give enough time for sediments to accumulate and for the rebuilding of small dunes, leading to cumulative destabilizing effects on the coast [6].

As the frequency of storms in the past two to three decades is becoming especially prevalent at higher latitudes, it is expected that sediment loss and widespread coastal erosion will continue occurring [7]. This sediment movement along beaches provides a mechanism of interaction between erosion processes and flood risk [8]. However, when human activities interfere with the natural dynamic movement of the coast, the ecosystem may be irreversibly altered through erosion [9]. Savard et al. [9] report that "shoreline hardening with various protection methods (walls, rip-rap, dikes, groins, pavements and landfill) and dredging have altered coastal circulation patterns and sediment transport, potentially exacerbating shoreline erosion and reducing the ability to attenuate flooding" (p. 115).

In Atlantic Canada, milder winters are also affecting the rate of erosion due to changes in the timing of ice formation along the coasts and less ice cover with warmer sea surface temperature, leading to enhanced abrasion of the coast [10]. Because more variables than just sea-level rise and increased storminess are affecting coasts, research needs to examine other climatic parameters as well as combine marine-terrestrial erosion processes (see [10]). Subsidence (i.e., the post-glacial movement of the terrestrial crust) also affects Atlantic Canada leading to an amplified impact of sea-level rise [1].

Relatively stable surfaces are deposition-dominated, and areas where vegetation can establish, and act to further stabilize landforms. For instance, narrow beaches with low waves and low energy are less prone to erosion, which, allows for the establishment of upland vegetation (e.g., beachgrass, sea lyme-grass) [11]. Along active coastlines, coastal management plans need to be in-place and protection strategies are needed (e.g., vegetation protection, beach nourishment) to counteract coastal erosion and associated geohazards [12]. Human impacts, such as constructions, have affected sediment supply at the coast, leading to beach erosion and the landward retreat of sand barriers that protect the shoreline from storms [13] or could, alternatively, starve down-drift beaches of much needed beach protection [8].

Human impacts on coasts are among the multitude of factors that influence shoreline development. Activities such as vehicle use and foot traffic result in compaction as well as coarsening and steepening, as evident on Mobile Beach in eastern Newfoundland, Canada [14]. According to Catto [14], other stressors contribute to beach change and development, including natural local factors, such as the angle of wave attack and past event frequency. Several hurricanes [1] and strong (winter and autumn) storms (at least nine) impacted this coast between July 1989 and December 2005. Often, these physical landscapes are considered in isolation from socioeconomics and an integrated environmental approach is necessary, such as that of a social–ecological systems (SES) perspective [15]. Such an integrated approach is increasingly acknowledged as part of Anthropocene landscape evolution (e.g., [16]), during when humans have impacted landscapes around the world to such an extent that physical landscapes can no longer be considered independently of human inputs or alterations (cf. [17]).

Conversely, humans are affected by their landscapes and any changes that occur due to climate and environmental changes will impact these natural landscapes, especially in resource-dependent communities (e.g., fishing villages, etc.). For this reason, landscape change needs to be coupled with human dynamics, as for example is the case with affected property values along coastlines that have high rates of erosion and, hence, where stabilization costs are high [18]. The integration of social and ecological systems can contribute to an understanding of how to manage adaptation strategies for a greater sustainability of these coastal communities.

This paper examines the physical landscapes that are visible from small rural communities in the provinces of Québec (QC), New Brunswick (NB), and Prince Edward Island (PEI) located in Atlantic Canada. In particular, the focus is on any landscape change stemming from climatic impacts that are associated with the 2010 winter storms. Landforms, including cliffs, beaches, and marshes will be examined from the perspective of residents' perceptions of change. Specifically, based on interviews conducted in 2011–2012, perception- and experience-based views will be gauged in order to determine any environmental change derived from the winter storms and effects (e.g., storm surge, high waves, etc.) that are linked to climate change (sea-level rise, more intense storm activity, etc.) that impacted these communities through flood and coastal erosion hazards. Risks created by these include damage to people and property as well as infrastructure and affect the insurance industry and general socioeconomics as well as the physical environment locally to regionally within the study area.

2. *Materials and Methods*

This study was part of a larger project called Coastal Community Challenges-Community-University Research Alliance (CCC-CURA), which aimed to develop adaptation plans and attempted to improve the resilience of these communities (see [19]). Prior to any intervention, interviews were completed in 10 communities located in QC, NB, and PEI (Figure 1). These coastal communities were selected on the basis of their interest to be part of the project; having populations of less than 10,000 inhabitants, and many less than 3000, half of them having been affected by the series of storms in December 2010 and January 2011; and not received prior interventions from governments or institutions regarding climate change adaptation. All of them mainly relied on natural resource (i.e., fisheries, forestry, and agriculture) activities as income and all these communities had aging populations.

Interviews were held singly and in couples with 74 residents of these communities in their native language (French or English). Participants were originally identified by personal and public invitations; and a snowballing sampling strategy was subsequently deployed in order to increase the sample size that was based on interviewee referral. The number of interviews was limited by the concern of saturation of interviews, as these were small communities and there was currently a diversity of projects (not only on climate change) in those communities. Prior to doing the interviews, human research ethics was sought at universities and pretests were completed in one of the communities.

Questions were based on six research themes: (1) experience with storms; (2) financial capital; (3) social capital; (4) vision for the future; (5) information sources; and (6) understanding of what is resilience. In this study, the authors targeted the themes and information that attested to the state of the physical environment and how landscapes were affected by the 2010 winter storms. The most relevant research themes addressed in this paper tended to be themes (1) and (4) because of their focus on experiences (and any perceptions that can be derived from these) as well as future vision based on their experiences, as for instance views of coastal protection. Perception can also be gleaned from any lessons that were learned based on experiences.

The demographic characteristics of the study sample were tracked for each person or couple; and the influence of gender, for example, has already been published by the authors [20]. Semi-structured interviews held in people's homes lasted 40–75 min. They were completed by two research assistants, who kept the same order of questions, and were audio-recorded. They were then transcribed by a research assistant and verified by one of the researchers. Finally, the data were coded using NVivo v.10 software (QSR International) by one researcher and rechecked by a second one. As some of the interviews were in French, they were later translated into English.

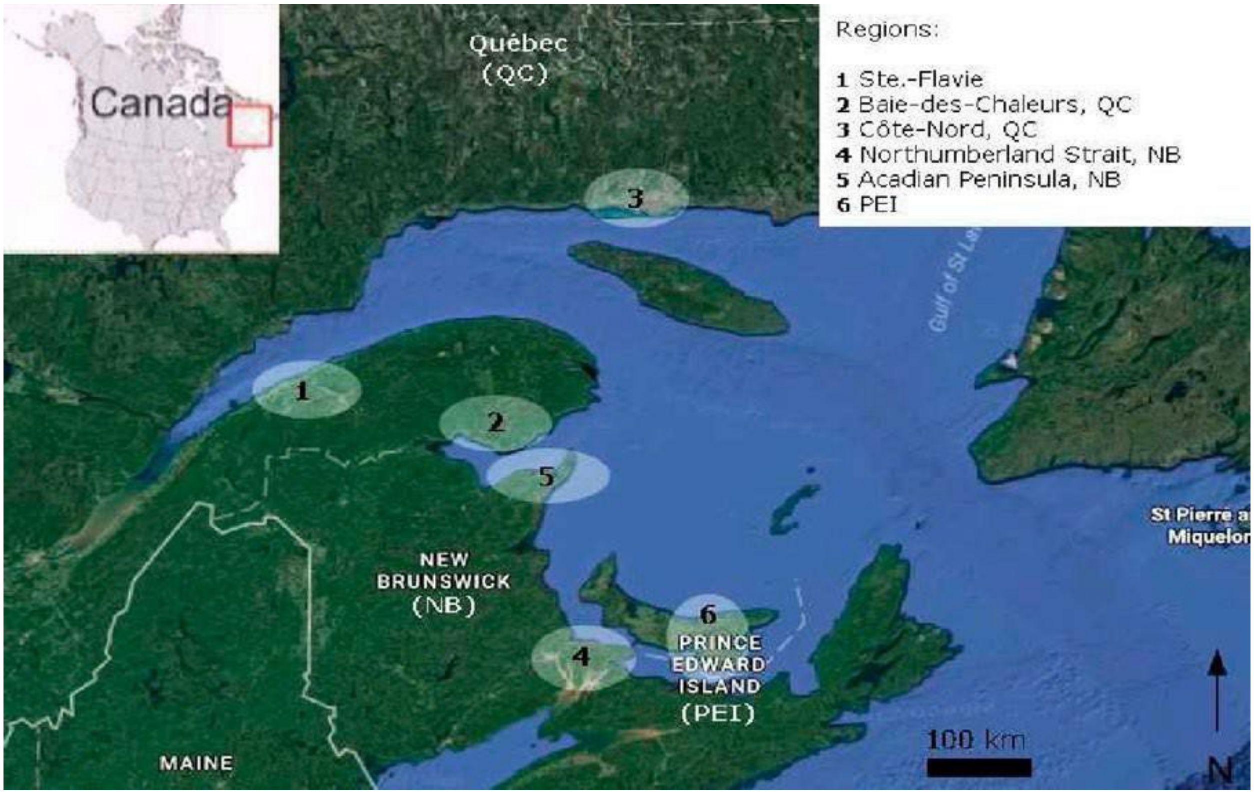

Figure 1. *Map of the study communities in the study area.*

3. *Results*

Communities experienced different levels of storm damage following the 2010 winter storms. Those located in Rivière-au-Tonnerre and Bonaventure (QC), Shippagan and Dundas (NB), and Stratford (PEI) experienced none to very little storm damage. The damage mainly affected the communities of Ste.-Flavie and Maria (QC), Ste.-Marie-St.-Raphael and Cocagne-Grande Digue (NB), and Morell (PEI), where there were various impacts from storm surge causing flooding and erosion. It appeared that the most impacted communities were located in Ste.-Flavie and Maria (QC), where there was the greatest amount of damage, including houses on the coast being swept by the storms.

When asked about any observed changes, participants reported that the most notable observed changes had occurred in the last 5–10 years. Participants believed that there is an increasing intensity of storms in this region and a cause to become more nervous than before, particularly following the 2010 storms: “And it is the intensity of the experience that makes this a moment. The intensity and then the repetition of the experience” (R.C., Baie-des-Chaleurs, Bonaventure). Although this participant was not impacted by the 2010 storms, the sentiment remains the same as affected people because members of his family were seriously affected. These impacts were, therefore, evident not only at the local (community) level but also at the regional scale (R.C.’s family was in other communities of the region). Commonalities related to stronger (more intense) storms that were shorter in duration, but produced heavier rainfall and increased erosion. In the Acadian Peninsula, there was less sea ice reported in the winter. This change in sea ice was quite important, as it increased damage during storms in the winter, when wave action was stronger at the coast.

Table 1 provides a summary of the regional weather patterns that could be contributing to landscape patterns. It is clear (from Table 1) that most interviewees observed and experienced a greater number of storms and that this had an impact on the landscape. Erosion, for example, was a major factor. Moreover, human activities appeared to have exacerbated the situation. More runoff was evident and attributable to deforestation and agriculture, indicating that human impacts are having an effect on the physical landscape. Owners of properties on the shore in Ste.-Flavie were faced with a new reality during the December 2010 storms when some houses were destroyed by coastline erosion. The interviewees of this community were aware of the power of the ocean and its effects on the shoreline.

Region	Weather	Landscape
Ste.-Flavie	more storms unpredictable weather	erosion loss of land
Baie-des-Chaleurs, QC	longer autumn, winter more intense storms [1] water rises high	erosion river rising in autumn (not spring) more runoff [2]
Côte-Nord, QC	less winter snow unpredictable weather [3]	erosion more sand on beaches [4]
Northumberland Strait, NB	higher tides stronger waves stronger winds increase temperature increased rain intensity extreme summer weather increased storm frequency increased storm severity	changed river flow reduced streamflow increased water temperature floodwater indundation higher water level
Acadian Peninsula, NB	reduced sea ice [5] stronger winds bigger storms higher, stronger tides more summer drought milder winters autumn, winter start later less snow	more erosion/loss of land [6] higher seawater levels [7] overflowing rivers/creeks
PEI	more intense storms shorter storms changed wind direction more rain less snow shifting seasons less ice	more erosion increased river siltation

[1] More heavy rain in a shorter period of time. [2] Attributed to deforestation. [3] Especially temperature. [4] E.g., Ste.-Flavie. [5] Most common observation in this region. [6] Second most mentioned observation in this region. [7] E.g., Shippagan.

Table 1. *Physical changes that participants observed along their coastal communities.*

In Table 2, social and ecological patterns for each region of the study area are summarized. It shows that on the ecological side, as most of these communities are fishing villages, natural resources were a significant concern and the interviewees have seen changes related to fishing. The social changes varied among communities and reflected their main concerns in their region. For example, in Ste.-Flavie the damage caused by the storms of 2010–2011 led to more conflicts and social stress. In the Acadian Peninsula, however, the perspectives were ambivalent, spurred by more cottages and positive issues to greater stress in the fisheries sector with larger boats.

Region	Ecological	Social
Ste.-Flavie	loss of lands coastal restoration	more nervousness social conflicts desire to reduce environmental damage out-migration
Baie-des-Chaleurs, QC	none noted	greater awareness more nervousness
Côte-Nord, QC	none noted	more tourism investments more development [1] desire to reduce environmental damages [2] out-migration [3]
Northumberland Strait, NB	planting new species [4]	thinking more about storms
Acadian Peninsula, NB	new aquatic species [6] habitat change variation in lobsters harder to collect shellfish	more environmental perspectives [5] fish-processing plants more aware of coastal erosion changed perspective of coastal living but still more cottages on coast larger fishing boats
PEI	shrinking Atlantic salmon [7] strawberries grow earlier more birds overwintering different bird species die back of white spruce more cord grass growing	community closer due to landing built [8] rise in consumerism

[1] More chalets since 1978. [2] At community level. [3] Noted in the past 1–2 years. [4] Those that were not planted 10–15 years ago, e.g., peaches, cherries. [5] Especially among young people; over 50 years. [6] E.g., sharks. [7] Fewer on southern range. [8] In St. Peter's.

Table 2. *Social–ecological changes based on participant observations.*

3. *Discussion*

The regional analysis presented in this study reveals interesting patterns affecting physical landscapes (environment) and socioeconomics that are important from a sustainability standpoint. Most respondents observed that storms are occurring more frequently in Atlantic Canada and several also stated that they were more intense, although current data do not completely support their perceptions in terms of intensity [2]. These storms have led to coastal inundation and enhanced erosion, causing flooding and property damage as well as reduced landmass at the coast that is available for occupation and development. For small communities with limited tax-based financial support, the loss of land and having houses that need to be relocated due to erosion can become a major financial burden and a strong political issue [21]. Vasseur and Catto [1] report that in Atlantic Canada, rural communities do not have the financial capacity to relocate houses or build protection walls and differ greatly from larger urban centers (e.g., Halifax) in the effect. It is important to note that most of these communities have an aging population, with more than 15%

being over 64 years old and increasing, due to youth out-migration (compared to 13% in the rest of Canada) [1]. In addition, as stated by [1] and [19], people affected by these storms have suffered not only financial losses (due to infrastructure damage and unemployment), but also in many cases mental health issues, including depression. Ste.-Flavie represents a good example of these challenges, where the aftermath of the 2010 storms included significant out-migration of youth and families, one divorce, and increased social conflicts [19]. Its population decreased by 3.4% and 225 out of 884 inhabitants are over 65 years old (25.4% versus 18% for the rest of the province). Similar trends are found in Bonaventure with 26.5% versus 18%, Shippagan with 24.6%, and Cocagne with 25% being over 65 years old, while the rest of NB is 19.9% [22].

A combination of natural and human effects should be considered when interpreting the damage, as both have cumulative effects when storms hit the coasts. For instance, the shape of the shoreline may affect the recovery of the shoreline. Communities built very close to a low coastline, like in Cocagne, Ste.-Flavie, and Maria, can have a greater potential for flood damage and could expect buildup effects of floodwaters due to shoreline shape and sea level rise. More research is needed to address the effects of shoreline shape in order to inform territorial or landscape planning and any future relocation policy.

Communities located in NB also observed more intense rainfall, with rain falling heavily over a shorter period of time. In a previous study, [23] reported that people in NB have noted climatic extremes in the summertime, such as too much wetness or drought. They explained that such seasonal changes have affected river flow, such as that of the Bouctouche River and the Little Bouctouche River, in particular, the water level of which has been reduced. This is possibly attributable to dry spells when river temperatures increase to 30 °C, leading to shallower rivers and infilling with debris and siltation. In the Acadian Peninsula, fishing seasons have been affected; for example, fishing herring is now possible in August (rather than July). The location of shrimp has changed farther offshore due to warmer near-shore waters. This is also affecting lobsters, that are now bigger due to milder winters and because they are eating more. However, it is more difficult to collect shellfish because of the lack of low-water areas in places that are undergoing sea-level rise and/or subsidence. Places are affected differently, for example, L'ile-aux-Puces is being inundated by water. Reduced winter sea ice is prohibiting people from walking on beaches in January; for example, they can no longer walk out 4.8 km (3 mi) since 1998. Also frequently mentioned were higher seawater levels (e.g., [19]), with sunken places evident in Shippagan, Lameque, etc., and with cottage waterlines affected as water creeps up the shore. Consequently, people are more aware of erosion and coastal change, causing reduced demand for real estate (after 2008) in affected areas. Greater affluence is also influencing people living by the coast who want to be right by the sea and have their own private beaches [23].

In PEI, seasons are also shifting in such a way that freezing does not occur until December. Moreover, wind is coming from a different direction (more southerly and from the southwest rather than from the west) and wave action is changing due to ice severity decline in winter [24]. In PEI, people are questioning whether human-made coastal defenses (hard engineering) are actually beneficial or whether this has worsened problems associated with coastal erosion. However, built infrastructure, such as a landing built in St. Peter's, aids movement and thereby reduces isolation. The latter point is important when considering evacuation routes and procedures.

Future challenges for resource-dependent communities involve changing climatic influences of seasonality affecting fish and seashell species, such as Atlantic lobster [25]. In addition to these biological challenges, there are also physical ones, such as damages to buildings and infrastructure [1]. Community infrastructure, including storm wastewater systems, groundwater sources, roads, bridges, the power grid, etc., need to be repaired and maintained, and government inputs are required for this. Options to address the physical challenges include some expensive solutions, as for instance protection measures in order to deal with erosion, flooding, wind, etc.; however, many require government inputs to be able to afford expensive hard defenses, even though some people already incur some economic costs of their own for this at the individual-to-household level [21]. These aged communities are financially dependent and cannot resolve these issues on their own. On the other hand, retirees are available to volunteer in their communities and can work toward improving the situation where they live.

Governance has become an issue in small rural communities that are not incorporated in municipalities. In the Northumberland Strait of NB, Cocagne, and Grand-Digue are local service districts, and there are conflicting views as to whether community members or the government should take more responsibility [26]. Developing regional emergency management plans can be tricky, as it requires the provincial government to give its approbation. This can frustrate communities that do not have the financial means to contribute to a community generator, for example, in case of emergency [19]. In most coastal communities, in order to develop sustainable plans that consider social, ecological, and physical features of their landscape, there is a need for accompaniment by experts and organizations to enhance governance and improve resilience [27].

Alternative solutions to coastal physical impacts were provided, including relocation/retreat (moving out of the risk zone in the community or out of the region). Coastal retreat was an option that was considered by some respondents: "The long-term challenge is to withdraw quietly from the sides and really adapt our way of life in function of this" (Acadian male, Petite Lameque, affected by 2010 storms, 2012). However, not everyone favored relocation as a solution. In QC, people from Ste.-Flavie felt that hard decisions were needed, but that personal choices were involved rather than a concerted community effort. In most coastal communities, protection (retaining) walls and other hard structures have been deemed important to bring a sense of safety to people [28]. However, as stated by Savard et al. [9], "hardening of the coastline by rigid, linear, coastal protection structures can also lead to rapid loss of biodiversity and contribute to coastal squeeze by trapping coastal habitats and ecosystems between the rising sea and landward [human]-made barriers. Another disadvantage of hard-protection measures is that they are generally irreversible" (p. 136). In general, people were aware that these structures might not be efficient in the long term and, in fact, could become a maladaptation to erosion; however, they were often seen as a quick fix by some of the participants in this study. For example, in the Baie de Kamouraska, QC, the construction of dykes to increase agricultural land along the coast has led to coastal squeeze and loss of beaches and intertidal zone [9]. How to pay for these structures remains a challenge and, as stated by [19] and [28] in regards to these communities, most people do not want to pay and are instead expecting that the government cover the costs. Participants in this study are part of aging communities that mainly rely on natural-resource extraction as economic activities, and they cannot afford coastal defenses

4. *Conclusions*

There are many physical changes along the coast of Atlantic Canada that have been identified with communities in the course of this research. These landscape alterations stem from extreme events, such as heavy rainfall, storm surge, and high waves that have increased under climate change, leading to coastal erosion and affecting the natural and built environments. They have also been reported in several assessments (e.g., [1,2]). It is, therefore, clear that alternative solutions are necessary to adapt to climate change and ensure the sustainability of these coastal communities. Relocation does not suit everyone, however, and people encourage increasing awareness and education so that community members can make informed hard decisions regarding which actions to take. Some respondents called for government action to make important decisions and for concerted efforts in response to climate-evoked landscape change. The expense of hard defenses at a time when governments are strapped for funds may be unrealistic, however, and local efforts, including soft-engineered responses, are preferred. Solutions need to accommodate short- and long-term trends as well as respond to physical and social problems.

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Conflicts of Interest: The authors declare no conflict of interest.

VIDEO: Sea Level Rise and What You Can Do About It!

https://youtu.be/l2r-1WxeKg0

SEA LEVEL RISE

ATLANTIC CANADA

Global Sea Level Rise = the average amount water levels are rising in all of the oceans on the planet

By **2100** global sea levels are expected to rise approximately **1 m** above current levels.

Sea-level rise predictions are presented by the Intergovernmental Panel on Climate Change (IPCC). The **IPCC ASSESSMENT REPORT 5**, published in 2013/2014, is a result of the collaborative efforts of **830 scientists** from over **80 countries** along with **1,000 contributing authors** and **2,000 expert reviewers**, assessing more than **30,000 scientific papers**. The AR5 is over **4,800 pages long** and is the **MOST COMPREHENSIVE** assessment of climate change ever undertaken.

2 Main reasons

sea levels are rising globally:

These are **both** caused by a **warming Earth**.

GREENHOUSE GASES → WARMER EARTH → INCREASE IN SEA LEVEL

1 Thermal Expansion = The oceans increase in volume and take up more space as they heat up.

As a pot of water is heated, the water molecules move faster. The faster they move, the more space they take up, causing volume to expand.

The ocean is absorbing **90% of the heat** from global warming.

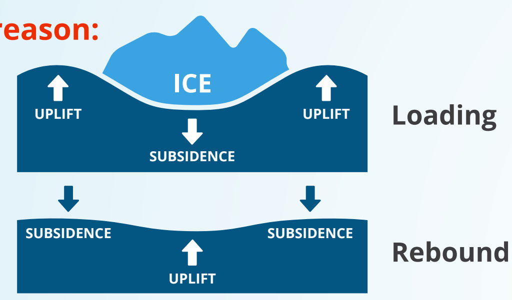
2 Melting Land Ice

(glaciers, ice caps, ice sheets)

As temperatures rise, land ice meltwater enters the ocean and causes sea levels to rise.

In **Atlantic Canada**, sea levels can be different than global averages.

Main reason: VERTICAL LAND MOVEMENT



During the last ice age, **Canada** was covered in a **massive glacier**, which was so heavy that it gradually caused the center of the country to sink and the edges to rise. Once the glacier melted, the center began rebounding and the **edges began sinking**. **THIS IS STILL HAPPENING TODAY!**

= **Greater** SEA-LEVEL RISE AMOUNTS for **Atlantic Canada**

For southern parts of **Atlantic Canada** this means that not only are sea levels rising but **land** is also **subsiding**.

70% of the **population** of **Nova Scotia** lives in coastal communities.

Nova Scotia will experience the **greatest** local **sea-level rise** amounts in Atlantic Canada.

No place in **Prince Edward Island** is farther than **16 km** from the coast

60% of the population of **New Brunswick** lives within **50 km** of the coast.

90% of the population of **Newfoundland & Labrador** lives in coastal communities.

Inundation

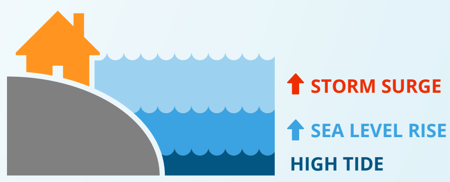
A permanent submergence of the coast and a new normal water level.

Coastal Flooding + Storm Surge

Storm surge can cause higher than normal water levels that temporarily flood homes and properties.

Coastal Erosion

The degree of coastal erosion depends on factors such as exposure to wind and waves, the strength of those waves and the type of coastal landform (beaches erode more easily than rocky cliffs!). This is likely to increase in areas where sea ice is reduced in the future.



Salt Water Intrusion

Occurs when salt water seeps into fresh groundwater. It can impact drinking water and freshwater species and cause coastal vegetation to die.

Extreme Water Levels

(sea-level rise + storm surge + tide level + seasonal oceanographic variability) are one of the most damaging impacts of sea-level rise.

Atlantic Canadian Coast

IN NUMBERS

Atlantic Canada has over **50,000 km** of coastline.

As of 2001, over **60%** of the **population** in **Atlantic Canada** lived within **50 km** of the shoreline.

km of Coastline:

NEWFOUNDLAND & LABRADOR	29,000
NOVA SCOTIA	13,300
NEW BRUNSWICK	5,500
PRINCE EDWARD ISLAND	3,200

What Can You Do?

Team up with other community members to push for change in your area.

Think before you build or buy.

Visit **www.sealevelrise.ca** to find local sea-level rise adaptation tools that can help you start planning for sea-level rise in your community.

The ECoAS PROJECT — **Educating Coastal Communities About Sea-level Rise** | www.sealevelrise.ca #SLRandYou

PROJECT PARTNERS: Ecology Action Centre; Fisheries and Oceans Canada / Pêches et Océans Canada

VIDEO: On the Rise- Conservation & Sea Level Rise in Atlantic Canada

https://youtu.be/IA6KNU4zkhs

Net-Zero Emissions by 2050

The transition to a cleaner, prosperous economy needs to be both an immediate priority and a sustained effort over the years and decades ahead. Canada must keep innovating to meet this long-term goal, strengthening and building on existing measures that fight climate change and transform the economy.

To avert the worst impacts of climate change, the Government of Canada is committed to achieving net-zero emissions by 2050.

This goal will require support and engagement from all parts of society, including provinces and territories, cities, Indigenous Peoples, youth, and businesses.

What is Net-Zero?

Achieving net-zero emissions means our economy either emits no greenhouse gas emissions or offsets its emissions, for example, through actions such as tree planting or employing technologies that can capture carbon before it is released into the air. This is essential to keeping the world safe and livable for our kids and grandkids.

Canada has joined over 120 countries in committing to be net-zero emissions by 2050, including all other G7 nations (United Kingdom, United States, Germany, Italy, France, and Japan), A number of provinces and cities have already made net-zero-by-2050 commitments, including Guelph, Vancouver, Hamilton, Toronto, Halifax, Newfoundland and Labrador, and most recently Quebec. Prince Edward Island has also pledged to reach netzero greenhouse gas emissions by 2040. Nova Scotia and British Columbia have put into place, or plan to put into place, provincial net-zero-by-2050 legislation.

Canada's plan to reach Net-Zero

The Canadian Net-Zero Emissions Accountability Act, which became law on June 29, 2021, enshrines in legislation Canada's commitment to achieve net-zero emissions by 2050. The Act ensures transparency and accountability as the government works to deliver on its targets. The Act requires public participation and independent advice to guide the Government of Canada's efforts.

2030 Emissions Reduction Plan: Clean Air, Strong Economy

Building on the actions in Canada's strengthened climate plan (2020), and the Pan-Canadian Framework (2016), the 2030 Emissions Reduction Plan (2022) provides a roadmap to how Canada will meet its enhanced Paris Agreement target to reduce emissions by 40-45% from 2005 levels by 2030.

VIDEO: Climate Action Co-Benefits

https://youtu.be/9QQI3yn9_Zc

2023 NCF-Envirothon New Brunswick

Adapting to a Changing Climate

Current Environmental Issue Study Resources- Part B

Key Topic #2: Social and Economic Impacts of a Changing Climate in Canada

5. Explain the impacts of a changing climate on human health.
6. Describe how the Canadian government and Indigenous peoples will partner on climate change challenges.
7. Explain the importance of social elements that must be taken into consideration when planning for climate change, such as disproportionate impacts to Indigenous communities, aging populations, residents' sense of place, personal and spiritual connections to the land, et cetera.
8. Describe the economic impacts of climate change in New Brunswick/Atlantic Canada (depending on what resources are provided).

Study Resources

Resource Title	Source	Located on
Adaptive Communities	Government of New Brunswick, 2022	Page 20
Physical and Mental Health Impacts of Climate Change in New Brunswick	*Climate Data Canada, 2022*	Pages 21-24
Healthy Climate, Healthy New Brunswickers	*Conservation Council of New Brunswick, 2019*	Pages 25-31
Impact of Climate Change on Human Health	*National Center for Environmental Health, 2022*	Page 32
VIDEO: Adapting to Sea Level Rise	*Indian Island First Nation, New Brunswick-Climate Atlas of Canada, 2018*	8 minutes; Page 33
Canada's Partnership with Indigenous People	*Environment and Climate Change Canada, 2020*	Pages 34-38
Tip of the Iceberg: Navigating the known and unknown costs of climate change for Canada	*Canadian Climate Institute, 2020*	Pages 39-45

Study Resources begin on the next page! ➡

Adaptive Communities

Can Reduce Climate Change Impacts on Health

Protect **Water Quality** by ensuring healthy ecosystems for both plants and animals.

Increase **Food Security** through support for growin g food at home and buying local products.

Provide places of refuge for those at greater risk to cope with **Extreme Temperature and Extreme Weather Events**.

Address **Social Inequities** and build social connection s to reduce challeng es for those at greater risk.

Improve **Air Quality** by investing in green energy and supporting active transportation.

Prevent illness from **Ticks and UV Radiation** by using and educating others on outdoor safety practices.

Support local efforts to build **Community Well-being** and community resiliency.

Populations at greater risk of health challenges from climate change due to social and other factors:

- Older adults
- Pregnant people and young children
- People who are underhoused and socio-economically disadvantaged
- Socially isolated people
- People with pre-existing health issues
- Systematically marginalized groups
- Outdoor workers

Developed for the New Brunswick HealthADAPT Project 2022

New Nouveau Brunswick CANADA

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Health Canada Santé Canada

The views expressed herein do not necessarily represent the views of Health Canada

Physical and Mental Health Impacts of Climate Change in New Brunswick

In New Brunswick, as elsewhere, climate change is now a public health problem. The occurrence of extreme weather events (such as floods causing coastal erosion and damage to infrastructure, etc.) worsen the physical and mental health conditions of the population.

Summary

A report from the Conservation Council of New Brunswick (CCNB) explores how climate change will affect people's physical and mental health. The study combines climate projections for the period 2021-2050 and existing community health profiles for 16 communities in New Brunswick.

Context

In New Brunswick, as elsewhere, climate change is a public health problem. Changes in temperature and precipitation cause daily inconvenience (with the potential to increase the risk of contracting Lyme disease, worsen allergies due to pollen, eco-anxiety, etc.), and the occurrence of extreme weather events (such as floods causing coastal erosion and damage to infrastructure, etc.) worsen the physical and mental health conditions of the population.

Rising Temperatures

Temperature influences natural cycles, our lifestyles, and our health. Heat waves can cause the death of elderly and sick people, as well as an increase in domestic violence and criminal activity.

In New Brunswick, average temperatures in the 16 communities surveyed will increase in the future, particularly during the winter and spring months. These increases will add to existing warming.

By 2050, extremely hot days will become more frequent in the province. For example, the number of days when temperatures reach at least 30 degrees Celsius in Fredericton will double or triple over the 2050 horizon depending on the RCP (Representative Concentration Pathway) selected.

New Brunswickers can also expect to experience significantly fewer frost-free days. These mild temperatures will increase the risk of exposure to ticks that carry Lyme disease. In 2017, 29 confirmed cases of Lyme disease were reported to New Brunswick Public Health, more than triple the eight cases reported in 2016.

A minimum of 2800 degree-days above 0°C has been identified as necessary for tick survival. Thus, the possible extent of Lyme disease occurrence can be mapped using this information

Increase in Precipitation

Climate projections predict an increase in average annual precipitation in the future. More rain in winter in northern New Brunswick, combined with warmer temperatures in spring, could lead to a greater risk of flooding during the spring flood, similar to that which prevailed in this province in 2018 and 2019.

Effects on Health

The Canadian Association of Physicians for the Environment (CAPE) reported some important health effects of climate change across Canada (Table 1). Rising temperature, changes in precipitation, changes in frequency and intensity of extreme weather events have an effect on air quality, forest fires, heat waves, habitat of disease vectors, crops, which in turn, increase the exposure of the population at risk.

Table 1 Examples of climate-related health impacts and causal pathways of relevance in Canada

Health Outcome	Hazard/Exposure	Environmental Effect	Climate Change Driver
Cardiovascular disease	Air pollutants	Formation of air pollutants	Rising temperatures
		Forest fires	Extreme weather events
		Droughts and dust storms	Changes in precipitation
	Extreme heat	Frequency and duration of heat waves	Rising temperatures
			Extreme weather events
Respiratory conditions	Air pollutants	Formation of air pollutants	Rising temperatures
		Forest fires	Extreme weather events
		Droughts and dust storms	Changes in precipitation
	Extreme heat	Heat waves – hot days & warm nights	Rising temperatures
			Extreme weather events
Allergic reactions	Pollen & spores	Longer growing season	Rising temperatures
	Mould	Heavy rainfall & flooding	Extreme weather events
Heat stroke/exhaustion	Extreme heat	Frequency and duration of heat waves	Rising temperatures
			Extreme weather events
Cancer	Air pollutants	Formation of air pollutants	Rising temperatures
	UV radiation	Ozone layer depletion	Temperature-related changes
		Longer summer season	Rising temperatures
Traumatic injuries	Physical trauma, dangerous travel, drowning, violence	Floods, forest fires, tornadoes, hurricanes, storm surges, winter storms, melting permafrost	Extreme weather events
			Rising temperatures
			Sea level rise
Vector-borne diseases	Infected mosquitoes, ticks and rodents	Expanding habitat conducive to disease vectors	Rising temperatures
		Conditions for vector propagation	Extreme weather events
			Changes in precipitation
Food-borne illness	Food-borne pathogens/toxins	Contaminated food/flood waters	Extreme weather events
		Conditions for bacterial growth	Rising temperatures
Water-born illness	Water-borne pathogens/toxins	Contaminated water sources	Extreme weather events
		Conditions for bacterial growth	Changes in precipitation
Malnutrition	Food insecurity	Drought, crop loss, biodiversity loss	Rising temperatures
	Water shortages	Floods	Extreme weather events
Mental health stress & anxiety	Population displacement	Floods, forest fires, hurricanes/ tornadoes, droughts, heat waves	Rising temperatures
	Multiple stressors	Prolonged and repeated climate-related events	Extreme weather events
	Climate-induced stress	Catastrophic events	Sea level rise
	Mood and behaviour effects		Changes in precipitation
Socio-economic impacts	Social disruptions	Floods, forest fires, hurricanes/ tornadoes, droughts, heat waves	Rising temperatures
	Loss of incomes and culture	Prolonged climate-related events	Extreme weather events
	Quality of life	Catastrophic events	

Source: Perrota, K. (2019). Canadian Association of Physicians for the Environment

New Brunswickers are at risk of the adverse effects of climate change on mental health. While damage to components of social infrastructure has many serious consequences, climate-related hazards may have significant psychological and psychosocial consequences, such as:

- Trauma and shock
- Post-Traumatic Stress Disorder
- Stress
- Anger
- Tensions in social relations
- Aggression and violence
- Depression
- Anxiety and eco-anxiety
- Suicide ideation
- Substance misuse
- Loss of a sense of place
- Loss of autonomy and control
- Feelings of helplessness, fear, fatalism and worry

Adaptation strategies

In New Brunswick, about 40% of households use a stand-alone or central air conditioner, compared to almost 80% in Ontario and Manitoba. Elderly or ill people, especially if they have low incomes, may have less tolerance for extreme heat. Hence the importance of the Heat Alert and Response System (HARS) to manage health risks. This tool has three alert levels based on three factors that characterize an extreme heat event: intensity, duration, and exposure to heat during the night.

There are provincial public education programs in the province regarding the growing presence of blacklegged ticks carrying Lyme disease (such as Be Tick Smart and Lyme NB), as well as the risks of flooding.

Post-tropical storm Arthur in July 2014 and the ice storm of January 2017 in the Acadian Peninsula made it possible to learn lessons to help the most vulnerable. In Lamèque, door-to-door visits during the ice storm revealed worrying levels of isolation for people on low incomes. Church leaders at Notre-Dame-des-Flots responded by building a community kitchen, shower and laundry room, and offering free meals and counseling. These types of services are useful for building relationships and building community resilience.

Local food self-sufficiency has potential benefits for food security, particularly if climate change disrupts global food production and imports of food to places like New Brunswick become more expensive.

In terms of mental health, researchers from the American Psychological Association recommend that the authorities help people to believe in their own resilience, to encourage optimism, to cultivate adaptive capacities, to maintain practices that help make sense of and promote connectivity with family, place, culture and community.

Key takeaways

• Future climate scenarios show significant increases in temperature and precipitation for the 16 communities studied in New Brunswick.

• Climate change has and will have an impact on the physical and mental health of residents, particularly the very young, the elderly, the isolated and the low-income.

• Various coping strategies and programs can help mitigate these effects, including heat alert systems, public education programs on various health risks, self-help and mental health support initiatives.

Healthy Climate, Healthy New Brunswickers

A proposal for New Brunswick that **cuts pollution and protects health**




Dr. Louise Comeau

Daniel Nunes

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Executive summary

This report summarizes existing research in a unique way to tell a story about how climate change can affect physical and mental health in New Brunswick. Making the link between climate change and health is important because most people do not realize that climate change affects the environmental and social determinants of health and can undermine provincial strategies to improve well-being. Damage from extreme weather events (e.g., flooding and ice storms) is already disrupting our lives, and harming our physical and mental health.

Slowing climate change requires drastic cuts in greenhouse gas emissions (also called carbon pollution), mostly from phasing out coal and oil to make electricity and gasoline for transportation. A clean electricity system – one that relies mostly on renewable sources such as hydro, solar, wind, and sustainable biofuels – will power zero-emitting transportation, homes, buildings, and industrial processes. At the same time, a clean energy system also cuts air quality pollution. The co-benefits of less air pollution are lower risk of cardiovascular disease, chronic and acute respiratory illnesses, lung cancer, and preterm births, according to the Canadian Association of Physicians for the Environment. A clean electricity system can improve indoor air quality, and help reduce energy poverty because energy bills can be lower in an energy-efficient home.

A more active lifestyle can reduce reliance on gasoline-powered vehicles and co-benefits can be improved mental health and well-being. We can increase food security by growing more food locally, reducing imports, all the while cutting carbon pollution from the trucks and planes used to move food products. We can change forestry and agriculture to increase conservation so plants, trees and soil absorb more carbon through photosynthesis. More green space in our communities can keep us cool on hot days, creates places for us to walk and play and improves our mental health and well-being.

New Brunswick Health Council community profiles show New Brunswick communities face physical and mental health challenges. Canadian Climate Atlas data suggest how climate change-induced changes can add to existing health challenges communities face, and can undermine health promotion strategies. It is important that climate change mitigation, adaptation and emergency preparedness planning consider social and physical and mental health if we are to take advantage of the co-benefits associated with climate protection.

New Brunswick needs to move quickly to address climate change risks and cut greenhouse gas pollution in line with science-based targets to protect our health.

We ask stakeholders interested in protecting New Brunswickers' health to encourage the provincial government to make physical and mental health protection and promotion a driving force behind climate change mitigation and adaptation planning and implementation.

Accelerating investments in clean electricity and transportation, active transportation and community greening can all reduce greenhouse gas emissions while advancing provincial objectives for well-being.

How are you feeling today? If you experienced spring flooding in 2018 and 2019, you might not feel as good as you do when spring gardening. If instead of gardening, you had to deal with mould, the loss of cherished possessions, or had to make decisions about whether to repair your home or move, you may feel anxious. Coping with extreme events like spring and winter flooding, ice and windstorms, and the power outages that go with these events, affects our **physical and mental health**. Acute, or extreme, events are becoming more intense because of human-caused climate change. Rising temperatures fueling these extreme events are also associated with chronic concerns like increasing exposure to ticks causing Lyme disease or ragweed worsening allergic reactions.

Making the link between climate change and physical and mental health is important because most people do not realize that climate change affects the environmental and social determinants of health and can undermine provincial strategies to improve well-being. A senior woman, for example, living alone on a low income, with one or more chronic health issues, and who has few social contacts is especially vulnerable to the mental and physical health effects of extreme events made worse by climate change. Hospital and community health-care workers, in turn, must accommodate these climate change-influenced cases, whether from flooding due to extreme rainfall and snowmelt, winter ice storms, increased cases of Lyme disease, or respiratory illnesses. Hospital administrators also must ensure their facilities operate during extreme events. Climate change has the potential to undermine provincial wellness and aging, as well as strategies aimed at protecting drinking water.

The goals of this report are first, to increase awareness in New Brunswick of the links between a changing climate and our physical and mental health and, second, to build stakeholder and government support for action to slow climate change and protect health. The Conservation Council of New Brunswick (CCNB) will pursue these goals by (1) sharing this report with our supporters, provincial stakeholders and government representatives; (2) hosting a workshop in Fredericton in June 2019; and (3) doing presentations and webinars based on its contents. CCNB will update this report and our recommendations to stakeholders and governments as we receive feedback and learn more about opportunities to protect New Brunswickers health from a changing climate.

The good news is that solving climate change in an integrated and coordinated way has many co-benefits that can make us healthier. A clean electricity and transportation system cuts greenhouse gases, as well as air quality pollution, which affects asthma and heart and lung health. **Community design** can increase active living, reduce reliance on personal vehicles, and add urban forest and gardening spaces. More active lifestyles and healthier diets lower carbon pollution and help improve mental health and well-being. We can respond to the climate change emergency while protecting and improving health. But getting there will take work.

The structure of this report is as follows. We first introduce climate change and its potential health effects. We then summarize Canadian Climate Atlas temperature and precipitation projections for 16 New Brunswick communities. We then review **New Brunswick community health profiles** for these same communities. We close with conclusions and recommendations.

Table 1. Climate-related health impacts and causal pathways of relevance in Canada

Health Outcome	Hazard/Exposure	Environmental Effect	Climate Change Driver
Cardiovascular disease	Air pollutants	Formation of air pollutants Forest fires Droughts and dust storms	Rising temperatures Extreme weather events Changes in precipitation
	Extreme heat	Frequency and duration of heat waves	Rising temperatures Extreme weather events
Respiratory conditions	Air pollutants	Formation of air pollutants Forest fires Droughts and dust storms	Rising temperatures Extreme weather events Changes in precipitation
	Extreme heat	Heat waves - hot days & warm nights	Rising temperatures Extreme weather events
Allergic reactions	Pollen & spores	Longer growing season	Rising temperatures
	Mould	Heavy rainfall & flooding	Extreme weather events
Heat stroke/exhaustion	Extreme heat	Frequency and duration of heat waves	Rising temperatures Extreme weather events
Cancer	Air pollutants	Formation of air pollutants	Rising temperatures
	UV radiation	Ozone layer depletion Longer summer season	Temperature-related changes Rising temperatures
Traumatic injuries	Physical trauma, dangerous travel, drowning, violence	Floods, forest fires, tornadoes, hurricanes, storm surges, winter	Extreme weather events
Vector-borne diseases	Infected mosquitoes, ticks and rodents	Expanding habitat conducive to disease vectors Conditions for vector propagation	Rising temperatures Extreme weather events Changes in precipitation
Food-borne illness	Food-borne pathogens/toxins	Contaminated food/flood waters Conditions for bacterial growth	Extreme weather events Rising temperatures
Water-borne illness	Water-borne pathogens/toxins	Contaminated water sources Conditions for bacterial growth	Extreme weather events Changes in precipitation
Malnutrition	Food insecurity Water shortages	Drought, crop loss, biodiversity loss Floods	Rising temperatures Extreme weather events
Mental health stress & anxiety	Population displacement Multiple stressors Climate-induced stress	Floods, forest fires, hurricanes/tornadoes, droughts, heat waves Prolonged and repeated climate-related events Catastrophic events	Rising temperatures Extreme weather events Sea level rise Changes in precipitation
Socio-economic impacts	Social disruptions Loss of incomes and culture Quality of life	Floods, forest fires, hurricanes/tornadoes, droughts, heat waves Prolonged climate-related events Catastrophic events	Rising temperatures Extreme weather events

Source: Perrota, K. (2019). *Climate Change Toolkit for Health Professionals, p. 2. Retrieved from: https://cape.ca/campaigns/climate-health-policy/climate-change-toolkit-for-health-professionals/*

TABLE 2	Health equity: Populations most at risk from the health effects of a changing climate
Health inequity	Examples of climate-related inequity multipliers
Income and social status	Risk from extreme heat, air pollution, UV exposure and extreme weather events Limited financial resources/ability to take adequate protective action (e.g., seek shade, access cool spaces, afford air conditioning, make needed repairs to housing, and avoid sources of air pollution, such as high-traffic corridors
Food security	Risk of food insecurity due to extreme weather events such as droughts, heavy rainfall and flooding that damage or destroy food crops, leading to increased cost of healthy foods
Employmentandworking conditions	Exposure to extreme heat, air pollution, UB radiation and extreme weather events for outdoor workers (e.g., agriculture, forestry, landscaping/snow management, utility workers, construction, fire fighters and other first responders)
Housing and homelessness	Risk from extreme heat and extreme cold for people who are homeless or living in housing with inadequate heating or cooling Risk of damage from flooding and storms if living in home in need of major repair or living in flood-prone areas Risk of poor indoor and outdoor air quality if living close to sources of air pollution
Children and persons	Sensitivity to extreme heat, air pollution Risk from extreme weather events due to lower mobility and higher reliance on care-givers Risk from mental health following disasters and extreme weather events
Indigenous people	Existing inequities (e.g., access to traditional cultural practices, access to safe water, access to health care) Risk food insecurity due to general warming and lower availability/access to traditional food sources
Health status	Risk from extreme heat, air pollution, infectious diseases and extreme weather events for persons who are immunocompromised or living with chronic diseases or disabilities
Access to health services	Risk for northern, remote and low-income communities that currently experience inequities in terms of access to health care Risk from extreme weather events as health, community and social supports may be disrupted by evacuations, population displacement and damage to critical infrastructure (e.g., hospitals, water, wastewater and transportation systems)
Social support networks	Persons who are marginalized or socially isolated are more vulnerable to extreme heat and extreme weather events
Personal behaviours& coping skills	Risk from extreme weather events, extreme heat and climate variability and change While the general population is vulnerable to climate-related stress and distress, risks are amplified for persons with existing mental health conditions

Source: Perrota, K. (2019). *Climate Change Toolkit for Health Professionals,* p. 17. Retrieved from: https://cape.ca/campaigns/climate-health-policy/climate-change-toolkit-for-health-professionals/

Precipitation

Average precipitation rates (1976 to 2005) for our 16 communities range from a low of **991 millimetres (mm) at Dalhousie** to a high of **1,243 mm at Saint John**. Models project a six to seven per cent increase in annual average precipitation for 2021 to 2050, compared to the 1976 to 2005 mean. **Table 7** also summarizes results for spring and winter, the two seasons where precipitation will increase most.

Projected annual spring precipitation could increase seven to nine per cent in the immediate to medium-term, with winter precipitation increasing eight to 11 per cent, and higher amounts expected in northern communities. In the longer term (to 2100), in a high-emissions scenario, annual precipitation increases throughout the province could double to 12 per cent from the six to seven per cent expected by 2050.

More snow and rain in winter in northern New Brunswick, combined with warmer temperatures in spring helps explain projections for greater flood risk during the spring freshet, similar to what New Brunswick has experienced in 2018 and 2019.

A recent Canadian Broadcasting Corporation (CBC) story cites University of Moncton hydrologist Nassir El-Jabi who estimates that in New Brunswick frequent but minor floods could see water levels increase **30 to 55 per cent by 2100** and extreme floods like those in 2018 and 2019 could be **21 per cent bigger by 2100.** Flooding damages our properties and homes, disrupts home and work life, which, in turn, causes stress and anxiety.

7 Projected increase in precipitation 2021 - 2050

NewBrunswick Community	Mean mm 1976 - 2005	Mean mm 2021 - 2050	Annual mm Increase	Annual % Increase	Spring mm change (1976 – 2005 mean)	Winter mm change (1976 – 2005 mean)
Edmundston area	1021	1089	68	7%	247 (228)	257 (232)
Campbellton area	1070	1142	72	7%	260 (242)	277 (250)
Dalhousie area	991	1059	69	7%	238 (222)	257 (231)
Bathurst area	1026	1097	71	7%	265 (247)	285 (258)
Caraquet area	1028	1099	74	7%	259 (241)	292 (263)
Miramichi area	1052	1124	72	7%	276 (258)	293 (265)
Moncton	1117	1188	71	6%	300 (280)	327 (300)
Sackville area	1131	1198	67	6%	298 (276)	329 (303)
Sussex area	1163	1236	73	6%	301 (281)	345 (317)
Oromocto area	1103	1174	71	6%	284 (264)	314 (288)
Fredericton	1111	1182	71	6%	284 (265)	311 (285)
Minto area	1097	1168	73	6%	283 (264)	315 (288)
Woodstock area	1112	1185	73	7%	280 (261)	300 (273)
Grand Falls area	1048	1118	70	7%	250 (232)	271 (246)
St. Stephen area	1151	1218	67	6%	300 (281)	326 (302)
Saint John area	1243	1319	76	6%	322 (301)	372 (344)

Source: Averaged for high-and low-emissions scenarios by CCNB using Canadian Climate Atlas data.

In Laméque, New Brunswick, door-to-door check-ins during the ice storm revealed disturbing levels of isolation for low-income people. Church leaders at the Notre-Dame-des-Flots responded by building a community kitchen and shower and laundry facilities, and creating free meals and counselling programs. These kinds of services are essential to creating connection and building community physical and mental health resiliency.

When asked in NBHC surveys about the state of their mental and physical health, two-thirds in the 16 community areas have a positive view of their mental health **(Table 10)**. Fredericton has the most positive view at 76 per cent. Older people, however, have less positive views of their physical health, with seniors in the Campbellton, Dalhousie, and Grand Falls areas well below the provincial average of 36 per cent for health, and Sussex and Fredericton above average.

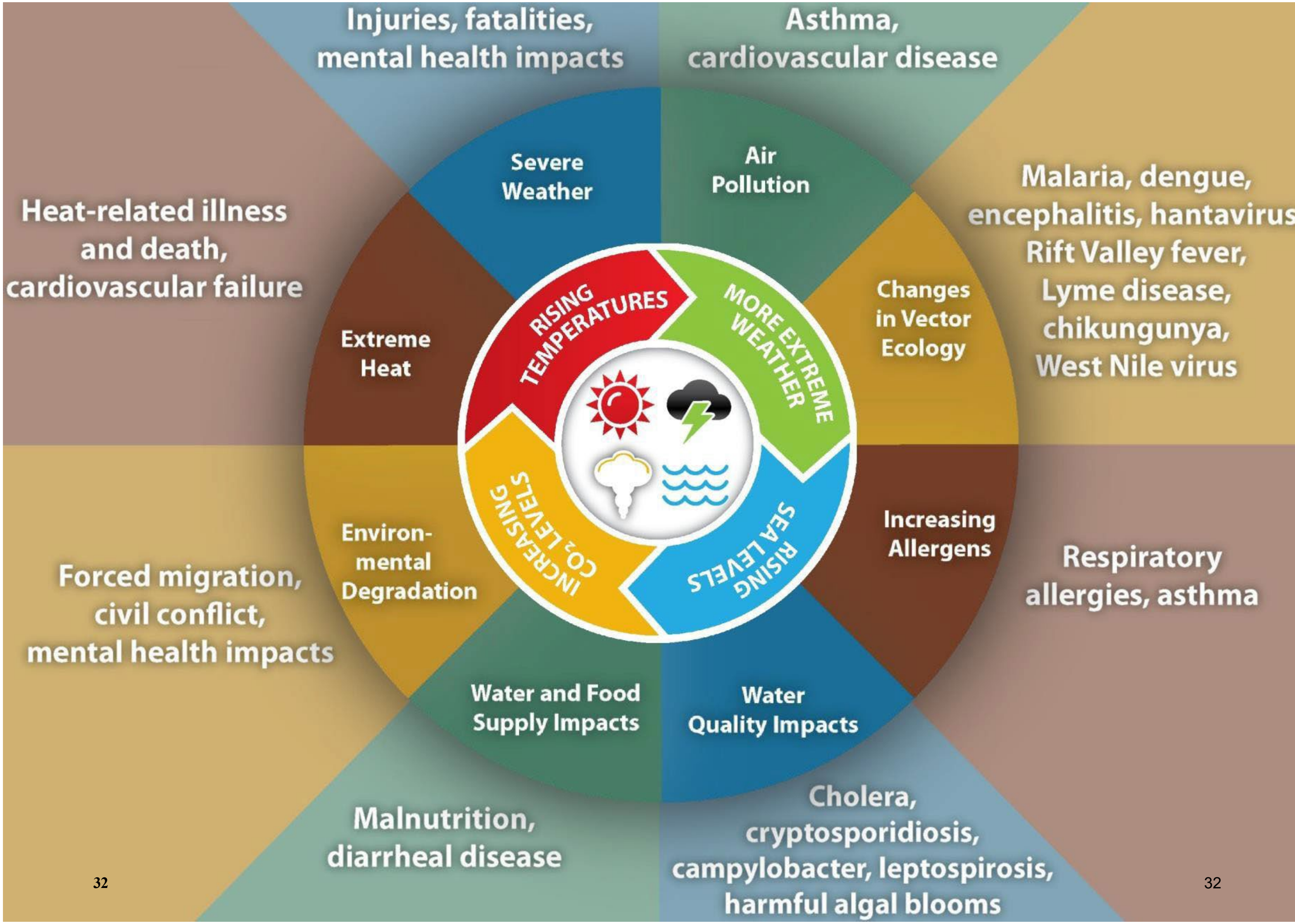
The American Psychological Association mental health assessment describes some of the effects of extreme events, including post-traumatic stress syndrome, anxiety, and anger. Seana Creaser from the Fredericton Mental Health and Addiction Centre noted in a recent CBC interview that these kind of symptoms compound in people with pre-existing mental health issues.

10 Quality of life

	See their mental health as being very good or excellent (%): 18 to 64 years old	See their mental health as being very good or excellent (%): 65 years and over	See their health as being very good or excellent (%): 18 to 64 years old	See their health as being very good or excellent (%): 65 years and over
New Brunswick	67	60	54	36
Edmundston area	71	63	52	40
Campbellton area	70	60	53	28
Dalhousie area	61	55	38	28
Bathurst area	64	65	50	38
Caraquet area	63	62	53	38
Miramichi area	63	64	50	34
Moncton	64	63	58	35
Sackville area	68	64	54	40
Sussex area	69	61	57	44
Oromocto area	63	51	57	35
Fredericton	76	62	65	42
Minto area	55	54	40	33
Woodstock area	67	55	54	36
Grand Falls	61	63	45	27
St. Stephen area	63	64	53	36
Saint John area	68	57	52	34

Source: Table compiled by CCNB using New Brunswick Health Council 2017 Community at a Glance data.

Impact of Climate Change on Human Health



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VIDEO: Adapting to Sea Level Rise

https://youtu.be/IBWqVXilv5s

Canada's Partnership with Indigenous Peoples

It is well understood that Canada's changing climate exacerbates existing challenges and health stressors for Indigenous peoples in Canada, including wildfires, permafrost thaw, changing wildlife patterns, diminishing access to traditional food sources, and flooding. Each of these is already having a direct impact on the social and economic well-being of First Nations, Inuit and Métis peoples.

Indeed, there is strong evidence that Indigenous peoples already face and will continue to experience climate pressures that exceed their current adaptation capacity. On average, more than 100 natural hazard emergencies affect First Nations reserves every year. Flooding alone has resulted in over 160 community evacuations between 2009-2017 across Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia. It is estimated that 25% of the $5.2 billion worth in existing infrastructure assets across 33 communities in the Northwest Territories – approximately $1.3 billion – is at risk due to permafrost impacts. A 2018 study further estimated that up to 3.6 million people and between 48-87% of Arctic infrastructure could be threatened by thawing permafrost over the next 30 years. Greenhouse gas emissions originating from Indigenous communities are modest – estimated at less than one million tonnes per year across the country. In contrast, when compared to other segments of Canadian society, the impacts of climate change on Indigenous peoples are disproportionally greater. Indigenous rights-holders, and their representatives and organizations are critical partners to conversations about addressing climate change at all levels of Canadian society, and have demonstrated their commitment to advancing positive climate outcomes through Indigenous-led solutions.

Successfully meeting these challenges head-on is dependent upon a series of enabling factors, including strong nation-to-nation, Inuit-to-Crown, and government-to-government partnerships, socio-economic resources, institutional capacity, access to information and technologies, strong linkages to external governance bodies, and enabling policy, regulatory, and legislative frameworks.

To help support Indigenous peoples advance their climate priorities and adapt to the changing climate, the Government of Canada is committed to renewed nation-to-nation, Inuit-to-Crown and government-to-government relationships with First Nations, Inuit, and Métis peoples, based on the recognition of rights, respect, cooperation, and partnership. The Government of Canada also supports without qualification the United Nations Declaration on the Rights of Indigenous Peoples, including free, prior and informed consent. Supporting self-determined climate action is critical to advancing Canada's reconciliation with Indigenous peoples.

Canada recognizes that the Government must continue to support co-development, collaboration, and Indigenous self-determination. This includes improving food security, community health, clean energy, resilient infrastructure, and the protection of biodiversity, while building capacity to lead on climate action. Many of the proposed measures in *A Healthy Environment and a Healthy Economy* will support these objectives, and the Government of Canada will continue to work in partnership with Indigenous peoples to address their unique circumstances and support them with the tools they need to respond to a changing climate.

CANADA'S ESTABLISHED PARTNERSHIPS AND ACTIONS UNDER THE PAN-CANADIAN FRAMEWORK

Climate change presents significant environmental, economic, and social risks to Indigenous peoples and their communities. To help respond to these challenges, in 2016, the Prime Minister along with the leaders of the Assembly of First Nations, Inuit Tapiriit Kanatami and the Métis National Council established three distinct, senior-level bilateral tables to support self-determination and enable Indigenous-led climate solutions. Through these tables, government officials and Indigenous partners have learned from one another, leading to stronger climate action that better responds to the unique needs and circumstances of Indigenous peoples.

The partnerships built through the bilateral tables have directly contributed to improvements in the way Canada supports Indigenous climate leadership. These include:

- Investments of over $770 million to support Indigenous-led projects under the Pan-Canadian Framework, in support of adaptation planning, clean energy, health, infrastructure, climate monitoring, and more;
- The creation of the Partnership stream of the Low-Carbon Economy Fund, which provided additional support for Indigenous projects reducing greenhouse emissions;
- Amendments to the Clean Energy for Rural and Remote Communities program, such that the program now supports capacity building, training, skill development and knowledge dissemination to help communities transition away from diesel dependence; and,
- A new commitment to improve Indigenous peoples' access to the Disaster Mitigation and Adaptation Fund.

INDIGENOUS CLIMATE LEADERSHIP

First Nations, Inuit, and Métis peoples have been at the forefront of the impacts of climate change. Many Indigenous leaders have reinforced the need to take action to reduce pollution, to adapt to the impacts of climate change, and to improve the ways in which the natural environment is respected and protected. In doing so, they reinforce that leadership by Indigenous peoples is critical to achieving the foundational changes required to address climate change.

WATAYNIKANEYAP POWER PROJECT

In March 2018, the Government of Canada announced a $1.6 billion investment in the Wataynikaneyap Power Project to connect 16 remote First Nations to the provincial power grid in northwestern Ontario. Wataynikaneyap Power is a licenced transmission company which is owned by 24 First Nations alongside industry partner, FortisOntario. In December 2018, the fly-in community of Pikangikum First Nation was the first community connected to the Ontario power grid, eliminating their dependency on diesel for electricity generation. Work is continuing to connect the 15 other diesel dependent First Nations by the end of 2023. Over 40 years, this project is estimated to result in over 6.6 million tonnes of avoided carbon dioxide emissions, which is comparable to taking almost 35,000 cars off the road.

KUGLUKTUK, NUNAVUT – SOLAR PHOTOVOLTAIC SYSTEM

In the Hamlet of Kugluktuk, Nunavut, the Government of Canada supported the installation of a 10 kilowatt solar photovoltaic system on the community recreation complex, which was later expanded to a total of 60 kilowatts. The system saves the recreation centre $170,000 a year in energy costs with savings being re-invested in recreational programming, which is often the first to be cut. Two employees were trained to maintain and monitor the solar array and the hamlet now wants to install more solar panels on other community buildings.

To position Indigenous climate leadership as a cornerstone of Canada's strengthened climate plan, the Government of Canada will partner with First Nations, Inuit and Métis peoples to set an agenda for climate action and a framework for collaboration. Recognizing Indigenous climate leadership means investing in the agency of Indigenous peoples and communities, supporting Indigenous-led and delivered solutions, equipping Indigenous peoples with equitable resources, and ensuring appropriate access to funding to implement self- determined climate action. Canada's *A Healthy Environment and a Healthy Economy* plan builds on the foundational principles of Indigenous climate leadership, including:

- Recognizing the unique realities, needs, and priorities of Indigenous peoples across and within distinctions;
- Respecting and promoting self-determination;
- Advancing early and meaningful engagement;
- Incorporating inclusiveness-by-design principles in all of its climate actions;
- Advancing co-development and other collaborative approaches to find solutions;
- Creating a space for Indigenous voices across and within distinctions;
- Positioning Indigenous peoples to have a say at governance tables; and,
- Supporting Indigenous approaches and ways of doing, by acknowledging traditional, local, and Indigenous Knowledge systems as an equal part in policy development, programs, and decision-making.

In practice, this means working closely with Indigenous peoples to learn from their systems of knowledge, empowering their communities and organizations, and supporting their self-determined climate priorities.

As an initial step in the direction of strengthened Indigenous climate leadership, the Government has identified some early opportunities to partner with Indigenous organizations and communities. The Government proposes to:

- Work with First Nations, Inuit and Métis peoples to co-develop decision-making guidance that will ensure all of Canada's future climate actions help advance Indigenous climate self-determination.
- Support the implementation of Indigenous-led climate strategies for First Nations, Inuit and Métis peoples, such as the National Inuit Climate Change Strategy.
- Engage Indigenous groups in the development of protocols under the Federal Greenhouse Gas Offset System.
- Work closely with Indigenous peoples on the development of a National Adaptation Strategy.
- Create a legislative requirement in the proposed *Canadian Net-Zero Emissions Accountability Act* that the Minister of Environment and Climate Change must provide Indigenous peoples of Canada with the opportunity to make submissions when setting or amending a national greenhouse gas emissions target or an emissions reduction plan under this legislation.
- Continue developing a new national benefits-sharing framework for major resource projects on Indigenous territory.

Canada also understands how critical it is for First Nations, Inuit and Métis peoples to find solutions to the changing climate now, on the ground, in their communities and their homes. This is why *A Healthy Environment and a Healthy Economy* sets out a range of actions designed to respond to Indigenous peoples' climate priorities, from infrastructure resilience to food security to clean energy.

To accomplish this, the Government of Canada will:

- As described under "Making Canada a World Leader in Clean Power", invest an additional $300 million over five years to transitioning diesel-reliant rural, remote and Indigenous communities onto clean energy, and to engage with Indigenous communities on ensuring this funding is delivered in a streamlined fashion.
- Starting in 2020-21, triple the net fuel charge proceeds available to Indigenous governments in federal backstop jurisdictions. These proceeds will be returned through co-developed solutions.
- Explore opportunities to strengthen federal adaptation programs for Indigenous communities.
- Integrate climate risk assessments and adaptation solutions into infrastructure management to improve the climate resiliency of First Nations on reserve.
- Enhance responsiveness to addressing vulnerabilities in Indigenous food systems and improving food security, including developing an evidence base that leads to strengthened food security programs and interventions.

- Through the commitment on Nature-Based Solutions, partner with Indigenous communities and organizations in the two billion trees initiative, as well as efforts to conserve wetlands, grasslands and restore land and habitat.
- In pursuing Canada’s goal of protecting 25% of its lands and oceans by 2025, partner with Indigenous communities to lead the development and management of Indigenous Protected and Conserved Areas.

CLIMATE COSTS ARE FAR-REACHING AND PILING UP

Insured losses and other disaster-related costs represent just a fraction of the total economic costs of extreme weather events. Other costs—including business interruption, long-term physical and mental health effects, and depletion of government resources—profoundly add to the price tag. Further, the impacts of climate change will not be limited to those associated with larger and more frequent extreme weather disasters. Slow-onset changes will have impacts and costs of a similar magnitude to extreme weather events.

This section provides a view of the range of costs attributable to extreme events and to slow-onset changes across social, economic, and environmental systems in Canada. Based on our review, the Institute identified five types of climate-related damages that are happening now and likely to continue:

- **Household, business, and infrastructure assets are losing value.**
- **Productivity losses and business disruptions are slowing economic growth.**
- **Human health is at risk.**
- **Impacts on ecosystems generate tangible costs.**
- **More government resources will be required to address climate change damages.**

The information below is organized under these five types of damages, presenting a mix of historical and projected cost information intended to signal the scope and scale of Canada's climate change costs.

Limitations in existing analysis make a truly comprehensive assessment challenging, however. Based on existing information, the costs of climate change for Canada are likely to be large and pervasive. And that's before accounting for all the unknowns that make up the rest of the iceberg.

Household, business, and infrastructure assets are losing value

The value of household, business, and infrastructure assets at risk are considerable. For example, real estate represents more than 75 per cent of Canada's produced wealth, with a value of over $8.5 trillion. Canada's transportation and electric power infrastructure alone have a replacement value of over $400 billion, and the reliability of this infrastructure is vital to the economy and to the everyday lives of Canadians.

Homes, buildings, and infrastructure are extremely sensitive to several climate hazards that are expected to become more frequent and intense because of climate change. Until very recently—and in many cases, continuing today—urban development, public infrastructure such as roads and power lines, and industrial facilities were not designed to withstand future climate change, adding to their vulnerability. The climate change hazards placing infrastructure at risk include flooding from heavy rainfall and storm surges, more frequent wildfires, and thawing permafrost—all of which will be exacerbated by steady warming.

- **In the absence of adaptation, coastal property losses could equal half a year's GDP growth by mid-century.** Withey et al. (2015) assess the national costs to dwellings and agricultural and forest lands from sea-level rise and storm surges under various future climate scenarios. Between now and mid-century, they estimate cumulative property damages nationally could range between 0.39 and 0.80 per cent of current GDP. For some regions, the cumulative impact to mid-century exceeds one per cent of their current GDP: notably New Brunswick, Quebec, the territories, and British Columbia.

- **Permafrost thaw will degrade community infrastructure.** In the North, accelerated permafrost thaw will continue to undermine building foundations and municipal infrastructure, forcing early replacement, higher maintenance costs, and impaired function. Permafrost thaw in the Northwest Territories' 33 communities is estimated to rack up $1.3 billion in costs over the next 75 years, equal to about 25 per cent of current territorial GDP (EnviroEconomics and Tetra Tech, 2018). Because housing and infrastructure are very expensive to build and maintain in remote Northern Indigenous communities, these impacts will exacerbate the inequities Indigenous peoples are already experiencing as a result of low individual incomes, restricted community budgets, and a lack of government investment.

Productivity losses and business disruptions are slowing growth

- **Wildfires shuttered oil production, reducing economic value.** The Fort McMurray fire reduced oil production by approximately 47 million barrels with a market value of $1.4 billion (Antunes, 2016). It is unclear if this production was delayed or lost entirely due to supply constraints to get oil to market, but it likely led to economic losses given the size of the shutdown. At the peak of the fire, about 40 per cent of Canada's total oil production was taken offline, resulting in lost profit, royalties to government, and wages.

- **Alberta floods left many without work temporarily, lowering overall productivity.** The 2013 Southern Alberta floods left 300,000 individuals, or 14 per cent of Alberta's workforce, unable to work over a two-week period. This equalled 5.1 million hours of lost work due to the flooding and resulted in $601 million of lost economic output that is equivalent to 0.2 per cent of provincial GDP (Government of Alberta, 2015).

- **Recent spring floods impacted small and financially vulnerable businesses.** For weeks, the spring floods of 2019 in New Brunswick, Quebec, and Ontario inundated areas where 3,800 businesses were located. The vast majority were small businesses in the retail and construction industries with fewer than five employees (Statistics Canada, 2019). Financial data indicates that small business is much more vulnerable to business disruptions than the rest of the economy, with operating profit levels well below the average for all business.[9]

Of course, acute disasters receive the attention.

But the slow-onset changes also impact productivity. Recent analysis by Kabore and Rivers (2020) used Statistics Canada survey data from industry to estimate a link between manufacturing output and temperature. They conclude that when the temperature exceeds certain thresholds, defined as below -18° C or above 24° C, has historically dropped annual manufacturing output by 2.7 per cent on average, with extreme hot and cold temperatures contributing about equally to this impact. Given that manufacturing accounts for 10 per cent of Canada's GDP, even small drops in manufacturing output equate to large productivity losses.

[9] In 2018-19, retail trade had profits that were one third the level of all industries in Canada, while the level for construction was about half (Statistics Canada Table 33-10-0008-01). Small businesses tend to underperform larger enterprises across a range of financial performance indicators (Government of Canada: Financial Performance Data. Accessed June 25, 2020, from https://www.ic.gc.ca/app/sme-pme/bnchmrkngtl/rprt-flw.pub?execution=e1s1).

People’s health is at risk

Disasters, extreme weather events, and slow-onset climate changes have been linked to increased deaths and illness, which increase stresses and costs on the health care system and reduced quality of life (Heath Canada, 2016). The range of health vulnerabilities and costs is broad:

- **Extreme events make mental health worse.** In the Northwest Territories, the 2012 and 2013 wildfires exacerbated feelings of loneliness, fear, stress, and uncertainty, including among Indigenous peoples (Dodd, et al., 2018). Symptoms of mental illness were also elevated after the Fort McMurray 2016 wildfire and included depression, moderately severe depression, suicidal thinking, and substance use (Brown, et al., 2019).

- **Wildfire smoke harms people.** Health Canada estimates that between 620 and 2,700 deaths per year can be attributed to fine particle emissions from wildfires between 2013 and 2018, excluding the Fort McMurray wildfire of 2016 (Matz et al., 2020).

- **Extreme heat causes children to miss school.** Only 128 of the 583 schools in the Toronto District School Board have air conditioning, which exposes students and workers to significant heat stress and has led to parents keeping children home from school (Flanagan, 2018).

- **Extreme heat is deadly.** In Ontario, each 5° C increase in daily temperature has been shown to result in a 2.5 per cent increase in non-accidental deaths (Chen et al. 2016). The Quebec heat wave in summer 2018—the hottest summer in 146 years of record-keeping—caused 86 deaths; 291 deaths were recorded during the 2010 heat wave (ClimateData, 2020). Families with less money are disproportionately impacted by these tragedies as they are often unable to afford air conditioning.

Ecosystem impacts generate tangible and intangible costs

Ecosystem costs can manifest as losses in market value—for instance, when crop yields change—but also in less tangible ways, such as cultural loss or changes in recreational experiences and opportunities. Examples include:

- **Fisheries will be disrupted.** Warming and acidification of Canada's oceans and warming of inland waters may decrease the overall productivity of fisheries and impact the food security and cultural practices of Indigenous communities (Campbell et al., 2014; Weatherdon et al., 2016). A reduction in the overall size of fisheries can create tensions between Indigenous and non-Indigenous communities as they compete for a diminishing resource. These tensions have, at times turned violent.

- **Harmful algae blooms wreck beach days and hurt tourism.** Harmful algae blooms in Lake Erie, if left unchecked on their current trajectory as the climate warms, could reduce recreational values by $155 million annually to mid-century, impairing the enjoyment of recreational fishers, boaters, and swimmers. Impacts on the tourism industry are estimated to be in the order of $110 million annually to 2040 (Smith et al., 2019).

- **Early heat waves compounded with frost to kill apple blooms.** A March 2012 heat wave in Ontario caused fruit trees to blossom weeks earlier than usual making them vulnerable to the April frosts, which ultimately killed 80 per cent of the apple blossoms. The resulting lost harvest value was estimated at $100 million (Government of Canada, 2015).

- **Wildfire prevention is increasing land management costs.** The direct costs to the forest sector for wildland fire protection has increased by approximately $120 million per decade since the 1970s and routinely costs more than $1 billion annually (NRCan, 2017 and 2019). Some of these costs are for adaptive responses, such as controlled burns, to avoid future damages.

- **More pests ruin harvestable wood.** The mountain pine beetle outbreaks in British Columbia between 2003 and 2005, which have been linked to a warming climate, decreased harvestable pine by over 50 per cent, with a present value cost of $60 billion in lost production (Corbett et al., 2016).

More government resources will be required

Canadian governments of all levels are spending more to adapt to climate change and respond to the disasters and healthcare stresses that climate change creates. Those expenditures have opportunity costs: funds could otherwise be used to deliver other benefits or priorities. Typical costs experienced include:

- **Increased capital expenditures** linked to accelerated asset depreciation and upkeep for transportation infrastructure, public buildings, land easements, underground infrastructure, and water treatment facilities.
- **Increased operation and maintenance costs,** as demand for healthcare services rise, disaster response becomes more frequent, government self-insured liabilities and insurance premiums rise, and potential transfer payments rise between levels of government to backstop liabilities.

Specific examples of increased government spending due in part to climate change-related impacts include the following:

- **More disaster spending is needed to cope.** In 2016, the Parliamentary Budget Office concluded federal spending for disaster recovery in the provinces and territories was on the rise and would continue to climb well above historical levels. Canada's Disaster Financial Assistance Arrangements program is projected to cost on average $673 million annually for floods and $902 million for weather-related disasters in the next few years. This is well above the hundred million-dollar annual spending forecast for the DFAA (PBO, 2016).

- **Fire management costs for government are rising.** By the end of the century, total average national fire management costs are projected to increase to just under $1 billion a year (a 60 per cent real increase from the 1980–2009 period) under the low greenhouse gas emissions pathway and $1.4 billion a year (a 119 per cent real increase from the base period) under the high emissions pathway (Hope et al., 2016).
- **Damage to community infrastructure is on the rise.** As one example, the National Capital Commission estimated that repairing infrastructure damage from the spring floods of 2019 would cost $6 million to $10 million representing 20 per cent of its forecast annual expenditures for operations. This cost is on top of $2 million in repairs required after the 2017 floods (Porter, 2019).

In the next section we discuss the role that climate change adaptation can play in reducing these costs.

2023 NCF-Envirothon New Brunswick

Adapting to a Changing Climate

Current Environmental Issue Study Resources- Part B

Key Topic #3: New Brunswick in a Changing Climate

9. Describe climate change adaptation measures that communities in New Brunswick are developing.
10. Explain how New Brunswick proposes to transition to a low carbon economy.
11. Describe the specific climate change impacts New Brunswick faces due to its geographical location and ecological systems.
12. Define the different types of infrastructure and explain how each can be used to adapt to and/or mitigate the impacts of climate change.
13. Describe the causes and impacts of flooding in New Brunswick, and how communities can plan and prepare for floods.
14. Evaluate the advantages and disadvantages of different climate adaptation and mitigation solutions in the context of real-world scenarios.

Study Resources

Resource Title	Source	Located on
Climate Change in New Brunswick	*Government of New Brunswick, 2021*	Pages 47-50
Our Pathway Towards Decarbonization and Climate Resilience	*Province of New Brunswick, 2022*	Pages 51-57
Understanding Climate Change in Saint John	*ACAP Saint John, 2020*	Pages 58-82
VIDEO: Lorne St Naturalized Stormwater Pond/ Projet d'atténuation des eaux de pluviales de la rue Lorne	*New Brunswick Environmental Network, 2020*	Page 83, 5 minutes
VIDEO: Flooding in NB ENG With Subtitles	*Government of New Brunswick, 2022*	Page 84, 3 minutes
VIDEO: Flood Hazard Maps Tutorial ENG	*Government of NEW Brunswick, 2022*	Page 85,4 minutes

Study Resources begin on the next page! ➡

Climate Change in New Brunswick

The effects of climate change are being experienced in New Brunswick and are expected to further impact the province in the future. Climate change will affect all aspects of the environment, economy and society in New Brunswick.

The environmental effects of greenhouse gas (GHG) emissions will continue to increase unless action is taken to limit their production. However, efforts to reduce greenhouse gas emissions cannot stop climate change from occurring. Therefore, New Brunswick must also take measures to adapt to the effects of climate change.

Where do New Brunswick's GHG emissions come from?

Figure 1 shows the distribution of GHG emissions among the various sectors in New Brunswick, with industry, transportation and electricity generation identified as the largest contributors to New Brunswick's GHG emissions.

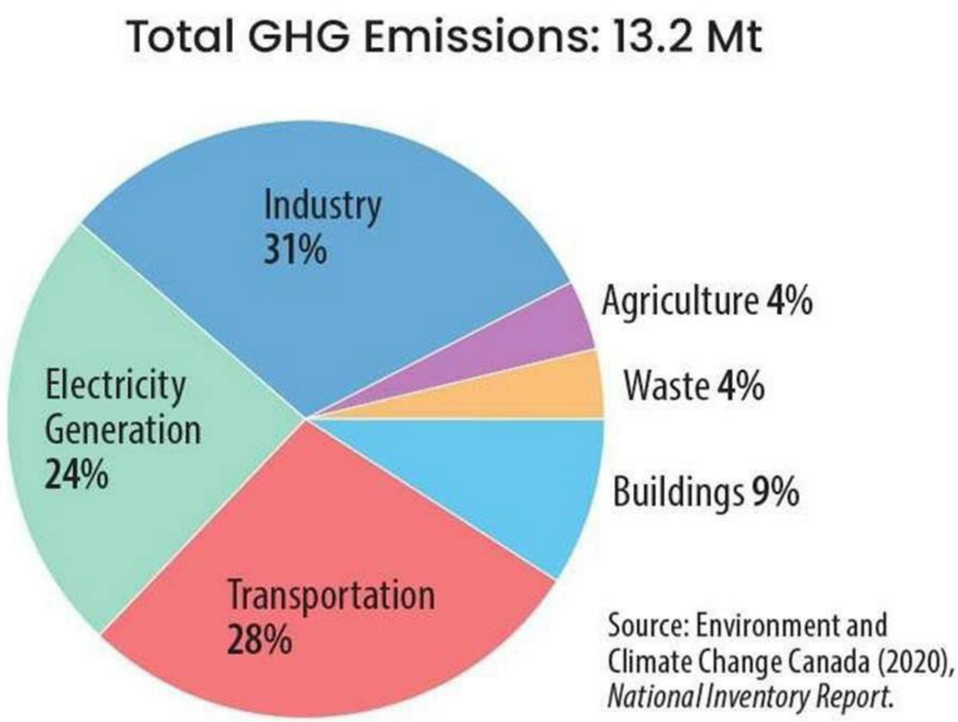


Figure 1: Current NB GHG Emissions by Sector (2018 data)

How has climate change affected New Brunswick?

The Province is already experiencing the impacts of climate change. New Brunswick's mean annual temperature has already increased by 1.1°C in the last 30 years. Rising sea levels have also increased the risk of flooding and coastal erosion. Historically, the province has experienced extreme weather events that have caused catastrophic damages. Since December 2016, a number of these weather events have occurred including a snow and freezing rain storm that moved across the province causing a long duration of power outages and destroying much of the electrical distribution infrastructure in the Acadian Peninsula. In 2018 and 2019, the province experienced back-to-back spring flooding along the St. John River causing record setting flooding and the highest damage costs of any flood event. Additionally, in late summer of 2019, post-tropical storm Dorian brought high winds and rain to the region that resulted in extensive property, infrastructure, and shoreline damage.

How will climate change affect New Brunswick in the future?

Climate projections datasets indicate the province will become warmer, wetter, stormier and will experience rising sea levels, which represents significant challenges and opportunities for New Brunswick's communities and resource sectors.

Warmer temperature
In New Brunswick, projections indicate an anticipated increase of approximately 5°C across the province, with some areas becoming warmer than others. Projections also indicate a substantial increase in very hot days (days above 30°C) and longer growing seasons. Potential effects of warmer temperatures include an increase in risk to water quality, increase in pests/invasive species, more freeze-thaw events or potential for health impacts such as heat stress.

Wetter
Annual precipitation is projected to increase with a shift toward more rain days and less snowfall days. Potential effects of changing precipitation include increased run-off, flooding and erosion and increased risk of damage and failure or key infrastructures.

Stormier
High intensity precipitation events are becoming more common. Projections indicate that New Brunswick can expect more extreme and variable weather patterns. Potential effects of stormier weather include increased damage to trees and to infrastructure such as buildings, homes and critical services like the electrical grid from high winds, ice storms and extreme storm surges.

Rising Sea Levels
Sea level rises primarily as a result of the melting of glaciers and ice caps and the rate at which they are melting has increased due to global warming. In New Brunswick, sea level is predicted to rise by approximately 1m by 2100. Sea level rise combined with high tidal cycle and storm surge can lead to increased flood elevations and increased risk of coastal flooding and coastal erosion risks, potential loss of natural habitat and damage to infrastructure.

How is New Brunswick responding to climate change?

New Brunswick is committed to being part of the solution to this global challenge. In 2016, the province released Transitioning to a Low-Carbon Economy New Brunswick's Climate Change Action Plan. The Action plan calls for greater emphasis on renewable energy, a broad-based and coordinated approach to energy efficiency in homes and businesses, and a phase-out of coal-fired electricity. It also focuses on initiatives related to education, awareness, capacity-building and adaptation planning. In January 2021, the province released a report outlining progress on actions to date New Brunswick's Climate Change Action Plan Progress Report 2020

Reducing our GHG Emissions

Under the Paris Agreement on Climate Change, Canada, along with 193 other countries, agreed to limit the global temperature increase to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels. For its part, Canada committed to reducing its GHG emissions by at least 30% below 2005 levels by 2030 and achieving net-zero emissions by 2050.

New Brunswick has already made significant progress in lowering emissions, having reduced our emissions by 34% since 2005. To date, GHG reductions in New Brunswick have been achieved through significant actions related to closures of coal and oil-fired plants; the incorporation of wind energy; restructuring in the forestry sector; and investments in energy efficiency, fuel switching and increased penetration of natural gas into the markets.

Action 31 in the Climate Change Action Plan and the New Brunswick Climate Change Act also commits the province to continuing to reduce GHGs with emissions targets of: 14.8 mega tonnes (Mt) by 2020; 10.7 Mt by 2030; and 5 Mt by 2050 (Figure 2).

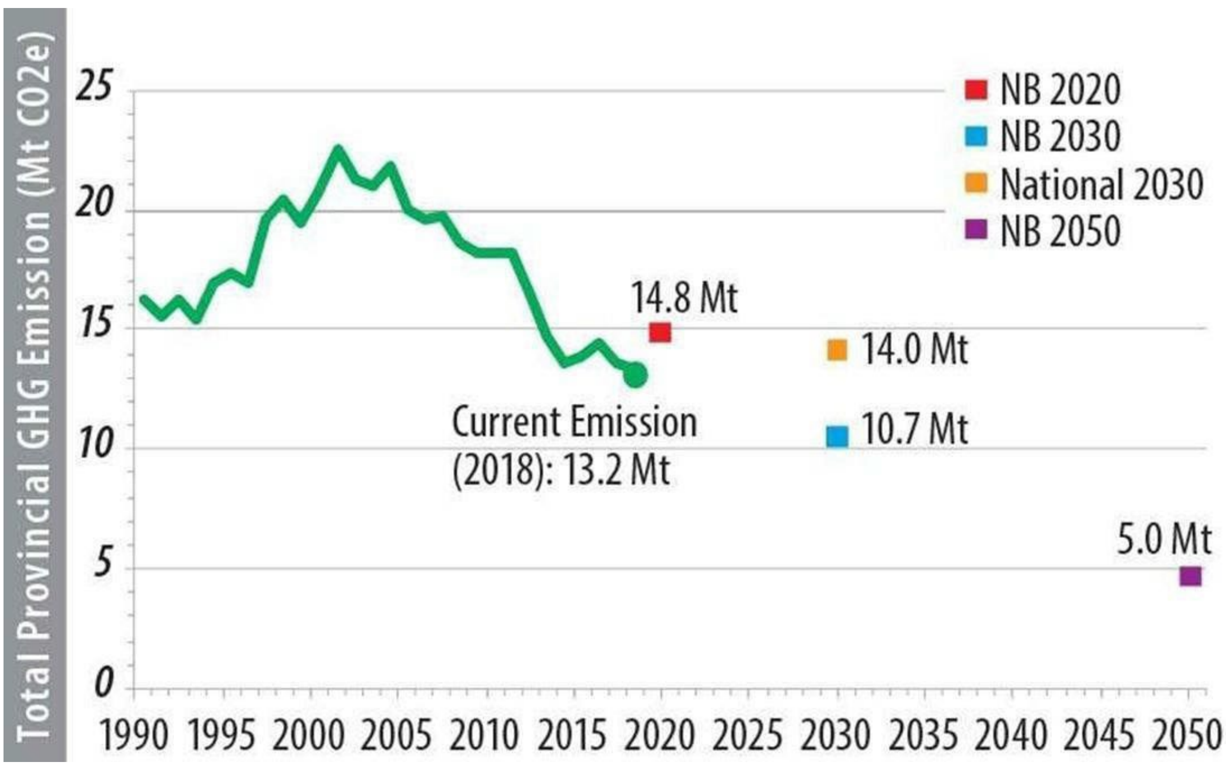


Figure 2. NB GHG Emissions and GHG Targets

Preparing for the Changing Climate

Climate change adaptation is about making well informed forward-looking decisions that take into consideration future climate conditions. New Brunswick's Climate Change Action Plan contains a climate change adaptation strategy supported by actions to build resilience into our communities, businesses, infrastructures and natural resources. Acting early and adapting to our changing climate is far more effective and cost-effective than dealing with climate impacts after they have occurred. For example, since 2017, the provincial government has supported community adaptation planning throughout the province, with all New Brunswick cities and highest risk coastal municipalities having completed vulnerability assessments and adaptation plans. To learn more about ways the province is preparing for the impacts of climate change, visit the Climate Change Action Plan Progress Report.

Pillar 3
PREPARING FOR CLIMATE CHANGE

New Brunswick is already experiencing the impacts of a changing climate, and these impacts are predicted to worsen. The current levels of GHGs in the atmosphere are expected to last for decades, and they will continue to affect weather patterns that lead to warmer temperatures, more precipitation, sea-level rise, and more extreme weather events. Preparing and adapting to future climate conditions will be essential for New Brunswick to minimize impacts on our communities, natural resources, and infrastructure, and to ensure the health and safety of the public.

The actions outlined in this section will strengthen New Brunswick's capacity to prepare and adapt to future climate conditions. These actions build on extensive climate adaptation work completed to date and will be critical in minimizing the impacts of climate change. Building resilience and thriving in a changing climate will require all communities, businesses, individuals, and governments to be proactive in understanding their risk to climate change, planning accordingly, and taking appropriate adaptation action. We all have a role to play, and by working together to plan and act early, we can be ready for the challenges and opportunities climate change is expected to bring.

3.1 Understanding and communicating climate change risks and opportunities

Understanding climate change risks and how best to adapt to the new climate realities will be important for all New Brunswickers. Having access to the most up-to-date and regionally relevant climate information and projections is critical to ensuring that decisions are made based on the best available information. The newly created Climate Change Services Centre for Atlantic Canada, CLIMAtlantic, will play a vital role in these efforts by engaging clients, stakeholders, and partners in multiple sectors, to deliver the latest climate change data, climate change education and awareness, training, and climate tools and products that are essential in raising awareness and ensuring climate considerations and expertise informs decision-making. Meanwhile, the implementation of enhanced monitoring systems will further our understanding of New Brunswick's changing climate and inform decision-making and the implementation of adaptation actions. Improving our understanding of climate change and how it will influence our lives is the first step to preparing New Brunswick for future changes.

As part of the commitment to understand and communicate climate change risks and opportunities, the provincial government will continue to:

- Share with New Brunswickers up-to-date localized climate information and raise awareness of climate science and projected impacts.
- Update flood hazard mapping as new climate information and projections become available.
- Consider future climate conditions when making decisions about replacing or repairing infrastructure (i.e. building back better).

- Promote and support opportunities to share information amongst adaptation practitioners, academia, emergency management officials, public health officials, and the public to increase our collective resilience to climate change.
- Identify research priorities into the impacts of climate change and develop a research network and share information across partners.
- Increase awareness of sea-level rise and erosion through public education.
- Explore opportunities to expand freshwater quality monitoring to improve understanding of climate change impacts on freshwater quality.
- Monitor changes in the physical environment.

NEW ACTION

THE PROVINCIAL GOVERNMENT WILL:

22. Improve New Brunswickers' understanding and awareness of climate

change risks to ensure preparedness by:

a. Developing and beginning implementation of a New Brunswick flood education and awareness program by 2025 to provide local governments and individuals with the tools necessary to better understand and plan for the risks associated with flooding;
b. Designing and beginning implementation of an environmental health monitoring program by 2027 to understand and communicate the environmental health risks associated with a changing climate in New Brunswick;
c. Establishing a FireSmart program by 2025 for communities deemed at risk to wildfires to support improvements in emergency planning, preparation and response while increasing overall resilience to the impacts of wildfire;
d. Establishing a drought index and public advisory reporting system by 2026 to inform the public and local governments when water conservation strategies should be implemented; and
e. Releasing the most up-to-date predictive climate change information for all regions of the province by 2025.

3.2 Adaptation planning and implementation

Adaptation planning has significantly increased in recent years due primarily to work achieved under the 2016 Climate Change Action Plan, helping to build our collective resilience to the impacts of climate change. As part of our comprehensive plan to address climate change, a more ambitious, strategic, and collaborative approach is required to move from adaptation planning to implementation across a broader suite of sectors.

New Brunswickers need a clear understanding of the greatest risks posed by climate change. A province-wide risk assessment will build on several existing assessments to identify key risks to infrastructure, public safety, natural ecosystems, heritage and culture, marine and terrestrial environments, and economic sectors. Informed by the provincial risk assessment, a provincial climate change adaptation plan will help prioritize the adaptation measures required to pre- pare for and reduce identified risks.

As part of the commitment to adaptation planning and implementation, the provincial government will continue to:

- Support local governments, rural districts, key sectors, and NGOs in efforts to prepare for a changing climate and share progress and successes.
- Ensure that climate change vulnerabilities are integrated into municipal asset management strategies.
- Incorporate climate change considerations into provincial park management planning.
- Improve the resiliency of Crown Road infrastructure to climate change.
- Ensure climate change and extreme weather events are considered in all major projects, plans and funding applications.
- Partner with the federal government's Ocean Program on climate-related impacts to the aquaculture and fisheries sectors such as eutrophication, anoxic events, harmful algal blooms, and associated biodiversity loss.
- Enhance the Road Weather Information System by identifying gaps in the existing system, upgrading current sites, and expanding the network coverage.

New action

The provincial government will:

23. Conduct and release a comprehensive provincial climate change risk assessment by 2025 to identify risks, set priority areas for adaptation action and inform decision-making across New Brunswick.

24. In response to the priority vulnerabilities identified in the provincial climate change risk assessment, develop a provincial climate change adaptation plan by 2026, followed by climate change adaptation plans for priority government departments by 2027.

25. Implement statements of public interest that include climate change under the *Community Planning Act* by 2025 with the objective of assisting communities in adapting to a changing climate.

26. Collaborate with regional service commissions, local governments, and rural districts to ensure that:

   a. Beginning April 1, 2024, progress on climate change adaptation plan development and implementation is reported annually.

b. Adaptation plans are updated and completed for 50 percent of all local governments and rural districts by 2025 and 100 percent by 2030; and
c. Beginning April 1, 2025, and each year thereafter, as adaptation plans are completed, implementation schedules are developed within one year so that communities can begin the delivery of priority adaptation measures.

27. Increase the resiliency of the provincial transportation network to future climate conditions by:

a. Developing a Long-Term Flood Mitigation Plan by 2024 to establish priority locations for infrastructure upgrades;
b. Completing a Large Culvert Assessment Study by 2024 to prioritize at-risk infrastructure for replacement; and
c. Developing an Infrastructure Decision Guideline by 2024 to ensure the impacts of climate change and extreme weather events are considered in infrastructure decisions.

28. By 2024, evaluate options to optimize available disaster financial assistance so that New Brunswick property owners have increased access to funds needed to implement proactive measures that reduce the impacts of future climate conditions and extreme weather events.

3.3 Biodiversity and nature-based solutions

Nature offers some of the best solutions to strengthen our response to climate change. Nature-based solutions are actions that can protect, sustainably manage, and restore ecosystems in ways that benefit people while also maintaining and enhancing biodiversity and ecosystem function. Using nature-based solutions to manage the impacts of climate change will help conserve the natural diversity and functions of New Brunswick's forests, wetlands, watersheds, and coastal features. Nature-based solutions will also allow New Brunswick to become more resilient to climate change while avoiding future costs related to climate-induced clean-up and restoring impacted natural ecosystems along with the services they provide.

As part of the commitment to biodiversity and nature-based solutions, the provincial government will continue to:

- Recognize and promote the importance of ecosystems and natural infrastructure to buffer against climate change impacts.
- Identify climate-vulnerable species, habitats, and landscapes as targets for adaptation action and manage landscape connectivity to allow for species migration.
- Support nature-based solutions as an approach to adapt to climate change through training and knowledge-exchange activities to build capacity among stakeholders

New action

The provincial government will:

29. Maintain biodiversity and increase resilience through nature-based solutions by:

   a. Developing a renewed Biodiversity Strategy by 2025 that recognizes the sensitivity of biodiversity to climate change, the need to adapt the way New Brunswick manages and uses the natural environment, and the role that nature can play in climate solutions. As an interim measure, the provincial government will publish a list of climate-sensitive species by 2023 and update the list as new information becomes available.
   b. Setting a new target for protected areas by 2024, which will take New Brunswick beyond protecting 10 percent of the province's land and freshwater.

30. Implement a Living Shorelines program by 2026 that promotes natural adaptation approaches and nature-based solutions through training, science-based tools, and best practices made available to New Brunswick property owners.

Moving forward

The need for accelerated action is clear. New Brunswick remains committed to ensuring our province does as much as possible to combat climate change and transition to a resilient, low-carbon economy.

The provincial government has listened to what was heard from New Brunswickers and is delivering an ambitious plan to achieve our commitments.

Significant achievements have already been accomplished with the help of all New Brunswickers, all levels of government, Indigenous communities, businesses, educational institutions, and researchers and are reasons for optimism as we face the global challenge of climate change.

This plan builds on initiatives already in place and is pivotal to reaching our 2030 target and setting the foundation for New Brunswick to achieve net-zero emissions by 2050. It will help us use the resources and expertise we have to achieve clean economic growth in the short-, medium- and long-term. It will take time, but with participation from all New Brunswickers, we can accelerate our transition to a strong, healthy, and resilient economy that is equitable, diverse, and inclusive.

Appendix B
Potential GHG emission reductions

Potential GHG emission reductions were estimated based on the actions, assumptions assigned to each, and a business-as-usual scenario. Table B1 presents the estimated total potential GHG emission reductions that could occur by 2030 as a result of implementing the actions in our plan. Results are shown by sector and include all new actions related to each individual sector.

Potential GHG emission reductions in 2030 were aggregated by sector and compared to a GHG impact scale (Table B2) to determine the qualitative impact of the actions with respect to the current total provincial GHG emissions and their sector's current GHG emissions. Results show the relative importance of actions on current total provincial and sectorial GHG emissions.

These results represent the current best estimates of potential GHG emission reductions and are subject to change over time as more information and data become available.

Based on the results of this analysis, by implementing the actions in this plan, it is estimated that the total provincial GHG emissions could be between 8.73 – 9.54 Mt in 2030. The province would meet and exceed the 2030 GHG target of 10.7 Mt and would be on track to meeting the provincial net-zero commitment for 2050.

Table B1

Summary of potential emission reductions in 2030 from actions.

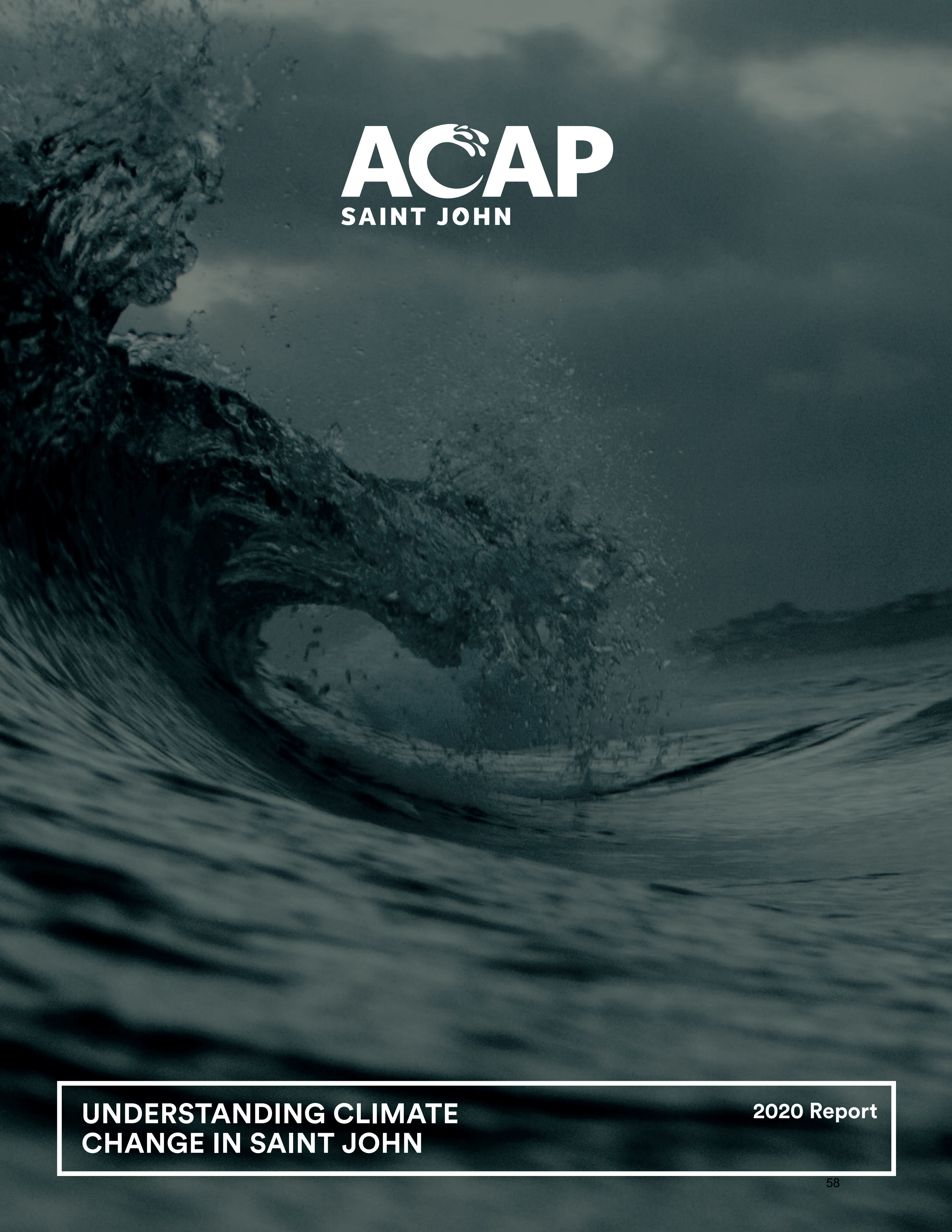
SECTOR	TOTAL POTENTIAL GHG EMISSION REDUCTIONS IN 2030	IMPACT ON PROVINCIAL GHG EMISSIONS	IMPACT ON SECTOR GHG EMISSIONS
INDUSTRY	TBD[1]	TBD[1]	TBD[1]
TRANSPORTATION	265 – 400 kt GHGs	High	Very High
ELECTRICITY	1,555 – 1,870 kt GHGs	Very High	Very High
BUILDINGS	330 – 610 kt GHGs	High	Very High
WASTE	160 – 200 kt GHGs	Medium	Very High
AGRICULTURE	40 – 80 kt GHGs	Medium	Very High
NATURAL CARBON SINKS [2]	TBD[2]	TBD[2]	TBD[2]
GREENING GOVERNMENT [3]	15 – 65 kt GHGs	Medium	Very High
LOW - CARBON COMMUNITIES [3]	120 – 165 kt GHGs	Medium	Very High
BUSINESS & INNOVATION [3]	40 – 50 kt GHGs	Medium	Medium
TOTAL	2,350 – 3,160 kt GHGs	Very High	-

1. To be determined based on approval of NB Output-Based Pricing System for 2023-2030.
2. For natural carbon sinks, potential GHG reductions are to be determined as the actions are implemented.
3. Numbers are not included in the total to avoid potential double-counting of emission reductions.

Table B2

GHG impact by range of estimated ghg emission reductions.

RANGE OF ESTIMATED GHG EMISSION REDUCTIONS	GHG IMPACT
1, 000,000 + TONNES GHGS	Very High
250,000 – 1,000, 000 TONNES GHGS	High
50,000 – 250,000 TONNES GHGS	Medium
5, 000 – 50,000 TONNES GHGS	Modest
0 – 5, 000 TONNES GHGS	Minor



ACAP SAINT JOHN

UNDERSTANDING CLIMATE CHANGE IN SAINT JOHN

2020 Report

INTRODUCTION

Climate Change is one of the greatest challenges facing human civilization today. It directly affects fundamental needs like food, water, and shelter. In Canada, the rate of warming is nearly twice the global average and impacts are already being felt. This report is intended to be a resource for residents, businesses, developers and Council members who are eager to learn more about the changing environment in Saint John, New Brunswick, Canada.

The primary challenges posed to Saint John as a result of Climate Change include increasing temperature, sea level rise, and higher intensity precipitation events. These result in severe inland and coastal flooding, accelerated rates of coastal erosion, and loss of land. This report introduces Climate Change science and describes the predicted weather changes for Saint John. These changes include warmer annual temperatures, warmer winters, increases in rainfall events, rising sea levels, and changes to storm frequency and intensity.

Inland flooding, a historical climate-related challenge for Saint John, is discussed as the result of changing seasonal temperature and precipitation patterns. The benefits of green infrastructure or low impact development strategies are investigated as a solution to reduce the risk of property damage from flooding. The impacts of extreme weather events, including post-tropical storms, ice storms, and wildfires in Saint John are also discussed. Understanding how Climate Change will affect the community is critical for developing effective strategies and reducing negative outcomes.

As a coastal city, sea level rise is of great concern for Saint John. Predictions suggest that a Higher High Water Large Tide (HHWLT) can be expected to be 6.2 m by 2100 for a 100 year return period. Sea level rise projection data for various flooding scenarios are provided in this report and social and environmental impacts are discussed. The largest challenge for areas impacted by sea level rise is the high economic cost associated with damage, relocation, or long-term monitoring. Strong partnerships between multiple stakeholders will be required to protect public and industrial spaces against rising sea level.

Climate Change compounds reoccurring challenges experienced in Saint John around water: changes in seasonal riverine flooding, overflow from precipitation events, and sea level rise. This report discusses challenges around freshwater availability and quality. Supporting healthy communities requires actions to ensure a safe water supply is available.

The City of Saint John must develop adaptation strategies to reduce the negative impacts associated with Climate Change. In Spring 2020, ACAP Saint John will release the Climate Change Adaptation Plan for Saint John, which will provide recommendations to reduce risks and increase the resilience of the community.

TABLE OF CONTENTS

GLOSSARY

Adaptation
Initiatives and measures that reduce the vulnerability of human and natural systems to actual or anticipated Climate Change effects.

Aquifer
A subsurface layer of rock that holds water. The pores and cracks in the rock allow water to be stored until it is pumped to the surface for use.

Blue Infrastructure
Landscape elements linked to water bodies, such as pools, ponds, artificial buffer basins or water courses.

Climate
The average weather measured by the statistical description of mean variability of wind, precipitation, temperatures etc. over time ranging from months to thousands or millions of years.

Climate Change
The long-term changes in climate variables, such as precipitation, temperature, sea level, lake levels, and changes in the frequency and intensity of extreme weather events.

Coastal Erosion
The process of removal and transport of soil and/or rock from shorelines as a result of weathering by streams, glaciers, waves, or high winds.

Coastal Squeeze
A form of coastal habitat loss, where intertidal habitats such as salt marshes, mudflats or sand dunes are lost or deteriorated due to high water levels. In response to sea level rise, defence structures (i.e. a sea wall) can prevent the inward migration of land.

Ecosystem
A system of living organisms interacting with each other and their physical environment ranging from very small spatial scales to entire regions, i.e. coastlines and watersheds.

Flood
A significant rise of water level in a stream, lake, reservoir or a coastal region from excessive rain, severe storms, rapid snow or ice melt, blocked watercourses, failure of dams, land subsidence or storm surges that inundates natural or built landscapes within city boundaries.

Flood Risk
The combination of hazards and vulnerability to floods that have a high probability to occur and/or have significant impact on property, health, or livelihoods.

Global Warming Potential (GWP)
A ratio of how much heat a gas traps in a specific time frame relative to CO_2 (IPCC, 2014). For instance, where CO_2 is estimated to have a GWP of 1 over a 100-year time period, methane is estimated to have a GWP of 28-36 over 100 years and nitrous oxide is estimated to have a GWP of 298 (United States Environmental Protection Agency, 2017).

Greenhouse Gas (GHG)
Compounds that can absorb infrared radiation and trap heat in the atmosphere, contributing to The Greenhouse Effect.

Green Infrastructure
Development that utilizes and promotes the benefits of ecosystem services including stormwater management, water filtration, carbon storage, enhanced biodiversity, and community well-being.

Grey Infrastructure
Engineering and building projects that are made from concrete and/or steel and are typically impervious in urban settings.

Harmful Algal Blooms (HABs)
Occur when colonies of algae grow to produce toxic or harmful effects on people, fish, shellfish, marine mammals, and birds.

Higher High Water Large Tide (HHWLT)
A representation of the storm surge impacts associated with the moon cycle on the high tide. It is determined by taking the average of highest predicted water levels over a 19 year period.

Inland Flooding
Flooding experienced as a result of heavy precipitation events or high river flows occurring in natural and built environments.

Low Impact Development (LID)
Urban infrastructure installed with an emphasis on conservation of natural features with the intention to reduce urban challenges around stormwater management.

Mitigation
Any policy, regulation, or project-based measure that contributes to the stabilization or reduction of greenhouse gas concentrations including renewable energy programs, and energy efficiency plans.

Resilience
The capacity of a system, community or society exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure.

Saltwater-Freshwater Interface
The boundary beneath the Earth's surface where saltwater and freshwater meet as a gradual transition zone where water becomes more saline as it moves seawards.

Saltwater Intrusion
The process of seawater infiltrating coastal groundwater systems, mixing with a local freshwater supply.

Storm Surge
A localized, temporary rise in water occurring during specific weather conditions.

Stormwater Runoff
Water from precipitation or snowmelt that flows across the landscape and is not stored or taken up by plants. This can be rain, melting snow or ice that washes off hard surfaces.

Stakeholders
A party, including residents, businesses, developers, First Nations, NGOs, academics, and City staff and Councillors who have an interest in a specific issue.

Vulnerability
The likelihood of a system suffering an adverse impact of Climate Change when exposed to extreme weather.

Water Security
The capacity of a city to protect urban water quality and availability to sustain livelihoods, well-being and socio-economic development.

Watershed
An area delineated topographically were all precipitation drains to one point or outlet.

Urban Heat Island (UHI)
The warming effect of built urban spaces on air temperature in comparison to surrounding rural areas.

LIST OF ACRONYMS

AR5........IPCC Fifth Assessment Report

AR6........IPCC Sixth Assessment Report

DFAA........Disaster Financial Assistance Arrangements

ECCC........Environment and Climate Change Canada

FTC........Freeze-Thaw Cycles

GCMs........General Circulation Models

GHG........Greenhouse Gas

GNB........Government of New Brunswick

GWP........Global Warming Potential

HABs........Harmful Algal Blooms

HHWLT........Higher High Water Large Tide

IPCC........Intergovernmental Panel on Climate Change

LID........Low Impact Development

NBDELG........New Brunswick Department of Environment and Local Government

NB EMO........New Brunswick Emergency Measures Organization

RCP........Representative Concentration Pathway

UHI........Urban Heat Island

1. CLIMATE CHANGE IN SAINT JOHN

Climate Change has become a regular focus of media across the world and more so than ever there is positive action being taken by local communities, nations, and municipalities to prepare and adapt to changing conditions. The City of Saint John has an opportunity to adapt to the changing climate and continue to develop as a thriving community. This chapter is intended to introduce Climate Change science including greenhouse gases (GHGs), climate modelling terminology and the changes projected for Saint John.

1.1 Introduction to Climate Change Science

The Intergovernmental Panel on Climate Change (IPCC), established in 1988, is a United Nations scientific body and the foremost authority on Climate Change science. In 2014, the Fifth Scientific Assessment Report (AR5) was released emphasizing the severity of our warming climate system. The Sixth Assessment Report (AR6), scheduled to be released in 2021, will provide stakeholders with modern solutions and updates about successful strategies to reduce Climate Change impacts.

1.1.1 The Greenhouse Effect

The global climate system is maintained by The Greenhouse Effect, which acts to regulate temperature by trapping greenhouse gases (Figure 1). This natural process controls the Earth's temperature and has allowed for ecosystems to develop and diversify. GHG emissions come from both natural and man-made sources and include carbon dioxide (CO_2), methane, water vapour, nitrous oxides, ozone, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. Each of these gases has a specific capacity for warming the atmosphere called the global warming potential (IPCC, 2001). While CO_2 is often the focus of Climate Change conversations, each of these gases play a significant role in The Greenhouse Effect.

In the atmosphere, GHGs can be transformed by chemical processes and released beyond the atmosphere, but most are trapped, left to absorb incoming solar energy and keep the planet's surface warm. The dramatic increase in GHG emissions by humans, or anthropogenic sources, has enhanced The Greenhouse Effect, trapping heat in the atmosphere and resulting in warmer temperatures that alter atmospheric and hydrologic processes. Higher concentrations of GHGs in the atmosphere have led to 2016 being the world's hottest year on record (World Meteorological Organization, 2020). This aligns with a trend in global warming that has

What is the difference between adaptation & mitigation?

Adaptation:
Process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Mitigation:
Human intervention to reduce the sources or enhance the sinks of GHGs. (IPCC, n.d.)

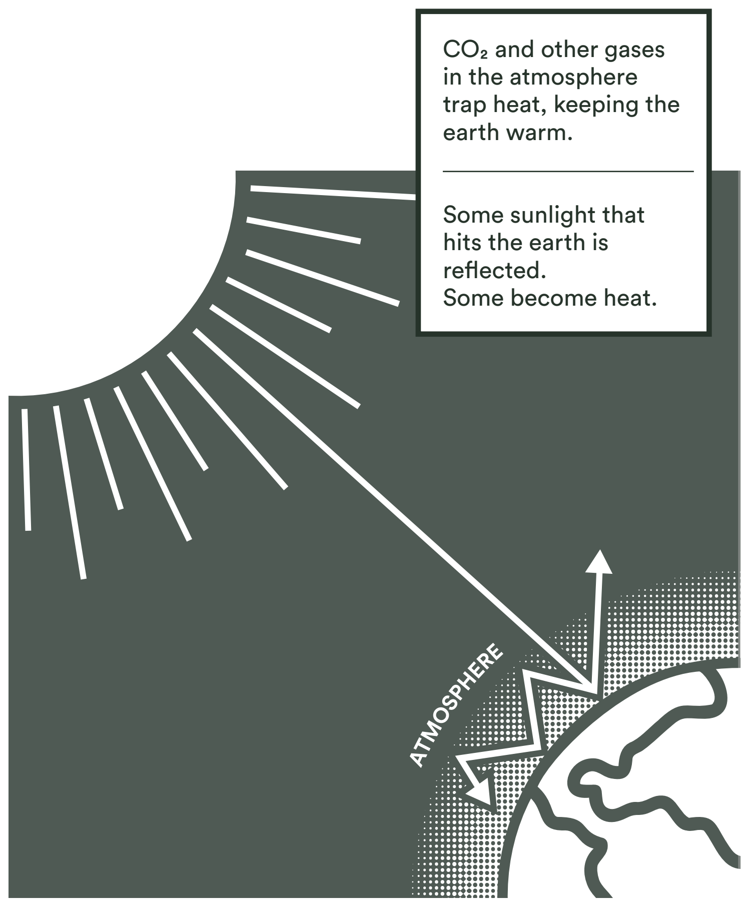


Figure 1: The Greenhouse Effect, where the sun's heat is trapped in the atmosphere by higher quantities of greenhouse gas emissions (Mathematics of Planet Earth, 2012).

been observed over the last 60 years confirming athat our climate is changing with abnormal rapidity (Figure 2).

1.1.2 Climate Modelling

The components and interactions of the climate system can be studied and simulated using climate models. The General Circulation Model (GCM) is the starting point for scientists who will use numerous models to generate accurate data (IPCC, 2001). For this report, the climate data was generated using outputs from 24 climate models by national weather services and research organizations from nine countries (Roy and Huard, 2016). To generate realistic projections, an emission scenario is applied during climate modelling to represent the concentration of GHGs that will be involved in the system. The data in this report is based on the highest emission scenario (RCP 8.5), which is closest to current trends.

Weather is defined as the fluctuating state of the atmosphere characterized by temperature, wind, precipitation, and clouds, and can only predictable over hours, days, or weeks. Climate is the average variability of these elements (or weather) over time. Climate can be observed over different scales, ranging from months to thousands or millions of years.

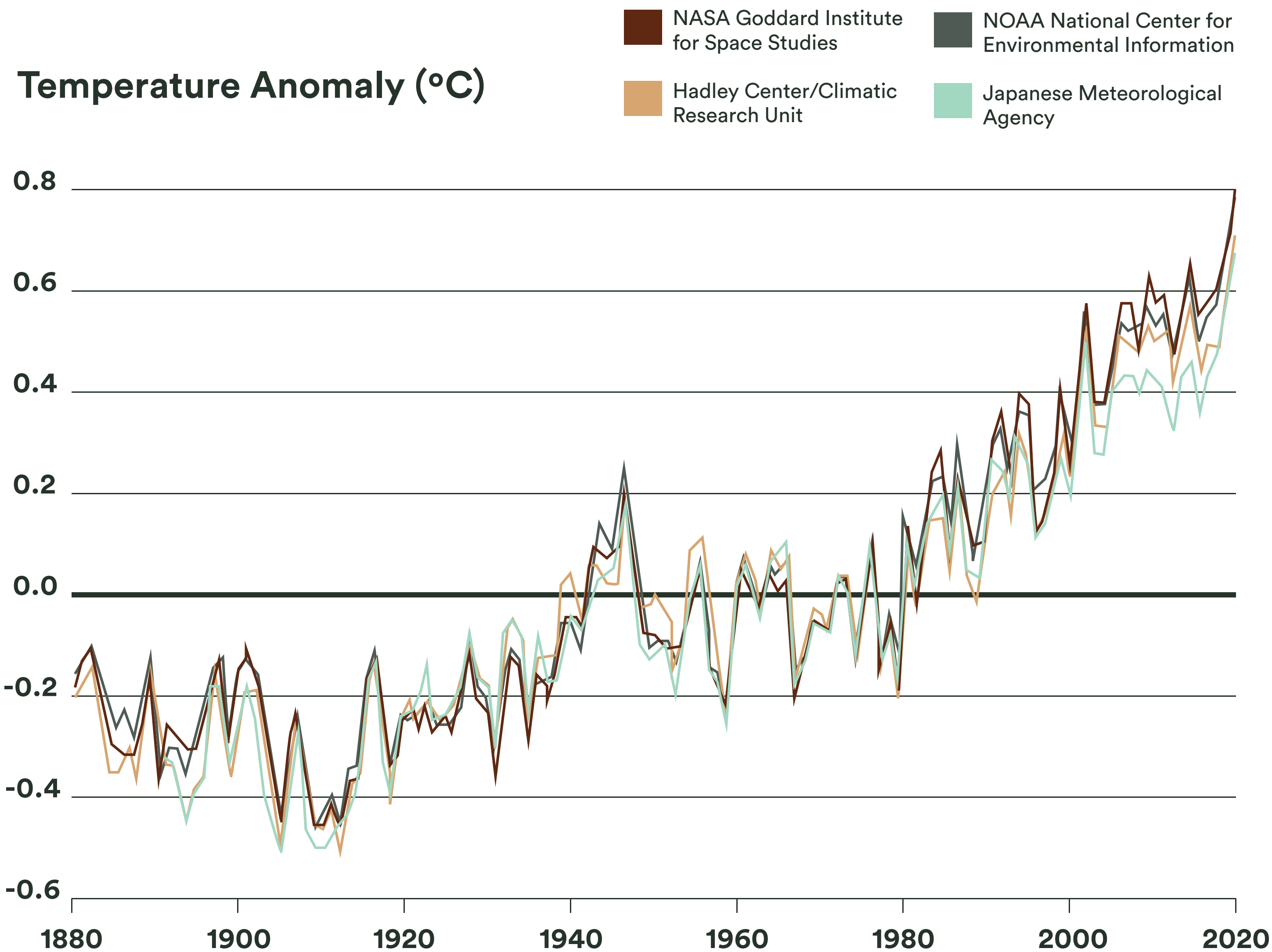


Figure 2: Temperature trends from 1880-2020 (National Aeronautics Space Agency, 2017).

What is a Baseline?

To generate future climate, a baseline of historical data is required. Reports will refer to this baseline when discussing the anticipated changes. For example: 1.5 degrees Celsius of warming compared to 2005 levels, where 2005 levels represent the historical data. The baseline period should be the same length of time as the projected term and is most often a 30 year period.

1.2 Conclusion

Chapter One has provided a brief overview of Climate Change science and modelling. The subsequent chapters will describe the climate projections for Saint John and discuss the associated impacts.

2. TEMPERATURE

The average annual temperature in New Brunswick, relative to 1990 levels has increased by 1.1°C over the last 30 years (NBDELG, 2018a). Compared to the same 1990 baseline, annual temperatures in the province are expected to increase 3.5°C by 2080 (Roy and Huard, 2016). In the Greater Saint John Area, hotter summers and shorter, warmer winters can be expected in the future decades. Temperature projections are displayed in Figures 3 and 4 and climate data is available in Appendix A (Table 1). The annual temperature in the Greater Saint John Area is expected to rise from 5.7°C up to 9.1°C by 2071-2100 (Figure 3). Mean summer temperature could rise 3.4°C by 2071-2100 with an increase in the number of hot days (above 25°C) from 9.5 in 1971-2005 to 70 days in 2071-2100 (Figure 4 A & B). Average winter temperatures will increase from -5.4°C up to -1°C by 2071-2100 resulting in more freeze-thaw days (Figure 4 C & D). The projection data shows the annual number of freeze-thaw days will peak mid-century (2011-2040) and then decline as mean winter temperatures approach zero in the late century (Roy and Huard, 2016). Winter temperatures hovering around zero degrees can be dangerous due to the threat of freezing-rain events which are challenging to predict. Weather alerts provided by Environment and Climate Change Canada (ECCC) are critical for ensuring communities are prepared and safe during periods of unpredictable weather conditions.

Average Annual Temperature Change For Saint John

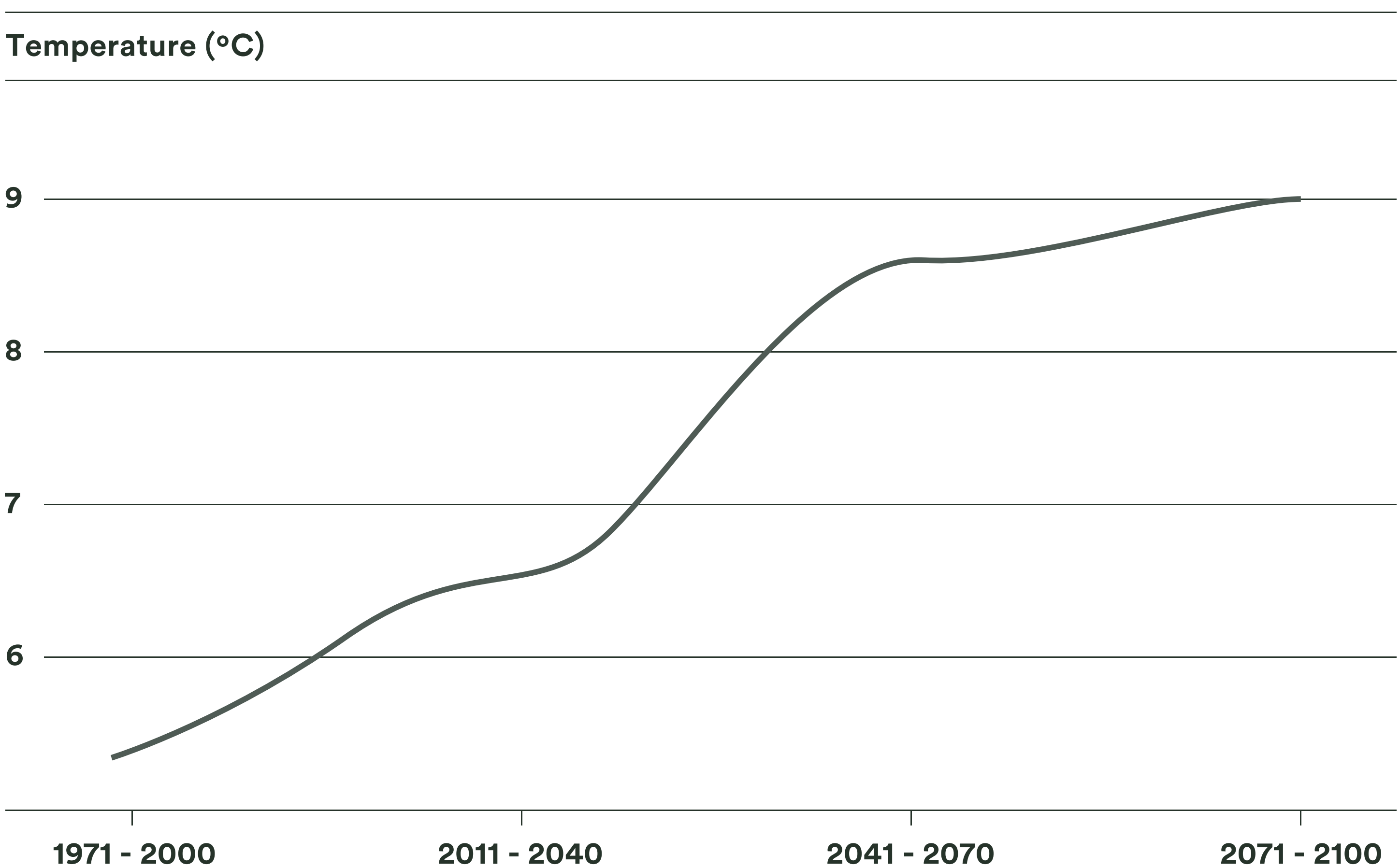
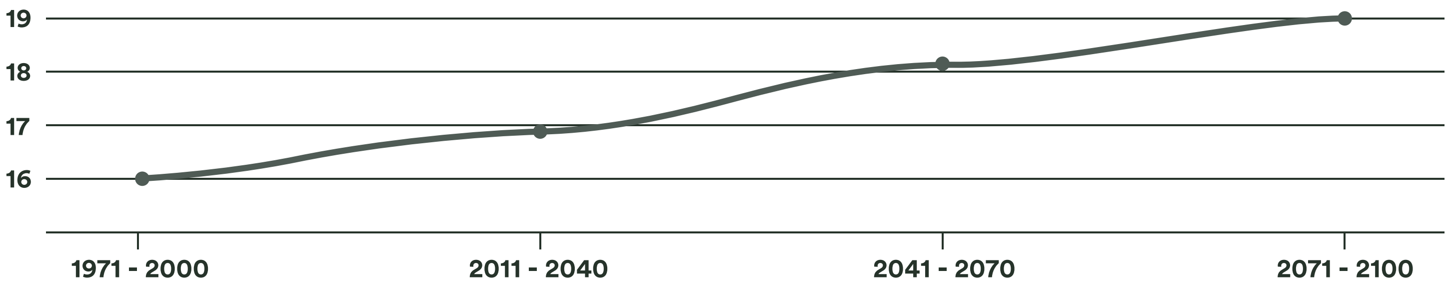


Figure 3: Average annual temperature change for Saint John up to the year 2100 by the Atlantic Climate Adaptation Solutions Association (ACASA) New Brunswick Climate Futures Projections (Roy and Huard, 2016).

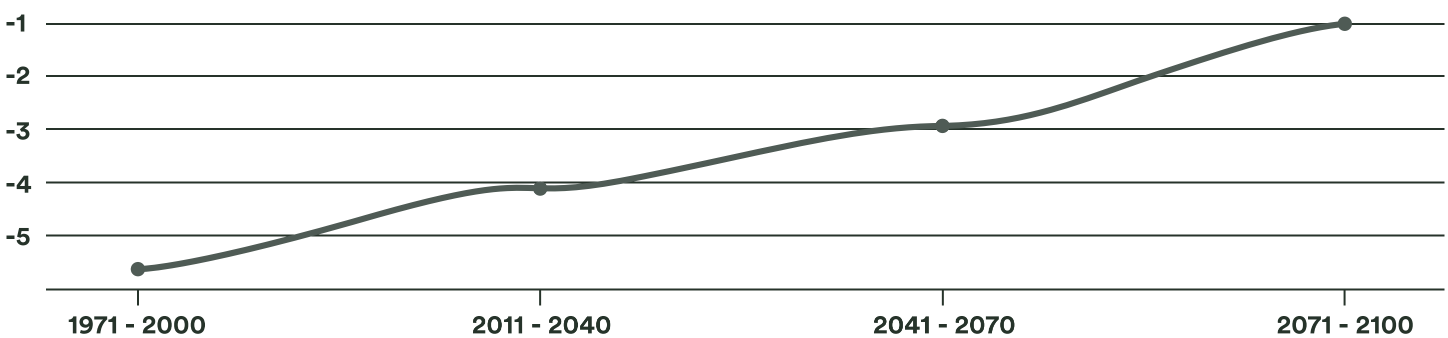
Temperature Changes For Saint John Up To The Year 2100

A Average summer temperature projections.



B The number of hot days where temperatures exceed 25°C.

C Average winter temperature projections.



D The number of freeze-thaw days where temperatures hover around zero degrees.

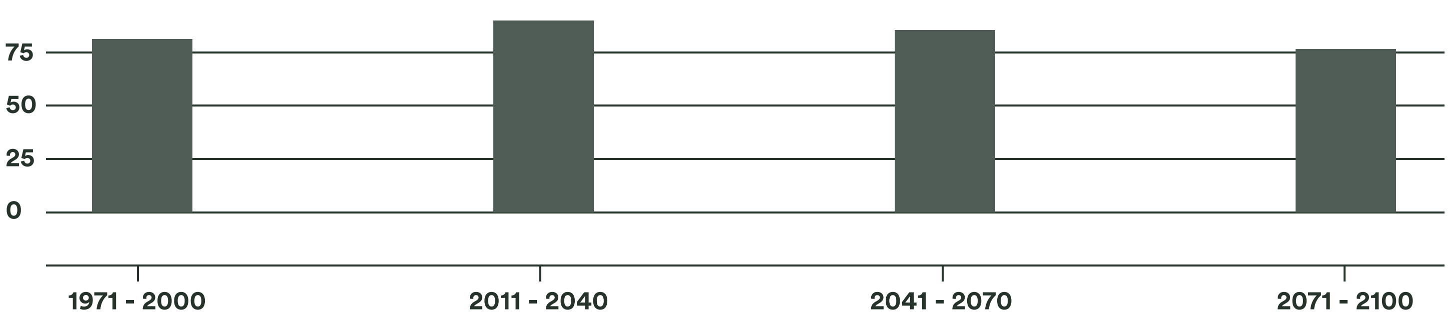


Figure 4: Temperature changes for Saint John up to the year 2100. (A) Average summer temperature projections. (B) The number of hot days where temperatures exceed 25°C. (C) Average winter temperature projections. (D) The number of freeze-thaw days where temperatures hover around zero degrees.

Did you know?

Freeze-thaw days occur when the daily maximum temperature is greater than 0°Cand the daily minimum temperature is less than 0°C. These freeze-thaw cycles (FTCs) are associated with ice and slush conditions which can directly result in damage to built infrastructure. Indirect impacts are challenging to predict and include increased use of road salt and changes to ecological cycles. FTCs are significant for plants or animal species that require stable temperatures for dormancy or are sensitive to cold spells. The production of maple syrup is an example of an industry that relies on FTCs and will need to adapt to these changing climate conditions (Roy and Huard, 2016).

In urban spaces, concrete infrastructure and dark surfaces absorb heat resulting in higher air temperatures when compared to the surrounding rural areas. In climate science, this is known as the Urban Heat Island (UHI) effect (Figure 5). Residential and commercial heating and cooling systems, vehicles and other appliances generate heat and contribute to the UHI. In combination with increasing annual temperatures, many large cities are experiencing dangerous extreme heat events. In Saint John, the UHI effect is moderated by the coastal setting. As temperatures increase, monitoring and education around heat related illness will be necessary to avoid hazards associated with heat and the UHI effect.

As the average annual temperature increases, Saint John will experience earlier snowmelt, mid-winter thaws, and ice breakups which can lead to significant infrastructure damage when combined with intense rainfall (NBDELG, 2014). In 2018 and 2019, Saint John experienced extensive inland flooding due to the combination of spring freshet and extreme rainfall. New Brunswick communities are beginning to adjust to the impacts of warmer temperatures, however education and awareness about adaptation will be needed to reduce the health risks of warmer temperatures in Saint John.

The Urban Heat Island Effect

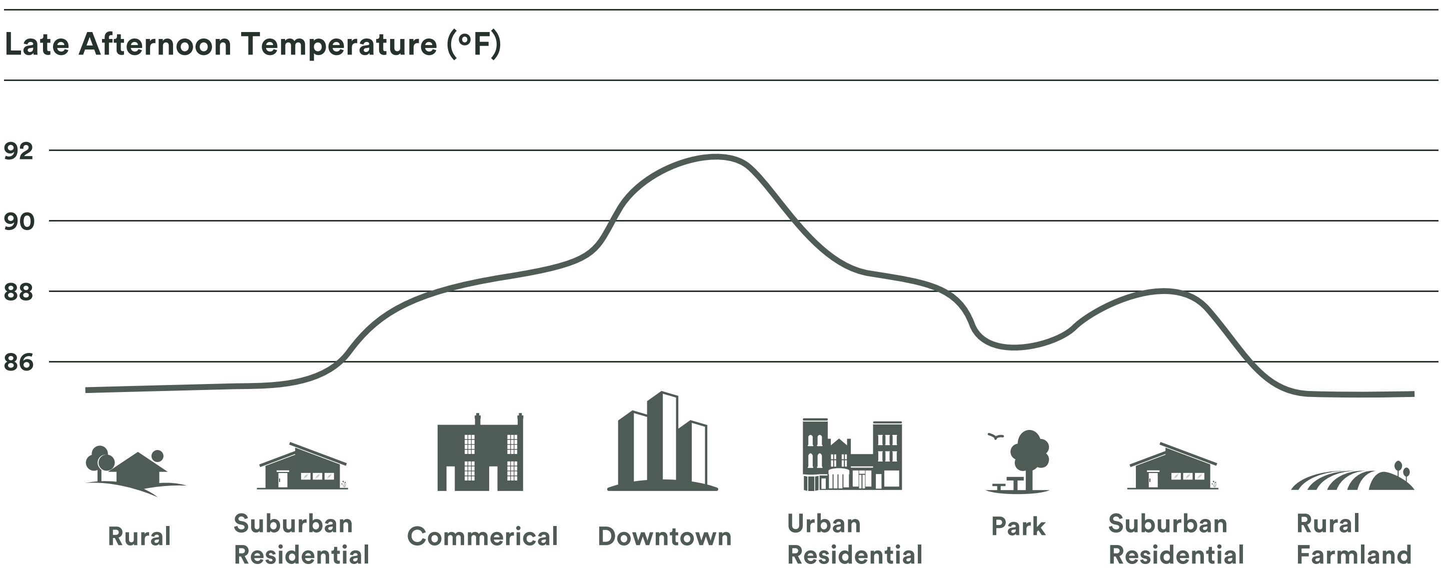


Figure 5: The Urban Heat Island effect: heat is absorbed and held by concrete and asphalt in cities. Tall buildings and lack of vegetation prevent heat from dissipating and diminish natural shade and evaporative cooling (Warren and Lemmen, 2004).

3. PRECIPITATION

Precipitation trends tend to vary more than temperature, making patterns of rainfall in the Greater Saint John area difficult to predict. Climate models project that New Brunswick will experience an extension of dry periods and an increase in heavy precipitation events resulting in a net increase in mean annual precipitation (Figure 6; NBDELG, 2018a, Roy & Huard, 2016). This means that more precipitation will be falling during shorter periods, increasing the amount of stormwater that will be running through sewer infrastructure and into nearby waterways.

The type of seasonal precipitation (rain, snow, sleet, hail, etc.) in the Greater Saint John area is expected to change. As temperatures rise, the annual number of snow days will decrease which correlates to an increase in rain days and may result in more flooding than historically observed (Roy and Huard, 2016). River flows will become more variable as spring peak flow will occur earlier and summer minimal flows will be lower. During summer months, rivers may experience an increase in periods of very low or zero flow that can have significant ecological impact (NBDELG, n.d.). Climate data is available in Appendix A (Table 2).

Projected changes to precipitation in Saint John

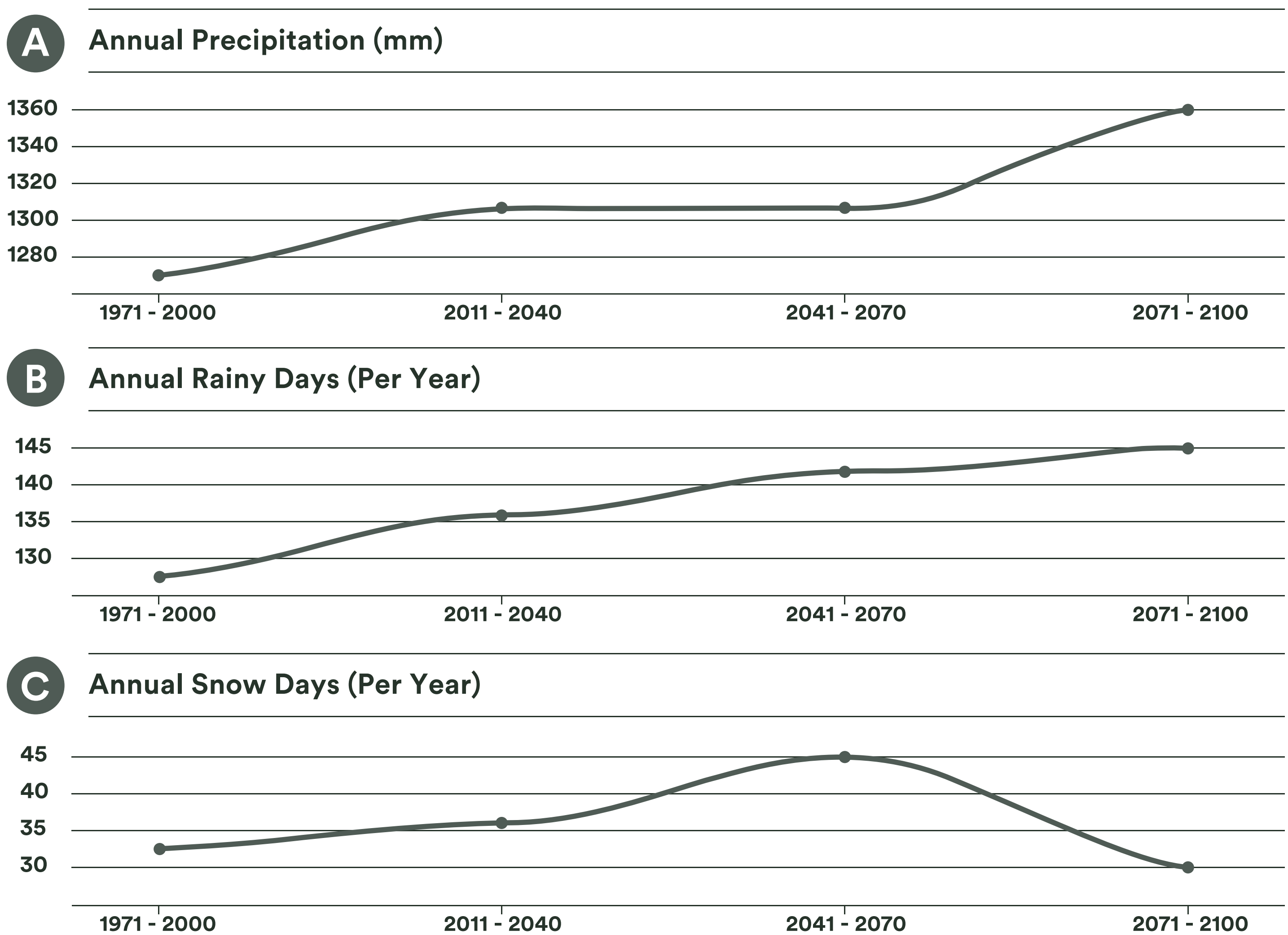


Figure 6: Projected changes to precipitation in Saint John. An increase in annual precipitation is anticipated (A) and changes in the annual number of rain days and snow days are shown (B) and (C). Precipitation projections up to the year 2100 by the Atlantic Climate Adaptation Solutions Association (ACASA) New Brunswick Climate Futures Projections (Roy and Huard, 2016).

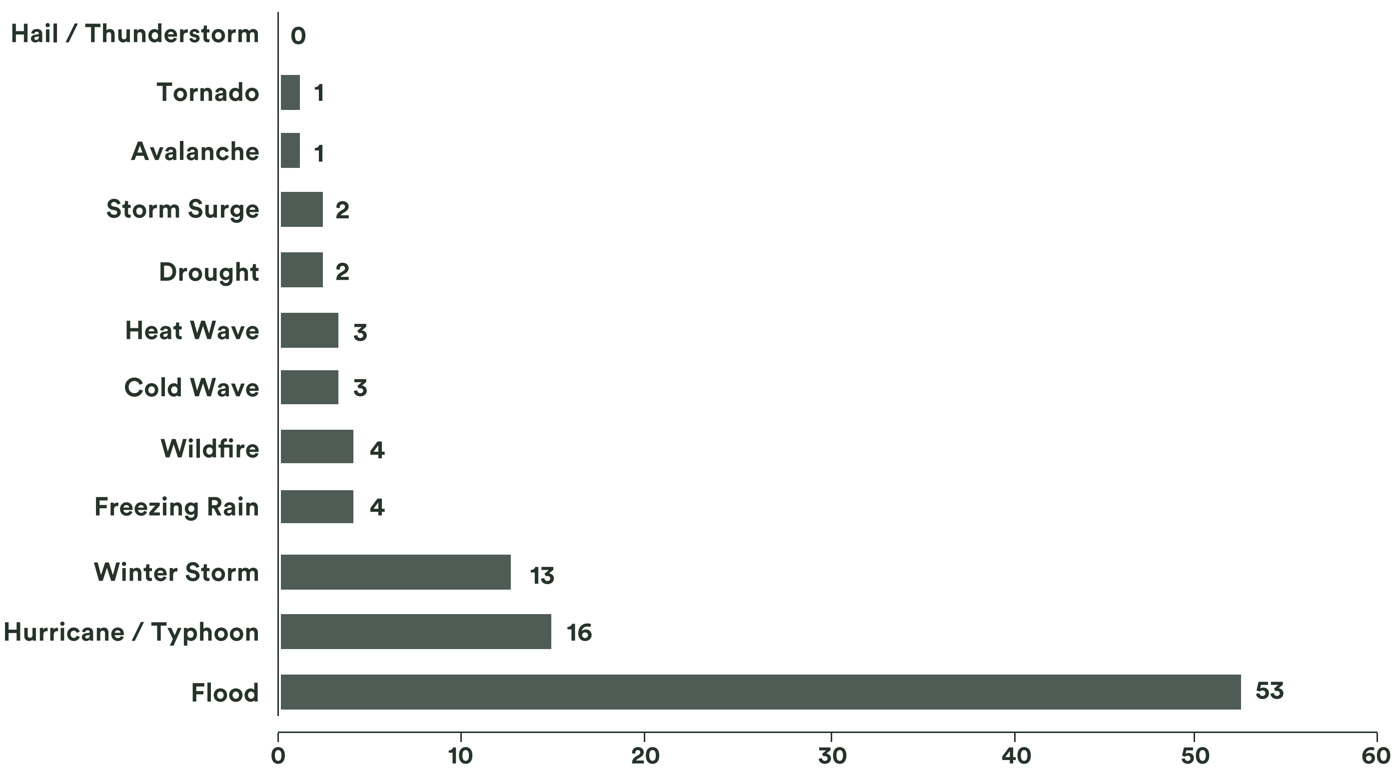
4. EXTREME WEATHER

Extreme weather events are controlled by changes in atmospheric temperature, pressure and moisture. They are expected to become more frequent and intense as a result of changing climate. For every 1°C rise in temperature the amount of moisture in the atmosphere increases by 7% or more (Daigle, 2012). In response to increased moisture, New Brunswick can expect 10 to 20% more extreme rainfall events per year (Canadian Center for Climate Modeling and Analysis, 2017). Historically, extreme rainfall events (50 millimetres or more over a 24-hour period) have caused millions of dollars in flood damage in Saint John, as well as within outlying communities. Most notable were damages in 2008, 2018, and 2019 when heavy rain events coincided with the melting of record-breaking snowfall (NBDELG, n.d.).

Projection trends show an increase in the annual temperature and precipitation in Saint John, however emphasis must be placed on the extremes of each variable, for example days of extreme heat or heavy precipitation events. The impacts of extreme wind, including power outages and fallen trees are already experienced throughout the City. Preparedness is essential to avoid injury and respond quickly as extreme wind events will continue to be experienced.

Natural disasters recorded in Atlantic Canada from 1900-2005

Figure 7: Natural disasters recorded in Atlantic Canada from 1900-2005, retrieved from Atlantic Climate Adaptation Solutions Association (2011).



From 1900-2005, Atlantic Canada experienced approximately 53 flooding events, 16 hurricanes, and 13 winter storms (Figure 7). With shifting hydrological conditions and warming temperatures, Saint John can expect an increase in the intensity and frequency of heavy precipitation, high winds, storm surges, summer convective storms (thunderstorms, hail storms, hurricanes), and severe winter storms. These events are often associated with high damage and recovery costs, emphasizing the importance of preparedness and adaptation. Learning from past extreme weather events can provide insights necessary to lessen future impacts.

In 2017, a survey was conducted by the Conservation Council of New Brunswick after post-tropical storm Arthur, which hit the Maritimes in July 2014. The responses highlighted gaps in emergency preparedness that should be addressed in all New Brunswick municipalities (Comeau, 2017). The biggest concerns for the citizens who participated were power loss, food, water, downed trees, and blocked roads. Municipal staffing and a lack of qualified contractors to conduct cleanup was also recognized as a significant issue.

4.1 Frequency and Economic Costs

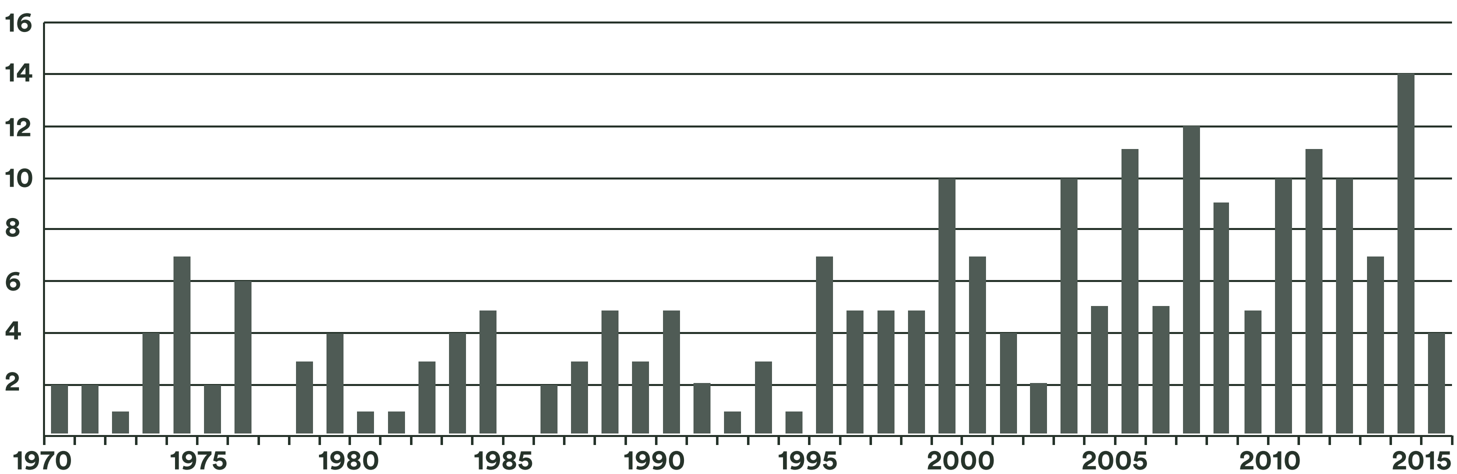
Canadian municipalities have experienced significant increases in the costs associated with property damage and emergency response caused by more frequent extreme weather events (Moudrak and Feltmate, 2017). Public Safety Canada has found that the number of incidences where provinces and territories have required or obtained Disaster Financial Assistance Arrangements (DFAA) significantly increased between 1970 and 2015, well in excess of population growth (Figure 8).

Despite a general trend of increased frequency, anticipating extreme weather events continues to be a challenge. Unlike overall temperature and precipitation trends, windstorms, heavy precipitation, heat waves, forest fires, drought, and ice storms are not accurately represented through climate models, especially on a regional scale (Université Virtuelle Environnement et Développement Durable, 2016). Without an accurate model, the statistics from DFAA and the Insurance Bureau of Canada highlight the need for municipalities to prepare for an increasing trend in more severe weather events. Over six years (2009-2015) the total of DFAA costs associated with extreme weather was greater than the previous 39 fiscal years combined. In those years, flooding accounted for 75% of all expenditures (Moudrak and Feltmate, 2017).

4.2 Post-tropical Storms, Hurricanes and Ice Storms

The City of Saint John is at risk to damages from post-tropical storms and hurricanes which bring strong winds and heavy precipitation. When compounded by higher sea levels these events can lead to power outages, flooding, and isolation which can result in significant economic and public health risks (NBDELG, n.d.). During the winter, ice storms create hazardous conditions for citizens travelling throughout the City. As the winter temperature increases closer to zero degrees Celcius more freezing rain and ice accumulation is anticipated.

Figure 8: Number of natural disasters in Canada requiring DFAA from 1970-2015 (Moudrak and Feltmate, 2017).



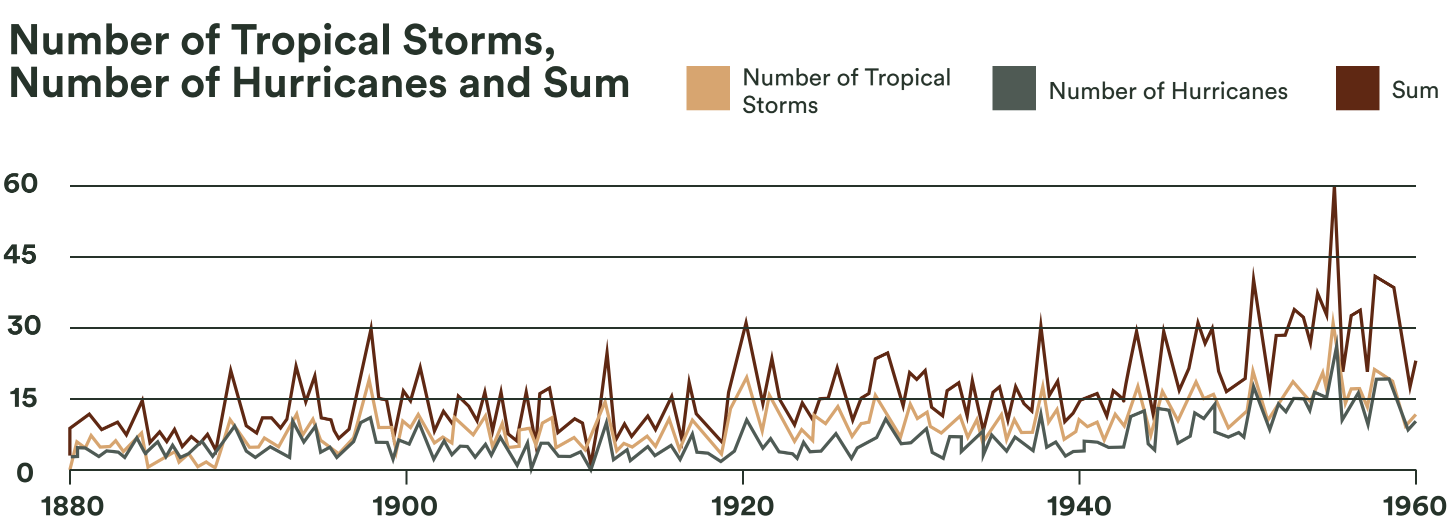


Figure 9: Frequency of tropical storms and hurricanes in the North Atlantic region since 1850 displaying cyclic variations but an overall increase (ACAP Saint John, 2016).

4.2.1 Tropical storms, hurricanes and post-tropical storms

A tropical storm describes a storm system with a low-pressure centre that develops over tropical or subtropical waters in the Atlantic Ocean. If temperature conditions are suitable, a tropical storm can develop into a tropical cyclone, commonly known as a hurricane. A post-tropical describes a storm that maintains strong winds and heavy precipitation but does not qualify as a tropical storm as it no longer exists in tropical regions.

This type of storm system develops when sea surface temperatures are above 25°C (NOAA, 2019). As a result of increases in both annual surface temperatures and sea surface temperatures, more frequent and severe storms are predicted around the world. Trends in the North Atlantic support this prediction showing an increase in the number of tropical storms and hurricanes compared to historical events a(Figure 9). This trend emphasizes the need for adaptation and preparedness in the Greater Saint John area.

Figure 10: The conditions after an ice storm can be extremely hazardous for pedestrians and motorists (Photo: ACAP Saint John).

4.2.2 Ice Storms

As a result of increased temperature and precipitation, freezing rain, and ice storm events will create new challenges for municipalities. During January of 2017, a multi-day ice storm along the coast of New Brunswick led to road closures, downed trees and powerlines, resulting in power outages for over 300,000 residents. Extended power outages from ice accumulation on power lines and fallen trees are especially dangerous during cold temperatures. Following this event, the Government of New Brunswick developed a series of recommendations to reduce vulnerability during these types of storms (GNB, 2017).
In Saint John, winter temperatures will increase creating ideal conditions for freezing rain events and ice storms. When combined with poor visibility, low temperatures and high winds, the presence of ice can be extremely hazardous for residents (NOAA, n.d.-a). Adaptation strategies to reduce the hazards associated with ice storms include tree trimming around power lines and education around emergency preparedness.

4.3 Drought and Wildfires

Climate Change is expected to impact temperature and precipitation extremes in the Greater Saint John area. This means that warmer temperatures may be experienced in combination with periods of heavy precipitation or with periods of minimal precipitation. These changes will have severe impacts such as increased drought stress on crops and shortages of drinking water (NBDELG, n.d.). The City of Saint John is at low risk to these impacts due to the availability of drinking water from surface reservoirs.

The IPCC defines drought as a period of dry weather that leads to an abnormal balance of water in the system (IPCC, n.d).

Drought conditions create dry and warm forested regions, providing fuel for wildfires to break out. Occurrence of wildfires in Canada's boreal forest is the highest observed in human history, resulting in evacuations and stress on remote communities (WMO, 2019). Recent studies suggest that the number of forest fires in Canada will increase by 25% by 2030 and by 75 to 140% by the end of the century (Wotton, Nock, & Flannigan, 2010). By the year 2040, wildfires in Canada may last an average of 30 days and burn 1.5 times more forest area compared to the late 1990's (Government of Canada, 2018).

Increased fire hazard in New Brunswick will threaten infrastructure and ecosystems and reduce air quality. To adapt, the Government of New Brunswick recommends maintaining air quality tracking and advisory programs, increasing the number of health studies to better understand the risks of forest fire smoke, and to promote appropriate forest fire risk prevention or mitigation behavior on a municipal level (NBDELG, n.d.). In Saint John, similar wildfire adaptation is necessary for properties with large woodlots and park spaces.

4.4 Conclusion

As the frequency and severity of extreme weather events increases, adaptation strategies must be taken to reduce negative impacts on municipalities. Results from the public survey conducted by the Conservation Council of New Brunswick provides several recommendations for municipalities to reduce vulnerability to extreme weather. Some adaptations include: cyclical tree trimming around power lines to reduce potential power outages; backup power options with the capacity to sustain residents for 3 to 7 days; and training for emergency officials to handle mental health impacts that may require additional support (Comeau, 2017). Exploring response and recovery from more recent storm events including post-tropical storm Dorian (September 2019) can help identify where support is required to build resilience to these types of extreme weather.

5. SEA LEVEL RISE (SLR)

Global sea level is predicted to rise by a maximum of 0.98 metres by 2100 (Daigle, 2012; IPCC, 2014). Between 1911 to 2000, sea level increased by approximately 30 centimetres (International Council for Local Environmental Initiatives Canada, n.d.). Research suggests the levels will continue to rise by approximately 86 centimetres (+/- 38 centimetres) by the end of the century (Daigle, 2014). As a result, New Brunswick will face more frequent and permanent coastal flooding.

5.0.1 Why is the sea level rising?

The rising sea level in Saint John can be attributed to a combination of melting polar ice, warming ocean temperatures and vertical crustal movement. The addition of freshwater from melting ice caps has a direct effect on sea level. An increase in ocean temperatures results in the thermal expansion of water, meaning water molecules will take up more space and contribute to rising water levels. Lastly, the geologic setting of Saint John has a large role in understanding sea level rise. During the last ice-age, the weight of glaciers located over Quebec and the St. Lawrence River put pressure on Earth's crust. This resulted in crustal uplift throughout Nova Scotia and southeastern New Brunswick (Koohzare et al., 2007). When the pressure of the ice was removed, the crust began to subside to its original position.

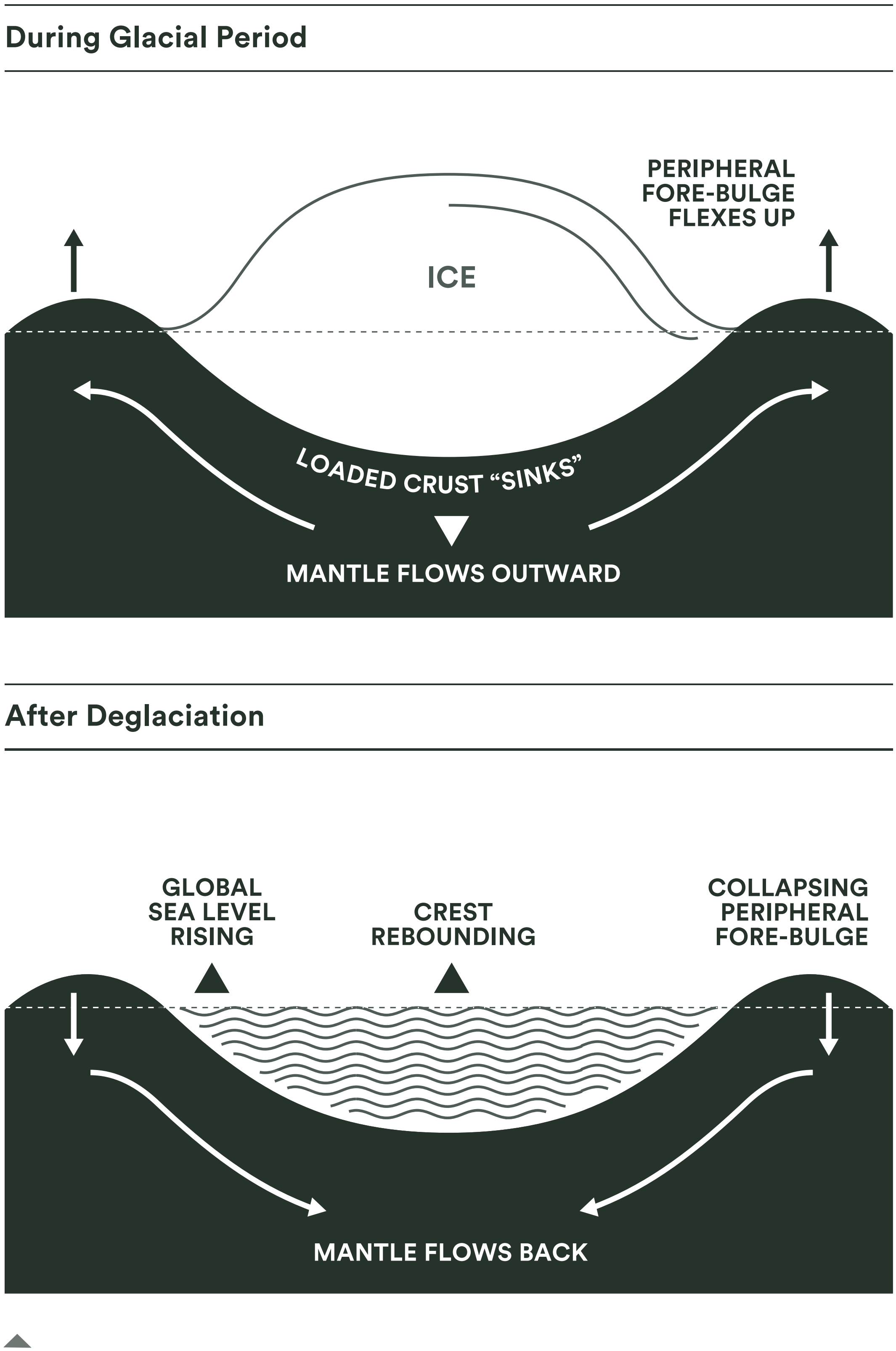


Figure 11: The process of crustal subsidence being experienced in Saint John due to the pressure from glaciers during the most recent ice age (Henton et al, 2006).

Saint John experiences a gradual subsidence of approximately 0.4 millimetres per year (Daigle, 2014) (Figure 11).

5.0.2 SLR Predictions for Saint John

Flooding scenarios up to the year 2100 have been projected for coastal communities in southeast New Brunswick (Daigle, 2017). This research provides values for total sea level over different return periods (Figure 12). Total sea level is the sum of Higher High Water Large Tide (HHWLT), anticipated regional sea level rise, and highest storm surge amplitude. Using different return periods provides a range of severity that can be anticipated depending on the intensity of storm events. The flooding scenarios also include the glacial collapse of the West Antarctic ice sheet, which could result in further sea level rise of approximately 65 cm (Figure 12B; Daigle, 2017). Sea level rise data can be found in Appendix A (Table 3).

Sea level rise has many impacts including coastal erosion, coastal squeeze, changing tidal amplitude, and increased storm surge. Ultimately, these can result in significant flooding events and the permanent loss of land and habitat. The costs of coastal flooding are higher in New Brunswick than any other Atlantic province and five times higher than the Canadian average. The cost of damages to homes in New Brunswick are expected to reach $730 to $1,830 per resident per year by the year 2050 (NBDELG, 2014). To adapt to Climate Change, the City of Saint John must take action to protect coastlines and reduce the hazardous impacts of sea level rise.

100 Year
50 Year
5 Year
1 Year

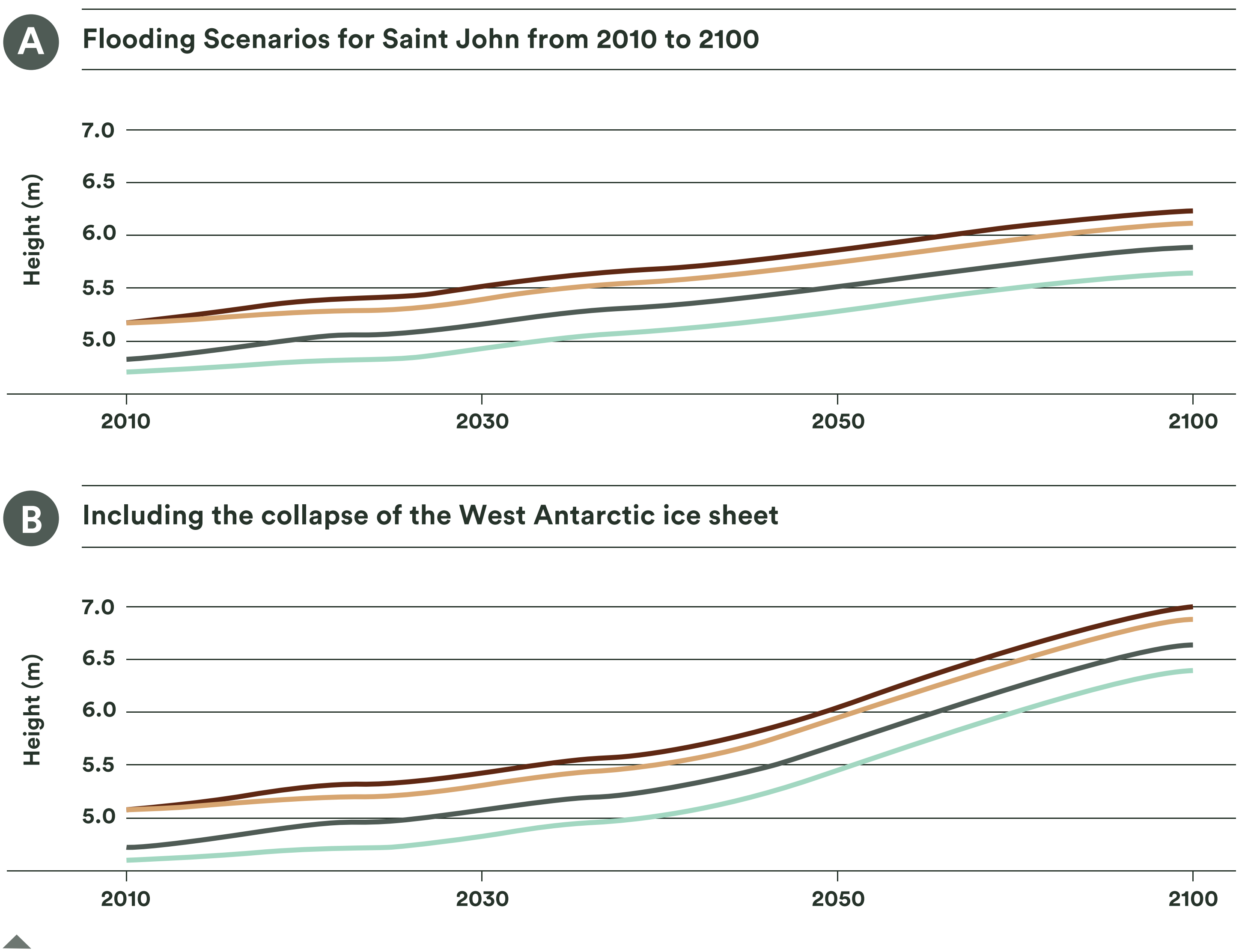


Figure 12: (A) Flooding Scenarios for Saint John from 2010 to 2100, expressed as the total sea level for various return periods. (B) Flooding scenarios include the collapse of the West Antarctic ice sheet which by the year 2100, would cause sea levels to rise substantially more than projections suggest (Daigle, 2017). In both (A) and (B), an increase in sea level is observed.

Return periods express the probability of a flood or storm event. For example, a 1 in 100-year event has a 1% chance of occurring in any given year; a 1 in 5-year event has a 20% chance of occurring; and a 1-year or annual event is likely to occur every year. Return periods are calculated based on current weather patterns and do not include changes in future climate. A 1 in 100-year event could become a 1 in 50-year event as the climate changes.

Figure 13: Shoreline erosion at Sand Cove Road in West Saint John (Photo: ACAP Saint John).

5.1 Coastal Erosion

Sea level rise will not only lead to more severe flooding but will also increase erosion of coastline areas. Coastal erosion can threaten homes, businesses, bridges, roads, and historic sites in coastal zones. Roads and railways built near shorelines are now recognized to be vulnerable to coastal erosion and flooding. Repairs and consolidation of embankments, bridges, abandoning old roads, and relocating routes are expensive adaptation responses (Université Virtuelle Environnement et Développement Durable, 2016). Aside from the high costs of damage, coastal erosion can cut off essential supply chains, limit opportunities in tourism, curb new development, and increase ecological sensitivity of an area. Red Head Road, Sand Cove Road, Bayshore Beach, Sheldon Point Road and Lorneville Cove have already been identified as experiencing coastal erosion in Saint John (Figure 13). New Brunswick coastlines are eroding at 0.59 to 0.88 metres per year due to sea level rise and sensitivity to storm surges (O'Carroll and Bérubé, n.d.). In areas that experience instability, slope movement can be hazardous depending on the amount of material being shifted. Monitoring of areas experiencing high erosion is of significant importance, in order to warn residents about high risk areas that may pose danger to commuters, residents, or recreationists.

In critical areas, the City has the option to protect, accommodate or retreat and accept the loss of land (Figure 14). Each strategy will have different risks and costs specific to the rate of erosion. The expense of accommodation and protection strategies may also deter property owners, leaving retreat as the only option.

Grey infrastructure in Saint John was designed to accommodate a 0.7 metre rise in sea level. However, with sea level rise projected to reach 0.86 metres rise by the year 2100, the City needs to recognize the increased risk of coastal erosion, flooding and infrastructure damage (NBDELG, n.d.). Properties in high risk erosion zones are vulnerable to seawater contamination in drinking wells and permanent loss of land. Ultimately, coastal erosion, exacerbated by sea level rise and increased storm surge, leads to negative impacts on harbours, native species, and nearby homes and businesses (NBDELG, 2014; Lemmen et al., 2016).

Hard protection infrastructure includes dykes, seawalls, rock armouring, or geosystems that consolidate retreating coastal zones. Soft infrastructure can be measures such as heightened conservation efforts or reinstating vegetation (bioengineering) that will buffer shoreline protection for beaches and wetlands (i.e. planting willows, maintaining mangroves, or beach renourishment).

Flood Mitigation Strategies For Sea Level Rise

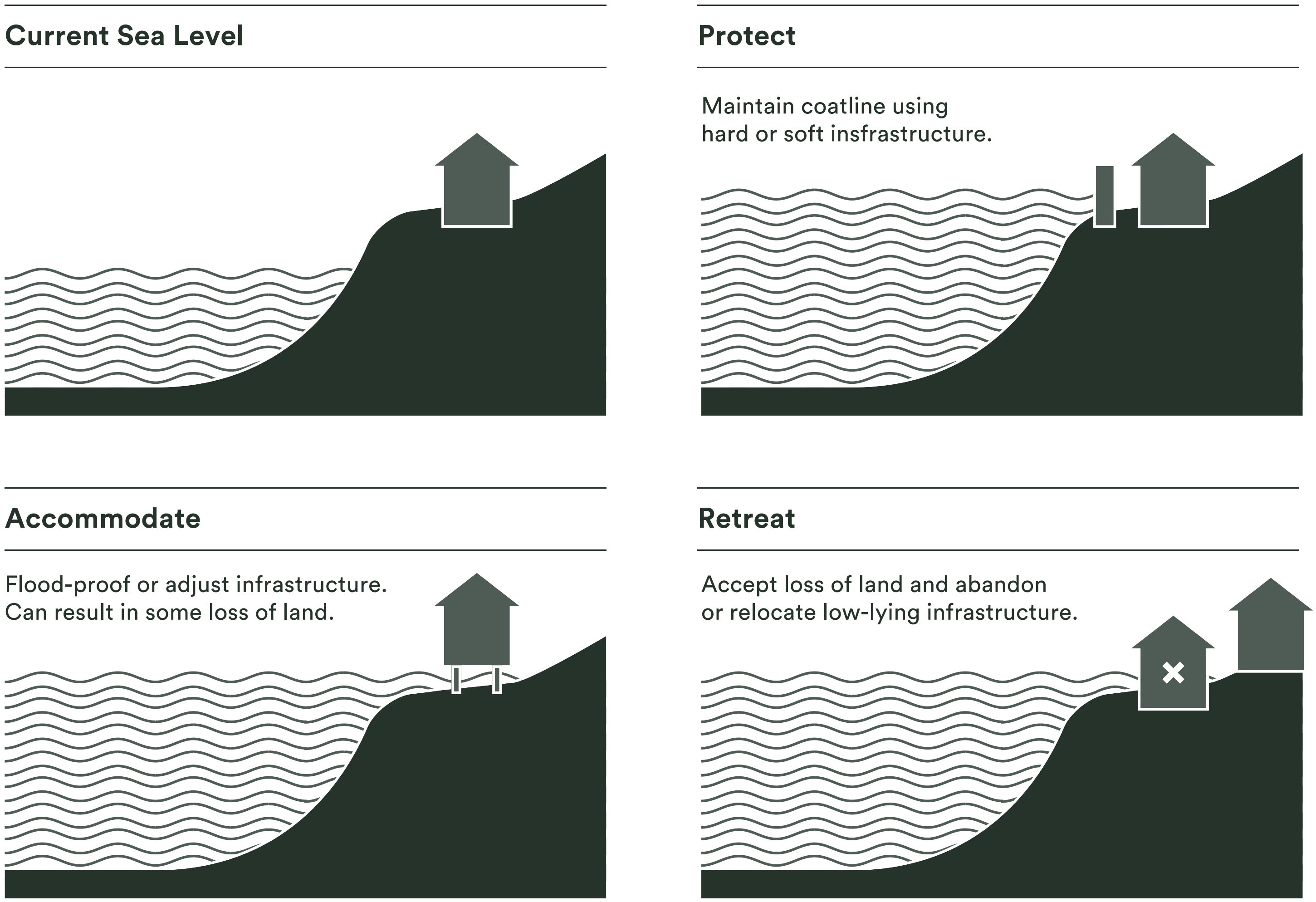


Figure 14: Flood mitigation strategies for sea level rise (Lemmen et al., 2016).

5.2 Coastal Squeeze

Coastal squeeze is a term that describes the inland movement of coastal wetlands as sea level rises. As environmental factors, such as wind or waves, alter the landscape, coastal habitat will naturally reestablish further inland as an extension of the existing habitat. The progression of coastal squeeze depends on the presence of hard infrastructure or natural barriers can prevent salt marshes, mudflats, and sand dunes from migrating inward (Pontee, 2013). Figure 15 shows three coastal squeeze situations including (a) where there is no obstruction, (b) where a barrier to migration is in place, and (c) where a natural obstruction to landward migration exists.

Available conservation techniques to protect ecosystems include coastal restoration and development of migration corridors (Borchert et al., 2018). These corridors control the migration of displaced species, reducing the risk of wildlife in urban spaces. Educating homeowners and developers about coastal squeeze can help prevent habitat loss by transitioning commercial and residential lawns into natural coastal plantings (Powell, 2018). By monitoring species movements and coastal erosion, the negative impacts of coastal squeeze can be reduced.

Sea level rise describes the average increase in water due to melting glaciers, increasing water temperature and geologic setting. Storm surge is a temporary rise in water occurring during specific weather conditions. Problematic situations arise when these two are combined.

5.3 Storm Surge

Storm surge describes the temporary rise of water levels instigated by severe weather conditions. Often, a strong onshore wind combined with a low atmospheric pressure system will intensify wave amplitudes resulting in shoreline flooding (Natural Resources Canada, 2007). Storm surge events pose a significant financial risk to the City due to flood damage, road closures, loss of property, habitat loss, landslides, and debris flow.

There are several well documented storm surges that have caused severe damage to communities around the Bay of Fundy, such as the Saxby Gale of 1869 and the Groundhog Day Storm of 1976 where tides rose up to 2.5 metres above predicted levels (Desplanque and Mossman, 1999). When high water is experienced in combination with heavier annual precipitation the likelihood of a 1 in 100-year flooding event from storm surge increases (Public Health Agency of Canada, 2018).

Conservation of coastal habitats is a Climate Change adaptation strategy that can provide flood water storage, storm surge buffering and coastal erosion control. Research indicates that storm surge amplitude can be reduced by approximately one foot for every 1.6 kilometres of vegetated wetland that exists between a coast and urban development (NOAA, n.d.-b). In situations where natural conservation will not accommodate projected storm surge levels, the City can use hard infrastructure (i.e. dykes and sea walls) to prepare for the coastal impacts.

5.4 Conclusion

Adaptations to protect urban areas or relocate infrastructure due to sea level rise are often expensive and involve collaboration between multiple stakeholders. The challenges created by coastal erosion, coastal squeeze, and storm surge are site specific and require long term monitoring. As the water levels rise, the City will have to evaluate and prioritize the options for maintaining the coastline and relocating at-risk infrastructure.

Predicting storm surge levels can be difficult, but there are tools available for early warning. For instance, the Smart Atlantic Saint John Inshore Weather buoy has collected meteorological and oceanographic data since 2015. The buoy enhances public safety and operational efficiency of harbour activity by providing online access to real-time weather and directional wave data.

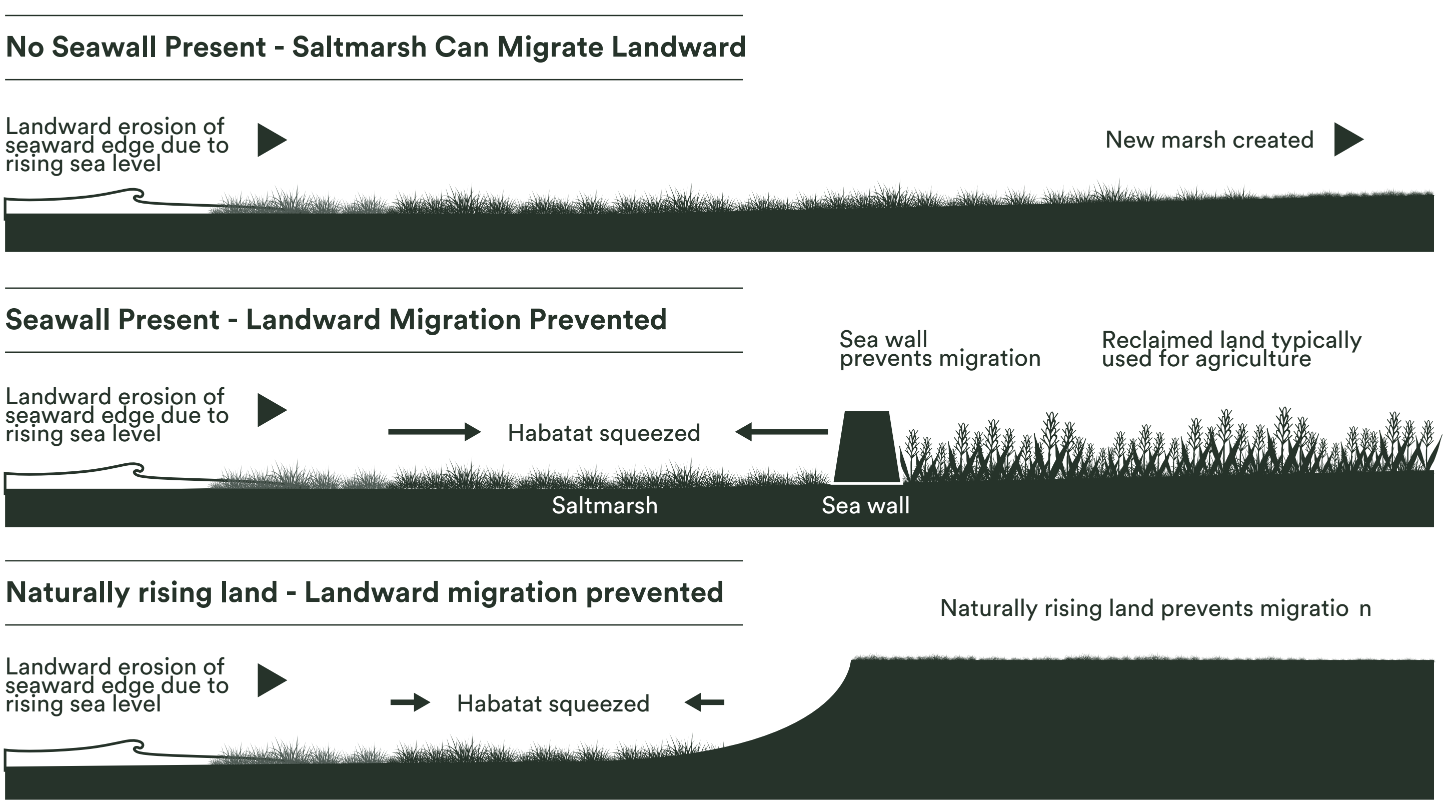


Figure 15: Habitat migration scenarios under sea level rise: (a) No seawall is present and new marsh land is created, (b) A seawall prevents migration and habitat is lost, (c) Naturally rising land prevents migration and habitat is lost (Savard et al, 2016).

6. FLOODING

Flooding is the most frequent natural disaster in Atlantic Canada. Between 2007 and 2017 the Government of New Brunswick spent $185 million on disaster recovery primarily from flooding events. The Flood Risk Reduction Strategy for New Brunswick aims to build resilience through accurate hazard identification, old infrastructure retrofits, new infrastructure regulations, and informed mitigation practices (GNB, 2014b). In Saint John, there are two types of flooding that can be expected: inland flooding from heavy precipitation and high river flows; and coastal flooding due to sea level rise or storm surge. This chapter will discuss inland flooding in Saint John.

6.1 Damage to Urban Built Environment

As discussed in Chapter 3, Climate Change is expected to increase precipitation resulting in more frequent and severe flooding in Saint John. Adaptive approaches to planning, development and infrastructure management can reduce the damage associated with flood events.

6.1.1 Grey Infrastructure

The term grey infrastructure is used to describe infrastructure that has low infiltration capacity and easily becomes flooded during periods of high runoff (Depietri and McPhearson, 2017). Municipal infrastructure is mostly impermeable, meaning water does not naturally soak back into the surface. This makes urban environments especially vulnerable to flooding and puts pressure on stormwater systems to transport the water elsewhere. In Saint John, facilities vulnerable to flooding include residential and commercial buildings, sewage treatment, water services, power generation, industrial activity, communications, and healthcare services.

The City of Saint John can plan to reduce flooding risks by adjusting building standards to account for 1 in 100-year storm water levels. The Intact Center on Climate Adaptation provides recommendations for municipalities and homeowners to reduce flooding in urban spaces. A few of their suggestions include: designing roads to be at least 30 cm below the lowest building openings, ensuring backup power is available for wastewater pumping stations, building driveways to slope away from homes and garages, installing backwater valves in basements, and having heating, ventilation, and air conditioning (HVAC) systems installed above grade to avoid destruction or damage to property (Moudrak and Feltmate, 2017).

Figure 16: Road closure during the 2019 spring freshet flooding of the St. John River (Photo: ACAP Saint John).

Figure 17: Grey infrastructure in Saint John includes roads, bridges, railways, buildings, stormwater drainage, and sewers. These images depict the low infiltration capacity in urban areas (Photo: ACAP Saint John).

6.1.2 Green Infrastructure

Green infrastructure, also known as Low Impact Development (LID), refers to stormwater management methods that promote infiltration and retention rather than methods that focus on directing surface runoff into water treatment facilities, storage ponds, or natural systems (Buckland-Nicks, 2016). Studies have shown that green infrastructure significantly mitigates flooding risk in urban spaces (Depietri and McPhearson, 2017). In watersheds with greater than 25% impermeable surfaces, the likelihood of a 1 in 100-year flood is increased to a likelihood of 1 in 5 (Trice, 2017).

For municipalities, green infrastructure and natural asset restoration can be more cost effective to maintain then engineered structures (Depietri and McPhearson, 2017). Besides the cost, the co-benefits of natural assets include a range of ecosystem services that provide flood and erosion control, heat moderation, pollination, carbon dioxide storage, and enhancement of community well-being.

Figure 18: In 2019, ACAP Saint John installed a rain garden on Queen Square West as a pilot project for the City. Green infrastructure can include implementing rainfall capture systems, permeable pavement, green roofs, bioswales, and rain gardens (Photo: ACAP Saint John).

6.1.3 Hybrid Approach

The value of grey and green climate adaptation solutions has been assessed by researchers Depietri and McPhearson (2007), who highlight the dependence of cities on natural ecosystems for urban disaster risk reduction. The findings suggest a hybrid approach (green infrastructure integrated with grey infrastructure) to be the most effective at reducing risk in complex urban systems. An example of this hybrid approach is a wetland restoration coupled with engineering measures (i.e. a small levee, bioswales, rain gardens, green roofs, or street trees) to enhance flood protection while taking advantage of low impact development (Table 1).

Grey	Hybrid or mixed approaches	Green and Blue
Hard, engineering structures	Blend of biological-physical and engineering structures	Biophysical, Ecosystems and their services
Very limited role of ecosystem functions	Allows for some ecosystem functions mediated by technological solutions	Mainly relying on existing or restored ecosystem fuctions and water bodies
e.g. canals, pipes and tunnels of the drainage system; dikes; wastewater treatment plants; water filtration plants	e.g. biowales; porous pavement; green roofs; rain gardens; constructed wetlands; Sustainable Urban Drainage Systems (SUDS)	e.g. wetlands restoration; installation of grass and riparian buffers; urban trees; stream restoration; rivers, lakes, ponds, oceans and seas

Table 1: Grey, hybrid, or green and blue infrastructure adaptation options (Depietri and McPhearson, 2017).

6.2 Planning for Flooding

Flood risk mapping technologies can be used to estimate the extent of potential flooding under different scenarios. These resources are extremely useful for emergency preparedness and adaptation planning. The Climate Change Adaptation Plan for Saint John by ACAP Saint John will use flood risk mapping to identify roadways, residential and commercial lots, industrial sites, and other areas at risk for flooding. These maps can be used by the City to limit development in at-risk areas.

Aside from development restrictions in flood-prone areas, early warning systems play an increasingly important role in flood risk preparedness. The New Brunswick Emergency Measures Organization (NB EMO) has developed a River Watch program to alert residents to potential flooding events and provide a flood forecasting system to predict high water levels on the Wəlastəkw (St. John River) up to two days in advance.

6.3 Conclusion

In the coming century, Saint John will experience higher river flows and heavier precipitation creating flooding challenges that we are not currently prepared for. Flood risk mapping will play a significant role in restricting development and building awareness for homeowners living in floodplains. Adaptation is required to reduce the negative impacts that can result including property damage or contamination from combined sewer overflows. Green or hybrid infrastructure approaches are recommended as proactive adaptation practices.

7. URBAN WATER QUALITY AND SECURITY

The quality and availability of drinking water is of primary concern for municipalities who rely on local aquifers and surface ponds to sustain residential needs. In Saint John, drinking water is sourced privately from wells or through Saint John Water, which is sourced from surface reservoirs in Spruce Lake and Loch Lomond.

According to the United Nations, water security is the capacity of a population to ensure sustainable access, availability and quality of water necessary to "sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems" (United Nations Water, 2013).

7.1 Saltwater Intrusion

Saltwater intrusion occurs when seawater enters into the coastal groundwater system and is a recognized hazard to coastal communities around the world (Giudice & Broster, 2006). This has a direct effect on human health and industrial sectors (including agriculture, forestry, and fisheries) resulting in increased demand on freshwater resources. In Saint John, surface reservoirs for drinking water are monitored for saltwater intrusion.

Various strategies can be employed by local governments in areas impacted by saltwater intrusion. Desalination plants are facilities where salt and minerals are removed from saline water. City planners may favour relocation and changes to zoning laws over desalination because of its costliness which is estimated to $0.25 to $0.50 per resident per day in Canada (Université Virtuelle Environnement et Développement Durable, 2016). Saltwater intrusion is a growing concern in Saint John, specifically the West Side drinking water supply. By observing invasive species, groundwater quality, and changes in coastal habitats and species, City officials could be alerted about changes in the saltwater-freshwater interface before the most severe impacts are felt.

7.2 Water Quality and Availability

Other than saltwater intrusion, changing climate conditions pose significant risk to urban water quality and availability. Changes in precipitation patterns can diminish freshwater supplies (Government of New Brunswick, n.d.). Warmer annual temperatures and lower summer river levels can alter water quality, creating more favourable conditions for bacterial growth and harmful algal blooms (HABs). As well, increased stormwater runoff can introduce pollutants, viruses, and sewage backup into drinking water reservoirs (Fann et al., 2016).

In Saint John, flooding of stormwater systems can cause combined sanitary and stormwater systems to backup and contaminate waterways. After a heavy rainfall, faecal coliform levels are commonly observed above recommended guidelines (ACAP Saint John, 2017). Increased effort to separate combined sewer infrastructure and monitoring of waterways are actions required to improve water quality in Saint John. Processing water through a treatment facility can reduce hazards in municipal drinking water sources. However, when detected, toxins can be costly to remove (United States Environmental Protection Agency, 2018). Routine monitoring is undertaken by Saint John Water to reduce health hazards that can result from exposure or consumption.

7.2.1 Cyanobacteria

Cyanobacteria, sometimes referred to as blue-green algae, has been observed in New Brunswick waterways, and can release cyanotoxins which are toxic to both humans and animals. Exposure can result in itchy eyes and skin, rashes, blisters, nausea, fever, vomiting, gastrointestinal issues, headaches, and/or dizziness (NBDELG, 2018b). If drinking water reservoirs are contaminated by cyanobacteria, the water is unsafe for consumption until the bloom has subsided. Using water contaminated with cyanobacteria to bathe, wash clothes, or clean is not recommended. In addition, fish from contaminated waters should not be consumed. Monitoring and education around cyanobacteria is necessary to ensure the safety of residents in Saint John.

7.3 Ocean Warming and Acidification

Similar to the atmosphere, Earth's oceans absorb CO_2 from the atmosphere. As a result of increased GHG emissions, excess CO_2 dissolves in oceans where it breaks down to carbonic acid, carbonates and bicarbonate. Higher CO_2 quantities have caused ocean acidity to rise by 30% since the beginning of the industrial revolution (Université Virtuelle Environnement et

Développement Durable, 2016). Warmer, and more acidic waters significantly affect already fragile ecosystems and intertidal zones.

Ocean warming and acidification is a severe threat for ecosystems along the Bay of Fundy including sponges, anemones, sea squirts, crustaceans, and mollusks. These species have a significant role in the economic and recreational prosperity of coastal communities in New Brunswick (Université Virtuelle Environnement et Développement Durable, 2016). Important species like haddock, winter flounder, lobster and herring fisheries will be threatened by changes in the coastal ecosystem (CPAWS, n.d.).

7.4 Tourism and Fisheries

As a coastal city, Saint John has a long history of tourism and fishing industries. Climate Change has indirect impacts on these sectors and how they are managed.

7.4.1 Sustainable Tourism in Saint John

Coastal tourism in the Greater Saint John Area is dependent on the maintenance of natural landscapes that are vulnerable to Climate Change. Many ecologically sensitive tourist attractions in the area such as wetlands and beaches will require protection from coastal erosion. More extreme weather can dissuade tourists and cruise ships from visiting attractions in the Bay of Fundy. The United Nations Environment Programme and the World Tourism Organization (2005) have presented a range of measures to adapt coastal tourism to changing climate conditions including soft protection of coastlines to fight erosion and drainage management to reduce the risk of flooding. Adaptations intended to enhance and protect natural tourism attractions will also increase climate resiliency along the coastline. The tourism sector in Saint John has a unique opportunity to share the natural beauty of New Brunswick while also demonstrating the need for Climate Change adaptation.

Figure 19: A large cruise ship bringing in thousands of tourists is seen docked at the Marco Polo Terminal in Saint John's Central Peninsula (Photo: ACAP Saint John).

7.4.2 Fisheries

Fishing is an important economic and recreational activity in Saint John. The City promotes fishing as a recreational activity and tourist attraction, offering licenses for stocked lakes like those in Rockwood Park. As the climate changes, habitat for numerous fish species are threatened which has significant impacts on both commercial and recreational fisheries. For example, fisherpeople will need to adjust to the disappearance of some species and the emergence of others (Université Virtuelle Environnement et Développement Durable, 2016).

7.5 Conclusion

The major threats to the drinking water supply in Greater Saint John include saltwater intrusion, and the growth of bacteria or HABs as a result of increasing temperatures and precipitation. These changes, as well as ocean acidification, will have a large impact on ecosystem function. Monitoring water quality and species populations is important as it helps to address hazards associated with urban water quality. Alteration of water resources in Saint John will significantly alter the tourism and fishing sectors. Sustainable and restorative practices and monitoring programs are strategies that can be taken to reduce negative impacts associated with changing water quality and availability.

Figure 20: While aquaculture plays a significant role in reducing the overharvesting of wild stocks, the industry has significant impacts to the natural environment and is vulnerable to climate changes. Species under stress from aquaculture practices have an increased sensitivity to changes in environmental conditions. (Photo: ACAP Saint John).

VIDEO : Lorne St Naturalized Stormwater Pond/ Projet d'atténuation des eaux de pluviales de la rue Lorne

https://youtu.be/UgCvS5AvDxI

VIDEO: Flooding in NB ENG With Subtitles

https://youtu.be/u6250sq-n_4

VIDEO: Flood Hazard Maps Tutorial ENG

https://youtu.be/yDnXkRS7gus