

Adapting to Climate Change in New Brunswick

Natural Solutions for New Brunswick and Other Maritime Communities

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1.0 Introduction

1.1 Global Climate

Earth's climate experiences natural cycles of warming and cooling. Changes in the elliptical orbit of the Earth around the sun drives climate and results in shifts between glacial and interglacial periods. This process is called the Milankovitch Cycle (Imbrie et al. 1992; Berger 1988). Ice over Canada has advanced and retreated many times throughout history. The last major glaciation event was the Wisconsin Glaciation which ended approximately 10,000 years ago (Blaise et al. 1990). We are currently living in an interglacial phase – the warming part of the cycle. Unfortunately, human activities are exacerbating Earth's natural warming causing the global temperature to rise higher than what is expected (Hackett 2017). From the scientific view point, this is climate change. The purpose of this report is to provide insight on possible adaptation strategies in order to prepare for the damaging effects of climate change.

According to the Intergovernmental Panel on Climate Change (IPCC), the signs of climate change are clear. The impacts of climate change are seen all over the planet affecting both the natural and anthropogenic world. The atmosphere and oceans have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentration of greenhouse gases have increased (IPCC 2013). As a result of these impacts, each of the last three decades has been successively warmer around the world. A major contributing factor to this warming are greenhouse gas emissions. Currently, greenhouse gas emissions are not on track for stabilization. Emissions from industrialized countries are about 5x higher than low income countries (Victor et al. 2014). With the rising global issue of climate change, the United Nations established the Paris Agreement in December 2015. The Paris Agreement aims to improve the global response to the threat of climate change by keeping a global temperature below 2°C (Schleussner et al. 2016). It is predicted

that an increase in global temperatures of more than 2°C will result in irreversible impacts. Although this initiative is constructive, the goal will be difficult to achieve due to the lack of global political will and that some degree of climate change is inevitable due to past pollution (Chan 2018). Furthermore, the current level of greenhouse gas emissions is expected to raise global temperatures by 3.5°C by the end of this century (Government of New Brunswick 2016).

1.2 New Brunswick and Climate Change

In terms of local impacts, average temperatures in Canada have increased by 1.7°C since the 1950s. As a result of these changes, Canadian communities are expected to experience increased risk of flooding, sea level rise, erosion of topsoil, and extreme weather events such as heat waves and severe storms (Lemmen et al. 2004). These impacts will bring supplementary impacts including health problems, infrastructure failure, agriculture loss, and property damage. Additionally, CO₂ emissions and greenhouse gases are lowering the air quality and increasing the risk to public safety (Loria 2018). The anticipated impacts of climate change in New Brunswick are warmer temperatures, longer frost free seasons, more significant coastal erosion and flooding, and more variable weather patterns (Government of New Brunswick 2018). The importance of implementing a variety of adaptation approaches to mitigate emissions and prepare New Brunswick communities for these impacts is references in various recommendations in the Government of New Brunswick's recent Transitioning to a Low Carbon Economy: New Brunswick's Climate Change Action Plan report. To reduce the impacts of climate change and to prevent further degradation, immediate action must be taken because the cost of adaptation increases when action is delayed (Leung et al. 2018). There is no single approach to adapt to climate change but there are a number of strategies we can implement to minimize the effects. These can include using renewable energy, restoring or conserving natural lands, and raising public

awareness. However, as discussed in this report, nature-based solutions are the most environmentally friendly strategies.

1.3 Nature Based Solutions

Nature based solutions use natural systems, mimic natural processes, and work with traditional knowledge to address the impacts of climate change (Leung et al. 2018). They can be customized from community to community depending on type, location, and hazard addressed. If implemented properly, they can support healthier environments, healthier communities, improve local economies, and decrease the damaging effects of natural disasters such as floods and erosion (Leung et al. 2018). Additionally, nature based solutions will strengthen over time, opposed to anthropogenic solutions which get weaker over time, providing long term solutions for communities. New Brunswick has already implemented some adaptation strategies such as flood mapping and improving drainage systems in communities (Government of New Brunswick 2016). However, the magnitude of climate change requires the involvement of non-governmental organizations as well. An example of such organization is Nature NB and members of the Maritime Natural Infrastructure Collaborative (www.planwithnature.ca). The nature based solutions presented here are referenced from successful projects, publications, and news reports from across the country and can be adapted to New Brunswick communities across the province and Maritime region. Both current and new future opportunities for adaptation are discussed. Two assumptions are made for this report. First, funding is secured and available for the strategies presented. Second, experts are available to provide assistance in the formation of these projects.

2.0 Nature Based and Engineered Adaptation Solutions

2.1 Current Adaptation Strategies

2.1.1 Active Transportation: Promoting Mitigation and Adaptation

In communities, with natural adaptations, there are opportunities for active transportation. Although active transportation is not a natural adaptation, it is a co-benefit. It requires the use of your own energy to travel instead of using any motorized vehicle. This can be walking, biking, rollerblading, etc. New Brunswick cities, such as Moncton, and Fredericton, are expanding roads and sidewalks to accommodate active transportation (Barnes et al. 2002; City of Fredericton 2017). One driving force of climate change is the greenhouse effect which is exacerbated by greenhouse gas emissions (IPCC 2013). Encouraging active transportation improves air quality by reducing CO₂ levels and greenhouse gases in the atmosphere. It also benefits human well-being and health as it provides opportunities for the public to be physically active on a regular basis. Active transportation includes access to public transportation such as busses or subways. With the reduced traffic on the roads, public transit also reduces CO₂ emissions thus improving air quality (Barnes et al. 2002).



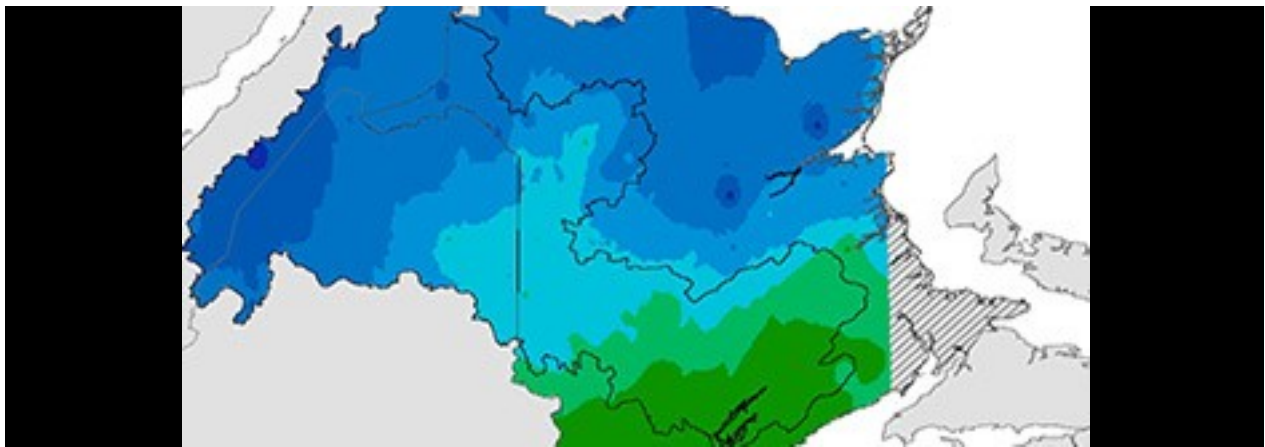
Government of New Brunswick

2.1.2 Adaptation Planning and Policies

As a preparation strategy, local governments can implement planning approaches to reduce natural hazards. This requires the community to identify areas at risk, and create a plan to identify strategies to reduce community vulnerability. Knowledge of future climate projections can reduce and prevent the risk of future natural hazards (Naturally Resilient Communities 2018). There are many different types of planning approaches. They include risk assessment, hazard mitigation, and post disaster planning (Naturally Resilient Communities 2018). Planning for long term and hazard specific events is essential for creating a more resilient community. Adaptation planning can help to influence change in government policies and local laws that protect natural habitats and reduce vulnerability. Policies are often crucial in implementing plans and managing natural based solutions. Identifying hazards, establishing projections, and implementing solutions are the steps to a more resilient community. An example community that has implemented this approach is the City of Bathurst. Established in 2017, the City of Bathurst's Climate Change Adaptation Plan presents an assessment of projected climate change impacts as well as potential adaptation strategies (Dietz 2017). In the Bathurst plan, the community identifies increasing sea level rise and storm surge events as a primary expected impact. To reduce the risk of flooding associated with these impacts, the City of Bathurst has outlined a number of adaptation strategies including shoreline buffers, improved storm water management, and continued land use planning and development (Dietz 2017).

2.1.3 Climate Modelling

The City of Moncton and the Greater Moncton Area (Town of Riverview and Town of Dieppe) sits at the head of the Bay of Fundy and intersects with the Petitcodiac River. As a result, the Greater Moncton Area is at risk of flooding from tidal surges and extreme weather events. Infrastructure and wastewater management problems along with property damage are expected to occur with the continuation of sea level rise. To help prepare for these impacts, the City of Moncton has undertaken climate modelling (New Brunswick Department of Environment and Local Government 2012). Climate models are a (usually digital) representation of projected climate change. An example can be found at - <http://arcgis.mta.ca/> from the Geospatial Modeling Lab at Mount Allison University. Climate models can incorporate interactions within the atmosphere, oceans, and land. Additionally, climate models can help organizations work through complicated problems and test possible solutions (NOAA 2018). In Moncton's case, models are focused on flood plain mapping. Flood plain models provide insight on flood prone areas allowing the municipality to plan and develop policies, reinforce infrastructure, and monitor target areas (Miller 2016; Djokic n.d.). Climate models can also depict land use, greenhouse gas emissions, and radiation from the sun (NOAA 2018).



Government of New Brunswick

2.1.4 Sea Dyke

The Tantramar marsh, which links Nova Scotia to New Brunswick, is one of the most vulnerable areas in the region to coastal flooding. Dykes were originally constructed to expand available agriculture areas in the region. Dykes are large anthropogenic barriers that hold back the tides preventing water from flooding these farmlands. They are typically made with a sand core, a watertight outer protective layer, and a drainage channel. The surface is protected with grasses, or stones (Cornell et al. 2010). One noticeable weakness is that dykes require regular maintenance to maintain functionality. For instance, as sea levels rise, there is a need for additional material to be added to the dykes in order to increase their height (McClearn 2018) and even then they could be overtopped. This is a costly adaptation approach that presents additional challenges to the region. If this critical transportation corridor floods, the highway will shut down stopping the route of billions of dollars in trade exports. Additionally, parts of Sackville, New Brunswick would be at risk of flooding and Nova Scotia would most likely become an island (Letterick 2018). As sea levels rise, further strategies (e.g. living breakwaters and natural salt marsh restoration) may be needed to slow major flooding in the Tantramar Marshes.



Mike Johnson for Sackville Tribune

2.2 Future Adaptation Strategies

2.2.1 Flood & Wildfire Friendly Culverts

Culverts are pieces of infrastructure that allow more water to flow underneath a road than conventional culverts without disrupting traffic (Schlafly 1910). They are particularly sensitive pieces of infrastructure that require correct measurements relative to location to function properly. If a culvert is outdated or improperly designed, it can increase the velocity of water or flood adjacent areas (Naturally Resilient Communities 2018). An undersized culvert can be improved by identifying the vulnerable road crossing, prioritizing problem areas, and upgrading the culvert based off the assessments to improve functionality (Poplar Jeffers et al. 2009). A sufficiently designed culvert can reduce the risk of flooding by moving water through an area, preventing any backup floodwater, and mimicking a natural flood path. They are also able to pass water through a system at a quick and efficient speed (Naturally Resilient Communities 2018). One co-benefit of culverts is the resulting reconnection of waterways. Migratory fish species rely on waterways for reproduction. Increasing the number of fish friendly waterways can improve the health and resilience of both fish and fisheries (Poplar Jeffers et al. 2009). Costs can vary but generally upgraded culverts are less expensive than replacing outdated culverts. Additional costs come from regular maintenance. Culverts have been implemented all over Canada. For example, the City of Toronto has implemented over 150 large culverts with diameters larger than 3m, and countless smaller culverts (Dickson 2011). These culverts were established to aid in the management of the city's infrastructure.



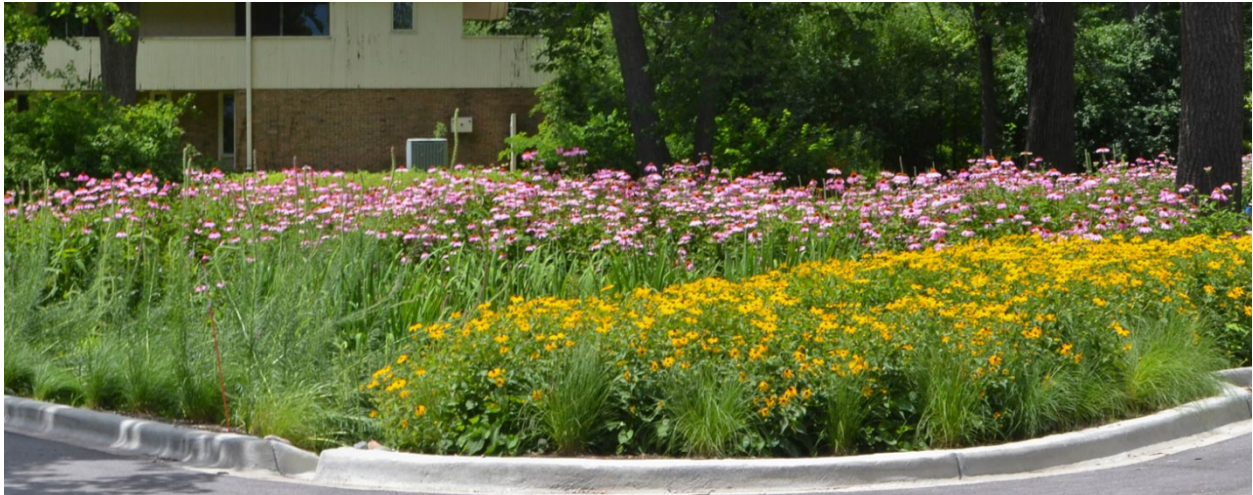
Ausable River Association

2.2.2 Green Infrastructure

One adaptation strategy that is becoming more and more common in across the globe is green infrastructure. Green infrastructure incorporates natural components into urban and rural infrastructures with the goal of creating more environmentally friendly communities (Hamilton 2016). With the added green space in communities, green infrastructure can contribute to environmental, social, and economic sustainability (Benedict and McMahon 2006). It also increases the overall aesthetic of a community. Green infrastructure is an all-encompassing term for natural urban adaptations including rain gardens, green roofs, and bioswales. These approaches are described below.

Bioswales are a combination of dry grassed swales and infiltration trenches. They are sloped vegetated channels that are designed to collect storm water runoff from large impervious areas such as a roads or parking lots (Soil Science Society of America, 2018). As a result, bioswales reduce the risk of inland flooding by slowing down water within the swale. They are typically planted with grasses and low maintenance plants which can increase the overall aesthetic of the community. A co-benefit of bioswales is that they remove pollutants, such as nitrates and phosphates, in the water through filtration by the vegetation (Naturally Resilient Communities 2018). They can be implemented in any region of any size because they can be customized by location with the use of native plants. Bioswales are particularly well suited to highways and roads because they run parallel to the roadway. An example Canadian city that has implemented bioswales is Calgary, Alberta. Since 2007, Calgary has been encouraging the development

bioswales to treat storm water runoff (Vanderstoop 2007). Today, Calgary has over 1,000 acres of bioswales spread all over the city (Bolin 2015).



Center for Neighborhood Technology

In our towns and cities, there is an abundance of roof area. Green roofs are building roofs that are partially or completely covered with vegetation. They typically are made of a waterproof membrane, a drainage layer, and plant material. Green roofs are established to maintain and improve air quality, absorb and store rainfall, and reduce the effects of urban heat islands. Furthermore, because of the increase in vegetation, green roofs can increase urban biodiversity by providing a habitat for wildlife (Naturally Resilient Communities 2018). Green roofs are often established for aesthetic reasons as they add green space in downtown metropolitan areas (Berndtsson 2010). Additionally, this green infrastructure can be further expanded to green walls, green streets and green parking lots which serve the same purpose. Today, green roofs have been established all across the Maritime provinces. Halifax, Nova Scotia has become a leader in implementing green roofs. Some notable locations include St. Mary's University, Nova Scotia

Community College, Citadel High School, and the Halifax Seaport Farmers Market. These green roofs have been implemented for research, leisure, and environmental purposes (Henderson 2014).



Zinco Urban Climate Roof

The last type of green infrastructure covered in this report are rain gardens. A rain garden is a landscape feature that is designed to collect storm water (Clean Foundation 2018). Rain gardens are different than regular gardens in that they offer increased water filtration, are specially placed downstream to maximize storm water catch, and are primarily composed to native plants (Kurtz 2013). The use of native plants is important as they are already adapted to local rainfall patterns. Rain gardens provide a reduced risk of inland flooding, erosion, and drainage problems. In addition, they can also provide a habitat for insects and small birds (Naturally Resilient Communities 2018). Rain garden projects are being coordinated by a variety of NGOs and local government groups throughout Canada. For example, the City of Toronto and the Greater Toronto Area has seen a rise in the number of rain gardens over the past decade as the initiative has been widely promoted in the community. Many Toronto residents are taking it upon themselves to construct their own rain gardens at home and around their communities. Rain gardens have become

increasingly popular in communities due to their aesthetic appeal and their economic and environmental benefits.



Virginia's Soil and Water Conservation District

2.2.3 Living Breakwater

A natural based solution that can be implemented in the case of coastal erosion and coastal flooding are living breakwaters. Living breakwaters are offshore barriers that limit wave energy and reduce the power of the tides (Naturally Resilient Communities 2018). As the name suggests, living breakwaters are made of natural habitat components and vegetation while providing protection to the coastline from erosion and flooding (Scyphers et al. 2011). The natural growth of these living breakwaters allows them to strengthen over time. They can be used in any coastal area regardless of size. There are different types of living breakwaters. Examples include oyster reefs and reef balls.

Oyster reefs are naturally occurring ecosystems that are often found near salt marshes (Scyphers et al. 2011). Just like all living breakwaters, oyster reefs limit wave energy from tide cycles and storm surges, reducing rates of coastal erosion on shore. Engineered oyster reefs are made of natural habitat components and vegetation. The goal is to create a stabilized habitat that

oysters will colonize, thus creating new oyster reefs. Whether they are naturally occurring or engineered, oyster reefs provide protection to the coastline from erosion and flooding (Naturally Resilient Communities 2018). Along with acting as a buffer, oyster reefs also provide a variety of ecosystem services. They provide a habitat for benthic invertebrate colonies and support an increasingly complex ecosystem (Scyphers et al. 2011). Additionally, the water filtering capacity of oysters also allows for the filtration of pollutants from the water such as sediment and nitrogen thus improving the water quality (Koenig 2017). In Canada, oyster reefs can be found along the Atlantic coast including PEI and the Bay of Fundy.



Northeastern University Marine Science Center

Reef balls are a relatively new initiative in shoreline protection. Invented in 1994, reef balls are artificial reefs that can create new aquatic habitats and provide shoreline protection (Barber et al. 1994). They come in 10 different sizes ranging from a basketball to a car, which allows for the customization and flexibility of individual projects (Barber et al. 1994; Clean Foundation 2018). All reef balls are made with a pH neutral concrete that allows for coral and algal settlement. They are designed to mimic natural reefs and are used in many restoration projects (Reef Ball Foundation 2003). Fully established reef balls act as a buffer between land and water and thus decrease the risks of coastal flooding and erosion. Reef balls also help to create or restore marine

habitats by providing shelter for marine species (Clean Foundation 2018). In Atlantic Canada, reef balls have been implemented in the Halifax Harbour. Since 2012, the *Clean Foundation* has deployed approximately 400 reef balls worth \$200,000 in the hopes of creating an artificial ecosystem (Clean Foundation 2018).



Fish Reef Project

2.2.4 Open Space Preservation

Open space or undeveloped land can take the form of forests, farmland, wetland, or streams and rivers within a rural or urban community (United States Department of Agriculture 2018). Undeveloped land is shrinking as communities expand outward. Many of these areas are being converted to houses, industrial/commercial buildings, and roads. Open space preservation focuses on purchasing undeveloped land for adaptation purposes (e.g. flood risk reduction), and for the preservation of aesthetic and habitat qualities (Silverstone 1974). Governments, land acquisition organizations, and private landowners (donation of land) can all play a role in advancing land preservation (Naturally Resilient Communities 2018). Conserving open land protects valuable habitats, increases adjacent property values, and removes vulnerable land from the market. It also provides many social-economic benefits such as recreation opportunities, improved public health, and eco-tourism (Naturally Resilient Communities 2018). Many organizations such as the Nature

Conservancy of Canada and Nature Trust of New Brunswick deal with land acquisition. Private landowners can donate land through Environment and Climate Change Canada's Ecological Gifts program. One Canadian city that has implemented open space preservation is Guelph, Ontario. Guelph has over 1000 hectares of established parks and open spaces. These natural features also include 70km of walking trails that are open to public recreation (City of Guelph 2018).

2.2.5 Property Buyout

Coastal communities are highly vulnerable to climate change (Schwartz 2018). Property buyout reduces the impacts of flooding by moving vulnerable communities and/or infrastructures from areas that are likely to flood by purchasing properties out of harm's way (Naturally Resilient Communities 2018). This reduces the chances of damage and injury in future flooding events. The scale and timeframe is flexible. Planning for how and when communities move involves many variables. Buyouts can range from a few properties as a single program to a whole residential area as a long term effort. Co-benefits of property buyouts include allowing for the possibility of implementing new natural adaptation strategies and reducing the overall risk and vulnerability in a community (Gray 2017). Cost is solely based on how large the buyout aims to be and the asking price of the land. One criticism is that buyout programs are often not pursued until after a natural disaster has occurred. Therefore it is up to the local government to work efficiently and in a timely manner to build relationships with land owners before an event occurs (Reiblich et al. 2018) In Canada property buyouts are not the most common form of adaptation. However, occasional property buyouts have occurred in Calgary, Alberta due to flooding, and in Fort McMurray, Alberta, due to wildfires (Gray 2017).

2.2.6 Traditional Ecological Knowledge

One important aspect of environmental planning and adaptation we should recognize and utilize is traditional ecological knowledge. Traditional ecological knowledge refers to the knowledge, innovations, and practices used by Indigenous communities to sustain and adapt themselves to their environment (IDRC 1993). Indigenous peoples were the original cultivators of the lands and have gathered centuries of information about the land and environment. They have seen and adapted to climate change first hand. Many strategies from indigenous culture can be implemented in our communities such as fire management techniques, farming and agriculture techniques, sustainable management of marine resources, and medicinal plant uses. Collaborations on research studies between scientists and First Nations communities can provide a better understanding of our ecosystems and changing climate (Huntington 2000; Berkes et al. 2000).

One major advantage of traditional ecological knowledge is that it provides location specific knowledge allowing for improved information of environmental changes. Many research studies in Canada have collaborated with First Nations communities and have used traditional ecological knowledge in their research. Most of these studies involve conservation or natural resources planning. Some examples of these studies include the Ethno Botany Project in British Columbia, the Forest Management Pilot Program in Alberta, and the Traditional Land Use Occupancy Study in Alberta (Government of Canada 1999).



Spirit of the Salmon

Table 1.1 Summary of natural conservation adaptations

ADAPTATION	DESCRIPTION	HAZARD(S) ADDRESSED	CANADIAN EXAMPLE
ACTIVE TRANSPORTATION	The use of human powered methods of transportation instead of motorized vehicles	Greenhouse gas emissions	Fredericton, New Brunswick https://tinyurl.com/activetransportation
ADAPTATION PLANNING AND POLICY	The identification of areas at risk of natural disasters and creating a plan to protect the community	Variety	Bathurst, New Brunswick https://tinyurl.com/bathurstadaptation
CLIMATE MODELLING	The use of a digital model to predict the impacts of climate change for a certain area and hazard	Variety	Mount Allison University New Brunswick http://arcgis.mta.ca/
CULVERT	The use of infrastructure to allow the movement of water without the disruption of traffic	Inland erosion Inland flooding Water quality	Toronto, Ontario https://tinyurl.com/toculvert
GREEN INFRASTRUCTURE			
Bioswale	The use of vegetated channels to collect storm water runoff	Inland erosion Inland flooding Water quality	Calgary, Alberta https://tinyurl.com/bioswales

Green Roof	The planting of native vegetation on building roofs to improve quality of life in urban areas	Inland flooding Air quality	St. Mary's University, Nova Scotia https://tinyurl.com/halifaxgreenroof
Rain Garden	The use of specialized gardens to catch storm water runoff	Inland erosion Inland flooding	Toronto, Ontario https://tinyurl.com/diyraingarden
LIVING BREAKWATER			
Oyster Reef	The use of natural oyster colonies to buffer the strength of tidal surges	Coastal erosion Coastal flooding	Bay of Fundy https://tinyurl.com/oysterreefnb
Reef Ball	The use of artificial reefs to buffer the strength of tidal surges	Coastal erosion Coastal flooding	Halifax, Nova Scotia https://tinyurl.com/halifaxreefball
OPEN SPACE PRESERVATION	The preservation of undeveloped land for adaptation and conservation purposes	Variety	Guelph, Ontario https://tinyurl.com/guelphparkplan
PROPERTY BUYOUT	The relocation of people and/or infrastructure in high risk areas	Inland flooding	For McMurray, Alberta

			https://tinyurl.com/buyoutcase
SEA DYKE	The use of large artificial barriers to prevent tidal water from flooding communities	Coastal erosion Coastal flooding	Sackville, New Brunswick https://tinyurl.com/sackvilledykes
TRADITIONAL ECOLOGICAL KNOWLEDGE	The use of ecological knowledge from indigenous communities to improve local adaptations	Variety	Ethno Botany Project, British Columbia https://tinyurl.com/gov-tek

3.0 Restoration Strategies

Along with adaptation, restoration strategies are crucial in protecting our environment. Restoration is the process of creating or recreating an ecosystem or habitat that closely resembles its natural conditions. Ecological restorations provide ecosystem services and have social and economic benefits. Furthermore, restoring productivity to degraded or destroyed natural landscapes is essential to avoiding further destruction of natural ecosystems.

3.1 Reforestation

The world's forests are home to 80% of all terrestrial biodiversity. However, each year more than 13 million hectares of forest are lost around the world. Deforestation causes approximately 15% of the world's carbon emissions (UN 2010). To mitigate these effects, reforestation strategies are being implemented all over the country. By definition, reforestation is the replanting of trees on areas of land where forests have been cleared by harvesting or natural causes (A Dictionary of Biology 2004). Climate and forestry experts say that reforestation is the most inexpensive and effective way to combat climate change (UN 2010). Reforestation provides a variety benefits. Mainly, reforestation improves air quality by decreasing the amount of CO₂ in the atmosphere. It also regulates climate, and increases biodiversity by stabilizing ecosystems (Mykleby et al. 2017). Reforestation initiatives have been implemented all over New Brunswick. Since 2007, reforestation has occurred in Fredericton, Miramichi, and Fundy (Government of New Brunswick 2008).



Ecoprint

3.2 River

Rivers have economic, ecological, and cultural value. They provide communities with fresh drinking water and act as a habitat for many plants and animals (NOAA 2018). Rivers are vulnerable to flooding from heavy storms and snow melt. Furthermore, destruction and flooding of riparian zones can result in downstream erosion. River restorations aim to restore natural conditions and improve the resilience of river systems. It aids in sustainable water management, improves water quality, supports biodiversity, and contributes to flood risk management by supporting the natural ability of rivers to retain water (Naturally Resilient Communities 2018). Restoration can be achieved via bioengineering. Bioengineering uses living plant material to strengthen degraded streams or riparian zones (Whalen 2007). Additionally, the use of natural materials allows for the growth of semi aquatic habitats over time. River restorations in New Brunswick have been implemented in the Petitcodiac River and the Kennebecasis Watershed (Babin 2018; Whalen 2007).



Sophia Bunker for JBA Consulting

3.3 Salt marsh

The Chignecto Isthmus, a small transportation corridor along the low-lying Tantramar Marsh, is threatened by high tides, rising sea levels and severe storms. The New Brunswick, Nova Scotia, and federal governments have announced \$700,000 in funding for a new study on how to protect this passage (Letterick 2018). The Trans-Canada Highway, a gas pipeline, and the CN Railway all pass through the Chignecto Isthmus connecting Nova Scotia to the rest of the country. In addition to the dyke system, groups have been exploring natural adaptation in the form of salt marsh restoration. Salt marshes recycle nutrients, stabilize shorelines, and provide habitats for many species (Broome 1988). They also have one of the highest rates of primary production due to the inflow of nutrient rich tidal water (Naturally Resilient Communities 2018). In relation to the Chignecto Isthmus, the Tantramar Marsh can provide flood protection and erosion control by absorbing the wave energy from storms and tide cycles. Additionally, restoring the salt marsh will improve the water quality by filtering chemicals and sediment out of the water before it is released back into the ocean (Environmental Protection Agency 2018). Marshes do not have a high production costs and are self-sustaining so little management is needed once they are established lowering overall maintenance costs.



Naturally Resilient Communities

3.4 Sand dune

Dunes serve as a barrier between land and water and can absorb the impacts of storm surges (Naturally Resilient Communities 2018). As a result, they provide protection to coastal properties and aquaculture sites. Dunes also provide habitats for many endangered plants and animals such as piping plovers and seashore lupines (National Park Service 2015). Traditionally, dune restoration involves the transplantation and planting of grasses, shrubs, or other vegetation which reinforces the dunes by providing an anchor (Naturally Resilient Communities 2018). This makes it harder for wind and waves to erode the dunes. Ideal species for dune restorations are native dune grass, *rosa rugosa*, and bayberry (Clark and Clark 2008). Occasionally, manmade dunes can be assembled by building and shaping a rock skeleton and topping it with sand and dune grasses. Dredge material, old Christmas trees, or old lobster traps have been used as a skeleton (Capozi 2017). Fences can be implemented to stop wind-blown sand from spreading and to keep the public away from fragile dune vegetation (O'Connell 2008). New Brunswick communities that have implemented dune restoration strategies include Cap Pelé, Côte Sainte-Anne, and Bathurst (Vision H20 2018; Capozi 2017; Dietz 2017).



Parks Canada

3.5 Seagrass bed

Seagrass beds are naturally occurring submerged aquatic vegetation. They are found in shallow salty and brackish water all over the world (Reynolds 2018). Seagrass beds provide many ecosystem services. They support commercial fisheries, provide a foundation for coastal food webs, and improve air quality via photosynthesis. In fact, one square meter of seagrass can generate 10L of oxygen every day (Reynolds 2018). Seagrass beds are referred to as “sponges” because they absorb wave energy during storms and tide cycles which decrease wave heights thus reducing the chance of coastal flooding and erosion (Naturally Resilient Communities 2018). Additionally, they are able to stabilize the sea floor with their extensive root system which anchors loose sediment and maintains the integrity of the local shoreline. The protection and restoration of seagrass beds can greatly reduce the impacts of sea level rise (Reynolds 2018). It should be noted that seagrass beds are vulnerable to major storms and thus are most effective when working in tandem with other offshore features such as mangroves, coral reefs, or coastal marshes. In Canada, seagrass bed restoration is occurring in British Columbia’s south coast.



NOAA

3.6 Wetland restoration

New Brunswick's wetlands support biodiversity from the Caribbean to the sub-Arctic (DUC 2018). However, Atlantic Canada has seen considerable wetland loss over the past century which is still continuing today. Approximately 65% of wetlands have been altered or destroyed. Wetland systems provide numerous valuable social, economic, and ecological functions. They collect and purify storm water, provide habitats and food for many species, and protect shorelines from flooding and erosion (Erwin 2009). They also can contribute to the eco-tourism industry by giving communities places to fish, hike, and canoe (DUC 2018). Additionally, some wetlands have provincial, national, or international significance and therefore are deserving of protection. In New Brunswick, the responsibility for managing and protecting wetlands falls on the Department of Energy and Resource Development and the Department of Environment and Local Government (Government of New Brunswick 2002). Currently, wetland restoration efforts have been implemented in St. John, the Bay of Fundy, and Sackville (DUC 2018). These efforts aim to restore the natural function of wetlands to benefit both humans and wildlife.



Apache Ecological Services

Table 1.2 Summary of natural restoration adaptations

ADAPTATION	DESCRIPTION	HAZARD(S) ADDRESSED	CANADIAN EXAMPLE
REFORESTATION	The restoration of harvested forest areas via the planting of new trees	Variety	Fredericton, New Brunswick https://tinyurl.com/reforestationnb
RIVER RESTORATION	The restoration of rivers and riparian zones to improve flood management	Inland flooding Water quality	Petitcodiac River, New Brunswick https://tinyurl.com/petitcodiacriver
SALT MARSH RESTORATION	The restoration of marshes to absorb wave energy from storms and tide cycles	Coastal erosion Coastal flooding	Tantramar Marsh, New Brunswick https://tinyurl.com/saltmarshnb
SAND DUNE RESTORATION	The restoration of sand dunes to act as a barrier between land and water	Coastal erosion Coastal flooding	Cap Pelé, New Brunswick https://tinyurl.com/sanddunesnb
SEAGRASS BED RESTORATION	The restoration of sea grass beds to absorb wave energy from storms and tide cycles	Coastal erosion Coastal flooding	South Coast, British Columbia https://tinyurl.com/seagrassbc

WETLAND RESTORATION	The restoration of wetlands to improve the watershed and aquatic resources	Inland flooding Water quality	St John, New Brunswick https://tinyurl.com/ wetlandnb
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4.0 Conclusion

Nature based solutions help to mitigate the effects of climate change, enhance natural ecosystems for wildlife, and sustain our collective well-being. They can be incorporated in any environment, large or small, at any location (Naturally Resilient Communities 2018). The implementation of nature based solutions is a complex process requiring time, collaboration, and funding. The first step is to identify key vulnerabilities and hazards in the community. This can involve climate change adaptation planning, consultation with experts and the community, and establishing monitoring and modeling programs. The second step is public education and awareness. This can take the form of information panels, public documents, or workshops for businesses. Bringing the issue of climate change to the public encourages communities to get involved and become advocates for change. Once communities have a better understanding of the risks, they may be more likely to better prepare for climate change. Ultimately, nature based solutions offer a unique pathway forward to address the impacts of climate change at a variety of scales and context. For more information on these approaches and examples discussed in this report, please visit www.planwithnature.ca.

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