Climate Change Adaptation Plan for the Marconi Trail

April 2015

Canada

ACAP CAPE BRETON

This project was undertaken with the financial support of the Government of Canada.
Ce project a été réalisé avec l'appui financier du gouvernement du Canada.

Project Highlights

This project was conducted by ACAP Cape Breton and funded by Environment Canada in 2014, to identify vulnerable areas in Port Morien, Main-a-Dieu, South Head and Big Glace Bay Beach through hazard mapping and community workshops. Applicable adaptation methods were then selected based on the site conditions.

1.1. Project Objectives:

i. To quantify the extent of coastal erosion through the analysis of historical aerial photographs.
ii. To establish the areas at risk of inundation and increased erosion by applying projected sea level rise scenarios to current digital elevation models (DEM).
iii. To incorporate local knowledge of the shoreline into our study.
iv. To produce a Climate Change Adaptation Plan containing the results of our study, community feedback, along with recommendations to support planning and land use management.

1.2. Proposed Short-Term Adaptation Actions:

- Continued maintenance on Main-a-Dieu and Port Morien breakwater structures.
- Maintain current boardwalks in Main-a-Dieu Beach and reposition when necessary to accommodate a changing shoreline.
- Beach nourishment methods for Main-a-Dieu Beach.
- Protection measures to address erosion and flooding at Port Morien Sandbar Beach.
- Maintain a vegetation buffer of 20 meters from the coast.
- In areas of moderate erosion use native vegetation with deep root systems for shoreline stabilization.
- Avoid coastline armouring unless important infrastructure cannot be easily moved.
- Bank grading in priority areas where undercut erosion and high bank height with steep slopes exist to protect road infrastructure.

1.3. Proposed Long-Term Adaptation Actions:

Long-term adaptation actions should incorporate community engagement including public, business and stakeholder groups to ensure increased resilience to climate change related impacts.

- Policy amendments to include horizontal setbacks of a minimum of 10m-50m to reduce loss of property on eroding cliffs.
- New construction should maintain a vertical setback or allowance of 0.41m for 2050 and 1.15m for 2099 to allow for predicted sea level rise and storm surge.
- Alterations to current land use zoning to restrict new developments in hazardous areas, which should consider past and future erosion rates and predicted sea level rise when selecting an area for new construction.

Acknowledgements

We acknowledge the contributions to this project including the in-kind support from the Cape Breton Regional Municipality (CBRM) Planning Department. We would also like to thank the Main-a-Dieu Community Development Association and the Port Morien Development Association for being part of our Climate Change Workshop Series and their in-kind support. Their participation was invaluable to the success of this project and we are deeply grateful for their community perspectives.

This project was designed with the use of a toolkit developed by the Ecology Action Centre based on their experiences of a project undertaken in the Chéticamp area. With their approval, we used this report to help design our project to effectively engage communities along the Marconi Trail in adapting to a changing coast.

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Glossary

Beach Nourishment: Placement of sand along a beach shoreline to increase the beach width and raise the elevation of the nearshore area.

Climate Change: A change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2012).

Ecosystem Services: Direct and indirect contributions of ecosystems to human well-being. Benefits can include cleaning water and decomposing wastes.

Fetch: The distance across open water over which wind blows and waves are generated. This distance is measured at all angles from the shoreline.
Low: 0 – ½ mile; Moderate: between ½ - 2 miles; High: greater than 2 miles

Grade Bank: Reduce the steepness of a slope to allow for wave run-up and to improve vegetation growing conditions.

Intertidal Zone: The part of the shoreline between tidal extremes; intertidal areas are exposed at low tides and submerged at high tide.

LiDAR: Light Detection and Ranging; is a remote sensing method that uses light in the form of a pulsed laser to measure variable distances to the Earth in order to generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

Regional land subsidence: Subsidence is the movement of the earth's surface downward relative to sea level.

Resilience: The ability of a system and its components to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner.

Sea Level Rise: This document is utilizing predictions of sea level rise as an increase in sea level of 0.34 metres by the year 2050 and 0.82 metres by the year 2099.

A rise is sea level results from thermal expansion, vertical land motion (subsidence) and melting of global ice sheets and continental ice masses linked to changes in temperature in the atmosphere.

Setbacks: A construction control line that separates a land use, structure, property line, or natural feature, which is designed to minimize conflict or minimize impact. Vertical setbacks protect against flooding, while horizontal protects against coastal erosion.

Subsidence: The motion of the Earth's surface as it shifts downward relative to sea-level.

Thermal Expansion: The increase in volume that results from warming water. A warming of the ocean leads to an expansion of the ocean volume and hence an increase in sea level.

Transect: A line or narrow section through natural feature, along which measurements taken.

Undercut Erosion: Loss of soil only at bank toe due to tidal action or water currents.

Upland Management: Capture rainfall and runoff from impervious surfaces rather than allowing it to flow or be directed toward the waterway. Examples of these management practices can include relocation or elevation of buildings that are routinely flooded or threatened by erosion.

Vegetated Buffer: Refers to a vegetated strip immediately adjacent to a watercourse in which activities are limited.

Vulnerability: The extent to which climate change may damage or harm a system. This is influenced by not only on a system's sensitivity, but also on its ability to adapt to new climatic conditions.

2. Introduction

2.1. Project Overview

The Atlantic Coastal Action Program (ACAP) Cape Breton is a non-profit charitable community organization. Established in 1992, the original mission was to develop a comprehensive ecosystem management plan for the watershed area of industrial Cape Breton. ACAP Cape Breton is built upon five pillars: environmental education; science, monitoring and research; community engagement; service delivery; and advocacy and influencing policy. It has grown into a dynamic group that integrates environmental, social and economic factors into projects focusing on action, education and ecosystem planning. ACAP Cape Breton, located at 582 George St. in Sydney is a non-profit, charitable community organization with a community vision in which local people are actively engaged, working, and learning together to build a healthy and sustainable Island.

In April 2014, funding was received by the Government of Canada to prepare a Climate Change Adaptation Plan for the Marconi Trail - a 70 kilometer roadway that follows along the most eastern point of Nova Scotia. The rugged shoreline along the Marconi Trail receives the full force of ocean wave energy. Communities along this Trail possess long standing knowledge of the natural shoreline which provides a unique opportunity to connect with community members and develop a local approach to adapt to climate change. Four areas of interest, which extend from one end of the trail to the other, were selected for this project:

- Big Glace Bay Beach
- Port Morien
- South Head
- Main-a-Dieu

The overall goals of this project are to reduce vulnerability to the negative effects of climate change, increase protection of natural resources, and decrease the threats to shorebirds and their habitat.

A Municipal Climate Change Action Plan (MCCAP) was developed in April 2014 for the Cape Breton Regional Municipality (CBRM). Current data gaps related to climate change hazards where identified in the CBRM, one of which included a need for erosion rates and erosion maps in coastal areas of CBRM. Further, community-based mapping was identified as one of the steps needed to help prioritize climate change adaptation issues, to help identify hotspots of common concern, as well as informing the public on how climate change can directly impact their community (CBCL

Ltd., 2014). It was revealed through consultation with the CBRM Planning Department the value of the information that could be produced in this project as “a powerful tool we can use to convince our Council of the need to recognize climate change and to protect our constituents”. ACAP Cape Breton’s Climate Change Adaptation Plan for the Marconi Trail main goals sought to focus on areas highlighted in the MCCAP including the use of community mapping, the identification of localized erosion rates and increasing community awareness of the issues related to climate change.

The CBRM Planning Department provided in-kind support for the project by providing access to the CBRM GIS database, including LiDAR (Light Detection and Ranging) data and land use data. This information was invaluable in projecting sea level rise predictions over the study areas to identify future climate change impacts. Aerial photography was also provided by the CBRM and supplementary photography was purchased from the National Earth Observation Data Framework Catalogue to help track historical erosion in the target areas of this study. Workshops were held in two communities to introduce the project and gain feedback on coastal changes in their area. By using mapping technology, community vulnerabilities were identified and community workshops aided in prioritizing these concerns. Adaptation solutions were then selected to address the concerns with an emphasis on solutions that could be carried out at a community level.

2.2 What is Climate Change?

For many years, the scientific community has recognized that changes in the world’s climate are linked to human activity. This has led to the incorporation of adaptive measures to reduce the current vulnerabilities (e.g. sea level rise, erosion) resulting from a changing climate. Adaptive measures have been implemented at the national, regional and local scale, and are continuously being updated as new research unfolds.

Climate change refers to changes in frequency, intensity, spatial range, duration, and timing of extreme weather, and can result in unprecedented extreme weather and climate events (IPCC, 2012). These changes may be gradual and the effects can vary depending on the region. Multiple effects will result from climate change including a rise in the overall air temperature of the Earth, global sea level rise, more variable weather patterns, and increases in extreme weather events. These effects will become more and more apparent to coastal communities where the growing frequency and intensity of hazardous conditions will influence their day-to-day lives.

By assessing current literature, this study used a regional approach to evaluate predicted climate change impacts for our target area along the Marconi Trail in Cape Breton, Nova Scotia. Adaptive measures that could be implemented at a community scale were identified to increase their resiliency to future coastal hazards.

2.3 What is Adaptation?

Adaptation, rather than mitigation, is the process of reducing vulnerabilities to climate change through the adjustment of natural or human systems. This report was designed to provide a series of adaptation methods available at a community level to address coastal vulnerabilities along the Marconi Trail.

The three basic strategies to reduce hazard vulnerability in coastal zones revolve around the terms protect, retreat and accommodate (Klein, 2001).

- Protect: Defend existing coastal land uses (e.g. infrastructure, homes, etc.) by implementing measures.
- Retreat: Relocate structures and infrastructure away from areas of potential flooding.
- Accommodate: Measures that compensate for climate-related changes (e.g. raised homes).

Further, practices and policies that are unrelated to climate but which do have an impact and increase the area's vulnerabilities to climate change are referred to as "maladaptation"; examples include developments in hazardous zones, coral mining, and altering coastal habitat (e.g. removal of dune grass).

It is important to consider the feasibility of the adaptation solutions; vulnerable areas and resource management should be top priorities. Historically, shoreline stabilization and adaptation involved a reactionary approach that didn't consider the potential impacts of such measures or the long-term viability of the proposed solutions.

Using geographic information systems (GIS) tools, spatial planning can be applied to visualize and analyze spatial data. In particular, this project used GIS tools to overlay sea-level rise scenarios with digital elevation models (DEMs) to predict how the coastline will change over time. This technology can be used to identify vulnerable areas, such as potential areas at risk of inundation, and assist with selecting appropriate adaptation measures.

Figure 1. Three strategies to costal adaptation (Modified from Klein, 2001)

Accommodate

- Emergency planning:
  - Early-warning systems
  - Evacuation systems
- Hazard insurance:
- Modification of land use and agricultural practice
- Modification of building styles
- Strict regulation of hazard zone
- Improved drainage
- Desalination (removal of salt from water or soil)

Retreat

- Increasing or establishing setback zones
- Relocating threatened buildings
- Phased-out or no development in susceptible areas
- Rolling easements
- Managed realignment

Protect

Hard engineered options:

- Hard structures:
- Dikes, levees, floodwalls
- Seawalls, revetments, bulkheads
- Groynes
- Detached breakwaters
- Floodgates and tidal barriers

Soft structural options:

- Saltwater intrusion barriers
- Periodic beach nourishment
- Dune restoration and creation

Indigenous options:

- Wetland restoration and creation (Living Shorelines)
- Afforestation
- Wooden walls
- Stone walls

2.3.1. Shoreline Stabilization Measures

The overall recommendations of this report are to use a proactive strategy when considering the implementation of coastal adaptation methods, with emphasis being placed on vulnerable areas along the Marconi Trial. The consensus of workshop participants was that all components of the shoreline should be considered in the decision making process. Therefore, this plan prioritized adaptation methods that would accomplish the following: (i) recognize and maintain the different habitat types of the shoreline; (ii) rank protection methods based on site vulnerability to coastal hazards; and (iii) mitigate negative impacts that could result from implementation of protection measures.

Since coastal erosion is a natural, continuous process, it is important to understand that methods aimed at mitigating it are temporary and may not be worth the investment. If possible, shorelines should be left in their natural condition, as they provide their own ecosystem services, unless erosion has the potential to lead to significant loss of property. Maintaining or enhancing the natural shoreline should be considered a priority before implementing other erosion control methods. Furthermore, erosion control methods should only be implemented where they will have the least overall impact to the ecosystem.

There are many factors to consider when evaluating potential adaptation measures to coastal erosion including bank height; level of bank erosion; presence or absence of vegetation, marsh, and beaches; wave energy and exposure; and water depth. The Center for Coastal Resources Management (2010) used these factors to develop a manual that details various methods of shoreline management based on the characteristics of the shoreline. A decision tree was developed in this manual which is useful for site evaluation. Some low intensity stabilization measures for shorelines experiencing light bank erosion include the use of riparian buffers, planting native vegetation, and enhanced management practices in surrounding upland and forested areas. Possible measures for banks with high or undercut erosion include bank grading and vegetation solutions with additional measures depending on the level of fetch and the presence or absence of marsh or beach features. Fetch refers to the distance across open water over which wind blows and waves are generated, the larger the fetch the greater the wave exposure. The coastline along the Marconi Trail is subjected to high wave energy, with many areas experiencing high fetch and undercut erosion. This environment can prohibit many soft approaches to coastline protection such as vegetation and living shorelines and therefore more intensive levels of shoreline management solutions may be required. The majority of the vegetated shoreline stabilization methods discussed in this report will only be applicable to select areas along the study sites that display suitable coastal characteristics.

> *"Land was surveyed in 1951 at 225 feet; in 2014 new survey at 147 feet."*
>
> - Property owner at the Main-a-Dieu Climate Change Public Meeting (October 30, 2014)

Setbacks in Coastal Zones

A setback is a line that separates a land use, structure, property line, or natural feature from the coast to minimize impact (Rideout, 2012). A setback does not need to be vegetated; it refers to a distance from an area that is prone to natural processes such as erosion, sediment deposition and flooding. Benefits of setbacks can include providing protection to public, private property and infrastructure from damage due to storm surges, flooding and erosion by separating structures from coastal hazards; it also improves beach access and privacy for property owners (IPCC, 2007).

Damage prevention to property and infrastructure can reduce cost to homeowners, municipalities, and the province. Relocation of major infrastructure and implementation of policy setbacks can greatly reduce the risks associated with climate change and increase community resilience to projected hazards.

Setback policies have been adopted in other areas of the Maritimes. For example, Halifax Regional Municipality instituted a horizontal setback of 20 meters with no removal of natural vegetation or altering land levels, and a vertical setback of 2.5 meters from the high water mark. Another example is the New Brunswick Coastal Areas Protection Policy, which describes a 30 meter building setback along coastal beaches, dunes, and marshes to protect ecological integrity.

Table 1. Vegetation buffers, setbacks and armouring required for shoreline stabilization (Modified from Rideout, 2012)

Services Provided	Vegetation Buffer (meters)	Horizontal Setbacks (meters)	Vertical Setbacks	Armouring
Riparian Bank Stabilization	10 to >100	N/A	N/A	Yes
Bird Habitat	50 > 100	N/A	N/A	No
Dune Stabilization	10 to >100	N/A	N/A	Yes
Cliff Stabilization	10 to >100	N/A	N/A	Yes
Reduced Loss of Property - Slowly Eroding Cliffs	20 >100	10-100 or 60x erosion rate	> 100 year storm surge	Yes
Reduced Loss of Property – Rapidly Eroding Cliffs	>100	50-100	> 100 year storm surge	Uncertain
Coastal Flood Protection (storm surge & sea level rise over next 50 years)	20 to >100	20-100	> 100 year storm surge or 4 meters	Uncertain

[a] Setbacks and armouring provide almost no ecological services beyond protecting property.

Vegetation Buffers

A vegetation buffer is a form of setback designed to maintain the benefits provided by natural riparian or coastal zone plants. Coastal vegetation aids in holding soil in place to prevent bank and shoreline erosion. Further, riparian or vegetative buffers offer numerous ecosystem services (Rideout, 2012). The installation of vegetative buffers can be carried out by a homeowner to reduce erosion and improve water run-off. These techniques are often a good choice due to their relatively low cost and ease of implementation, however selecting the appropriate technique based on site's conditions is imperative (Table 2).

Table 2. Vegetation buffers for low to highly eroded slopes (Modified from Cornell University Cooperative Extension Onondaga, 2013).

Methods	Site Conditions	Technique
Re-Vegetation	Low to moderate erosion	• Replant native vegetation • Mulch to ensure stabilization • Easiest and lowest cost method for homeowners
Live Staking	Slopes with light erosion	• Drive the cuttings of woody plants (willows and dogwood) into soil • Temporarily mulch between cuttings
Contour Wattling	Slopes with light erosion	• Lay live bundles of stems and branches into trenches • Cover with soil
Brush Layering	Badly eroded slopes	• Dig holes into the side of the slope • Insert plant cuttings at an angle
Brush Matting	Badly eroded slopes	• Create a bed of live plant cuttings on an eroded area to take root and grow
Erosion Control Matting	Moderate slopes along roads or waterways	• Place biodegradable erosion-control fabric to an overexposed slope • Plant grass seeds on the matting • Cover with soil • Most expensive and demanding method for homeowners

Living Shorelines

Living shoreline techniques enhance the natural function of the coast while reducing the risk of erosion; they generally consist of an upland area, followed by an intertidal zone, and a shallow water habitat. Living shorelines offer protection from various impacts related to climate change including flooding and sea level rise. By using salt marsh vegetation (e.g. Spartina alterniflora), and small structures, living shorelines reduce the amount of wave action and defend against erosion. Literature has shown the use of marsh vegetation has been effective at dissipating up to 95% of wave energy (LSS, 2006). Methods for living shorelines and marsh creation can include: bank grading; marsh planting such as direct planting, bag planting, marsh terracing, and Submerged Aquatic Vegetation (SAV); sills; marsh toe revetments; and other structures. An alternate approach is to create a hybrid living shoreline; it uses structures such as marsh sill or bank toe revetments used to support vegetation growth (Bilkovic and Mitchell, 2012).

Soft Engineered Approaches and Shoreline Armouring

The use of shoreline armouring as a method to stabilize the coastline is one of the most common erosion control choices in Nova Scotia. Some of the examples of hard, engineered management options include breakwaters, revetments, groins, riprap or cement walls (Hardaway, Milligan and Duhring, 2010). There are some benefits to using shoreline armouring in high wave energy areas, such as reducing erosion rates. Armour stone alters the preexisting natural state by destroying intertidal and submerged vegetation, and by introducing novel habitat features (e.g. boulders placed on sand beach).

"Coastline change in Port Morien is not only resulting from natural erosion. Has been affected by human structures, seawall, ATV use…"

- Community member at Port Morien Climate Change Public Meeting (December 11, 2014)

Hard erosion control methods are highly expensive and require a skilled professional for maximum effectiveness. Additionally, some methods are more suitable for different site conditions (Table 3). Although armouring can provide immediate shoreline protection from erosion, the disadvantage of these methods include exacerbating erosion in other areas, damage to habitat and provision of few ecological services (Rideout, 2012). Further, engineered approaches are not a long-term solution to erosion. Due to the unpredictable nature of these solutions, such as damage to adjacent property, they are not recommended unless important infrastructure is at risk.

Table 3. Hard erosion control methods (Modified from Cornell University Cooperative Extension Onondaga, 2013).

Methods	Site Conditions	Technique
Stone Rip-Rap	Stable soil	• Place layer of stones along a slope face or bank to protect against wave action • Base of stone layer is below lakebed and ends above mean high water
Vegetated Rip-Rap	Stable soil	• Rip-rap prevents erosion from wave action • Plant roots bind the earth
Vegetated Gabion Mattress	Moderate slopes to resist wave action, ice, and surface erosion	• Mattress shaped cage is filled with rocks • Branches or cuttings are inserted through rocks into the cage
Vegetated Cribbing	Non-vegetated slopes with a lot of backfill and little wave action	• Interlock planks along the bank • Plant vegetation between the planks
Slope Grading and Terracing	Steep shoreline with erosion	• Grade or terrace the slope • Plant vegetation to provide stabilization

Beach Nourishment and Restoration

There are various approaches to protect beach spaces from increased sediment migration and recession. Beach nourishment projects restore an eroding beach by artificially adding sand along the shoreline; they are engineered to preserve natural beach processes such as shifting of sand in response to natural variations in waves and water levels (Krechowski, 2015). Benefits of such a project include maintenance of the beach area for recreational and ecological purposes as well as protection of the structures behind the beach. Unfortunately, beaches are not static and it is natural to experience erosion over time; therefore, this type of project has temporary effectiveness without regular maintenance. There is also a chance of damage to marine and beach life from heavy machinery changing the shape of the beach and making the water too muddy. Beach nourishment studies should be carried out to evaluated the impacts of the proposed project on the fill area and the site where sand will be obtained (i.e. borrow site), as well as potential impacts to endangered or threatened species (Krechowski, 2015).

Dune restoration is another form of beach protection which can also lessen flood hazards. Volunteer beach restoration projects have been used in Parks Canada beach protection programs and range from grass pulling projects to planting dead pine trees to allow for deposition of sediment and build-up of the dune systems. However, newly constructed dunes lack long standing vegetation, making them more susceptible to erosion. This reduces their effectiveness as a one-time only project without assurance of future maintenance

"Lack of sea ice has made erosion worse."

- Community member at Port Morien Climate Change Public Meeting (December 11, 2014)

Stormwater Management

Stormwater management is an important component of climate change adaptation. Due to increases in air temperature there is also greater potential for more high intensity rainfall events and their associated runoff. Impervious surfaces (e.g. paved parking lots) are also becoming more prevalent, and may exacerbate erosion issues related to an increase in rain event runoff. Therefore, it is important to consider good upland management approaches to reduce runoff volume by using methods that increase infiltration into the soil, promote evaporation, direct flow to waterways, and capture water. Examples can include bioretention areas, rain gardens, increasing permeable surfaces (e.g. depaving), planting grass on exposed soil, and avoiding the removal of topsoil when developing new areas. Using barrels is an example of capture and reuse of rain water on private property.

3. Discussion of Current Vulnerabilities

3.1. Anticipated Climate Change Impacts in Cape Breton

Climate change can lead to a variety of impacts including damage to infrastructure, property, human health, and the ecosystem (Table 4). According to the Intergovernmental Panel on Climate Change (IPCC) (2007), coastal flooding hazards are projected to worsen as climate change causes an increase in sea level rise, annual precipitation and frequency of extreme storm events. The results of these changes include increased frequency of storm surge, inland flooding, and accelerated erosion rates.

Table 4. Anticipated impacts related to climate change in Cape Breton (modified from Bikova & Hatcher, 2010; IPCC, 2014 and WHO, 2014).

Overall Impacts	Human Health Impacts	Ecosystem Health Impacts
❖ Sea level rise leading to permanent inundation ❖ Erosion and degradation of shorelines and coral reefs ❖ Reduced sea ice ❖ Warmer temperatures could create conditions for more severe weather events ❖ More intense rainfall, snowfall, and wind ❖ Changing patterns of wind direction affecting the effectiveness of shore protection measures ❖ Episodic (Occasional/Irregular) flooding during storms ❖ Infrastructure damage: sewer and water lines, roads and bridges	❖ Salt water intrusion in well water, estuaries and freshwater aquifers ❖ Mortality associated to heatwaves, floods, and droughts ❖ Air temperature and air quality ❖ Water and sanitation: increased water borne diseases and other health concerns related to accessing clean water ❖ Spread of disease ❖ Increased stress on emergency services	❖ Inundation and displacement of wetlands and lowlands ❖ Forest dispersion ❖ Increase the risk of forest fires ❖ Disturbances to ocean ecology due to changes in currents, waves, freshwater run-off and sediment dumping ❖ Damage or loss of breeding areas for birds and other coastal species

3.2. Sea Level Rise Scenarios

In Atlantic Canada, the rise in relative sea level is a result of three main processes: long-term global mean sea level rise since the end of the last ice age; regional land subsidence; and accelerated global sea level rise resulting from a warming climate. Climate-based sea level rise is driven by the expansion of ocean water with increasing temperatures and melting of global ice sheets (CBCL Ltd., 2009).

Based on a review of the most recent scientific literature, the expected range of sea level rise for North Sydney is an increase in sea level of 0.34 metres by the year 2050 and 0.82 metres by the year 2099 (Zhai et al., 2014). The impacts of sea level rise include an increase in flooding hazards and salt water intrusion into well water. Additionally, sea level rise further compounds the effects of coastal erosion by exposing more land to wave action (Richards & Daigle, 2011).

> *"In Little Lorraine we used to play on the sea ice as children"*
>
> - Property owner from Little Lorraine, 82 years as a community resident. Main-a-Dieu Climate Change Public Meeting (October 30, 2014)

For this project, mapping technology was used to display sea level rise predictions, aiding in the identification of areas at risk of inundation and increased erosion. The technology applies projected sea level rise scenarios onto current digital elevation models (DEM). In this study, inundation maps were created by developing a raster image of future predicted sea level rise expected for the year 2099 (msl=0.82m), which was converted to a polygon shapefile and superimposed on the four study areas in this project along the Marconi Trail (Figure 2-4). Risk maps were created to identify vulnerable infrastructure (Table 5). Vulnerable areas included roads and bridges, private residences and areas of recreation within communities at risk of permanent inundation. Identifying these vulnerabilities will help to prioritize adaption methods.

Figure 2. Predicted sea level rise in Main-a-Dieu of 0.82 meters by the year 2099. The red line indicates areas of permanent inundation.

> *"Where I used to walk as a kid is now 20 feet away. Paths to shore have changed; maybe a loss of 10-15 feet since I was young."*
>
> - Property owner from Main-a-Dieu, 43 years as a community resident. Main-a-Dieu Climate Change Public Meeting (October 30, 2014)

Figure 3. Predicted sea level rise in Port Morien of 0.82 meters by the year 2099. The red line indicates areas of permanent inundation.

Figure 4. Predicted sea level rise in Big Glace Bay Beach of 0.82 meters by the year 2099. The red line indicates areas of permanent inundation.

Private Residences

Primary assessment of the risk mapping based on predictions of sea level rise by the year 2099 and the CBRM civic address records confirmed there were minimal risks associated with permanent inundation to private residences in the target areas (Table 5). One of the areas of focus in this plan was Big Glace Bay Beach; however, the vulnerability analysis extended to the communities of Glace Bay and Port Caledonia. The four private residences within the Glace Bay study area at risk of permanent inundation are located along Gallant Street and Harbour Street. The eight private residences in Main-a-Dieu which are at risk are on the Main-a-Dieu Road. The three private residences within areas of permanent flooding in Port Morien and South Head are located along Highway 255 (Black Brook) and Hiawatha Road (South Head).

Structures

Through an analysis of sea level rise scenarios some structures have been identified within the area of permanent inundation. Maintenance may be required for some structures such as wharfs and breakwaters, and relocation may be required for others.

Glace Bay: Structures at risk are comprised of 55 industrial, residential, commercial and accessory buildings with various uses. Descriptions of at risk structures included:

- Structure associated with seafood processing plant
- Storage building
- Vacant residential
- Single unit dwelling
- Seafood sales and commercial buildings
- Plant
- Wharf
- Accessory building
- Breakwater

Main-a-Dieu: Structures at risk include 15 industrial and utility structures. Descriptions of at risk structures include:

- Lighthouse
- Storage building
- Plant
- Wharf
- Breakwater

Port Morien and South Head: Structures at risk included 18 industrial, residential, recreational, utility, residential and accessory buildings with various uses. Descriptions of at risk structures included:

- Church camp
- Storage building
- Seasonal single unit dwelling
- Single unit dwelling
- Wharf
- Harbour light

- Accessory building
- Breakwater

Infrastructure – Roads & Bridges

Road infrastructure identified potentially at risk of flooding and permanent inundation based on predictions of sea level rise by the year 2099 extended through both municipal and Nova Scotia Department of Transportation and Infrastructure Renewal (TIR) jurisdictions. Further risk to infrastructure in the target area extends to sewer and water supply systems, including salt water intrusion into private well systems.

Within Glace Bay, five roads maintained by the municipality are at risk, including Bell Street, Gallant Street, Commercial Street, Main Street and Harbour Street. The Donkin Morien Highway in Glace Bay and the Donkin Morien Highway in Port Caledonia are maintained by NSTIR. Lastly, one privately owned road, Xstrata Donkin Coal Exploration Project Road, is within the zone of inundation in Glace Bay. In Glace Bay, two bridges are at risk of flooding: Donkin Morien, which is the responsibility of NSTIR; and Commercial Street Bridge, which is within the CBRM's jurisdiction.

The roads at risk of flooding and permanent inundation in Main-a-Dieu within the provincial jurisdiction included Main-a-Dieu Road and Baleine Road. Further, a portion of Main-a-Dieu road within the municipal jurisdiction is vulnerable to sea level rise.

In Port Morien and South Head, five sections of roads are at risk and fall with the NSTIR jurisdiction. Possible inundation extends through Highway 255 in Port Morien and Highway 255 in Black Brook, Breakwater Street, South Head Road in Homeville, and South Head Road in South Head. In Port Morien and South Head, a total of four bridges are vulnerable to sea level rise. Three bridges within the NSTIR jurisdiction and one unpaved, privately own bridge are also at risk.

Recreation

Recreational areas vulnerable to sea level rise include beach and park spaces along the Marconi Trail. Through the community workshops, some recreational areas have been deemed a priority because of their value to the community and the ecosystem. Vulnerable areas include Main-a-Dieu Beach, Renwick Park, Big Glace Bay Beach and Schooner Cove Beach, Port Morien Breakwater Beach, and Port Morien Sandbar Beach.

Table 5. Areas at risk of inundation within a predicted sea level rise of 0.82m by the year 2099

Private Residence	Structures	Infrastructure		Recreation	Community
		Roads	Bridges		
8	15	3	0	Main-a-Dieu Beach	Main-a-Dieu
1	13	4	2	• Port Morien Breakwater Beach • Port Morien Sandbar Beach	Port Morien
2	5	1	2	N/A	South Head
4	55	7	2	• Big Glace Bay Beach • Schooner Cove Beach • Renwick Park	Glace Bay
15	**88**	**16**	**6**	**6**	**Total**

3.3. Historical Erosion

Recent digital orthoimagery was provided to ACAP Cape Breton by the CBRM Planning Department. Additional hard copies of photo imagery dating back to 1931 were available from the National Earth Observation Data Framework Catalogue. The hardcopy imagery was scanned, georeferenced and the shoreline digitized. This provided a decadal view of the state of the coast for 1930, 1960 and 1990. Distances of the shoreline retreat were then measured to quantify the change in shoreline area. The source of error in the georeferencing process was addressed by following the same methods discussed in ACASA (2011).

Standardized methods for measuring coastal change such as those used in the Shoreline Studies Program rely on identifying a fixed structure on the shoreline and measuring the coast from that point (Hardaway et al. 2010). The target areas in this study were rural and did not have sufficient permanent structures to use as reference points. As a result, we used methods described in a study by ACASA (2011). This involved tracking erosion in beach areas of PEI by dividing the land into transects and measuring coastal change.

$$\boldsymbol{Erosion\ rate} = (\boldsymbol{change\ in\ coastline\ width}) \div \#\ \boldsymbol{of\ years\ elapsed}$$

Equation 1. Erosion rate per year

Digital transects were placed every 50 metres perpendicularly along the coastlines in the four areas of interest and the change in coastline width was measured at each transect. The change was then divided by the number of years that elapsed to determine an average erosion rate per year and to highlight erosion hotspots and areas impacted by human disturbances (Table 6).

Table 6. Erosion and deposition rates along the Marconi Trail

Community	Length of Coastline Measured (km)	Erosion Rates (m/year)			Deposition Rates (m/year)		
		Min.	Max.	Average	Min.	Max.	Average
Main-a-Dieu	9.65	0	1.32	0.42	0	0.57	0.17
Port Morien	8.65	0.02	1.32	0.40	0	2.50	0.63
South Head	16.55	0	1.70	0.34	0.02	4.23	0.58
Big Glace Bay Beach	8.60	0.03	3.8	1.54	0.02	5.72	1.13

Through an analysis of historical imagery, areas prone to high erosion rates were identified for central Main-a-Dieu, in particular the south portion of Main-a-Dieu beach (Figure 5, Appendix A). In addition, property owners in Main-a-Dieu referred to land surveys where a loss of 78 meters was recorded, indicating an erosion rate of 1.23 meters per year for their property (Image A – Appendix A, Workshop). Additional areas vulnerable to coastal erosion with the highest erosion rates for this area include the most northern tip of Main-a-Dieu.

Through an evaluation of the coastline measurements, Port Morien Sandbar Beach displays erosion rates from 0.86m/yr to 1.32m/yr (Figure 6, Appendix A). Highway 255 and Morien Highway in central Port Morien also display high erosion rates and are particularly vulnerable due to their proximity to the coastline (Figure 7, Appendix A). Anecdotal evidence from stakeholder interviews highlighted property loss north of the Port Morien wharf caused by exacerbated erosion resulting from the installation of the wharf, with a loss of 40 feet (Image C – Appendix A, Figure 8 - Appendix A).

3.4. Local Knowledge Acquisition

Local knowledge was acquired through four workshops and one public meeting to present the final plan. Open workshops were held in Main-a-Dieu on October 30th, 2014 and in Port Morien on December 11th, 2014 to gather community input for the Climate Change Adaptation Plan. These sessions included an introduction to climate change, community mapping sessions, and acquisition of local knowledge and photographs, community mapping sessions were used to record anecdotal data and eyewitness accounts by members of the local community. This information was considered during the GIS risk mapping to aid in determining coastal adaptation priorities. In-person interviews and anecdotal information was collected to gather additional knowledge and supplement the GIS data analysis. Incorporating local knowledge served the dual purpose of strengthening our geographic data set and building community involvement and awareness of climate change issues. Overall, coastal erosion was emphasized as the primary concern for all communities involved

The second sets of workshops were held in Main-a-Dieu on February 7th, 2015 and Port Morien on February 11th, 2015 to present draft recommendations to the communities and to collect public feedback. These comments were recorded and incorporated into the final adaptation plan.

Community members identified areas of particular concern which included:

- **Social/cultural importance**: churches, recreation space;
- **Economic concern**: home insurance, real estate values, damage to infrastructure;
- **Environmental concern**: habitat, marine use, land cover, hydrology;
- **Personal**: health (well systems), emotional; and
- **Erosion**: erosion hotspots

In Main-a-Dieu, primary concerns were impacts related to coastal erosion. Property owners provided first-hand accounts of the changing coastline and described finding remains from a historical cemetery along the coastline and beach. Community feedback emphasized maintaining the recreational space and ecological integrity of Main-a-Dieu Beach; protecting private property from coastal erosion; and utilizing soft engineered methods, policy change, and vegetation techniques.

Workshops held in Port Morien focusing on Glace Bay, Port Morien and South Head identified coastal erosion as the primary concern. Property owners provided first-hand accounts of the changing coastline, and changes to local beach landforms. Due to high tidal action and water currents, property along central Port Morien has undercut erosion. Vegetation techniques were deemed not feasible for many areas along Port Morien as a result of the high wave energy, undercut erosion, high bank height, and steep bank slope.

> Port Morien property owner: originally had 100 feet of property. In a 2005 survey of their land showed a loss of 12 feet.
>
> - Community member at Port Morien Climate Change Public Meeting (December 11, 2014)

Community feedback included two main components: the need to address maintenance for the area's breakwater, and protection of Port Morien Breakwater Beach and Port Morien Sandbar Beach for both recreational space and ecological integrity. Community members attending the workshops have already experienced salt water intrusion into private well systems. South Head was identified as less vulnerable due to its lower erosion rate compared to other areas along Marconi Trial and less vulnerable infrastructure or private residences. Community feedback varied, with some opinions favouring long-term policy changes and implementation of municipal or provincial setbacks. Conversely, community members were also in favour of more hard engineered structures, as their primary concern was short-term protection of private property.

4. Proposed Adaptation Options

Through this project, vulnerable areas were identified through hazard mapping and community workshops. Applicable adaptation methods were then selected based on the site conditions.

4.1. Maintenance of Breakwaters in Main-a-Dieu & Port Morien

Proposed Action

Community workshops identified the maintenance of breakwater structures as a priority. Resource allocation and maintenance will be required for breakwater structures in Port Morien and Main-a-Dieu.

4.2. Beach Protection

Proposed Action

Community feedback during workshops strongly supported the protection of public beach areas and public feedback was collected on potential adaptation methods.

Main-a-Dieu Beach was prioritized as a community concern because it provides ecological habitat, recreational space, and protects structures behind the beach. As this site has high fetch and experiences strong wave energy, a dune nourishment project could maintain this site for community use; however, this would not be a long-term solution. Strong community commitment as well as multi-year monitoring would be required for maintenance to effectively design the project. Further protection measures could include maintenance of boardwalks to continue to protect vulnerable beach habitat from foot traffic. During community workshops, public comments included the support of vegetation based solutions such as living shorelines. However, due to the high energy nature of this site a living shorelines approach may not be appropriate and would require more research into such an application.

Port Morien Breakwater Beach and Port Morien Sandbar Beach were identified through community workshops and risk mapping as priority areas for climate change adaptation measures to protect both the recreational space and ecological integrity. Port Morien Sandbar has low to moderate fetch and experiences some sediment migration (Figure 6, Appendix A). Further, through stakeholder interviews, flooding concerns were identified on the Port Morien Highway 255 at the entrance of the Port Morien Sandbar (Figure 12, Appendix A). Due to the low fetch and shallow depth at this site, developing a marsh with fiber logs may be sufficient to address the concern while avoiding hard engineered structures which could increase erosion along the beach (Center for Coastal Resources Management, 2010). As beach migration in Port Morien is a natural process, a beach nourishment program may not be the best use of community resources. Alternatively, maintaining and planting beach vegetation provides a low cost solution collecting and maintaining sand.

Big Glace Bay Beach (Figure 11, Appendix A) is part of Big Glace Bay Lake Migratory Bird Sanctuary, established in 1939, and is home to American Black Duck, Canada Goose, Common Goldeneye, Bufflehead, Common Tern and Willet and the endangered Piping Plover. It is owned by Province of Nova Scotia and Atomic Energy of Canada Limited and is managed by the Canadian Wildlife Service. Due to the important bird habitat on Big Glace Bay Beach, impacts resulting from beach protection methods should be considered during the design of any project. Maintaining beach vegetation and using dune restoration projects would be the most beneficial measure, while emphasizing limited disturbances to the ecosystem.

4.3. Shoreline Stabilization

Proposed Action

Through stakeholder interviews and community workshops, erosion was identified as the most pressing concern for residents. Overall upland management options should be considered in Port Morien, Main-a-Dieu, and Glace Bay area to reduce stormwater runoff, coastal erosion, and water quality issues. Maintaining a vegetation buffer of 20 meters from the coast where possible should also be implemented as a low cost solution to stabilize the coast and buffer waterways.

Further, armouring should be avoided along the coast to reduce lateral erosion in neighbouring coastlines, unless important infrastructure cannot be easily moved or is at immediate risk. Main roads, highways and bridge structures previously identified at risk of inundation should be evaluated by the responsible government departments and prioritized based on infrastructure that cannot be relocated.

Where undercut erosion occurs, bank grading will be required to utilize any erosion control methods previously discussed. Much of the coastline along the community of Port Morien possesses these characteristics. High wave energy often limits less costly, ecosystem friendly shoreline protection methods from being used in areas with high erosion, undercut erosion and high fetch. Shoreline protection solutions in areas with the site conditions specified above will require more costly hard structures. The long-term cost of maintaining erosion control structures should be taken into account prior to installing any structures. Hard engineered solutions are temporary and will eventually require maintenance or replacement. Accommodation methods are the only viable long-term solution to coastal hazard concerns, particularly to increases in erosion rates and sea level rise.

Native vegetation with deep root systems (live staking, brush mats, living shorelines) are recommended in areas with low erosion rates, and bank heights less than 30 feet. Areas along southern Main-a-Dieu could benefit from these techniques, with the use of woody plants such as dogwood, providing bank stabilization.

4.4. Setbacks and Land Use Zoning

Proposed Action

New construction should maintain a vertical setback or allowance of 0.41m for 2050 and 1.15m for 2099 to allow for sea level rise and storm surge predictions. These recommendations are based on the study conducted by Zhai et al (2014). Horizontal setbacks are also recommended between 20-100 meters to protect against coastal flooding and property loss on rapidly eroding cliffs (Table 2).

Alterations to current land use zoning should also be considered to restrict new developments in hazardous areas. Past and future erosion rates as well as predicted sea level rise should be considered when selecting an area for new construction.

4.5. Adaptation for Precipitation and Extreme Weather

Additional short-term adaptation actions to increase community resiliency and reducing risks to increases in precipitation and extreme weather:

- Increase community awareness using communication tools such as social media and traditional media outlets to warn public about basement flooding.
- Maintenance of roads and sidewalks during snow or extreme weather events to reduce risk of injuries.
- Stormwater management solutions to reduce runoff. Examples include rain gardens, permeable surfaces, and avoiding the removal of topsoil when developing new areas.
- Ensure there are emergency response plans in place within the community to increase resiliency to major events.
- Install backwater valve if connected to municipal sewer system and sump pit drainage systems to reduce the risk of basement flooding to individual homes.

5. Continued Development of the Climate Change Adaptation Plan for the Marconi Trail

This document was intended to guide communities towards adaptation solutions based on the conditions in their area, while complementing the CBRM's Municipal Climate Change Action Plan. It is the intent of this project to research and inform communities on the past, present and potential future conditions. This plan should not be the conclusion of the climate change discussion in these communities, as the overall goal of this project was to initiate change for a more resilient Cape Breton.

Long term adaptation strategies will require lobbying government to change policies regarding land-use zoning and adaptation. For individuals within the communities who are interested in such action there are a few paths available. Initially, it is recommended to research effective methods for influencing policy change. There are official and unofficial community based movements to advocate for such policy changes; these include groups presently advocating for the development of an updated and active coastal strategy. Organizations are lobbying for changes such as the implementation of provincial policy, which includes setbacks and other adaptive measures. Further, individuals can discuss their concerns with relevant government representatives.

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Appendix A: Shoreline Erosion Maps and Site Photographs

Figure 5. South portion of Main-a-Dieu Beach was identified as an area prone to high erosion rates when compared to the community's average erosion rates.

Figure 6. Black box highlights area on the Port Morien Sandbar Beach as it was identified as an area prone to high erosion rates when compared to the community's average erosion rates. Port Morien Sandbar Beach displays erosion rates between 0.86m/year to 1.32m/year

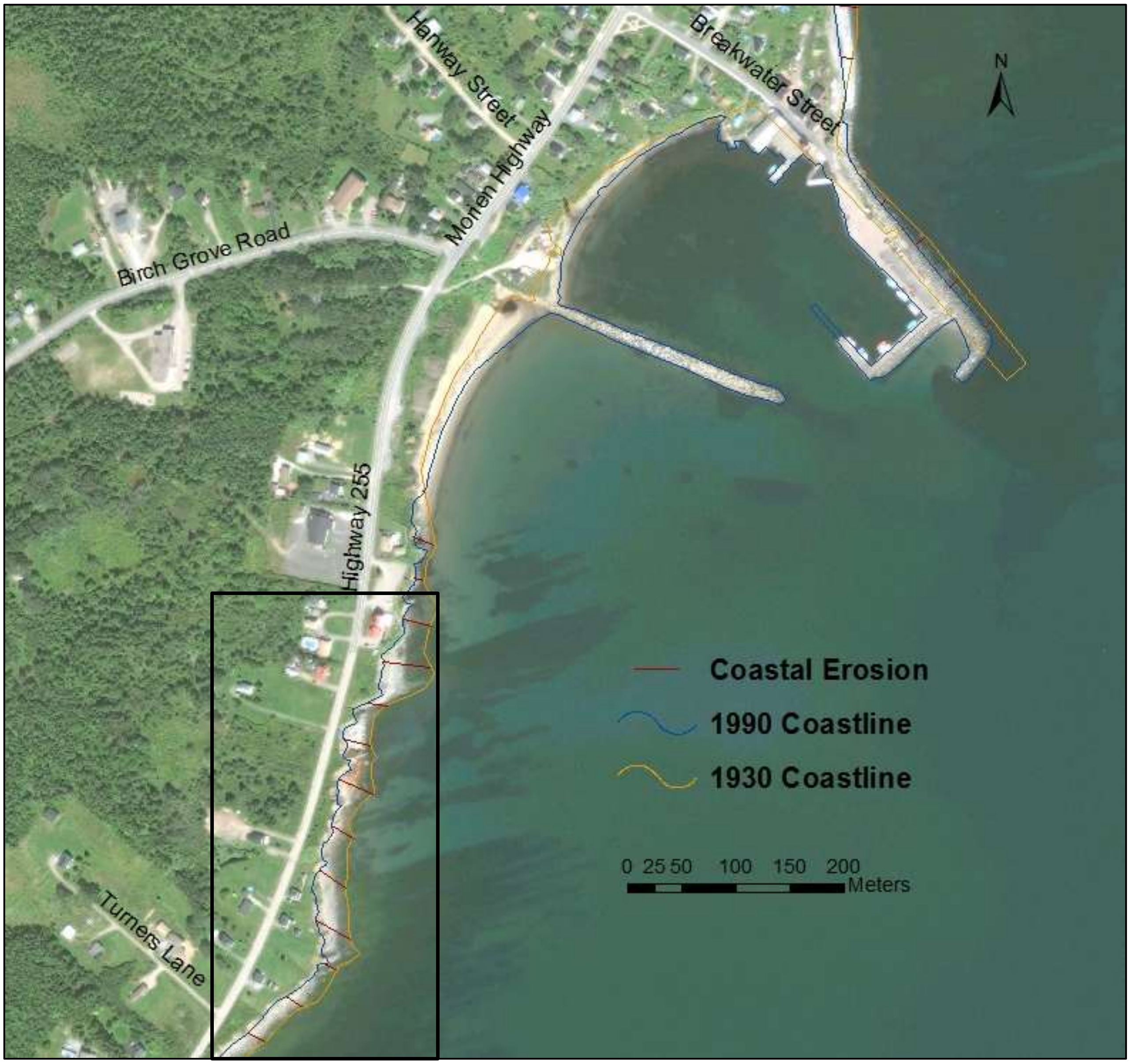

Figure 7. Black box highlights area on Highway 255 – Morien Highway which displays high erosion rates and are particularly vulnerable due to their proximity to the coastline.

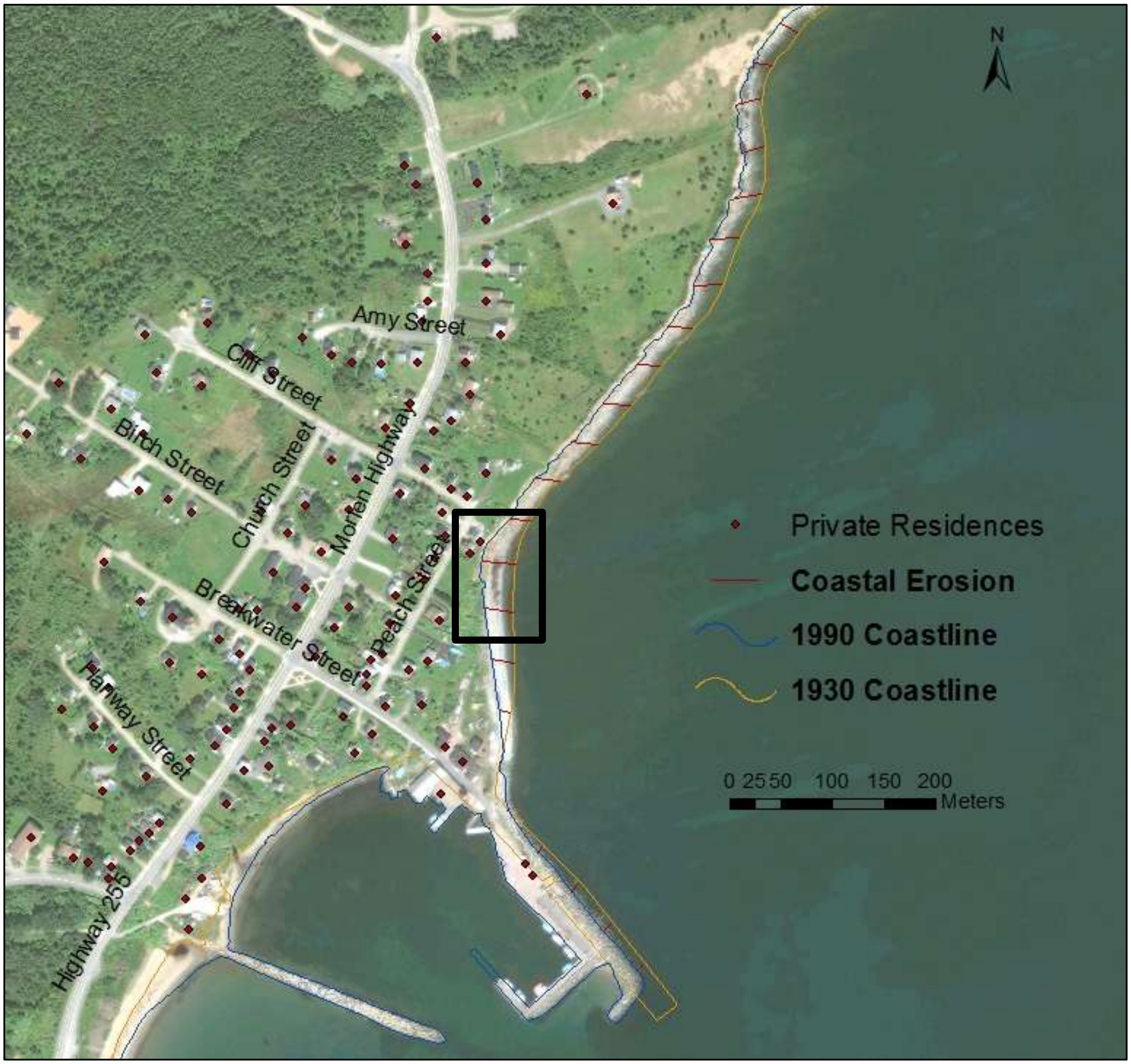

Figure 8. Black box highlights area north of the Port Morien wharf. Stakeholder interview highlighted that property experience exacerbated erosion resulting from the installation of the wharf.

Figure 9. Black box highlights area near South Head Road, which experiences high erosion rates.

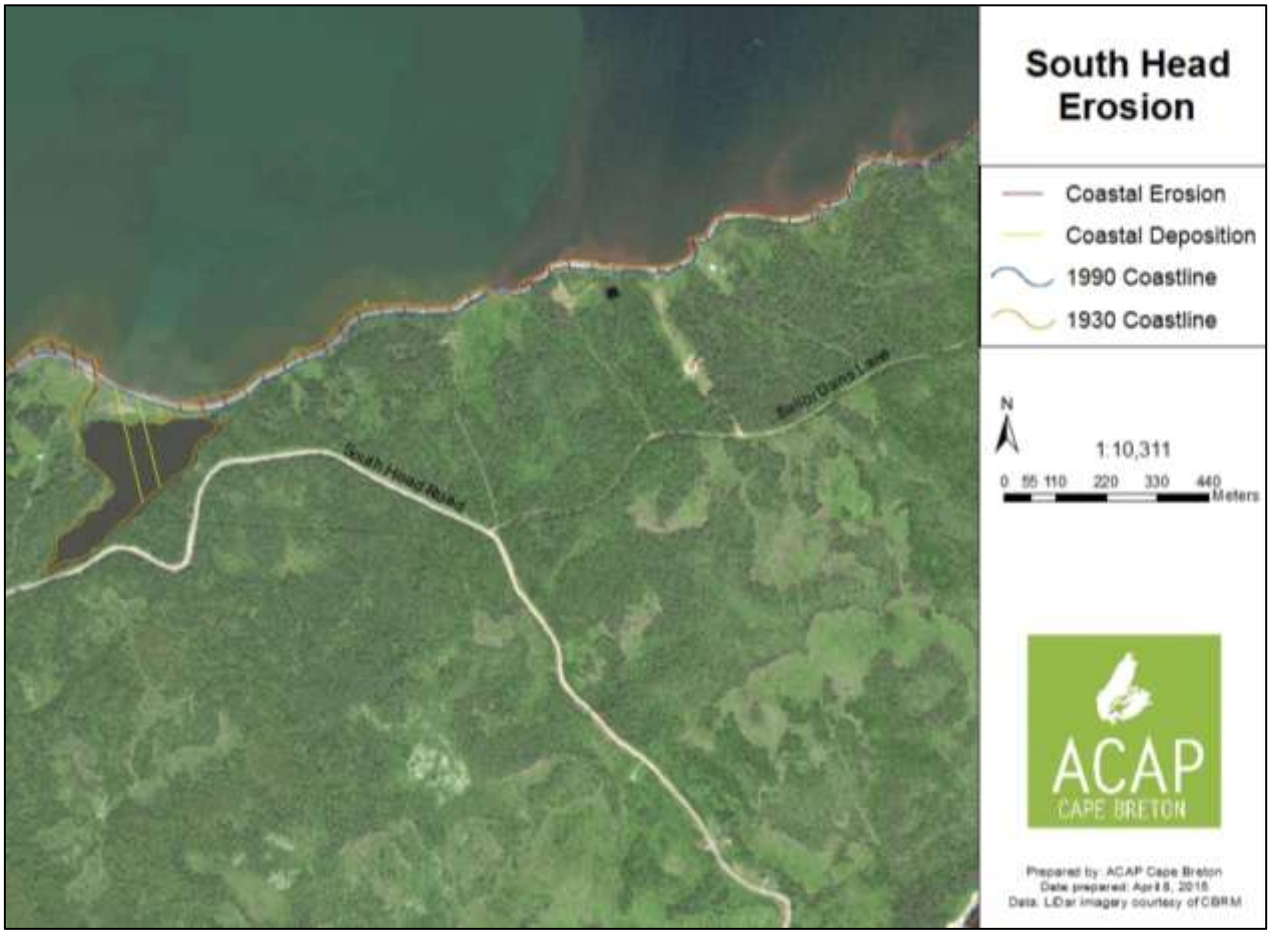

Figure 10. Coast along South Head Road experiences both high erosion and deposition rates.

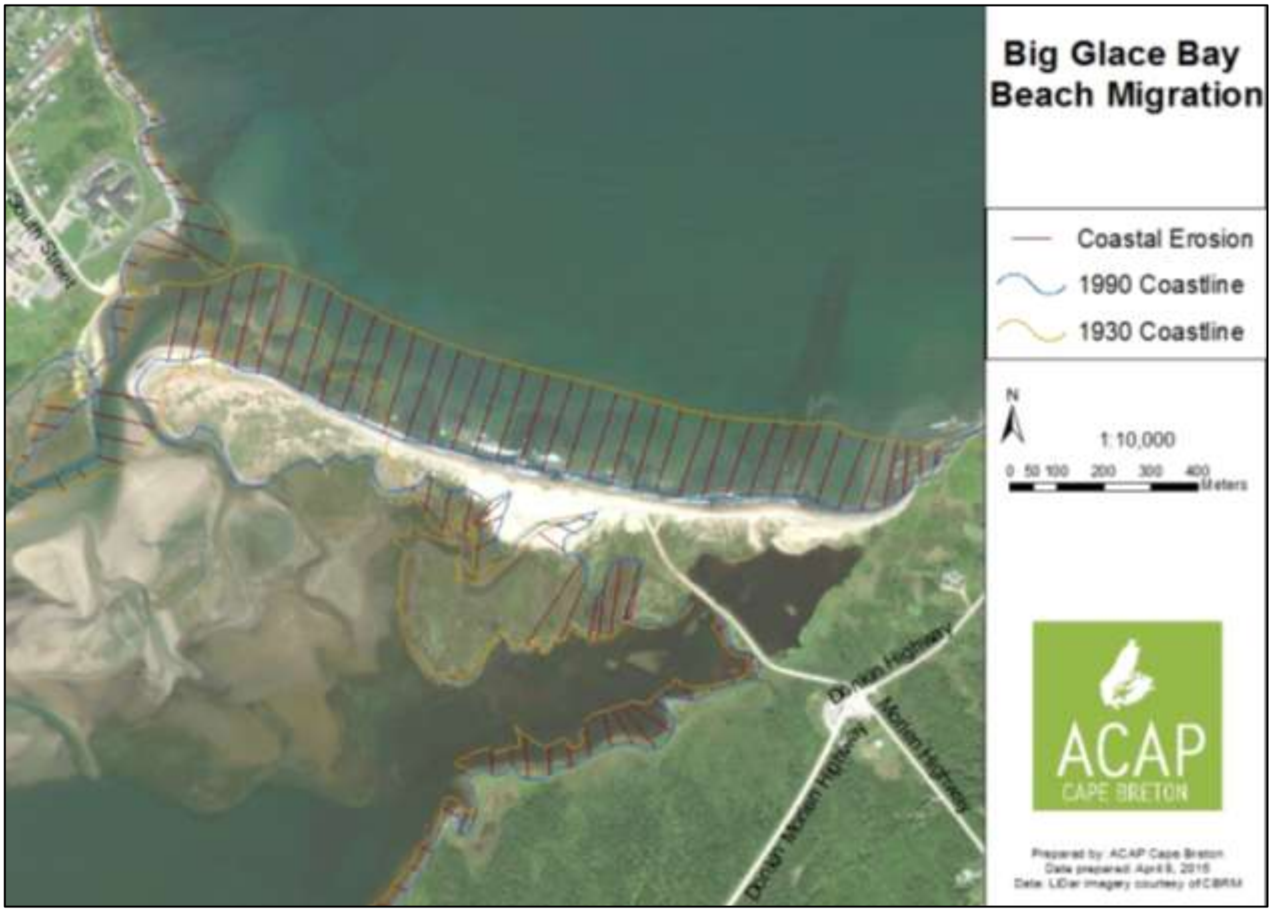

Figure 11. Big Glace Bay Beach has experienced beach migration and erosion.

Figure 12. Stakeholder interviews identified flooding concerns on the Port Morien Highway 255, at the entrance of the Port Morien Sandbar Beach. The black box highlights the area of concern.

Image A. Main-a-Dieu – Phillips's Property (February 27, 2015)
Images were taken along Phillips's property line north of Main-a-Dieu Beach.

Image B. Main-a-Dieu Beach (February 27, 2015)
Images were taken on the Main-a-Dieu boardwalk.

Images C. Port Morien – Boulet's Property (December, 2014)
Images were taken along the back of property line. Photo credit Kay Boulet.

Images D. Port Morien (March 5, 2015)

Images were taken along property line north of Morien Wharf.

Image E. (right) Port Morien Sandbar 2005 (Photo credit DNR) & (left) Port Morien Seawall 2014 (Photo credit LeRoy Peach)

Images F. Big Glace Bay Beach (December 15, 2014)
Images were taken along Big Glace Bay Beach. Bottom images include bird nesting area.