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A Geological and Coastal Vulnerability Analysis of Point Michaud Provincial Park, Richmond County, Nova Scotia

P. W. Finck

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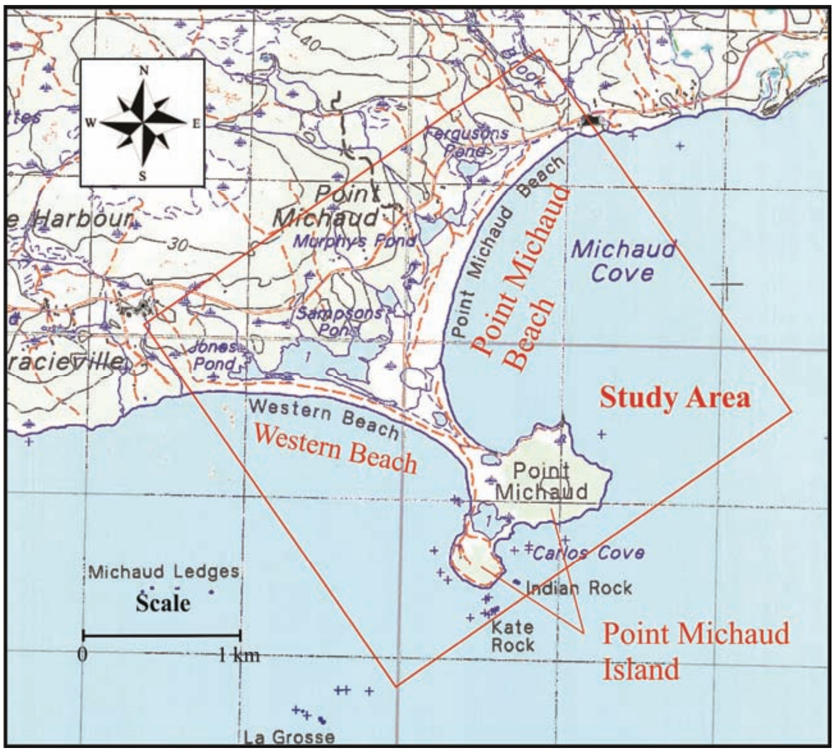

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Introduction

This report contains a geological and overall coastal vulnerability assessment of Point Michaud Provincial Park. The analysis is part of a Parks Division planning process. The report covers (1) geomorphology and general geology, (2) coastal processes and sedimentary characteristics of the beach, (3) shoreface stability, erosion and/or progradation (growth seaward), (4) cyclical changes within the beach and backshore environment, (5) sea-level rise and (6) implications for present and future infrastructure and park sustainability. This report is not heavily referenced to the scientific literature as it is a general overview. The report is not overly technical and is primarily designed to be read by a general audience.

Location, General Geology and Physiography

The study area is located within the Maritime Plain as defined by Grant (1994). It is part of an exhumed Tertiary (2.6 – 65 million years old) unconformity peneplain that was originally at or near sea level. Point Michaud is located on the southeastern coast of Cape Breton Island facing the Atlantic Ocean. It is a small community approximately 19 km northwest of St. Peters off Highway 247. The study area encompasses Point Michaud Beach, Point Michaud Island and Western Beach **(Fig. 1).**

Point Michaud Beach and Western Beach are wedges of Holocene (<10,000 years old) sand and gravel deposited along and on top of Late Hadrynian (544 million – 1 billion) year old volcanic and sedimentary rocks (Barr et al., 1996). The main beach area is underlain by metamorphosed lithic arenite (a very fine-grained rock containing over 50% rock fragments), metamorphosed conglomerate (a rock composed of coarse-grained rounded clasts typically within a fine-grained matrix), siltstone (a rock composed of silt sized particles), and dolostone (magnesium-rich limestone). Bedrock exposed at the easternmost end of the park is volcanic tuff (deposits of volcanic ash). It is commonly composed of 2 – 64 mm sized particles of originally molten to semi-molten lava. Point Michaud Island is also composed of volcanic tuff. These rocks are cut or intruded by younger (circa. 575 million year old) granite dikes.

Point Michaud Provincial Park is located at the northeast end of Point Michaud Beach in Michaud Cove. The park consists of two separate pieces of Crown land. A third piece of Crown land is located on Western Beach. Point Michaud Beach and Western Beach are separated by a northwest – southeast oriented double tombolo joining the mainland to Point Michaud Island **(Fig. 2).** Both Western Beach and Point Michaud Beach are backed by freshwater ponds. The landward sides of the ponds abut drumlins draped over seaward-sloping bedrock. The drumlins form arcuate coves and headlands on the landward sides of the ponds **(Fig. 3).**

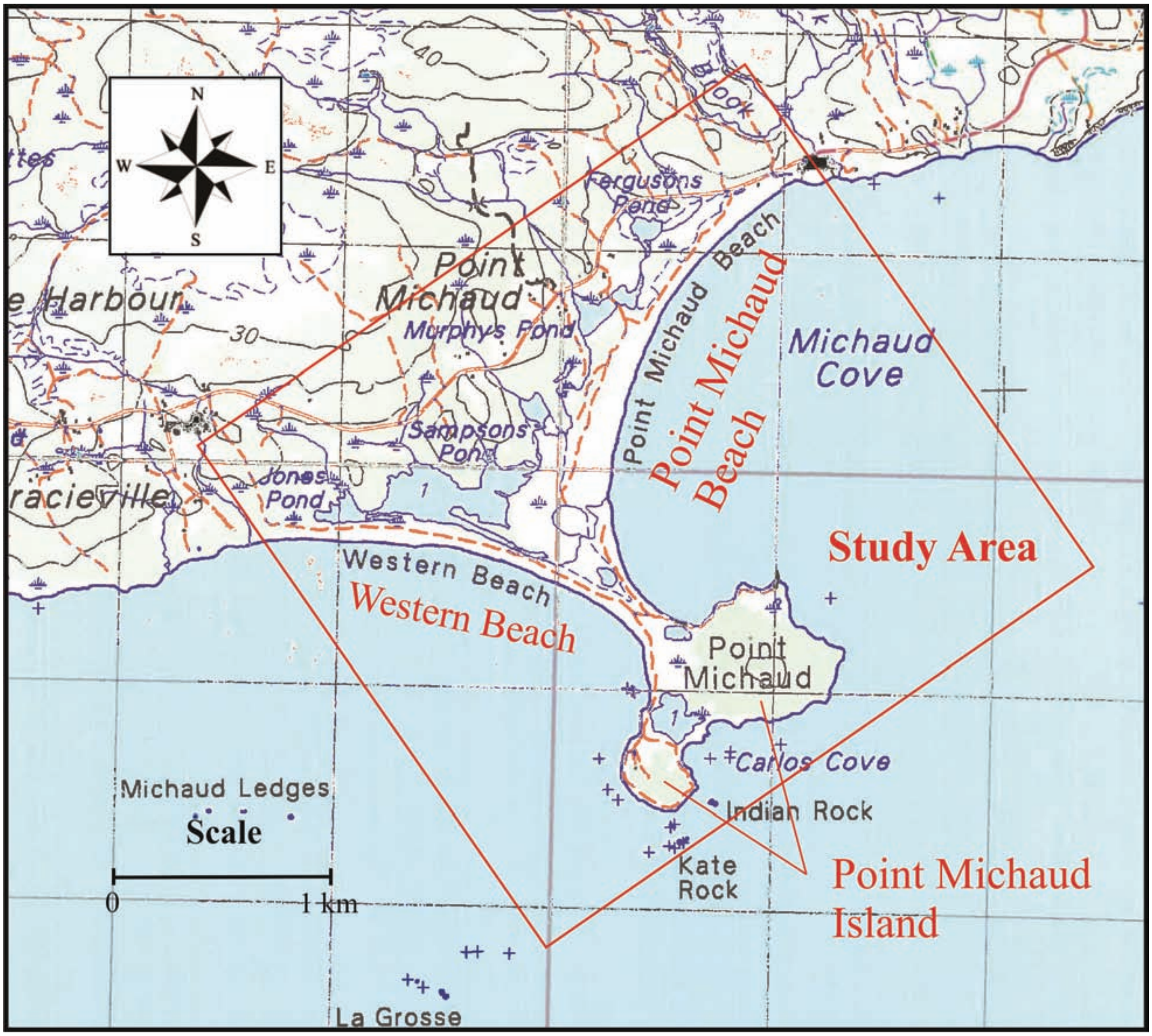

Figure 1. Location map of the Point Michaud study area.

Coastal Processes and Sedimentary Environment

A wide variety of factors influence both coastal processes, such as erosion, transportation and deposition of sediments, and the long-term evolution of a shoreline. Below is a listing of the factors that specifically affect the present study area with respect to the formation, stability, and longer term evolution of Point Michaud and Western beaches. These factors include:

- orientation of the shoreline, in particular with respect to prevailing winds, winter storms, hurricanes, other extreme storm events, and tidal range;
- presence of offshore sheltering islands or ledges, and the presence of sheltering headlands;
- presence or absence of bedrock within the sub-tidal, intertidal or supra-tidal areas;
- the amount of unconsolidated sediment exposed to active erosion along the shoreline;
- captive or stored sediment in the backshore, shore face, sub-tidal and offshore proximal area;
- water depth in the off-shore;
- variations in the directions and magnitude of near shore currents;

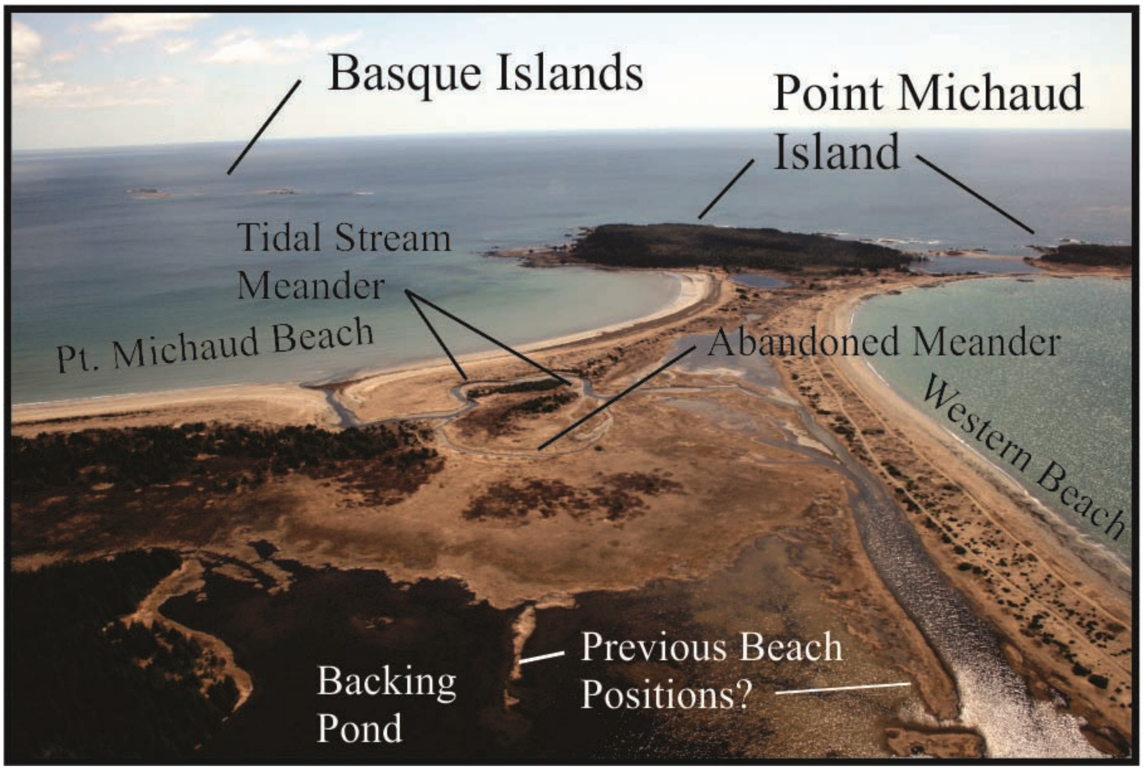

Figure 2. A view looking southeast showing Point Michaud Island and the tombolo connecting it to the mainland.

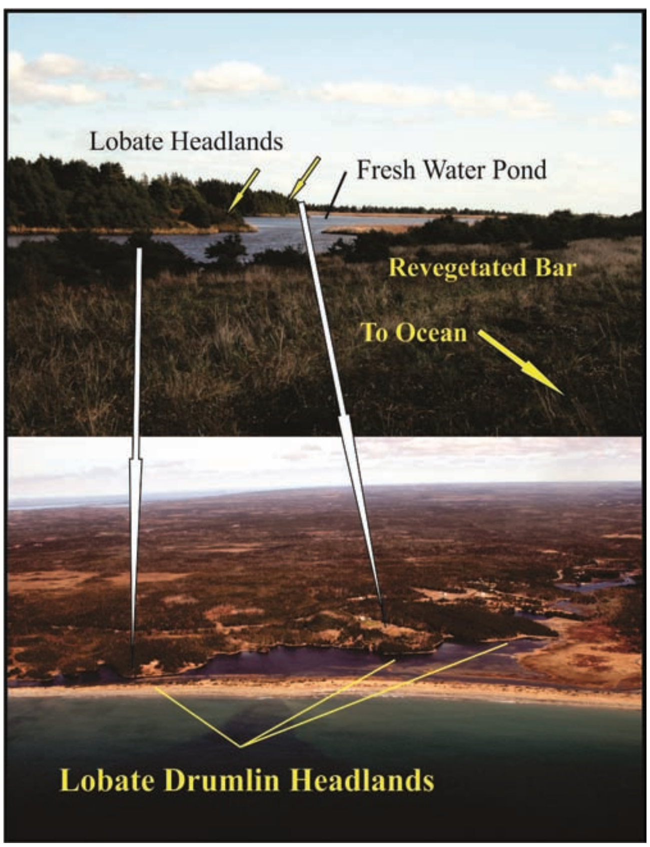

Figure 3. Lobate, non-eroded drumlin headlands in the pond behind Western Beach and the southwest end of Point Michaud Beach.

- width and slope of the beach, potential for wind-blown sand; and
- sea level rise.

Shoreline Orientation, Storm Events and Tidal Range

The coastline of southern Cape Breton Island between Isle Madame and Scatarie Island is oriented approximately northeast – southwest and thus faces approximately southeastward toward the Atlantic Ocean. It is directly exposed to deep ocean swells, wind generated waves, and storm surges. Thus on a macro scale the shore is classified as a high energy environment. A wind rose diagram based on long term wind measurements at Eddy Point, 42 km west of Point Michaud, is shown in **Figure 4** (modified from Jacques Whitford Environmental Limited, 2004). The prevailing winter wind is northwesterly while the prevailing summer wind is southwesterly. These data must be used with caution when extrapolated to the Point Michaud area, however. Eddy Point is located on the Canso Strait, which is oriented northwest – southeast and bordered on both sides by high topography. This creates a funneling effect that exaggerates the prevailing northwesterly winter winds when extrapolated to areas removed from the Canso Strait. Likewise, Eddy Point is partially sheltered from southwesterly winds, reducing the prevailing summer southwesterly wind when extrapolated outside of the Strait of Canso area. In addition the wind station is sheltered from easterly and northeasterly winds by mainland Cape Breton Island and Isle Madame.

Examination of Figures 1 and 4 illustrate that the Point Michaud area is sheltered from the prevailing northwest winter winds. Other large winter storms are typically associated with north-northeast to easterly winds with large associated storm surges. The largest surges are found in the Gulf of St. Lawrence in the area of Prince Edward Island and the Northumberland Strait. Because of the orientation

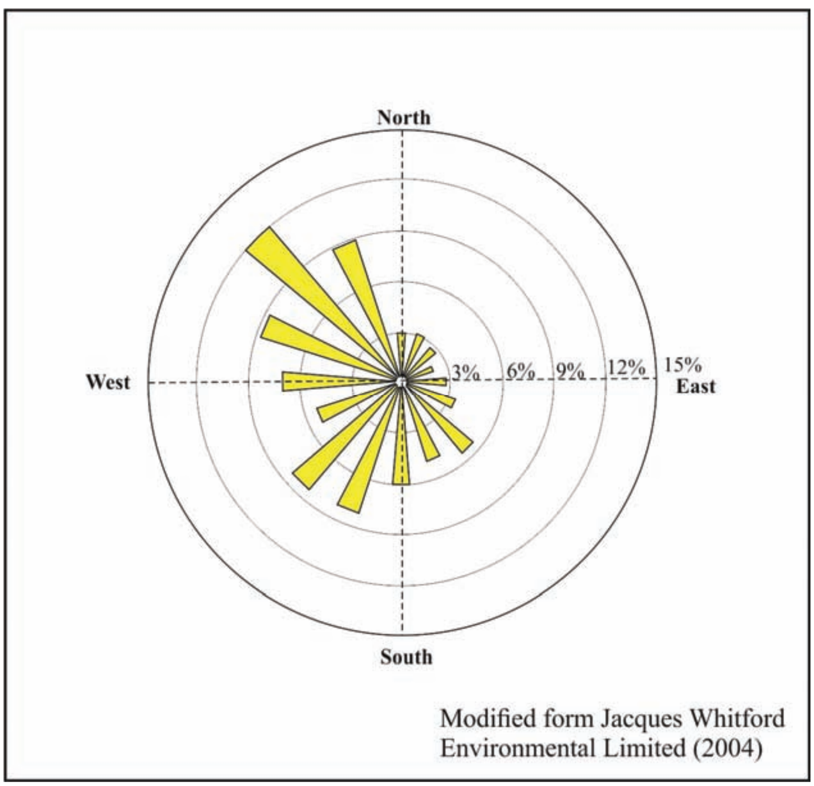

Figure 4. Wind rose showing prevailing winds at Eddy Point, Strait of Canso, Nova Scotia.

of the shoreline, and other sheltering effects discussed below, the Point Michaud area has a low probability of major storm damage due to these winter winds.

Western beach is exposed to the prevailing summer southwest winds, but Point Michaud Beach is sheltered from the southwest prevailing winds by Point Michaud Island. Point Michaud Beach is exposed to the less common southeasterly gales (**Fig. 4**). The eastern end of Western Beach is less exposed to southeasterly gales due to the shelter provided by Point Michaud Island (**Figs. 1 and 2**).

Hurricanes, large post-tropical storms, and named tropical depressions impacting this shoreline bring with them the potential for significant storm surges and damaging winds. The Environment Canada web site http://www.ec.gc.ca/hurricane/default.asp?lang=En&n=6DA4287E-1 contains information on land falling hurricanes in Nova Scotia from 1851 to present. It is based on the historic hurricane data base maintained by the United States National Ocean and Atmospheric Administration (NOAA). **Figure 5** shows the land falling position of historic hurricanes and hurricane strength post-tropical storms in Nova Scotia, wind speed at landfall, and their classification on the Saffir-Simpson scale. In the case of hurricanes (e.g. Juan) and hurricane strength post-tropical storms (e.g. Noel) sustained winds may occur

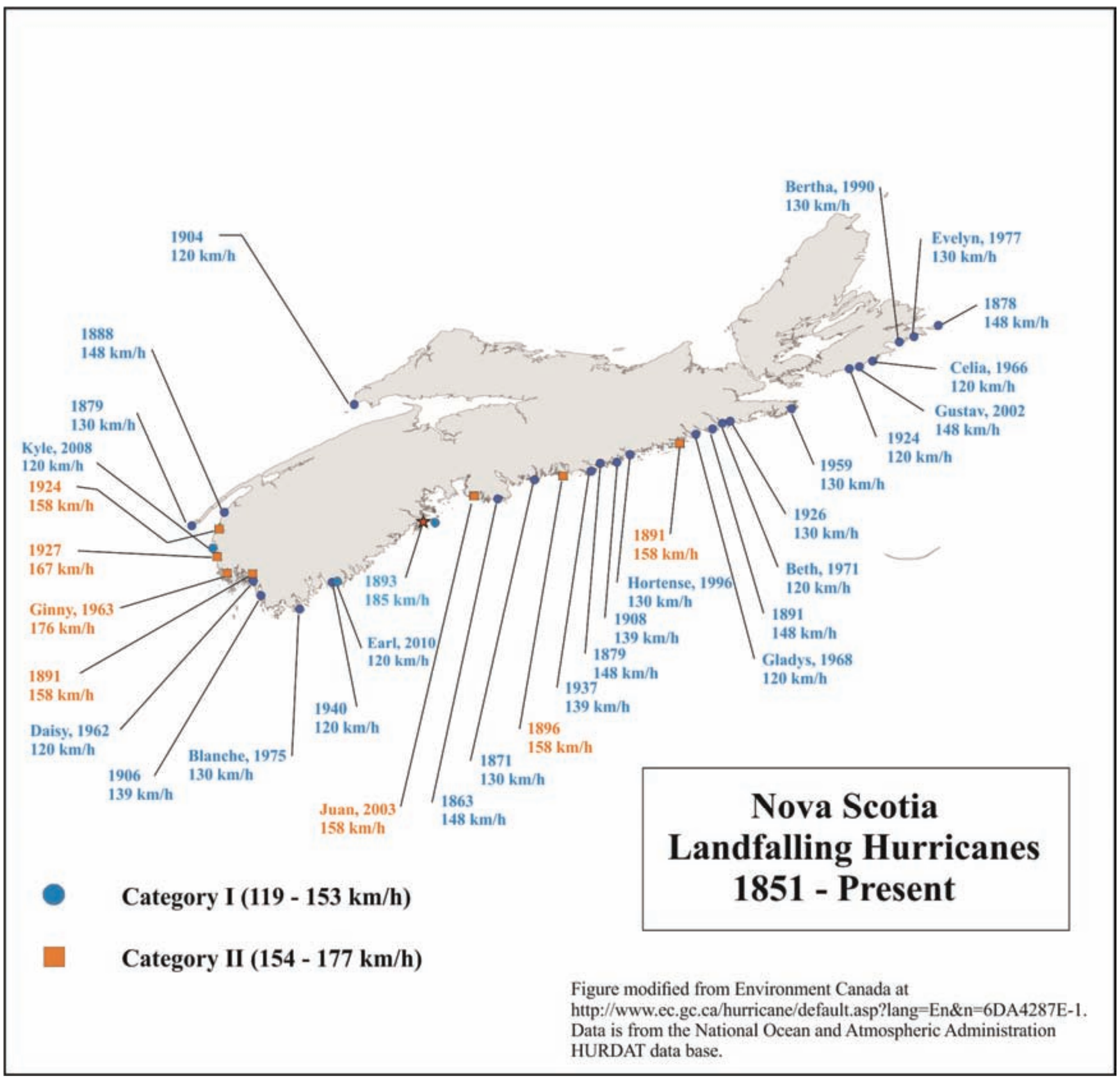

Figure 5. Map of Nova Scotia showing the location, wind speed, and category on the Saffir-Simpson scale of land falling hurricanes, from 1851 up to and including 2014.

up to Category I (119 - 153 km/h) or rarely Category II (154 - 177 km/h) on the Saffir-Simpson scale. There was only one possible Category III hurricane (178 – 209 km/h) ever recorded in Nova Scotia and that was on August 22, 1893, making initial landfall near Lunenburg and then tracking across the mouth of Mahone Bay and again making landfall at the Head of St. Margarets Bay, west of Halifax. However, recent re-analysis of historic hurricanes by the National Ocean and Atmospheric Administration (NOAA) downgraded this former Category III hurricane to a Category I hurricane as shown on **Figure 5**. Based on records from NOAA, there has never been a Category II or III hurricane make landfall on Cape Breton Island since records began in 1851. There were three Category II hurricanes making landfall on mainland Nova Scotia in the 1890s. Two Category II hurricanes made landfall in the 1920s, one Category II hurricane in the 1960s, and one Category II hurricane in the 2000s. It is clear that there is no evidence for an increase in the size or frequency of hurricanes making landfall in Nova Scotia over the latter part of the 19th, the 20th and the beginning of the 21st century. It is also apparent (**Figure 5**) that the area in Nova Scotia with the highest risk of being impacted by a Category II hurricane is the coastal area in southwest Nova Scotia between Yarmouth and Digby.

The potential for damage to coastal ecosystems and infrastructure in an area such as Point Michaud is not only proportional to the strength and size of tropical cyclones it is also directly related to the local tidal range. At Point Michaud the tide range is approximately 1.8 m, using data from Arachat and Canso Harbour (http://www.tides.gc.ca/eng/find/zone/27). Compare this to Yarmouth where the tide range is over 5 m. A hurricane with a 1 m surge striking Yarmouth 1.5 hours before or after high tide (i.e. at three-quarter tide) would produce a water level of 4.75 m, which is lower than a normal high tide. The same hurricane striking Point Michaud at three-quarter tide would produce a 2.35 m water level, which is 0.55 m higher than normal high tide. What is obvious is that for a given storm surge, the smaller the tidal range in any given location, the greater the risk of damage to the shoreface and any associated infrastructure. With the exception of the Bras d'Or Lakes, tidal range in Nova Scotia typically ranges (and varies) as follows:

- tidal range is approximately 2 m in the Gulf of St. Lawrence, around Cape Breton Island, and along the Eastern Shore;
- tidal range increases west of Halifax, along the South Shore, and reaches approximately 5 m near Yarmouth;
- tidal range continues to increase north to Digby and within the Bay of Fundy.

This is why large cyclonic events with for example, a 1 metre surge making landfall at low or half tide in Nova Scotia, typically have minimum impact with respect to erosion and coastal infrastructure damage.

As hurricanes approach Nova Scotia they tend to be losing strength or rapidly lose strength as they approach land due to encountering colder water and colder air temperatures. Hurricanes are typically smaller (aerial extent), i.e. the high winds and associated storm surge pass quicker than sprawling post-tropical storms such as Post-tropical Storm Noel. As such, surges associated with short duration cyclonic events have a lower probability of occurring close to high tide when compared to a longer duration post- tropical storms. Large post-tropical storms may in fact have a duration that crosses a full high–low tide cycle. Thus, damage due to large storm events can be predicted in the Point Michaud area if one knows the approximate location of landfall, predicted surge, wind speed, approximate time of arrival and the associated tide height at that time. The highest wind speeds occur on the north and east side of the eye of a hurricane as it makes landfall.

Sheltering Islands, Ledges and Headlands

As discussed in the section above, the Point Michaud - Gracieville area faces southeast and is sheltered by the land from northwest to northeast winds. Point Michaud Island is the dominant coastal feature controlling the coastal processes and sedimentary environment along the shoreline near Point Michaud

(**Figs. 1 and 2**). It is composed of highly erosion-resistant bedrock, is approximately 1.2 km long, and has sufficient topography to prevent overwash, even in the most extreme storm conditions.

The island forms a low energy area on its northwest-facing side since it breaks the energy of approaching waves and swells from the south to southeast. These waves and swells also refract around the island, losing energy due to bottom drag effects, and thus allow sediment to accumulate north and northwest of the island. It is close enough to the mainland so that this shadow effect or low energy area extends to the main shoreline. There are also bedrock outcrops between the island and the mainland that contribute to sediment build-up. This sheltering effect, combined with input of sediment from locally eroding drumlins to the west, has aided in creating the tombolo (**Fig. 2**). The tombolo in turn controls to a large extent the sedimentary characteristics of Western Beach and Point Michaud Beach.

Western Beach is sheltered from east and southeast winds by Point Michaud Island and the associated tombolo. The Michaud and La Grosse ledges, 1.5–2 km offshore, attenuate to a small degree deep sea swells approaching from the south and southwest. Isle Madame and Petit De Grat islands, though 15–20 km away, provide limited shelter from west-southwest to westerly winds and swells. Red Point and Bar Cape headlands west of Western Beach provide shelter from westerly winds blowing out of Lennox Passage and St. Peters Bay.

Point Michaud Beach is sheltered from south and southwest winds by Point Michaud Island and the associated tombolo. The Basque Islands and associated ledges located 2.5 km offshore provide limited shelter from southeasterly wind-generated waves and the associated shallow water helps to attenuate approaching deep ocean swells **(Figs.** 2 **and 6)**. The vegetated islands are composed of unconsolidated till in drumlins overlying exposed bedrock. The ledges are supra- and inter-tidal exposed bedrock that was probably overlain by drumlins.

Effects of Bedrock and Sediment Supply on Beach Stability

In a simplistic sense the presence of bedrock outcrop along a coast will typically lead to a more stable and less erodible shoreline. The same is often the case for beaches. If there are outcrops along a beach the rock will often act to reduce longshore transport and thus trap sediment within the beach system. In the case of Point Michaud Beach, there is no bedrock outcrop either within the intertidal zone or exposed along the upper foreshore. On the extreme northeast end of the beach there is a small rock

Figure 6. The Basque Islands, which are the remnants of bedrock-cored drumlins.

headland that serves to trap sediment. There is no outcrop on the southern end of the beach before the outer end of the tombolo between Point Michaud Island and the mainland. As noted previously, Point Michaud Island significantly reduces the energy level and currents on Point Michaud Beach. This allows the accumulation of extensive sand deposits both on and offshore of Point Michaud Beach. This is extremely important for the long-term stability of the beach, as it has no or only limited direct sediment input into the local system. Point Michaud Beach may receive minor amounts of sediment from eroded till that overlies the rock headland on the northeast end of the beach. Instead, three other sources of sediment are believed to sustain Point Michaud Beach.

The first source is trapped sediment eroded from former drumlins that have now been totally or mostly eroded. Examples of mostly eroded drumlins are the small rock-cored remnants of drumlins that exist on the Basque Islands (**Fig. 6**). These drumlin remnants would have been much larger in the past. It is common in Nova Scotia for sediment from eroded drumlins to be trapped between rock headlands. In some instances there is little or no modern sediment input but the beaches are still relatively stable.

On the southwest and southern side of Point Michaud Island thick unconsolidated glacial deposits (drumlins) are exposed to wave action and erosion during major storm events **(Fig. 7).** These deposits are the second source of sediment for Point Michaud Beach. During certain storm conditions some of the sediment may be transported northward onto Western Beach. Much of the fine sediment, however, is

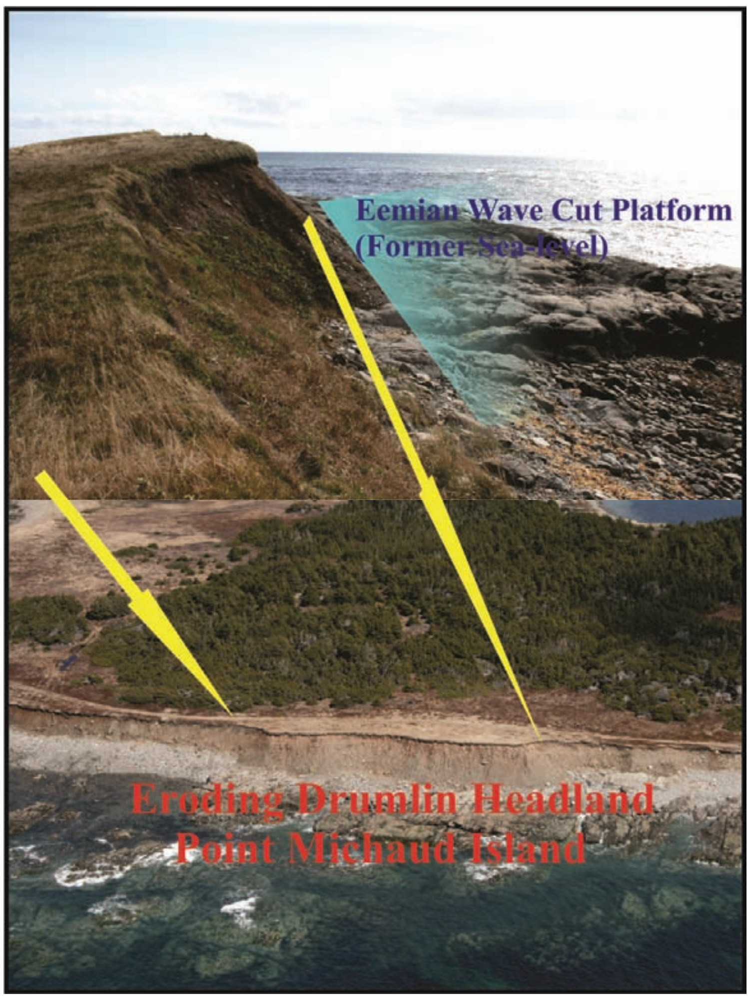

Figure 7. Eroding drumlins on the southwest side of Point Michaud Island.

ultimately transported out around the southern end of Point Michaud Island where it then becomes part of the Point Michaud Beach system.

The third source of sediment is eroding drumlins along the shore west of Western Beach **(Fig. 8)**. The drumlins are composed of boulder- to silt- and clay-sized material, and thus provides a source of both coarse and fine sediment to the local beach environment. Bar Cape and the other headlands provide a large and long-term supply of sediment to the coastal system. At least part, and in the author's opinion probably most, of the sediment is transported eastward to the shoreline and Western Beach. The shoreface between Bar Cape, the other drumlin headlands and Western Beach is composed of much coarser sediment than Point Michaud Beach, with large amounts of cobble to gravel sized material **(Fig. 9).** This is also true of the western half of Western Beach. Moving east along Western Beach toward the tombolo the sediment fines are predominantly sand. This is in contrast with Point Michaud Beach, which along its entire length is predominantly sand and very minor gravel, with only rare cobble sized stone. In a qualitative sense, it does not appear that there is sufficient sand on Western Beach to account for the amount of sand (verses cobbles) that would be eroded from the drumlin headlands to the west. This leaves the question, where is all of the sand sized material? It appears that Western beach is leaking the fine sediment (sand) out around the end of Point Michaud Island where it is then captured within the Point Michaud Beach system. A second explanation is that the sand is being stored in the back beach area of Western Beach.

As mentioned above, Point Michaud Beach, and possibly Western Beach to a more limited degree, has a captive supply of sediment. For maximum stability, however, beaches require active sediment input as most beaches lose sediment to deep water over time. Thus, when considering the stability of a beach on the scale of many decades and centuries it is necessary to consider not just the present sediment supply,

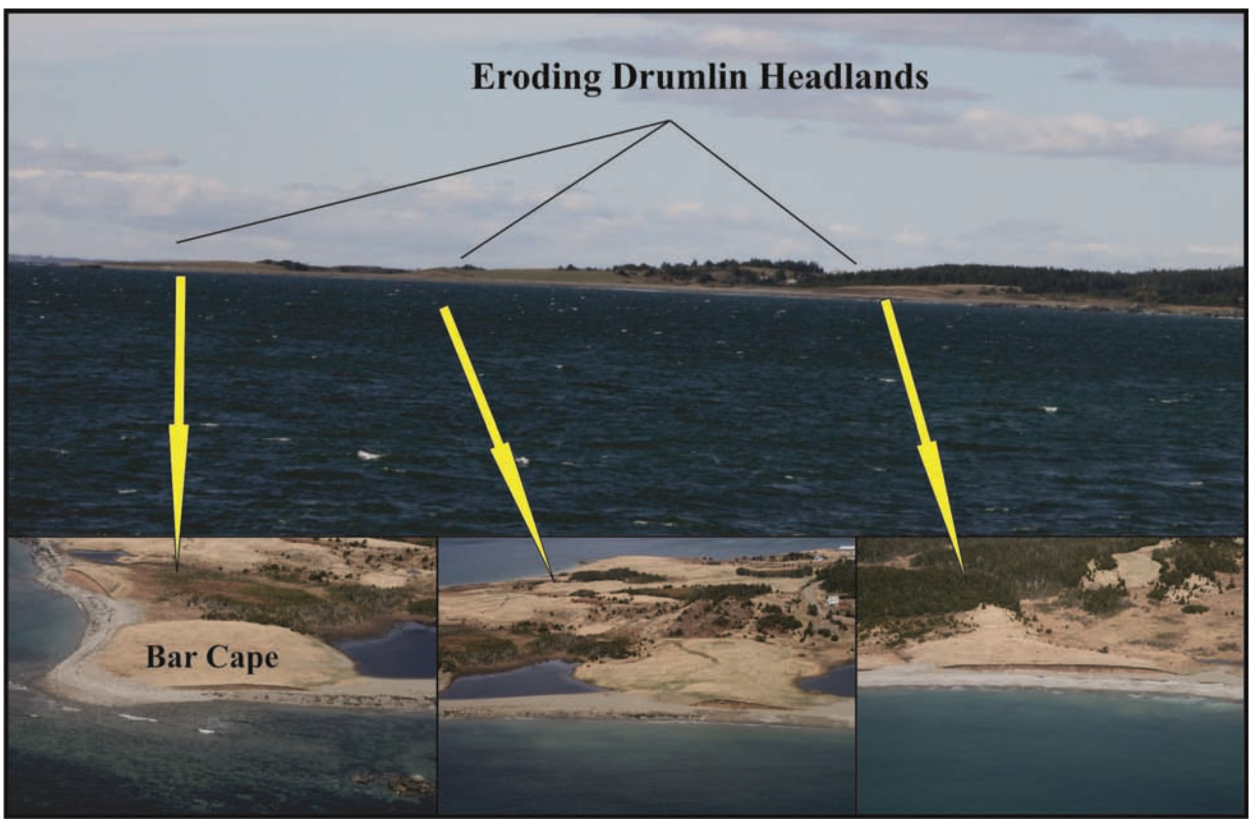

Figure 8. Eroding drumlins along the coast west of Western Beach.

Figure 9. Cobble and gravel on Western Beach, west of Jones Pond (Figure 1).

but also whether there are future sources of sediment once the present source(s) are exhausted. On the southwest and southern side of Point Michaud Island the thickness of the largest eroding drumlin decreases landward (**Fig. 7**). Thus, the time when that drumlin was able to supply the maximum amount of sediment per unit of erosion has passed. In the future the amount of sediment per unit of erosion for this particular drumlin will decrease, and the amount of sediment input to the beach systems will decrease. However, the drumlin is surrounded by fairly thick till so the individual impact will be minimal. In addition, in the author's opinion it will be multiple decades or a century or more before the present sediment supply in the drumlin is exhausted, barring a sudden increase in the local rate of apparent sea-level rise. In addition, it is possible that over time, as erosion progresses landward and sea level rises, additional thick deposits of till will be exposed at the coast for erosion.

In the author's opinion the largest source of sediment to both Western and Point Michaud beaches is from the eroding drumlin headlands west of Western Beach. It is evident that it will take many decades if not centuries to erode the three drumlins shown in **Figure 8**. That is, of course, again barring a sudden increase in the local rate of apparent sea-level rise. However, consider what will happen in the future when the Bar Cape drumlin and the drumlin immediately to the east have undergone further and extensive erosion **(Fig. 10).** In **Figure 10** (left image) the Bar Cape drumlin is approximately two-thirds eroded and the smaller drumlin to the west has been completely eroded. Material will still be actively eroding from the Bar Cape drumlin and a new larger erosion scarp will have formed to the west. The Bar Cape drumlin may now be attached to the mainland by a tombolo, though this is admittedly speculative. The drumlin immediately east of Bar Cape (**Fig. 8**, middle image), will continue to erode landward (**Fig. 10**, right image). An erosion scarp, possibly larger than present will be maintained. The gravel and cobble bay mouth bars (**Fig. 10**) will migrate landward as the drumlins erode. As the bars migrate against higher topography the ponds behind the bars will disappear.

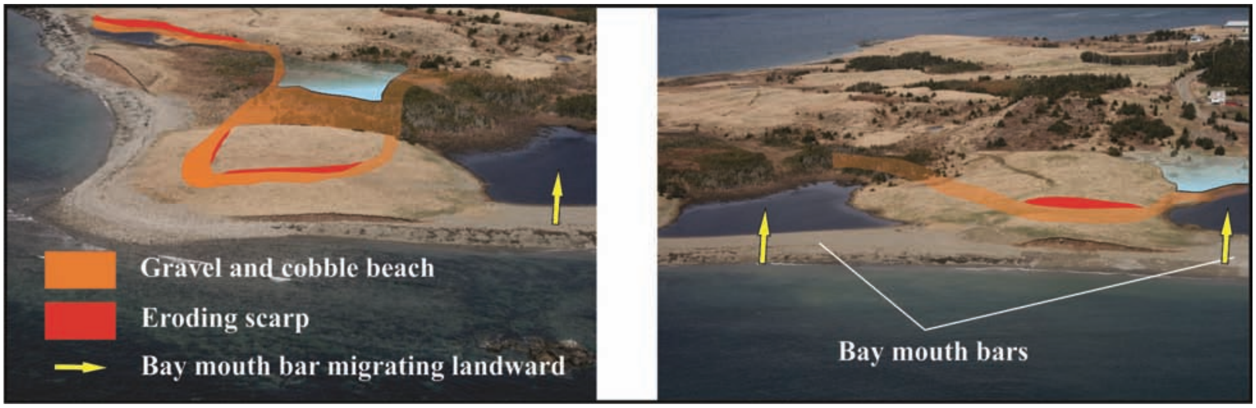

Figure 10. Schematic illustration showing a possible erosion scenario for drumlins west of Western Beach.

Beach Characteristics and Nearshore Coastal Processes

Along the southeast coast of Cape Breton Island, offshore currents are generally stronger during the summer months than during the winter months (Chasse, 2001). The tidal and wind-forced current generally flows in a northeast direction, parallel to the gross northeast orientation of the southeast-facing coast of southern Cape Breton Island (Chasse, 2001). Wind forcing of the current is probably enhanced during the summer due to the prevailing southwest winds (**Fig. 4**). However, in areas where water depth shoals, so that the base of ocean swells and wind-generated waves start to experience bottom drag, then current flow varies from the gross offshore northeast direction of transport. It is beyond the scope of this report to determine nearshore current flow directions. This could be done on a theoretical basis but the currents will vary based on local seafloor topography, coastal orientation and wind direction. Thus, on a scale of tens of metres to a couple of kilometres (i.e. on the scale of individual bays, coves, around headlands, and along different parts of an individual beach), local features control the important coastal processes such as current direct and sedimentary environment. The important point to recognize is that Western Beach and Point Michaud Beach, both located along the same shoreline but separated by only a narrow tombolo, exhibit dramatically different sedimentary characteristics, slopes and shapes.

An idealized beach system consists of four main areas: the (1) foreshore, (2) beach face, (3) berm and (4) back beach **(Fig. 11).** The foreshore is the subtidal area extending offshore to a depth where waves and swells no longer create bottom drag and move sediment. The beach face is the area of beach between normal low and high tide and may undergo significant change over time frames of only a few hours. The slope of the beach face can range from only a few degrees up to around 30º. Located at the landward side of the beach face is the berm. On beaches with a steep beach face and coarse sediment the berm may have a well-defined steep seaward face. On beaches with a low sloping, finer grained sandy beach face the berm is typically less well defined. Behind the berm is the back beach. It varies in width depending on the type of beach, and may not even be present. It may be vegetated or non-vegetated. The back beach merges into dunes (if present) and/or overwash deposits and fans.

Point Michaud Beach

Point Michaud Beach is composed primarily of fine to medium sized sand. As discussed previously it is sheltered from wind and ocean swells by the Basque Islands and Point Michaud Island. This allows large amounts of sand to be trapped in the foreshore area. The slope of the foreshore and the bottom of the beach face is low (< 2º), with the result being that the offshore water depth is greatly reduced and the sand extends well offshore **(Fig. 12).** As a wave approaches Point Michaud Beach, the base of the wave

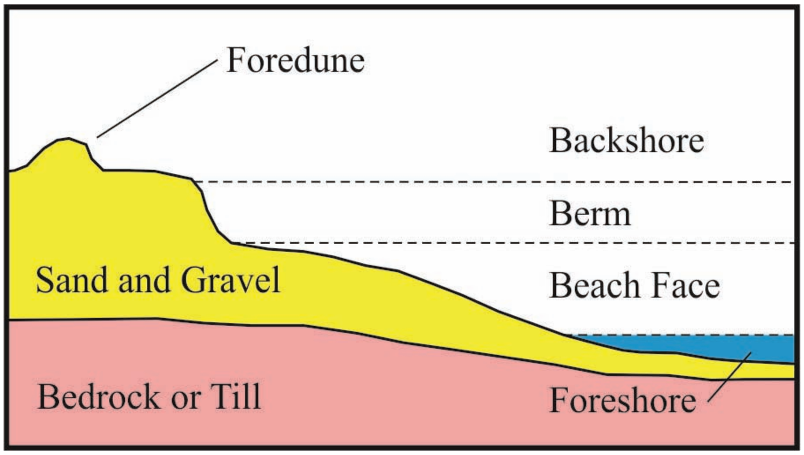

Figure 11. Schematic cross section showing major zones within an idealized beach system.

starts to drag on the bottom and loses energy. When the wave enters shallow water its height increases and the wavelength decreases. Its steepness increases until the wave becomes unstable and it forms a breaker. This happens when the height of a wave (measured from trough to crest) is about 0.78 times the water depth. As the wave breaks it rapidly loses energy. Water depth and the slope of the foreshore strongly influence the form of the impacting wave on a beach. In the case of Point Michaud Beach classic spilling waves (**Fig. 12**) were observed, which are associated with a low angle to almost flat foreshore. The wave breaks offshore by spilling down the front of the wave and much of its energy is dissipated prior to impacting the beach.

Under higher energy conditions waves run up the face of the beach (called swash) carrying with them sediment. The wave then runs back down the beach (called backwash). Since Point Michaud Beach is predominantly sand, the fine particles reduce the amount of water that can percolate down into the beach

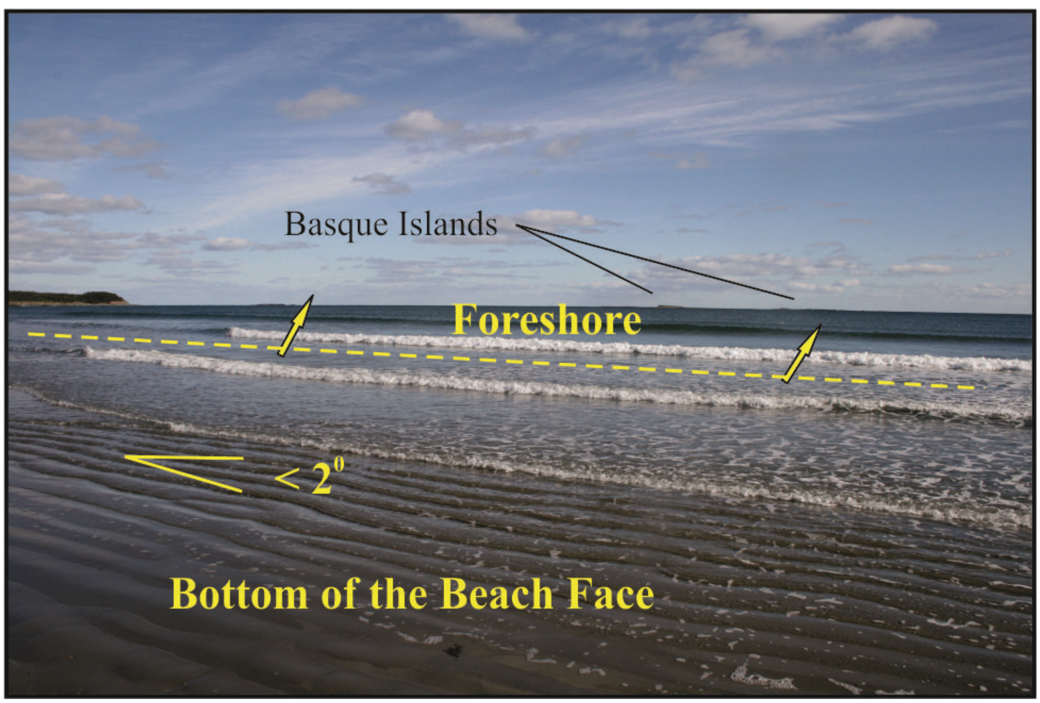

Figure 12. Image looking seaward showing the base of the beach face and the foreshore on Point Michaud Beach.

and when the wave runs back down the beach it is able to carry the sediment (sand) back down the beach face. This creates a beach face with a low slope angle, such as the Point Michaud Beach face with an angle of 3º.

At the top of the beach face a low, poorly defined berm was observed with a slope of approximately 7º. Poorly defined, low angle berms are typical of low angle, wide, sandy beaches. Above the berm, Point Michaud exhibits a wide, low angle backshore. The backshore is extensive and changes from non-vegetated to heavily vegetated, predominantly wind-blown sand. The transition from bare sand to vegetation is abrupt **(Fig. 13).** The vegetation, once established, acts to trap wind-blown sand allowing vertical accretion of the backshore (**Fig. 13**).

In 1990 Hurricane Bertha, with maximum sustained winds (1 minute or longer) of 130 km/h, made landfall approximately 55 km east of the study area near Gabarus Bay. In 2002 Hurricane Gustave, with maximum sustained winds of 148 km/h, made landfall immediately east of the study area.

Point Michaud Beach has a distinct erosion scarp along the landward edge of the backshore **(Fig. 14).** The erosion scarp is cut into what appears to be a foredune along the central and western part of the beach. The age of this erosion scarp is uncertain. As a result of the erosion, a snow fence was erected at the eastern end of the beach along the face of the scarp in the later 1990s. It is possible that a severe winter or spring storm cut the erosion scarp. However, it is the belief of the author that the erosion scarp was formed during the passage of Hurricane Hortense. Hurricane Hortense made landfall east of Halifax

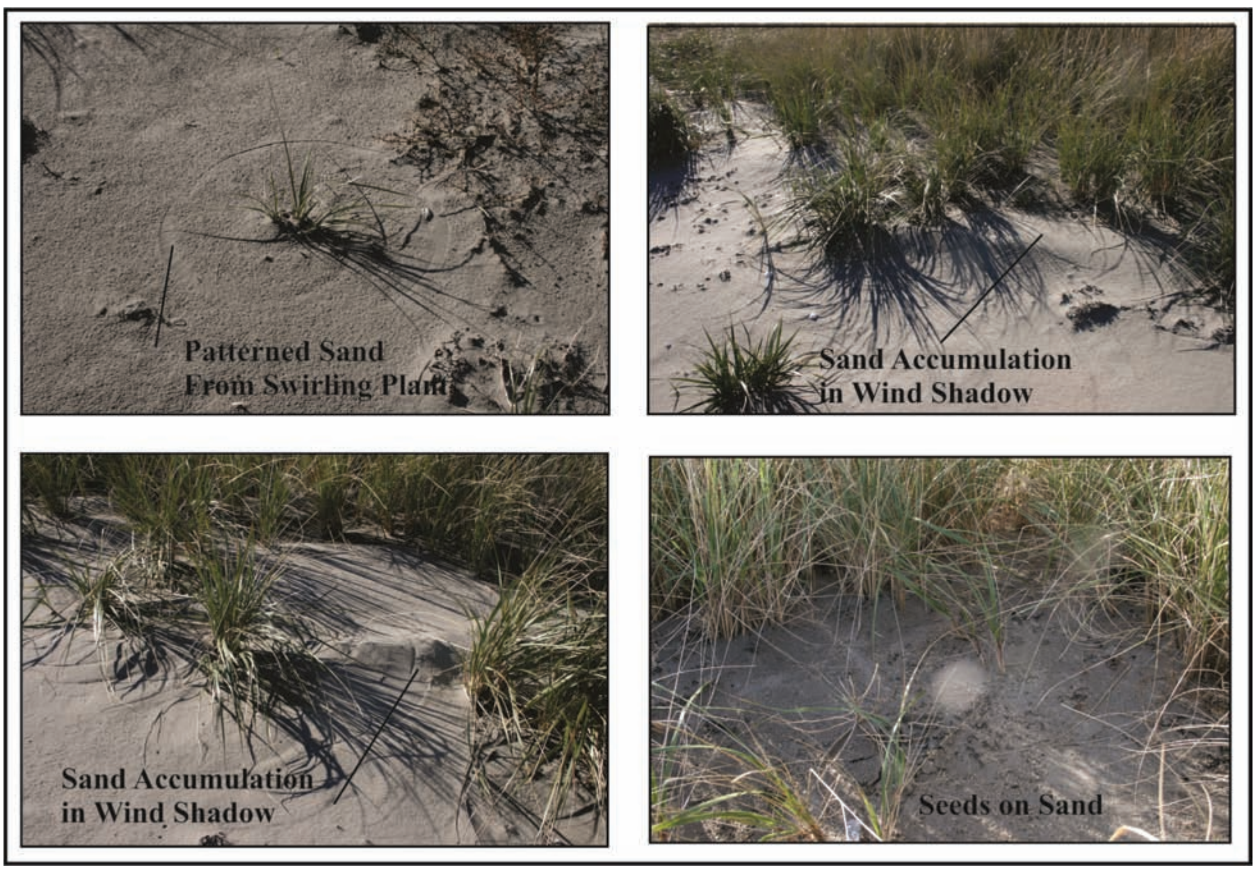

Figure 13. Images show wind-blown sand trapped by vegetation on the back beach area of Point Michaud Beach.

Figure 14. Image shows sediment build up, re-vegetation, and over 14 m of back beach progradation on the seaward side of the former erosion scarp along the central and western part of Point Michaud Beach.

as a Category I hurricane with maximum sustained winds of 130 km/h. The hurricane tracked along the Eastern Shore of mainland Nova Scotia, crossed the Canso Strait and continued a short distance inland parallel to the south–southern coast of Cape Breton Island. If this is what occurred, then it is an excellent example of what commonly happens to an otherwise stable beach when it is subjected to an extreme erosion event.

The fact that a snow fence was installed along the eastern end of the scarp in an attempt to trap sand and prevent further erosion **(Fig. 15)** allows examination of how the beach reacted subsequently to the erosion event. When first examined by the author it appeared that the snow fence had been highly successful with an area of now vegetated sand approximately 8.5 m wide deposited seaward of the snow fence (**Fig. 15**). This represents significant progradation (seaward building of the back beach). However,

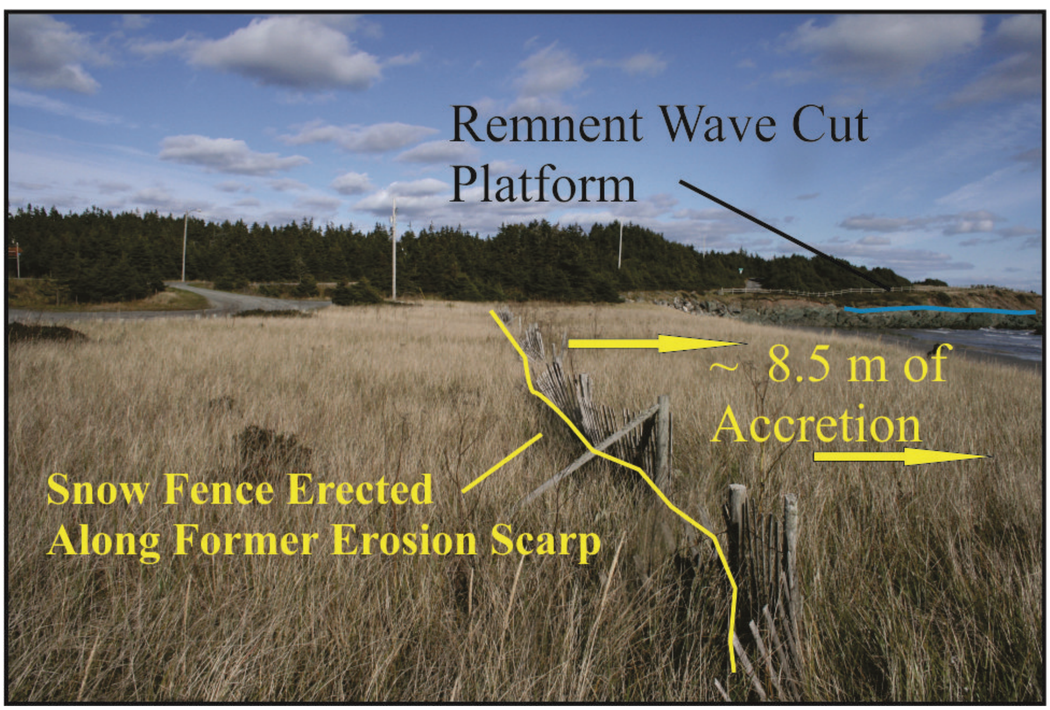

Figure 15. Snow fence erected along the base of a former erosion scarp with subsequent sediment build up and re-vegetation on the seaward side of the snow fence.

upon further examination it was observed that the former scarp, marked by the position of the snow fence, extended to the west along the entire length of the beach. To the west, in front of the scarp where no snow fence was ever present, there was re-vegetation and sand deposition across an area over 14 m wide (**Fig. 14**). That area, when traced eastward, is the same height and merges with the area in front of the snow fence shown in **Figure 15**. The reason that the scarp is still visible along most of the beach is that the backshore area prior to the erosion event was higher than the area landward of the snow fence in **Figure 15**. It is apparent that the snow fence did not actively trap sand and cause the back beach to build seaward. This happened across the entire beach without the presence of the fencing. This is an instance where correlation does not equate to causation, a very common mistake by both scientists and members of the general public.

As discussed above, both the backshore without vegetation and the beach face are very wide. Such a wide area of dry sand typically allows significant wind-blown sand transport. When referring to wind-blown sand transport the author is not referring to sand grains picked up by the wind (suspended) and blown a significant distance. Rather the sand is rolled along the surface of the beach (creep), or briefly and repeatedly lifted and then dropped by the wind. The sand grain repeats this motion and saltates (bounces) along the beach.

Wind-blown sand transport on a beach such as Point Michaud typically results in the formation of a significant dune system in the back beach area, but in this case such a system is mostly lacking. In its place is the paleo-scarped foredune. Its elevation varies along Point Michaud Beach, being generally higher in the central part of the beach. It is possible that there is sufficient near-surface groundwater, precipitation, and resulting vegetation that sand transported landward is trapped and forms a foredune ridge, rather than a dune system behind the foredune. Further, it is unknown how much of the foredune was eroded by Hurricane Hortense. During the late spring, summer and early fall the beach is sheltered from the prevailing southwest wind by Port Michaud Island and the connecting tombolo. This would also limit sand transport. Another factor that can limit sand transport may be the possible presence of sand (or a fraction of the total sand) that is too coarse to be transported easily by the wind. As the wind blows it transports finer sand on the surface of the beach landward. However, the coarser sand remains, creating a lag or cover on the surface, preventing the wind from reaching the finer sand below and limiting wind-blown sand transport, as described by van der Wal (1998).

The recovery of Point Michaud Beach after a period of erosion or a major erosive event emphasizes the long-term stability of the beach system. The extensive, low angle foreshore limits the size of waves impacting the beach. The low slope of the beach face allows wave energy to dissipate rather than erode the beach and the wide vegetated backshore holds the sand in place and also dissipates wave energy under major storm conditions. It is likely that the back beach will continue to trap sand, build upward and possibly seaward. Without a change in the overall beach system it is the author’s opinion that that the beach will remain stable over a period of several decades, even with a long-term rise in sea level. However, natural systems often respond to small changes in one part of a system with large changes in the overall system. Such systems are referred to as being chaotic and such chaotic systems are very difficult to predict or model over longer periods of time (e.g. beyond a decade or two).

Western Beach

Western Beach is not sheltered from winds and swells approaching from the south to west. Because of the high energy conditions large amounts of fine sediment are suspended and transported offshore around the end of Port Michaud Island. As an example, southwest winds impacting Western Beach and the west side of Point Michaud Island would create two opposing currents: one flowing north and northwest along the west side of Point Michaud Island and the west side of the tombolo, and a second flowing east along the face of Western Beach. Where the two currents meet water would build up creating an offshore-flowing rip tide. The rip tide carries the sand offshore where the northeast-flowing current carries the sediment past the outer end of Point Michaud Island. Since there is less sand stored in the foreshore, the result is deeper water in the foreshore area seaward of the main beach face. This allows larger, higher energy waves to impact the beach face, eroding the finer sediment and leaving gravel and cobbles (**Fig. 9**). As the larger waves hit and run up the beach face, material is transported landward. However, in the backwash, because of the coarse nature of the sediment on the beach, the water rapidly drains downward into the beach. This limits the amount of water and sediment transported back down the beach by the backwash. In turn this creates the steep slope of the central and western end of Western Beach. These types of conditions also favor formation of larger, steeper storm ridges or berms (**Fig. 9**).

Moving from west to east along Western Beach the sheltering effect of Point Michaud Island increases (**Figs. 1 and 2**), creating a lower energy environment at the beach's eastern end. Here the sediment is finer but is still dominated by gravel and cobbles **(Fig. 16, left image).** There is a low elevation erosion scarp in the back beach and a lower, less well defined berm or storm ridge. In addition, higher energy, coarse-grained beaches with a steeper beach face favor the formation of beach cusps or scallops (**Fig. 16**, left and **Fig. 17**). Overall Western Beach is stable or prograding seaward, though there are areas of transient erosion, particularly in the central part of the beach **(Fig. 18).** However, moving east along the beach conditions start to appear similar to Point Michaud Beach **(Fig. 16**, right). Here a well-developed back beach is present. At the seaward edge of the back beach vegetation consists of pioneering species. A pioneering species is a species that is first to establish itself in an area where nothing is growing. Landward is the area labelled as a successional species zone. The author recognizes that not being a biologist this may not be strictly accurate. The author is not able to identify the main plant species in this zone. However, based on past experience the main plant species are likely to be either sand couch (a pioneer species) or marram grass. Regardless, plants are trapping wind-blown sand and are causing the back beach to build up in front of a former, now completely vegetated and abandoned, erosion scarp (**Fig. 16**, right). The abandoned and revegetated erosion scarp is interpreted to be the same age as the revegetated and abandoned erosion scarp on Point Michaud Beach because of their physical similarity and apparent continuity, being separated only by the tombolo.

The back beach area of Western Beach, behind the erosion scarp, is a high wide foredune **(Fig. 19)**. It is now completely vegetated with young softwoods, identified as white spruce by the local NSDNR forest

Figure 16. (Left) Poorly defined erosion scarp fronted by a low berm. Beach scallops characteristic of a coarse gravel and sand beach. (Right) A former erosion scarp now fronted by an aggrading back beach vegetated with successional and pioneering species.

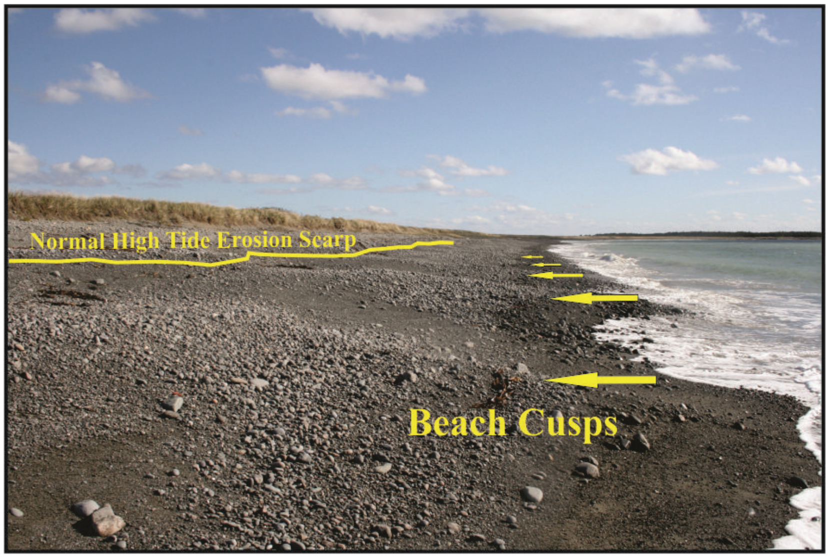

Figure 17. A well-defined berm (storm ridge) fronted by well-formed beach cusps on the middle of the beach face.

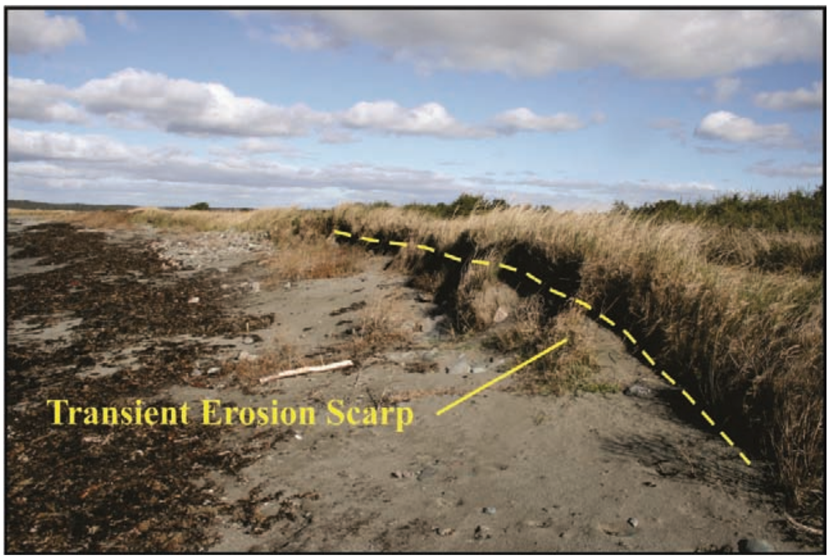

Figure 18. Erosion at the face of the foredune is atypical of Western Beach.

technician from the St. Peter's office, Mark Vanderhoeden. The foredune has a significant upward slope from the backing ponds seaward to the paleo-erosion scarp (**Fig. 19**). This indicates that the former position of Western Beach was landward of its present position, certainly where the seaward side of the pond is presently located, and that over time the beach has prograded or built seaward. When it was located near the pond, sea level would have been significantly lower than it is today. In response to an ample sediment supply, possibly even an increase in sediment supply, the beach prograded, but at the same time that sea level was rising. The beach responded to increasing sea level by growing upward (**Fig. 18**). Within the main pond backing Western Beach there are several ridges of sediment that are parallel to the present foredune backing Western Beach **(Fig. 20).** The author feels that these ridges also represent former positions of the top of the back beach or possibly foredune at a time of lower sea level. Along with sand transported eastward around the end of Point Michaud Island, this large prograding foredune represents a major sediment sink and storage area of sediment eroded from drumlin headlands west of Western Beach.

Figure 19. An increase in the height of the foredune from landward to seaward is typical of a prograding beach under conditions of rising sea level.

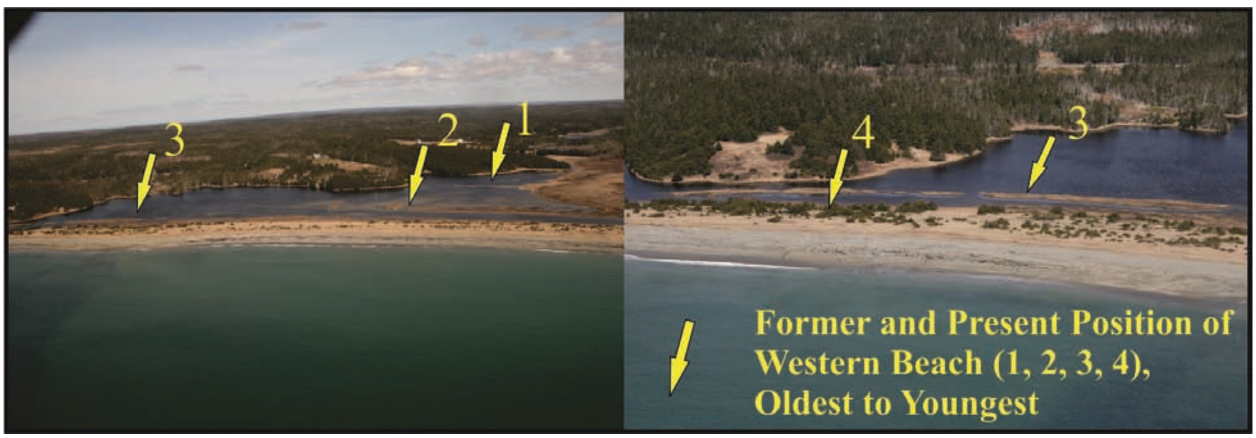

Figure 20. Sediment ridges in the backing pond parallel to the present foredune probably represent former positions of the fordune over the last approximately 1000 years.

What this succession of beach ridges indicates is that beaches along with their associated ecosystems do not necessarily erode and collapse in response to sea level rise. Beaches may remain stable in the face of sea level rise for long periods of time. Ultimately however, as has happened over the last 18,500 years since deglaciation, and the following 100-120 m of apparent sea level rise, beaches will ultimately migrate landward, possibly disappear and/or reform in different areas as the overall shape of the coastline changes with time due to variations in the shape and resistance to erosion of the underlying bedrock.

Two other features on Western Beach caught the attention of the author. First was a mechanism that the author will refer to as 'bio-transport' **(Fig. 21).** In this instance cobble sized rocks are found in the foreshore region of Western Beach. Over time kelp attaches to and grows on the cobbles or anchor stones. At first the kelp is too small to move the cobble, thus the use of the term anchor stone. The kelp, however, is buoyant and also creates resistance as water moves past the plant. Once the kelp becomes large enough the result is that the cobble is lifted and dragged. When the kelp grows large enough a threshold is reached where under storm conditions the cobble and accompanying kelp is transported onto

Figure 21. Pieces of kelp growing on individual cobble sized clasts or 'anchor stones'.

the beach face. As can be seen in **Figure 21**, the beach face is composed of gravel representing in general the size of material that is transported and deposited on the beach face under the present energy conditions. However, by reducing the amount of wave energy required to move the cobble, the cobble's effective weight/size is reduced allowing it to be transported onto the beach where energy levels are only sufficient to transport and deposit gravel. What happens to the cobbles once on the beach is speculative. They may be transported back offshore, or the cobbles may be buried by gravel (the kelp would die and rot away) and become part of the beach face. As can be seen in **Figure 21**, significant numbers of cobbles are transported onshore. This process is not restricted completely to Western Beach. A few cobbles were noted on Point Michaud Beach that had been transported onshore in the same manner.

The second feature was the presence on the back beach, along the seaward side of vegetation, of conical piles of sand with a hole in the center **(Fig. 22).** The author has noted beetles emerging from similar burrows on other beaches after dark.

Sea-level Rise and Glaciation

Background

As mentioned previously, sea level along the coast of Nova Scotia has been rising since the start of deglaciation or melting of the Wisconsin Ice Sheet, approximately 18,500 years ago. The total rise of the ocean relative to the land is estimated at being between 100 and 120 m. Prior to the Wisconsin Glacial Period, during the Sangamon Interglacial, temperatures varied from warmer to cooler than present. In a recently drilled ice core in Greenland, data indicate that during the period between approximately 130,000 to 115,000 years ago local temperatures in Greenland were up to 8°C warmer than present (Neem, 2013). Over a 10,000 to 15,000 year period 25% of the Greenland ice sheet in that area melted and global sea level rose by an estimated 5-7 m above present sea level (Neem, 2013). Colville et al. (2011) had similar results, estimating that Greenland during the last interglacial contributed 1.6 to 2.2 m to the sea-level high stand of greater or equal to 4 m. Antarctica was estimated to have contributed greater than 1 m and the remainder of the global sea-level rise (above present level) was contributed by thermal expansion of the oceans.

Figure 22. Biologically produced sedimentary features on Western Beach.

Evidence of the Eemian Sea-level High Stand at Point Michaud and the Later Wisconsin Glaciation

Examinations of modern beaches show that as wave action slowly erodes a beach face and foreshore, bedrock (where present) is eroded, creating a flat (parallel to the beach), seaward-sloping rock platform **(Fig. 23).** Such platforms extend seaward below low tide and may extend significant distances offshore. Similar wave cut platforms are also found within the geological record as evidence of former sea levels. An example of the 130,000 to 115,000 year old Eemian wave cut platform is shown in the inset on Figure 23.

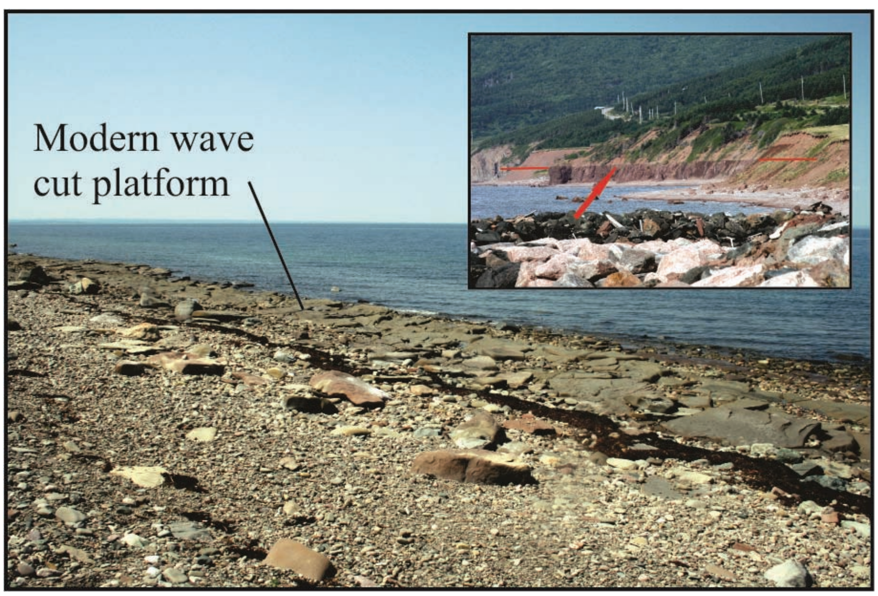

Figure 23. Image shows a modern example of a wave cut platform south of Judique and north of Long Point, Inverness County, Cape Breton Island. The inset shows a well preserved, Eemian wave cut platform between Neils Harbour and Ingonish, Victoria County, Cape Breton Island.

A similar Eemian wave-cut platform is also found on the southwest side of Point Michaud Island **(Fig. 24).** In this specific area the numerous rounded depressions in the bedrock are interpreted as potholes, a feature that is common on exposed bedrock near the bottom of the beach face and extending seaward below low tide in the foreshore on modern beaches. The wave cut platform is also found on the south and east sides of Point Michaud Island and cut in bedrock at the eastern end of Point Michaud Beach. The wave-cut platform can be traced along the southern coast of Cape Breton Island. It extends west from Point Michaud Island to the western side of the Strait of Canso and east from Point Michaud Island to the Louisbourg area (Grant, 1994).

It is important to recognize that the wave-cut platform doesn't necessarily represent the highest or the most landward extent of the Eemian ocean. Rather it is more likely to represent the low tide or offshore extent of the erosive wave base. To determine the actual landward extent of the Eemian ocean at Point Michaud, one would need to be able to find the most landward (highest) point of the wave-cut platform and also the extent of beach sediment preserved on top of the Eemian platform. The highest point of the platform might be found on Point Michaud Island, particularly if some excavation was undertaken. The most landward extent is also controlled by the height of bedrock inland of Point Michaud and Western Beach. It doesn't depend on the height of the existing land, since many of the high areas are drumlins composed of till (glacial sediment) that was deposited over bedrock during the later Wisconsin glaciation (in the range of 40,000 to 18,500 years before present). This is illustrated in **Figure 24**, where a drumlin is deposited on top of the Eemian wave-cut platform, thus hiding the landward extent of the platform except along the coast where erosion has exposed the platform.

Readers might assume that during a glaciation ice simply builds up over the land and flows in one direction. This is not the case and the ice typically flows in several different directions over time. As a glacier slides across bedrock rocks are frozen into the ice. As the rocks are dragged across underlying

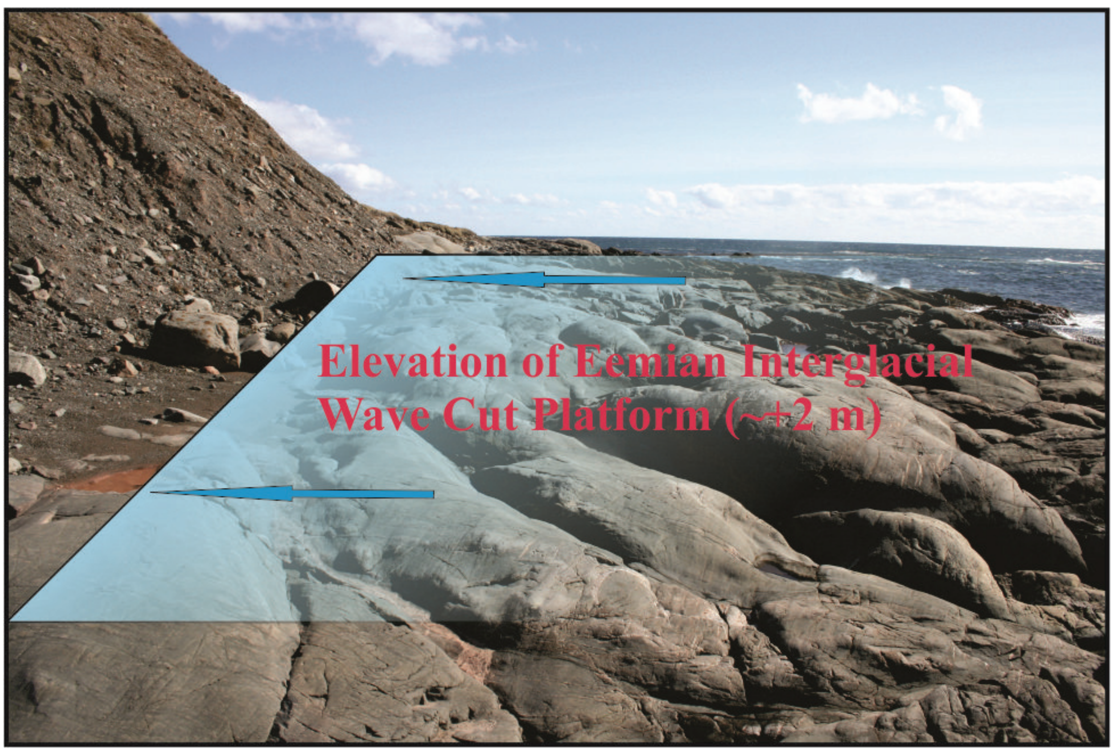

Figure 24. An Eemian wave cut platform (illustrated by blue semitransparent surface) on Point Michaud Island.

bedrock they act as tools cutting grooves into the bedrock. These grooves and/or scratches are called glacial striations and are formed parallel to the direction of ice flow at the time of formation. Striations are commonly found on bedrock with different orientations, indicating different directions of ice flow at different times. Not all directions of ice flow are shown in an individual location. The formation of striations depends on a complex set of conditions under and within the ice sheet that may (or may not) result in formation of striations. In addition, older striations may be completely eroded by younger striations or ice flow.

Figure 25 shows two different sets of striations carved into the bedrock surface at Point Michaud Island, which is also the surface that represents the Eemian wave cut platform (**Figs. 7, 14 and 24**). In **Figure 25** (left) the bedrock has been shaped by glacial erosion, creating a shallow slope facing toward the advancing ice (the stoss) and a steep slope facing the down-ice direction (the lee). Striations on the bedrock are oriented 140^0 – 320^0, and based on the stoss-lee relationship they indicate that the ice was flowing generally toward the southeast. In **Figure 25** (right), two different sets of striations are shown on the same outcrop. The striations that indicate ice flow toward the southeast (i.e. 140^0) are cut into bedrock that is stained and dark. The striations that indicate ice flow toward the east (i.e. 85^0) are cut into bedrock that has a much fresher, lighter appearance. This staining relationship, plus several other factors not discussed here, indicates that the ice flow toward the southeast is older than the ice flow toward the east.

Future Changes and Conclusions

It is apparent that both Point Michaud and Western Beaches are stable and appear to have prograded seaward despite rising sea level. The closest tide gauge is located at North Sydney and it shows net sea level rising at a rate of 29.2 cm/century over the last 35 years (**Fig. 26**). It is the author's opinion that, though there may be fluctuations in this stability in response to major storm events, overall the two beach systems are likely to remain stable on a time scale of years to possibly several decades. However, there are many factors that influence stability of a beach system (more than discussed in this report). A change in any one factor can have a cascade effect that dramatically alters other factors, which in turn can dramatically increase or decrease stability. This is typical of chaotic, non–linear systems, examples being weather or climate, that are difficult to predict on scales of weeks to years. Readers should recognize that predicting the future is easy; being right is the hard part.

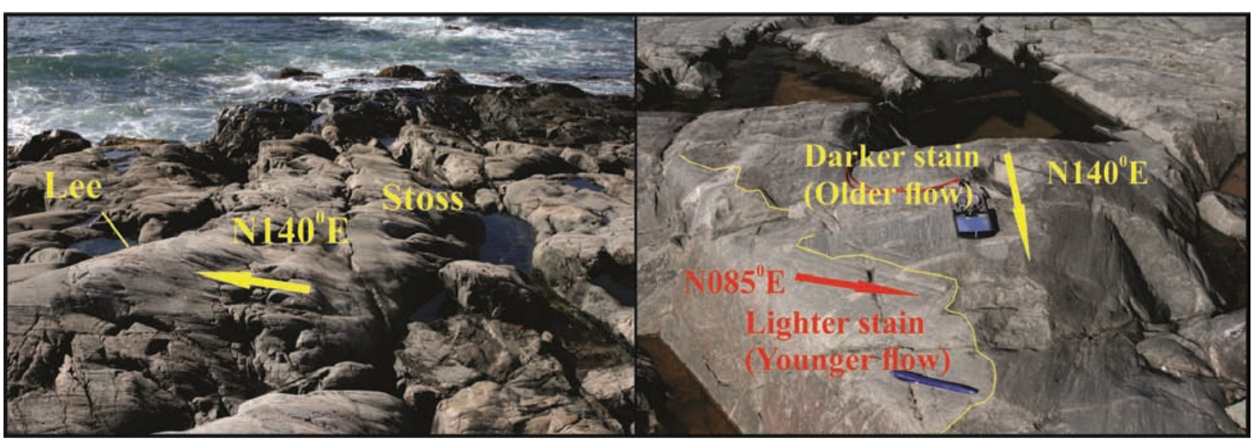

Figure 25. Glacial striations indicating the directions of ice flow during the last Wisconsin Glacial Period at Point Michaud.

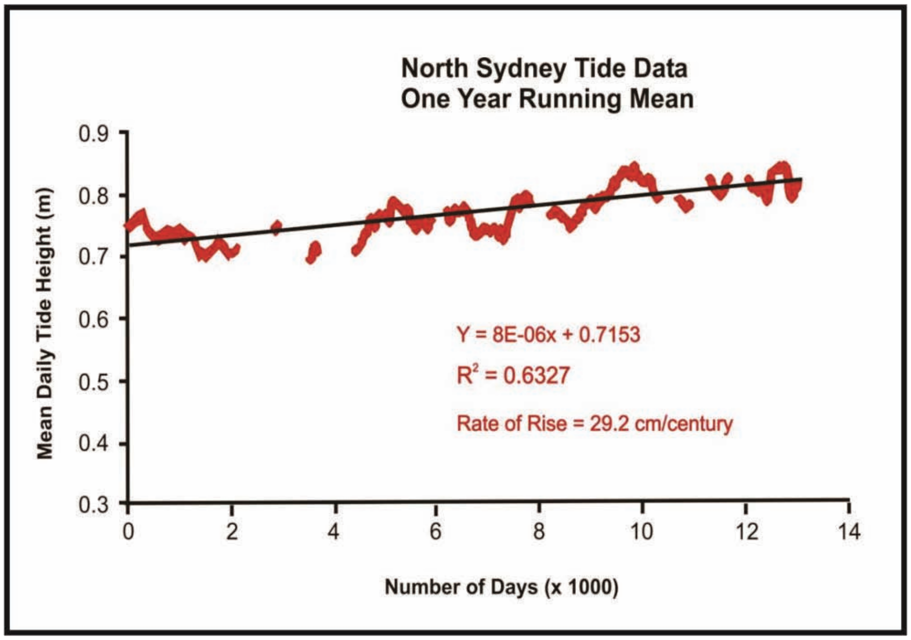

Figure 26. Sea-level rise measured by the Canadian Hydrographic tide gauge at North Sydney, Cape Breton Island, 1975 - 2010.

The long term, continued sheltering effect of Point Michaud Island is the easiest and most reliable factor to predict. The island can be considered as one island, or alternatively it can be considered as two separate islands connected by two bars and intertidal bedrock ridges. Regardless, the island is composed of high and resistant bedrock. It will not erode quickly. Due to its height it will also not be submerged quickly by rising sea level, whether that is the 29.2 cm/century present rate or a rise of 1 m or more by 2100, as suggested in various global sea-level rise models. Over time the sediment being supplied to the beach system from the drumlins on the western side of Point Michaud Island may disappear. However, the actual sediment input from these drumlins is in the author’s opinion less important than sediment eroded from drumlins to the west of Western Beach.

As sea level rises over time the sheltering effect of offshore islands and shoals will gradually decrease. Likewise sediment supply from areas such as the Basque Islands will disappear over several decades as the drumlins overlying bedrock on several of the islands are gradually eroded. However, these islands are well offshore and the loss of sediment and the much longer term decrease in their sheltering effect will not affect the stability of Point Michaud or Western Beach.

An increase in the size and frequency of land falling tropical cyclones would likely increase erosion rates at least temporarily, but over time the beaches could recover. However, there is no evidence that there has been an increase in the size or frequency of land falling tropical cyclones in Nova Scotia. In fact the opposite is the case, as discussed previously in this report. Whether tropical cyclones and typhoons will increase in frequency or size in the future is uncertain. It is suggested in the scientific literature that even if there is a long-term variation in the frequency and/or strength of such events it will be many centuries if not longer before a clear pattern is discernable given the large natural and cyclical variation in the frequency and strength of tropical cyclones.

Breaching of the tombolo or double tombolo that connects Point Michaud Island to the mainland (**Figs. 1 and 2**) has the greatest potential to rapidly and dramatically impact the stability of both Western and Point Michaud beaches. However, the main tombolos are wide, relatively high on the western side, stable, and actually connect to the eastern part of Point Michaud Island(s). Point Michaud Island comprises two bedrock highs connected by low bedrock outcrops (often intertidal) and two bars (**Fig. 2**, top right). It is this area that will see the first breaching.

The outermost or southeastward-facing bar is high, composed of cobbles, and is stable. It may move landward toward the northwest but is unlikely to breach. On the other hand, the inner northwest bar connecting the two parts of Point Michaud Island (**Fig. 2**, top right) is low and narrow. In one area it was observed that above high tide, between the beach and the backing pond, there are only a few metres left of eroding material. It is only a matter of time before a large storm or hurricane washes through into the fresh or brackish pond. Due to the orientation of the bars it is unlikely that the pond will fill to a sufficient height to breach the southeast facing bar ‘from the inside out’. At this point the pond could become an intertidal lagoon. Alternatively, the small breach could be subsequently infilled by sand and cobbles. Regardless, it is unlikely, though not out of the question, that this event would cause instability in the main tombolo.

It is the author’s opinion that the main tombolo or double tombolo is unlikely to breach in the next several decades. This is because sediment supply, transported from the west onto Western Beach and the western side of the tombolo, is likely to be maintained over the time scale of many decades, possibly centuries. However, energy levels may vary over time on Western Beach and the western side of the tombolo as its position relative to the eroding shoreline to the west evolves. The Western Beach area may continue to prograde seaward and build upward in response to high sediment supply and rising sea level. However, as the drumlins to the west erode landward, and sea level continues to rise, there will come a point where the beach will likely either be over-washed and or will erode. This would correspond with erosion of the western side of the tombolo. At some point the most likely scenario is the occurrence of a hurricane with a large accompanying storm surge (or possibly a large southeaster), that breaches the main tombolo. Since much of the tombolo appears to be sand it could erode or be cut by a large channel very quickly. The channel might naturally heal, but ultimately the tombolo would again breach and the area would become a series of mainly intertidal and subtidal bedrock shoals. At this point sediment from Western Beach would be transported by longshore drift directly onto Point Michaud Beach. The result would be that Point Michaud Beach, whatever its form at that time, if still a sand beach would come to quickly resemble the present Western Beach.

This is one scenario for the future evolution of Western and Point Michaud beaches. I do not personally expect this scenario, if correct, to occur for many decades, possibly centuries. However, such events can occur quickly in response to an extreme event. For planning purposes, I anticipate that the beach system will remain stable, possibly eroding and then rebuilding in response to major storms, on a time scale of several decades.

Acknowledgment

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