Geological Observations Relating to Coastal Erosion along the Tidnish - Amherst Shore Area of Nova Scotia

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Background

Nova Scotia's coastline is approximately 7500 km long. The province is bordered to the north by the Gulf of St. Lawrence, to the east and south by the Atlantic Ocean, and to the west by the Bay of Fundy. It is connected to New Brunswick across the 25 km wide Chignecto Isthmus.

Nova Scotia is the second smallest province in Canada with a population of less than 940,000. A large proportion of the province's population live near the coast. Many industries are directly or indirectly dependent on the province's proximity to the ocean. Tourism and leisure activities, and our historic maritime traditions depend on access to the coast. Weather patterns and climate are also strongly influenced by proximity to the ocean and interactions of the cold Labrador Current and the warm Gulf Stream. These interactions mute the normal effects of latitude and elevation on climate.

Changes in the physical and biological environment of Nova Scotia's coastal areas due to a net rise in sea level have direct impacts on the welfare of the people of the province. It is important, therefore, to recognize and understand these changes. Examples of these impacts include flooding, coastal erosion and retreat, changing floral and faunal distributions, and destruction of coastal infrastructure. Jurisdictions across Canada and the United States have undertaken both regional and targeted coastal study programs. One specific example is a study on *Impacts of sea-level rise and climate change on the coastal zone of southeastern New Brunswick* (Environment Canada, 2006), with research compiled and conducted by a multi-disciplinary group of scientists representing several federal and provincial agencies.

Geologists working for the Nova Scotia Department of Natural Resources (DNR) have the expertise to address many aspects of coastal change, such as geological factors affecting rates of erosion, geological responses to rising and falling sea-level, coastline migration and sediment movement. Previous research undertaken by various levels of government and universities provides historical data relating to these processes, which can assist in predicting the magnitude and effects of future coastal changes.

Because of the importance of this issue DNR has assigned staff and is undertaking a new Coastal Mapping Project as part of a larger Environmental Geology Program. The project has a broad mandate to undertake specific studies, both on a regional and local scale, that relate to Nova Scotia's changing coastline. This will include examining causative factors and mapping examples of present day coastal erosion and migration. Compilation and examination of historical sea-level changes, driven by factors such as glaciation and related climate change, are relevant to future sea-levels as the past is the key to the present and the future. The effects of armouring on the coastal environment (both short term and long term) are important as human infrastructure is 'hardened' to prevent or slow erosion. The project mandate includes building upon existing expertise in DNR and providing sound scientific information on these topics to other government agencies, interest groups and the general public.

Historical Context

Marine coastlines are areas where energy transferred from waves to the shoreline does work in the form of erosion and movement of sediment. The coastal zone is typically a rapidly changing and diverse geological environment; not only when viewed from the perspective of geological time but also in the order of recorded history. In areas where the net change in sea level and land level (eustatic

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and isostatic uplift) is zero, coastal change will be muted. Modern coastlines, however, are generally superimposed upon and have transgressed older shorelines produced during earlier interglacial periods.

The coastline of Nova Scotia, like many other coastal areas in the world, is a dynamic environment where post-glacial sea-level rise is a controlling factor in erosion and sediment transport. Over the last several hundred thousand years, worldwide sea level has fluctuated dramatically due to repeated continental scale glaciation and de-glaciation. As an example, on Cape Breton Island Grant (1994) mapped tilted and faulted wave cut benches formed during an earlier interglacial period exposed at elevations typically ranging from 1 m to 7 m above present sea level (Fig. 1). At the onset of de-glaciation during the Late Wisconsin, approximately 18 000 years ago, sea level was greater than 100 m below its present position (Dyke and Prest, 1987; King and Fader, 1986). Most of the continental shelf south of Nova Scotia was dry land as large quantities of fresh water were contained in the predominantly terrestrial-based glaciers.

During deglaciation large quantities of meltwater flooded back into the oceans and eustatic sea level rose rapidly. As ice melted the earth's crust, depressed by the weight of glaciers, acted elastically. Regional isostatic uplift was rapid and in part contemporaneous with deglaciation, then decreased and in most areas of Nova Scotia became regional subsidence. Over the last several thousand years rising ocean levels, coupled with rising and/or sinking areas of coastline, have resulted in the net present rate of submergence of between 2.5-4.5 mm/year (25-45 cm/100 years) across most of the Atlantic Provinces (Grant, 1994). This relative rise in sea level is well documented by the dating of submerged peat, wood, paleo-strandlines and

Figure 1. Exposure of a wave cut bench on Cape Breton Island.

marine-terrestrial transitions in sediment cores. The net result of world wide sea level rise, localized rebound of continental crust due to glacial unloading, and secondary crustal subsidence due to migration of the glacial forebulge, has determined the position and physical make-up of our coastline today. The coastline has changed, is changing, and will continue to change or 'evolve' in a geologically systematic manner.

Project Area

A section of coastline along the Northumberland Strait from Tidnish Dock Provincial Park east to Amherst Shore was chosen for initial examination (Fig. 2). This coastal segment was selected because most areas along the Northumberland Strait and the Bay of Fundy shore historically report large rates of erosion with resulting property loss and infrastructure damage. In addition, the availability of the Environment Canada (2006) report *Impacts of sea-level rise and climate change on the coastal zone of southeastern New Brunswick* will provide detailed relevant information as that study area is very close and within the same geological environment as the Amherst Shore.

Information on rates of erosion, factors affecting coastal erosion, an examination of the effectiveness of various erosion prevention structures (see Finck, this volume), and the effects on the local coastal physical environment are some of the many attributes examined. In addition, DNR's Library has a province-wide air photograph collection spanning 70 to 80 years. Using this image dataset successive coastline positions can theoretically be mapped over historical increments of approximately 10 years, given sufficient erosion and adequate geo-referencing.

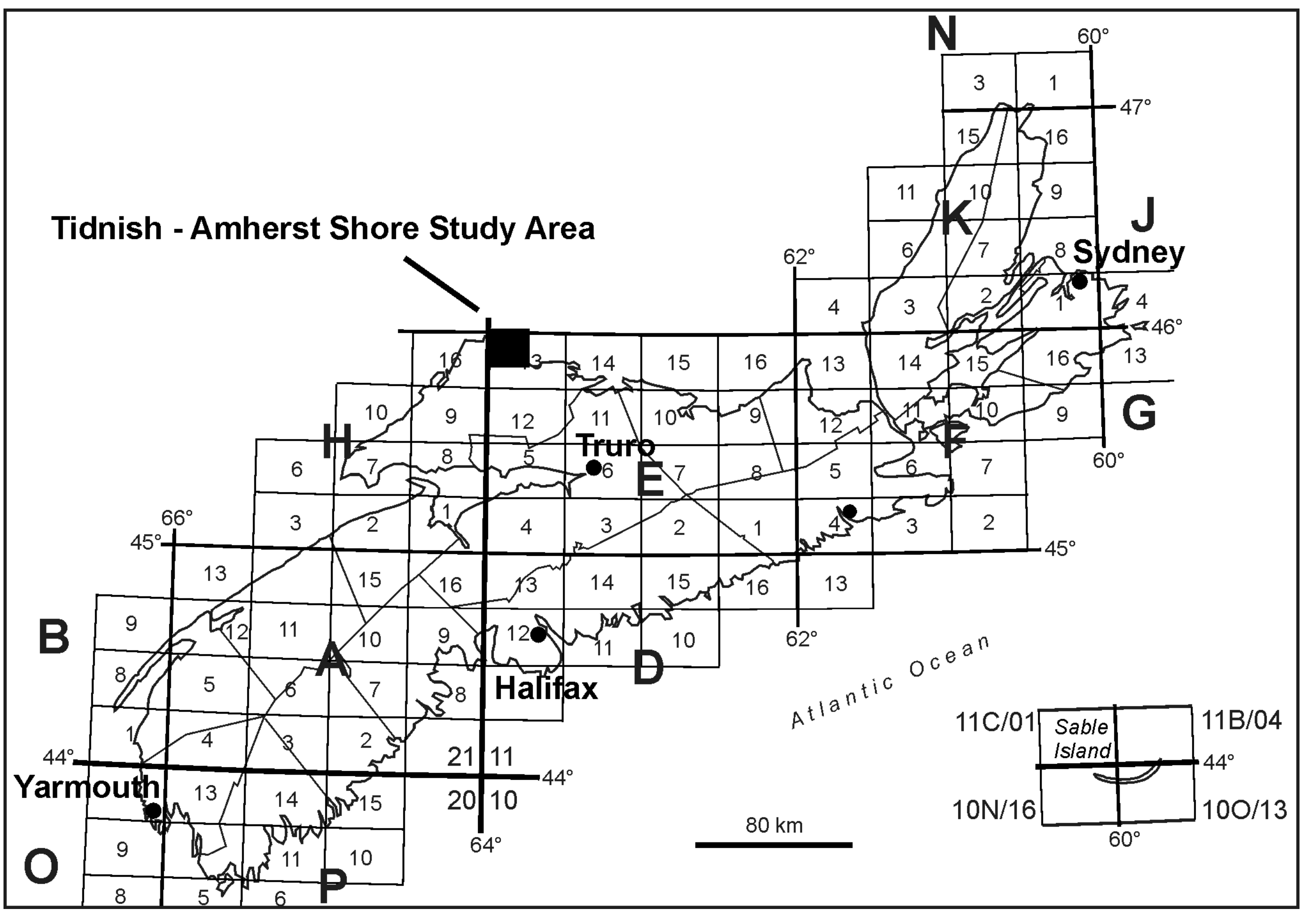

Figure 2. Map shows the location of the study area along the Tidnish - Amherst Shore area, northern Nova Scotia.

Bedrock and Surficial Geology

Bedrock Geology

The author refers to Ryan and Boehner (1994) for the following summary of bedrock geology in the study area. Rocks in the study area are mapped as the Balfron and Tatamagouche formations, forming part of the Pictou Group. From Tidnish Head to the east end of Amherst Shore Beach (approximately 500 m west of Boss Point) the author observed red-brown sandstone of the Balfron Formation outcropping at mid- to low-tide. The outcrops form a gently seaward-sloping bench that appears to be transitional to a wave cut platform below lowest low water within the surf zone (Fig. 3). The sandstone does not appear to outcrop in the cliff face. Sandstone outcrops across the intertidal bench are soft and the rock erodes as layers (on a cm scale), controlled by what appears to be trough crossbedding consistent with northward-trending trough axis-intersection directions mapped by Ryan *et al.* (1990). At the east end of Amherst Shore Beach steep cliffs were observed (vertical in some areas) composed of what is believed to be red-brown mudrock and mud-chip conglomerate of the Tatamagouche Formation. The bedrock grades upward into a weathered, shattered, and unconsolidated version of the underlying rock. This, in turn, is overlain by muddy till. Farther to the east sandstone forms the base of the shore face (Fig. 4). It is eroded, rounded and undercut along bedding planes. The upper beach face on the north side of the Boss Point bluff is armoured by slabs of hard sandstone eroded out of the glacial till immediately above the beach (Fig. 5). These rock slabs or erratics were ripped from underlying bedrock by glaciers during the Wisconsinan glaciation. The northeast-facing side of the headland is a low, almost vertical sandstone cliff

Figure 3. Soft sandstone outcropping across the upper and mid-foreshore.

Figure 4. Sandstone outcrop along the base of a cliff, overlain by glacial sediments (till).

overlain by a silty sand till. The sandstones in both cases are believed to be channel deposits (R. J. Ryan, personal communication, 2006).

Surficial Geology

The study area is covered by a thick, laterally extensive till. Till is typically an unsorted and non-stratified material containing a variable mixture of clay, silt, sand, gravel and large boulders; the boulders being referred to as erratics. Till is deposited underneath and directly by a glacier. Till in the study area was mapped by Stea and Finck (1988) and is called the Eatonville Till. This till is typically reddish-brown with a silty sand matrix. More than 50% of the till clasts (cobbles and pebbles in the till) are Carboniferous sedimentary rocks. In the study area bedrock outcrop is absent west of the Boss Point bluff. The unconsolidated cliff face is composed of a moderately compact to compact till (described above). The clasts are predominantly pebble sized, with a striking absence of larger stones in the cliff face exposures. Till on the cliff face around and east of the Boss Point bluff is lighter brown and sandier than the till west along the coast. This till has incorporated sand from the underlying light brown to beige sandstone bedrock by glacial erosion. It also contains boulder sized slabs of sandstone ripped from the bedrock as the glacier flowed southward.

Figure 5. Glacial erratics and collapsed slabs of bedrock armour the face of the beach. This may not reduce erosion rates significantly but may help to preserve the beach sediment.

Erosion

Observing Historic and Recent Bank Erosion

Observing bank erosion in the study area is problematic as the historically ‘high rate of erosion’ resulted in an unexpected complication. The Tidnish, Seagrove and Amherst Shore areas have been a favoured cottage destination for many years, with cottages at Seagrove being built around 1900. Coastal hardening was undertaken by many of the early cottage owners as they recognized that erosion of their oceanfront properties was a problem (Fig. 6). The result is that lengths of the coastline have been protected from erosion for up to 100 years. As an example, at Seagrove the author visited a cottage originally purchased in 1936. The unconsolidated waterfront bank was initially stabilized by a wood barrier in 1937. The bank has been continuously protected from erosion by successive barriers, illustrating the difficulty in examining true rates of erosion in this area.

Selective prevention of natural coastal erosion is a complicating factor when attempting to examine or measure these rates. You can’t map erosion if it doesn’t occur. Equally problematic is that coastal hardening (a term used in this paper to refer to any form of protection against coastal erosion) results in an artificial reduction in sediment supply to the littoral cells along the coast. This reduction in sediment supply not only results in beach deflation but would also likely increase rates of erosion on adjacent properties located ‘down shore’ in the direction of the seasonally predominant longshore current.

Figure 6. The shore face has been widely hardened in the study area using a combination of wood retaining walls and more recent armour stone.

Measuring or observing the historic amount of cliff erosion in many areas along this shore is, therefore, difficult or impossible, as larger lengths of the coast have been hardened over successive years. In addition, coastal hardening has likely increased the rate and amount of erosion on adjacent properties and prevented the coastline from eroding to become more stable geomorphological forms, such as relatively stable beach forms. It is believed that this is particularly the case along this section of shore where there is no significant secondary input of sediment from the hinterland by river erosion.

Factors Controlling Bank Erosion

Relative sea level along this part of Nova Scotia's coast is rising (see Historical Context). As a result, the shoreline erodes or retreats as it attempts to form a shape and profile in equilibrium with the eroding forces of the ocean waves. Readers should refer to the paper "Factors affecting coastal armour stability along the Amherst Shore, northern Nova Scotia" (Finck, this volume). It describes wave forms, their relative energy levels, and effects on coastlines with different shore face slopes. Since the effects of waves are described in that paper, this discussion will be limited to erosion on and at the base of the coastal cliffs.

The stability or susceptibility of bedrock to erosion is highly dependent on its hardness. Additional factors, such as the presence of joints and faults (breaks) in the rock and the orientation of the breaks with respect to the direction of erosion are also important. Many other factors affect the rate of erosion, such as the presence of soft zones in an otherwise hard, massive rock and rate of removal of debris from the base of the slope. Given the nature of the bedrock in the study area the author feels that a complete review of factors controlling slope stability is not warranted. Hardness or cohesion, and in particular the rate of removal of debris from the slope base, is believed to be the dominant factor controlling the rate of erosion in this area.

The author met and discussed property erosion with numerous residents in the study area. A recurring theme arose in these discussions: the idea that property bank erosion was being caused in large part due to surface runoff, surface water permeating into the soil along the edge of the banks, and freeze-thaw cycles. Because of this belief property owners were often taking measures to attempt to reduce surface water runoff. This idea has been reinforced and encouraged by incorrect information and comment provided by other professionals. While those factors influence erosion, they are not the dominant or controlling factor in the study area.

In general, sediment on a slope is stable if it is at an angle that is less than its natural angle of repose, as determined for a dry state (angle of repose being the slope angle above which a sediment collapses or slides down hill due to the force of gravity). If the slope of a bank is higher than the angle of repose of the sediment, it will internally fail and collapse over time. The bank will also collapse if the sediment (for a given grain size) becomes wet and the slope of the wet sediment exceeds its wet angle of repose (sediments with the same grain size have a lower angle of repose when wet). Likewise freeze-thaw cycles may cause a bank to collapse.

Central to this theme is the concept of what might cause or trigger erosion in the short term (over several years), versus what conditions or processes are necessary to allow erosion to continue over longer periods of time (decades). Consider a steep cliff of unconsolidated sediment. Over a period of months to a few years, typically after rains and freeze-thaw cycles, most likely in the spring, the cliff will collapse. As a result, the slope of the cliff will be quickly lowered, vegetation will grow and the slope will become stable. Further movement of the material will occur (e.g. creep) but over time frames so long that it will be of no consequence to a land owner. In order for slope collapse to continue the sediment on the slope and in particular the sediment at the base of the slope must be removed. In the study area this is accomplished by wave erosion during high tides and storm-related events. With the removal (erosion) of sediment from the base of the cliff the slope again exceeds its angle of repose, becomes unstable and collapses. This process repeats and continues with the result being the observed loss of property. A landowner can reduce surface runoff, which will initially slow the rate of property erosion. However, the ocean will continue to erode the base of the slope and in time it will become over-steepened and collapse. A steady state will quickly develop where the rate of cliff erosion without surface runoff is equal to the rate experienced with surface runoff. The same will hold true for vegetating the slope. In the short term erosion will be reduced or stopped but in the longer term the slope failure will simply be more spectacular (and dangerous).

Wave erosion would also reach an equilibrium in the situation where net sea level rise is zero. As discussed in Historical Context, however, net sea level is rising and erosion continues. An exception to the above example would be if surface runoff was severe enough that it actively carried sediment away from the base of the slope, which is generally not the case in the study area.

Rates of Erosion

Unconsolidated Till

Figure 7 is a 2005 air photograph of a section of coastline between Seagrove and Lorneville. The relative position of the 1964 coastal trace (shown in red) was traced on 1964 imagery, then transferred onto the 2005 airphotograph with an appropriate adjustment of scale. The two images were georeferenced using roads and waterfront cottages that existed on both the 1964 and 2005 images. The position of the 2005 shoreline (shown in black) was added to Figure 7. In several areas this position could not be determined exactly due to recent armouring of the shoreline (shown in yellow) that effectively hides the actual position of the 2005 shore front. The shoreward edge of the armouring is shown as the yellow trace. In areas where the black trace is landward of the yellow, the black line

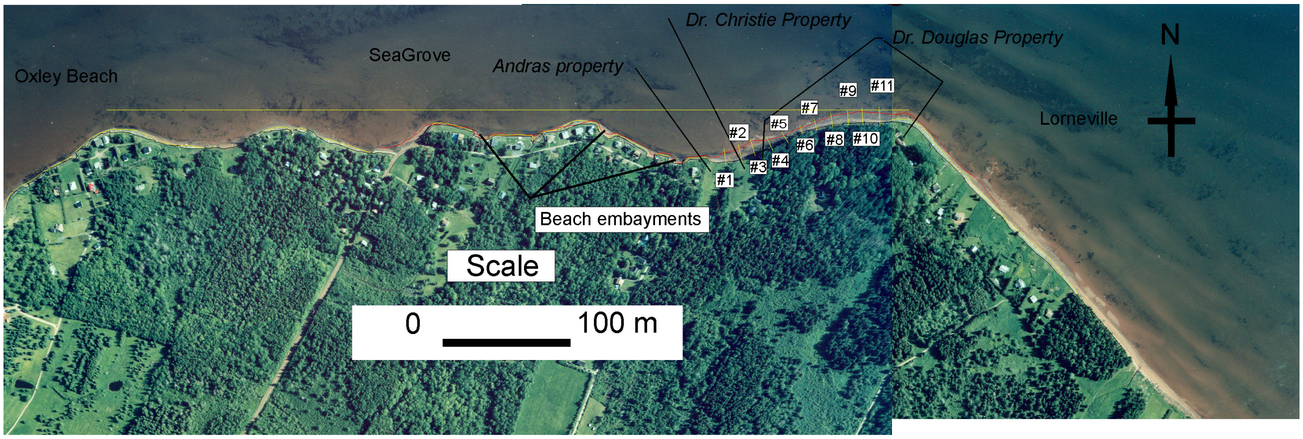

Figure 7. Airphotograph of shoreline from Oxley Beach east to Lorneville. Position of coastline in 1964 (red), 2005 (black), and armouring limit in 2005 (yellow).

marks the position of the landward extent of the armouring. This can be seen east of the Douglas property. Erosion rates in that area could not be measured using the combined 2005 and 1964 imagery.

Two very different coastlines are shown on this figure. West of the Andras property (Fig. 7) the 1964 coastline is close to the same position as it is in the 2005 imagery. However, from the Andras property eastward to Dr. Douglas's home, the coastline was and is not armoured, either by wood retaining walls or stone (Figs. 8 and 9). Eleven transects across the 1964-2005 coastal traces were drawn perpendicular to the shore, the retreat distance was measured and average rates of erosion are given in Table 1. There is obviously considerable variation in the erosion rate, ranging from 0.2 m/yr to 0.6 m/yr with an average of 0.4 m/yr (± 1⅓ ft./yr) (Table 1). Erosion rates for soft sandstone- and till-faced cliffs along the New Brunswick Northumberland Strait range from 0.1 m/yr to 0.4 m/yr (Environment Canada, 2006). The Environment Canada (2006) report also noted that erosion rates were increasing to the east-southeast. Thus, the two studies and data sets appear to be consistent.

Looking at Figure 7, it can be seen that transects 1-3 are across property fronted by lawn and the remainder of the transects are across property fronted by trees. The average rate of erosion on the lawn-fronted properties is 0.5 m/yr and on the wooded property is 0.4 m/yr. The sample size and study area that these two numbers are based on is probably not large enough to draw any numerical conclusions with respect to lawn- vs. tree-fronted erosion rates. Looking at Figures 8 and 9, both areas appear to be slumping and the trees (shallow-rooted evergreens) are simply toppling seaward. Qualitatively, it is doubtful that the presence of softwood trees on this shoreline would make any difference in long-term erosion rates.

Bedrock

At Boss Point, sandstone bedrock delays erosion by protecting the base of the slope from rapid undercutting and at the same time protects the overlying till from erosion. As bedrock erodes, the till retreats at a corresponding or balanced rate. As the fine-grained portion of the till erodes it leaves behind the large sandstone boulders that then fall onto the beach. These boulders serve as a natural wave break protecting the base of the slope. This area is one of the few where the coast is not hardened by man-made structures. A private landowner at Boss Point indicated that he had been forced to move his cottage landward several years previous. As part of the move his property was surveyed. This survey, compared to an earlier survey, indicated that his property had eroded approximately 1 foot per year (0.33 m/yr). This provides a survey controlled measurement of the rate of erosion of a sandstone-based cliff in the study area. Though the sandstone is competent compared to till, it is still relatively erodeable. This result is also consistent with the conclusions of the Environment Canada (2006) study.

Table 1. Rate of coastal erosion along a section of non-armoured shore face composed of silty sand Eatonville Till; 1964-2005 (over 41 years).

Transect	Distance (m)	Average (m/yr)	Range (m/yr)
#1	18.4	0.5	Min. = 0.2
#2	22.2	0.5	Max. = 0.6
#3	25.7	0.6	
#4	18.1	0.5	
#5	11.4	0.3	
#6	8.6	0.2	
#7	11.7	0.3	
#8	16.1	0.4	
#9	17.9	0.4	
#10	21.8	0.5	
#11	18.4	0.5	
Average (11)	17.3	0.4	
Average (9)	17.3	0.4	

The Changing Face of Beaches

Natural Beach Recovery

In a normal sequence of events a beach face often erodes in storms, with sand being transported and held in offshore deposits. Beach material, either sand, gravel, cobbles or mixtures, may also be driven landward forming storm ridges or wash-over fans that fill depressions (e.g. ponds, swamps, lagoons, estuaries) and possibly burying organic material. The sediments may be trapped in the depressions or stabilized by vegetation, forming low relief deposits. During periods of low energy when net sediment movement is shoreward, sand from the offshore bars, as well as new sediment entering the littoral cell, can rebuild the beach and even result in progradation.

In a situation where net sea level is rising, as it is in the study area, the entire beach tends to migrate landward over time. An exception would be where high levels of sediment supply to the beach enable it to maintain its position or even prograde. This could happen where erosion reaches a new source of sediment, such as a drumlin along the coast that starts eroding. This sediment supply may result in temporary progradation. Once the drumlin is eroded, however, and the sediment supply is cut off, the beach system will be highly unstable and is likely to collapse and move landward in a catastrophic fashion.

Beach Loss at Seagrove

The above highly simplified description of beach evolution on a coast with a rising sea level no longer applies in most of the study area. When the shoreline is armoured or stabilized two critical factors in beach and/or coastline evolution have been compromised. These are sediment supply and shore-face equilibrium. Sediment is derived from offshore sub-tidal and intertidal sand deposits, up-current supplies from rivers, or by active erosion of the coast (either unconsolidated sediment or bedrock). In the study area erosion of soft bedrock or glacial till is the dominant sediment source. When the coast is armoured this supply is greatly reduced or eliminated. The result is that as sediment is permanently lost to ‘deep water’ there is no replacement material available. Over time as storms (or other normal high energy events) occur the foreshore becomes steepened, wave action increases on the supratidal area, the beach deflates (is washed away) and a rocky, slimy intertidal trough is left at the base of many segments of armoured coastline.

This is particularly apparent where the coast has been stabilized for many years, as in the Seagrove area. Here wood palisades consisting of large trees driven into the supratidal area have been constructed since the early 1900s. When these ‘breakwaters’ were first constructed, older cottage residents told the author that they could sit on well developed beaches that were exposed at high tide at the base of the structures. As the coastal hardening continued, however, sediment supply to the beaches was reduced and the sand deposits were eroded. Based on the observed large amounts of

Figure 8. Extensive erosion of Eatonville Till along the bank of a shore front property. The owner has chosen not to armour the shore face; his cottage is located well inland from the bank edge. Note the armouring in the background and the lack of exposed beach at near high tide.

coastal armouring occurring over the last 20 years, this deflation of the beaches will and probably has already accelerated.

Residents report large amounts of sea level rise along this coastal area. Where a typical high tide historically left a sand beach exposed at the base of a retaining wall, now at high tide the water extends up the face of the wall. In the last 100 years net sea level rise was in the range of 25 cm to 35 cm. The severe loss of sediment supply to these areas, coupled with a relatively minor amount of sea level rise, has resulted in the complete erosion of the upper beach down to a level below that of the top of the intertidal sand ridges, leaving the slimy intertidal trough as described above. Thus, the perceived amount of sea level rise is just that, a perception rather than a reality.

Collapse of the Ship Rail Sand Spit

In a 1939 air photograph, a +700 m long sand spit can be seen immediately east of the Tidnish Dock Provincial Park. The author will refer to it as the Ship Rail Sand Spit. Colleague J. MacNeil, using GIS applications, georeferenced the 1939, 1964, and 2005 images to a base map and superimposed the 1939, 1964 and 2005 traces of the front of the spit (Fig. 10). The 2005 air photograph is used as the base for Figure 10. Six transects were measured across the sand spit perpendicular to the spit's long axis (Fig. 10). These transects were used to measure and calculate the rate of shoreward migration of the spit between 1939 and 2005 (Table 2). In addition, a transect parallel to the length of the spit (Fig. 10) was used to measure its shortening (Table 3). Over the period 1939-2005 the spit moved landward an average distance of 128 m and decreased in length by almost 550 m. Data for the periods 1939-1964 and 1964-2005 are relatively consistent (Tables 2 and 3). The average rate of landward migration is 1.9 m/yr and average shortening was 6.1 m/yr.

An average rate of retreat of 1.9 m/yr for the

Figure 9. Erosion of Eatonville Till along the bank of a heavily wooded shorefront property. Trees are undercut and collapse outward onto the beach, suggesting that the shallow spreading root systems of the softwoods are having little effect in reducing the rate of erosion.

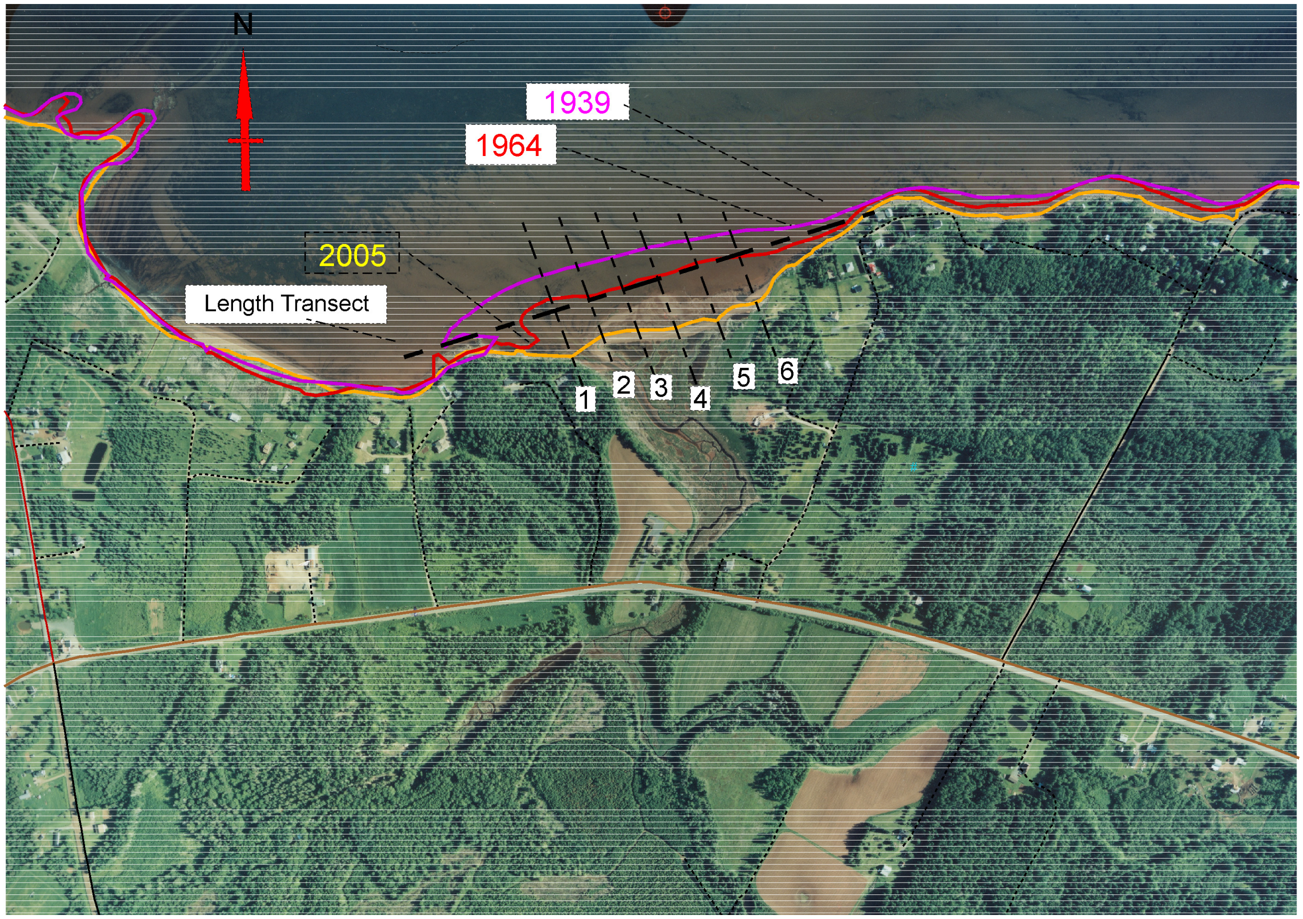

Figure 10. Airphotograph showing the changing positions of the Ship Rail Sand Spit east of the Tidnish Dock Provincial Park. The 1939 position is shown in purple, 1964 position in orange and the 2005 position in yellow. This figure was produced and georeferenced by J. MacNeil, NSDNR.

Ship Rail Sand Spit is greater than the rates of retreat (commonly >0.5 m/yr) for beaches, spits and barrier beaches in the New Brunswick study (Environment Canada, 2006). The authors of the New Brunswick study, however, also noted that at the higher end of this range, the “point of attachment of the Pointe-aux-Bouleaux spit retreated at an average rate of 2.4 m/yr between 1944 and 2001.” Thus, data in this study are again consistent with those of the far more extensive New Brunswick study.

The answer to the question of why the Ship Rail Sand Spit collapsed so dramatically over the last 66 years is subjective. Historic sand mining of the spit is known to have occurred and is a possible culprit in the short term. Sand mining can have a dramatic effect on beaches, but this is particularly true where the beaches are ‘sediment starved’. The Ship Rail Sand Spit, however, would normally have a very high rate of sediment supply and recovery from sand mining (once it ceased) should be relatively rapid. During recovery of the spit the rate of down-current coastal erosion might increase. This is because the normal sediment supply from up current would be interrupted.

Examination of the sand spit’s morphology indicates that the predominant direction of sediment transport along the coast is from east to west. Seagrove was one of the first areas developed for cottages around 1900 and this was followed by extensive construction of wood sea walls. It is believed that this coastal hardening has reduced the long-term sediment supply to the spit and resulted in the dramatic reduction in size and the large shoreward migration. It is anticipated that as the spit continues to migrate it will shorten and simply form a small sand bar across the face of the brackish marsh, with a narrow opening to allow the small brook to drain past to the Northumberland Strait.

Table 2. Magnitude and rate of retreat of the sand spit between Tidnish Dock Provincial Park and Seagrove.

1939-1964		1964-2005		1939-2005	
Transect	Distance (m)	Transect	Distance (m)	Transect	Distance (m)
#1	41	#1	96	#1	138
#2	54	#2	64	#2	119
#3	51	#3	73	#3	125
#4	48	#4	86	#4	135
#5	38	#5	96	#5	135
#6	41	#6	77	#6	119
Average	46		82		128
Avg. m/yr	1.8		2.0		1.9

Table 3. Magnitude and rate of shortening of the sand spit east of the Tidnish Dock Provincial Park.

Year of Image	Time Interval (yr)	Length (m)	Interval Shortening (m/yr)	Total Shortening (66 year)	Average Shortening m/yr
1939		717			
1964	25	585	5.3		
2005	41	302	6.9		
				547	6.1

Beach Recovery in the Lorneville Area

Figure 11 is a 1995 air photograph showing a section of coastline (low relief beach) northeast of Lorneville. Several cottages are protected by a low section of wood palisade backfilled with stone. In the 1995 air photograph a previous storm event is shown as salt water incursion 50 m inland (east side of wall) with the main beach being moved approximately 20 m shoreward. This salt water incursion occurred on both sides of the wall. By the fall of 2006 (View 2) the beach had recovered and prograded 11 m on the east side of the wall. On both ends new vegetation stabilized the top of the beach (View 1 and 2) above the highest high water mark and showed typical vegetation zoning (View 1) presumably based on its salt water resistance.

This small segment of sand beach is one of the few areas where normal beach shoreline processes can be observed. In this case the beach face had partially recovered or prograded toward its former position following a significant erosional event. Since most of the coastline is armoured, however, normal beach processes no longer occur across most of the study area.

Artificial Beaches

During the course of this investigation several residents inquired about the long-term outcome if they allowed their property to recede versus potential beach loss if they armoured their property. In general this arose with respect to leaving a segment of property unprotected and the question of whether a beach would form in that unprotected area.

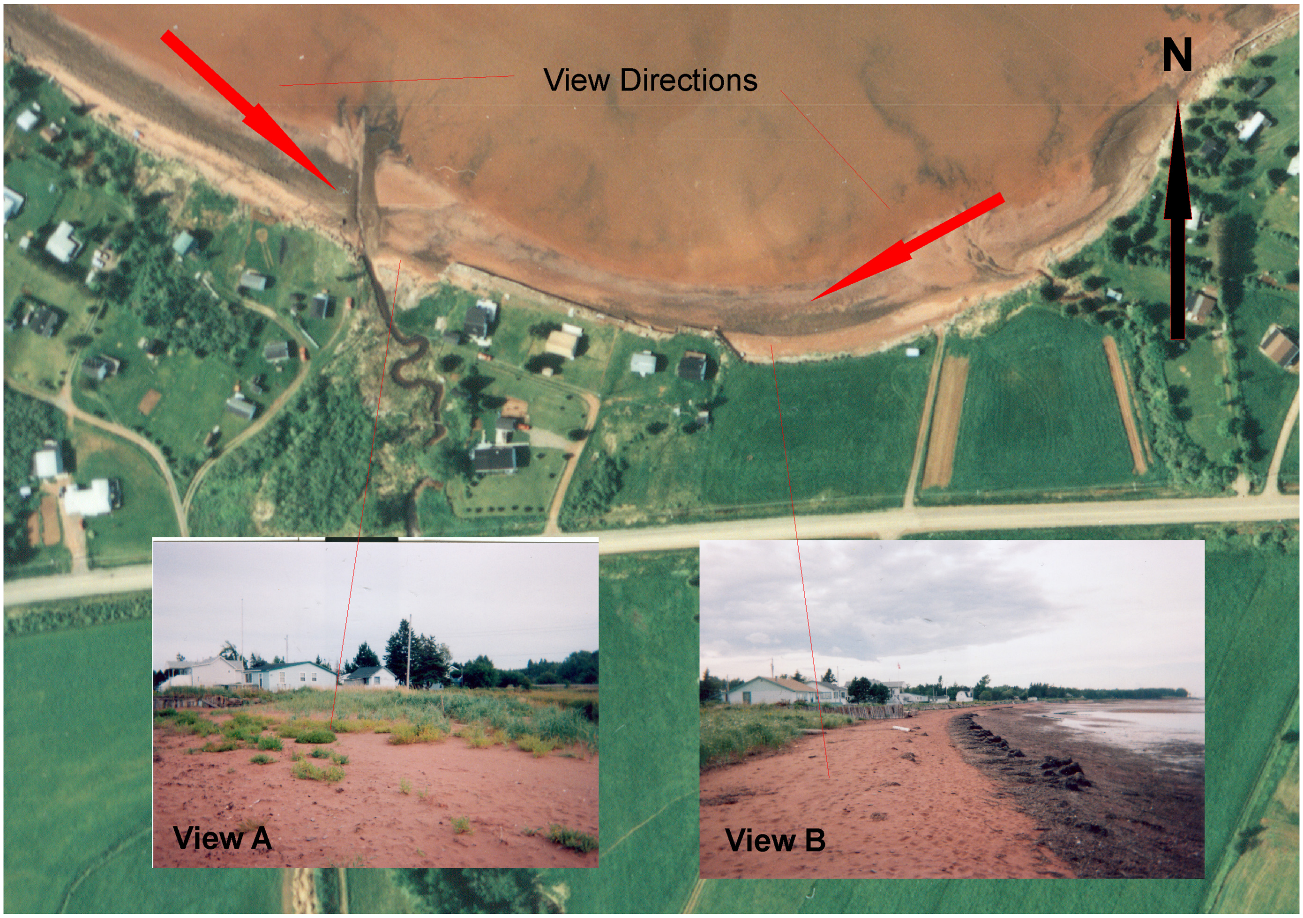

Figure 11. Airphotograph showing a 1995 aerial view of the beach at Amherst Shore after an intense erosional event. Inset views are photographs of the same location taken in October, 2006 showing beach progradation and revegetation.

Theoretically, leaving a segment of shoreline unprotected will produce a beach. The bank will recede to the point where wave energy is insufficient to erode and a stable landform, a beach, will develop. Like all beaches, however, this beach will come and go depending on seasons and fluctuating energy levels. The important point is that as the bank erodes the sides of the embayment must be walled back to the top of the 'new beach' (and preferably a little farther). This will prevent flanking of the main wall or walls on adjoining properties by waves. An additional consideration is that waves naturally over-top beaches in storms. Thus, during a storm residents should expect the waves to flood onto their lawn. This could be mitigated by placing sporadic large stones at the landward end of the embayment above the highest high water mark. The author observed several areas where hardened embayments were left to allow access to the shoreface (see small embayments on Fig. 7 located west of the Andras property). A small sand beach developed in these embayments. These allow not only beach access but also a swimming area at high tide.

Conclusions

The absolute position of sea level relative to the land has been rising for over 10 000 years and will continue to rise in the study area. Assuming present and constant conditions, the rate of sea level rise will remain constant over a period of decades, between 25 cm and 45 cm/century (100 yr). If the absolute rate of sea level rise accelerates due to changing conditions (e.g. accelerated melting of polar ice caps) then the rate of sea level rise relative to the land will also increase.

The average rate of coastal erosion over several decades will be relatively constant, but short-term rates may vary over a period of several years due to the time-variable impact of severe storms.

An additional critical variable will be sediment supply. Where sediment supply to the near- or foreshore is reduced, erosion rates will increase. At present, the average rate of erosion measured in this study area is 0.4 m/yr.

Shore front properties can be protected from erosion by armouring the coast with stable, properly constructed wave breaks. To be effective, however, the entire coastline must be hardened. In doing so sediment supply to the foreshore areas will be reduced with the result being the loss of sand beaches. Other features such as sand spits and or swamp/lagoonal areas will move landward. Over time, due to rising sea level, these changes will become more apparent and severe.

Armoured shorefront property will become more unstable with time such that when or if a wave break fails during a storm, the resulting erosion will occur more quickly and be more dramatic. Over decades to centuries, properties in low-lying areas will become more subject to storms overtopping the coastal protection structures. This will result in salt water flooding behind the coastal properties.

Over time naturally occurring coastal land forms will disappear. Given sufficient time and sea level rise, coupled with coastal hardening, the shore face will become a slimy, stony lag with the salt water rising and falling along the faces of stone walls. Natural occurring shore front features will disappear. The only long-term alternative is to allow the coastline to erode and retreat in a natural sequence of events, accepting the resulting loss of property and infrastructure.

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