Coastal Erosion at Inverness Beach, Cape Breton Island

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Introduction

On May 3, 2013, the Parks and Recreation Division of the Nova Scotia Department of Natural Resources requested a brief overview of coastal erosion along Inverness Beach (a protected beach) near Inverness, Cape Breton Island, including parts of the sensitive dune-wetland complex immediately inland of the beach (Fig. 1). Parks and Recreation were also interested in obtaining information regarding general shoreline stability and storm impacts on adjoining lands.

Inverness Beach, located at the north end of the town of Inverness, is one of 92 protected beaches in Nova Scotia (Fig. 1). The beach, dunes and wetlands are adjacent to and partly underlie MacLeod's Inverness Beach Village. To prevent erosion, guests of the resort are discouraged from walking on the dunes and wetlands except along a narrow pathway that connects the cabins and campsites to the beach. Two 18-hole golf courses (Cabot Links, which opened in 2012, and Cabot Cliffs, currently being developed) are located immediately south and north of Inverness Beach, respectively (Fig. 1). The success and international prestige of the new golf courses has already increased the number of tourists to the town of Inverness and its beaches.

As for all of Nova Scotia, the rate of relative sea-level (RSL) rise at Inverness is expected to accelerate in the future due to global warming. In Charlottetown, P.E.I. (~140 km west of Inverness), sea-level projections for the year 2099 range from ~0.5 to 0.7 m above 2010 levels; for Halifax the projections are ~0.6 to 0.8 m above 2010 levels (Zhai *et al*., 2014). Higher sea-levels will very likely increase rates of erosion at Inverness Beach over this time. For Inverness Beach to remain stable or aggrade as sea level rises, a concomitant increase in sediment supply (well above current levels) is required. Increased precipitation, including spring snowmelt (which may be expected in the near future due to climate change), could potentially increase inland erosion and transport of sediment to the coast above modern rates, but it is unlikely to counter the effects of such rapid rates of sea-level rise. Other factors that influence erosion versus growth of beaches include sea ice and shorefront development (i.e. coastal hardening), both on-site and up and down the coast from Inverness Beach. The ongoing reduction of sea ice in Northumberland Strait (Senneville and Saucier, 2007) will increase the likelihood of erosion during winter storms as sea ice normally forms a protective barrier. Coastal hardening also forms a protective barrier where it exists, but can cause an intensification of erosion along adjacent, natural shorelines. The relict dunes behind Inverness Beach provide some assurance that there will be a sandy beach there for a long time to come unless the dunes are destabilized or mined by humans. Nonetheless, to predict how Inverness Beach will be affected by future changes in sea level, climate and human development, a better understanding of past changes is required. The purpose of this paper is to describe geological and geomorphological observations made during the first site visit to Inverness Beach and to present interpretations of the aerial photography analysis. Future visits and more in depth analyses are planned for 2014.

Methods

To determine past rates of coastal erosion at Inverness Beach, aerial photographs were examined, orthorectified and georeferenced to allow for a comparison of changes in the position of the primary frontal dune crest over time. Coastal cliffs are commonly used to measure coastal retreat; in the present study, the crest of the primary frontal dune is used. The crest is adjacent and parallel to the shoreline. This approach avoids the

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Figure 1. A) Map of Cape Breton Island, Nova Scotia. Red 'x' indicates location of Inverness Beach. B) 2009 aerial photograph of Inverness Beach, Inverness, Cape Breton Island. Red box outlines approximate area of protected

uncertainty of identifying modern sea level (m.s.l.) on aerial photographs, which may have been taken at any time during the tidal cycle, and thus may expose more or less beach area in any given aerial photograph.

Follow-up fieldwork at Inverness Beach was undertaken on July 3, 2013 to ground truth aerial photo interpretation and to document the existing physical character of the beach-dune-wetland system. Baseline data such as these are critical for identifying and understanding future change, guiding and planning management operations, and for appraising the performance and impacts of management.

Geological and Physiographical Observations

Inverness Beach is located at the mouth of a broad, shallow valley (~40–65 m wide) underlain by till and Carboniferous bedrock. Inland from the beach and within the valley itself are dunes, wetlands, ponds and glaciofluvial deposits (kames and eskers; Stea *et al*., 1992). Two streams (labelled “southern stream” and “northern stream” in Fig. 1) exit the valley and traverse Inverness Beach. Coastal cliffs at the northern end of Inverness Beach (Fig. 2) expose ~4 m of Late Carboniferous bedrock (red sandstone, shale and conglomerate of the Broad Cove Formation, Pictou Group) and ~1–2 m of overlying glaciofluvial deposits (Stea *et al*., 1992). A horizontal surface that truncates the steeply dipping beds of the bedrock (Fig. 2) may represent a raised wave-cut platform that was eroded during the last interglacial (75,000 to 125,000 years BP), as it is similar in elevation to several other bedrock benches documented along the Northumberland coast (4–6 m above m.s.l.; e.g. Goldthwait, 1924; Stea *et al*., 2002). Cliffs anchoring the southern end of Inverness Beach are formed in silty till draped by dune sand and fluvially reworked dune-sand (Fig. 3A). The sand drape pinches out ~5–10 m south of the beginning of the coastal cliffs at the south end of the study area (Figs. 1, 3B), and the silty till forms extensive coastal cliffs (~8 m high) that continue past Cabot Links and the town of Inverness. Late Carboniferous bedrock (Inverness Formation, Pictou Group) underlies the till but is not exposed locally (Keppie, 2000).

Immediately inland from Inverness Beach is a primary frontal dune, secondary dunes and relict blowouts (Figs. 1, 4A, 4B). All of the dunes are well vegetated with Marram grass, including along the seaward-facing frontal dune, indicating no recent erosion by storms (Fig. 4B). The beach ranges from ~3–12 m in width, is composed mainly of sand, and represents the main source of sediment for dune growth. The two streams (southern and

Figure 2. Looking east at a horizontal wave-cut platform at the north end of Inverness Beach. The cliff is ~6 m high. Note the angular unconformity (white dashed line) between tilted red beds of Late Carboniferous sandstone, shale and conglomerate (Broad Cove Formation, Pictou Group) underlying unconsolidated late Quaternary glaciofluvial deposits (Stea *et al*., 2002) and/or till. This former sea-level stand was likely formed during the last interglacial (~75,000-125,000 years BP). A coarse cobble lag-deposit from a former meltwater channel or stream is visible on the right side of the photo.

Figure 3. A) Looking southeast at silty till underlying slumping dune-sand and fluvially re-worked dune-sand. Southern stream in local valley on left side of photo and stairs leading up to Inverness Beach Village on the right. B) Looking southwest down the coast at dune sand pinching out and giving way to silty-till plain exposed in coastal cliffs.

northern streams) may also deliver abundant sediment to the coast during peak flow times as they migrate and erode through unconsolidated glaciofluvial deposits and sand dunes. This sediment will eventually be re-deposited onshore (on the beach and in the dunes); however, the timing of this cycle depends on storm frequency, longshore currents, offshore sinks, and sediment transfer rates and residence times within the local littoral cell (currently poorly defined). The volume of fluvially transported sediment to the littoral cell that includes Inverness Beach is unknown and may increase or decrease in the future depending on the availability of erodible sediments upstream and climate change (for example, if winter snowfall were to decrease, there would be less spring melt and reduced erosion and transportation of sediment to the coast). Nonetheless, without an attendant increase in sediment supply, the expected acceleration in the rate of relative sea-level rise will enhance erosion and/or inland migration (transgression) of Inverness Beach. Any increase in

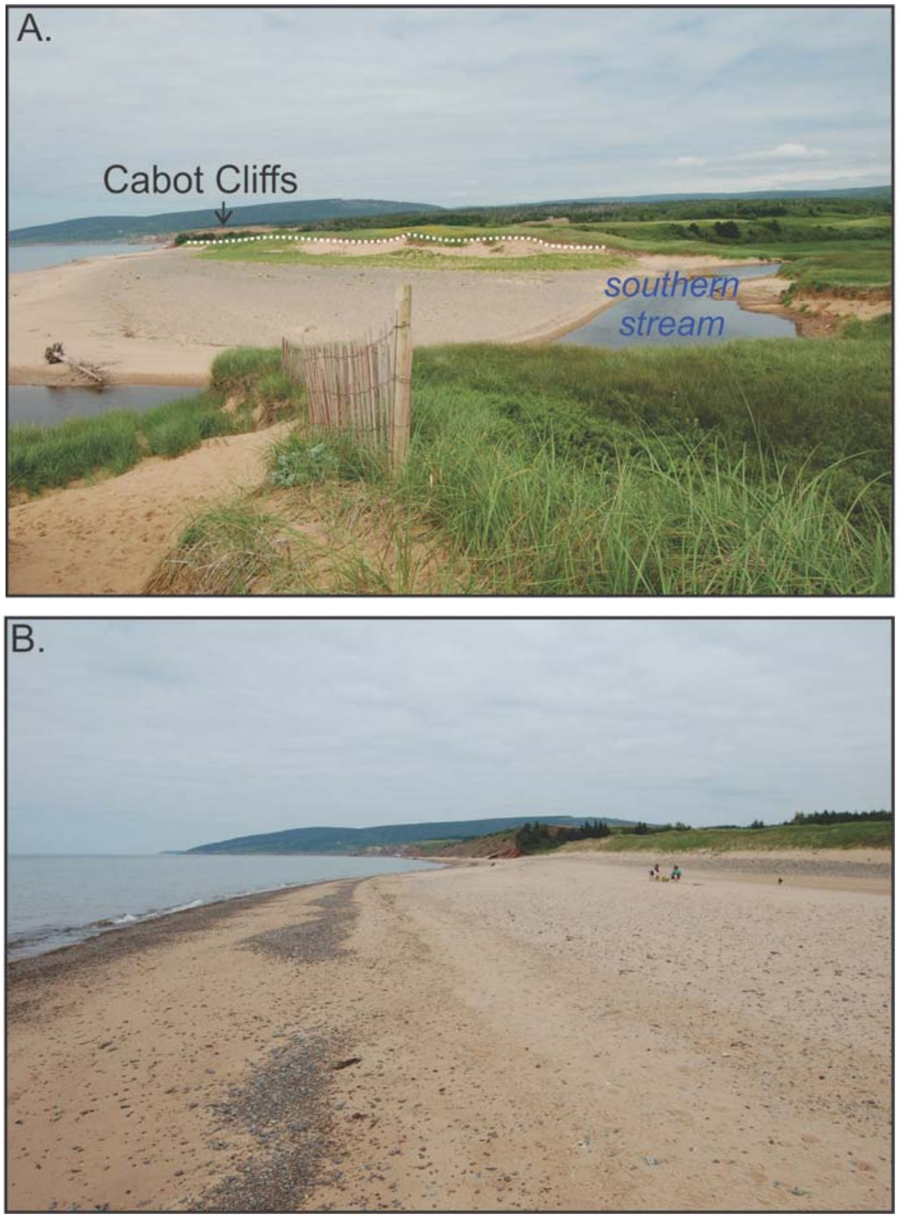

Figure 4. A) Looking north at primary frontal dune (crest highlighted by white dashed line). Unvegetated/eroded path to beach stairs in foreground. B) Looking north at Inverness Beach. Note the well vegetated lee slope of the primary frontal dune, indicating little recent erosion.

storm frequency and/or intensity will further augment erosion.

Aerial Photograph Analysis: Erosion and Inland Migration of the Sand Dunes

As a first assessment of recent coastal erosion at Inverness Beach, aerial photographs representing four time slices were examined: 1936 (earliest available), 1993, 1999 and 2009. Erosion and inland migration of the foredune crest was clear from a cursory examination of the photos (Fig. 5). To determine rates of inland migration, aerial photographs from 1993, 1999 and 2009 were orthorectified (the 1936 aerial photograph was not included due to poor quality) and georeferenced in ArcMap 10. The crest of the foredune was then traced on each of the three images. Based on this analysis, the crest of the foredune appears to have migrated ~16 m between 1993 and 2009 (i.e. at a


N
0.5 km
1993 position of dune crest
1999 position of dune crest
Gulf of St. Lawrence
MacLellans Pond
Inverness Beach Village

rate of 1 m/a). Dune-crest migration between 1999 and 2009 was ~4 m (i.e. at a rate of 0.4 m/a). Errors on these rates may be up to 50% due to distortion of the photos themselves and any error acquired during orthorectification and georeferencing.

Conclusion and Recommendations

For the past 16 years, inland migration of the sand dunes at Inverness Beach has occurred at an average rate of ~1 m/a. Generally speaking, coastal erosion tends to progress gradually, punctuated by large erosion events during storms. As such, the longer the record of coastal erosion used to calculate erosion rates, the more accurate they will be. A long-term, precise coastal erosion monitoring system is recommended for this site given its ecological sensitivity and recent boom in tourism. Factors that may drive future rates of erosion include development of the coast and adjacent coasts (especially coastal hardening and alteration of the sand dunes, including their protective vegetation cover), changes in precipitation and sea ice conditions, sea-level rise and storminess.

Future work at Inverness Beach should include a more complete survey of the beach and inland areas, delineation and analysis of the local littoral cell, installation of a coastal migration survey marker, and the initiation of a long-term coastal erosion monitoring program with the purpose of developing a database from which precise rates of erosion or accretion may be determined in the future. Such monitoring will help determine whether future erosion is cyclical or part of a long-term trend. Further research into past development at Inverness Beach would also help elucidate its current state and future change.

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Figure 5. 2009 aerial photograph of Inverness Beach. The black line on the aerial photo represents the position of the dune crest in 1993. The red line marks the dune crest in 1999. The distance between the 1993 and the 2009 dune crest is ~16 m in most places, thus ~16 m inland migration in 16 years. The distance between the 1999 and the 2009 crest is up to 4 m. The thinner blue and red lines were used for orthorectification purposes.