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COASTAL MONITORING IN NEWFOUNDLAND AND LABRADOR: 2012 UPDATE

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ABSTRACT

Coastal monitoring of beach and cliff sites continued on the Island of Newfoundland and southern Labrador, as part a multi-year coastal monitoring program, initiated in 2011. The objectives are to assess rates of shoreline erosion, determine changes in beach profiles and to delineate areas at risk from coastal hazards. In total, eighty-eight sites were monitored in 2011 and 2012.

During the 2012 field season, fifty-four sites were monitored and surveyed. For most of the current sites, there is insufficient data to provide reliable estimates of coastal change. However, in 1981, the Geological Survey of Canada (GSC), and the Geological Survey of Newfoundland and Labrador (GSNL), established a coastal monitoring program, and there are data available, covering a twenty-year period, for some sites, e.g.*, Point Verde, and Seaside Drive in Kippens. This earlier data was made available, and was compared to data collected in this program.*

Preliminary analysis show coastal retreat is variable and in some places, rapid e.g.*, Point Verde. Ongoing work will monitor at regular intervals coastal sites; data analysis of these observations will provide estimates of rates of coastal erosion and beach-profile change and this information will be publicly available on-line through the Geological Survey Resource Atlas.*

INTRODUCTION

Coastal environments are always changing, impacting people and infrastructure. Past incidents of coastal flooding, slope movement, and cliff and beach erosion have resulted in expensive and extensive damage to infrastructure (Plates 1 and 2), loss of areas of cultural or environmental importance and, in some instances, death or injury. The history of coastal disasters in Newfoundland and Labrador are documented in Batterson *et al*. (1995, 1999, 2006) and Liverman *et al*. (2001, 2003).

This report describes a multi-year coastal monitoring program established by the Geological Survey of Newfoundland and Labrador (GSNL) in 2011 (*see* Irvine, 2012). The objectives are threefold: 1) provide estimates of rates of shoreline erosion, 2) monitor changes in beach profiles, and 3) define areas at risk to coastal hazards. This program uses, and builds upon, coastal monitoring data provided by the Atlantic Geoscience Centre of the Geological Survey of Canada (GSC) (D. Forbes, personal communication).

Plate 1. *Coastal erosion is occurring along this road in O'Donnels, Avalon Peninsula. Ground- and surface-water flow are causing the sand and gravel to wash down the bank. During high tides, waves impact the base and wash the sediment away from the base of the slope.*

Plate 2. *Storm surge caused coastal flooding, erosion and overwash on the main road in the Beaches, White Bay.*

FACTORS INFLUENCING COASTAL CHANGE

Coastal environments are dynamic, with changes caused by both terrestrial and marine processes (Moore, 2002). Terrestrial processes include slope movement (*e.g.*, landslides, rockfalls, gullying and slumps), and surface- and ground-water flow (Plate 1). Wave action is one of the primary causes of coastal change, with most of the erosion and retreat occurring when waves produced by a storm or storm surge (defined as an increase in the level of the water due to pressure and wind changes) coincides with a high tide. Material is deposited when waves transfer energy as they reach the shoreline, and examples of landforms formed by deposition include spits, bars and tombolos.

The vulnerability of a coastal environment to change is influenced by the dynamics between coastal processes and the location, topography, geology, physical properties and supply of sediment (Forbes *et al*., 1997; Moore, 2000; Westley *et al*., 2011). For example, the continued existence of the Holyrood Pond barrier on the southern Avalon Peninsula is due, in part, to the continued supply of sediment. Waves remove sediment from the barrier, but the unconsolidated cliffs south of the pond provide sediment to the beach, maintaining the barrier (Forbes, 1984).

Sea-level rise also affects coastal stability; with erosion and flooding occurring in new areas over time (Shaw and Forbes, 1990; Liverman *et al*., 1994; Nicholls *et al.,* 2007). Sea level is rising across most of the coastal zone of the Island, is stable or rising along the northern section of the Northern Peninsula and southern Labrador, and is falling along the central and northern Labrador coasts (Batterson and Liverman, 2010). The Avalon Peninsula is predicted to experience the greatest rise in relative sea level for the Province, with a projected increase of more than 100 cm by 2099; elsewhere in the Province relative sea-level change is projected to rise between 70 to 90 cm by 2099 (Batterson and Liverman, 2010).

PREVIOUS STUDIES OF THE COASTAL GEOLOGY OF NEWFOUNDLAND AND LABRADOR

Shaw *et al*. (1998) completed a national assessment of the sensitivity of coastal areas with respect to sea-level rise. The GSC has conducted detailed studies in select areas on the Island since 1981 (Forbes, 1984), including areas subsequently ranked by Shaw *et al.* (1998) as having a high sensitivity (*e.g.*, the bayhead barriers on the Avalon Peninsula and St. George's Bay). In the early 1980s, the GSC conducted photogrammetry and shore profiles at 79 sites across the Island that included beach, barrier, lagoon, estuarine, tidal flat and cliff areas (Forbes, 1984). In 1991, five sites were surveyed between Port au Port and Kippens on St. George's Bay by the GSC (Forbes *et al*., 1995). In 1993, the GSC and the GSNL established monitoring sites on the Avalon Peninsula in Topsail–Chamberlains, Placentia–Point Verde, Big Barasway–Ship Cove, and Holyrood Pond–St. Stephens (Liverman *et al*., 1994). In 2007, the GSNL installed five coastal monitoring sites near Frenchman's Cove on the Burin Peninsula (Batterson, 2009).

Provincial initiatives focusing on coastal issues include geological hazard mapping (Batterson and Stapleton, 2011), desktop modelling of coastal vulnerability (Westley *et al*., 2011) and flood-risk mapping by the Department of Environment and Conservation.

COASTAL MONITORING PROGRAM 2012

The aim of the second year of the coastal monitoring program was to revisit the earlier network of sites established by the GSC and the GSNL, expand the geographic coverage of the monitoring program, and to include areas of known coastal hazards (Irvine, 2012). Established sites were re-visited, survey pins relocated if possible, and the site resurveyed. New sites were installed on the Island and in southern Labrador.

LOCATIONS

During the 2012 field season, fifty-four sites were monitored on the Island of Newfoundland, and in southern Labrador southwest of Red Bay (Figure 1, Plate 3). Twelve new sites were installed, in southern Labrador, Fogo Island, Daniel's Harbour, in the Twillingate area, and on the Baie

Figure 1. *Location of coastal monitoring sites around Newfoundland and southwest of Red Bay, Labrador.*

Plate 3. *Examples of coastal monitoring sites: A) The sandy delta in the community of Sandy Cove is exposed at the coast as a bluff up to 35 m high and 1 km long. Summer houses are built along the top of the delta, and the beach is used by locals and tourists. The cliff is eroding due to foot and ATV traffic, surface- and ground-water flow, and wave impact during high tides and storms. B) Sand dunes at Western Brook–Broom Point area in Gros Morne National Park. A sand-dune management plan was initiated in the 1970s to stabilize the dunes and decrease erosion. Adaptations included the construction of boardwalks, stopping of animal grazing, construction of snow fences, planting of marram grass, and informing users of the importance of maintaining the sand dunes (Betts, 1988). Currently, marram grass has vegetated the area resulting in most of the dunes being stabilized. C) Well-rounded cobble and boulder beach at Olivers Cove, Fogo Island. D) Unconsolidated bluff at Ferryland; lighthouse in background. This bluff is eroding, and waves have damaged the low-lying road that leads out to the lighthouse, residential homes and the Colony of Avalon, a 17th century Archaeology site. Significant damage to the road occurred in 2004, 2009 and 2010 despite boulders being placed along the shoreline to protect the area from erosion.*

Verte Peninsula. Eight sites previously established in 2011, were re-visited and expanded to include a longer section of the coastline. Thirty-four sites earlier established by the GSC and the GSNL were re-surveyed.

FIELD METHODS

Coastal surveys were conducted using Lecia GS09 Global Navigation Satellite System (GNSS) Real Time Kinematics (RTK) (Plate 4). The base station was set up

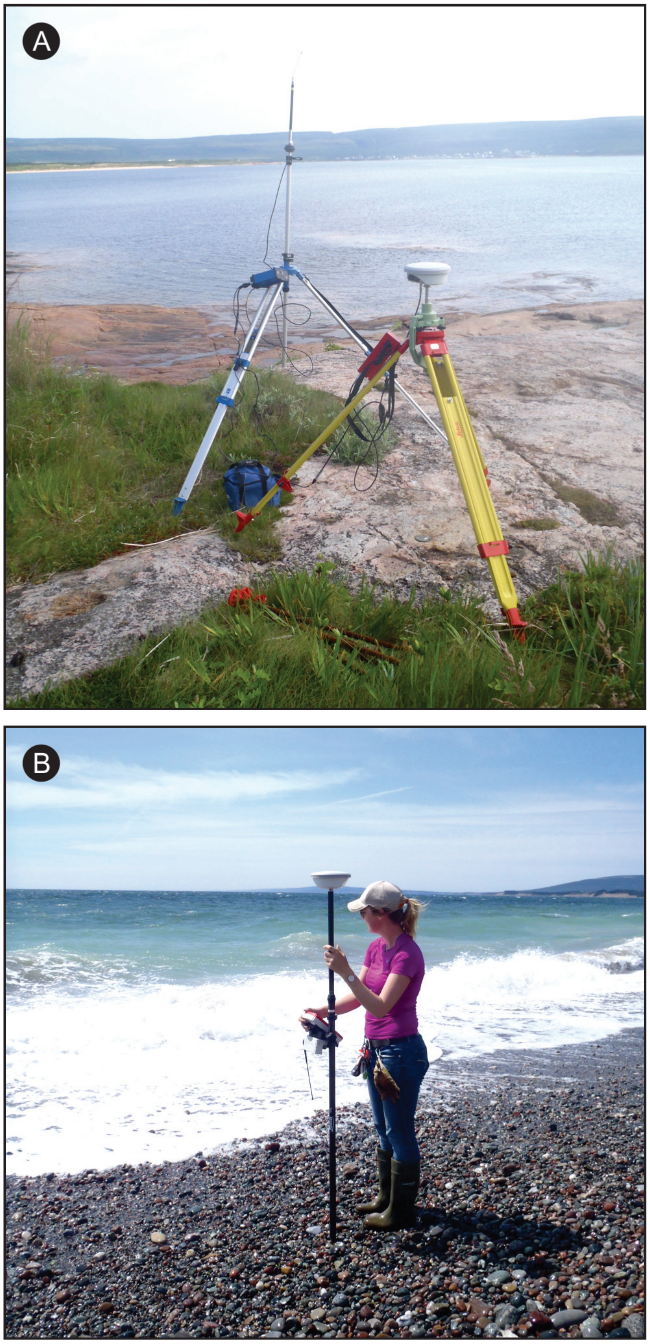

Plate 4. *Real Time Kinematics survey equipment. A) The base station (yellow tripod) is set up over a previously established survey monument with known coordinates. The base station transmits reference position information to the roving receivers through the radio (blue tripod). B) The hand-held roving receiver, consisting of an antenna and field controller attached to a telescopic pole is used during surveying. At each site, where appropriate, profile lines from a survey pin to the sea, the cliff top and base, backshore, turfline, vegetation line, sediment changes, dune crest and beach cusps were surveyed using the hand-held receiver.*

over a permanent survey benchmark. Two roving receivers with a GS09 GNSS antenna, modem and GS09 field controller attached to a telescopic pole were used. Data were collected in North American Datum (NAD) 83 and included location (easting, northing and elevation), time, date and site details such as sediment characteristics, presence and type of vegetation, areas of erosion or slope movement and type of infrastructure.

A RTK is a type of positioning system that collects sub-centimetre accurate location data. It consists of a stationary base station, a radio link and a roving Global Positioning System (GPS) receiver. To collect accurate data in real time, the base station is set up over a point of known location, such as a survey benchmark. By establishing the base station over a point of known position, accurate relative and absolute data are collected. The base station sends its reference position to the roving GPS receiver through the radio, allowing for the position of the rover to be corrected (Dail *et al*., 2000). The base station should be set up close to (less than 10 km), and in clear line of sight of the monitoring site.

DATA INTEGRATION AND AVAILABLE RESULTS

The RTK survey data have an accurate relative position, but the absolute position of the data is only as accurate as the base-station position, and to properly integrate the RTK data from different years, the absolute position must have a high accuracy. During data collection for this program, the base station was set up over a benchmark with a known location, ensuring an accurate absolute position. Data, collected by the GSC, did not always follow this procedure, and in some cases, the base station was set up over a survey pin installed by the GSC, and therefore the absolute position was less accurate. At these sites, if the survey pin could be found, its position was re-surveyed, and the differences in the coordinates of the survey pin between the two surveys were used to correct the data of the older survey. This increased the accuracy of the absolute position and allowed datasets to be incorporated into ArcGIS and for a comparison of data properties. At some sites established by the GSC, the survey pins could not be located.

To calculate rates of cliff top erosion, data from different survey years were incorporated into ArcGIS as point data and a separate shape file feature class was created for each year. Using the point to line tool, a line shape file was created. The distance in the cliff top position between each year was measured at an interval along the cliff line (*e.g.*, 2 or 5 m) and the retreat rate along the cliff top measured. To calculate changes along a transect, data was imported into a database and plotted on a graph showing the elevation change over distance from the survey pin to the sea.

Figure 2. *Seaside Drive site showing the location of the cliff-top position at Seaside Drive in 2000 (blue) and 2012 (red), and Transect 1 (green) superimposed on an airphoto.*

Currently, there is not a sufficient period of data collection to allow for the analysis of shoreline change at most sites; reliable estimates of coastal change require measurements over a period of five years or more (Liverman *et al.*, 1994). Two sites that have sufficient data are Seaside Drive in Kippens, which was established in 1991, and Point Verde on the Avalon Peninsula, which was established in 1983. Preliminary results from these are provided below.

CASE STUDIES

Seaside Drive, Kippens

Seaside Drive is located in Kippens, 2 km west of Stephenville on the north shore of St. George's Bay. It is an exposed coastal area with a dynamic wave environment, with a maximum fetch of 500 km from the southwest to the east coast of New Brunswick. The predominate wave approach is from the west and southwest (Shaw and Forbes, 1992; Forbes *et al.*, 1995). The coastline is composed of 10- to 20-m-high bluffs of unconsolidated sand, gravel and silty-clay. Although sections of the cliff are vegetated, and appear stable, other areas are non-vegetated and show evidence of erosion, slumping and gullying. The cliff is fronted by a 15- to 25-m-wide beach composed of pebbles and cobbles, with minor sand and boulders.

Field surveys (beach transects, cliff top and cliff base) started by the GSC in 1991, were monitored again in 1993 and 2000, and in 2011 and 2012. Based on the available data, a comparison between the cliff-top position between 2000 and 2012, and changes in the profile of Transect 1 between 1993 and 2011 were made (Figures 2–4).

Based on these results, at Transect 1, the cliff top retreated at a rate of 8.3 cm/a and the cliff base retreated at a rate of 9.3 cm/a (Figure 3). Cliff-top retreat between 2000 and 2012 was determined by measuring the distance between the cliff-top position in 2000 and 2012 every 2 m along the cliff line (Figures 2 and 4). A negative retreat rate means the area is accreting and a position retreat rate means the area is eroding. Between 2000 and 2012, the cliff top at

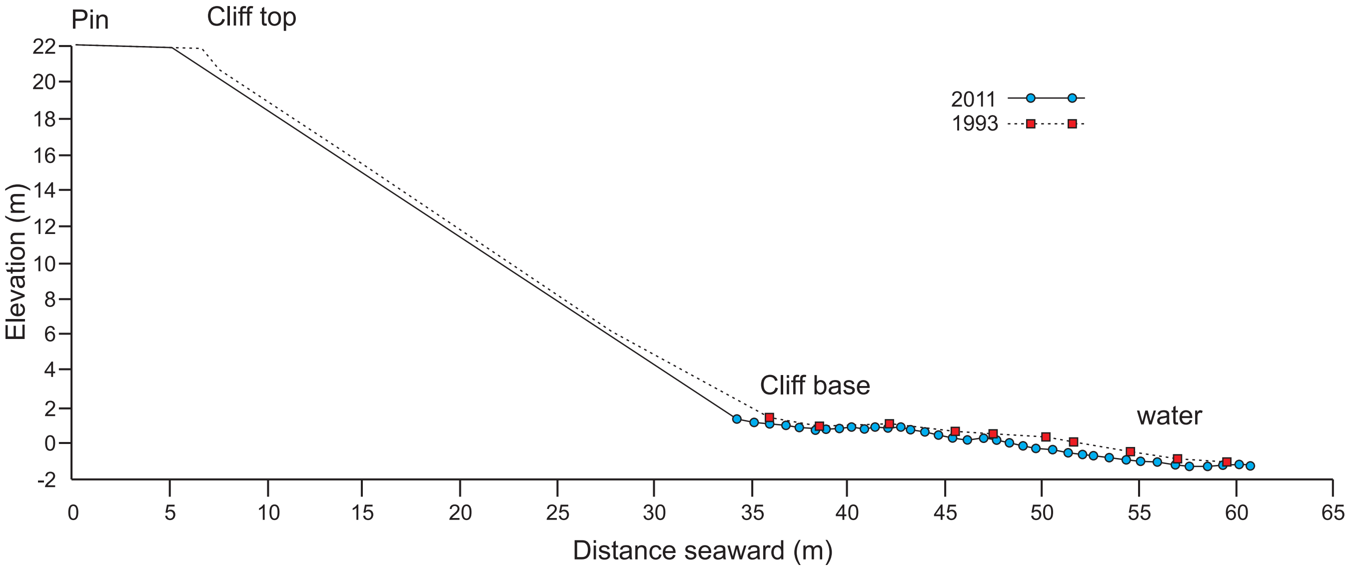

Figure 3. *Cliff and beach profile for Transect 1 at Seaside Drive in 1993 and 2011. The cliff top receded at a rate of 8.3 cm/a and the cliff base at a rate of 9.3 cm/a. Erosion rates are currently not rapid, but as shown in Plate 5, visual change to the area was observed between 2011 and 2012 and increased erosion rates are anticipated for the area.*

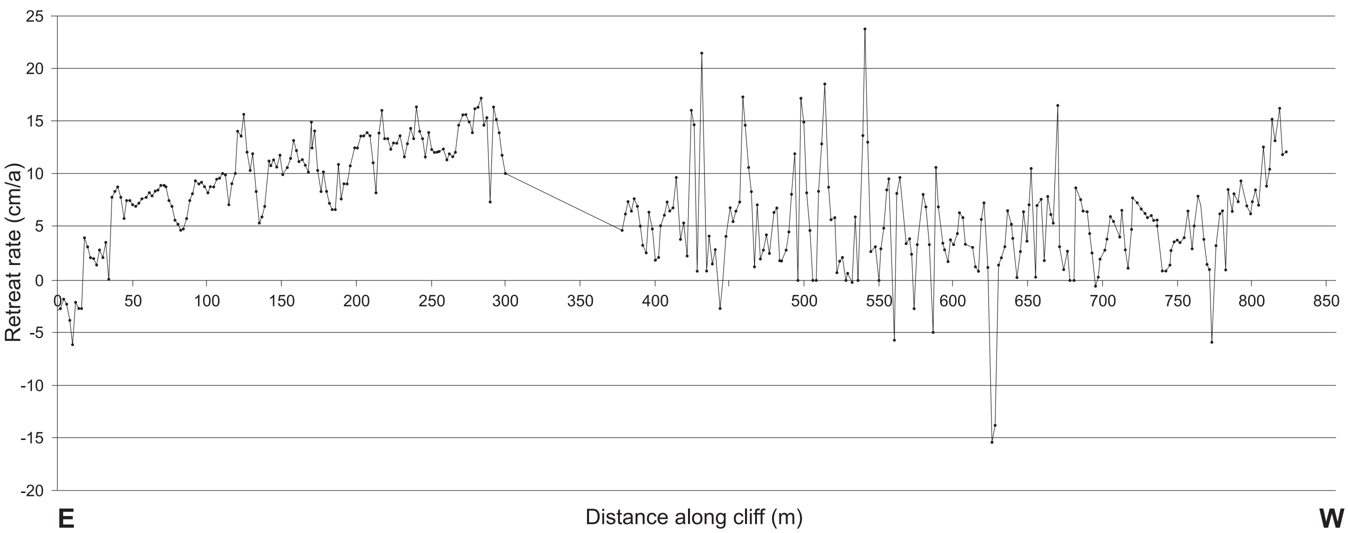

Figure 4. *Cliff erosion as a function of distance along the cliff line at Seaside Drive between the years 2000 and 2012. The retreat rates ranged from -15.5 to 23.73 cm/a with an average retreat rate of 6.9 cm/a. A negative retreat rate means the area is accreting and a positive retreat rate means the area is eroding.*

Seaside Drive was actively retreating with an average retreat rate of 6.9 cm/a, and retreat rates ranged from -15.5 to 23.73 cm/a (Figure 4). With the exception of seven small sections of the cliff top that showed accretion, the entire area retreated between 2000 and 2012. For the areas that showed accretion at Seaside Drive, errors in data collection or material being deposited along the cliff top could be related to the negative retreat rates. Erosion rates at Seaside Drive are currently not rapid. However, change to the cliff-top area was observed between 2011 and 2012, with new development in the area changing the landscape (Plate 5).

Point Verde

Point Verde in Placentia Bay is a gravel and sand peninsula at the end of Placentia Road, west of Placentia. The Point Verde Peninsula provides protection to Placentia from some of the impact of coastal storms. Parts of the community are built close to modern sea level and on raised beaches, and flooding has occurred as a result of high water levels (Liverman *et al.*, 1994).

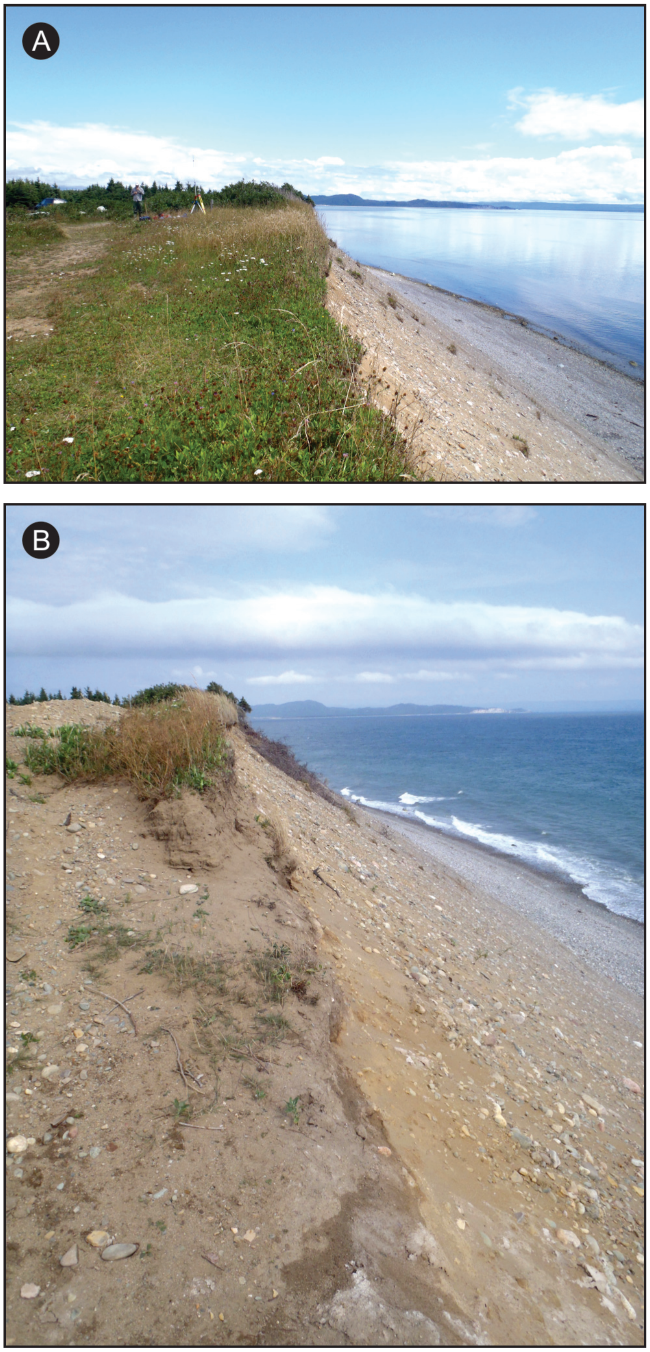

Plate 5. *Cliff-top change at Seaside Drive. A) Coastal cliff in 2011. B) Coastal cliff in 2012. In 2011 this portion of the site had grass on the top of the cliff. Between 2011 and 2012, this property had been developed for a new house, and the vegetation from the cliff top was removed. Removal of vegetation will impact the surface water flow.*

The western flank of the Point Verde Peninsula has a 15- to 20-m-high cliff, which is fronted by a 20- to 30-m-wide beach consisting of rounded boulders, cobbles and pebbles. The site is exposed to large waves from the southwest with a fetch greater than 100 km. The fetch is 45 km to the west and less than 15 km to the northwest. The cliff face is devoid of vegetation, and erosion and gullying are visible (Plate 6).

The area was visited in 1983, and surveyed in 1991 and 2000 by the GSC, and as part of the current project in 2011 and 2012. Data from 1991, 2000 and 2012 are shown on Figures 5 and 6, and were examined to determine the rate of cliff-top erosion. Between 1991 and 2012, erosion occurred along the entire cliff line, with an average retreat rate of 40 cm/a, ranging from 18 to 63 cm/a. The average erosion rate along the cliff between 1991 and 2000, and between 2000 and 2012 was 40 cm/a, and rates of erosion ranged from 7 to 96 cm/a, and 17 to 66 cm/a, respectively.

There is an active aggregate operation in the centre of the Point Verde Peninsula. The outside wall of the pit operation is within 10 m of the cliff edge, and the active pit wall lies 28 m from the cliff edge. If erosion continues and the peninsula is breached, the system will be altered. The peninsula will no longer protect the community of Placentia from the impact of storms from the southwest.

Coastal Processes

At Seaside Drive and Point Verde cliff-top and cliff-face erosion are likely caused by surface- and ground-water flow that form gullies in the permeable sand and gravels, and this material accumulates as fans at the base of the cliff (Plate 7). Waves, particularly during high tides and storms, remove the sediment from the base of the cliff. At Point Verde there are not many boulders or other large material to amour the base cliff from erosion, and wind erosion transports sand away from the cliffs.

The difference in erosion rates may be attributed to the variable presence of vegetation, fetch, wind direction, human disturbances and the amount of surface- and ground-water flow. The geotechnical properties (such as porosity, permeability, and compressibility) of the cliff affect the susceptibility to erosion. Areas of the cliffs with a higher percentage of silt and clay are generally less susceptible to erosion than areas with a higher percentage of gravel and sand, and consequently have lower erosion rates (Jones *et al*., 1993).

Coastal retreat at Point Verde and at Seaside Drive are likely to continue and increased rates of erosion are possible. Climate-change projections for the North Atlantic show an increase in the severity of hurricanes, which could increase the rate of erosion due to large waves and an increase in the number of storm surges (Field *et al*., 2007). There is also a predicted increase in the frequency of heavy

Plate 6. *Cliff erosion at Point Verde. A) Cliff line in 1995. B) Cliff line in 2005. C) Cliff line in 2012. The concrete structure associated with the lighthouse shown in the 1995 and 2005 photos has now fallen to the base of the cliff.*

Figure 5. *Location of the cliff-top position at Point Verde in 1991 (black), 2000 (blue) and 2012 (red) superimposed on an airphoto. The gravel pit has expanded and is now within 10 m of the cliff edge.*

rain events, which could lead to increased erosion from surface-water flow (Field *et al.*, 2007). In the Seaside Drive area, increased urbanization is leading to more roads and houses being built close to the coastline, which could increase surface run-off due to more impermeable surfaces.

CONCLUSIONS

Preliminary results from coastal surveys from Seaside Drive in Kippens and Point Verde show that erosion of these coastal bluffs is variable, and can be rapid (up to 96 cm/a at Point Verde). Although only two sites were reported on, there is variability of erosion rates both within and between monitoring sites. By having a complete, extensive and representative network of regularly monitored sites in the Province, data will be collected and analyzed to determine the range of recession rates, and to delineate areas of high and low vulnerability to erosion in the Province. To meet this need, ongoing work will involve re-surveying coastal monitoring sites. Data can then be imported into a GIS soft-

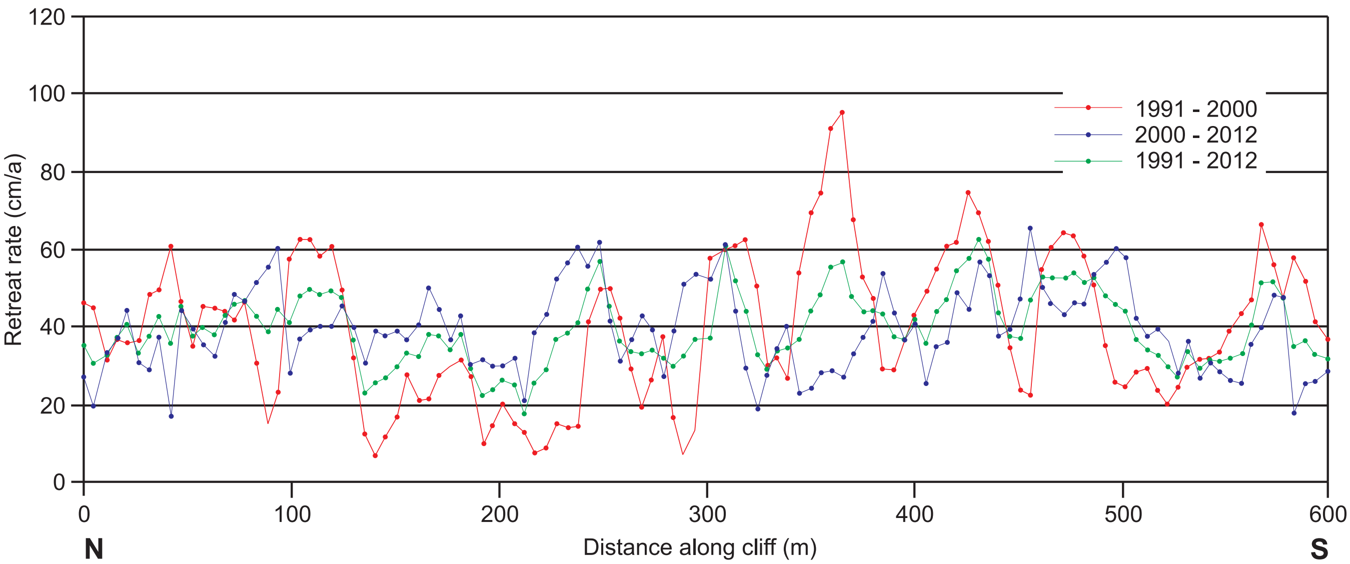

Figure 6. *Cliff retreat as a function of distance along the cliff line at Point Verde for the time period 1991-2000, 2000-2012 and 1991-2012. The data show that recessions rates are variable along the coast and temporally, ranging from 7 to 96 cm/a.*

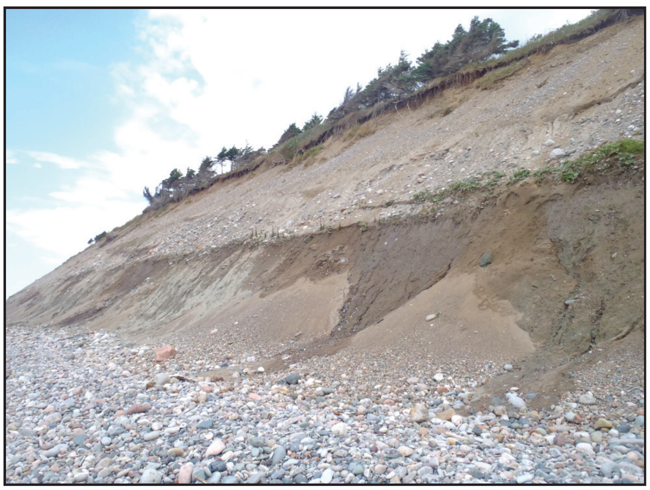

Plate 7. *Coastal cliff on the western part of the Seaside Drive site in 2012. Note the ground water in the sandy gravel in the lower cliff face in the contact between the sandy gravel and compact diamicton.*

ware package, analysis performed and estimates of erosion and vulnerability to change made. Site specific information will be provided for long-term planning and decision making in coastal environments. The GSNL will create and maintain a database, which will be made publicly available through the on-line Geological Survey Resource Atlas.

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