Mapping and Monitoring Coastal Erosion in Nova Scotia

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Introduction

Coastal erosion is a chronic problem in many parts of Nova Scotia where it creates risks to public safety and damages property and infrastructure (e.g. Finck, 2007, 2011, 2014; Taylor *et al*., 2013; Taylor, 2014; Dunham, 2014). Accelerating rates of relative sea-level (RSL) rise (James *et al*., 2014) and other impacts of climate change, including the ongoing reduction of winter sea ice in the Gulf of St. Lawrence (Senneville *et al*., 2013) and projected increases in temperature and precipitation (Ouranos, 2010), ensure that coastal erosion and inland migration of shorelines will continue to negatively impact people and property. As sea level rises, the landward reach of storm surges and waves will also increase. Erosion may be further enhanced due to the loss of protective and wave-attenuating sea ice. Exacerbating the problem is the continued practice of shoreline hardening (either deliberate or a by-product of coastal development) that decreases or ceases local erosion temporarily, but often causes increased erosion on adjacent shores. To address the issue of coastal erosion in Nova Scotia and to provide a solid foundation upon which effective coastal management and planning may be based, a thorough understanding of the basic geology and geography of Nova Scotia's coastline is required.

One of the chief aims of the Department of Natural Resources (DNR) Mapping and Monitoring Coastal Erosion in Nova Scotia project (henceforth, MMCENS; a recent expansion to the pre-existing DNR Coastal Program, which has been ongoing for ~10 years) is to develop standard, repeatable methods for mapping and analyzing shoreline movement so that periodic, systematic and internally consistent updates regarding coastal erosion and land loss can be made. To achieve this goal, program planning has included consultation with fellow Atlantic Canada-based researchers, managers and policy experts from universities and colleges, non-governmental organizations, consulting firms, other provincial departments, and other levels of government to standardize data collection and model construction as much as possible and to determine the best way to utilize the skills of the DNR geologists. Such consultations, conducted over the past two years, have resulted in the development of five key objectives for the MMCENS program: 1) identify coastal regions in Nova Scotia that are vulnerable to erosion; 2) map the geology (surficial and bedrock) and other physical and biological features relevant to determining current and future vulnerability of these coasts to erosion; 3) select sites for measuring coastal erosion and develop long-term monitoring programs; 4) create maps and reports describing the physical characteristics of the coastline and how these relate to the vulnerability of that region to erosion, both at present and in the future (which will rely partly on an understanding of past rates of erosion and shoreline change); and 5) determine the best way to make the maps and reports available, accessible and meaningful to the public, and develop additional products describing the results of the DNR MMCENS program (e.g. website, pamphlet, public outreach talks and other events). This report describes progress made in 2014 on objectives 1-3.

Methods

Site Selection

Three regions were selected for study in 2014: northeastern Cape Breton Island, the central north shore of Pictou County and eastern St. Margaret's Bay in Halifax Regional Municipality (1, 2 and 3, respectively, in Fig. 1). Selection of these regions was based on consideration of the following variables: natural resistance to erosion (based on geology and geography); population;

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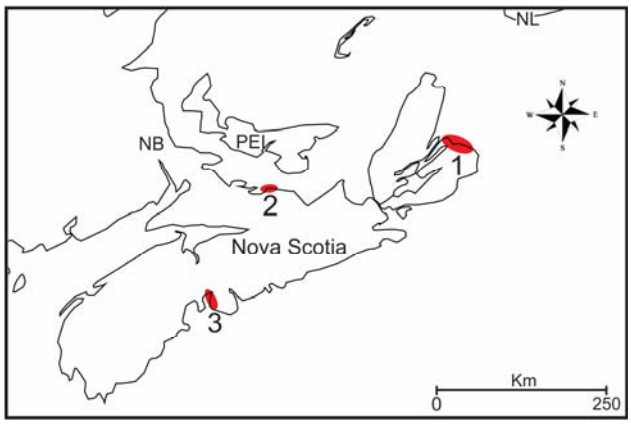

Figure 1. Approximate locations of the three study regions in Nova Scotia (red shaded regions). Region 1 includes three littoral cells: MacLean Cove to Point Aconi, Little Pond and Grace's Cove near Lingan. Region 2 includes an unnamed bay west of Skinners Cove and the coastline extending from Cape John to the marina at the end of Cape John Road. Region 3 includes eastern St. Margaret's Bay, including Cleveland Beach Provincial Park.

transportation, buildings, and other types of infrastructure on or near the coast; social and cultural assets; environmental assets; available data (e.g. lidar surveys); input from municipalities and communities; and presently known hot spots of coastal erosion.

Within each of the three regions, a significant amount of time was spent locating individual littoral cells (see definition below) for detailed mapping and monitoring. In choosing sites, it was important that the selected littoral cells were typical of the regional coastline in terms of their physical characteristics (e.g. geology, geography, exposure) such that a cell-based assessment of coastal erosion, including future risk, would be relevant to the wider region. A littoral cell is defined as a coastal compartment within which a complete cycle of sedimentation—including sources, transport paths and sinks—is contained (although some sediment leak between cells and offshore is common; Inman, 2005). The boundaries of the littoral cell (usually headlands in Nova Scotia) delineate the area within which the budget of sediment is balanced, providing the framework for quantitative analysis of coastal erosion and accretion (Inman, 2005). Establishing such a framework is particularly important for understanding how shoreline development (e.g. coastal hardening) in one part of the cell may or may not impact other parts of the cell.

Mapping and Characterizing the Coastline

What follows is a list of data to be collected and analysed for the purpose of determining areas where the risk of significant coastal erosion is high. The list was compiled from expert interviews and peer-reviewed studies on assessing flood and erosion risks and monitoring programs conducted previously in Atlantic Canada (Catto *et al*. 1999; Tibbets and van Proosdji, 2013; Irvine, 2014; van Proosdji, pers. comm., 2014):

1. Slope (backshore to foreshore);
2. Geology (resistance to erosion);
3. Exposure (i.e. exposure of the coast to wave energy, determined from dominant wind direction and/or storms, fetch length and water depth);
4. Beach width;
5. Presence of vegetation at the coastline;
6. Presence of anthropogenic or natural protection at the coastline;
7. Morphological resilience, including sediment supply, geomorphology, littoral cell structure and dynamics, and freeboard (freeboard is defined here according to Tibbets and van Proosdij (2013) as the height of the coastline in relation to combined elevation of the tide and storm surge height);
8. Ground- and surface-water flow;
9. Past and present rates of erosion or aggradation (determined from coastal monitoring, aerial photo analysis and previous research).

Much of the above data must be collected in the field and will be mapped and surveyed using a GPS camera and a Trimble YUMA hand-held tablet computer. If available, digital elevation models derived from lidar data will be used to determine and map such variables as slope, cliff-top and dune-crest elevation and beach width. Such measurements would be ground-truthed during fieldwork.

Monitoring Rates of Coastal Erosion

Cross-beach profiles and the positions of coastal cliffs and dune-crests will be surveyed and monitored in each of the mapped littoral cells at least once per year at the same time of year; they may also be surveyed following large storms. Special permanent DNR survey markers (Erosion Control Points; ECPs) will be emplaced at the monitoring sites in the future. These permanent monuments will be surveyed (x, y, z coordinates) to <10 cm accuracy using a Leica Viva GS14 Global Navigation Satellite System (GNSS) Real Time Kinematic (RTK) following guidelines outlined in Irvine (2014). The position of the ECP monuments with respect to the cliff top or beach profile surveys will be published and available to the public in various DNR publications. Cross-beach profile data will be analyzed using Microsoft Excel to determine changes in elevation along the profile (indicating accretion or erosion), while rates of change between successive cliff-top and dune-crest surveys will be analysed in ArcGIS (Irvine, 2014). For both beach profiles and coastal cliff surveys, measurements will be taken every 2 m. For the coastal cliff surveys, measurements will made 1 m inland (perpendicular) of the cliff edge for safety reasons. Where there is ambiguity in the precise location of the cliff edge, the point at which there is maximum change in slope shall be measured. Erosion rates will be calculated for the clifftop along transects normal to the local cliff trend at a set interval (2 m; Irvine, 2014).

2014 Fieldwork

Between July and November 2014 data were collected from six sites in three different coastal areas of Nova Scotia. In northeastern Cape Breton Island, the study locations included MacLean Cove, Little Pond (Fig. 2), and Lingan, all in Cape Breton County. On the north central shore of Pictou County, two unnamed coves adjacent to Cape John were studied. In St. Margaret's Bay (Halifax Regional Municipality), the study site was Cleveland Beach Provincial Park. Data collection included the geology (bedrock and surficial) of the backshore, slope of the beach, beach materials (e.g. sand, gravel, boulders or exposed bedrock platform), observations of surface and groundwater flow, nearshore currents, sediment sources and sinks, evidence of recent erosion, and geomorphology. An example of one of the littoral cells at Little Pond, Cape Breton, is shown in Figure 2.

Each of the three regions are different in terms of their underlying geology (an important factor in terms of resistance to erosion), sediment sources, exposure to storms and waves, and winter sea ice conditions. All regions have significant populations and infrastructure at risk from coastal erosion, and all face similar projections of accelerating rates of sea-level rise, increased precipitation and reduced sea-ice cover over the next ~85 years. Observations made in 2014 are currently being entered into a GIS.

In addition to mapping, a significant amount of fieldwork in 2014 was devoted to surveying points (benchmarks) in close proximity to each of the six littoral cells. This was done so that GPS RTK base stations, which must be set up over a point with precise x, y and z coordinates (all points measured subsequently with the rover are related to the position of the base station), can be set up locally during future surveying (part of the long-term coastal erosion monitoring program). Establishing high-precision local benchmarks will increase efficiency during future coastal monitoring as the surveyor will not have to rely upon the closest, but sometimes too distant (i.e. out of range), Nova Scotia High Precision Network monument. The precisely surveyed points will ultimately be published and marked with a permanent Nova Scotia ECP monument.

Future Work

Once fieldwork and background research are complete, the coastal characterization and cliff-top and dune-crest coastal erosion monitoring data will be combined in a GIS to determine vulnerability to coastal erosion within the areas mapped. Methods for combining these data will be decided during the next phase of work, as will the presentation of the results in a clear and meaningful way using maps, websites, reports, and outreach materials and

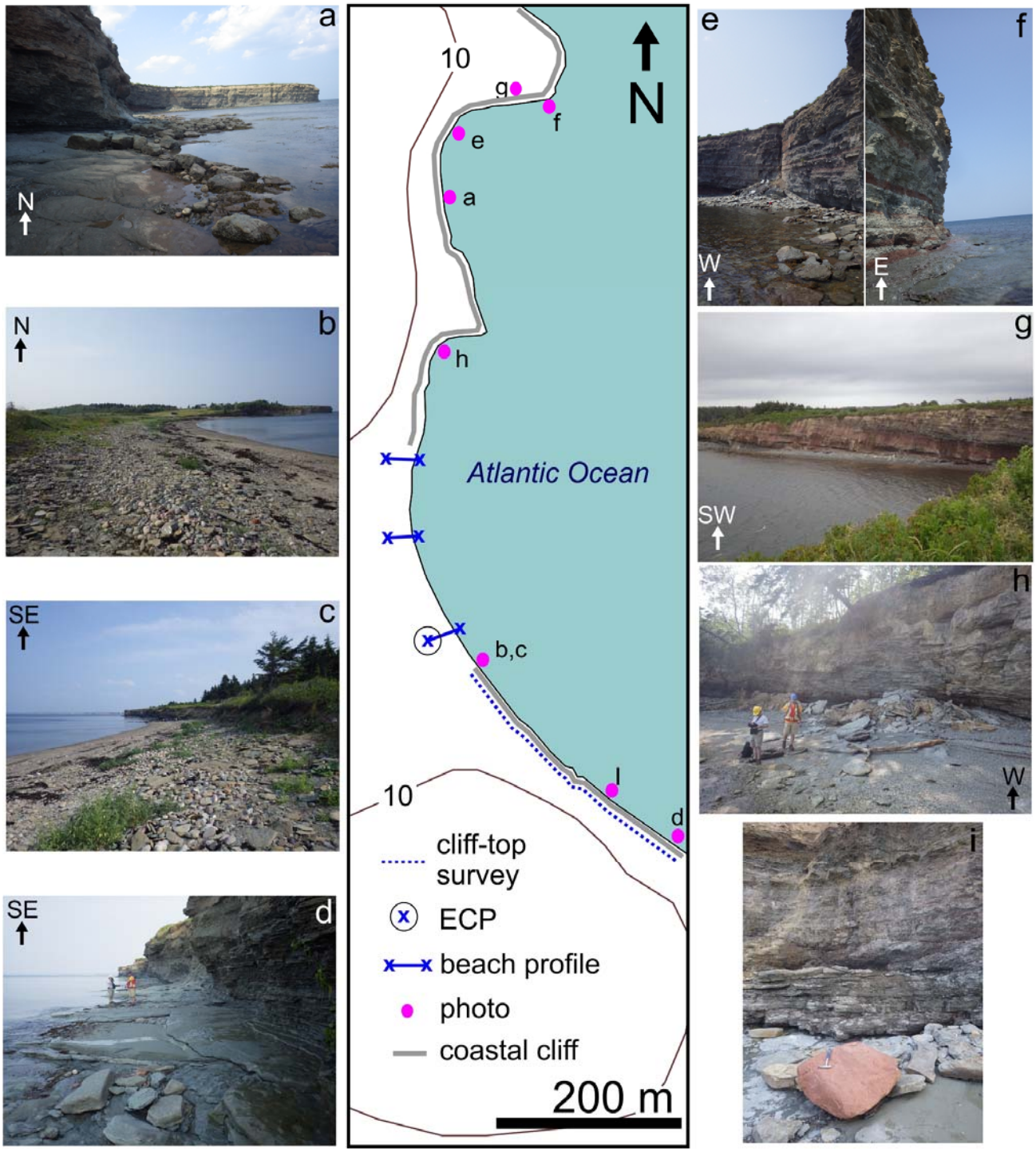

Figure 2. Littoral cell near Little Pond, Cape Breton County. Foreshore materials range from exposed bedrock platforms (photos a, d, f) to thick accumulations of sand and gravel (b, c, h) to natural boulder armouring (i) where erratic boulders are eroding out of the till that overlies the bedrock cliffs. The character of the backshore in this coastal cell varies between steep bedrock cliffs (g) to vegetated lowlands (b). Note evidence of recent erosion of coastal cliffs in photo h, where trees are leaning out over the top of the cliff and rockfall on the beach below. Another larger rockfall event occurred recently in the north corner of the cell (photo e) beneath near vertical cliffs and a suspected fault. ECP stands for Erosion Control Point.

presentations (i.e. objectives 4 and 5). The final results of this work will be published upon completion as a DNR Open File Report and accompanying map. Fieldwork at other vulnerable coastal sites in Nova Scotia is being planned for 2015.

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