Yarmouth Coastal Mapping, a Component of the Atlantic Climate Adaptation Solutions (ACAS) Project

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Introduction

An 11,000 year old submerged delta off Halifax Harbour (Stea et al., 1994), a 6,000 year old flooded lake shoreline in Bedford Basin (Fader and Miller, 2008), and 250 year old flooded historic features at the Fortress of Louisbourg (Parks Canada, 2011) all attest to the fact that sea level is, and has been, rising in Nova Scotia for thousands of years since a post-glacial lowstand (Shaw et al., 2002). The rate of sea level rise has varied with time and location: a rate of ~32 cm/century has been measured in Halifax (Forbes et al., 2009) and Yarmouth (Fig. 1) based on tidal gauge data (Fisheries and Oceans Canada, 2011). This rate of rise is expected to continue or accelerate because of global warming (Intergovernmental Panel on Climate Change, 2007). In combination with sea level rise, global warming may also increase storm events affecting coastal ecosystems and infrastructure. Sea level rise may increase the risk of flooding and coastal erosion, affecting coastal ecosystems and infrastructure

To improve planning and decision making within a context of rising sea level, the Geological Services Division is working with other partners in the Atlantic Climate Adaptation Solutions (ACAS) project. Within this project, the division is focusing on three study areas for coastal hazard mapping: Yarmouth, Lunenburg and Oxford-Pugwash (Fig. 2). These areas represent approximately 130 km of coastline (ten 1:10 000 map sheets), with diverse coastal environments.

This report outlines the approach for the project, with specific reference to the Yarmouth area. The approach can be subdivided into three scientific components: coastal characterization, coastal change analysis, and coastal sensitivity mapping. A key additional component of the project is termed knowledge transfer, where effort will be made to provide local planners and other decision makers with information on coastal hazards.

Coastal Characterization

Coastal characterization is a systematic analysis (i.e. mapping) of the coastline, delineating shoreline features (landforms and anthropogenic features), processes and sediment characteristics. The approach selected for this project is to map the surficial materials of an entire 1:10 000 NTS map area adjacent to the coast. The advantage with this approach over mapping only a strip along the coast (e.g. Finck, 2009) is that it provides users with additional information (especially in the backshore) in a more readable format, and can compliment coastal ecosystem mapping (e.g. Utting et al., 2010). Coastal characterization maps will be the basis for interpretation of coastal hazards. This information is collected from a number of sources, both by remote sensing (aerial videos, satellite imagery, LiDAR and aerial photographs) and by field observation. Field data were recorded using a modified version of Ganfeld. (F. Keppie, this volume, p. x-y)

The Yarmouth area (Fig. 3) has a range of material types along the coastline. Materials mapped include exposed bedrock, drumlins, thin till over bedrock, mudflats and saltmarsh (Fig.4), dunes, sandy beaches (Fig. 5), beach berms (Fig. 6) and anthropogenic armouring (Fig. 4).

Coastal Change Analysis

Change analysis provides a measure of erosion or accretion rates, which are significant for coastal

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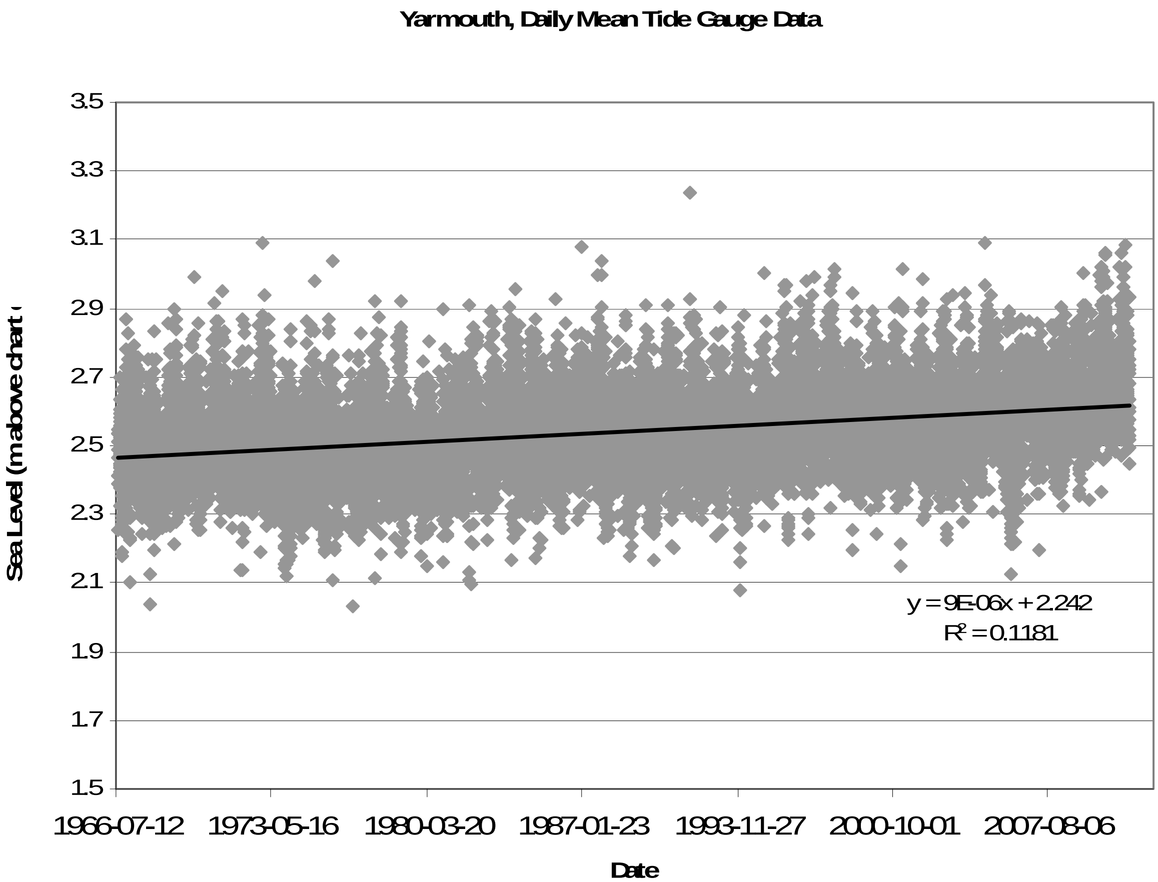

Figure 1. Daily mean tide gauge data from Yarmouth (data from Fisheries and Oceans Canada, 2011). These data show a rise of 32.85 cm/century from 1966 to 2011, based on a linear trend line.

management. A simple method of measuring coastal change is comparing the shoreline from archival aerial photographs to the present-day shoreline. In some coastal environments indicators other than the coastline might be used to measure change. For example in mudflats and salt marshes, mapping channels and/or the seaward edge of the feature, or mapping changes in vegetation levels reveal cyclical or permanent changes in these environments.

Aerial photographs were georeferenced in ArcMap (Geographic Information System-GIS), and coastal change will be measured using the 'endpoint' method (i.e. comparing the oldest available aerial photography to the most recent). In areas of higher susceptibility, coastal change may be measured using photographs from intervening years.

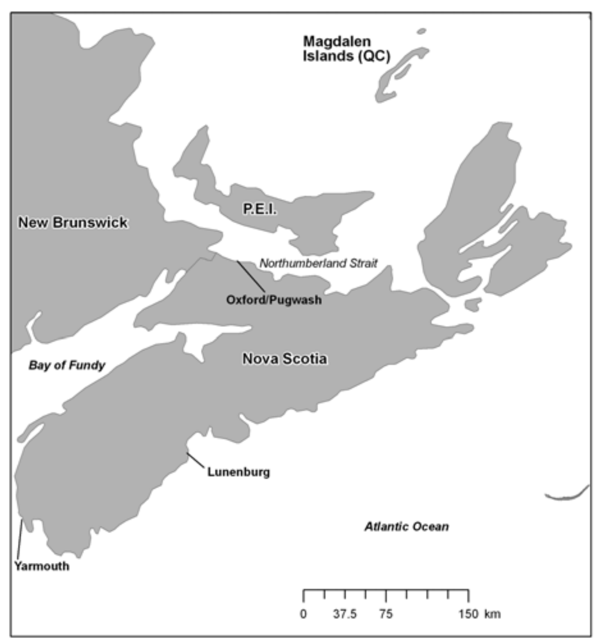

Figure 2. Location of study areas in Nova Scotia.

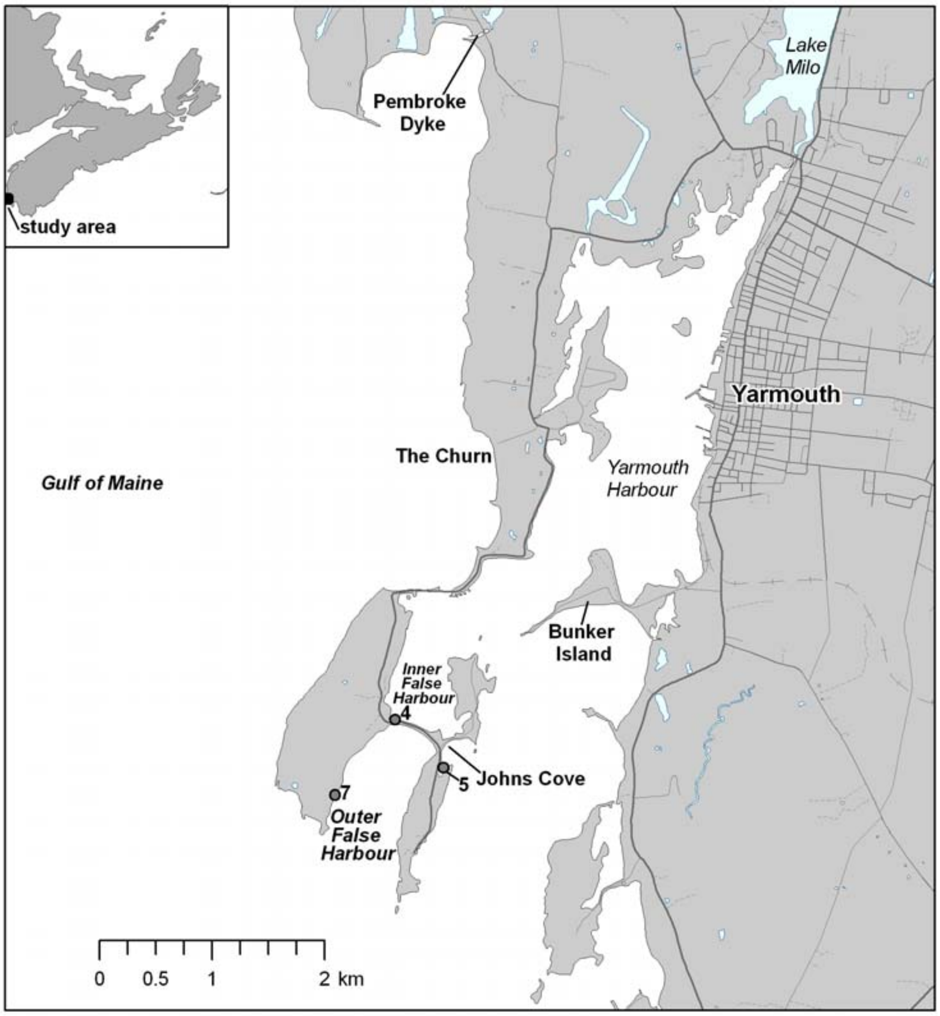

Figure 3. Map of the Yarmouth study area showing locations of features discussed in text and locations of photographs**.**

Figure 4. Photograph of mudflats (right) and saltmarsh (left) at Inner False Harbour.

Figure 5. Sandy pocket beach (flanked by headlands of bedrock) at Johns Cove. Note armouring in front of house.

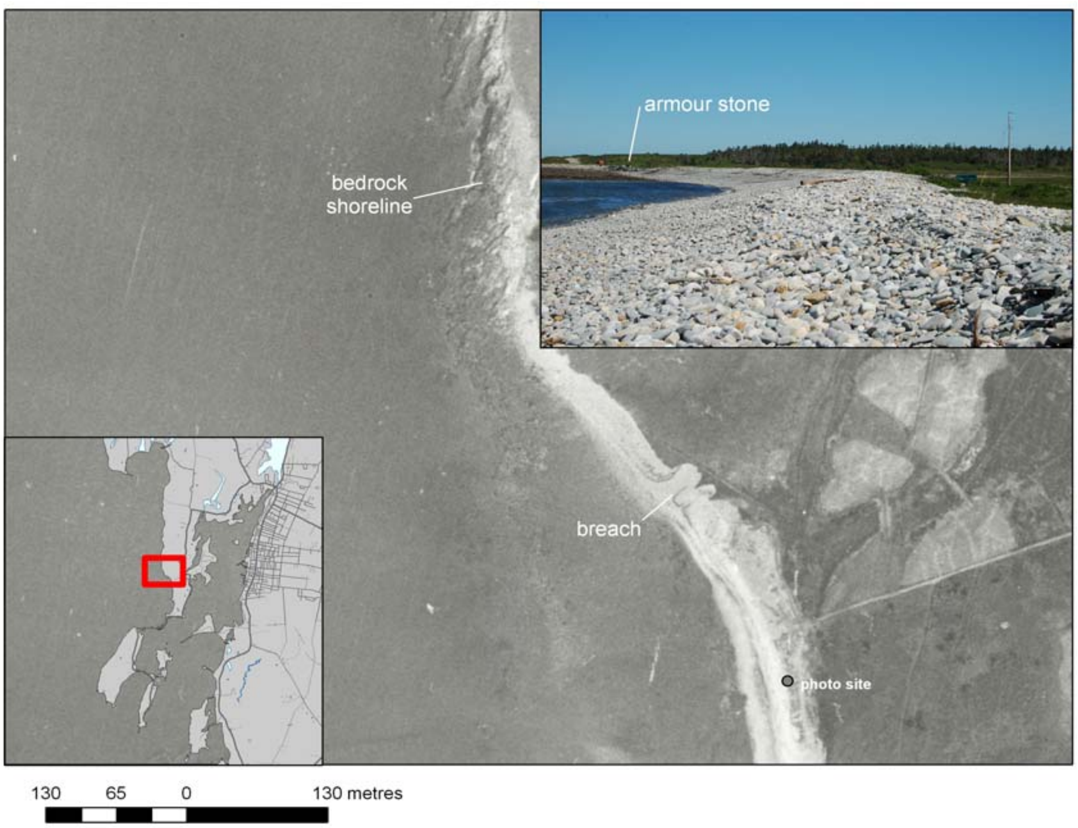

Figure 6. Aerial photograph from 1955 of breached berm near The Churn. Inset photograph (May 2010) shows cobble barrier with armour stone indicated, used to repair berm. Inset photograph taken from location indicated by "photo site" on aerial photograph.

In the Yarmouth area, the durability of a cobble barrier near The Churn (Fig. 3) can be examined using archival aerial photographs. In the 1955 aerial photograph a small breach is evident that was later repaired with boulders (Fig. 6). This example shows that natural features like this barrier, which protects the backshore marsh, are susceptible to overwash and potential breaches. By examining archival photographs we get a sense of processes occurring along the coastline.

Coastal Sensitivity Mapping

This component will integrate all of the available data, collected in the ACAS project and from existing sources, to produce a map of the sensitivity of the coastline. It is anticipated that this product will be primarily used by planners and other decision makers.

Work on this project has identified that the slope of the coastline is a good indicator of potential slope instability and, by association, erosion potential. Areas of unconsolidated material (e.g. till) that form steep slopes tend to have evidence of active mass wasting processes (Fig. 7). Slope measurements can be easily generated using the LiDAR DEM (Fig. 8). As a predictive tool, the slope map must be combined with the surficial geology map. For example steep bedrock cliffs have a lower potential for mass wasting than steep cliffs in unconsolidated material. In this approach, the surficial geology map must indicate if bedrock is present beneath unconsolidated materials (i.e. a till cover over bedrock erodes more slowly than till not on bedrock).

Along with the morphology of the coastline and the material type, the exposure of the coast plays a significant role in the potential for erosion. For example a till bluff exposed to the Atlantic has a greater risk of erosion than one that is within a protected bay. A potential proxy for exposure is fetch (a measure of the distance on water affected by a particular wind direction), and can be calculated by a GIS. The main limitation of this method is that storm events are thought to have a significant influence on coastal erosion (e.g. Forbes et al., 2004; Manson, 2002). Also, this method doesn't account for tidal currents or bathymetry (for example waves breaking on a nearshore shoal).

Figure 7. Mass movement in a till cliff**.**

Alternative methods of determining exposure, such as using computer models, will be investigated.

A map of the sensitivity of the coast will combine the material (from the coastal characterization maps), the morphology of the coastline (LiDAR DEM), erosion rates (coastal change component), and exposure of the coastline to wave attack (interpreted from available wind, bathymetric and topographic data). The resulting product will identify areas of high, low or moderate risk to erosion or flooding, based on present and modelled future sea levels.

Knowledge Translation

A key component of this project is to develop geoscience products that can be used in the planning community. Technical geoscience maps (e.g. coastal characterization maps) must be produced with a scientifically defendable approach;

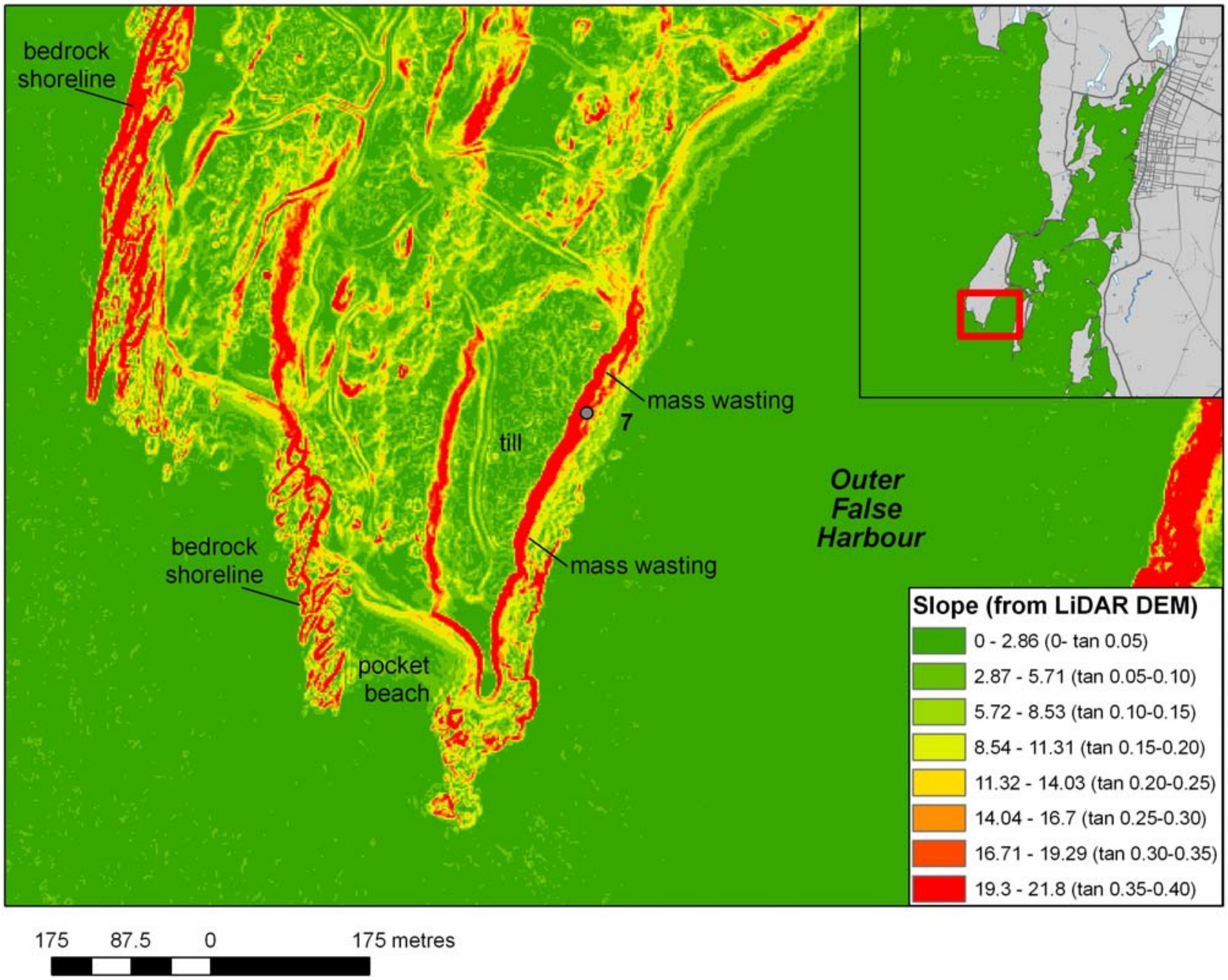

Figure 8. Slopes, calculated from LiDAR DEM. In the southeast of this peninsula, steep slopes (red) and unconsolidated material are prone to mass wasting. The western portion also has steep slopes, but is exposed bedrock and is thus less prone to erosion.

these maps may be too detailed and technical for a non-specialist, however. For this component we will endeavor to communicate with local planners to determine what information is of most use to their work, and develop products accordingly.

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