Monitoring Coastal Erosion Using Remotely Piloted Aircraft

P. Horne

Introduction

The coastal environment is a dynamic system with a multitude of processes governing its evolution. Understanding the current state of coastlines in Nova Scotia, and the stresses being placed upon them, will lead to a broader understanding of how to develop, protect, and live within the coastal regions of the province.

The coast of Nova Scotia stretches over 7500 km and consists of a diverse bedrock geology and geomorphology (Finck, 2007). Coastal erosion has been identified as an issue throughout Nova Scotia, affecting public safety and infrastructure (Nixon, 2015; Utting and Gallacher, 2009). Nova Scotia has areas that are under a high rate of erosion. Past studies have shown erosion rates for coastal bluffs in Nova Scotia as high as 10 metres per year (m a^{-1}) for newly exposed headlands (Taylor, 2007), with an average rate ranging from 1.1 m a^{-1} for drumlins along the Eastern Shore to 0.4 m a^{-1} for the South Shore (Shaw et al., 1998). Along the North Shore (Northumberland Strait) an erosion rate of 0.4 m a^{-1} was found at monitoring sites (Finck, 2007). Although there have been past studies on establishing erosion rates throughout Nova Scotia, there has been a void in the literature regarding how the underlying geology impacts the erosion process, particularly with respect to the orientation of the bedding planes, joints, and induration of bedrock formations. The goal of this program is to establish erosion rates throughout Nova Scotia based on the underlying bedrock and surficial geology, exposure to wave energy, tidal influence, and groundwater. This paper provides an overview of the newly created coastal monitoring program, which looks to address the impacts that the underlying geology plays in coastal erosion rates.

Program Overview

Aerial photography and GPS transects have long been the primary method for studying coastal erosion (Stratford and Langfelder, 1971; Hanslow et al., 1997; Nixon, 2015). Historical aerial photography is typically used to capture longer-term changes in coastlines, which can be impacted by short-term position changes of coastlines, leading to increased error in the analysis (Smith and Zarillo, 1990). Additional error in historical aerial photography analysis of coastlines is also introduced by the challenges of georeferencing the aerial photography. Finding suitable ground control points can be quite daunting, due to the changing nature of the coastline and features over time. In addition to accuracy issues in georeferencing historical photos, it can also be challenging to digitize the edges of bluffs, due to vegetation and the lack of three-dimensional information. The GPS transects also present challenges as they are very labour intensive, and surveying near the edge of cliffs can be dangerous. The profiles also only provide two-dimensional views of the coastal line.

With the development of Remotely Piloted Aircraft Systems (RAPS), more commonly known as drone technology, high resolution (1 to 2 cm) aerial photography can be captured and, using photogramtrey software such as Pix4D, high resolution point clouds can be produced. Photogrammetry utilizes the geometrical relationship that exists between the spatial position of points within the two-dimension image to their corresponding position in three-dimensional space (Hanslow et al., 1997). An example of the three-dimensional point cloud from Cheverie along the Bay of Fundy is shown in Figure 1.

In 2019 a multiyear coastal monitoring program was launched using the remotely piloted aircraft to capture 3D models of the coastline throughout Nova Scotia. The 3D models will be used to measure erosion rates, storm surge vulnerability, and beach stability, as well as to monitor the impacts of sea-level rise on the different coastal regions of Nova Scotia. The main goal of the program is to develop localized erosion rates at a community level throughout Nova Scotia based on

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Figure 1. High density 3D point cloud of Cheverie, Nova Scotia, showing an active erosion site with gypsum and anhydrite outcrop at the base of the slope.

the underlying geology. In 2019, more then 60 sites were surveyed. The aim for the 2020 field season will be to re-survey these 60 sites and, if time permits, an additional 10 sites along the Eastern Shore, and up to 30 sites throughout the Cape Breton, South Shore, and Annapolis Valley regions to fill in gaps (Fig. 2).

The primary objective of the 2019 and 2020 field seasons is setting benchmarks for the yearly quantity of surveys to measure the rate of change along the coastline. During 2019, sites along the North Shore, Cape Breton, Bay of Fundy and South Shore were collected. The Eastern Shore will be captured in spring of 2020. The sites provide regional coverage and capture the distinct differences each region faces from large tidal influence, wave direction, and exposure.

Though most areas expect to see an eroding shoreline, it is important to note there are also selected sites to measure progradation. Progradation is the seaward advancement of shoreline, often in areas such as salt marshes. Sites have also been selected to examine the effects that underlying bedrock and surficial geology play in erosion rates. When selecting sites, exposure to wave energy, tidal ranges, and anthropogenic structures, such as armouring, are also considered. This study also aims to capture the effectiveness of different armour practices; from hard armouring, such as placing large stones, to soft armouring, using vegetation.

Methods

The monitoring sites are surveyed using a survey-grade Real-time Kinematic (RTK) GPS system and RTK RPAS. The GPS system is used to survey in-photo targets throughout the monitoring site. The photo targets help to align the RPAS photos

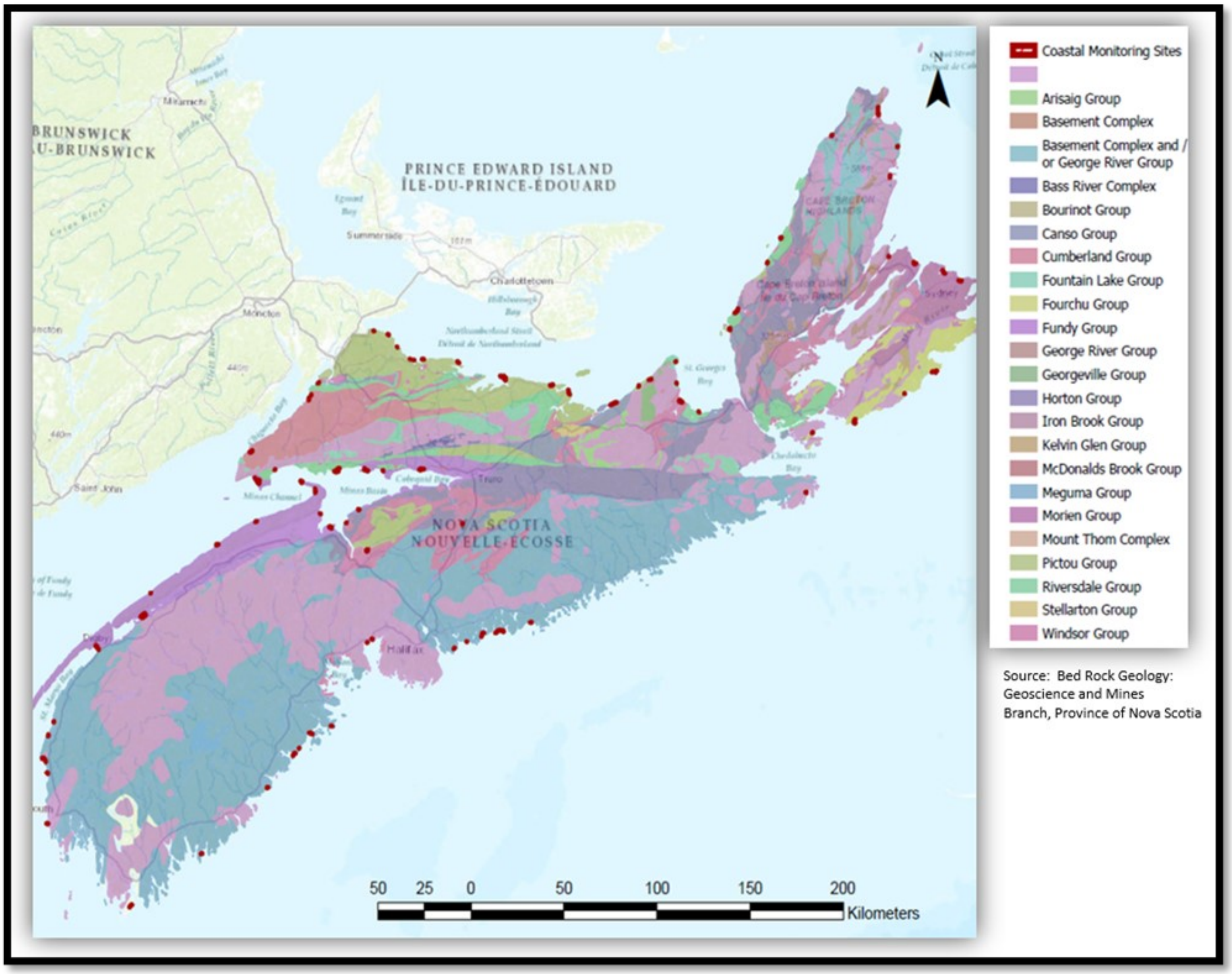

Figure 2. Overview of coastal monitoring sites. Red dots indicate the location of 2019 survey sites.

and tie them to the local coordinate system being used (Fig. 3).

The RPAS are flown over the monitoring sites in a grid formation at a set elevation with significant overlap (80% front & 70% side). The location of the photo is captured by the on-board RTK GPS system, and the orientation and direction of the camera is also assigned to the survey's metadata.

The aerial imagery from the RPAS is combined with the GPS information within PiX4D, a photogrammetry software used to produce orthophoto mosaics from the images along with 3D point clouds. The point clouds have approximately 200 pts per square metre, with accuracy in the 3 to 5 cm range over non vegetated regions. Vegetation will affect the accuracy of the ground points, as the ground needs to be visible from multiple photos to determine a location co-ordinate.

Field observations are also conducted at each site, recording the site's characteristics with ArcGIS Collector, which is a mobile GIS application. The use of ArcGIS Collector allows for the GIS feature class to be generated in the field capturing: the presence of active erosion, slope/height of the shoreline, surficial to bedrock ratio, strike/dip measurements, induration, bedding thickness, grain size, fissility, rock type, surficial sediment type, slope of beach, and the presence of groundwater discharge.

Initial Results

To date, the program has focused on capturing baseline surveys at 100 sites throughout Nova Scotia. The actively eroding sites will be surveyed annually, and those deemed to be lower erosion risk sites (hard bedrock outcrops) surveyed on a 2

Figure 3. Geological field assistant Justin Tupper conducts a GPS survey in 2019 of aerial photo targets for an RTK Phantom 4 drone, shown in bottom right of photo.

to 3 year interval. To date, 60 of the planned 100 sites have been surveyed and there have only been repeat surveys conducted along the North Shore to capture damage from Post-tropical Storm Dorian. The repeat surveys along the North Shore allowed for erosion rates to be captured, showing the effects of the storm. At Heather Beach on the North Shore, the edge of the bank retreated up to 2.4 m from April 2019 to October 2019. Heather Beach has a relatively low shoreline with a 2 m high till bank. There was no bedrock outcrop observed, but there are sandstone boulders imbedded up to 1.5 m in the bank (Fig. 4). The lack of outcrop leaves the till bank exposed to wave action. Armouring has been attempted at each end of the monitoring site at Heather Beach. The smaller stones, which were placed on the western side of the site just above the sandstone armouring, were washed away. The armour appears to have migrated seaward, causing the till to slide and the edge of the bank to retreat.

Future Work

Future work will entail providing yearly reports from each of the monitoring sites, and documenting the retreat or progradation of the coastline, along with the volume of material that has been added or removed. Yearly site observations will be made to document any changes in underlying conditions, such as slope of beach and banks, height of shoreline, exposed bedrock outcrops, and armouring. As the study progresses, we hope to be able to better predict the rates of erosion throughout Nova Scotia when identifying sites with various characteristics of wave energy, bedrock and surficial geology, along with documenting the effectiveness of different shore-hardening practices.

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Figure 4. Heather Beach, Nova Scotia. The small rock armouring along the left side was removed between July 2019 and October 2019.

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