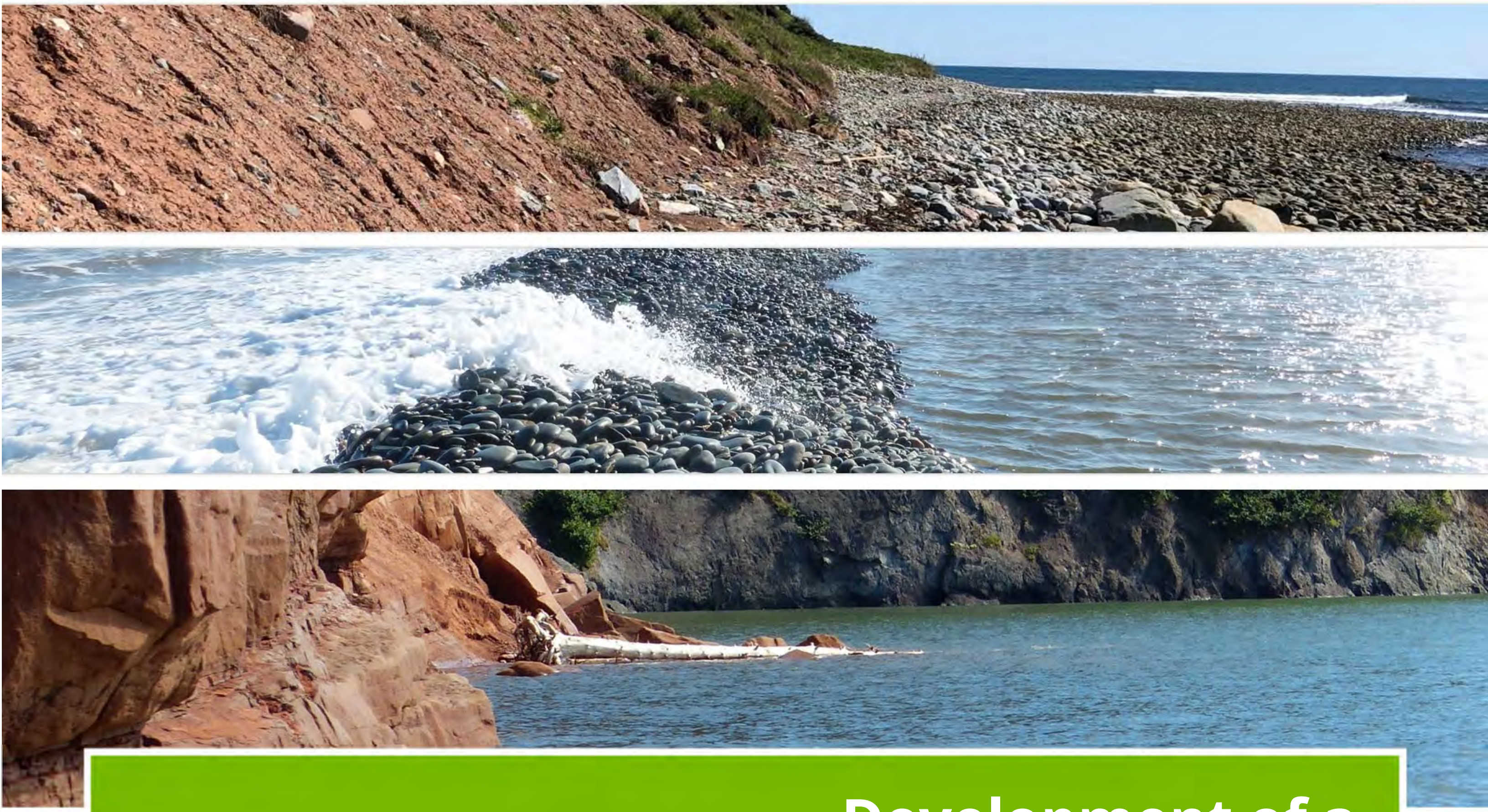

Development of a Coastal Erosion Risk Factor Assessment Standard

Technical Background and Guidance

201157.00 • March 2021

Executive Summary

Nova Scotia's new **Coastal Protection Act (CPA)** will establish a **Coastal Protection Zone (CPZ)** to prevent development that may either damage the natural bio-physical functioning of shorelines, or put people and property at flooding and erosion risks, which are increasing with sea level rise and climate change. Flooding risks to development will be mitigated through vertical setbacks from the high water. Erosion risks will be mitigated through horizontal setback distances. This project for Nova Scotia Environment (NSE) establishes a methodology to assign horizontal setbacks through a **Coastal Erosion Risk Factor Assessment (CERFA)**.

Horizontal setbacks must account for Nova Scotia's very diverse coastlines, notably in geology and wave exposure. Most other jurisdictions with established setbacks use either a fixed distance (not advisable given Nova Scotia's diversity), or a function of the observed erosion rates and planning horizon. Erosion rates are typically estimated from systematic historical air photo studies, which have not been conducted for NS and don't account for future climate change. Alternatively, the CERFA will assign horizontal setbacks from local observations of coastal profile (slopes and distances), geology and wave exposure. The CERFA will be conducted by a qualified Designated Professional hired by the property owner. As such it must balance required complexity with ease of use and affordability.

The CERFA calculation procedure is based on established methodologies for geological erodibility classification, combined with basic coastal engineering principles. The total setback obtained is the sum of three components:

1. **Erodibility allowance,** to account for ongoing erosion based on the combination of geologic material and wave exposure. The erodibility component was initially calibrated using a series of observed historical erosion rates throughout the Province.
2. **Sea level rise allowance**, to account for the likely erosion due to the coastal profile adjusting to future sea level rise over the planning horizon.
3. **Stable slope allowance**, to account for potential erosion due to sudden slope failure towards the end of the planning horizon.

CERFA setbacks are not intended to predict future erosion, but to provide a safe buffer using a precautionary approach. Based on initial pilot tests, the tool is deemed to provide defensible process-based setback allowances. To inform the discussion on CPZ width, setback distances were produced for a series of pilot tests for a proposed 80 year planning horizon, to align with flood mapping horizon. For precautionary purposes, the planning horizon should be as long as possible. Further testing and calibration of the tool is highly recommended, through targeted air photo studies and building of a long-term erosion observation network of sites as recently initiated by the Provincial Geological Survey. Regular updating of the CERFA tool should be conducted through an adaptive management framework i.e. implement, monitor, learn, modify. This is to allow the CERFA to adapt to a non-stationary coastal environment, with evolving climate change over long time horizons.

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Appendices

Chapter 1 Introduction

1.1 Project Context

1.1.1 Coastal Erosion Challenges

Nova Scotia features 13,300 km of extremely diverse coastline. It can range from convoluted bays with alternating pocket beaches and rock outcrops, to huge Fundy mudflats and rockfaces, as well as long stretches of sandy beaches and dunes. Much of this coastline is expected to become increasingly vulnerable to climate change in the coming years, which is compounded by land subsidence (i.e., the land mass of NS is sinking).

Coastal erosion is a natural process but becomes a problem for communities and land owners when it meets the built environment. Some areas can be relatively safe from coastal erosion, such as granite outcrops facing the Atlantic Ocean. However, other areas such as beaches and till bluffs can be extremely erodible. There can be significant variability in the coastline's physical characteristics and erodibility, even along short segments of shoreline (i.e. 10 meters or less). This variability makes it difficult to apply uniform coastal erosion mitigation strategies and broad policy measures along extensive stretches of shoreline. An innovative and robust regulatory framework accompanied by a set of assessment tools is therefore required to manage risk identification and response to shoreline erosion on a localized case-by-case basis.

Coastal development is frequently impacted by coastal erosion, causing direct and indirect disruptions and interference with the natural bio-physical coastal system and associated dynamics. Inappropriately-sited development is exposed to greater risk from flooding, wave damage and erosion. These coastal risks are compounded by climate change through sea level rise (SLR), and in some regions of the Province, the loss of protective sea ice in the winter. Keeping permanent structures out of high-risk areas is the most practical and cost-effective way of reducing these risks.

1.1.2 Nova Scotia's Coastal Protection Act (CPA)

1.1.2.1 Objectives

Nova Scotia's new Coastal Protection Act (CPA) was passed in the spring of 2019 in legislature as Bill 106[1]. The Act, which received the support of all political parties, will be proclaimed into law once regulations are approved by the Governor in Council. The **CPA's intent** is to restrict coastal development in cases where it may lead to either one of the following negative consequences:

- Damage to, or interference with the natural bio-physical coastal systems and associated dynamics.
- Structure damage from coastal flooding and/or erosion to residences and buildings.

Coastal ecosystems, such as tidal wetlands and barrier beaches, provide habitat, support biodiversity, sequester carbon dioxide, and provide natural infrastructure to defend upland areas from the force of the open ocean. When the Coastal Protection Act is proclaimed into law, Nova Scotia will be taking an important step to reduce the risks to new construction on our coastline, while strengthening protection for our important coastal ecosystems.

1.1.2.2 Regulatory and Risk Management Mechanisms

The specific mechanisms of the Act will be spelled out in regulations, which are currently being developed. Developing these regulations requires consideration of geomatics, geology, engineering, municipal planning and policy. In 2018, Nova Scotia Environment led public consultations, which helped inform the Act itself. NSE is continuing to engage a broad range of stakeholders to ensure it will be practical and effective. These include professional organizations, municipal staff, and environmental groups such as the Ecology Action Centre and East Coast Environmental Law.

Once the regulations are ready, the Act can be proclaimed into law and come into effect. The CPA introduces the following **regulatory and risk management mechanisms** applying to development:

- Coastal Protection Zone (CPZ) delineation, for which the provisions of the CPA and associated building setbacks would apply. Building setbacks will include both vertical (MBE-Minimum Building Elevation) and horizontal (from CERFA) components, as described in the next section.
- Coastal Protection Zone activities to be regulated.
- Regulations for Municipalities.
- Regulations for Designated Professionals.
- Coastal Erosion Risk Factor Assessment (CERFA) Standard to determine horizontal setbacks. The development of this standard is the purpose of the present project.

[1] https://nslegislature.ca/legc/bills/63rd_2nd/1st_read/b106.htm

- Shoreline Structures Standard which will apply to certain permits used by the Department of Lands and Forestry pursuant to the Crown Lands Act and/or the Beaches Act.

The provisions of the CPA will apply within a CPZ which will include areas immediately adjacent to and upland of the high water mark[2] to determine what construction can take place, and where. It must integrate with the NSL&F Crown Lands and Beaches Acts below the ordinary high-water mark (OHWM), which in terms of permits, will require compliance with the CPA regulations. NSE and L&F staff are collaborating to create regulations and/or regulatory standards governing the construction, repair, modification of shoreline structures within the CPZ that have the potential to disrupt natural coastal processes.

1.1.2.3 Linkages to Existing Regulations

The Act primarily works through existing permitting processes that are familiar to the public. From the ordinary high-water mark to the sea, the Coastal Protection Act will add regulatory strength to existing policies, guidelines and permitting processes under the Crown Lands Act and the Beaches Act. The regulations will build on existing guidelines for the construction of wharves, boat slips and shoreline armouring.

1.1.2.4 Exceptions

NSE recognizes that the coast is the centre for much of Nova Scotia's economic activity, so there are various exceptions under the CPA. These include commercial and or industrial uses that require direct access to the water, or that are governed under other legislations such as the Fisheries and Coastal Resources Act and the Marine Renewable Energy Act. Public infrastructure and federal crown lands are also exempted. The Act also provides for flexibility, where existing building permits are in play at the time it comes into effect.

1.1.3 Setback Distances for Risk Management

The Coastal Protection Act does not mean there will be no construction on or near the coast. It will, however, establish clear rules for building shoreline structures that may harm ecosystems, and a province-wide system of vertical and horizontal setbacks designed to avoid construction in coastal locations at risk from of coastal flooding and coastal erosion.

Setbacks are a forward-looking planning tool to prevent damage from flooding and erosion and protect coastal habitats and green space. Coastal setbacks enforce mandatory distances between the water and built structures. They minimize the vulnerability of infrastructure to coastal hazards, protect public health and safety, and limit environmental damage.

[2] Defined as the Higher High Water Large Tide (HHWLT) if available, or the more common survey metric Ordinary High Water Mark (OHWM).

Some municipalities in Nova Scotia already have both vertical and horizontal setbacks in place through land-use bylaws. Most do not, though, so the CPA regulations will include a province-wide schedule of vertical setbacks for all sections of the coast.

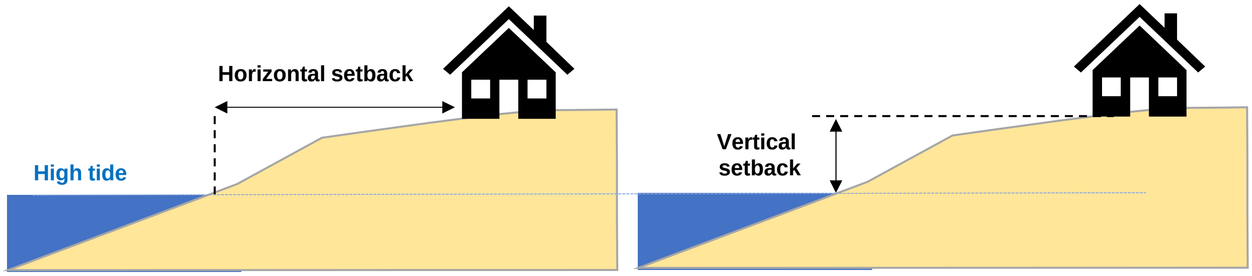

Figure 1.1: Horizontal vs. Vertical (Elevation) Setbacks

Vertical setbacks require structure at a certain elevation above sea level for flood protection. Horizontal setbacks are typically for erosion protection.

Minimum Building Elevations (MBE) will be set out in a schedule with vertical setbacks for all sections of the coast that fall within the CPZ. These vertical setbacks will be a vertical distance above-mean sea level, adjusted for local tides, and incorporating an allowance for relative sea level rise and potential storm surge.

In contrast, **horizontal setbacks** can be difficult to determine because the natural processes driving coastal erosion are complex and non-linear in time and space. Notably, due to the intricate diversity of the NS coastline, blanket regional horizontal setbacks would not be appropriate, and situations need to be examined on a case-by-case basis. The difficulty in getting an accurate erosion projection (which is often based on extensive study) must not slow down efforts to introduce a simple and accessible risk identification tool which has broader benefits for small coastal communities and its residents. Such a tool should incorporate sufficient allowance for uncertainty within a precautionary approach, and thoroughly document assumptions and limitations. The objective of this study is to develop such an assessment tool, as follows.

1.2 Coastal Erosion Risk Factor Assessment (CERFA)

1.2.1 Objectives

Horizontal setbacks are not a new idea; however, a novel aspect of the CPA is how they will be put into action across the province. The geology, topography and exposure to wave energy vary significantly around Nova Scotia's coastline, sometimes within a few tens of meters. This makes it impractical to set a single appropriate setback distance for the entire province, or even for a region. Once the CPA comes into effect, a property owner who intends to build in the CPZ will first be required to retain a Designated Professional (DP) to assess the coastal erosion risk at the building site.

The designated professional must use the specific CERFA methodology, developed as part of this project, to determine a site-specific horizontal setback. Rules around who can act as a designated professional will be set out in the regulations. The designated professional will perform the assessment at the landowner's expense and provide a DP Report specifying the setback for the proposed building site. If a landowner wishes to build in the Coastal Protection Zone, they must provide a copy of this report to the municipality, and the proposed location of the structure must comply with the setback determined by the designated professional in order for the municipality to issue a building permit.

The CERFA, using a set of standardized methods to characterize coastal erosion as defined in the present project, will assign a setback to the property. For a building permit to be issued:

- The elevation of the proposed location must exceed the MBE requirement.
- The proposed location must be compliant with the horizontal setback from the OHWM as determined by the DP, using the CERFA.

The CERFA has been developed to balance the required scientific basis with practicality and affordability. The CERFA is a general risk reduction tool and is not intended to guarantee that erosion will not impact the property.

1.2.2 CERFA Application and Limitations

The document presented here sets out descriptions of the methods to be followed and proposes reference documents to use in order to apply effectively the CERFA tool. It is intended to impart consistency to the approach taken across the Province. This document also presents the rationale for the methods selected and the approaches specified.

It is recognized that Nova Scotia is a province with wide ranging topographic, hydrologic, geologic, and coastal characteristics to name but a few. No model can accurately predict future erosion rates over such a wide range of complex conditions, with the additional impact of sea level rise and over a typical planning horizon. The tool developed as part of this project aims to provide a prudent risk management approach on a consistent basis to account for such variations, and provides an output that is reasonable relative to 'typical' erosion rates for the Nova Scotia coastal settings under assessment.

While the tool requires a range of common inputs, a certain level of qualified judgement is required for completing a CERFA. This judgement will be made by the Designated Professional, who is responsible for:

- Ensuring they have the adequate qualifications to complete the CERFA.
- Completing the CERFA as prescribed in regulations and the guidance documentation provided by NSE.

The actual erosion to occur at a property over the planning lifetime may differ from the setback allowance output by the CERFA. Application of the CERFA as prescribed in the present guidance does not constitute guarantee that the future erosion over the planning lifetime will be within the CERFA setback output.

1.3 Study Scope for Developing a CERFA

The project is structured around the following four critical scope components, with deliverables in bold:

1. Develop a detailed **prototype operational version of the CERFA**, based on the general framework outlined by NSE.
2. Determine **schedule of horizontal setbacks.**
3. **Field-test** the CERFA prototype.
4. Provide a **finalized version of the CERFA model to NSE**.

The determination of extreme water levels including storm surge and sea level rise, which may be incorporated in the CERFA at a later stage, is not included in the present project scope.

Chapter 2 Background Information

2.1 Coastal Processes

Coastal erosion defines the natural process where rock, cohesive sediment, and cohesionless beach deposits at the shoreline break down due to physical processes such as weathering and storm action. These include waves, tidal action, wind, storm surge, ice, rain, and surface runoff. This section introduces the natural coastal processes that impact coastal erosion, the most important being geology, water levels and waves.

2.1.1 Coastal Profile Definitions

Figure 2.1 illustrates the standard coastal zone terms adopted for the CERFA in NS.

- The nearshore region is where waves become steeper and break. The location where waves break in the nearshore is known as the surf zone.
- The foreshore is the region between the high and low water marks.
- The backshore is the beach area between the high water mark and the toe of the eroding shoreline feature (bluff, rockface or dune).

For rock and cohesive sediment, there will typically be a transition to a steeper slope (bluff, rockface, or dune) at the HHWLT, marking the transition from backshore to land. This steeper slope may also be fronted by a tidal wetland.

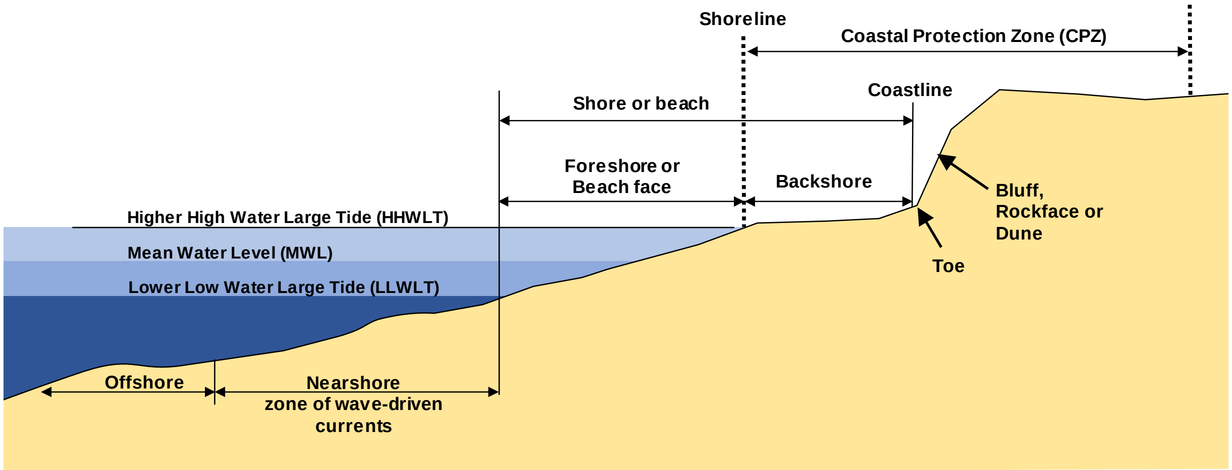

Figure 2.1: Definition of Shoreline Profile Terms – Adapted from Mangor et al 2017

2.1.2 Waves

In the long-term, the exposure of a coastline to wave energy is a key controlling factor in the magnitude of coastal erosion, along with the resisting properties of the materials. Winds can generate moderate waves over limited 'fetch' (i.e. over-water) distances in protected bays, or large waves over the open ocean with the greatest potential for causing coastal damage. Tsunami waves are rare in the Atlantic region and are not generally factored into coastal planning or design in Atlantic Canada. Large offshore waves occur with every major storm. Near the coast, approaching wave crests bend towards the shoreline, become steeper, and ultimately break. The breaking wave height is primarily controlled by water depth. As a result, storm surge events close to high tide with deeper water near the shoreline allow increased erosive wave action. Sea-level rise will cause higher waves at the shore. Therefore, coastal planning and infrastructure design must deal with both higher water levels and potentially stronger wave impacts.

Variations Across Nova Scotia

While each site is unique in terms of its coastal processes, Nova Scotia is characterized by the following trends:

- **North Shore –** Storm surges are highest in the Northumberland Strait, where the tidal range is relatively limited. Therefore, a strong storm surge can have an impact at most stages of the tide. The Gulf of Saint Lawrence will be impacted by the loss of ice cover from climate change, with increased wave impacts and erosion in the winter.
- **Bay of Fundy –** The large tidal range somewhat decreases the likelihood of storm surges hitting at high tide and causing damage. However, infrequent occurrences of a storm surge coinciding with an extreme high tide can have a particularly strong impact.
- **Atlantic –** Exposed to large swells and storm surges from hurricanes and post-tropical storms.
- **Bras d'Or Lakes –** Exposed to moderate wave action from locally generated wind waves, as well as water level variations from storm surges and lake oscillation. The tidal range is small (less than 0.2 m). As with the North Shore, the protective winter ice cover is expected to decrease with climate change, which will increase long-term erosion rates.

2.1.3 Sediment Transport

Coastal sediment transport typically occurs within 'coastal cells', also referred to as 'littoral cells' (Figure 2.2). A littoral cell is a section of the coastline bound by physical features which have major influence on the local coastal processes such as headlands or harbour structures (Mangor et al 2017). Coastal processes in each cell are relatively independent of those from adjacent cells. Each coastal cell contains a closed erosion and sedimentation cycle including the three following elements:

- Sediment sources e.g. eroding shores, rivers.
- Transport paths governed by waves, tides and rivers. Notably, in the case of waves, the direction of longshore sediment transport is driven by the prevailing wave direction.
- Sediment sinks e.g. tidal inlets, beaches, offshore deposits, tidal wetlands.

Understanding the location of a shoreline property within a particular littoral cell may provide valuable clues as to the local erosion and sedimentation trends. What is happening along one particular part of the coast (especially sand/gravel/cobble coastlines), for example the disruption of a sediment source or transport pathway, influences adjacent shorelines within the same coastal cell.

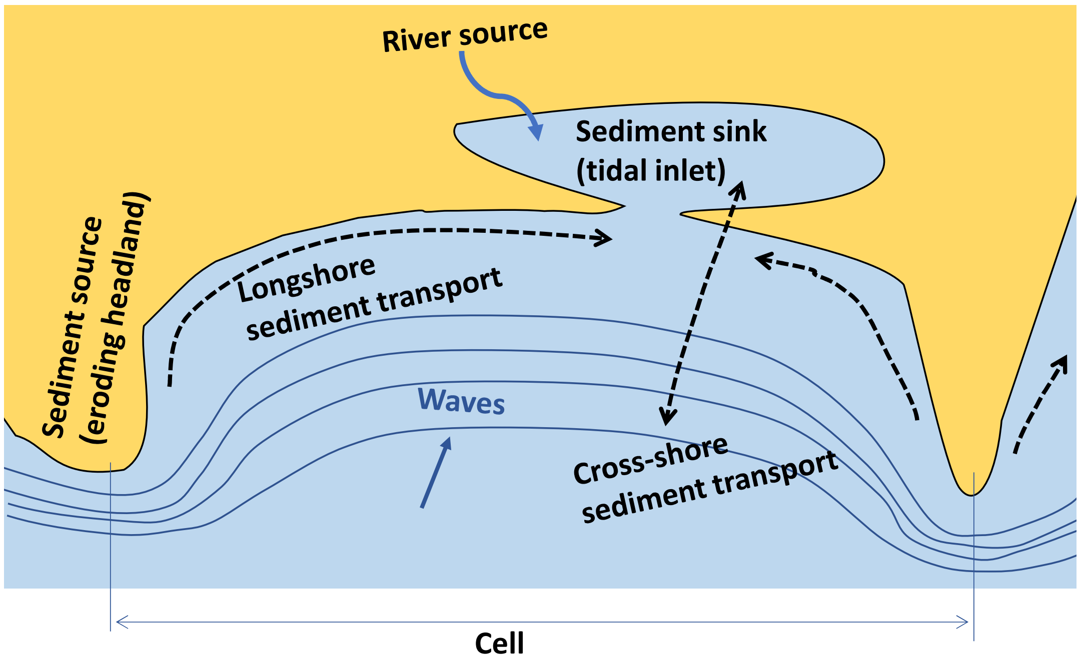

Figure 2.2: Illustration of Coastal Cell with Examples of Sediment Sources, Sinks and Pathways

2.1.4 Geology

Erosion rates can greatly vary depending on the geology, whether the shoreline is a rockface, beach or barrier beach system, or tidal wetland (Davidson Arnott, Ollerhead 2011).

Rocky Coast Types – Bedrock rockfaces are highly resistant to erosion and will remain so despite climate change.

Cohesive Coast Types – Weaker, faster-eroding rock such as sandstone is typically found along the NS North shore, parts of the Bay of Fundy or PEI. Till[3] bluffs generally erode much faster than rockfaces, and are common along the Atlantic Coast of NS, sometimes in the form of drumlins[4].

[3] Till refers to unsorted sediment material of varying size deposited directly by glacial ice and showing no stratification.
[4] A drumlin typically describes an oblong formation of mixed glacial deposits. Along the Atlantic coast of NS, drumlins are oriented southeastward following the prevailing direction of ice flow.

Beaches – Beach areas formed of cohesionless sediment (such as sand, gravel, or cobble) deposited by hydraulic and/or wind action and typically migrate, or may even disappear with accelerated sea level rise in the case of low-lying barrier systems for example.

Tidal wetlands (also referred to as salt marshes) are typically found along depositional areas with lower wave energy. Rising sea level may cause some tidal wetlands to become fully inundated, or migrate further inland given sufficient space and sediment supply.

Further description on coastal geology types is provided in section 2.2 for specific areas of NS, then within the CERFA tool description itself (section 3.4, including definitions).

2.1.5 Potential Human Causes of Erosion

For beaches, typical causes of erosion due to human interference are:

- Excavation of beach sediment (sand and gravel) or dredging for aggregate.
- Interruption of the movement of sand along a beach (longshore transport) by shore-perpendicular structures such as a groynes or breakwaters.
- Harbours trapping longshore drift and thereby reducing downdrift supply.
- Shoreline armouring, or shore parallel structures that interfere with natural cross-shore transport of sediment and beach recovery after storms, and can reflect breaking waves causing scouring at the base of the structure and loss of sediments. Erosion can also occur around the ends of the structure, depending on the wave angle and direction of longshore sediment transport.

Along bluffs or bank shorelines, human causes or erosion may typically include:

- Removal of vegetation on the tablelands, slope, and toe of bluff.
- Alterations to groundwater and overland flow patterns.
- Surcharging of unstable slopes.
- Isolated single lot shoreline armouring which may increase erosion along neighbouring shorelines.

2.1.6 Climate Change and Sea Level Rise

Sea levels have been rising in the Maritimes since the end of last ice age 10,000 years ago. The trend is expected to accelerate with climate change. Climate change impacts on waves and water levels in Atlantic Canada will increase flooding and erosion hazards (Greenan et al 2018), as shown in the summary flow chart.

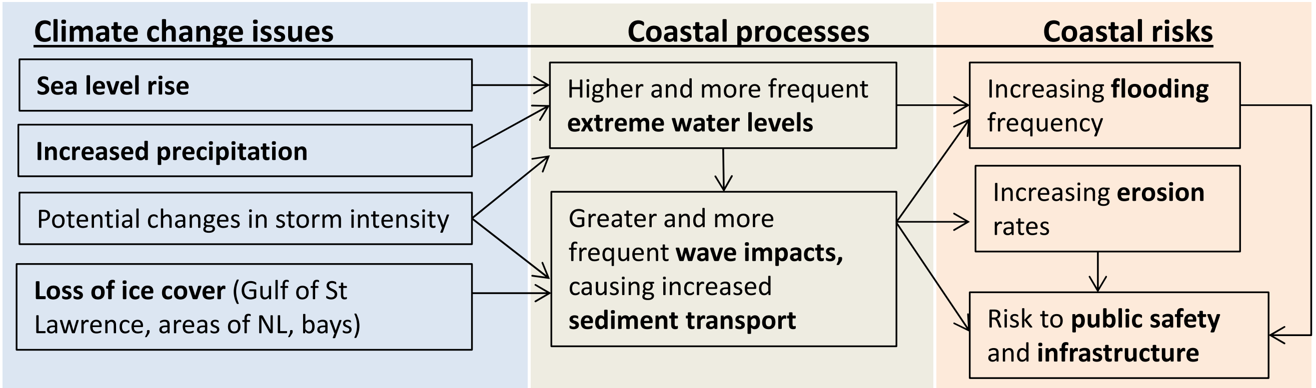

Figure 2.3: Climate Change Impacts on Coastal Hazards

SLR Projections for Halifax are summarized on Figure 2.4 (Greenan et al 2018, based on James et al 2014). The general projections for Nova Scotia are in the same order of magnitude as Halifax, i.e. potentially in the order of one metre towards the end of the century, with details as follows.

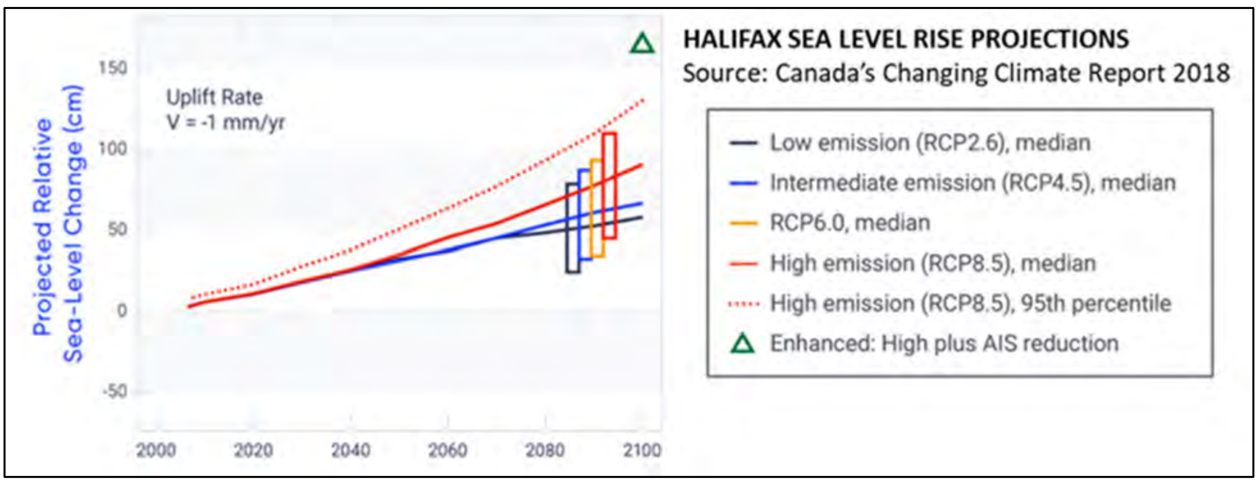

Figure 2.4: Halifax Sea Level Rise Estimates Reproduced from Greenan *et al* 2018

The green triangle is the projection of a scenario based on collapse of a portion of the West Antarctic Ice Sheet, providing an additional 0.65 m of Global Mean SLR to RCP8.5 by 2100.

Consensus Intermediate SLR Projections

The Intergovernmental Panel on Climate Change's Fifth Assessment Report (IPCC AR5 2013) estimated that the upper-bound Global Mean SLR could **be in the order of 1.0 m by year 2100**. This projection using process-based models was for Representative Concentration Pathways RCP 8.5 high-emission scenario. To derive Relative SLR, the Department of Fisheries and Oceans Canada (DFO) then developed the online Canadian Extreme Water Level Adaptation Tool (CAN-EWLAT), based on work by James et al. (2014) accounting for local vertical crustal movement. CAN-EWLAT is a science-based planning tool for climate change adaptation of coastal infrastructure related to future water-level extremes, based on IPCC AR5 projections improved upon by incorporating information on land subsidence measured with high-precision GPS instruments. It was developed to provide SLR allowances for DFO harbours across Canada. Allowances are estimates of changes in the elevation of a site that would maintain the same frequency of inundation that the site has experienced historically.

For the upper Bay of Fundy, tidal expansion should be added as a SLR component. Greenberg et al. (2012) examined long-term tide gauge observations showing that the amplitude of Bay of Fundy tides has been slowly increasing. By 2100, the combination of vertical land motion (VLM) and amplitude change would increase the amplitude of Bay of Fundy tides by 0.3 m in the Upper Bay. They assumed a VLM component of 0.2 m/century, leaving 0.1 m for tidal amplitude change.

Updated global estimates from the IPCC's Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC report, Oppenheimer et al 2019) remain generally consistent with AR5.

Upper-End Projections with High Uncertainty

Potential rapid Greenland and West Antarctic Ice Sheet (AIS) reduction may add a significant amount to long-term SLR in addition to the AR5 projections. The modeled AIS contribution from the 2019 SROCC report is an extra 0.12 m (0.03–0.28) by year 2100, with acknowledgment that results from recent probabilistic and semi-empirical projections are much higher, such as DFO Han et al. 2016, or NOAA Sweet et al. 2017. These upper-end SLR projections are based on probabilistic projections of the factors driving GMSL rise, which is different than the process-based model approach from IPCC AR5 or SROCC. The Greenan et al. report for Canada (2018, based on James et al. 2014) propose to add an additional 0.65 m (on top of the 1.0 m) by 2100 of Global Mean SLR to AR5 RCP8.5.

Selection of Scenarios

The appropriate scenario to use depends on the application, such as planning time horizon or risk tolerance of the area and infrastructure assets. The scenarios start to significantly diverge after a few decades (2050's and beyond). The CAN-EWLAT estimate for RCP8.5 high emissions scenario, which is generally recommended for precautionary use in long-term planning, would represent a projection typically close to 1 m to the end of the century.

The science of SLR will keep evolving with updated observations and improving model predictions. Implications for infrastructure and coastal flooding will need to be re-evaluated with periodic updates in SLR projections.

2.1.7 Sea Level Rise Impact on Shoreline Erosion

Accelerated sea level rise is expected to cause an increase in shoreline erosion rates. The erosion rate increase will be compounded by the loss of protective winter ice cover around the Gulf of St Lawrence. Storm events will continue to represent small steps in the long-term process. For the purposes of the CERFA, a simple conceptual model is required where precautionary principles and safety margins are favored over site-specific complex modeling that would be beyond the scope of the tool.

Most simple conceptual models of long-term shoreline response to rising sea levels are based on the assumption that the coastal profile is assumed to be at equilibrium between sediment size (stabilizing force) and wave action (destabilizing force) for a given range of tidal water levels.

Beach/Dune Systems

A simplified model for dynamic beach/dune systems assumes there are no significant new sources of sediment, so the eroding shoreline profile must translate landward and upward to conserve sand volume, as illustrated on the following figure. The shoreline retreat distance is then simply a function of the beach slope and the vertical amount of sea level rise. This simplistic model is known as the Bruun rule (1962). Alternatives have been proposed as summarized in various publications including but not limited to Dean and Dalrymple (2002) or Davidson Arnott (2005), or Rosati et al (2013). While conceptual models may vary, the conservation of sediment volume within the nearshore profile remains a common basis for evaluation. This model has shortcomings in complex cases including but not limited to longshore sediment losses or gains, presence of coarse sediment, dunes or hard material.

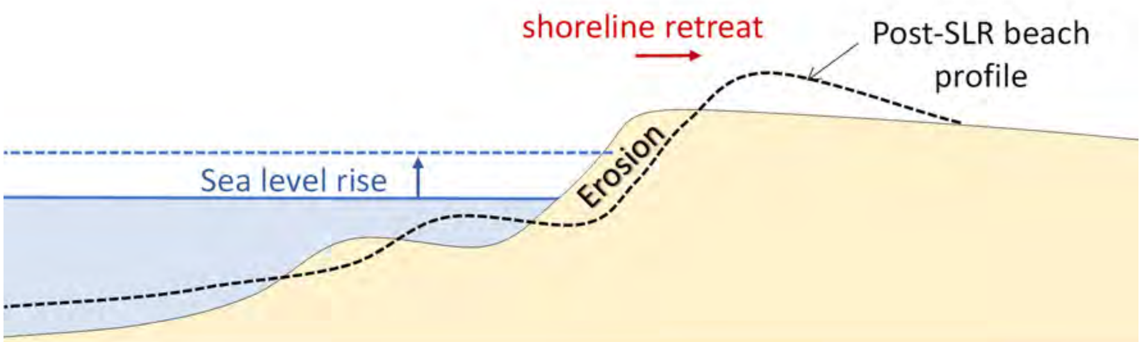

Figure 2.5: Effect of Sea Level Rise on Dynamic Beach Profile using Simplistic "Bruun Rule"- Type Model

Eroding Bluffs or Rockfaces

Eroding bluffs or rockfaces consist of cohesive sediment, sedimentary rock, or highly fractured rock. Erosion leads to the development of a wave cut platform[5], or beach deposits at the toe. The profile geometry develops in equilibrium with the tidal range and wave climate. With SLR, the original profile will be out of equilibrium and erosion rates will

[5] A wave cut platform is a flat rock ledge formed by erosion at the base of a cliff.

accelerate. With time, a new wave cut platform will develop at a higher elevation. During the re-adjustment, erosion rates are higher than the historical background rate prior to SLR. Then, the progressive build-up of eroded material at the toe of the slope may gradually slow down erosion again. The long-term erosion rate will depend on whether the supply of eroded material can keep up with sea level rise, which is highly site-specific.

2.2 Measured Erosion Rates in Nova Scotia

There has been no province-wide erosion mapping effort to date, based on historical air photo comparison or other surveys. Air photo analyses have the advantage of potentially covering a longer historical record. However, a number of factors limit the accuracy of air photo analyses using historical imagery, including but not limited to error range in georeferencing, or photo resolution. These types of potential errors decrease when higher resolution satellite images, orthophotographs and UAV surveys are used to characterize changes in the bluff position and thus more recent rates of erosion (e.g., last two or three decades). In some cases, erosion rates are not linear and a long-term measurement record is needed. For example, some bluffs can be stable for many years to decades, then fail catastrophically with a major rotational failure. For these types of sites, short term erosion measurements, even with high precision datasets and instruments, cannot accurately capture the long-term erosion rate. For an erosion measurement to have any value for long-term setback planning, it needs to represent the rate of change for at least three or four decades.

Direct measurements of coastal erosion rates in Nova Scotia are restricted to small study areas, typically from the Provincial or Federal Geological Survey, as well as academic research groups including but not limited to the Applied Geomatics Research Group (AGRG) of Nova Scotia Community College, Saint Mary's University, Dalhousie University or Acadia University. Measurements and analysis of erosion rates around the province do not cover wide areas, so it is not possible to derive generalized erosion rates for particular types of geology and/or wave exposure. Finck (2015) indicates that coastal erosion rates around NS typically vary from a few cm/year (or less) to 1.5 m/year or more, with 0.3 m/year considered a reasonable average estimate. This may represent 30 m/century, potentially up to 150 m/century or greater depending on the area.

2.2.1 Geological Survey of Canada Sites

Acknowledgments
The Project Team wishes to thank GSC Scientist Robert Taylor, who has provided valuable data on observed erosion rates across Nova Scotia, as well as references and feedback to support the development of this tool.

As part of their mandate to investigate coastal hazards to Canadians, the GSC has been monitoring erosion at a selection of coastal sites across NS for the last several decades, with varying degrees of time and spatial coverage. The majority of sites are along the

Atlantic Ocean. The authors of the present study have been in contact with GSC and obtained relevant information for the development of the CERFA tool. The key information is summarized in the present section.

Geological Context

A variety of rocky offshore islands, multiple headlands and long narrow embayments characterize the Atlantic Coast of Nova Scotia. Many of these embayments are the result of the glacial erosion of pre-glacial stream valleys, and their subsequent submergence by rising relative sea level. Erosion rates have greatly varied over the last few thousand years depending on the rate of sea level rise. Shaw et. al. (1993) coupled data on sea-level changes for the past 10,000 years with existing bathymetric information and estimated a mean shoreline retreat rates of approximately 2.0 m/year up to 7,000 years ago.

Recent Evolution

A variety of field monitoring programs, surveys as well as air photo observations along the South and Eastern shores of Nova Scotia have measured bluff-top retreat rates that range from 0.25 m/year to 1.2-2.1 m/year (Shaw et al., 1993). These observations in combination with measurements along the Minas Basin and the Eastern shore result in a retreat rate for bluffs up to 0.6 m/year at the more exposed sites and retreats of 1 to 1.2 m during extreme storms. Figure 2.6 reproduces Shaw et al's (1993) map showing mean and maximum shoreline retreat throughout Nova Scotia. Overall, typical rates of retreat for bluffs composed of glacial deposits in NS is 0.3 to 0.5 m/yr.

Erosion rates are influenced by a complex combination of time-varying processes such as wave action, slope, accumulation of coarse material at the base of the scarps, heavy precipitation, ground water percolation, etc. To be representative for planning purposes, a long-term erosion rate should be based on several decades of observations, ideally 50+ years (Ontario regulations use a minimum 35 years). The authors indicate that, for example, at Lawrencetown the bluff retreat rate decreased from 0.4 m to 0.1 m per year during the 1980's. In other locations such as Chezzetcook, drumlins headlands can retreat rapidly when initially exposed to wave attack, and retreat rates there increased from 5.4 m to 7.6 m per year from 1988 to 1990 (Shaw et al., 1993). The availability of sediment supply plays a fundamental role in the response of the coastline to changes in sea level. Sea level rise may accelerate coastal erosion and its inherent sediment production. Some of this sediment may deposit in neighbouring estuaries, including tidal wetlands, maintaining them as sea levels are rising.

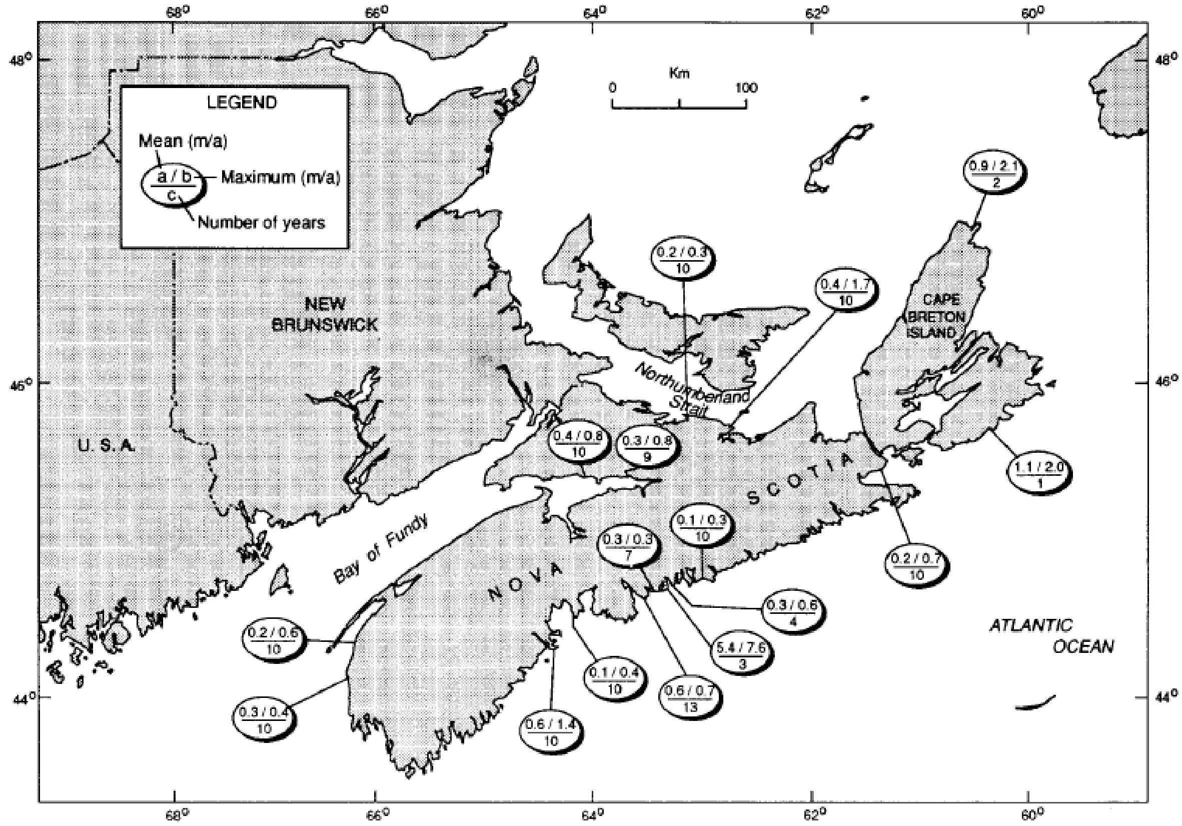

Figure 2.6: Mean and Maximum Rates of Retreat of Scarps at Selected Sites in NS (Reproduced from Shaw et al 1993)

The compilation is based on repetitive ground surveys between 1980 and 1991.

Geologic Factors Influencing Bluff Erosion Rates

Based on review of the GSC data and papers, as well as communication with GSC principal author Robert Taylor, the following factors are important influences in coastal erosion rates, notably at Atlantic drumlin sites:

1. Composition of drumlin till, e.g. presence of natural armouring elements such as cobble and boulders.
2. Width of the backshore beach.
3. Presence of foreland or low foreshore slope, which dissipates wave energy.
4. Presence of rotational slumping.
5. Presence of protective barrier beach.
6. Stage of drumlin erosion, with lower seaward and landward ends eroding rapidly and erosion decreasing across the higher middle section.

Factors 1-5 were included in the CERFA geology assessment tool. Factor 6 (stage of drumlin erosion) was not, due to the potential difficulty for quantifying it in the field. A preliminary summary of historical measurements by GSC was provided to CBCL by GSC for 36 sites (Figure 2.7), to assist in CERFA tool development and calibration. A few examples are shown on Figure 2.8 for sites with varying geomorphological factors affecting erosion rate.

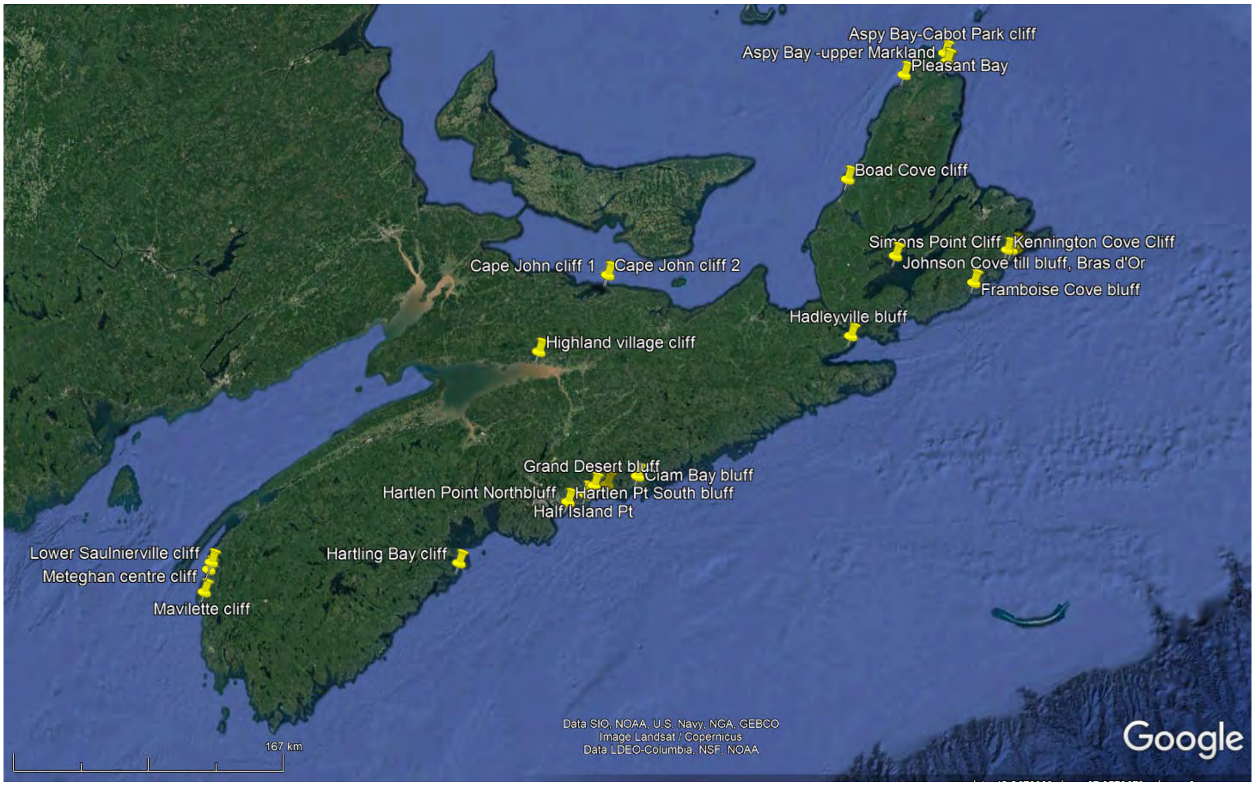

Figure 2.7: GSC Monitoring Sites with Erosion Rate Measurements Pending Publication (provided to authors by R. Taylor, GSC)

Figure 2.8: Example Bluff Sites along NS Eastern Shore with Different Geomorphological Factors Affecting Erosion Rate

Annual retreat rates (average-max) range from low (top, 0.1-0.3 m/year, 1980-2002), medium (middle, 0.3-0.6 m/year, 1980-1987) to extreme (bottom, 4.4-9.9 m/year, 1988-2005). The exceptionally high erosion rate at Grand Desert bluff started after the loss of a barrier beach in the early 1980’s that used to front a tidal lagoon, opening the bluff to the full Atlantic wave action. This is the only documented example in the GSC dataset with an average multiyear erosion rate exceeding 1 m/year. Credits: GSC (erosion rate estimates) and CBCL (photos).

Implications for Effective Adaptation Planning

The following conclusions and recommendations are supported by the GSC authors’ research (Taylor et al 2006):

- Surveys have documented different phases and rates of change depending on exposure and the evolutionary phase of specific shore types. Given the expected variability in future erosion rates based on a continually evolving coast, the precautionary principle should be adopted resulting in conservative setbacks.
- Beaches and marshes provide an important buffer against flooding and wave attack. These buffers are fed by shoreline erosion of exposed shorelines. Such sediment transport pathways should be maintained, and shoreline armouring should be discouraged except when critical infrastructure is at risk.

2.2.2 Bay of Fundy

Amos et al (1980) reported a mean recession rate of 0.55 m/year with considerable variation around the Minas Basin, and with maximum rates of 1.5-1.6 m/year along the north shore over 35 years (based on air photos from 1939-1974). More recently, Wilson et al (2016, 2017) conducted a series of measurements of erosion rate along the Minas Basin coastline based on the geo-spatial analysis of aerial photographs (dating back to 1964) and digital elevation models (DEM) as well as field measurements of 64 sites around the Minas Basin. Approximately 79% of the perimeter bounding the Minas Basin feature steep slopes consisting of unstable sandstone, basalt, sedimentary rocks and glacial till. In these formations erosion is the result of multiple factors including terrestrial processes (rainfall and rainwash, gullying and frost wedging), slope, climatic and marine processes (wave agitation, suspended sediment near the slope). The Wilson 2016 study found that over the course of approximately 50 years, erosion rates along the Minas Basin shoreline ranged between 0 to 1.4 m/year (Figure 2.9). The highest erosion rates were found on the coast section located between Five Island and Parrsboro, the north western shore of Cobequid Bay and near Selma and Blomidon.

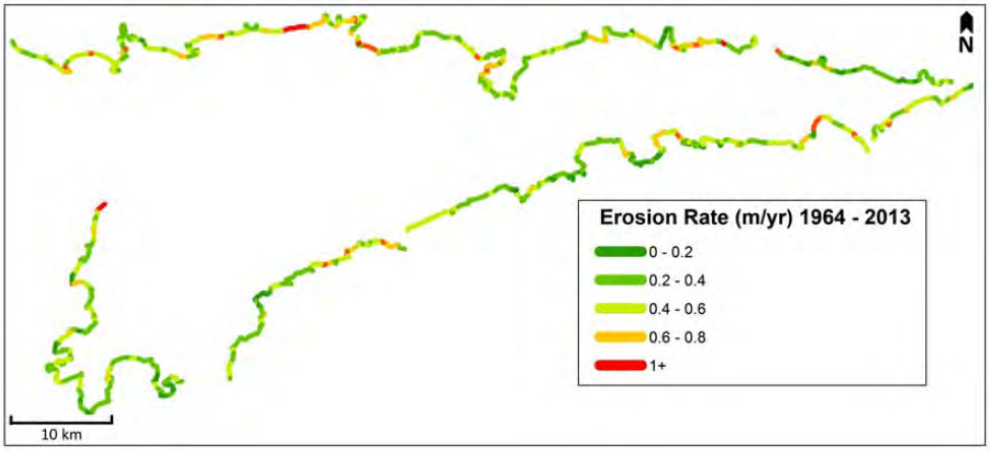

Figure 2.9: Estimated Rates of Coastline Erosion around the Minas Basin Based on Aerial Photographs from 1964 to 2013 – Reproduced from Wilson et al (2016). Rates are averaged over 500 m sections. The study identified significant temporal changes.

The author attempted to correlate erosion rates to several factors, including but not limited to fetch, scarp height, and presence of vegetation. Correlations were generally very weak, which points to non-linear processers and hinders the potential derivation of process-based predictions for the present CERFA work. There was no apparent correlation with fetch, but this finding has to be tempered by the fact most exposed sites along the Minas Basin have comparable fetch distance in the order of 50 km. There appears to be somewhat increased erosion at sites with forests at the top of high slopes, which may be due to the tree roots contributing to the breaking down of the bluff or rockface. Strong tidal currents at the base of the slope were also noted to be a contributing erosion factor, while tidal wetlands were indicative of sites with low erosion.

2.2.3 North Shore

Studies documenting erosion trends in the Northumberland stretch include geological observations at the Tidnish-Amerst shore of NS as summarized by Finck (2006). From Tidnish Head to the east end of Amherst Shore beach, the shoreline is characterized by soft sandstone outcrops across the intertidal bench. At the east end of Amherst Shore the coast features steep rockfaces composed of potentially sedimentary rocks. Generally extensive till covers the study area. During the study, the author identified the presence of coastal protection infrastructure over long stretches of the shoreline and their influence in erosion and sediment supply processes in the area. Based on the analysis of air photographs and available topographic surveys of the shoreline from 1964 and 2005 the author estimated erosion rates in the area ranging from 0.2 m to 0.6 m per year with an average of 0.4 m per year. These estimates are consistent with 0.1 m to 0.4 m per year erosion rates reported by Environment Canada (2006) for soft sandstones and till faced slopes along the New Brunswick Northumberland Strait.

2.2.4 Bras d'Or Lakes

Taylor and Shaw (2002) have studied coastal evolution in Cape Breton's Bras d'Or Lakes with a focus on barrier beaches. The 1,234 km of coastline are extremely varied. Many of the coastal areas in the Bras d'Or Lakes are covered by glacial till in the form of drumlins, providing sediment supply to many depositional features. As with the rest of the Province, sea level has been rising in the Lakes for thousands of years, resulting in continuous re-organisation of shorelines through erosion and deposition. While there are few documented sites with long-term erosion records[6], it is expected that the erosion processes would be comparable to those for Atlantic drumlins of similar geology, with erosion rates being moderated by the relatively smaller wave exposure.

2.2.5 Summary

In summary, there is limited long-term erosion rate observation data to support the development of a predictive tool based on geology and wave climate. The existing data indicates a wide variability of erosion rates dependent on site-specific geology and wave conditions. These conditions (e.g., geology) change over time as the coast erodes, so the erosion rate itself is non-linear and time-varying. This makes it very difficult to translate these processes into mathematical relationships. The CERFA tool developed as part of this project proposes to use a deterministic approach calibrated to the existing available long-term erosion rate information. Further details on the tool development and calibration are provided in Chapter 3 and 4, respectively, with additional air photo analyses conducted at field tests sites.

2.3 Sample Setback Policies from Other Jurisdictions

Coastal erosion results in the landward migration of the shoreline. This is an entirely natural process, however it presents a problem when fixed human infrastructure or property is located too close to the eroding coastline. Erosion rates are certain to increase with climate change, and a strategy for adaptation is both possible and necessary (Davidson Arnott and Ollerhead, 2011). Most jurisdictions recognize the difficulty of predicting erosion by developing setbacks either using erosion rates from historical air photo measurements, or using a fixed distance. Both approaches have limitations, not accounting for very localized conditions or impacts of climate change for example. Despite the limitations in their determination, minimum setback distances remain a proven way of mitigating coastal risk. The following summaries provide information on jurisdictions with potential relevance to the Nova Scotia context, however the list of jurisdictions is not intended to be an exhaustive review.

[6] As an example, erosion rate of a till drumlin face at Johnsons Cove on Big Harbour Island was estimated at 0.3 m/year, based on 29 years of data (pers. comm. R. Taylor). Fetch distance to the site is approximately 20 km.

2.3.1 Halifax

The Halifax Regional Municipality (HRM) has two principal setbacks:

- Horizontal setback of **20 m** of the ordinary high water mark of any watercourse.
- Vertical setback of 3.8 m above zero CGVD28.

With HRM, the area of Cow Bay off Eastern Passage is particularly exposed to coastal erosion. As such the horizontal setback is increased to **61 m** for exposed Atlantic shorelines (HRM 2017).

2.3.2 Prince Edward Island

All properties in Prince Edward Island have minimum building setbacks from the coast (PEI 2016). This distance is the combination of a 15 m **buffer zone** in which no buildings or structures are permitted, and a **building setback** which depends on the annual erosion rate for the property location, as estimated from provincial studies of historical air photos.

The building setback distance is measured between the proposed building and the top of the bank when adjacent to the beach, or the inland boundary of a dune, wetland or watercourse. This setback distance also applies to secondary structures such as decks and sheds. The only exclusions are for concrete/asphalt walkways, wells, fences, utility poles, clothesline poles, and playground equipment (e.g., swing sets).

Table 2.1: Minimum Building Setbacks in PEI

Coastal Boundary Type	Setback Distance
Beach	22.9 m, or 60 times the annual rate of erosion*, whichever is greater
Wetland/Watercourse	22.9 m
Sand Dune	30.5 m

*The annual rate of erosion determined during application processing.

2.3.3 New Brunswick

New Brunswick (NB 2019) divides its coastal region into three zones, and manages development differently in each as follows:

Zone A: Sensitive intertidal zone, plus dunes. This is the zone of highest risk and is defined as the intertidal area between HHWLT and Lower Low Water Large Tide (LLWLT), plus dunes extending beyond HHWLT. Development is highly restricted within Zone A.

Zone B: 30 m wide coastal lands buffer. Similar to Zone A, development is permissible with a Watercourse and Wetland Alteration Permit, and/or an Environmental Impact Assessment Certificate of Determination, and/or an Approval (Any Provincially significant wetland or coastal marsh in this region is an integral component of the marsh and only those activities permitted in Zone A are permitted).

Zone C: Under consideration for protection. This zone would include areas beyond the extent of Zone B but are identified as areas sensitive to impact and storm damage as a result of topography, elevation and geomorphology.

2.3.4 Ontario Great Lakes Region

The 2001 Technical Guide for Great Lakes - St. Lawrence River Shorelines describes Ontario's Provincial Hazard Policy (Ontario Ministry of Natural Resources, 2001). The erosion hazard involves the calculation of the cumulative impact of:

1. **Stable slope allowance**, using a default slope of 3H:1V or a site-specific value to be determined by a geotechnical study.
2. **Erosion allowance**. The allowance is the maximum value between:
    - A default erosion allowance is 30 m based on an average historical erosion rate of 0.3 m/yr for the general study area;.
    - 100 times the documented Annual Average Recession Rate (AARR), for areas where there is at least 35 years of observations.

Any deviation from the 3:1 stable slope and/or 30 metre erosion allowance standard is to be undertaken only in accordance with accepted scientific and engineering principles. A reduction in the 30 m allowance may be obtained for bedrock or sheltered shorelines, while it should be augmented for actively eroding cohesive bluff or low-lying cohesive sediments such as at river outlets.

In the case of a dynamic beach dune system, a 30 m buffer is implemented in order to protect coastal dune ecosystems from development.

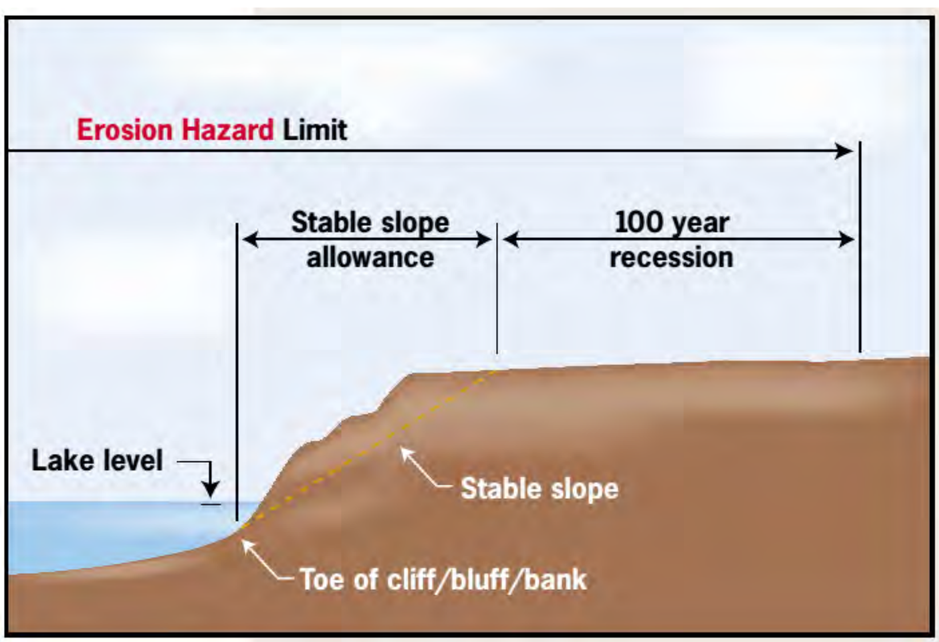

Figure 2.10: Ontario Great Lakes Horizontal Setback Components (reproduced from Ontario 2001)

Allowance for Shoreline Protection Structure

Another setback reduction provision applies to existing shoreline protection structures, where the 100-year planning horizon may be reduced by the projected remaining design life of the protection structure (up to a maximum of 30 years) as documented in a report by qualified professional. This policy has led to extensive armouring of the shoreline in order to locate development closer to the coast, cutting off sediment to beaches and causing accelerated breakdown of natural coastal systems relying on sediment supply (pers. comm. P.Zuzek). In addition, the Ontario setback calculation policy currently does not account for projected climate-change related increases in the long-term erosion rate, for example, due to the diminishing ice cover on the lakes.

Lessons Learned

The following lessons learned from Ontario are deemed relevant in the development of Nova Scotia's CERFA:

- The setback policy must include a mechanism for inclusion of climate change, as our climate is no longer stationary.
- There should be no provision to reduce the setback distance that may encourage shoreline armouring.
- The planning horizon should be as long as practically possible, since at the end of the planning horizon the proposed development will be exposed to erosion hazards.

2.3.5 International

Internationally, there are a wide variety of regulatory responses to the development, implementation and evaluation of coastal setbacks (Williams et al 2017). A summary of select jurisdictions is provided in the following Table, largely based on the work of Simpson et al (2012).

In summary, based on the Canadian and international jurisdictions reviewed, the width of other jurisdiction's equivalent of a horizontal setback typically varies from 30 to beyond 100 m. In Nova Scotia, the largest setback zone is in the Halifax area of Cow Bay, with 61 m. Some jurisdictions rely on fixed setback distances from the shoreline, while others use measured annual historical erosion rates to be applied over a defined planning horizon.

Table 2.2 Sample of Coastal Setback Distances Internationally (Partly Adapted from Simpson et al., 2012)

Jurisdiction	Horizontal Setback Distance (Typically from High Water Mark or Equivalent)
EU – Mediterranean	100 m
Denmark	100 m summer cottage areas 300 m rural areas
Germany	100 – 200 m
Norway	100 m
Poland	200 m
Turkey	50 m
CARIBBEAN, LATIN AMERICA	
Antigua & Barbuda	19-91 m
Barbados	30 m, or 10 m from top of slope
Colombia	50 m
Cuba	40-80 m
Dominican Republic	60 m
Jamaica	30 m
Nicaragua	50 m
Venezuela	50 m
UNITED STATES (Sample)	
California	30 m (100 ft) from wetland/stream/estuary 91 m (300 ft) from coastal bluff
New Jersey	30 times annual erosion rate (residential) 60 times annual erosion rate (commercial)

Chapter 3 CERFA Description and Guidelines

3.1 General Tool Requirements

3.1.1 Balancing Science, Risk and Practicality

To be effectively adopted and applied, the CERFA must strike a balance between several key concepts, mainly these are:

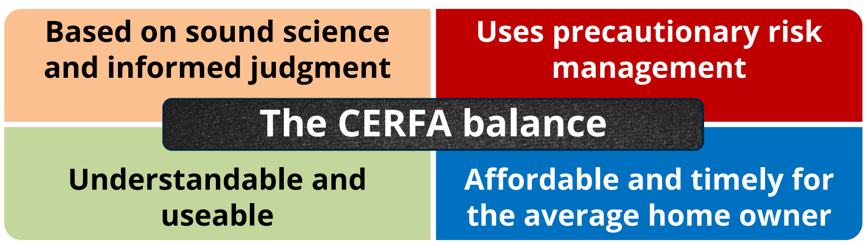

Figure 3.1: CERFA Requirements to Balance in Tool Development

There are significant challenges in implementing science-based horizontal setbacks with the CERFA in Nova Scotia, which were addressed as follows.

Table 3.1: Key Risk Management Strategies in CERFA Design

Challenges	CERFA Risk Management Strategies
Not enough data to accurately forecast erosion rates for all of Nova Scotia's coast at the individual property level.	▶ Use precautionary principles. ▶ Offset uncertainty with safety margins. ▶ Incorporate future risk from climate change, e.g. relative sea level rise and loss of sea ice.
Extreme diversity of coastlines, preventing regional assessments.	Use **simple prescriptive methodology** to ensure the tool leads to a practical and consistent approach to assessing coastal erosion risk across diverse coastlines.
Availability & capacity of Designated Professionals. Cost to homeowner must be reasonable.	CERFA Tool to be **practical and useable** by **qualified professionals**, to avoid unreasonable expense or delays for landowners and building proponents.

3.1.2 Private Shoreline Hardening and Existing Infrastructure

In addition to long-term protection of development and ecosystems, a second goal of establishing setbacks is to locate all permanent buildings in a manner that **negates the need for future protective works[7] during the specified planning horizon**. In other words, provisions for reducing setbacks by building seawalls are not recommended, as it would encourage shoreline hardening, require periodic maintenance and negate the environmental benefits of the setback for coastal ecosystems. Assessing the degree of protection existing shoreline armouring will provide over the planning horizon is beyond the scope of the CERFA tool and what can be expected of a DP. The recommended decision rule, therefore, is for the DP to assume the underlying geology is similar to that in adjacent areas and use this as a basis for erodibility and slope stability observations.

There should be no undue reliance on vulnerable infrastructure (including, but not limited to coastal roads) to reduce erosion risks. Vulnerable infrastructure only provides temporary protection that depends on regular maintenance. The reliance on potentially transient protective natural features such as barrier beaches is addressed in the tool (see section 3.7.3).

3.2 Setback Components

The following sections present information to guide the DP in the completion of the CERFA, as well as supporting technical information and assumptions governing the tool's internal calculations. The total setback distance calculated by the CERFA is the sum of three individual components: erodibility, sea level rise and stable slope allowances.

3.2.1 Erodibility Allowance

This setback component accounts for present ongoing erosion based on the combination of **geologic material** and **wave exposure**. Beaches and till bluffs are more susceptible to wave action than rock formations, and softer sedimentary and evaporite rock formations erode more readily than crystalline rock. The presence of joint sets and bedding planes will furthermore tend to increase the potential for erosion, and the orientation of these features may affect susceptibility to wave action or introduce potential for slippage and slope failure.

This methodology has been designed and calibrated to incorporate a practical and achievable level of field-based assessment, using established techniques to gather data. Geology and wave exposure inputs are compiled using tables to convert measurements into index values scaled between 0 (for low erodibility) and 1 (high erodibility). This setback component involves the most in-depth calculations in the tool, which were developed to obtain a reasonable order-of-magnitude match to historical erosion rates.

[7] Critical or public infrastructure, which may require shoreline protection, is excluded from this discussion.

Key Assumptions
The calibration is based on a common planning horizon and a maximum annual erosion rate value established for this study, which is then scaled down by geology and wave exposure indices.

3.2.2 Sea Level Rise Allowance

The SLR setback component calculated in the tool must make an allowance for potential erosion due to the coastal profile adjusting to future sea level rise over the planning horizon. As summarized in section 2.1.7, assessing the impact of SLR on shoreline erosion rates is a complex technical problem. Processes vary depending on shore type, e.g. dynamic beach/dune vs. bluff or rockface.

Based on the requirement for risk mitigation and the precautionary principle, and in the absence of a scientifically defendable generic alternative, it is proposed that the sea level rise setback component of the CERFA be estimated simply as the foreshore slope (Horizontal distance / Vertical height ratio) times the height of SLR over the planning horizon[8]. The calculation simply raises the existing coastal profile and translates it landward to conserve slopes as measured in the field by the DP. This follows a simplistic principle similar to that used for first-order assessment of beach response to sea level rise provided in section 2.1.7.

Key Assumptions
- Future shoreline profile shape is similar to existing.
- Amount of SLR depends on planning horizon.
- The beach slope allowed by the CERFA is no flatter than 20H:1V.
- For rockfaces, the rock slope is used instead of the foreshore slope.

[8] A slight modification to the approach was introduced to avoid theoretically double-counting SLR in the setback allowances. In the past century, SLR was approximately 3 mm/year at Halifax (Greenan et al 2018), which may have influenced historical erosion rates upon which the erodibility component was already based for the more erodible shorelines. Therefore, for determination of future SLR allowance (separate from erodibility allowance), the tool multiplies 3 mm/year by erodibility index, then subtracts the result from the future SLR over the planning horizon. For example, for a site with a 1.0 m SLR over an 80-year planning horizon, erodibility index of 0.5 and foreshore slope of 12H:1V, the SLR allowance output by the tool would be:

$$[1.0 \text{ m} - (80 \text{ years} \times 0.003 \text{ m/year} \times 0.5)] \times 12 = 0.88 \text{ m SLR} \times 12 = 10.5 \text{ m.}$$

The actual projected SLR amount (1.0 m in the above example) is still used in the geometrical determination of the toe of the bluff. This information is provided for reference; these calculations are done automatically in the background of the tool and do not require DP input.

3.2.3 Stable Slope Allowance

This setback component accounts for potential erosion due to sudden slope failure towards the end of the planning horizon and overall instability due to steep slopes that can threaten buildings and infrastructure.

Key Assumptions

- Based on post-SLR bluff/rock height and assumed stable slope depending on geology, between 3H:1V (bluff geology), 2H:1V (transitional geology[9]), to 1H:1V (rockface).
- Uses precautionary principles, in absence of site-specific geotechnical study.

3.2.4 Summary Sketches

Key factors influencing the three setback components are summarized in the following Table. The sequence of the component calculation is illustrated in the following Figures. Details on each of the tool components are provided in the remainder of this Chapter.

3.2.5 Total Setback Distance Bins

The total setback distance calculated fulfills a risk management objective, however it is not intended to be a precise representation of future erosion. As such, it is recommended that:

- For short setbacks under 30 m, the distance be rounded up to the next 5 m increment (e.g. minimum setback is 5 m, and 12 m is rounded up to 15 m).
- For longer setbacks greater than 30 m, the distance be rounded to the nearest 5 m increment (e.g. 32 m is rounded to 30 m).

Table 3.2: Relative Conditions for Low/Med/High Setback Distance Based on the Three Setback Components

Setback Distance	1. Erodibility	2. Sea Level Rise	3. Stable Slope
High	Erodible material AND high wave exposure.	Flat foreshore.	Bluff is high AND erodible.
Medium	Erodible material OR high wave exposure.	Moderately steep foreshore.	Moderately high bluff.
Low	Resistant material AND/OR low wave exposure.	Steep foreshore.	Low AND/OR resistant material.

[9] See section 3.6.2.

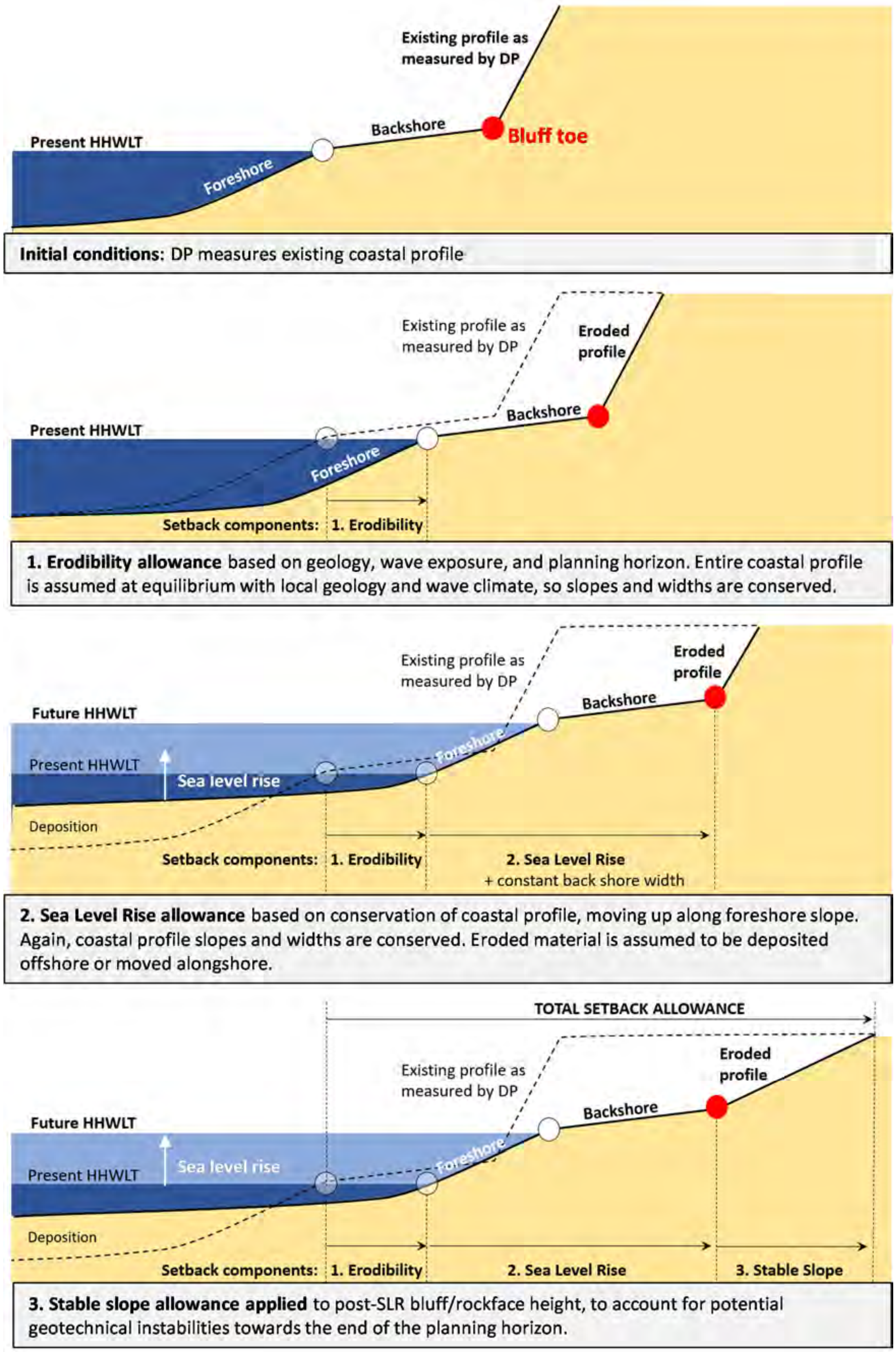

Figure 3.2: Assumed Simplified Evolution of Coastal Profile in CERFA Model

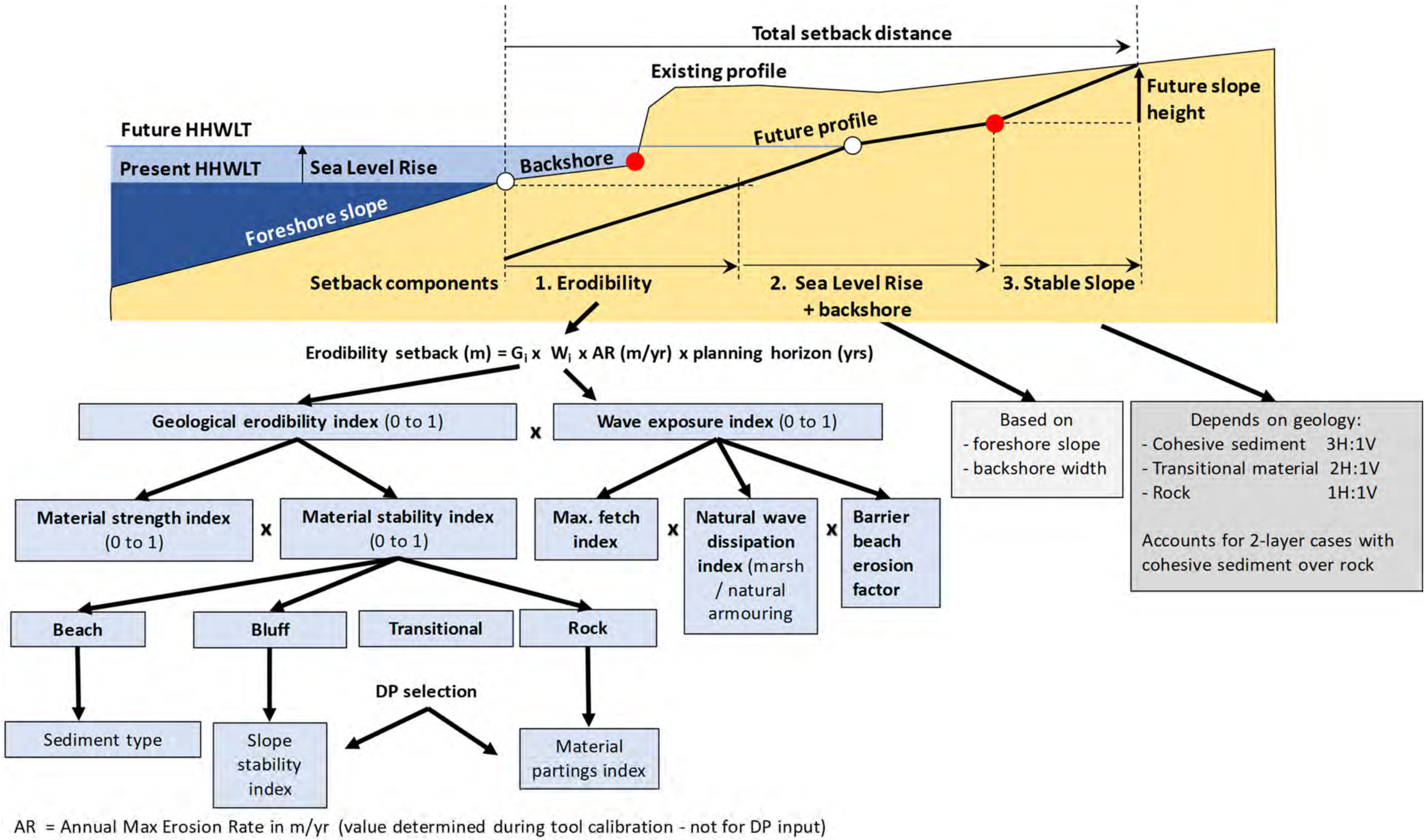

Figure 3.3: Summary CERFA Structure and Calculation Blocks for Setback Components

3.3 General DP Guidelines

3.3.1 Workflow and Input Checklist

The successive steps for the DP to complete the CERFA are shown in the following chart. The following Table lists the information required of the DP.

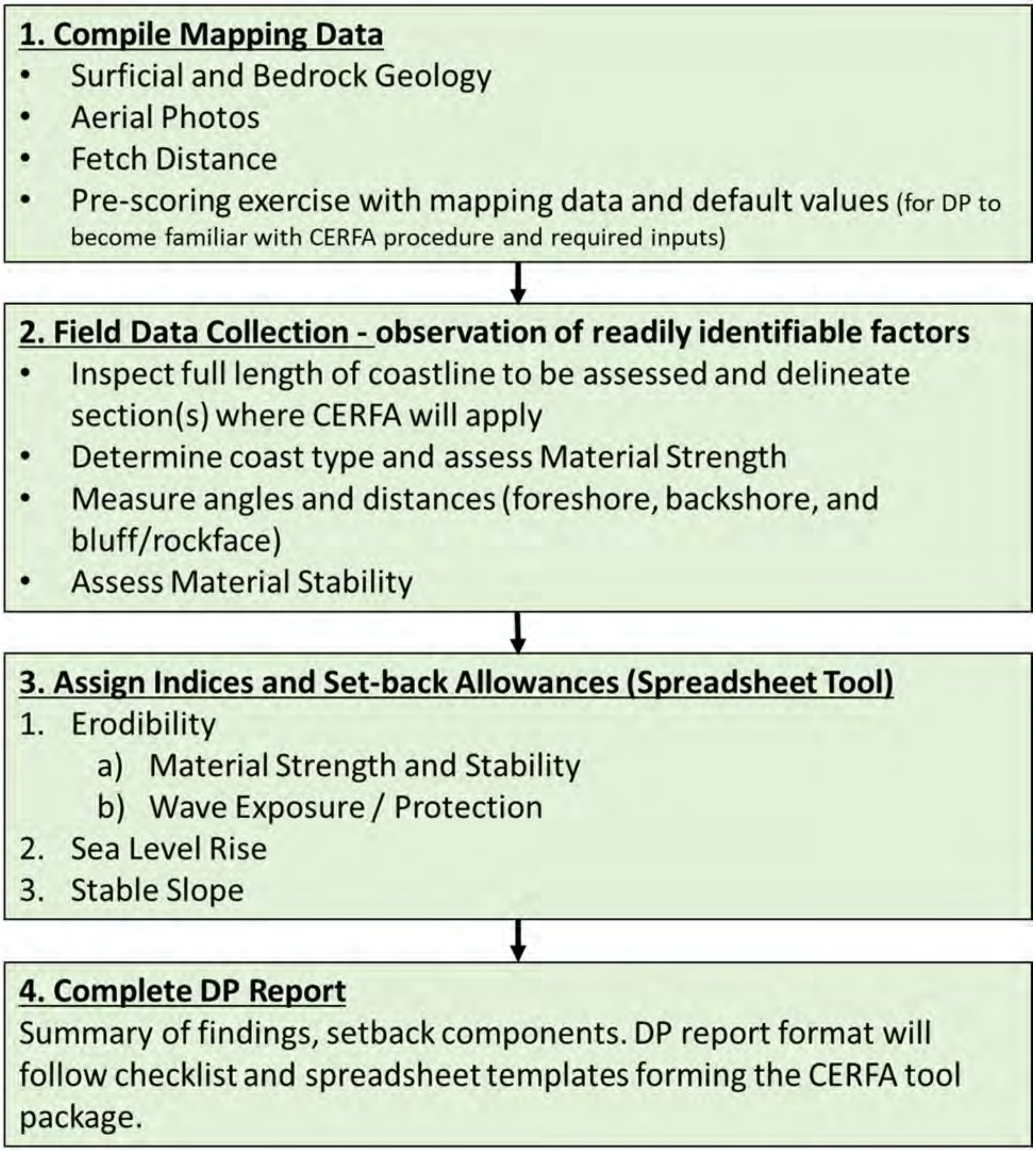

Figure 3.4: Workflow to Complete CERFA Tool

Table 3.3: CERFA Information Checklist for DP

	Description	Source
	Acquire Before Field Visit	
	CERFA Spreadsheet tool: Consult the spreadsheet tool prior to completing the field assessment. Complete a desktop scoping exercise, using mapping data to determine the range of potential index values and set-back distances. Unknowns identified at this stage can be used to help focus the field investigation. Specific desktop data sources are identified below.	
1	Site plan with air photo background	Google Earth or equivalent Use historical feature in Google Earth to observe variety of recent conditions.
2	Site topography	NSE contour mapping
3	Wind fetch distance	Bathymetric chart: Canadian Hydrographic Service paper chart or Electronic chart Fetch measurement: Google Earth, GIS platform or equivalent.
4	Tides: HHWLT	To be provided in NSE contour mapping.
5	Tide prediction for field visit to be scheduled at low tide	http://www.tides.gc.ca/eng
6	Surficial and bedrock geology of the area	https://novascotia.ca/natr/meb/download/mg/map/htm/map_2000-001.asp or https://fletcher.novascotia.ca/DNRViewer/?viewer=Groundwater
7	Sea level rise over planning horizon	To be provided in NSE contour mapping Reference: https://www.bio.gc.ca/science/data-donnees/can-ewlat/index3-en.php
	Acquire during field visit	
8	Supporting pictures, description for field entries: • Shoreline Profile (Slopes, distances and heights). • Material strength and stability. • Evidence of natural armouring.	See field checklist section. Also see Appendix C.
	Compile after field visit	
9	Final Report	Report template provided by NSE.

3.3.2 Desktop Assessment

The desktop assessment will help to prepare the DP for the field assessment and identify potential CERFA inputs.

3.3.2.1 Provincial Mapping and Aerial Imagery

A primary goal of this task is to determine, if possible, the expected material type, which is an input to the erodibility assessment. For example, the following material types show significant differences in susceptibility to erosion, in decreasing order:

- Cohesionless sediment (e.g. beach, sand).
- Cohesive sediment (e.g. silt and clay-rich till bluff).
- Transitional material (e.g. highly weathered rock or weakly lithified sediments).
- Sedimentary rock (e.g. sandstone).
- Crystalline rock (e.g. metamorphic, pyroclastic, and igneous rock).

The province offers a variety of freely available topographical and geological mapping data, which should be compiled as the first step in determination of setbacks. Topographical mapping provides indications of coastal morphology and related wind, wave, and geological data. For example:

- Steeper contours may indicate potential rock faces or bluffs.
- Quaternary geology mapping will indicate whether ice contact (till, drumlins) or other deposits (e.g. glaciofluvial) intersect the coast.
- Coves, marshes, and sandy beaches suggest generally lower energy environments.
- Mapping may indicate constructed features of concern such as roadways, utility corridors and buildings.
- The presence of freshwater bodies may indicate increased saturation of material, or increased potential for erosion due to stream flow.
- Historical satellite imagery may indicate if activities or development from adjacent areas have affected the shoreline of the property in question.

Provincial mapping data is available at local, regional, and provincial scales. Mapping at the local scale is preferred over regional mapping. DPs should avoid relying on provincial scale mapping if more detailed data is available.

Aerial imagery, from satellite sources or Provincial Mapping[10], will help to further define the morphology of the coastline and distinguish areas of beach, sediment bluff, and exposed rock. In many cases mapping will not indicate whether a beach, bluff, or rockface is present, and this determination will be deferred to the field phase of the investigation.

3.3.2.2 Fetch Distance

Fetch is the length of unobstructed open sea surface across which the wind can generate waves. Specific guidelines on wave exposure are provided in Section 3.7.

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10 https://nsgi.novascotia.ca/datalocator/indexing/

3.3.2.3 Tidal Elevation

The HHWLT elevation will be obtained from NSE mapping. Tidal predictions can be obtained from the online CHS tide predictions website.

3.3.2.4 Preliminary Desktop Assessment

It is recommended that the DP consult the spreadsheet tool prior to completing the field assessment. If possible, a scoping exercise should be completed, using mapping data to determine the range of potential index values and set-back distances. Unknowns identified at this stage can be used to help focus the field investigation.

3.3.3 Field Assessment

3.3.3.1 Objectives

The purpose of the field survey is to identify or confirm the material type, and to collect data (slope angles, distances) to allow for determination of an erodibility index. Initial work for the field survey will consist of the following:

- Shoreline profile (slope and height) measurements.
- Identification of major geologic facies and confirmation of primary material type.
- Identification of varying zones of the coastline, if any (e.g. if till bluff and exposed rock are present, these zones may need to be mapped separately).
- Identification and documentation of evidence of erosion.
- Identification and documentation of features that affect erosion, which may also be situated on adjacent properties or sections of coast.

3.3.3.2 Field Gear Checklist

Recommended field equipment includes:

- Camera, ideally GPS enabled.
- Notebook & printed maps.
- Tape measure (minimum length 10 m).
- Pocket Knife.
- Geologic pick or claw hammer.
- Spade.
- 20d common steel nail or equivalent.
- Laser-range finder or equivalent phone/tablet app for distances and angles (e.g. Theodolite).
- Geological compass (e.g. Brunton), an alternative for measuring slopes.
- Field data template (hard copy format provided in Appendix A).
- Safety equipment, as necessary.

The nature of data to be collected requires that the field assessment be scheduled in advance to occur at <u>low tide</u>. The intent is for the DP to access the beach to allow for direct measurement of the beach width, slope height, and characteristics of geologic material.

A template report has been developed to assist the DP in collecting and organizing all field data needed to complete a CERFA (provided in Appendices). In addition to a printable version, the tool includes a spreadsheet version that will calculate the recommended setback based on the DP's inputs.

3.3.3.3 Safety

The DP is responsible for ensuring safe working conditions at the site. The DP should not undertake any activities for which they deem conditions to be unsafe (e.g. rockface or bluff height, slope instability, tides etc.). In such cases, conservative values (i.e. on the worst-case end of what visual observations allow) should be selected. Alternatively, if available, high-resolution LiDAR-based maps may also be considered as a possible source of slope information.

3.3.3.4 Beach Access

The methodology for a field-based CERFA is designed for sites that allow for safe and practical access to the beach at low tide. If the beach is not accessible, the DP will need to rely on observations that can be collected from a safe vantage point. The DP should attempt to measure bluff and rockface heights using a range finder. Drone photography may provide helpful visual indications of the material slope and stability parameters. If the material strength and material partings cannot be assessed directly, the DP should use the precautionary principle and in cases of uncertainty select parameters which lead to a larger setback. Reporting must indicate if the beach was not accessed, including a discussion of the rationale for parameter selection.

3.4 Type of Coast for Assessment

The DP shall determine the coastal type under investigation. This is best done in the field by observing the type of material at the high water mark, which is affected by wave activity and subject to the effects of sea level rise. The DP should begin with a visual scan of the entire length of coastline to be considered under the CERFA, if necessary walking this entire length before selecting site(s) for CERFA data collection. The following geological terminology has been adopted to provide a consistent basis for CERFAs and will be used throughout these guidelines.

3.4.1 General Geology Definitions

Sediment – In this document sediment refers to eroded mineral grains deposited by wind, water or ice (including ice-contact deposits such as glacial till), which have not lithified (no formation of rock through compaction and/or cementation). Sediments may be cohesionless, as for beach material (e.g. sand and gravel), or cohesive, as for bluff material (e.g. silt, clay, till).

Cohesionless describes sediment that does not self-adhere or hold its shape when disturbed. Clay and silt are absent or present only in trace amounts.

Cohesive describes sediment that may self-adhere and hold its shape. Clay and silt are present in greater quantities and may be mixed with sand, gravel, cobbles, and boulders (i.e. till).

Toe – The toe of a bluff or rockface marks the transition between the gently sloped backshore area, and a more steeply sloped material face.

Material Strength represents a relative scale to measure resistance to erosion. Material Strength is a combination of density, consistency, and hardness. Measured using a series of qualitative field tests including pushing and striking with a geologic pick, peeling with a pocketknife, scratching with a common steel nail, and/or dislodging the material by hand. This allows for differentiation of Bluff, Transitional, and Rock material on a single continuous scale.

Material Partings refers to distinct structural features (discontinuities) within a rock matrix. Types of partings include bedding planes, joints, and faults (also collectively termed 'fractures').

3.4.2 Bluffs, Transitional Material and Rock

A steep slope may form in environments where the high-water level mark contacts cohesive sediment (e.g. glacial till) or rock. This visible scarp marks the transition from backshore to the developable land area, and may be fronted by beaches or tidal wetlands. The scarp may also be fronted by artificial armouring, i.e. typically local boulders or, may be a result of natural processes such as the deposition of cobble due to erosion. For the purposes of completing the CERFA, it is recommended that the DP assess armoured and infilled bluff faces according to the properties of the underlying undisturbed material.

Bluffs are formed by cohesive sediment. Clay and silt are present in higher quantities and may be mixed with sand, gravel, cobbles, and boulders (i.e. till). As this material tends to hold its shape, bluffs often form a well defined, steep slope at the interface with the backshore area. Bluff material can be classified using the Unified Soil Classification System (UCS).

Rock (forming a **Rockface**) is defined in this document according to material strength and by the presence of distinct material partings such as bedding planes, joints, and faults. Rock is resistant to erosion due to compaction, cementation, or formation at high temperature and pressure. Rock includes lithified sedimentary material (e.g. sandstone, conglomerate, siltstone, mudstones and soft shale) and evaporites (e.g. limestone, dolostone, and gypsum). Other, generally harder categories include metamorphic (e.g. slate, quartzite), plutonic (e.g. granite), and volcanic rock (e.g. basalt, tuff).

Transitional Material exhibits intermediate material strength (between that of a bluff and a rockface), and discontinuities are generally absent or poorly defined. Transitional material may be sedimentary material that is only partially compacted and/or cemented, or rock that has been extensively weathered, with a matrix that crumbles readily. For the purposes of the field assessment tool, transitional material has been included in the Rock category.

In some cases, the scarp may include two types of material, such as bluff material overlying a rockface, requiring a **2-layer assessment**. The DP will identify the number of layers to be assessed as a part of the geological field assessment, described in Section 3.6 and summarized in Table 3.9.

Certain shorelines have dense and sloping **natural armouring** (i.e. large boulders) which obscures the delineation of a clear scarp or rock face, notably along exposed areas of the Atlantic Coast, such as the rocky shoreline north of Crystal Crescent Beach referenced in the field tests. In such cases, the assessment should be treated as a bluff face with negligible height (e.g. 0.1 m) and wide backshore. The tool accounts for the wave dissipation of the naturally armoured slope through backshore width, angle and natural armouring coverage and type.

3.4.3 Beaches

Under the CERFA process, beach environments are formed by loose, cohesionless sediment, deposited by hydraulic and/or wind action. 'Beach' coastal types will lack a discernible bluff or rockface at the terminus of the backshore area if they are stable (i.e., not eroding), and will transition gradually to the land area under consideration for development (transition zone may include dunes). Clay and silt are absent or present only in trace amounts. Grain sizes on beaches are predominantly sand-sized or larger (fine sand to gravel, cobbles, and boulders). The term 'beach' is also used generally to describe the gently sloped zone between the low tide and high tide marks.

There should be no construction within the dynamic beach or dune area, and the CERFA should determine the setback toward the beach hinterland outside the dynamic dune area.

3.4.4 Special Case – Barrier Beaches

Barrier beaches, i.e. depositional sediment ridges between the sea and a lagoon, are dynamic shorelines that do not constitute sustainable building locations. As such, barrier beaches are not included in the assessment tool and future development should not be located in these areas.

3.4.5 Special Case – Artificial Armouring

Artificially armoured shorelines present several problems for erosion assessment. First, the design life of a shore protection structure can vary greatly, depending on the quality of the design, the construction, and future maintenance over the specified planning horizon, none of which can reasonably be assessed by a DP. Secondly, the intent of the CPA is to discourage unnecessary artificial shoreline armouring because it interferes with natural bio-physical coastal systems and associated dynamics. For example, armouring may cut off the natural sediment supply to nearby beaches, causing accelerated beach erosion. Therefore, its presence cannot be used by the tool to reduce the setback, and by design the tool does not make provisions for artificial armouring. Instead, the DP is to assess the natural shore type behind the armouring, which can be inferred from examining the bluff or rockface type around the edges of the artificial structure. The DP must be on site for such cases, in order to make the best possible determination based on the available information.

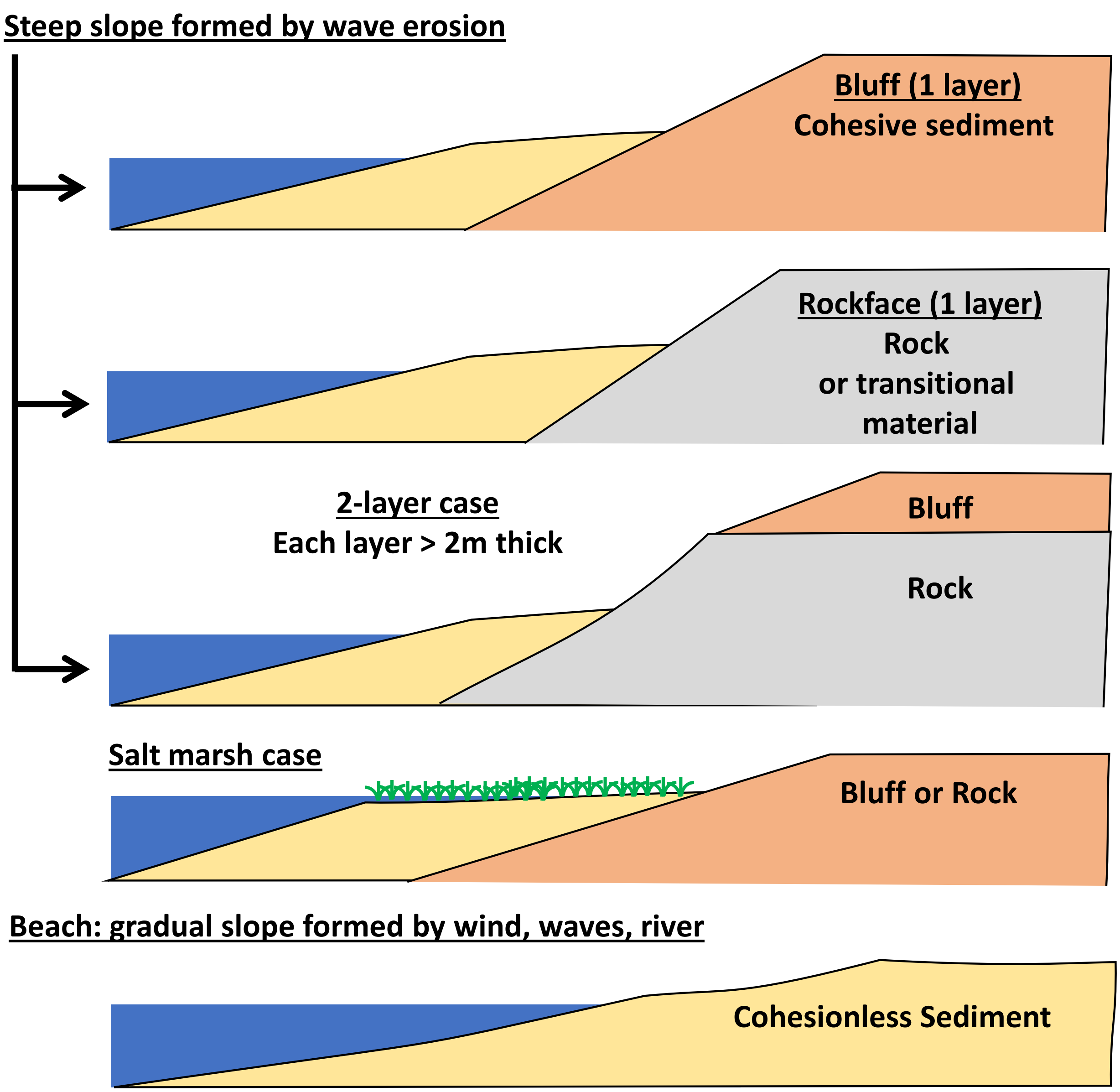

Figure 3.5: Schematized Coastal Types in CERFA

3.5 Shoreline Profile Field Measurements

3.5.1 Defining the High Water Mark

The Ordinary High Water Mark (OHWM) is a standard term used throughout planning documents in Nova Scotia. It represents the mark reached by the average of the mean high tides. The OHWM as surveyed is typically based on visual observations and can be relatively subjective depending on the season and timing of the survey. However, it can generally be identified from a wrack line, i.e. the line of debris left by high tide, or from a change in colour from light to dark on rocks. In time, for consistency, the Higher High Water Large Tide (HHWLT) should be the standard high water metric, to form part of the Province's coastal mapping database. For the foreseeable future and for practicality in the field, the high water mark will be defined in the field as the strand line of debris near the top of the beach left by high tide during a spring tidal cycle with calm wave conditions.

3.5.2 Shoreline Slopes and Distances

The foreshore slope enters in the setback calculation on two levels:

- Natural dissipation of wave energy for gentle slopes.
- Sea level rise allowance.

To determine the intertidal slope the DP will need to estimate the foreshore angle at low tide using a commercially available laser range-finder (using a model that measures both distance and angle). An inclinometer phone/tablet app is also recommended as an alternative method to measure slopes (however it cannot estimate distance). For cases of very large tidal range, the upper foreshore should be estimated i.e. within 2 m vertically from the HHWLT. For example, on Bay of Fundy sites, the measurements should generally not be made from the mudflat near low tide, but rather from the upper foreshore which is generally sandy in front of cliffs (except in tidal rivers). If a range-finder is unavailable the DP may choose to measure the beach width and use tide predictions to determine the high and low-tide elevations for the day of assessment. Similarly, the backshore slope and distance need to be measured.

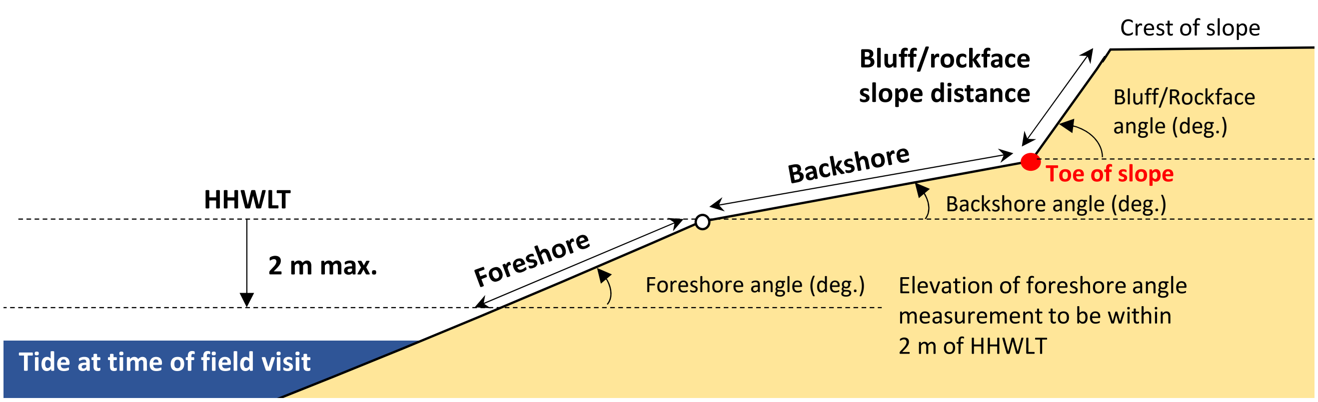

Figure 3.6: Shoreline Profile Angles and Along-shore Distance Measurements

3.5.3 Bluff/Rockface Height

For bluff/rockface heights (i.e. steep slope above the toe) of less than approximately 3 metres, the along-slope height may be measured directly from the toe of the bluff using a tape measure. For higher faces, a laser range-finder will be required to determine the bluff or rockface height. The DP may encounter rock cliffs with a further layer of transitional or unconsolidated material on top. Since these distinct layers have different properties, the CERFA provides for a two-layer calculation. Two-layer assessments (shown in Figure 3.5) will require several distance and angle measurements, as indicated below. If these methods are unavailable, the DP's most conservative estimate should be used for slope height.

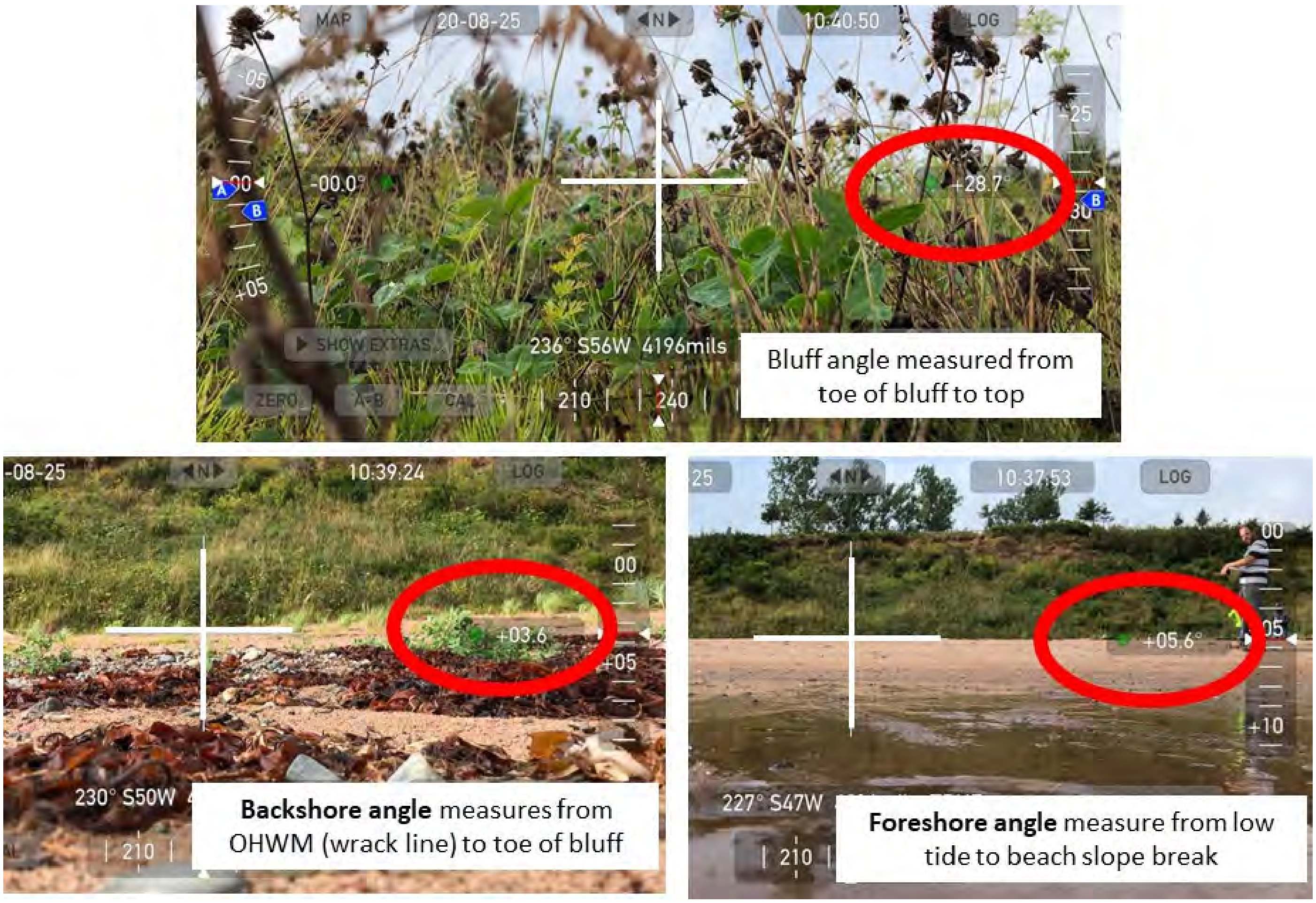

Figure 3.7: Example Angle Measurements using Theodolite App (Caribou Provincial Park, August 2020)

Typical angles are 1 to 10 degrees for foreshore and backshore, and 20-50 degrees for bluffs and rockfaces.

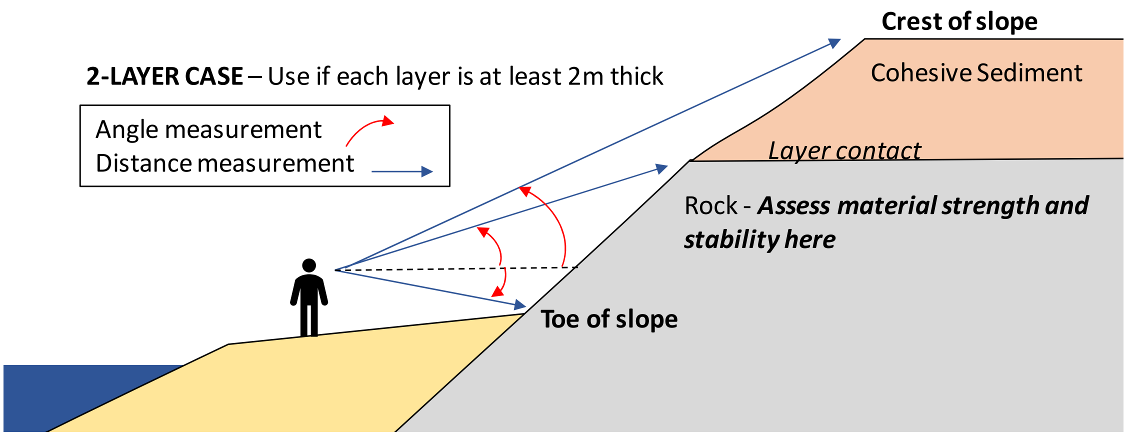

Figure 3.8: Bluff Angles and Distance Measurements – 2 Layer Case
Heights of each layer are calculated by the tool using standard trigonometry.

3.6 Geological Field Assessment

3.6.1 Geological Erodibility Index

General Description

The decision tree which leads to the calculation of the geological erodibility index is presented on the following Figure. The geological erodibility index (G) will be determined as the product of the material strength (MS) index, and the material stability (S) index corresponding to each type of coastal environment. Qualitative data are converted to index numbers using the indices listed in Table 3.4.

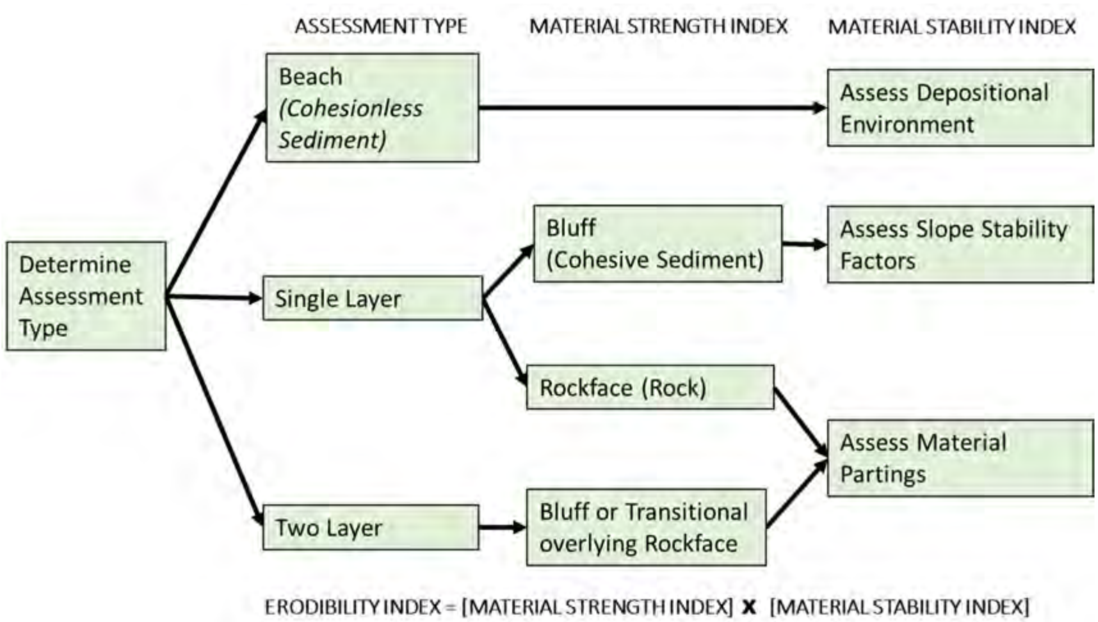

Figure 3.9: General Description of CERFA Geological Erodibility Index Calculation Procedure

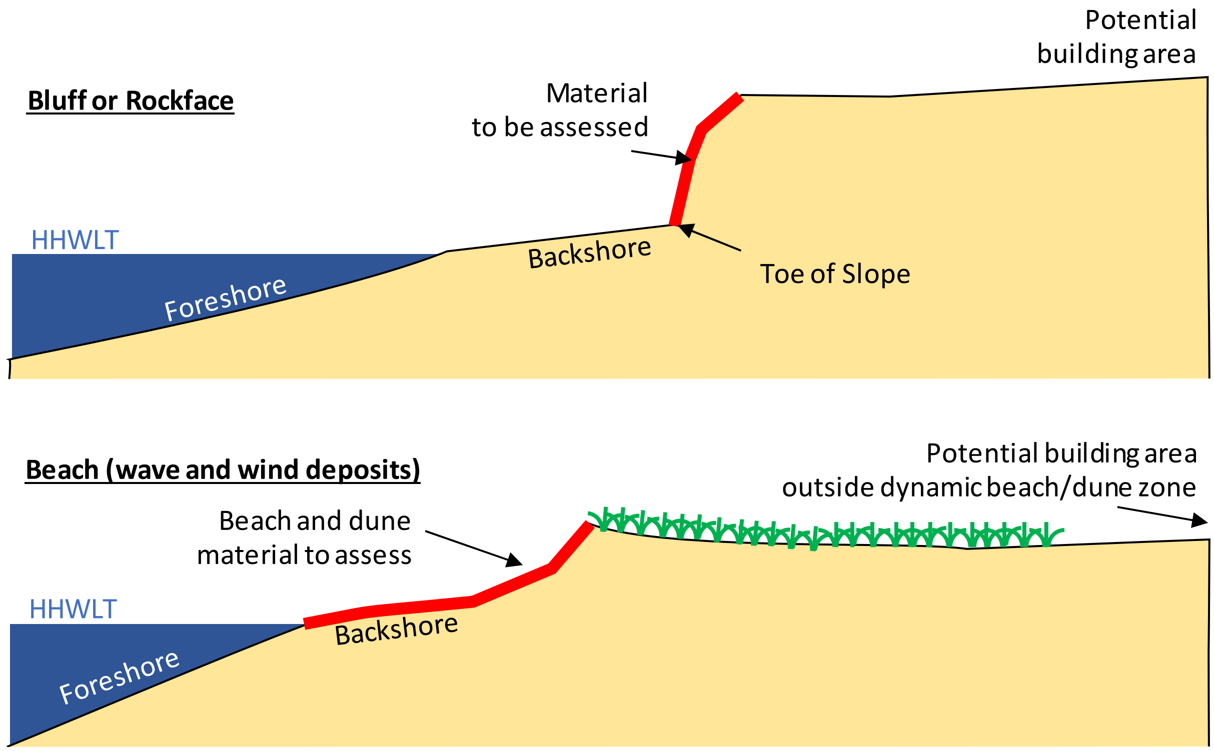

Figure 3.10: Selection of Area for Geology Assessment or Erodibility (See section 3.4 for decision criteria)

Table 3.4: Erodibility Index Categories

G (geological erodibility index) = MS (material strength index) x S (stability index)

Coastal Environment	Index
All	MS
Rock	S_{Rock}
Bluff	S_{Bluff}
Beach	S_{Beach}

DP Inputs

The DP will perform simple in-situ material tests to determine several factors describing material strength and stability, as described in Figure 3.11. Procedures to assess material strength and stability are provided in the next sections.

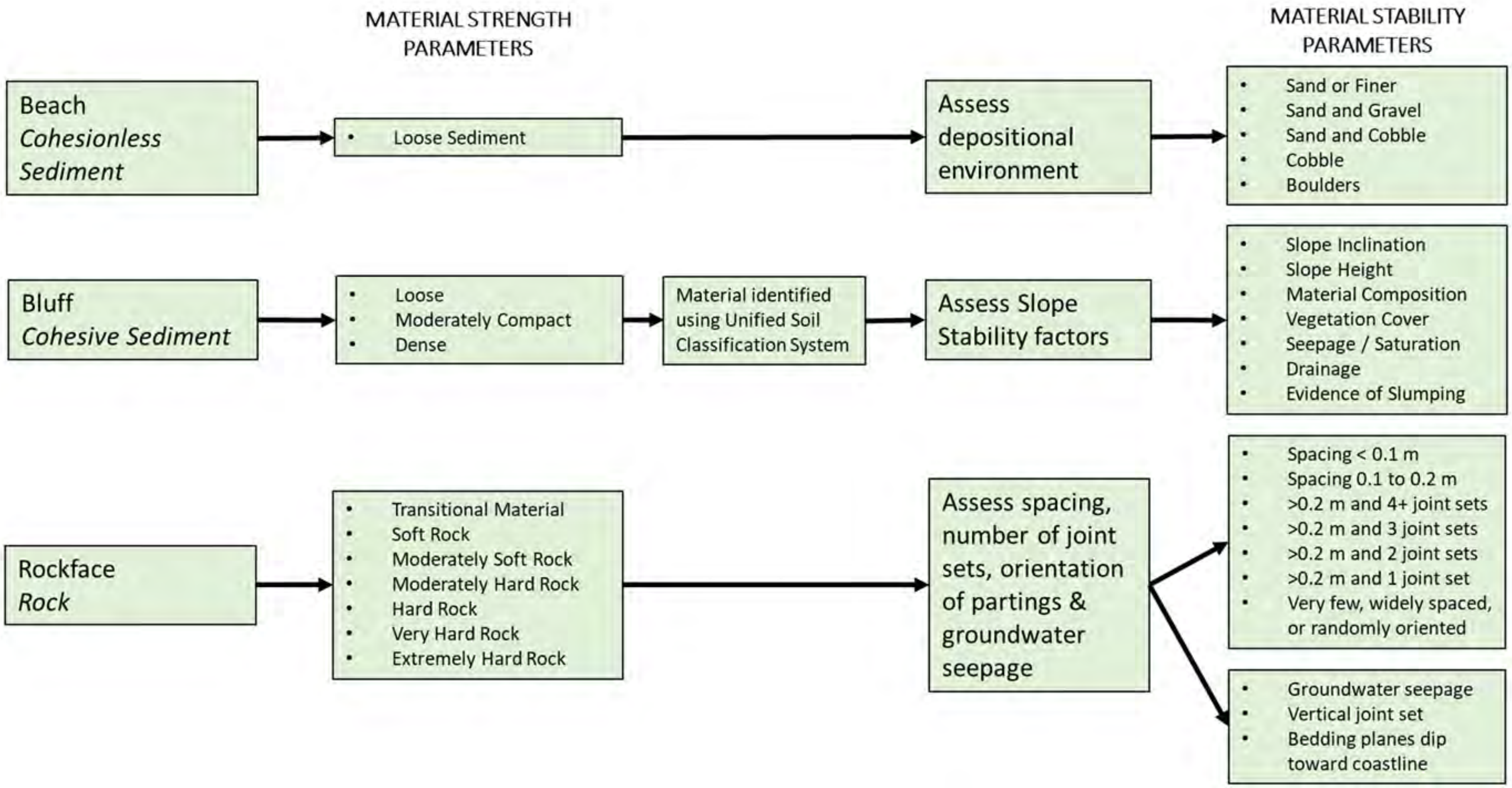

Figure 3.11: CERFA Geological Erodibility Index Components

Technical Background and Assumptions

Index values for geologic material were calibrated using previously documented rates of coastal recession at representative sites throughout the Maritimes. Select sites in Nova Scotia were field tested to further refine the calibration process. Index values were assigned using reference data and were modified based on the results of a sensitivity analysis.

- Index values for material strength (MS) were based on compressive strength.
- Index values for material partings (S_{Rock}) were based on the 'Block Size Number', a lumped parameter accounting for Rock Quality Designation (RQD) and the number of joint sets.
- Index values for bluff slope stability (S_{Bluff}) were based on source documentation, weighted linearly within individual categories, and 2:1 for the influence of [Slope, Material Type, Seepage] with respect to [Height, Vegetation, Drainage, Slumping].
- Index values for beach material (S_{Beach}) were developed based on calibrations.

3.6.2 Material Strength

DP Inputs

The hardness or strength of the geologic material that forms a bluff or rockface provides indications of erodibility. A material strength index will be assigned based on field observations to be recorded by the DP (Table 3.5). Steps for field assessment are as follows:

1. Select a representative 10-metre-wide section of the coastline, and complete the assessment at three or more locations. For heterogeneous sites, focus on areas showing the lowest material strength. Assess the material landward of the backshore, representative of the area that would support a building. The beach fronting a bluff or rockface is not the subject of the geology assessment.
2. Identify the earth material class as "Sediment' or 'Rock'. Use Table 3.5 to differentiate these categories.
   a. For sediment, classify the material according to the Unified Soil Classification System (UCS) / ASTM-D-2488 Visual-Manual Procedure for Identification of Soils. <u>Scrape away the weathered surface of the bluff</u> to expose fresh material that is representative of the undisturbed slope face. Indicate whether the material is:
      i. Cohesionless wave deposit (e.g. sand, gravel, beach, dunes); for material in this category proceed directly to determination of Beach parameters.
      ii. Cohesive Sediment (e.g. silty and clayey material, till[11]).
   b. Subject to the discretion of the DP, material that cannot be identified using ASTM-D-2488 should be classified as Rock (including transitional material).
   c. For rock indicate type (evaporite/sedimentary, metamorphic, igneous, or volcanic), and compare to geological mapping, noting any inconsistencies with available mapping data.
3. Determine the Material Strength Category and Index Value using Table 3.5.

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[11] Till refers to unsorted material of varying size deposited directly by glacial ice and usually showing no stratification.

a. Attempt to dislodge material, first by hand, then by peeling if possible using a pocket knife. If there is loose material on the surface of a bluff face, scrape this weathered layer away with a pick or shovel and assess the native, compact material underneath.
b. Carefully probe the bluff or rockface face with a pick or hammer and note degree of crumbling or indentation.
c. If material will not peel using pocketknife, attempt to scratch with steel nail.
d. If handheld specimen can be obtained, carefully attempt to shatter or break using pick or hammer, using appropriate Personal Protective Equipment (PPE).

Table 3.5: Material Strength Index for Material Landward of Backshore

	Category	Guidance	Index Value
Sediment	**Loose**	Easily dislodged by hand. No resistance to point of geologic pick when pushed. Raveling often occurs on excavated faces.	**1.00**
	Moderate	Difficult to dislodge individual particles by hand. Moderate indentation by point of geologic pick when pushed (>5 mm).	**0.99**
	Dense	Cannot dislodge individual particles by hand. Shallow indentation by point of geologic pick when pushed (<5 mm).	**0.98**
Rock	**Transitional**	Easily scratched with fingernail. Peels with pocketknife. Light blows of geologic pick required to make indentation. Particles may be cemented. Requires power tools for excavation.	**0.95**
	Soft	Difficult to scratch with fingernail. Peels moderately well with pocketknife. Firm blows of geologic pick required to make indentation. Handheld sample crumbles under single blow of hammer.	**0.86**
	Moderately Soft	Difficult to peel with pocketknife. Very shallow indentations (<5 mm) produced by firm blows of geologic pick.	**0.73**
	Moderately Hard	Cannot be scraped or peeled with pocketknife. Can be distinctly scratched with 20d common steel nail. Hand-held specimen breaks with single blow of hammer.	**0.54**
	Hard	Can be faintly scratched with 20d common steel nail. Hand-held specimen requires more than one hammer blow to break it.	**0.30**
	Very Hard	Cannot be scratched with 20d common steel nail. Hand-held specimen breaks only by repeated, heavy blows of hammer.	**0.01**

Heterogeneity of Material

The erodibility assessment will, out of necessity, require generalization of complex geologic environments. The DP must rely on professional judgement and use the precautionary principle where generalizations are necessary. Setback calculations have been designed to account for small variations in application of the tool.

At some sites, the geologic material will vary within the scale of the slope face to be assessed. Types of variation include (but are not limited to):

- Vertical variation: Cohesive sediment (i.e. bluff) may overlie a rockface; if the rockface and bluff are both at least two metres high, the Assessment Type will be based on a *two-layered system*; for a two-layered system the erodibility index is calculated for the rock layer, and the stable slope allowance is based on both units (using a 1:1 slope for harder rock, a 2:1 slope for soft rock or transitional material, and a 3:1 slope for cohesive sediment).
- Lateral variation: The material type may vary along the length of the coastline under assessment; the DP may select from one of the following options:
  - Complete separate CERFA calculations for each section of coastline that can be differentiated, and delineate clearly on a site map the location of each CERFA assessment.
  - Indicate clearly on a map or plot plan which section of the coastline was assessed; in this case the CERFA is valid only for a proposed development footprint that aligns with the section of coastline indicated on the accompanying map.
- The parameters to be assessed may show variations within the selected 10-metre section of coastline; the DP must use professional judgement and select from one of the following options:
  - Base the CERFA on material that may be considered representative of the bluff or rockface.
  - Base the CERFA on the parameters that produce the largest setback.

Technical Background and Assumptions

This method has been adapted from the United States Department of Agriculture (USDA) Field Procedures Guide for the Headcut Erodibility Index, *Dams National Engineering Handbook.* The descriptions for each material type shown in Table 3.5 are based on Tables 52-3 and 52-4 of this guide.

3.6.3 Selection of Material Stability Table

Steps for collection of additional field data will depend on the primary material type:

- For rock, assess material partings (Table 3.6).
- For cohesive sediment, determine slope stability parameters (Table 3.7).
- For cohesionless sediment, determine material type (Table 3.8).

Sites that exhibit a steep slope fronted by beach material should be assessed using the procedure for a rockface (Table 3.6) or bluff (Table 3.7). Two-layered sites should be assessed using the procedure for a rockface (Table 3.6).

3.6.4 Stability of Rock

The stability of rockfaces is dependent on the nature of bedding planes, joints, and faults, collectively termed Material Partings. More frequent partings tend to reduce the stability of the rock mass and increase the potential for slips, slumping, and mass wasting. Other special cases that tend to increase the potential for mass wasting should be documented. For example:

- Evidence of active groundwater seepage.
- Vertical Joint Sets.
- Bedding planes that dip toward the coastline.

DP Inputs

Complete an assessment of the material partings at three or more locations within a representative 10-metre-wide section of shoreline:

1. Base the assessment on a section that is representative of the rockface as a whole; if the material is highly variable, select a section with the most closely spaced partings.
2. Document the presence of bedding planes, faults, and geologic contacts (if applicable).
3. Document the number and orientation of observable joint sets (a joint set is a group of parallel, evenly spaced joints).
4. Determine whether there is a vertical joint set that is parallel to the coastline.
5. Document evidence of groundwater seepage and/or freeze-thaw activity.
6. Determine the representative or minimum spacing of material partings.
7. The DP may use professional judgement to adjust the stability category downward (less stable) if vertical joints or seaward-dipping beds are observed.

Technical Background

This method has been adapted from the United States Department of Agriculture (USDA) Field Procedures Guide for the Headcut Erodibility Index, *Dams National Engineering Handbook.* The descriptions for material partings shown in Table 3.6 are drawn directly from Table 52-7 of this guide.

Table 3.6: Material Stability Index for Rock as a Function of Representative Spacing of Rock Partings

Stability Category	Guidance (representative spacing of partings and number of joint sets)	Index Value
Laminated/Shattered	Spacing <0.1 m	**0.99**
Very Low	Spacing 0.1 to 0.2 m	**0.96**
Low	>0.2 m and 4 or more joint sets	**0.85**
Low-Moderate	>0.2 m and 3 joint sets incl. bedding planes	**0.70**
Moderate	>0.2 m and 2 joint sets incl. bedding planes	**0.52**
High	>0.2 m and 1 joint set or bedding planes	**0.37**
Very High	Very few / > 2 m spacing / randomly oriented	**0.25**

3.6.5 Stability of Cohesive Sediment

In cohesive sediment transitional and rotational failure can lead to mass wasting, accelerating the process of coastal recession. The flow chart for the stability index for such cases is provided in the following Figure.

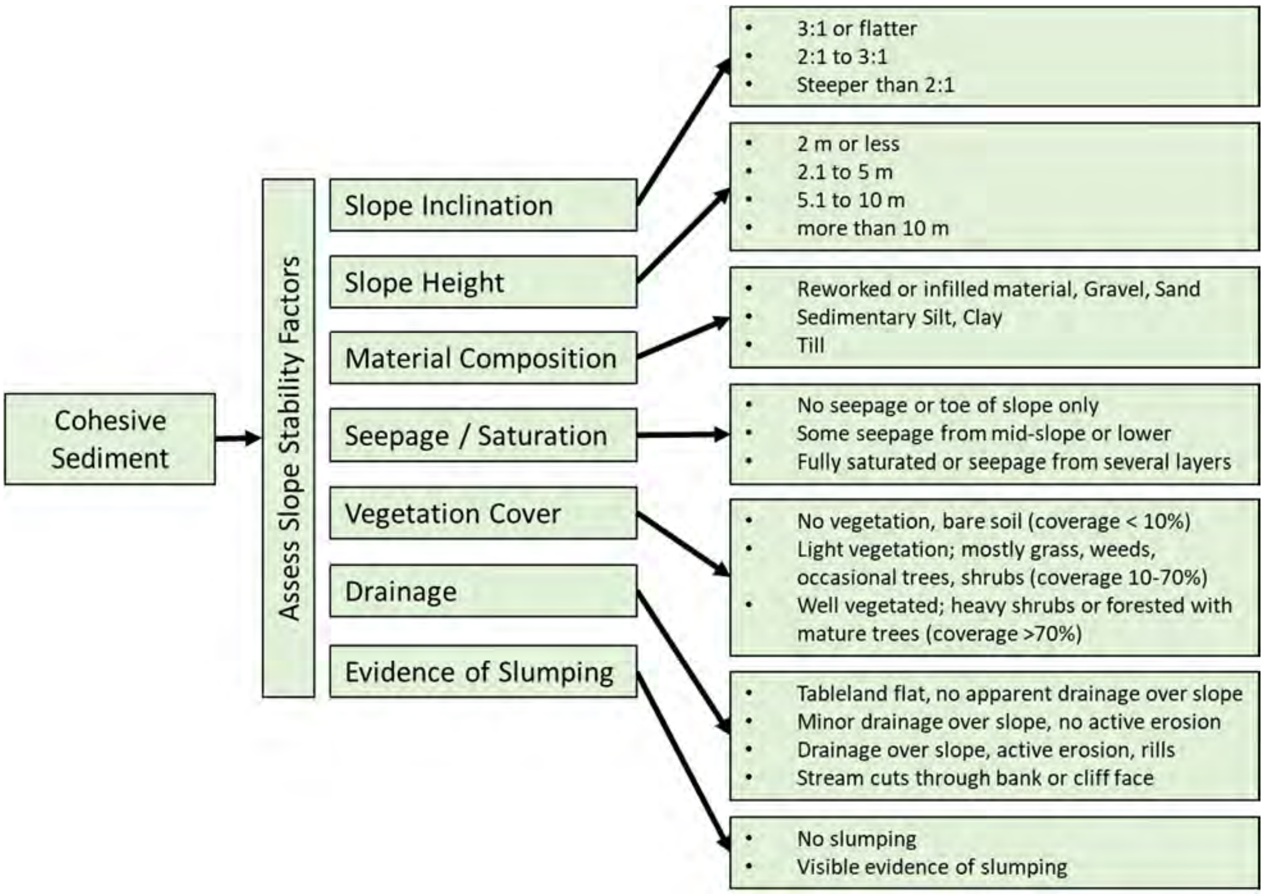


Figure 3.12: CERFA – Slope Stability Parameters for Cohesive Sediment (Bluff)

DP Inputs

The following screening-level procedure will help to scope the relative risk of slope failure using reconnaissance data.

1. Use a range-finder, camera application, or geological compass to estimate the slope angle of the bluff; the default value is at least 2H:1V or greater.
2. Confirm the bluff height from initial measurements.
3. Confirm the Material Classification in Table 3.5 using the UCS classification.
4. Examine the bluff face for evidence of seepage and document the approximate height(s) at which seepage emerges:
    a. Visible flow emerging from the face of the bluff.
    b. Zones of sheen or wetness on the surface of the material.
    c. Sections which show discolouration, are softer or deformed, and are wet or saturated when pinched.
    d. Visible and persistent wetness at bedding planes or partings.
    e. Vertical rills[12] which emerge mid-slope.
    f. Chemical staining (black or red) or leaching (light grey to white).
    g. Moss or vegetation growing only on a distinct bedding plane or parting.
5. Examine the bluff face for evidence of run-off that originates as surface water at the crest of the bluff:
    a. Slope, swales, diching, erosion and ground conditions on tableland/terrace above bluff.
    b. Evidence on bluff face of erosion, rills, or wash-out unrelated to seepage faces.
    c. Top of bluff notched/incised by flowing water.
    d. Flowing streams or indications of seasonal drainage courses.
6. Document visible evidence of material collapse, sliding, slumping, etc.

Technical Background

This method has been adapted from the Ontario Ministry of Natural Resources *Technical Guide, River & Stream Systems: Erosion Hazard Limit* (Table 4.2) and the *Technical Guide for Great Lakes – St. Lawrence River Shorelines, Part 4: Erosion Hazard* (Table 4.2). The factors for slope stability shown in Table 3.7 are weighted according to these sources, adjusted based on the results of a sensitivity analysis.

[12] A rill is a small shallow channel formed by water flow eroding into a soil slope.

Table 3.7: Material Stability Index for Bluffs

Slope Inclination	Steeper than 2:1 (>27 deg)	**0.2**
	2:1 to 3:1 (18 to 27 deg)	**0.15**
	3:1 or flatter (<18 deg)	**0.1**
Slope Height	More than 10 m	**0.1**
	5.1 to 10 m	**0.08**
	2.1 to 5 m	**0.06**
	2 m or less	**0.04**
Material Composition	Reworked or infilled material, Gravel, Sand	**0.2**
	Sedimentary Silt, Clay	**0.15**
	Till	**0.08**
Seepage from Slope Face	Fully saturated or seepage from several layers	**0.2**
	Some seepage from mid-slope or lower	**0.15**
	None or near toe of slope only	**0.05**
Vegetation Cover	No vegetation, bare soil (coverage < 10%)	**0.1**
	Light vegetation; mostly grass, weeds, occasional trees, shrubs (coverage 10-70%)	**0.05**
	Well vegetated; heavy shrubs or forested with mature trees (coverage >70%)	**0.01**
Tableland Drainage	Stream cuts through bank or cliff face	**0.1**
	Drainage over slope, active erosion, rills	**0.08**
	Minor drainage over slope, no active erosion	**0.06**
	Tableland flat, no apparent drainage over slope	**0.02**
Evidence of Slumping	Yes	**0.1**
	No	**0.05**

3.6.6 Beach Stability (Cohesionless Sediment)

Use the UCS classification of beach sediment to select the appropriate category in Table 3.8:

- Sandy material or finer (including riparian wetlands), associated with a generally lower-energy depositional environment.
- Sand and/or Gravel, associated with a moderate-energy depositional environment.
- Cobble, associated with a higher-energy depositional environment.
- Boulders, associated with very high energy depositional environments and/or an eroding rockface.

This method has been developed through preliminary calibration to erosion rates as observed at beach test sites in the Maritimes. It is stressed that there is great variability in beach shoreline change rates, even given similar sediment sizes and exposure. Some beaches will erode significantly faster than the rate given by the CERFA calculation, and some beaches may erode more slowly or accrete if the sediment supply exceeds the rate of removal by waves (e.g. material supplied by nearby eroding headlands). In the case of an accreting beach, a precautionary approach still warrants a setback distance because it is not known whether future sediment supply can keep up with accelerating sea level rise and its erosive effect.

Table 3.8: Material Stability Index for Beaches

Category	Description	Index value
Sand or Finer	Typ. grain size < 2mm	0.8
Sand and Gravel	Sand < 2 mm Gravel 2 to 60 mm	0.7
Sand and Cobble	Sand < 2 mm, Cobble 60 to 200 mm	0.5
Cobble	Grain size 60 to 200 mm	0.3
Boulders	Grain size > 200 mm	0.1

Note: the above coefficients were calibrated during tool development in conjunction with the annual erosion rate factor described in section 4.4.

3.7 Wave Exposure Assessment

3.7.1 Maximum Fetch Distance

DP Inputs

Fetch is the length of unobstructed open sea surface across which the wind can generate waves. The DP shall measure maximum fetch distance at high tide on navigation chart, Google Earth or equivalent. The measurement must follow the longest distance, and is not necessarily perpendicular to the shoreline.

Special Case: Fetch Distance between Islands or Headlands

If the path to maximum fetch runs through a gap between islands or headlands, the gap may partially reduce the offshore wave energy reaching the property. Very narrow gaps can fully block offshore wave energy. For the purposes of CERFA, the minimum gap width defined is one tenth (1/10) of the distance to the property. The DP must choose between the following two cases, based on the gap width Gw relative to the distance from gap to property GP:

- **Case 1 – If narrow gap, Gw < GP/10, apply limited fetch behind island** – See Properties 2 and 3 on Figure 3.13. If the gap is very narrow relative to the distance to the property, it is assumed that offshore swells are fully blocked for the purposes of the CERFA. The fetch distance must be measured in the lee of the obstacles, i.e. from the property to the island.

- **Case 2 – If wide gap, Gw > GP/10, apply full fetch** – See Property 1 on Figure 3.13. The CERFA tool then automatically applies a correction factor for wave attenuation[13] based on gap width relative to property distance.

Finally, the DP must select the case where the highest wave exposure index is obtained between (1) fetch in the lee of islands, and (2) fetch through the gap with correction factor. This determination is made possible by iteratively entering the values in the CERFA tool, and checking the output wave exposure index.

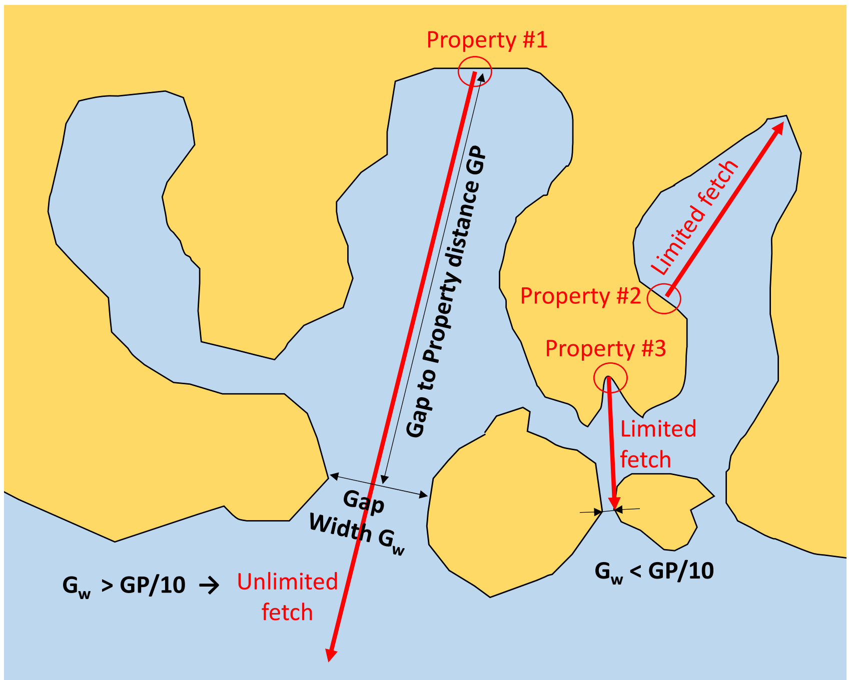


Figure 3.13: Fetch Measurements for 3 Example Properties

[13] Wave 'attenuation' typically refers to a reduction in wave height, while 'dissipation' refers to a reduction in wave energy. This technical distinction does not affect completion of the CERFA by the DP.

Technical Background and Assumptions

F_index = Fetch exposure index, from 0 to 1

The input fetch distance to achieve maximum F_index is 50 km, which was determined during calibration to account for the following facts:

- Large offshore waves from unlimited fetch will break some distance before impacting the shoreline, thereby reducing the influence of unlimited fetch distance. Wave breaking then depends on water level, itself a function of storm surge more than fetch distance. Storm surge is too complex and localized a process for the purpose of the CERFA assessment. For reference, a 100 km/hr wind blowing over 50 km would generate significant wave heights[14] of 3.2 m, which would start breaking in 4 m of water.
- There are some fetch-limited sites around the Bay of Fundy and Gulf of St Lawrence where estimated historical erosion rates are comparable to some open Atlantic Coast locations. While wave energy is a major influence on erosion rates, it cannot account for the full range of observed variability.

For straight fetch without islands, the index is calculated as:
$F\_index = (F\_km / 50)^{1.5}$, with a max value of 1 if F_km > 50 km.

The power relationship was found to provide the best calibration for a low fetch site (for example at Graves Island). It also provides the best fit line for wave energy[15] as a function of fetch distance using a standard Jonswap calculation (Kamphuis, 2010) of wind-wave growth.

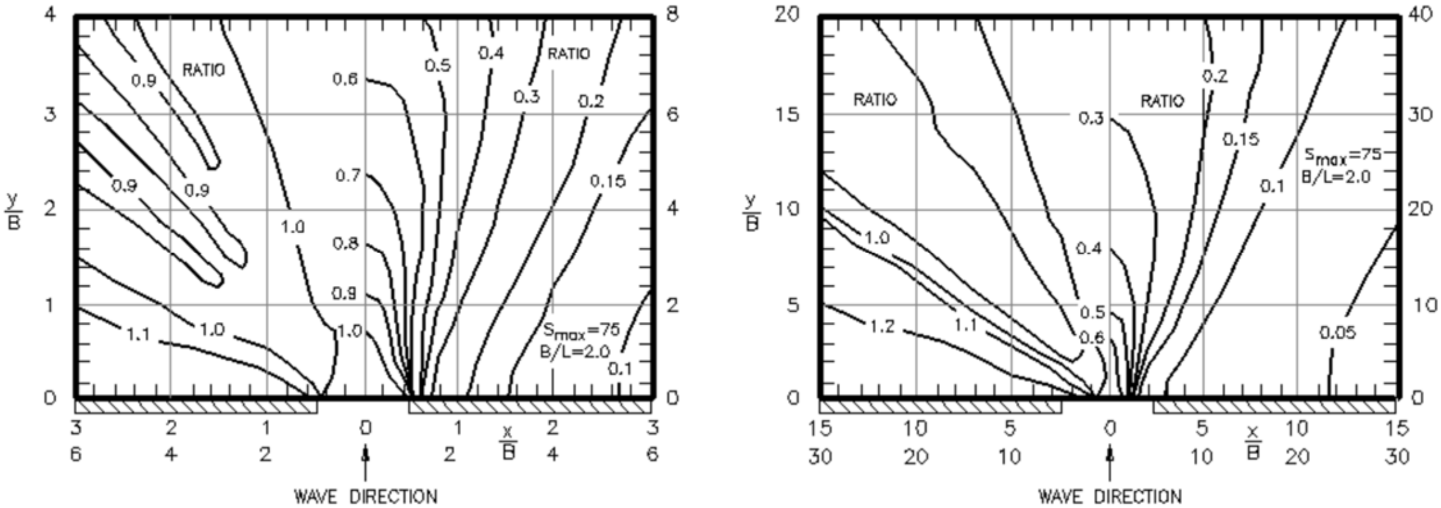
Special Case: Fetch Distance between Islands or Headlands

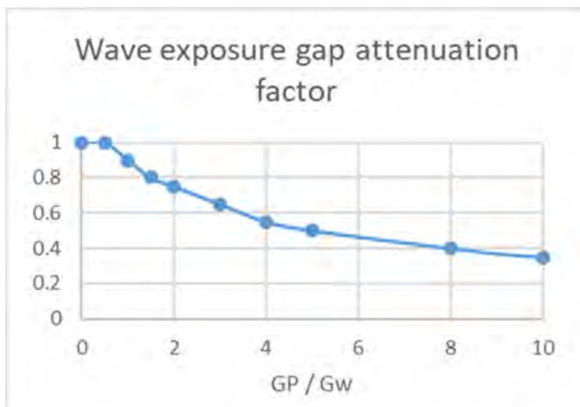
Wave dissipation coefficients are based on harbour breakwater diffraction diagrams as presented in the Coastal Engineering Manual (USACE CEM 2006 Part II Chap 7 – Harbour Hydrodynamics). In this case, F_index is modified as follows:

$$F\_index = F\_index \; x \; Gap\_factor$$

[14] Based on standard Jonswap wind-wave growth calculation (USACE Coastal Engineering Manual 2012).

[15] Wave energy, which drives erosion, is proportional to wave height squared.





Note: GP/Gw in bottom plot is y/B in top plot

Figure 3.14: Wave Height Attenuation Factor through Gap (Bottom) Derived from Diffraction Diagrams (Top) – Based on conservative assumption of perpendicular wave incidence. Note: the DP is required to use longest fetch distance which is not necessarily perpendicular to the shoreline.

3.7.2 Natural Wave Dissipation

3.7.2.1 Tidal Wetland

DP Inputs

The DP shall indicate the presence of a tidal wetland and its width, best measured at low tide. It can be generally assumed that the OHMW would outline the tidal wetland, which is therefore attenuating the wave energy impacting the area immediately on the upland side.

Technical Background and Assumptions

Table 1 presents a review of field results from the literature for wave height attenuation as a function of tidal wetland width for typical marsh grasses (i.e. Spartina species). The relationship can be complex, as the amount of attenuation is highly influenced by the depth of water (tide) and height of marsh vegetation. The relationship of Yang et al (2012) was deemed reasonable to use in the initial version of the tool. The relationship could be revisited in the future once there is sufficient new data available for local marshes, notably from ongoing research in the Bay of Fundy.

Table 3.9: Wave Height Attenuation Data for Tidal Wetlands

Water depths and wave heights for field studies, with vegetation species that quantify wave energy dissipation, comparable to those found in the Bay of Fundy (modified from Table 1 in Vuik et al., 2016 and Table 1 in Tempest et al., 2015). H = Significant wave height and h = water depth over marsh platform. All measurements in metres.

Publication	Max H (m)	Max H Attenuated (m)	Transect Length (m)	Average Wave Height Attenuation (%)
Jadhav *et al.*, 2013	0.89	0.39		
Knutson *et al.*, 1982	0.95	0.32	10 20 30	65 87 94
Möller, 2006	0.70	0.32	10 10	15-20 11-17
Yang *et al.*, 2012	1.61	0.73	51	79
Ysebaert et al., 2011	1.86	0.64	>50 m	80
Vuik *et al.*, 2016 - Hellegat	1.90	0.69	50	60 (h=0.4) 20 (h>0.8)
Vuik *et al.*, 2016 - Bath	1.27	0.59	50	80 (h=0.4) 50 (h=0.8)
Wayne, 1976			20	71

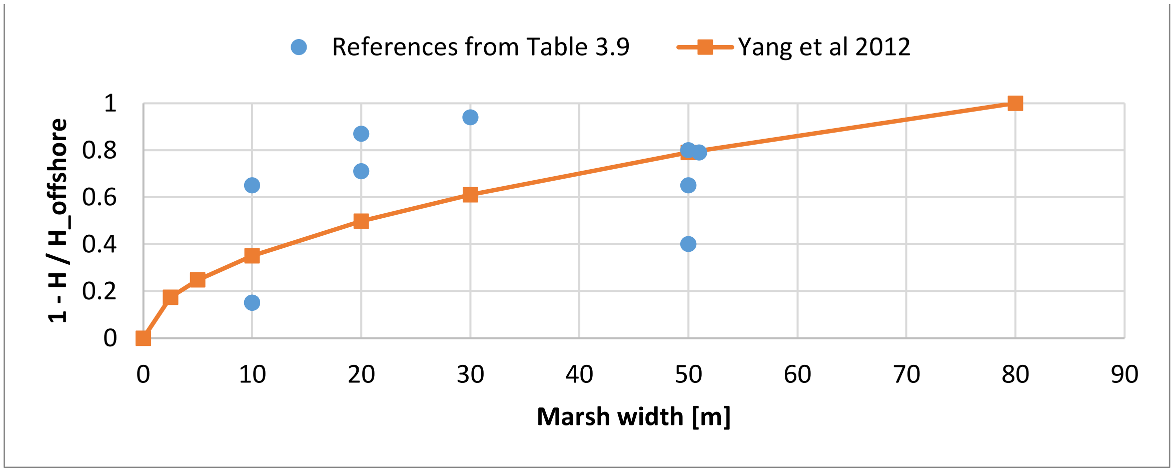


Figure 3.15: Wave Height Attenuation vs. Tidal Wetland Width

Salt_marsh_exposure_index = 1 – Salt_marsh_dissipation

CERFA tool uses the Yang et al 2012 relationship.

Please see section 3.7.4 for final wave exposure index calculation

3.7.2.2 Low-Angle Foreshore

DP Inputs

The DP shall indicate the foreshore angle, estimated over a vertical distance of no more than 2 m below HHWLT (see Figure 3-6).

Technical Background

Wave action to the shoreline is influenced by a range of complex factors, including profile slopes. More gentle slopes provide better dissipation, while steeper slopes allow a higher wave to break close to shore. The minimum slope that will provide some level of dissipation therefore depends on the wave exposure parameterized by the fetch distance.

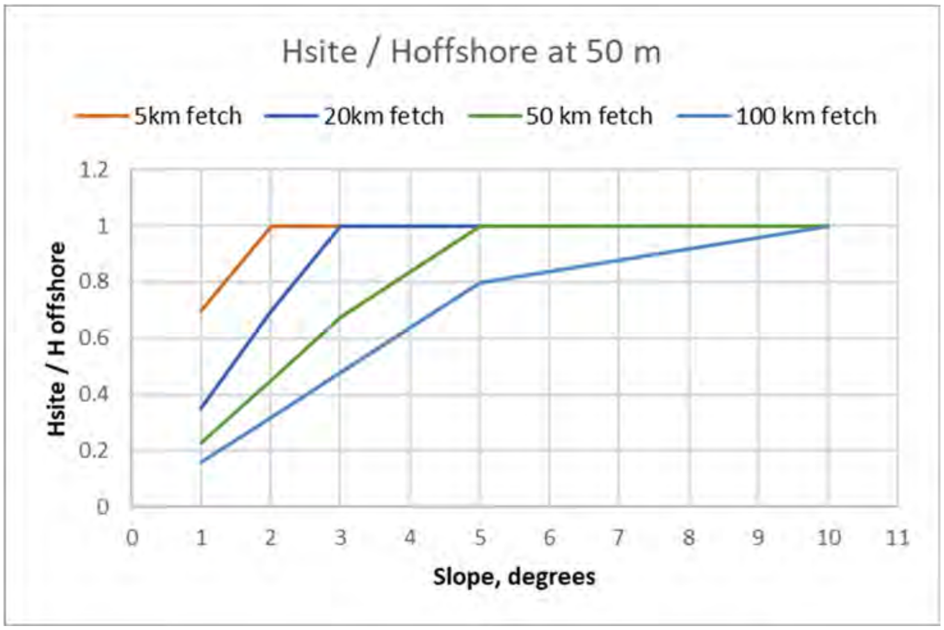


Figure 3.16: Wave Height Dissipation 50 m from Shore as a Function of Foreshore Slope

Assumes fetch limited wave growth for 100 km/hr wind and breaking wave criteria of

$$\text{H\_breaking} = 0.8 \text{ x water depth}$$

Note: the arbitrary 50 km fetch distance is a calibration value, along with the maximum annual erosion rate and the maximum fetch distance. These values were tested as a group to provide the best fit to a limited set of calibration sites with historical erosion estimates.

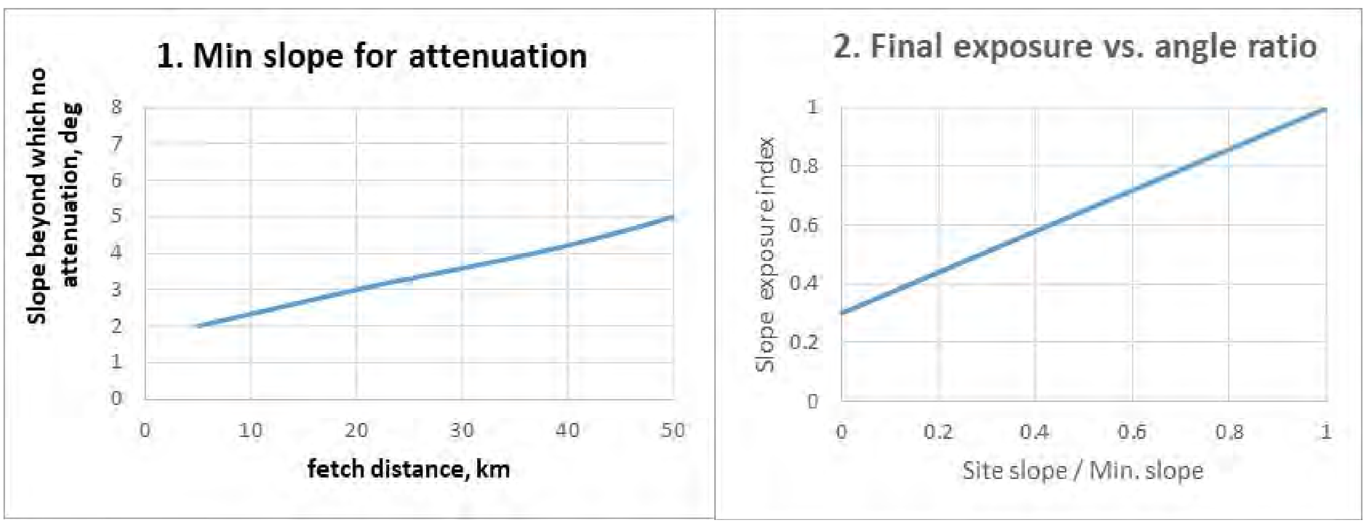


Figure 3.17: Calculation of Slope Exposure Index

The slope exposure index is intended to modulate the fetch index. The minimum slope exposure index cannot be set to 0 due to SLR. In order to avoid a tool that is overly sensitive to the field-measured foreshore slope, the slope exposure index was set to range between 0.3 and 1.0. The 0.3 m value was a calibration factor.

3.7.2.3 Backshore Natural Armouring

Eroding coastlines may produce material sufficient to form a wide backshore that provides additional wave dissipation. The eroded material may include larger boulders which form what is commonly referred to as 'natural armouring', the effectiveness of which is generally related to the size of the material and backshore width.

DP Inputs

The DP shall enter the following data:

- Backshore width.
- Ground coverage of natural armouring.
- Size of natural armouring (diameter of boulders).

Technical Background and Assumptions

Recent literature (Narayan et al 2016) on the effect of nature-based defences (coral reefs, mangroves, salt-marshes, seagrass/kelp beds) indicates that coastal habitats can reduce wave heights by between 35% and 71%. Natural armouring is difficult to parameterize because it is very site-specific. For the purposes of tool development, wave dissipation provided by the backshore has been assumed proportional to the following variables:

- Backshore width (as it is for tidal wetland width).
- Coverage of natural armouring.
- Size of natural armouring.

The proposed calculation is as follows:

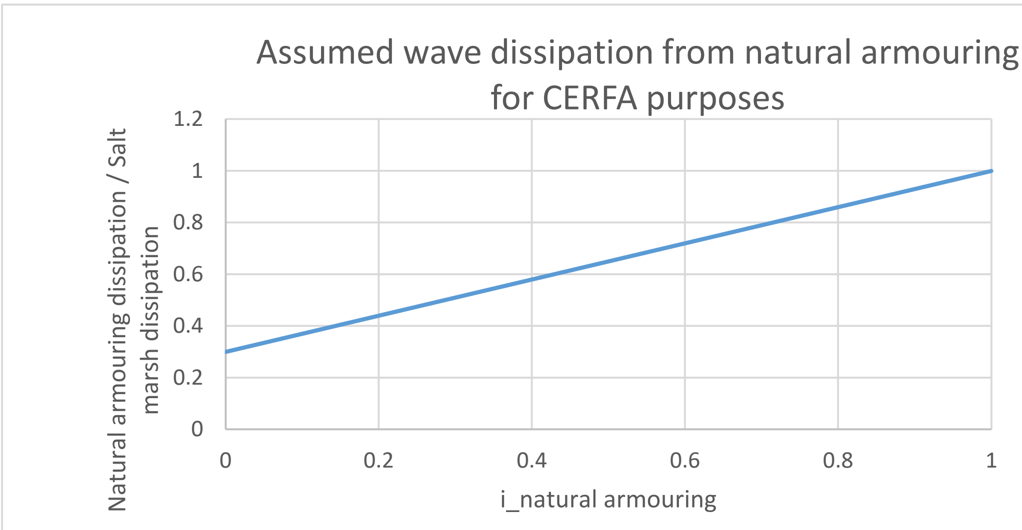
- The dissipation general curve shape is assumed to follow that of the tidal wetland, and is based on measured backshore width.
- The coefficient is then modified based on the natural armouring index defined in the table below.

As illustrated on Figure 3.18, it is assumed that for a given backshore width, the dissipation of the backshore width will be:

- 30% that of a tidal wetland of similar width in the absence of natural armouring (natural armouring index of 0).
- Similar to that of a tidal wetland of similar width with complete coverage of large boulders (natural armouring index of 1).

The above are preliminary assumptions that could be improved with additional calibration using multiple field sites and historical erosion rates for sites with and without natural armouring.

Coverage Index		x	Size Index		= Total Index
Coverage	i_coverage		Diameter	i_diameter	
< 50 %	0	x	Smaller than cobble < 0.06 m	0	= i_natural armouring (0 to 1)
50-75 %	0.5		Cobble 0.06-0.2 m	0.33	
>75 %	1.0		Boulders 0.2-1.0 m	0.66	
			Large boulders >1 m	1.0	



$$Backshore\_armouring\_index = 1 - Natural\_armouring\_dissipation\_index.$$

Figure 3.18: Calculation of Natural Armouring Dissipation Index

Note: For future improvements, backshore elevation and/or slope could be considered in the backshore dissipation estimate, provided there is enough calibration data.

3.7.3 Risk of Barrier Beach Blowout

The DP must determine the presence of protection that is at risk of being overwhelmed by sea level rise. This would typically include, but not be limited to, a low-lying barrier beach or causeway that, when breached, would allow increased wave penetration towards the property.

Most of the barrier beaches are at risk of blowout under accelerated sea level rise. If the site is on a waterbody now protected by a barrier beach, the DP must identify it. For risk mitigation purposes the wave exposure index as calculated by the tool is augmented by a provisional 50%, but still capped at 1.0.

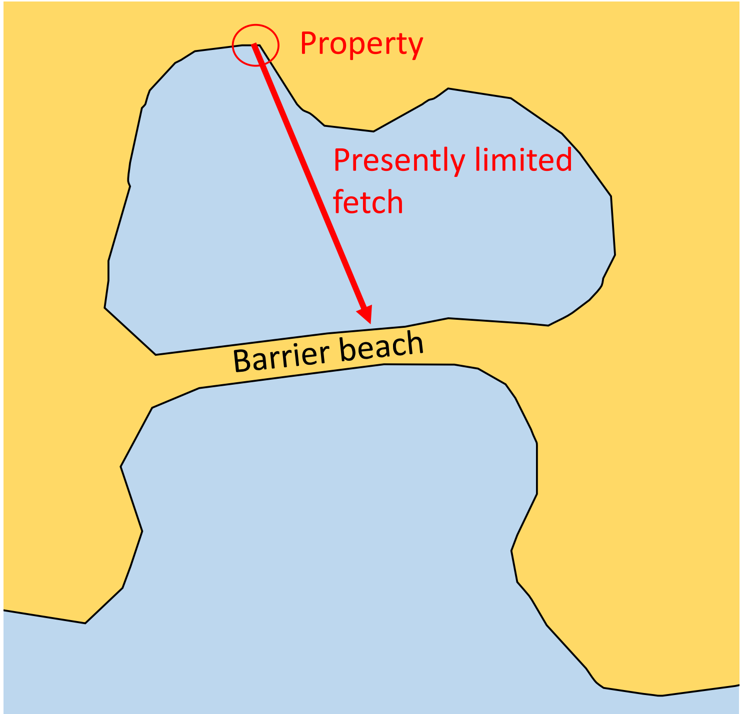


Figure 3.19: Illustration of Barrier Beach Blowout Risk

3.7.4 Wave Exposure Index Calculation

The index is calculated as follows:

$$Wave\_exposure\_index = Fetch\_index \; x \; Natural\_dissipation\_index$$

With

- $Fetch\_index$ as previously defined.
- $Natural\_dissipation\_index =$ $min\,(Salt\_marsh\_exposure\_index, Foreshore\_slope\_exposure\_index \; x \; Backshore\_armouring\_index)$) That is, the index is selected as that with the most dissipation either from the tidal wetland, or from the combination of foreshore slope and backshore width and natural armouring.

This implies that the CERFA calculation does not combine the tidal wetland index with the foreshore angle or natural armouring index.

3.8 CERFA Completion

Pilot-scale field testing presented in the next Chapter showed that the required field inputs for a single CERFA can be collected within 1 to 2 hours, not including travel time. Exceptional circumstances requiring other methods of data collection and field assessment could lead to longer field data collection times. A suggested report template is provided in Appendix A.

Chapter 4 Field Tests and Calibration of Erodibility Component

4.1 Objectives and Site Selection

Pilot-scale field testing was completed at 27 sites, to providing a diverse sample of wave exposure and geology across the three main coastlines of Nova Scotia, i.e. Atlantic, Fundy, and Gulf of St Lawrence. The objectives of the field tests were twofold:

- Test the tool in actual field conditions to ensure applicability to a wide range of conditions;
- Generate erosion rate outputs from the tool for comparison to historical erosion rates estimated from air photos.

Pilot scale tests were completed in August 2020 and February 2021. The test sites included beaches, bluffs, rockfaces, and two-layer cases[16]. Field test measurements are provided in Appendix B.

4.2 Tool Calibration of Annual Erosion Rate

The annual erosion rate calculated by the CERFA intervenes in the calculation of the erodibility setback component (see section 3.2). It can represent a large component of the overall setback for a site combining erodible geology and significant wave exposure.

The calibration of the tool's erodibility calculation is based on estimates of historical erosion rates either from GSC observations where available, or by historical air photo analyses conducted by CBCL and presented in Appendix D.

As presented on Figure 3.3, the erodibility setback component is calculated as:

[16] The dataset presented in the following charts also includes additional test sites conducted by CBCL in the course of the project, for which inputs are not formally documented in Appendix B but available upon request.

Erodibility setback component (m) = G_i x W_i x AR (m/yr) x planning horizon (years)
with:

- G_i = Geological erodibility index (0-1), determined based on in-situ geological inputs.
- W_i = Wave exposure index (0-1), based on fetch distance and moderated by foreshore slope, backshore width and coverage of natural armouring.
- AR = Maximum annual average erosion rate (m/yr), which is a calibration parameter.

The calibration procedure consisted in iteratively testing and adjusting the following parameters:

- Geological erodibility and wave exposure indices (resulting values shown on Figure 4.1), with calibrated input coefficients described in previous sections.
- Blanket maximum annual erosion rate, with calibrated value set at AR = 1.1 m/year.

The calibration procedure consisted in iteratively reducing the difference in annual erosion rate between the CERFA tool estimate and the historical estimate. The error estimates are listed in the following Table, and graphically presented on Figure 4.2. Typical error is in the 0.1-0.2 m/year range.

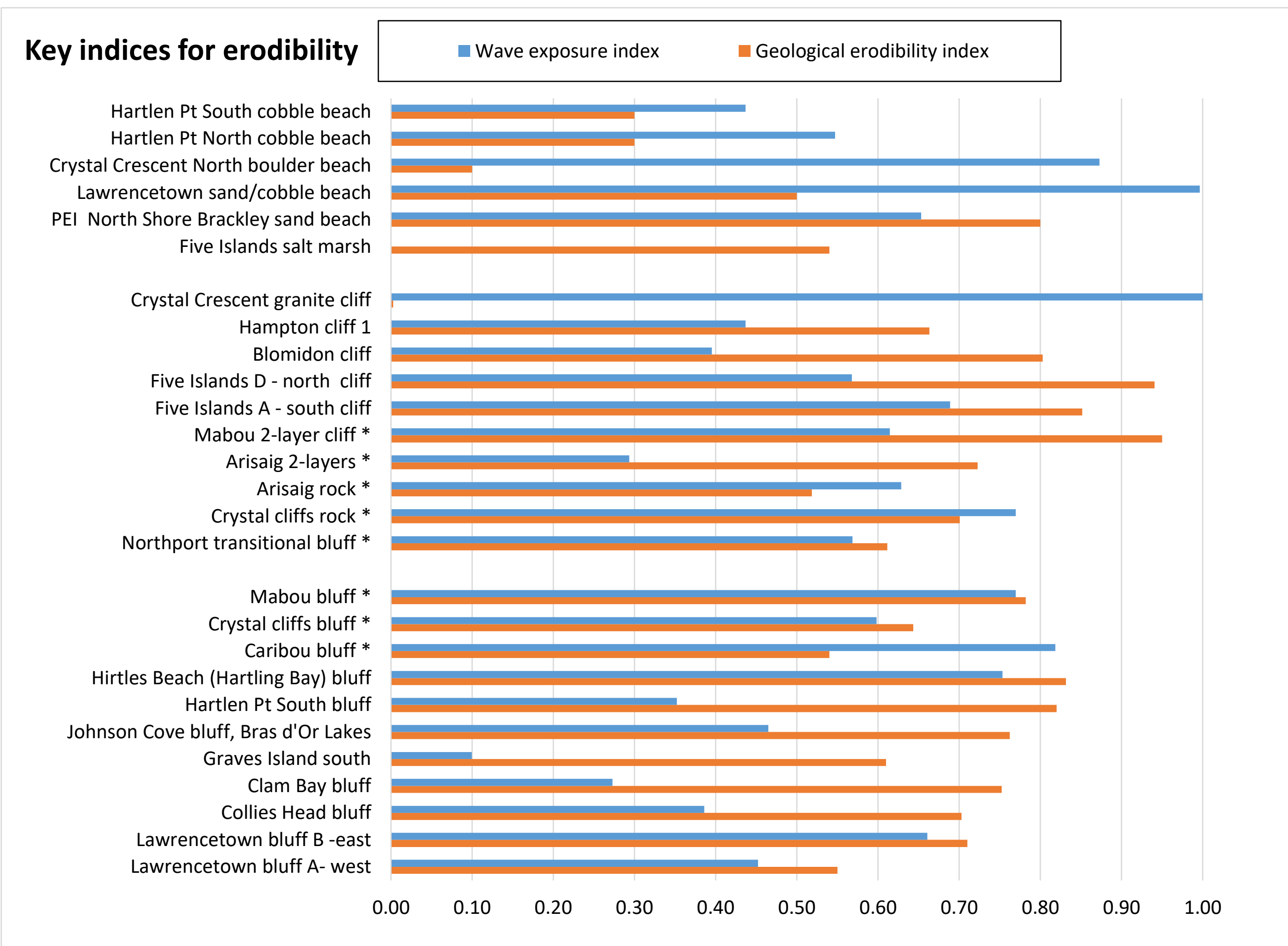


Figure 4.1: Geological Erodibility G_i and Wave Exposure W_i Indices for Test Sites

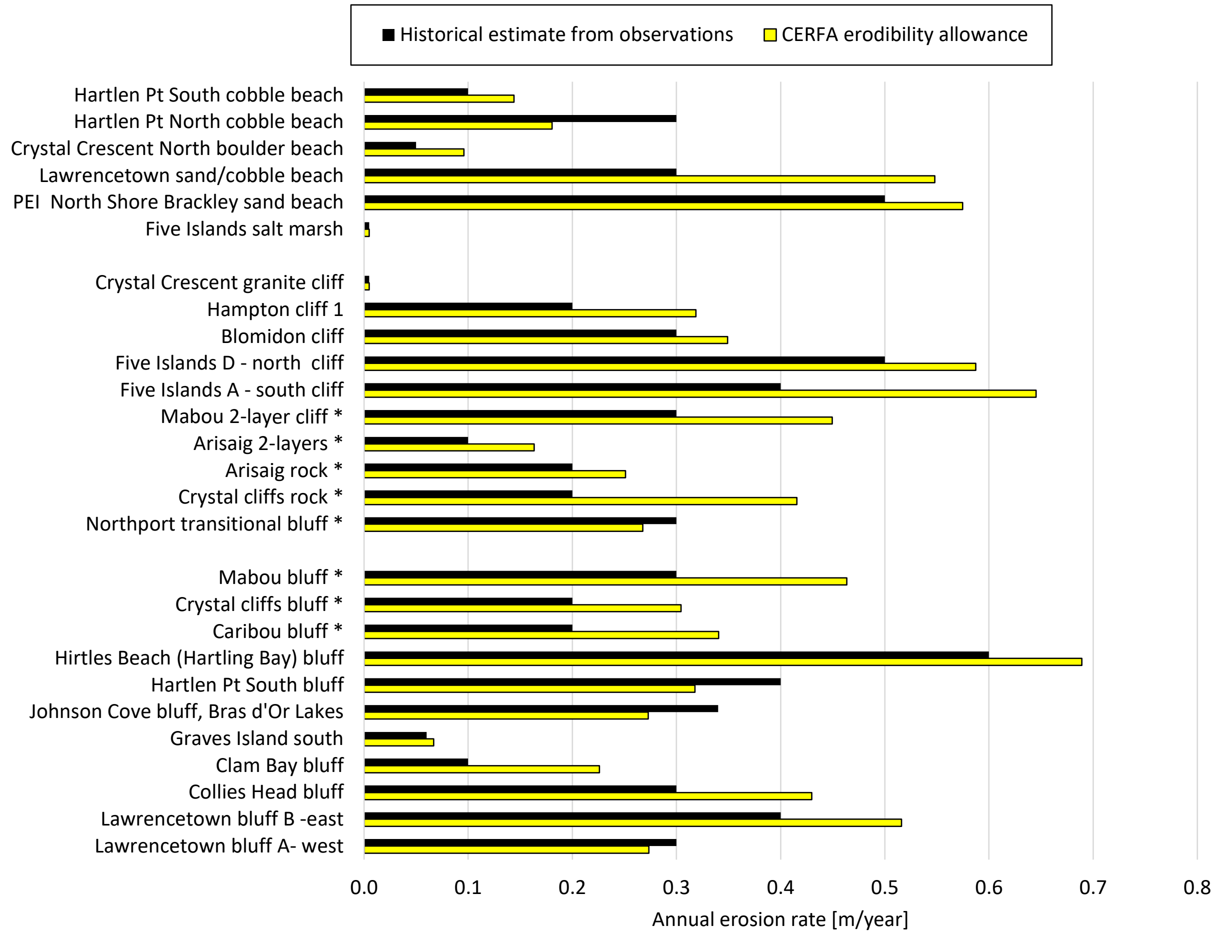


Figure 4.2: Comparison of Annual Erosion Rates –Model vs. Historical

(*) For sites on the Bras d'Or Lakes and Gulf of St Lawrence (North shore and West Cape Breton), historical erosion rates would have been influenced by the protective presence of winter ice cover, which is not accounted for in the CERFA output for future erosion rates. In the absence of long-term measurements, it is very difficult to estimate the historical erosion rate increase due to loss of ice cover directly from observations. Alternatively, sediment transport rates are correlated to wave power, which could be used as a theoretical proxy for erosion potential. For calibration purposes, a correction factor of 0.7 was applied to the tool's output erosion rate to represent past conditions as shown on the graph. This value was developed based on in-house calculations of wave power from long-term offshore wave hindcasts in the Gulf of St Lawrence i.e. Environment Canada's MSC50 dataset (1954-2018), which accounts for ice cover. Since ice cover is expected to significantly reduce due to climate change, the actual erosion rate considered for CERFA erodibility setback calculations assumes no ice cover, and the DP does not need to enter a correction value. That is, the CERFA erosion rate weighed by the erodibility index is the same for North Shore as well as Atlantic and Fundy sites.

Table 4.1: Error Estimates [m/yr] for Annual Historical Erosion Rate

	All Sites	Bluffs	Rock and Transitional Cliffs	Beaches
Root-Mean-Square Error	0.12	0.11	0.13	0.16
Median Error	0.09	0.11	0.08	0.04
Minimum Error	-0.12	-0.08	-0.03	-0.12
Maximum Error	0.25	0.16	0.25	0.25

4.3 Summary Comparison of Setbacks Components

Output setbacks are shown in Figure 4.3. The figure illustrates the wide variety of test conditions, which supports the use of a site-specific approach as developed for this project.

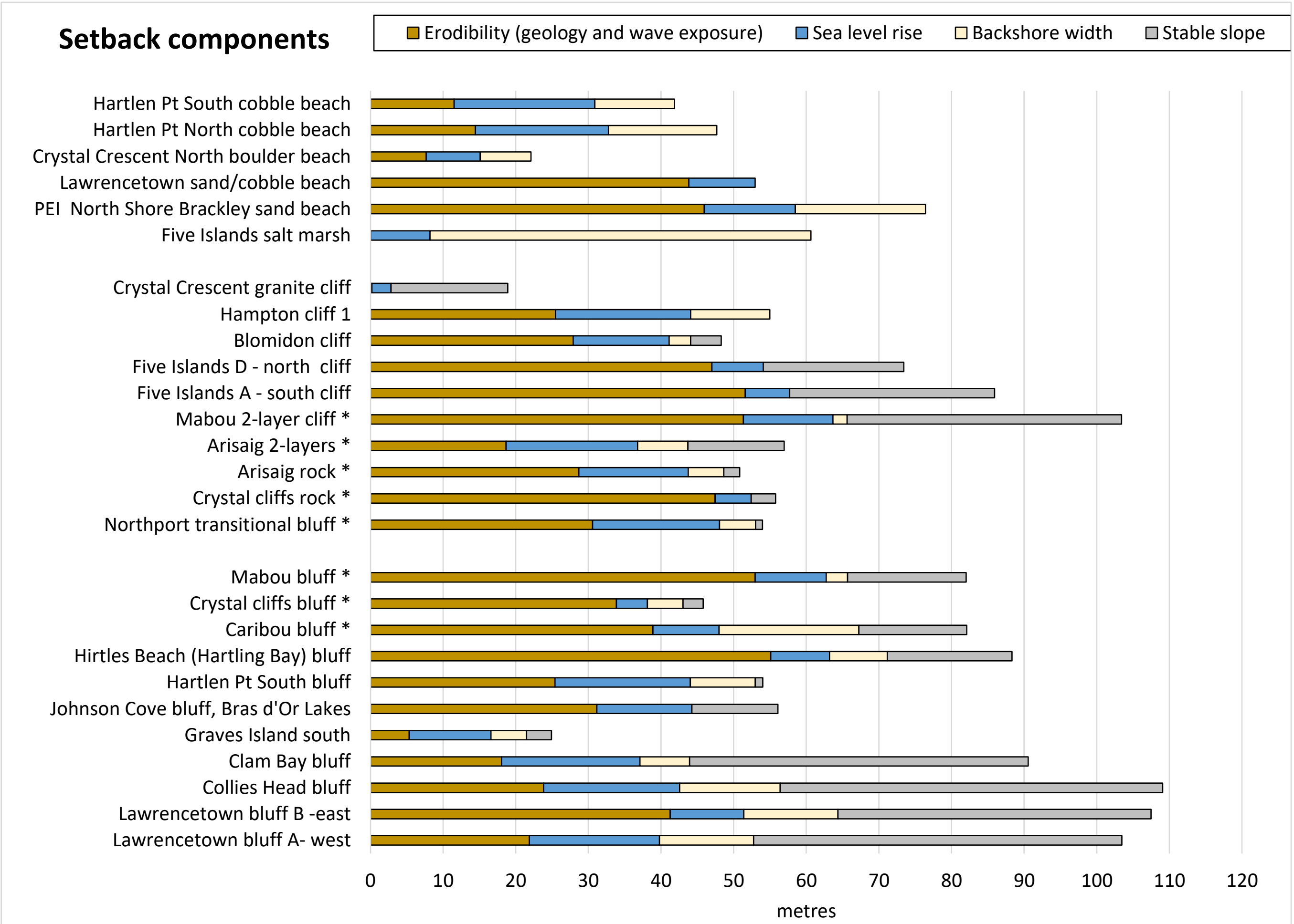


Figure 4.3: Calculated Output Setback Distances for Test Sites - Note: Based on 80-year planning horizon and 1.0 m SLR. Total setbacks shown are not intended to predict future erosion, but to provide a safe buffer using precautionary approach.

In conclusion, the tool is deemed to provide generally reasonable, process-based horizontal setback allowances. However, no erosion model designed for practical use can be expected to accurately reproduce the complex, localized and non-linear processes governing coastal erosion rates across the entire Province of Nova Scotia. Further research into critical components of the methodology are recommended to improve the predictive functionality of the CERFA.

Chapter 5 Recommendations

5.1 Required DP Qualifications

Required qualifications for a Designated Professional (DP) will be prescribed in regulations under the Coastal Protection Act. DPs are required to self-declare as being competent to complete the work, and must be a member in good standing of their respective professional body. Laws governing the DP's professional body and scope of practice will apply. The DP will need experience or capability with skills such as:

- Field identification and classification of sediment using the Unified Soil Classification System or equivalent, and including material strength category as defined in the CERFA guidance documentation;
- Field identification of major classifications of rock, including material strength category as defined in the CERFA guidance documentation;
- Field identification and assessment of geophysical parameters such as bedding planes, joints, faults, seepage features, vegetation, surface water features, and evidence of erosion.
- Identification and assessment of prevailing coastal geomorphology and coastal processes, including but not limited to shore type, depositional and erosional features, wave exposure.
- Measurement of slopes, distances, and elevations using methods as described in guidance documentation.
- Quantitation using topographic maps and marine charts.
- Accessing relevant supplementary materials.

The horizontal building setback in the DP Report is not a guarantee of safety of the building location against coastal erosion or inundation to either the building proponent or the municipality. The DP's responsibility under the CPA is to certify that they are qualified to act as a DP, that the property has been assessed in accordance with the CERFA methodology, and that the resulting horizontal building setback in the DP report, has been determined in a manner consistent with the CPA regulations.

5.2 CERFA Test Results Should Inform the CPZ Upland Width

The Coastal Protection Zone (CPZ) will establish the area for which the provisions of the CPA and associated building setbacks would apply. Building setbacks will include both vertical (MBE-Minimum Building Elevation) and horizontal (from CERFA) components. The CPZ should be wide enough to accommodate most coastal erosion risks encountered around the province's coastline.

The CERFA calculation tool was developed using a precautionary approach. The setback estimation procedure is based on established scientific principles accounting for three basic components of a horizontal erosion setback:

1. Historical erodibility.
2. Impact of climate change and sea level rise.
3. Slope instability towards the end of the planning horizon.

The planning horizon should be long enough to provide meaningful protection against the long-term risks posed by sea level rise and coastal erosion. The planning horizon used for demonstration and testing of the CERFA model was 80 years, consistent with many published SRL projections to year 2100.

Initial CERFA assessments were conducted at a limited number of pilot study sites, which included areas of high erodible rockfaces exposed to heavy wave action. Many comparable sites have documented erosion rates of 0.3 to 0.5 m/year on average, which can sometimes exceed 1 m/year. The calculated setback distances by CERFA reflect the reality of coastal erosion rates in exposed Nova Scotia shoreline. Output setback distances were well in excess of 60 m (the setback distance adopted for Cow Bay, NS) for the more exposed sites, up to 110 m at the exposed bluff test site for an 80-year planning horizon. Based on the preliminary blanket erosion rate of 1.1 m/year (which factors into the erodibility setback component, and is subject to further calibration), the theoretical maximum setback could exceed 130 m once stable slope and sea level rise components are added.

From a science standpoint, considering the additional risks posed by climate change, it is strongly recommended that the CPZ width be commensurate with the envelope of CERFA setback distances for a wide range of sites.

5.3 Default Small Setbacks and Low-Fetch Cases

In the interest of reducing regulatory burden on municipalities and landowners, and managing potential demand pressures for DP services, criteria for low-risk circumstances where the requirement for a CERFA could be waived by a municipality could be further explored. As per Chapter 2, erosion is mostly driven by the combination of wave action and erodible geology. Therefore, small setbacks may apply to locations with:

- Very limited fetch exposure which means low wave action (the subject of the present section), which can be determined from a map.
- Extremely hard shorelines, which cannot be determined from a map.

On a preliminary level, we have examined the potential output setback distances for low-fetch cases. The calculation procedure is illustrated in Table 5.1. These values are based on a case with a near-flat beach foreshore, which yields a sea level rise setback allowance (2) of 14 m. The additional allowances for erodibility (1) and stable slope (3) typically add 5 to 10 m depending on fetch distance and bluff elevation.

Based on these results, it appears reasonable to waive the requirement for a CERFA and apply a given setback for cases that meet the combination of low fetch and bluff elevation under the curves shown on Figure 5.1. The setback distance that would waive the requirement for a CERFA can be calculated from the curves on Figure 5.1, or from the equation provided.

Table 5.1 Estimation of Maximum CERFA Setback for Low-Fetch Cases

<table>
<tr><th colspan="2">Fetch Distance (km)</th><th>1</th><th>2</th><th>5</th><th>10</th></tr>
<tr><td colspan="2">(1) Max. erodibility setback component [m].</td><td>0.2</td><td>0.7</td><td>3</td><td>8</td></tr>
<tr><td colspan="2">(2) Max. SLR component based on 0.7 m SLR over 80-year planning horizon and 20H:1V beach slope limit in CERFA tool.</td><td>14</td><td>14</td><td>14</td><td>14</td></tr>
<tr><th>Bluff Elevation above HHWLT [m]</th><td>(3) Max. stable slope setback component after 1m SLR [m]</td><th colspan="4">(4) Max. total setback = (1) + (2) + (3)</th></tr>
<tr><th>3</th><td>6</td><td>20</td><td>21</td><td>23</td><td>28</td></tr>
<tr><th>4</th><td>9</td><td>23</td><td>24</td><td>26</td><td>31</td></tr>
</table>

Eligibility for waiving of CERFA could be expanded for certain well-defined geographical areas with hard shorelines and/or steep foreshores, which would significantly decrease the precautionary sea level rise setback allowance from the initial exercise above. For example, granite rockfaces along the Nova Scotia South shore should be considered in these categories despite their large fetch distance. Further testing of the tool in these areas would help better define the eligibility criteria.

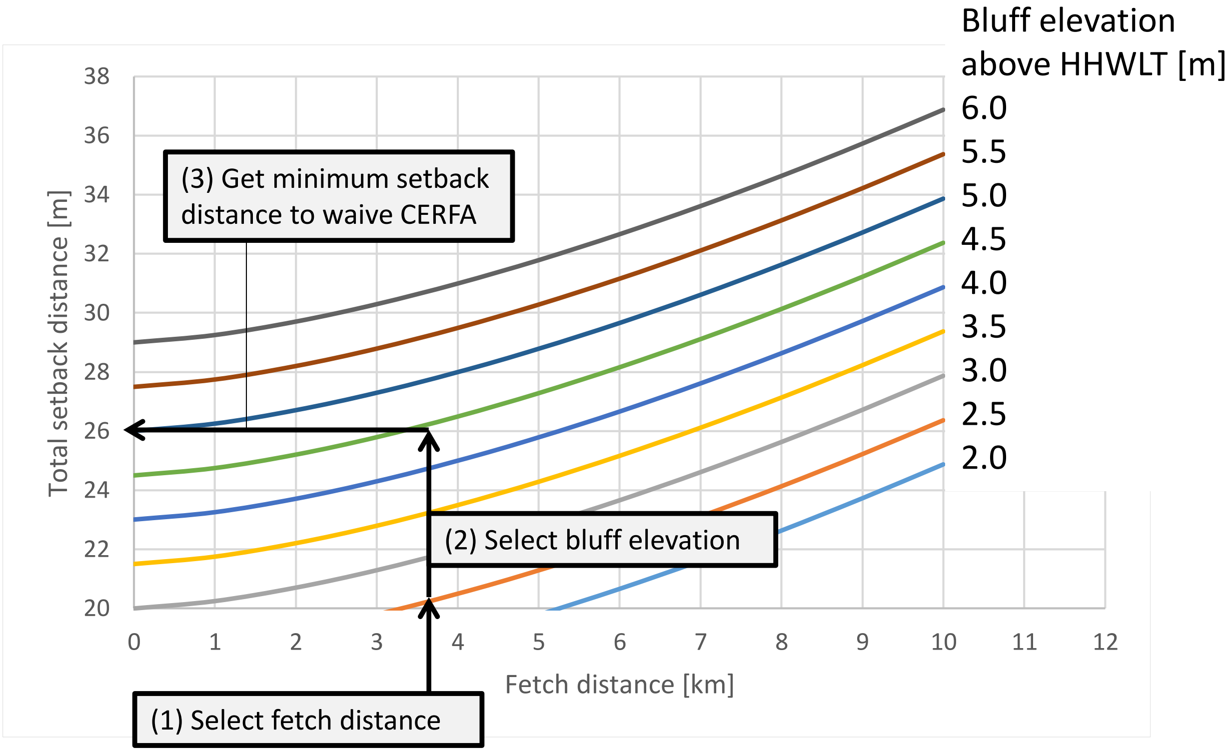


Figure 5.1: Maximum Setback Distances from CERFA Tool for Low Fetch Cases

Setback [m] = $11 + 3\,Eb + 0.0373\,F^2 + 0.4264\,F$

with :

Eb = Bluff elevation above HHWLT [m], and

F = Fetch distance [km]

5.4 CERFA Improvement and Adaptive Management

The tool as developed to date represents an initial platform to develop setback distances on a consistent basis, based on the available information at the time of preparation. Continuing the field monitoring and updating climate change research will contribute towards tool improvement.

It is recommended that NSE and the NS Geological Survey continue testing at sites with documented historical erosion rates, from historical air photos and field studies. Such extended testing will serve both to improve calibration of the erodibility component and to provide opportunity for feedback and improvement on the CERFA procedure itself.

Specifically, improvement and update of the CERFA tool should be focused around the following aspects.

5.4.1 Improved Calibration

The tool should be regularly improved notably along the following aspects:

- **Parameterization of physical processes** should be improved as new research or calibration data becomes available. The addition of new or improved processes in the tool will still need to be practical and function with the relatively simple data inputs from the DP. Improvements to processes may include, but not be limited to:
  - Influence of slopes and widths, notably backshore effect on wave dissipation.
  - Downcutting by tidal currents in Bay of Fundy rivers.
  - Wave dissipation over tidal wetlands for Bay of Fundy sites.
  - Revisiting Sea Level Rise allowance for bluffs. The formation of the wave cut platform in response to SLR should be better defined, as well as the effect of natural armouring with SLR (i.e. can the new profile keep up and self-armour at the same pace as SLR).
  - Two-dimensional spectral wave modeling to validate the fetch and gap width methodology.
  - Impact of prevailing wind directions in fetch distance calculation.
  - Geological aspects to better define or resolve.
- **The maximum annual erosion rate input** in CERFA, used as a calibration parameter, should be regularly revisited with additional data. Notwithstanding the error range associated with historical air photo analyses, these remain the best tool available in the absence of long-term physical monitoring data. It is conceivable that the calibration annual erosion rate may at some point be separated by geographical area, shore type, or some other defining variable, should sufficient long-term erosion data become available. Potentially, if historical air photos of the entire shoreline of NS are georeferenced and mapped, one may consider using a spatial database of annual erosion rates that could supersede the erodibility calculation in the tool. The additional sea level rise and stable slope allowances would still need to be evaluated by the tool.

5.4.2 Site-Specific Studies to Adjust CERFA

The CERFA setback is based on surface observations and measurements of the shoreline profile and geologic material to provide a consistent, risk-managed horizontal setback based on the precautionary principle. Consideration should be given to developing a process whereby a more in-depth, evidence-based investigation could be undertaken at the landowner's expense outside the CERFA process within set parameters. Adjusting the CERFA setback should be limited to adjusting the allowance for stable slope component of the setback, if further physical investigation (such as excavation or drilling) reveals harder material under the surface at a suitable depth and slope to support the proposed structure. No reduction to the CERFA setback based on altering the sea level rise or erodibility components of the CERFA setback is advisable.

5.4.3 Management of CERFA Information

Once operational, all completed CERFA's in the future could be catalogued in a database to develop the appropriate information test and re-apply the tool in the future as more data on measured erosion rates becomes available and other improvements to the tool are implemented.

5.4.4 Adaptive Management Framework

Finally, NSE should make provisions for regular updating of the CERFA tool (e.g., review and update as appropriate at 5 year intervals), using an adaptive management framework i.e**. implement, monitor, learn, modify**. This is to allow the CERFA to adapt to a non-stationary coastal environment, with evolving climate change over long time horizons.

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APPENDIX A

CERFA Report Template for DP

Coastal Erosion Risk Factor Assessment Report

Property Address
[Type Address]

Municipality
[Type name of Municipality]

Prepared by
[Type name and affiliation of Designated Professional]

On behalf of
[Type name of Property Owner]

Date
[Type Date]

CERFA Version
[Type version of CERFA Tool used in assessment]

Contents

Chapter 1 Desktop Inputs

1.1 Site Location

[Provide brief description of site location, including address (if applicable), site coordinates and the extent(s) of the assessment area. Provide land parcel information if available.]

1.2 Regional Geology

[Describe regional geology of the area based on provincial geology map and satellite photos if relevant - See Surficial and bedrock geology map at: https://novascotia.ca/natr/meb/download/mg/map/htm/map_2000-001.asp]

1.3 Elevations

[Describe property elevation based on available contour maps - NSE contour mapping]

1.4 Wave Exposure

[Provide fetch distance in km, and include attenuation by islands if applicable–
Data sources:

- Bathymetric chart: Canadian Hydrographic Service paper chart or Electronic chart
- Google Earth or equivalent - Use historical feature in Google Earth to observe variety of tide and wave conditions]

1.5 Water Levels

1.5.1 Tide

[Provide HHWLT, specify vertical reference datum (Chart, CGVD28 or CGVD2013)
Plan for site visit to be conducted at Low Tide – see tide predictions at http://www.tides.gc.ca/eng]

1.5.2 Sea level Rise (SLR)

[Provide SLR within allowance over planning horizon for RCP8.5 scenario]

1.5.3 Total HHWLT + SLR

[Provide HHWLT + SLR, specify vertical reference datum (Chart, CGVD28 or CGVD2013)]

Chapter 2 Field Inputs

2.1 Site Visit Conditions

[Describe general site conditions including both natural and built coastal infrastructure Provide time of visit and associated tide predictions]

2.2 Area of CERFA Application

[Describe area of application of the field assessment. Provide geographical coordinates for start and end of assessment, as well as photos. It is noted that the applicable width for applicability may be limited to 10 m or less in areas of large variability.]

2.3 Type of Assessment

[Provide supporting information and photo(s) to determine index and selection of coastal type:

- Bluff, i.e. cohesive soil bank.
- Rock face.
- Rock face topped by bluff (2 layer scenario).
- Beach, i.e. cohesionless soil from wave deposits without presence of backshore bluff or cliff).]

2.4 Coastal Profile Measurements

[Refer to supporting materials / diagrams for guidance, and provide supporting measurement method, photo(s) and sketches to estimate distances and slopes for:

- Foreshore.
- Backshore.
- Bluff/cliff].

2.5 Geology

2.5.1 Material Strength

Material Strength Index

[Insert copy of completed Material Strength spreadsheet]

2.5.2 Material Stability

Supporting Field Information
[Provide supporting information and photo(s) to determine index]

Material Stability Index
[Insert copy of completed Material Stability spreadsheet]

2.6 Wave Exposure Considerations

2.6.1 Natural Wave Attenuation

[***If applicable***, provide supporting information and photo(s) to determine presence of natural protection in front of the toe or bluff or rock cliff. This could be

- Salt marsh.
- Natural armouring.

Provide photos with scale and associated measurements for natural armouring if applicable.].

2.6.2 Increase of Future Wave Exposure

[***If applicable***, provide supporting information and photo(s) to determine presence of natural protection that is at risk of being overwhelmed by sea level rise. This would typically include, but not be limited to, a low-lying barrier beach that, when breached, would allow increased wave penetration towards the property].

Chapter 3 Output Setback

[Insert copy of completed output Spreadsheet with setback components and values]

Chapter 4 Conclusions

4.1 Summary

[Insert summary paragraphs describing the CERFA completion, with challenges, uncertainties, recommendations if applicable.]

4.2 Limitations

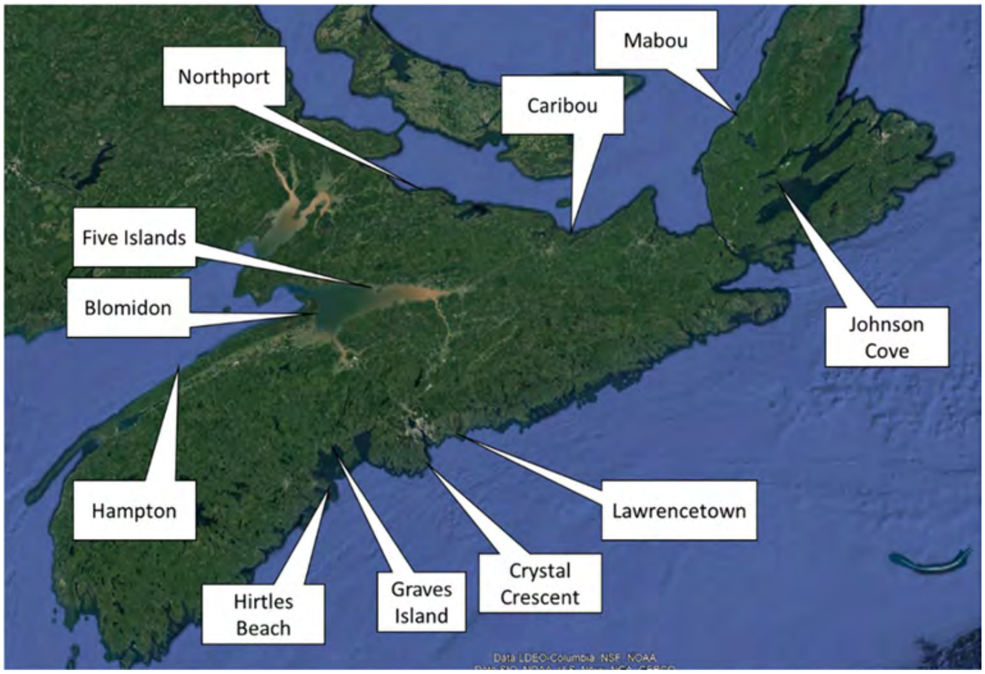
The CERFA was completed as prescribed in the guidance using qualified professional judgment. The CERFA provides information regarding the potential for long-term erosion at the property under assessment. However, erosion is very difficult to predict. The CERFA is no substitute for a detailed coastal/geotechnical engineering study. The actual erosion to occur at a property over the planning lifetime may differ from the setback allowance output by the CERFA. Application of the CERFA as prescribed in the guidance does not constitute a guarantee that the future erosion over the planning lifetime will be within the CERFA output setback.

[Insert Date and DP signature]

APPENDIX B

CERFA Field Site Observations

Visual and geological observations are provided in the following paragraphs. Shoreline profile measurements were entered directly in CERFA spreadsheets provided to NSE alongside the present report. The calculated results for setback components are summarized in section 4.3. The descriptions and data entries in this Chapter were intentionally summarized for the purposes of the present report. Details to be provided by a DP in an actual CERFA Report are listed in the CERFA report template in Appendix A.



Graves Island Provincial Park (Atlantic)

Site Location

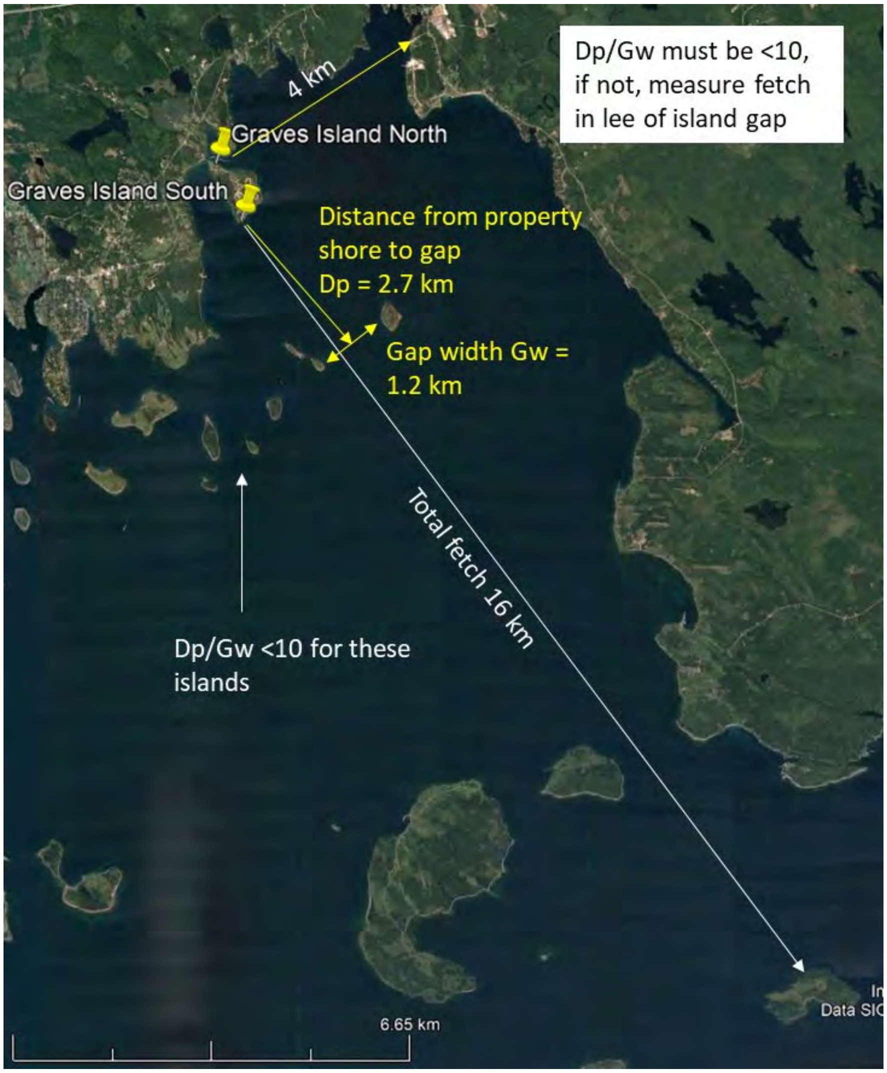
Graves Island is a provincial park located 3.5 km to the northwest of Chester. The island is located in Mahone Bay and connected to the mainland via a causeway.

Regional Geology

Geology mapping indicates that Graves Island consists of a low (silty till) drumlin oriented from southeast to northwest. Mapping indicates a ridge of exposed bedrock on the northwest part of the island, where the access causeway connects to the mainland. The underlying bedrock is mapped as evaporite rock of the Windsor Group.

Wave Exposure

The site is exposed to Atlantic swells mitigated by islands in Mahone Bay. Fetch distances were estimated with Google Earth, as shown in the following figure.



Grave Island Fetch Calculation

Test Sites

Elevation of slope crest from contour mapping: 5 m

South Side – Date 18 August 2020, 11:30, Lat 44.5545490, Long -64.2057228

North Side – Date 18 August 2020, 12:30, Lat 44.5622526, Long-64.2088328

Material Description (both sites): UCS Classification - moist brown fine sandy SILT with gravel and cobbles, trace clay. Material was dislodged easily by hand and crumbled readily.

Material Strength Category: Very Loose.

Lawrencetown (Atlantic)

Site Location

Lawrencetown Beach Provincial Park is located on the eastern shore of Nova Scotia, 17.5 km northeast of Halifax. The assessment was focused on the bluff point to the southwest of the main beach and immediately northeast of the Lawrencetown Lake estuary.

Regional Geology

Lawrencetown Head is formed by a drumlin oriented from southeast to northwest. The long axis of the drumlin forms an extended bluff in contact with the coastline, terminating in a point that marks the west end of Lawrencetown Beach. The underlying bedrock of the area is mapped as Halifax Formation Slate.

Lawrencetown Test Site Photos

Wave Exposure

The site is fully exposed to Atlantic swells (fetch distance >1,000 km).

Bluff Test Sites

Elevation of slope crest from contour mapping: 20 m

Bluff West Side

Date: 18 August 2020, 15:30, Lat 44.641986, Long -63.354972

High till bluff (drumlin) located on the southwest exposed seaward point of the beach. The foreshore includes a flat resistant cobble bed with the potential to provide dissipation of incoming waves. The slope is near fully vegetated in this area.

Bluff East Side

Date: 18 August 2020, 16:10, Lat 44.641820, Long -63.353575

High till bluff (drumlin) located on the windward side of the point. High sections of the bluff are eroding, show little to no vegetation cover, and show evidence of slumping.

Material Description: UCS Classification - moist brown fine sandy SILT with gravel and cobbles, trace clay. Material was dislodged by hand with difficulty and easily pried with a knife. The material could be compacted into a ball which crumbled readily when broken apart.

Material Strength Category: Loose sediment

Beach Test Site

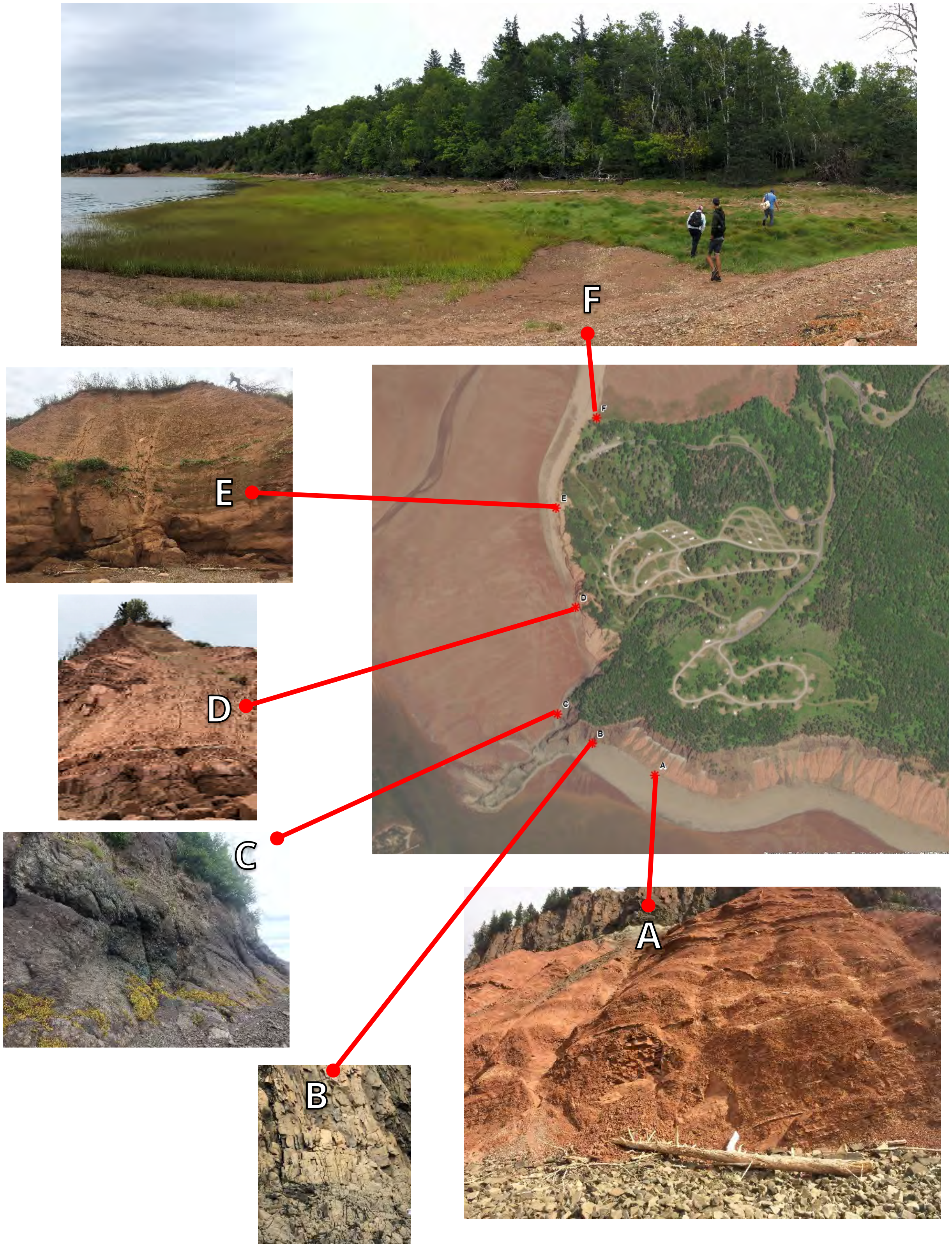
Date: 18 August 2020, 17:00, Lat 44.643778, Long -63.341420

Steep cobble beach with sandy foreshore.

UCS Classification: well sorted COBBLES fronted by fine to medium SAND.

Material Strength Category: Loose sediment

Five Islands Provincial Park (Bay of Fundy)



Five Islands Test Site Photos

Site Location

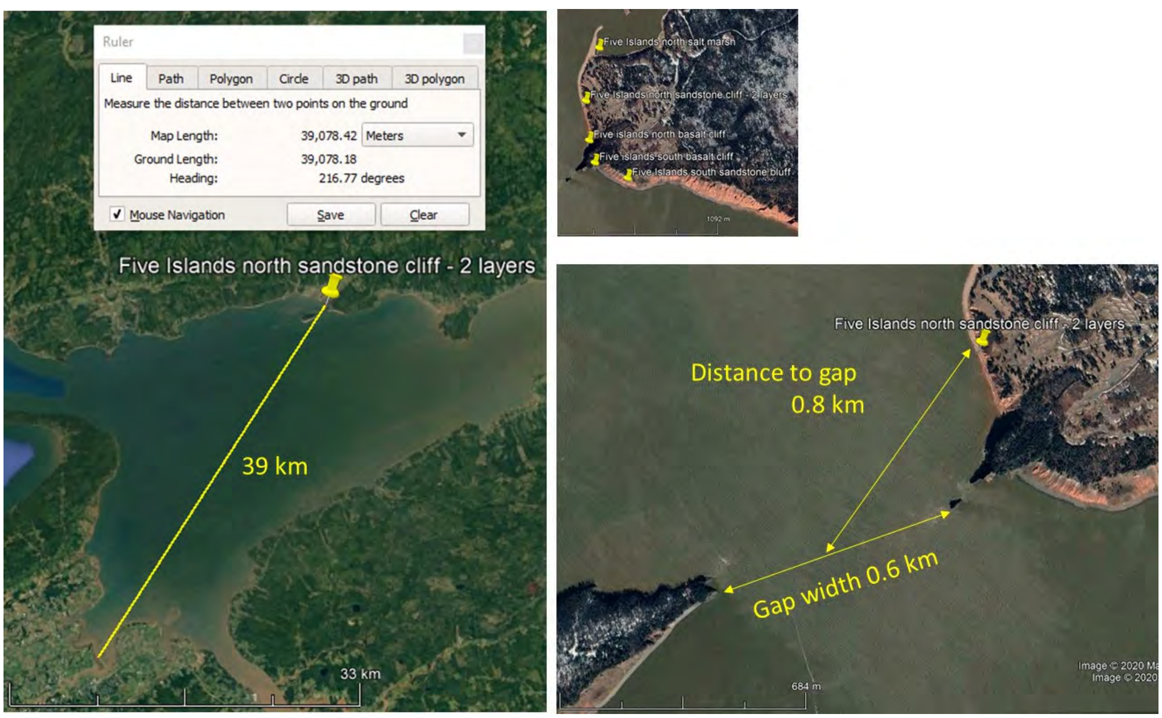
Five Islands Provincial Park is located on the Fundy shore of Nova Scotia, 60 km west of Truro. The assessment included several locations along the south-facing system of bluffs and rockfaces, incorporating two rock types and a 2-layer system of till bluff overlying fractured sandstone rock.

Regional Geology

Rock in the western part of the park is predominantly Triassic red sandstone, transitioning to sequences of basalt, and a section of columnar basalt overlying the sandstone unit. Surficial material in the area is sandy till. Structures in this part of the park are related to the Chedabucto Fault system.

Wave Exposure

South sites A and B are exposed to the full 39 km fetch distance across the Minas Basin. However, the north sites fetch runs through a narrow gap at high tide, which requires a lowering of the initial 39 km through the calculation procedure. The DP needs only to enter the gap width and distance to shore. The tidal wetland site (F) has almost negligible fetch across the river.



Five Islands Fetch Calculation

Test Site A

Elevation of slope crest from contour mapping: 60 m.
Date 21 August 2020, 11:00, Lat 45.387978, Long -64.058913

Material Description: Finely bedded to massively bedded red sandstone. Horizontal bedding planes. Overlain by columnar basalt showing substantial slope failure and rock slides.
Material Strength Category: Soft rock.

Test Site B

Elevation of slope crest from contour mapping: 60 m
Date 21 August 202011:30, Lat 45.389224, Long -64.061132
Material Description: Columnar basalt. Groundwater seepage. Three to four joint sets.
Material Strength Category: Moderately hard rock.

Test Site C

Elevation of slope crest from contour mapping: 60 m.
Date 21 August 2020 12:00, Lat 45.390702, Long -64.061129
Material Description: Massive amygdaloidal basalt.
Material Strength Category: Moderately hard rock.

Test Site D

Elevation of slope crest from contour mapping: 40 m.
Date 21 August 2020 12:30, Lat 45.392170, Long -64.061132
Material Description: Red to orange sandstone interbedded with grey siltstone, blocky to thinly bedded. Slope profile is predominantly rock, overlain by 2-3 metres of sandy till.
Material Strength Category: Soft rock.

Test Site E

Elevation of slope crest from contour mapping: 20 m.
Date 21 August 2020 13:00, Lat 45.394124, Long -64.062339
Material Description: Red to buff sandy till bluff (with rounded cobbles) overlying horizontally bedded sedimentary rock. Red to orange sandstone interbedded with grey siltstone, blocky to thinly bedded. Extensive erosion feature in bluff face related to surface water drainage course. Seepage face at contact between till and bedrock with associated vegetation growth.
Material Strength Category: Soft rock.

Test Site F

Elevation of slope crest from contour mapping: <5 m.
Date 21 August 2020 13:30, Lat 45.3961, Long -64.0605
Material Description: Limited scarp (<1 m) on marsh, projected by barrier beach.
Material Strength Category: Soft rock.

Caribou Provincial Park (North Shore)

Site Location

Caribou Provincial Park is located on the Gulf shore of Nova Scotia, 7 km northeast of Pictou. The assessment focused on a north-facing bluff, with observations of a barrier beach further to the west.

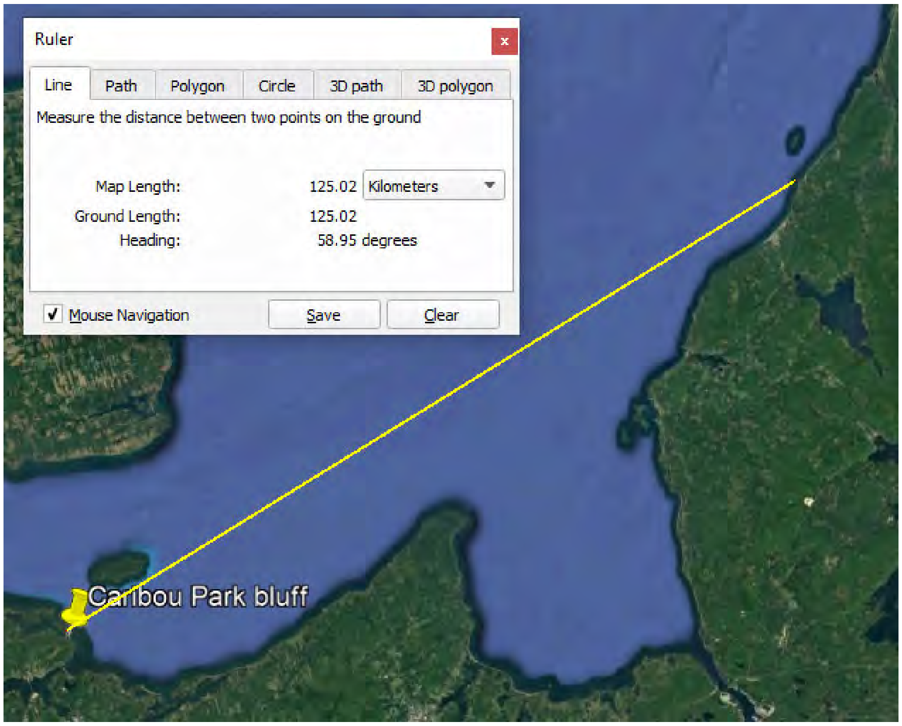
Caribou Test Site Photos

Regional Geology

Bedrock is mapped as Carboniferous aged undifferentiated sandstone and/or mudstone of the Pictou Group. The bedrock is overlain by silty ground moraine till.

Wave Exposure

Pictou Island provides some shelter to the north-northeast directions. The maximum fetch distance is approximately 125 km across the Gulf of St Lawrence to the northeast.



Caribou Fetch Distance Estimation

Test Site A

Elevation of slope crest from contour mapping: <10 m

Date 25 August 2020 10:30, Lat 45.726579, Long -62.652263

Material Description: Moderately compacted silt till, some fine sand, gravel, occasional cobbles. Extensive vegetation (shrubs and weeds), some slumping near crest of slope.

Material Strength Category: Moderately dense sediment

Test Site B

Elevation of slope crest from contour mapping: <5 m

Date 25 August 2020 11:00, Lat 45.728436, Long -62.3902

Material Description: Beach sand.

Material Strength Category: Loose sediment

Northport Beach Provincial Park (North Shore)

Site Location

Northport Provincial Park is located on the Gulf shore of Nova Scotia, 18 km northwest of Pugwash and 30 km northeast of Amherst. The coastline consists of a weathered, transitional sedimentary bluff fronted by sand and cobble beach.

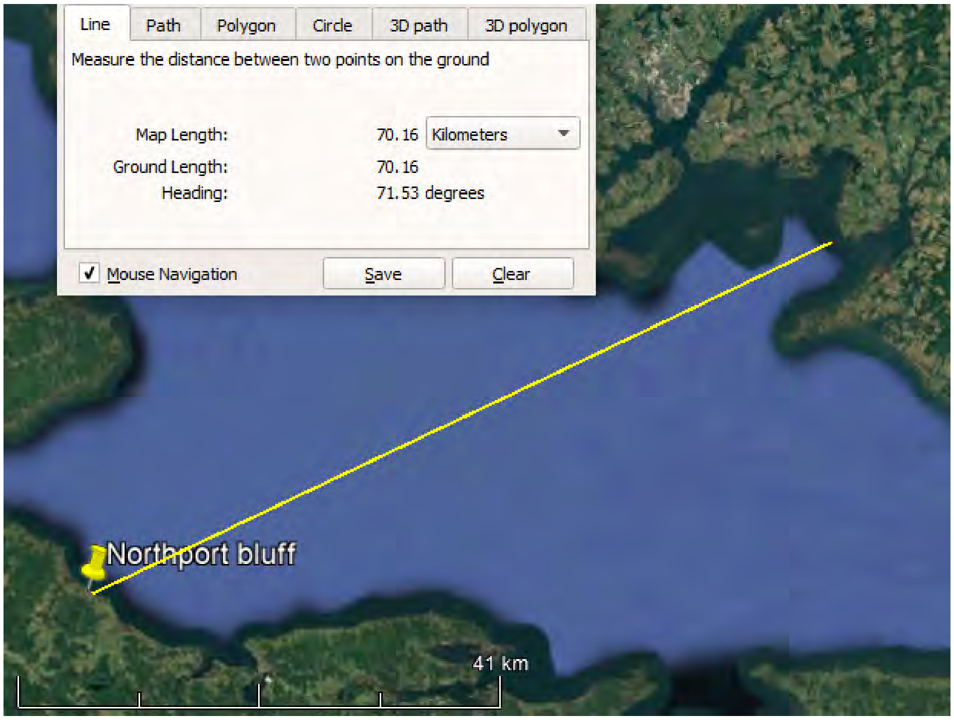
Regional Geology

Bedrock in the area is mapped as Cape John Formation red-brown mudrock and pebbly arkosic sandstone. The bedrock is overlain by silty ground moraine till.

Northport Test Site Photos

Wave Exposure

The fetch distance is approximately 70 km across the Northumberland Strait.



Northport Fetch Distance Estimation

Test Site A

Elevation of slope crest from contour mapping: 60 m.

Date 25 August 2020 13:15, Lat 45.926972, Long -63.841551

Material Description: Weathered, weakly lithified to unlithified sandstone and mudstone/silt. Occasional bedding plane and fracture can be distinguished; bluff is primarily free of distinguishable material partings. Degree of consolidation / weathering varies over different sections of the bluff.

Material Strength Category: Transitional (weathered soft rock)

Crystal Crescent Beach and Granite Cliff (Atlantic)

Site Location

Crystal Crescent Beach is located on the South shore of Nova Scotia, near Sambro, NS and 20 km south of Halifax. The coastline includes sandy beaches, sections of backshore armoured by large boulders, and exposed granite rockfaces.

Regional Geology

Bedrock in the area is mapped as leucomonzogranite of the South Mountain Batholith. The bedrock is exposed at the ground surface or overlain by limited soil cover.

Wave Exposure

The fetch distance exceeds 100 km to the open Atlantic.

Test Site W1C

Date Feb 5, 2021 Lat 44.460786, Long -63.615848

Material Description: Boulder beach backshore and foreshore.

Material Strength Category: Loose, Beach – sand and boulders

Test Site W1E

Date Feb 5, 2021 Lat 44.460786, Long -63.615848

Material Description: Moderately sloped granite rockface, widely spaced joints, very stable.

Material Strength Category: Very hard rock

Hirtle's Beach (Atlantic)

Site Location

Hirtle's Beach is located on the South shore of Nova Scotia, near Kingsburg, NS and 13 km to the southwest of Lunenburg. The coastline includes a cobble barrier beach, drumlin bluffs, and shale/slate cliffs on Gaff Point.

Regional Geology

Bedrock in the area is mapped as Halifax Formation slate. The bedrock is overlain by ground moraine (till) and drumlins (multiple till facies).

Wave Exposure

The fetch distance exceeds 100 km to the open Atlantic.

Test Site

Date Feb 5, 2021 Lat 44.266784 Long - 64.264893

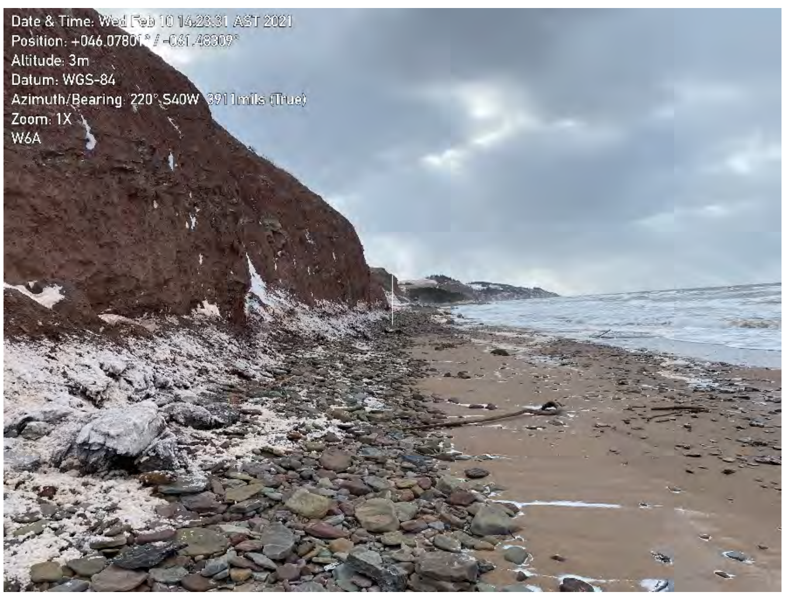
Material Description: 3 x 1 metre-thick subunits of till: [top] moderately compact gravelly silt till; [mid] hard cemented gravelly silt till (Fe hardpan); [bot] moderately dense silt till, almost no grit

Material Strength Category: Moderately dense sediment

Mabou Beach Provincial Park (Western Cape Breton)

Site Location

Mabou Beach Provincial Park is located on the western shore of Cape Breton, 7 km to the west of Mabou, NS. The coastline includes a sandy beach and dune system, till bluffs, and sedimentary rock.

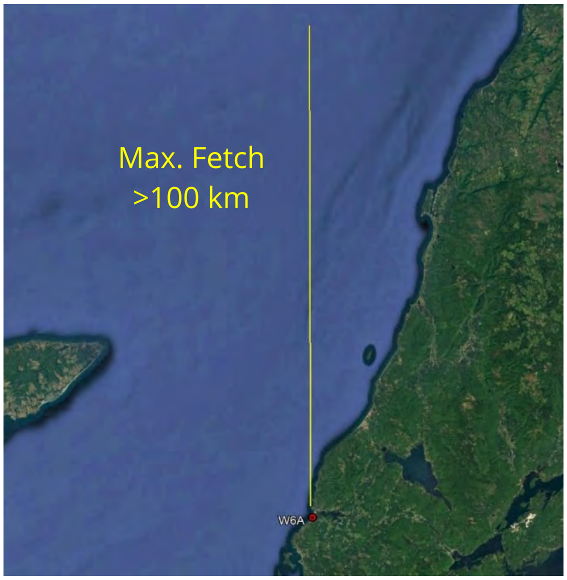


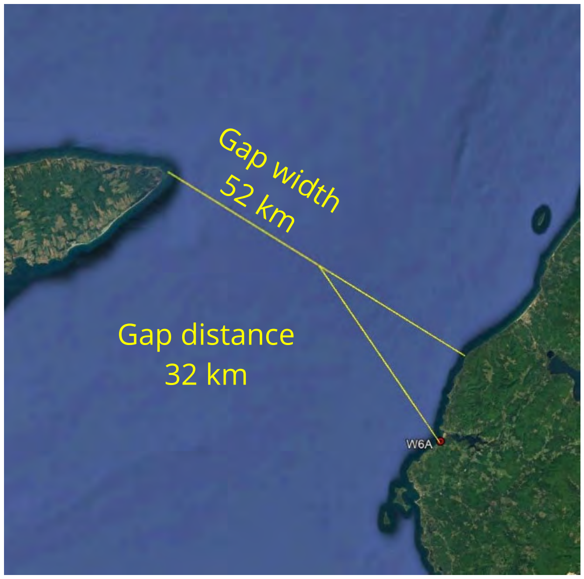
Regional Geology

Bedrock in the area is mapped as fluvial-lacustrine sandstone, shale, siltstone and limestone of the Port Hood Formation. The bedrock is overlain by a combination of silty and sandy ground moraine (till).

Wave Exposure

The fetch distance exceeds 100 km to the open Atlantic.





Test Site

Date Feb 10, 2021 Lat 46.077964, Long -61.483257

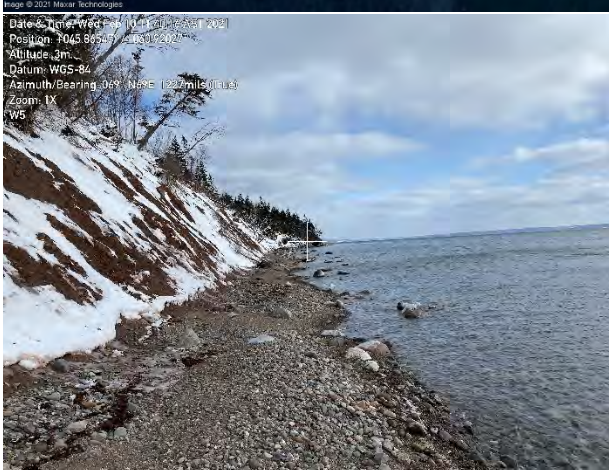
Material Description: Very soft red mudstone/shale under red gravelly silt till.

Material Strength Category: Transitional (bottom unit)

Johnson Cove (Bras d'Or Lakes, Cape Breton)

Site Location

Johnson Cove is part of a peninsula on the west side of Bras D'Or Lake in Cape Breton, 20 km to the southeast of Whycogomagh. The coastline includes cobble barrier beaches and a till bluff.

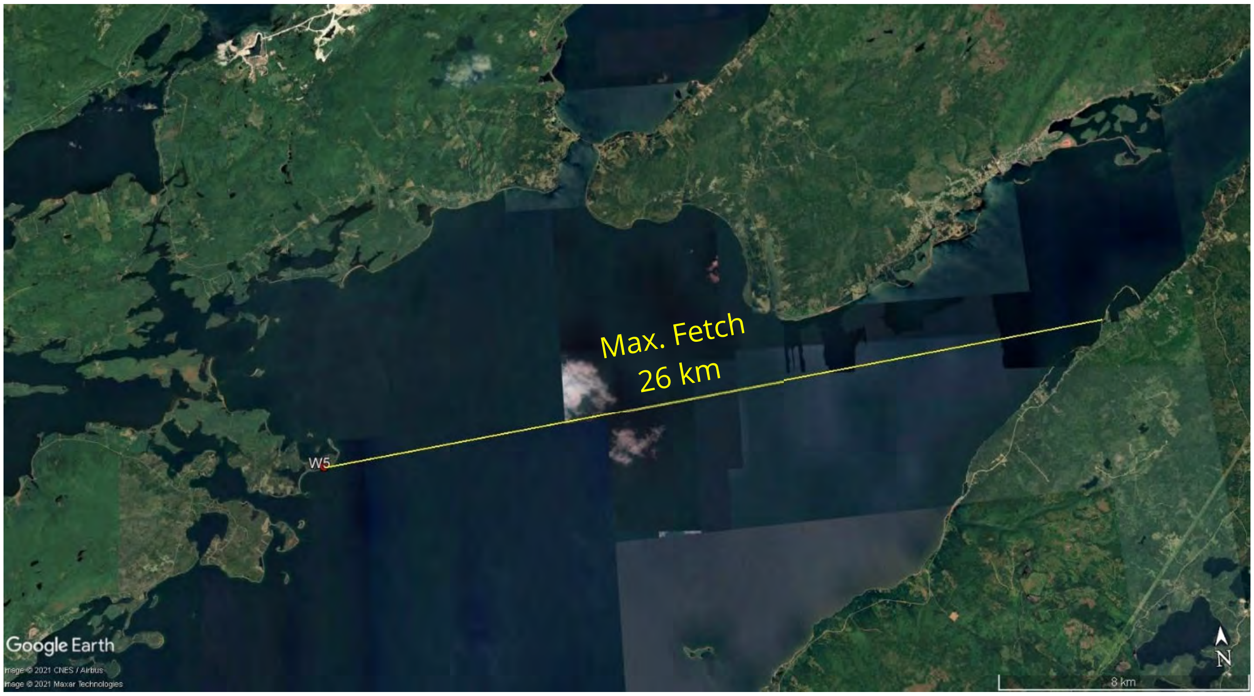


Regional Geology

Bedrock in the area is mapped as evaporites of the Windsor Formation (primarily gypsum-anhydrite). The bedrock is overlain by sandy stony ground moraine (till).

Wave Exposure

The maximum fetch distance is approximately 26 km.



Test Site

Date Feb 10, 2021 Lat 45.865638, Long -60.919644

Material Description: Red brown stony clay till, few small cobbles, medium dense, moist.

Material Strength Category: Moderately dense sediment

Hampton (Bay of Fundy)

Site Location

Hampton is located on the Fundy shore of Nova Scotia, 8.5 km to the northwest of Bridgetown. The coastline includes a sand and cobble beach and low basalt rockfaces.

Regional Geology

Bedrock in the area is mapped as basalt of the North Mountain Formation. The bedrock is overlain by glaciomarine gravel and sand interbedded locally with silt and clay, dipping seaward at 5 to 10 degrees.

Wave Exposure

The fetch distance exceeds 100 km, with a distance of >100 km to the nearest gap.

Test Site

Date Feb 18, 2021 Lat 44.913853, Long -65.338332

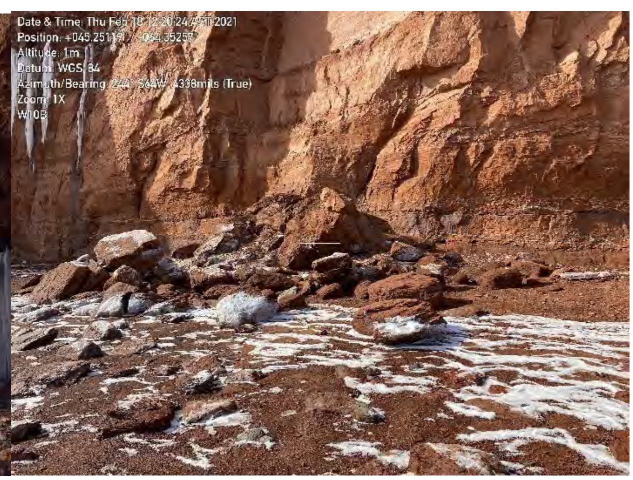
Material Description: Hard grey to black weathered basalt with cooling features and vertical jointing

Material Strength Category: Moderately hard to hard rock

Blomidon Provincial Park (Bay of Fundy)

Site Location

Cape Blomidon is located on the Minas Basin of Nova Scotia, 12 km to the northwest of Canning. The coastline is dominated by a rockface of sandstone and siltstone fronted by beach material of varying composition, including sections of exposed sandstone bedrock. The large tidal range of the basin results in an extended foreshore of over 100 metres at low tide.

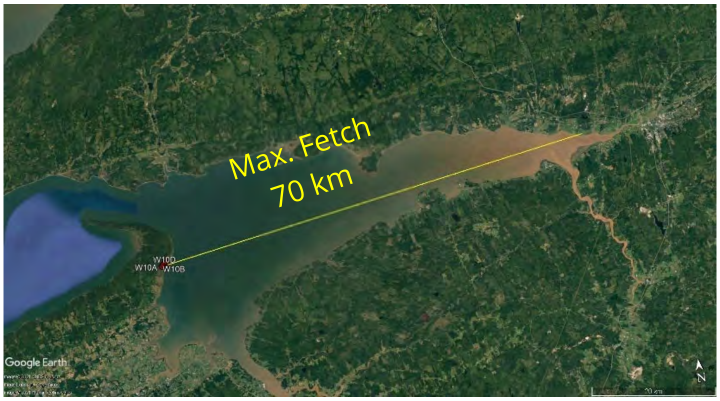


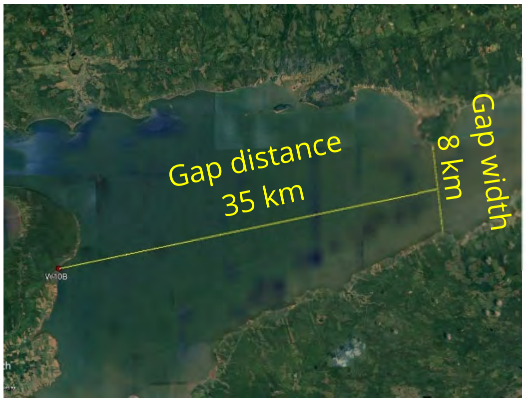
Regional Geology

Bedrock in the area is mapped as interbedded siltstone and sandstone of the Blomidon Formation. Surficial material near the coastline is a complex mixture of glacial deposits and weathered/frost-shattered rock/soils.

Wave Exposure

The maximum fetch distance is approximately 70 km, through a gap defined as the midway point of the narrow water body.





Test Site

Date Feb 18, 2021 Lat 45.253472 Long -64.352104

Material Description: Interbedded soft sandstone (30-50 cm beds) and siltstone (<10 cm beds), major joints and bedding planes at material contacts; extensive groundwater from major horizontal seepage planes at material contacts and through vertical joints.

Material Strength Category: Soft rock.

Additional

In the course of the project, CBCL also collected shoreline data for CERFA inputs at additional sites of interest, some of which have unpublished historical observations provided by GSC. While not formally reported in this report, CBCL's observations were included in the calibration data set. The additional sites include:

- Collie's Head and Philip Head bluffs (Atlantic)
- Clam Bay bluff (Atlantic)
- Sandy Cove (Bay of Fundy)
- Hartlen Point bluffs (Atlantic)
- Crystal Cliffs (North shore)
- Arisaig (North shore)

APPENDIX C

Example Steps for Field Data Collection

Example Field Assessment

1. If the beach can be accessed safely, walk the entire length of the coastline for which a CERFA setback (or multiple setbacks) will be defined. Observe and document the coast type(s) encountered, and delineate separate sections using a handheld GPS.
2. Identify the position on the beach of the *higher-high water large tide* (HHWLT), which could be approximated by the common survey metric Ordinary High Water Mark. Common identifying features include the wrack zone where seaweed/organic debris has accumulated, and/or a change in colour, contour, algae, or encrustations on rock surfaces.
3. Standing at the HHWLT, collect a panorama or series of photographs in a 360^{o} arc, showing the foreshore, backshore, and views in each direction along the coastline.
4. Standing at the HHWLT, measure the slope of the foreshore. In the case of two different slopes, measure the steeper section closest to the HHWLT. If using a phone/tablet application, ensure that the camera is as close to the ground surface as possible and level with the horizon.
5. Standing at the HHWLT, turn and measure the slope of the backshore, from the current position to the toe of the bluff/rockface. For Beach coast types measure to the crest of the beach.
6. Measure the distance from the HHWLT to the toe of the bluff/rockface or crest of the beach. If measuring distances using a range finder use several measurements to ensure consistency and follow manufacturer's instructions closely (e.g. select an appropriate target and be aware of the influence of scattering and highly reflective surfaces).
7. For two-layer cases, measure the distance and angle to the contact between the bluff and rockface.
8. For two-layer cases, measure the distance and angle to the crest of the bluff; if desired this method may also be used to manually calculate the height and slope of a single-layer bluff or rockface. Some range finders will provide this calculation automatically (see inset).

Cohesive Sediment (Bluffs)

1. Approach the bluff and identify the material using the USC.
2. For bluff material scrape away the upper 10 to 20 cm of weathered material to expose the underlying undisturbed formation.
3. Attempt to dislodge native material by hand.
4. If possible, peel material away using a pocket knife, pick, or other tool.
5. Push a geologic pick into the material.
6. Use results of steps 1-5 and guidance on CERFA template/Table 3.5 to classify material as loose, moderate, dense, or transitional.

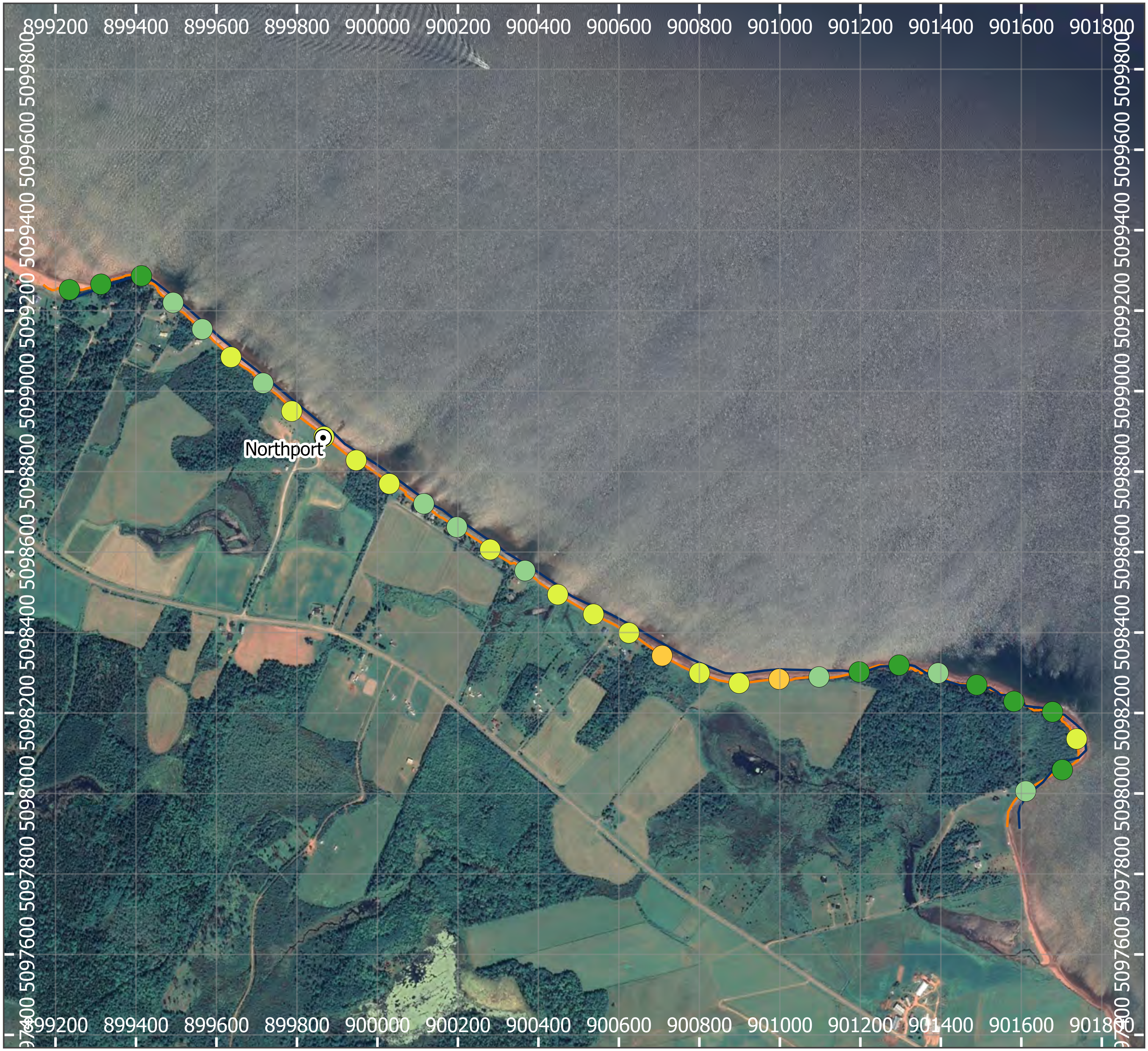
Rock

1. Approach the rockface and identify the major rock type.
2. Attempt to peel the surface of the rockface using a pocketknife.
3. If rock will not peel, attempt to scratch using a common steel nail (20d).
4. Carefully probe the rockface using a geologic pick using light and firm taps. For interbedded sequences of thin beds and massive beds, compare the penetration of the pick in each of these sections.
5. For harder material attempt to locate a handheld sample and attempt to break with taps of hammer, using appropriate PPE and safety precautions.
6. Use results of steps 1 to 5 and guidance on CERFA template/Table 3.5.
7. to classify material strength of rock.
8. Visually survey the rockface and identify bedding planes and parallel joint sets.
9. Record the number of joint sets, including bedding planes.
10. Identify groundwater seepage (indications include springs or wet surfaces that emerge mid-slope, algae growth, accretion of iron oxide and other minerals, and icicles perched mid-slope).
11. Document bedding planes that dip toward the coastline (see image).

12. Document vertical joint sets (see image).

APPENDIX D

Estimation of Historical Erosion Rates for Tool Calibration



Estimated Recession Rate (m/year)

- -0.6 - -0.5
- -0.5 - -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- <-0.1

Delineation

- 1939
- 2019
- Field Test Site

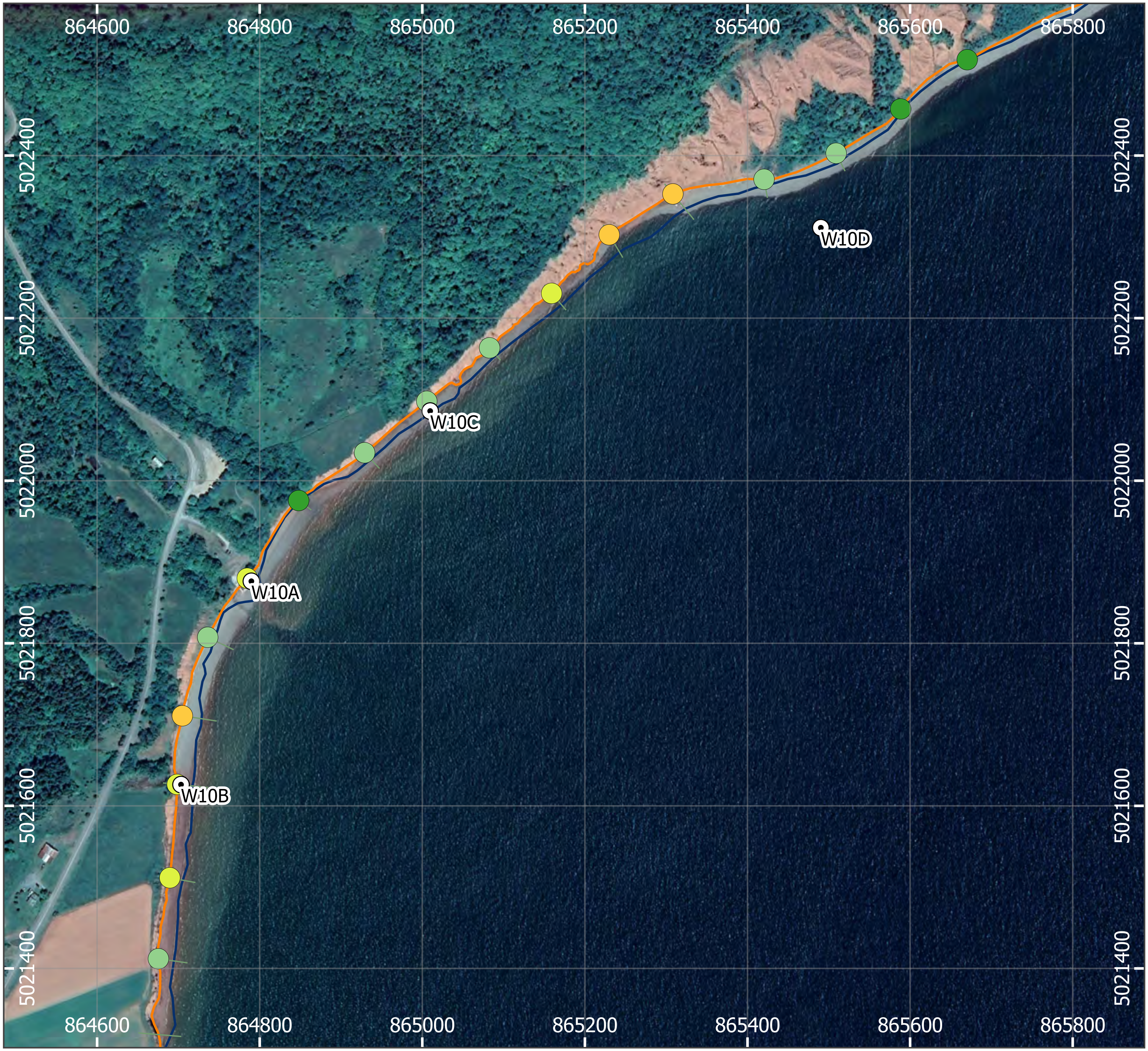
0 200 400 m

CRS: NAD83 (CSRS) UTM Zone 20N

Northport, NS
Shoreline Change Estimate

Date: 2021-03-09
Drawn: TK
Checked: VL

CBCL



Estimated Recession Rate (m/year)

- -0.6 - -0.5
- -0.5 - -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- <-0.1

Delineation

- 1945
- 2019
- Field Test Site

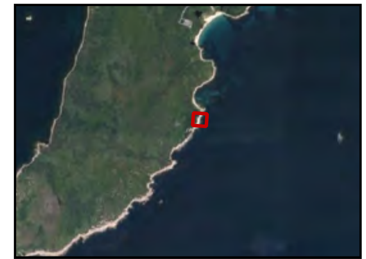
0 100 200 m

CRS: NAD83 (CSRS) UTM Zone 20N

Blomidon, NS
Shoreline Change Estimate

Date: 2021-02-23
Drawn: TK
Checked: VL

CBCL



Estimated Recession Rate (m/year)
-0.6 - -0.5
-0.5 - -0.4
-0.4 - -0.3
-0.3 - -0.2
-0.2 - -0.1
<-0.1
Delineation
1931
2019
Field Test Site

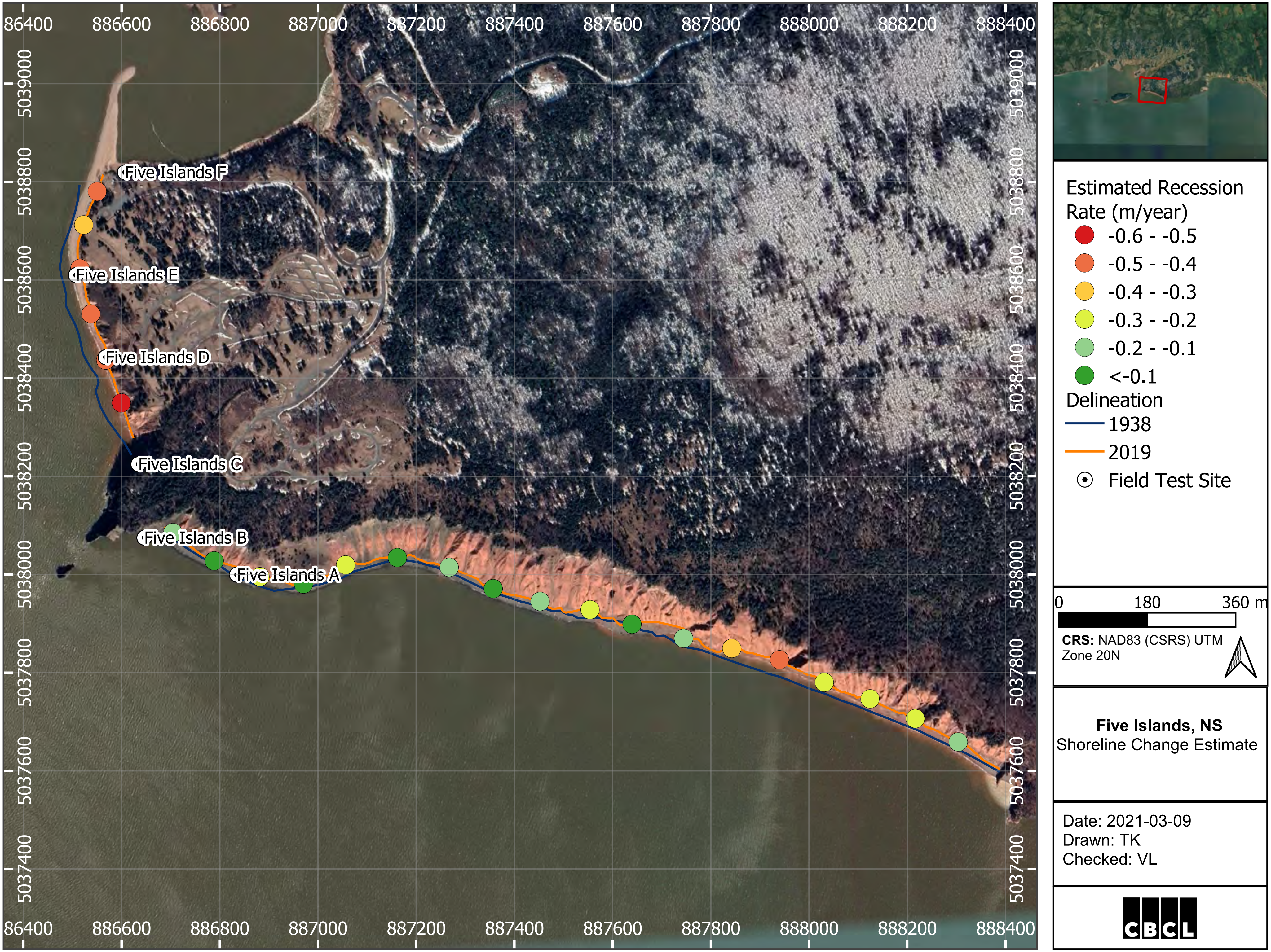
0 14 28 m

CRS: NAD83 (CSRS) UTM Zone 20N

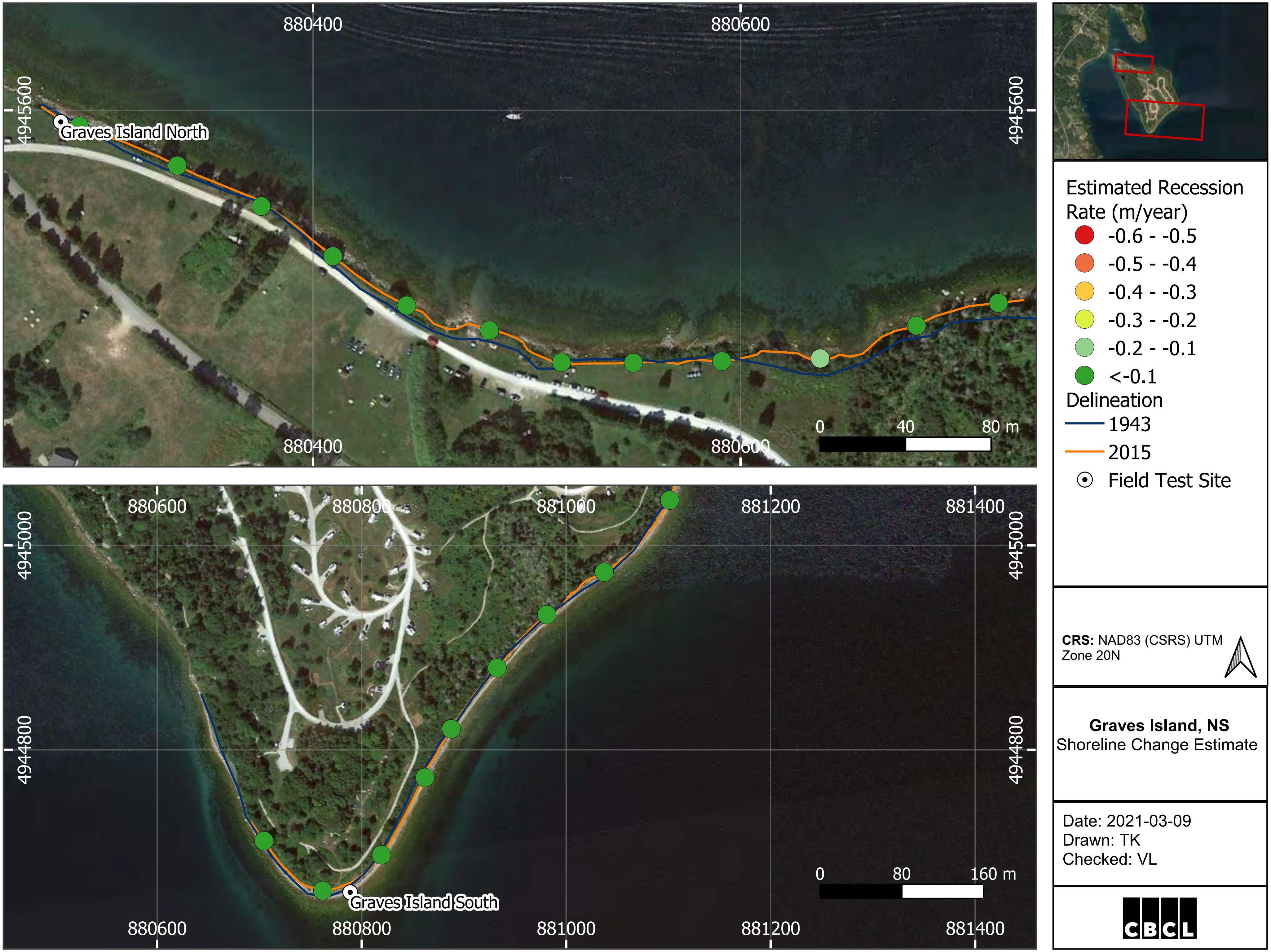
Crystal Crescent, NS
Shoreline Change Estimate

Date: 2021-02-25
Drawn: TK
Checked: VL

CBCL



86400
886600
886800
887000
887200
887400
887600
887800
888000
888200
888400
5039000
5038800
5038600
5038400
5038200
5038000
5037800
5037600
5037400
Five Islands F
Five Islands E
Five Islands D
Five Islands C
Five Islands B
Five Islands A
Estimated Recession Rate (m/year)
-0.6 - -0.5
-0.5 - -0.4
-0.4 - -0.3
-0.3 - -0.2
-0.2 - -0.1
<-0.1
Delineation
1938
2019
Field Test Site
0
180
360 m
CRS: NAD83 (CSRS) UTM Zone 20N
Five Islands, NS
Shoreline Change Estimate
Date: 2021-03-09
Drawn: TK
Checked: VL
CBCL


880400
880600
4945600
Graves Island North
0
40
80 m
880600
880800
881000
881200
881400
4945000
4944800
0
80
160 m
Graves Island South
Estimated Recession Rate (m/year)
-0.6 - -0.5
-0.5 - -0.4
-0.4 - -0.3
-0.3 - -0.2
-0.2 - -0.1
<-0.1
Delineation
1943
2015
Field Test Site
CRS: NAD83 (CSRS) UTM Zone 20N
Graves Island, NS
Shoreline Change Estimate
Date: 2021-03-09
Drawn: TK
Checked: VL
CBCL

Estimated Recession Rate (m/year)

- -0.6 - -0.5
- -0.5 - -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- <-0.1

Delineation

- 1945
- 2019
- Field Test Site

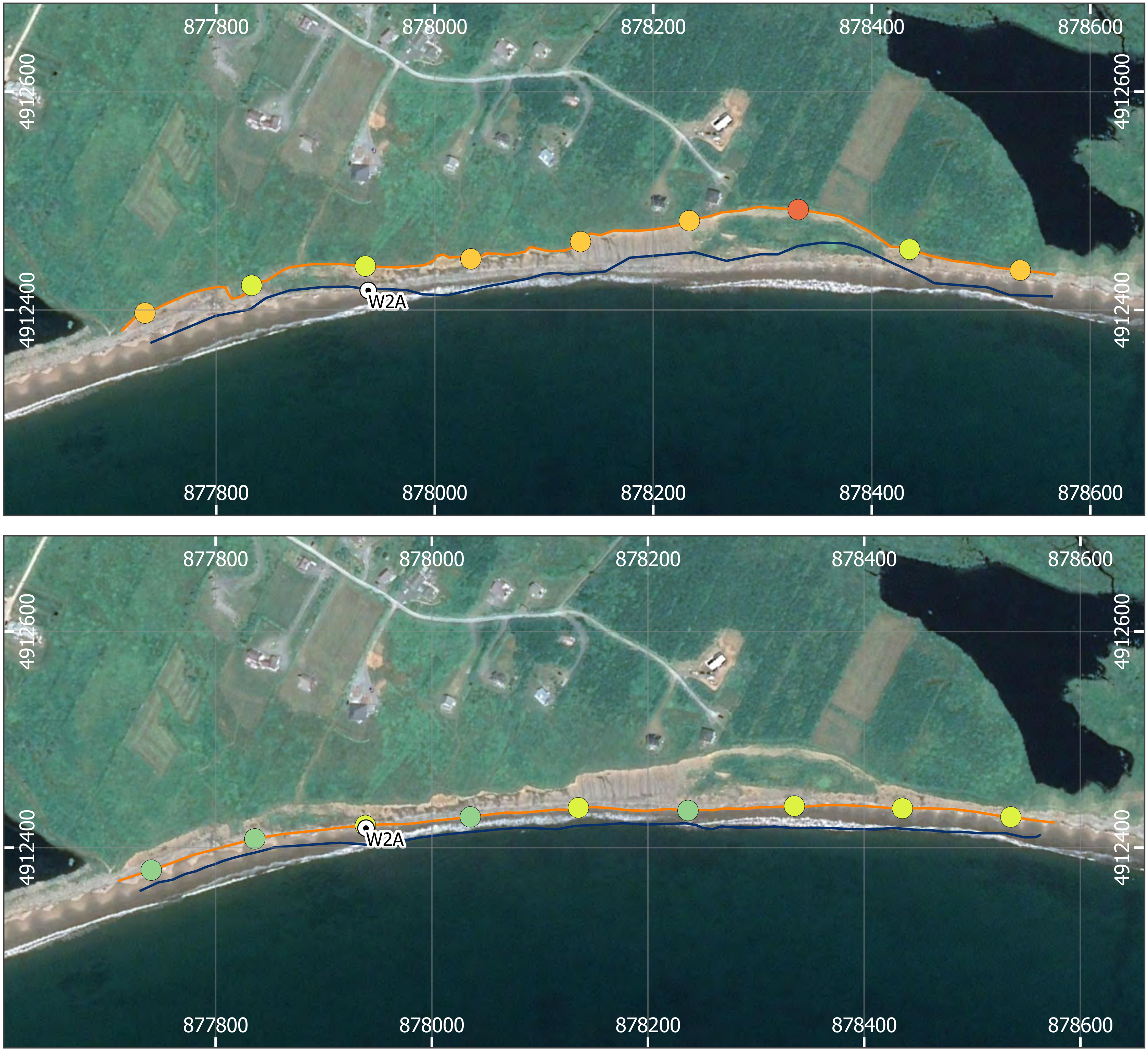
0 50 100 m

CRS: NAD83 (CSRS) UTM Zone 20N

Hampton, NS
Shoreline Change Estimate

Date: 2021-02-22
Drawn: TK
Checked: VL

CBCL



Estimated Recession Rate (m/year)

- -0.6 - -0.5
- -0.5 - -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- <-0.1

Delineation

- 1945
- 2019
- Field Test Site

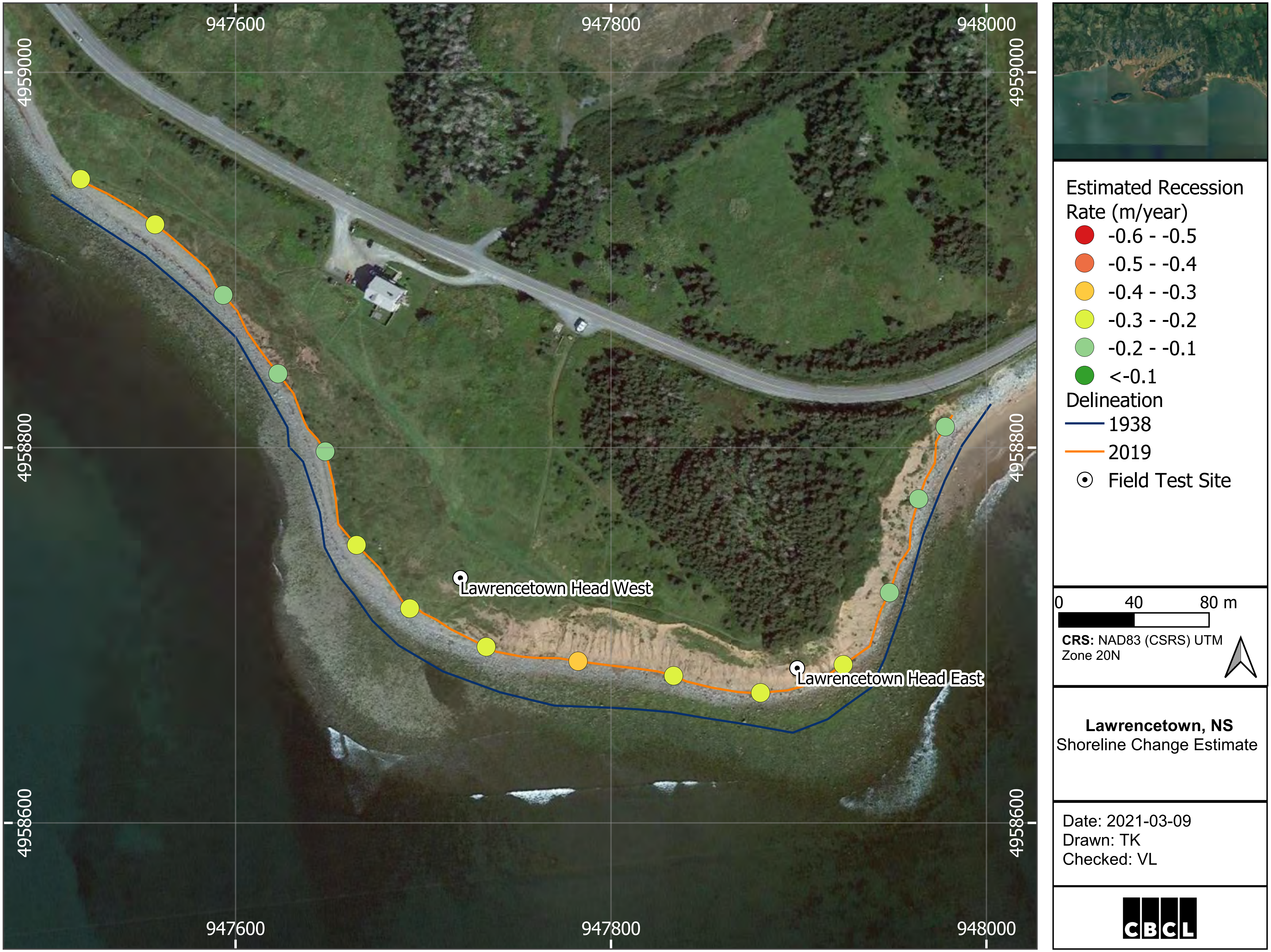
0 90 180 m

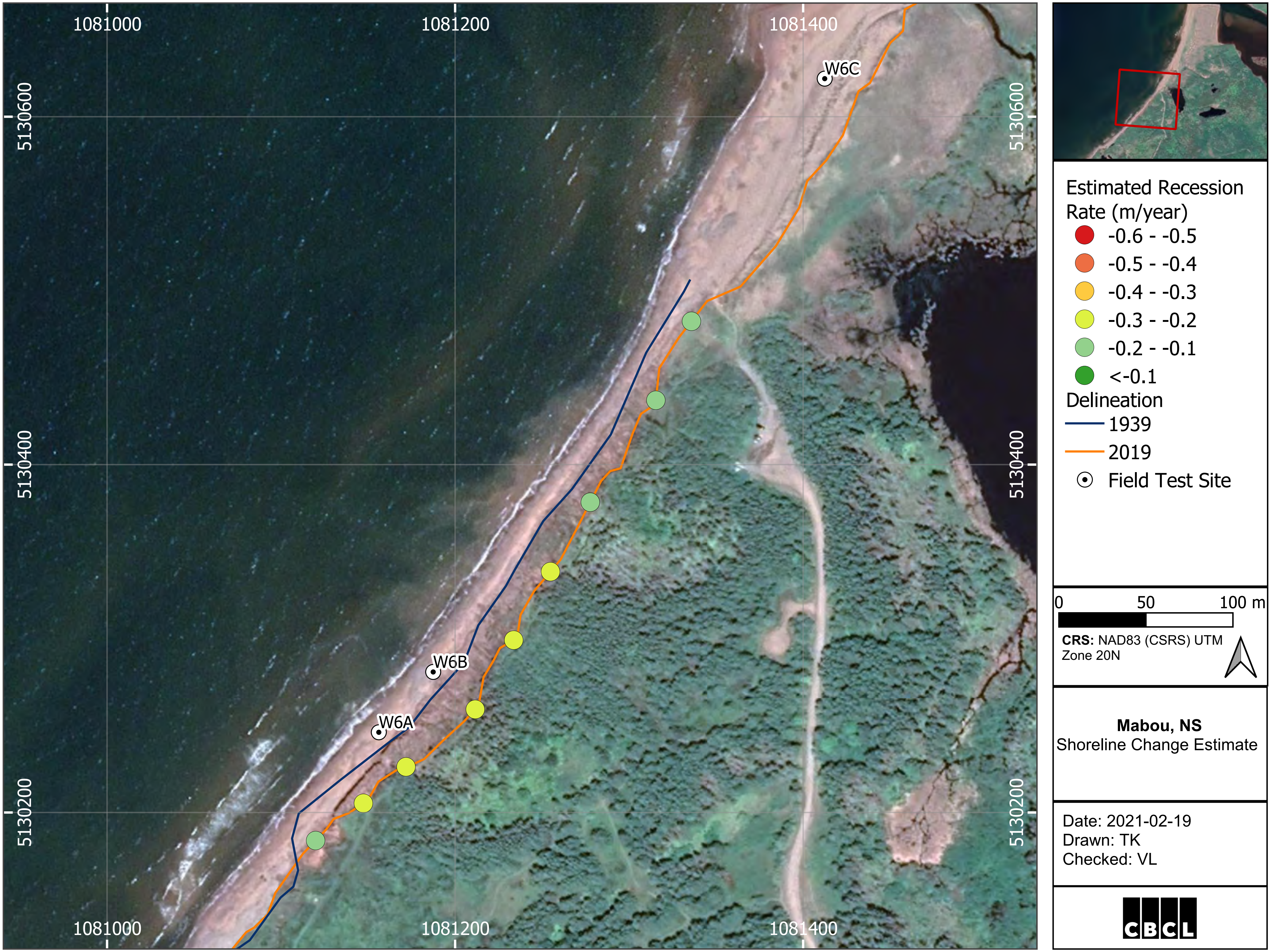
CRS: NAD83 (CSRS) UTM Zone 20N

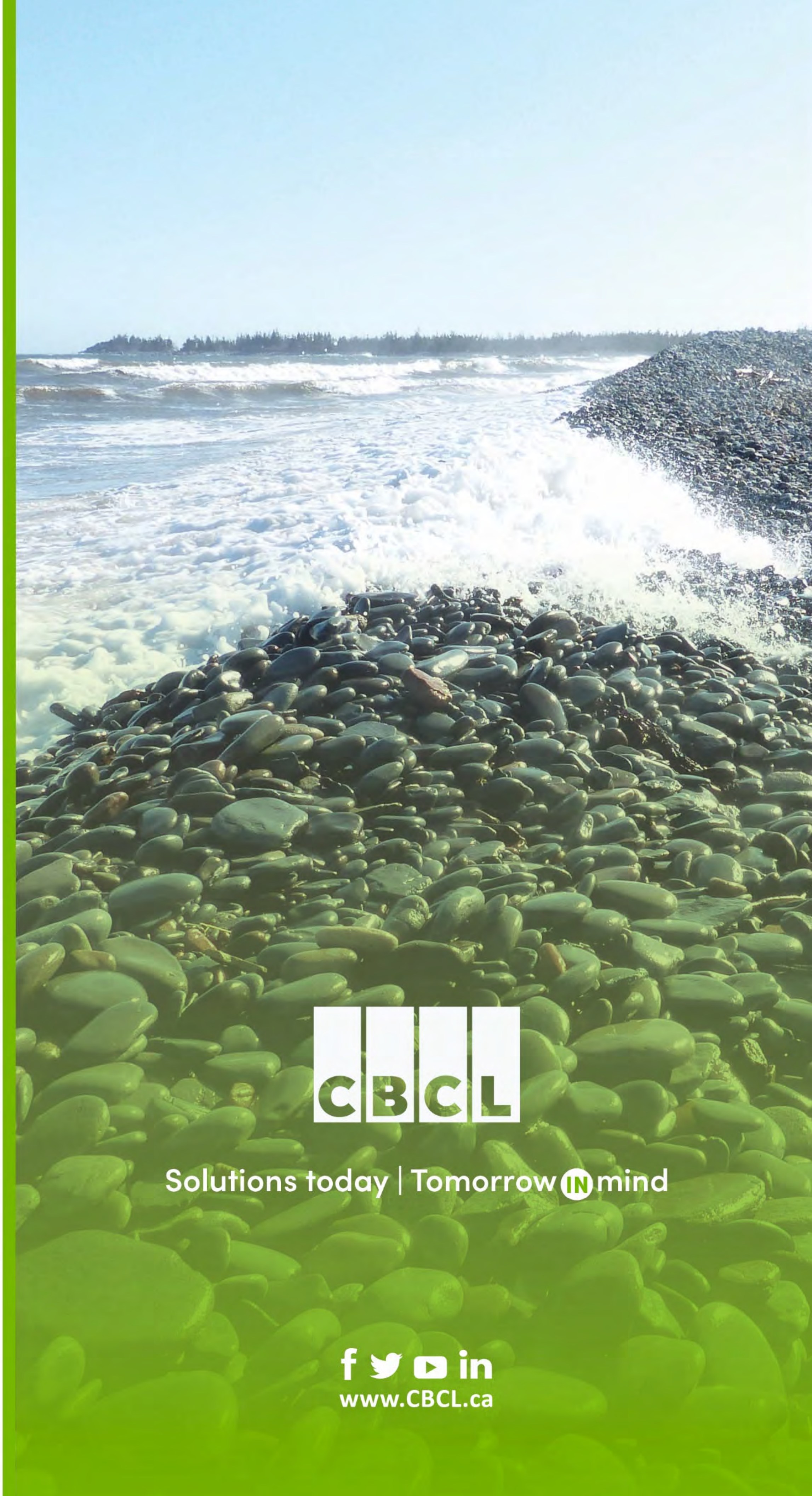
Hirtles Beach
Shoreline Change Estimate

Date: 2021-02-23
Drawn: TK
Checked: VL

CBCL


947600
947800
948000
4959000
4958800
4958600
Lawrencetown Head West
Lawrencetown Head East
Estimated Recession Rate (m/year)
-0.6 - -0.5
-0.5 - -0.4
-0.4 - -0.3
-0.3 - -0.2
-0.2 - -0.1
<-0.1
Delineation
1938
2019
Field Test Site
0 40 80 m
CRS: NAD83 (CSRS) UTM Zone 20N
Lawrencetown, NS
Shoreline Change Estimate
Date: 2021-03-09
Drawn: TK
Checked: VL
CBCL


1081000
1081200
1081400
5130600
5130400
5130200
W6C
W6B
W6A
Estimated Recession Rate (m/year)
-0.6 - -0.5
-0.5 - -0.4
-0.4 - -0.3
-0.3 - -0.2
-0.2 - -0.1
<-0.1
Delineation
1939
2019
Field Test Site
0
50
100 m
CRS: NAD83 (CSRS) UTM Zone 20N
Mabou, NS
Shoreline Change Estimate
Date: 2021-02-19
Drawn: TK
Checked: VL
CBCL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