Contents

Available online from the Cumberland County Soil and Water Conservation District

Maine Coastal Planting Guide:

http://cumberlandswcd.org/site/wp-content/uploads/2017/11/Attachment-E1-Maine-Coastal-Planning-Guide-November-2017-For-Electronic-View-Release-Version-1.1.pdf

All CCSWCD documents are online (as of 12-20-2017):

http://cumberlandswcd.org/site/2017/11/building-resiliency-along-maines-bluff-coast/

Building Resiliency Along Maine's Bluff Coastline

Technical Manual
for use of the
Shoreline Management Assessment Decision Tree
Finalized October 2017
Revised November 27, 2017

As part of a project for the Maine Coastal Program (MCP)/Maine Department of Agriculture, Conservation and Forestry (DACF), the Cumberland County Soil and Water Conservation District (CCSWCD), developed a **Shoreline Management Assessment** (**SMA**) to support coastal landowners, community organizations and boards, municipal officials, and other interested parties who need to manage assets at risk due to coastal bluff erosion. This work was supported by the National Oceanic and Atmospheric Administration (NOAA) Coastal Zone Management Cooperative Agreement #NA14NOS4190047 pursuant to the Coastal Zone Management Act of 1972 as amended.

The SMA allows the overall vulnerability of a coastal bluff to be quantified and helps the evaluator to determine whether a bluff restoration approach can

… incorporate "living shoreline" elements (mimicking natural systems by incorporating plants and biological materials)

or whether

…. only a "hard armoring" approach (using elements like rock-filled wire baskets, boulders, or concrete) can be used

and if

…. a mixture or both approaches is recommended

… to rebuild the bluff and prevent further erosion.

The SMA features three levels:

1) A *general* compilation of data and overview of the instability of a large area: the **reconnaissance level assessment** (**RLA**);
2) A limited *intermediate*, desktop-level ranking focused on specific study areas within the larger area: the **prediction level assessment** (**PLA**); and
3) A highly-focused first step to *recommend solution(s)* for a single study area: the **design level assessment** (**DLA**).

The data and elements that should be considered at each of these three levels (RLA, PLA, and DLA) are shown in the **SMA Chart** included in ***Attachment A*** (also available in a large format, for improved legibility, on the project website).

EOE

A **Decision Tree Flowchart**, included in ***Attachment B***, was developed to complement the SMA Chart by suggesting questions that an evaluator should ask as they review collected data and consider restoration methods. These questions are shown in blue, with potential outcomes in green; intermediate information that may be also required is shown in yellow.

The categories of information that should be collected and reviewed as part of an SMA is not always intuitive, so these **Technical Notes** define those categories and provide additional information on how to rank or quantify them. These Technical Notes also suggest sources for more information on some specialized or complicated types of data.

Neither the Decision Tree Flowchart, nor these Technical Notes, will provide the entire solution or specific recommendations for a specific site, but together, they will guide and support parties interested in using the SMA to restore and/or mitigate erosion of a coastal bluff.

Level I – Reconnaissance Level Assessment

The **reconnaissance level assessment (RLA)** is an inventory of the current site conditions and historic data for the site. This work can be completed by the landowner, a community organization focused on bluff restoration, a state or federal program, or by a professional hired by any of these entities.

As part of the RLA, the following information should be compiled:

Historic Data

1. **Aerial Photography, Orthophotos, and Ground-Level Photographs**

   The person performing an assessment should review aerial and ground-level photographs covering the widest possible time range.

   Historical aerial photos are available free on Google Earth™, by selecting "Historical Imagery" in the 'View' tab. A sliding bar allows you to see detailed changes to the area over time, and provides the date of the flyover that generated the aerial. Historical aerials beyond those available on Google Earth™ can be viewed on www.historicaerials.com, and purchased as digital images for a generally nominal fee.

   Orthophotos are similar to aerial photos except that they have been geometrically corrected to eliminate distortion and allow for a uniform scale to be provided. Orthophotos of Maine are available from the Maine Office of GIS at www.maine.gov/megis/catalog.

   The Iowa State University's Natural Resource Ecology and Management program has an excellent resource about how to interpret aerial photos. This document (www.nrem.iastate.edu/class/assets/nrem345/Week6_ALL.pdf) provides information on how to use size, shape (including what many types of trees look like in aerial photos), patterns (natural vs. man-made), tone, hue, texture, shadows, and association with adjacent properties to understand what an image is representing.

   The current landowner or a community organization will likely provide photographs of the nature and scale of bluff instability and other changes observed on the property. These ground-level photographs should be compared with aerial photographs to provide a sense of scale for the damage.

2. **United States Geological Survey (USGS) Topographic Maps**

   For more than 130 years, the United States Geologic Survey (USGS) has maintained and updated topographic (or "topo") maps that include contour lines (elevations), water bodies, resource areas (like wetlands), roadways, geographic place names, and many other features.

   Historic maps originally published as paper documents in the period 1884-2006 are available as scanned images, and are generally referred to as quadrangle (or "quad") maps because they were produced in a rectanglular shape. Current-generation (since 2009) topographic maps are created from digital GIS databases. For more information on the USGS mapping program, visit. https://nationalmap.gov/ustopo/index.html.

   To view the USGS topo maps for your study area, visit https://viewer.nationalmap.gov/basic/, zoom in to the study area in the map on the right side of the screen, click "US Topo" in the left hand window, and click "Find Products" to view USGS maps available for the area.

3. **Land Use Summary**

   Land use can be the cause of, or at least contribute to, bluff erosion. Land use adjacent to coastal bluffs may include agricultural, mining, timber harvesting, fishing/shellfishing, recreational, military, and residential activities, or a combination of these.

   The most common source of information about historical land use is from aerial maps. However, information on past land use may also come from the current landowner, residents or occupants of neighboring properties, a local historical society, the municipality's planning department, or the local library. The Maine Historic Preservation Commission, especially if it was the site has archaeological or historical significance. Learn more about the Commission's resources at www.maine.gov/mhpc.

4. **Landscape Modification Summary**

   Information on changes to a property will most likely be provided by the landowner. This summary should include not only the bluff instability and other changes observed on the property, but also when those changes were first observed (year and season), and under what condition the changes occurred (for example, during a certain storm). These reports and observations should be verified on historic aerial photographs.

   When available, photographs of any damage (for example, a large landslide) provided by the landowner should be compared with aerial photographs to provide a sense of scale for the damage, potentially highlighting similar conditions on nearby bluffs.

Existing Conditions Data

1. Current Land Use

The most common source of information about current land use is from the landowner.

However, the owner of a property that contains a coastal bluff may not have much information about drainage (runoff) from roadways and other properties that may be discharged onto their property via an engineered drainage system (such as pipes, catch basins, drain manholes, and green infrastructure). In this case, the municipal engineer or public works department may also be helpful in understanding how that system was designed and how the drainage arrives to the property. This person or department may also be able to provide information on maintenance easements the municipality owns for the system. A local municipal engineer would also be a useful partner in identifying improvements that may be more protective of the bluff (for example, installing rain gardens or other green infrastructure).

2. Structures

This source of data includes houses, sheds, barns and other buildings that are present on a property, but also impervious surfaces such as driveways, parking lots and sidewalks. Features such as engineered drainage systems, septic systems, retention ponds, farm dump sites, and green infrastructure are also of interest because they may contribute water (either by drainage or groundwater infiltration) in the direction of the bluff. This information will primarily come from the landowner, but as mentioned in the “Current Land Use” section, a local municipal engineer or public works department may also serve as a resource.

3. Vegetation

An inventory of the condition, type(s), and diversity of vegetation present below, on, and above the bluff is critical in understanding whether, and to what extent, vegetation can serve in restoration or mitigation efforts. For example, an inventory showing unsuccessful efforts to plant trees on the upper limits of a bluff may indicate that a woody shrub species is more appropriate for the soils.

This vegetation inventory information can come from an on-site visit by the person performing the assessment, through phone conversations and photos provided by the landowner, from aerial photo interpretation, via an inspection of the bluff from a boat, by drone flight, or by a combination of these.

Additionally, an inventory of the vegetation along any roadway or in any area that drains to the bluff, and information on what person or organization maintains that vegetation, should be completed. Use reference materials such as the “Coastal Planting Guide” developed by Cumberland County Soil and Water Conservation District for the Maine Coastal Program.

When available, photographs of vegetation provided by the landowner should be compared with aerial photographs to document and confirm the appearance of a plant type or species in those photographs and extrapolate this to adjacent properties and upgradient areas.

4. Upland Hydrology

The term "hydrology" refers to the movement of water over land, and it is important because drainage reaching a property- specifically, water reaching the top of a bluff- may contribute to instability of the bluff slope.

Hydrology includes both the size of the area draining to the property as well as:

- How water flows across the property. For example is it: channelized into a concrete ditch? Confined to a natural stream? Mitigated by green infrastructure?;
- How much water reaches the property under specific conditions;
- If any water infiltrates into the ground or whether all of the water reaches the top of the bluff; and
- How fast water flows once it reaches the property.

This information may be available to the landowner or visible during an on-site visit by the person performing the assessment. The USGS maintains a program called StreamStats that allows a user to visualize the boundary of the area draining to a point, get information on the size of that drainage area, calculate estimated flow from that area, measure distances, see elevation change between two points, and print or download the boundary.

The StreamStats program website for the State of Maine (available as Version 3 as October, 2017) is available at https://water.usgs.gov/osw/streamstats/maine.html, and User Instructions are available at https://water.usgs.gov/osw/streamstats/Version3UserInstructions-20160401.pdf.

Alternately, hydrology information may be provided by a professional, such as the local municipal engineer, public works department, or a consultant. Alternatively, it may be included in site plan applications or other reports in the municipality's files.

5. Tide

When assessing a coastal bluff for instability (or when developing potential restoration plans), the extent of high tide is generally most useful, as the impact of wave energy on bluffs during high tide events can be substantial.

There are several terms used by different agencies to describe high tides, many of which are used in different levels of the SMA. Brief descriptions of some of these types of high tides are in the following bullets.

- Highest Annual Tide: The Maine Geological Survey describes as the highest annual tide as a peak tide that exceeds all others in elevation. This tide- also known as a "spring tide", although it can occur any season - is caused by combinations of gravitational forces driven by the position of the earth and moon.

- Highest Astronomical Tide: The motions of the earth, moon, and sun change on a cycle that repeats every 18.6 years- a period is known as the National Tidal Datum Epoch. The highest tide at a specific station during a tidal epoch is known as the Highest Astronomical Tide for that station. This elevation is very similar to, but slightly higher than, the Highest Annual Tide.

- King tide: This term does not have a scientific definition, but is generally used to refer to especially high tides. This term has become more common as rising coastal waters, even during days without precipitation, are more frequently pushed upstream *into* pipes that normally flow *out* to the stream or ocean. When these pipes back up, the water comes up out of drainage structures. The severity of local street flooding in recent years has increased awareness of the public of sea level rise.

- Mean Higher-High Water (MHHW): Each day has two tidal cycles, and therefore two high tides and two high-water levels (one during each high tide). One of the high-water levels will be higher than the other. NOAA describes MHHW as "The average of the higher high-water height of each tidal day observed over the National Tidal Datum Epoch."

- Mean High Water (MHW): NOAA describes MHW as "The average of all the high-water heights observed over the National Tidal Datum Epoch".

- Ordinary High Water (OHW): This measurement is different from the others in this list in that it's determined through *visual* inspection of a shoreline, not from a calculation. The United States Army Corps of Engineers describes OHW as "the line on shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas."

An excellent resource that describes high tides, published by the Maine Geological Survey, is available at http://digitalmaine.com/cgi/viewcontent.cgi?article=1500&context=mgs_publications

Many stations within Casco Bay and along the coast of Maine track high tide data (for example, Potts Harbor in South Harpswell is station 5985). A history of high tide data for these stations is available at www.sailwx.info/tides/tidemap.phtml?location=3462, which includes a map centered on Orr's Island in Casco Bay. Scroll down the page to read descriptions of the available stations, and click on the station closest to the property of interest. The resulting page will show the predicted height of high and low tides for the current day, but you can scroll down to the "Time Control" feature to choose a specific date- for example, during a specific storm event or astronomical high tide. Tide chart data is compared to the chart datum for that station. Datum for many Maine locations can be found at: https://tidesandcurrents.noaa.gov/datums.html.

Figure 1, below, from a database managed by NOAA, shows many of the tide elevations described previously for station #8417988 located on Great Diamond Island in Casco Bay, Maine. As mentioned above, ordinary high water (OHW) is not shown on this image because this would be based on a visual inspection of the shoreline; it is not a calculation.

A number of low-tide orthophotos of the coast of Maine are available in the Maine Office of GIS online catalog, www.maine.gov/megis/catalog. See the notes associated with each data layer to learn more about the accuracy of each.

Elevations on Station Datum

Station: 8417988, GREAT DIAMOND IS., CASCO BAY, ME **T.M.:** 75
Epoch: 1983-2001
Status: Accepted (Apr 20 2004) **Datum:** STND
Units: Feet

Datum	Value	Description
MHHW	11.50	Mean Higher-High Water
MHW	11.07	Mean High Water
MTL	6.53	Mean Tide Level
MSL	6.57	Mean Sea Level
DTL	6.57	Mean Diurnal Tide Level
MLW	1.99	Mean Low Water
MLLW	1.64	Mean Lower-Low Water
NAVD88		
STND	0.00	Station Datum
GT	9.86	Great Diurnal Range
MN	9.08	Mean Range of Tide
DHQ	0.43	Mean Diurnal High Water Inequality
DLQ	0.35	Mean Diurnal Low Water Inequality
HWI	3.58	Greenwich High Water Interval (in hours)
LWI	9.75	Greenwich Low Water Interval (in hours)

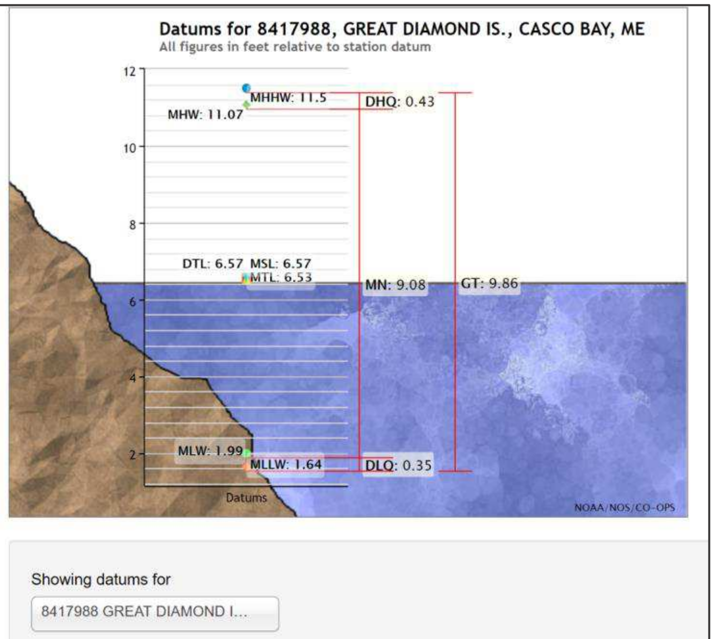


Figure 1: Source: National Oceanographic and Atmospheric Administration (NOAA) Tides & Currents Datum. Note that elevations are given in Station Datum. In this example subtract 1.64 feet, the elevation of MLLW to get values commonly used in tide tables. (https://tidesandcurrents.noaa.gov/datums.html?id=8417988)

Instability Assessment Rating

The last step of a Level I RLA is to perform an **Instability Assessment Rating** for the property or coastal bluff to assess erosion condition and potential. The Instability Assessment Rating system is similar to the Bank Erosion Hazard Index (BEHI) Ranking developed by Dave Rosgen of Wildland Hydrology, Inc., in that both assign point values to several categories of bank condition, providing an overall score that can be used to inventory the condition over large areas and prioritize eroding banks for remedial actions. The difference is that BEHI is limited to assessment of river and stream conditions, whereas the Instability Assessment Rating is used to assess coastal processes and factors.

A **Data Sheet** (form) that can be used to perform an Instability Assessment Rating is included in ***Attachment C***. Portions of this form can likely be filled out by a landowner, but other sections may require assistance from a professional with experience evaluating coastal bluffs.

The form includes a numeric score, ranging from 1 to 3, for twelve (12) different categories or measures of bluff stability. These include many of the types of data described in previous sections as well as soil properties, bank slope, the presence of active bank erosion, and the type of landscape on the bluff (native and vegetated vs. engineered and armored).

- A low score (1) means that the bluff condition is good for that category.
- A high score (3) indicates an element that is poor, contributing to instability of the bluff.

When fully completed, this form will provide an overall rating for the bluff. Forms can be completed for different, unique areas of concern on a property; this is useful because it allows restoration to be prioritized to the area that has the most overall instability. The completed form will enable a professional to understand the current site conditions that are critical when developing a site-specific design plan.

Once this data has been compiled and overall ratings calculated, the person doing the assessment can move on to Level II, the Prediction Level Assessment.

Level II – Prediction Level Assessment

A **prediction level assessment (PLA)** builds on the data gathering step of the RLA by allowing the person doing the assessment to focus on specific areas.

While the RLA may be completed by a landowner or local organization, the PLA will likely be performed by a professional using data collected during a RLA. The PLA will likely use engineering and planning software in order to develop a conceptual understanding of the site, as well as incorporate additional information.

A key aspect of this process is the analysis of the results from the Instability Assessment Rating, which will be the basis of the PLA.

Case studies of the assessment of bluffs in Falmouth (Mackworth Island), Brunswick (Mere Point), and Harpswell (Mitchell Field) are included as ***Attachment D.*** This provide examples of a Level II or PLA assessment.

Assessment of Hydrologic Processes

The assessment of hydrologic processes will be conducted by using HydroCAD or a similar engineering software that can be used to understand how water flows across a site. As part of this analysis, the following information about the site will be analyzed.

- Water and groundwater resources on the site
- Soil layer properties
    a. Soil permeability
    b. Soil drainage class
    c. Available water capacity
- Hydraulic properties
- Slope stability

In order to support this analysis, the following additional information will be compiled as part of the Level II PLA:

Inventory Mass Erosion

Symmetry

Identifying areas of asymmetrical erosion is an important initial step toward targeting areas of a bluff site which require further study and possible interventions. Based on the observations from the bluff site and relief from LiDAR data, the person performing the assessment will identify areas of symmetry on and around the bluff site in order to better understand the amount of erosion the bluff is experiencing.

In this context, symmetry refers to how even a bluff face is eroding. For example, is the entire bluff face receding at the rate of several inches per year? Or are there areas of the bluff that are eroding at a much faster rate than others?

When an area of a bluff erodes faster than another area, over time areas with higher erosion rates will form indentations into the bluff face, while areas of slower erosion may form protrusions. Areas with indentations may be characterized by small channels or large gullies. Indentations in bluffs will usually indicate places where upland drainage is concentrated, either due to natural topography or because of discharge from an engineered drainage system.

While asymmetrical rate of loss is often due to upland surface drainage, it may also indicate underground seepages. Factors influencing the speed of erosion at these sites include differing soil types, removal of vegetation, natural loss of vegetation (such as a single large tree), or the cascading effects of coastal erosion being caused by a nearby section of slope that has recently been armored.

An overview of bluff stability for the State of Maine, based in part on symmetry and other observed factors, is available from the Maine Geological Survey. See hwww.maine.gov/dacf /mgs/pubs/mapuse/series/descrip-bluff.htm for more information.

Height Ratios

If the symmetry analysis shows that some areas of a bluff may be eroding faster than other areas (gullies and channels), these features should be analyzed in more detail. The person performing the assessment will identify the height ratios of eroding areas by measuring the depth of the downward cut of the feature and its width. This information can be used to determine the probable cause of the erosion, such as upland discharge or undercutting due to wave action.

For example, if an erosion channel is forming which has a larger depth to width ratio, it is likely that concentrated upland flow is causing erosion at that location. However, a broad and even cut into a bluff may be more likely to indicate wave action is the primary factor, or that soils and geology are uniform along the shore.

Inventory Hillslope Processes

An assessment of hillslope processes at the study area will gather information that includes: degree of slope, inventory of running water, vegetation removal, changes in land use, and mass movement of soil.

This assessment will generally be completed by a professional, and the assessment will help the professional better understand the condition of the bank on the site.

Analyze Shoreline Processes

Wave Erosion / Coastal Inundation

Determine the effect wave energy is having on the bluff location. Sources for this information include Maine Geologic Survey fetch data. Bear in mind that the effect of wave energy will be modulated by the height of flooding during storm events. This can be determined by observing desktop data, such as FEMA Flood Insurance Rate Maps or other sources of inundation heights.

Slump

In the context of bluff stabilization and assessment, a "slump" is a relatively deep cut into the plane of the bluff's face, causing a rapid and sudden loss of material. It may be caused by wave erosion, upland discharge, or some combination of factors. Slumps are typically focus areas for stabilization measures. Note whether there are sediment fans deposited on the intertidal area from previous slump events.

Freezing Cycles

Freeze/thaw cycles are an important contributor to bluff instability in the State of Maine. Bluff faces are frequently locations where underground water seeps to the surface. These seeps will frequently melt and refreeze during Maine's colder months. Each freeze and thaw cycle potentially increases bluff instability, expanding fissures and weak points in the bluff face. South-facing slopes experience the most freeze-thaw cycles in any given year.

Fluctuations in weather patterns from year to year may play a role in the extent to which freeze/thaw cycles cause bluff instability. For example, a dry period in summer followed by a colder winter with more storms than typically seen may create "slip failures" where dryer and wetter layers abut.

Identify/Inventory Shoreline Changes

Recession Rates

The overall recession of bluffs is a natural process, and eventual loss of land is expected over long timespans. This set of tools and other guiding documents is only intended to provide landowners with tools to slow or temporarily halt recession rates.

One important factor to consider when addressing bluff slope erosion is that when material erodes, it doesn't disappear. Eroded material will migrate to adjacent areas, through a process known as sediment transport. The deposition of eroded material in the coastal environment can create or add to features including spits, ridges, or sandbars. Sediment transport is responsible for the creation of tidal flats, beaches and other economically and ecologically important intertidal environments.

An inventory of shoreline changes looks at the base of the bluff (and surrounding areas) by assessing how material accumulates and erodes over time. Certain trends, such as an overall deposition and erosion of sediment at the base of the bluff, can impact the solution prescribed for addressing erosion. Also note that characteristics of fringing salt marshes provide insight into shoreline stability seaward of the toe of a bluff.

The Maine Geologic Survey has prepared a series of maps to assist in the identification of shorelines with high risk of coastal erosion. You can view these maps at: [www.maine.gov/dacf/mgs/pubs/ mapuse/series/descrip-bluff.htm](www.maine.gov/dacf/mgs/pubs/mapuse/series/descrip-bluff.htm)

Inventory Direct Impacts to Shoreline and Bluff Form

Soil Layer Structures

This analysis takes into account the types of soils that comprise the bluff structure. Certain soil types can produce different results when experiencing erosion, and can call for different solutions in the design phase. In order to look up the soil type for a given location, please use the USDA "Web Soil Survey" tool, https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

The soil type can yield important factors related to bluff stability. These include:

- How porous is the soil? That is, how easily can water flow through it?
- Is the soil well-aerated?
- How deep below the soil is bedrock located?

These factors affect how much water can be absorbed before running off on the ground surface, and how much water can be absorbed before the soil becomes saturated.

In particular, the presence of clay can play a substantial role in bluff stability. Clay soils tend to be impermeable, meaning layers of high water saturation may form. These can form failure surfaces where whole layers slip against other layers, leading to landslide events.

The Maine Geological Survey has compiled the locations of known landslides on bluffs along the Maine coast (including those interpreted from aerial photography) and areas identified with a high landslide potential into a series of maps. These Coastal Landslide Maps are available at www.maine.gov/dacf/mgs/pubs/mapuse/series/descrip-slide.htm

Level III – Design Level Assessment

The design level assessment (DLA) is a description of design concepts that can be used in order to address erosion at a bluff site based on the results of a RLA and PLA. Level III of the Decision Tree Flowchart is not meant to be a stand-alone guide, and should be used by a professional as a suggestion rather than an answer. The exact solution that is designed should be based on the results of the RLA and PLA.

DLA recommendations are broken out into two types, each corresponding to the area of erosion that is being addressed in the design. These areas are:

Nearshore/Intertidal

Concepts described in this section should only be used in the nearshore or intertidal area of a bluff site, provided the RLA and PLA support the design concept. The "nearshore" area refers to the coastal waters adjacent to a site outside the intertidal zone. The intertidal zone refers to the areas between "low tide" and "high tide". In Maine, property owners can own land out to the mean low tide line. For the purposes of bluff management, "high tide" is typically demarcated by the "highest annual tide".

The DLA for this area can also include suggestions for assessment of additional bluffs for future work, or even Bluff Management Plans if the landowner is interested in adopting one.

Upland/Riparian Zone

A comprehensive approach to bluff management should include upland drainage areas which discharge at or near bluff sites. In areas where a substantial amount of freshwater flow is present, such as at the mouths of permanent rivers or streams, or even at perennial streams, special considerations must be made to incorporate best management practices for stream management.

Areas adjacent to streams and rivers are known as the "riparian zone". For example, wetland species, which can tolerate areas that are perennially wet, should be planted in in these zones. It is important to consider how riparian zones provide connectivity for wildlife between coastal and freshwater areas.

Where it is determined that vegetation can play a role in the restoration of a bluff or preventing erosion at one, the **Coastal Planting Guide** included in ***Attachment E*** can assist in selecting plant varieties for slope stabilization. It considers many factors, such as:

- Salt tolerance;
- Soil depth;
- Wave height;
- Slope of the bank;
- Water availability; and
- Sun requirements.

The Coastal Planting Guide recommends native Maine plants that can be used to stabilize coastal shorelines where restoration with a living, natural shoreline has been determined to be appropriate.

The goal of a DLA is to develop a comprehensive site management plan with a full understanding of parameters. The overall goal is to manage sites and install best management practices which mimic natural conditions and processes. By evaluating nearshore and intertidal processes, surface and ground water conditions, as well as native vegetation that promotes bluff stability, designs can be selected that are consistent with this overall goal.

Attachments

A: Shoreline Management Assessment (SMA) Chart

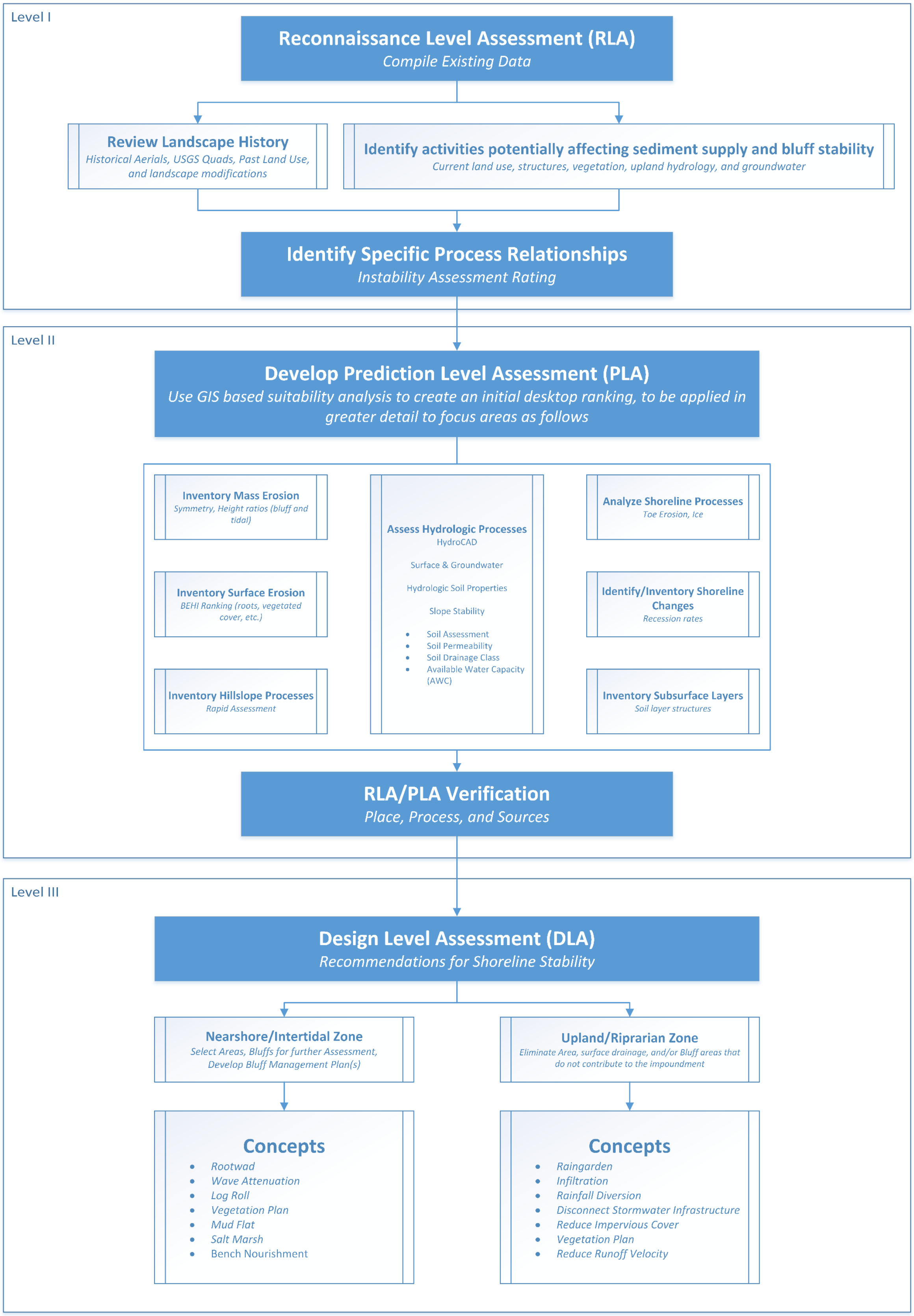
B: SMA Decision Tree Flowchart

C: Instability Assessment Rating Form

D: Case Studies
- Falmouth (Mackworth Island)
- Brunswick (Mere Point)
- Harpswell (Mitchell Field)

E: Coastal Planting Guide

Bluffs Task 1



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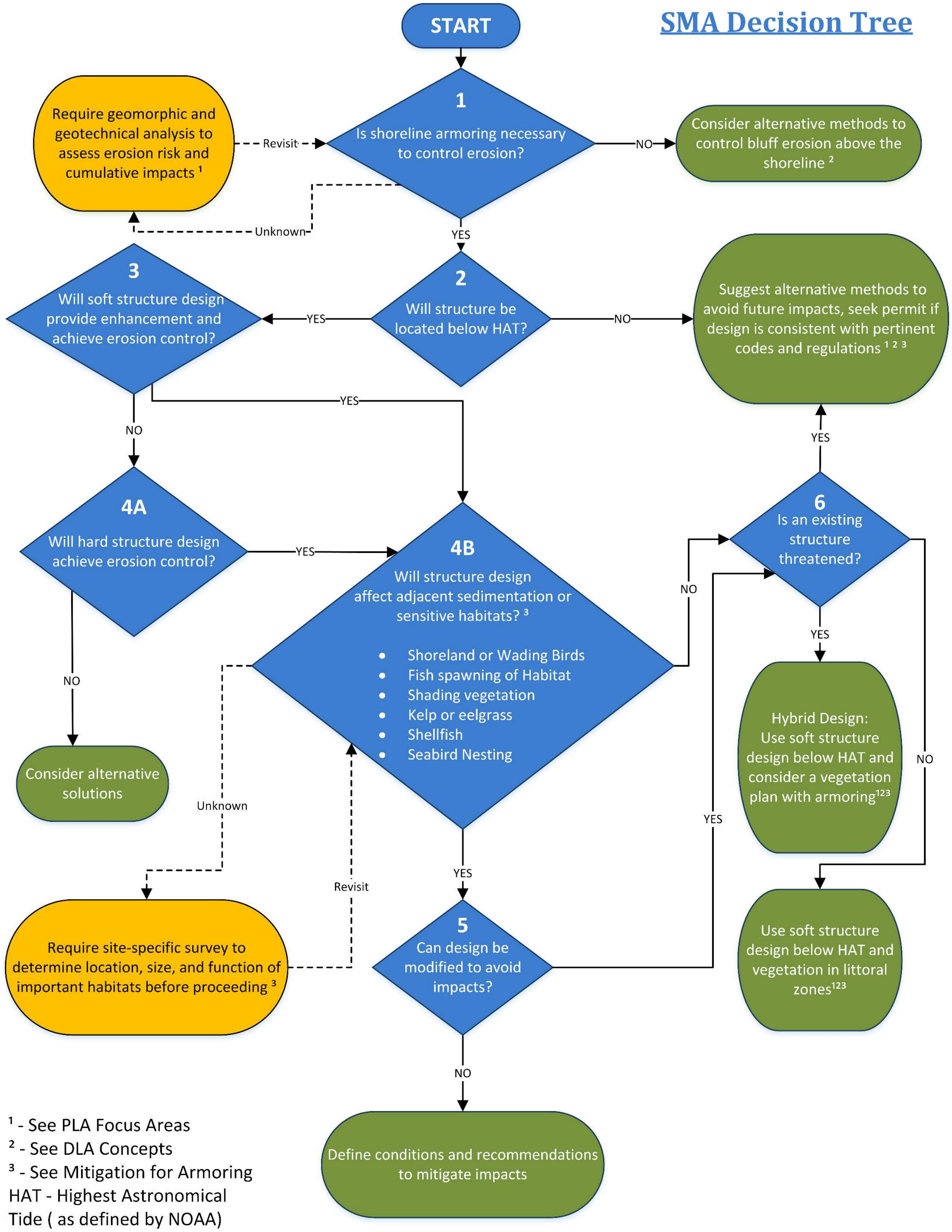
Cumberland County Soil & Water Conservation District

maine Department of Agriculture Conservation & Forestry

Maine Coastal Program

SMA Decision Tree



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Cumberland County Soil & Water Conservation District

Maine Department of Agriculture Conservation & Forestry

Maine Coastal Program

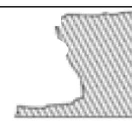
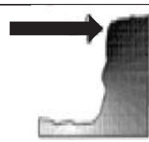
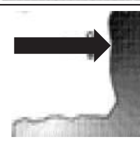
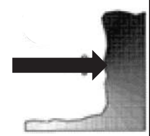
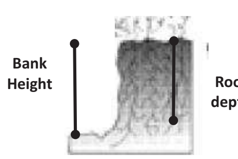
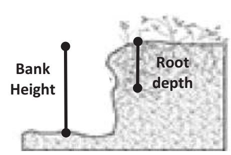
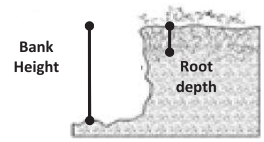
INSTABILITY ASSESSMENT RATING DATA SHEET

Location (Nearest Address or Coordinates) ______________________

Name and Affiliation of Inspector: ______________________

Date: ______________________

Photo(s): ______________________

	Category / Parameter / Measurement Method	Description of Bluff Condition: Good (1)	Fair (2)	Poor (3)	Rating (1, 2, or 3)
1	**Hydrology - Changes in Upland Runoff**	No recent alteration of upland area draining to study site. Drainage of bank has not been modified.	Minimal overland drainage changes upland from study site. Does not adversely affect hydrology or result in concentrated flow. No point discharge.	Surface drainage upland is discharging with an adverse affect to study site. Water is ponded above the bank. Seepage may be present.	
2	**Hydrology - Nature of Flow**	No apparent concentrated flow or channelized flow to study site from adjacent land use.	Some concentrated or channelized flow is directed to study site, causing point discharge. However, measures are in place to protect resources or discharge is limited.	Concentrated or channelized flow is heavy or results in a large point discharge observed at study site. No protection is in place.	
3	**Hydrology - Land Use**	Upland area is primarily native and undisturbed. Vegetated area is greater than 70% and is a mix of shrubs and trees. Trees larger than 12" diameter are at least 20 feet from top of bank.	Land development and/or active agricultural practices are occurring on less than 70% of the upland area. Vegetated area is between 20 and 70%. Trees larger than 12" diameter are between 5 and 20 feet from top of bank.	Upland is urban or primarily active agricultural practices (less than 30% is native or undisturbed). Vegetated area is less than 20%. Trees larger than 12" diameter are less than 5 feet from top of bank; tree roots may be exposed.	
4	**Hydrology - Distance to Roads**	No roads are on, or are within 20 feet of, the study site. No roads on or adjacent to site are proposed in 10 year plan.	No roads are on, or are within 20 feet of, the study site. No more than one major road on or adjacent are proposed in 10 year plan.	Roads are located on or adjacent to study site (less than 20 feet away) and/or multiple roads are proposed.	
5	**Hydrology - Seepage**	Upland runoff as a result of rainfall patterns, geology, and soils does not result in seepage in bank.	Upland runoff as a result of rainfall patterns, geology, and soils results in seepage in less than 10% of the bank area.	Upland runoff as a result of rainfall patterns, geology, and soils is creating seepage in more than 10% of the bank area.	
6	**Vegetation at Toe of Bluff** (strip = width of vegetation below highest annual tide line)	**Dense vegetation** >80% of contributing shoreline length has a strip >25 feet wide	**Average vegetation** 50 - 80% of contributing shoreline length has a strip >25 feet wide	**Low vegetation** <50% of contributing shoreline length has a strip >25 feet wide	
7	**Sediment Supply (Erosion)**	**Low soil erosion** Bank erosion shows no recent change or loss. Few runnels/gulleys are present on the bank face.	**Moderate soil erosion** Bank erosion is occurring: visual change and loss are observed. There are several runnels/gulleys on the bank face, all less than 6 inches deep.	**High soil erosion** Bank erosion is occurring with measurable change. There are numerous runnels/gulleys, or some that are more than 6 inches deep	
8	**Bank Slopes**	Slopes are between 3 and 8%. 	Slopes are between 8 and 20%. 	Slopes are 20% and greater or are undercut. 	
9	**Bank Height vs. High Tide Elevation**	High Tide Elevation is <u>at or near</u> Top of Bank 	High Tide Elevation is <u>1/3 below</u> the Top of Bank 	High Tide Elevation is <u>more than 1/3 below</u> the Top of Bank 	
10	**Soil & Geology**	Bedrock and boulders make up the bank. Or, cohesive soil types (sand/gravel mix) mixed evenly.	No bedrock or boulders, cohesive soils (sand/gravel mix) are dominant and mixed equally. Clay to very stony sandy loam.	Soils are non-cohesive and/or highly stratified. Sand/gravel mix with larger percentage of sand, sandy loam, silt,	
11	**Bank Surface Protection (%)** = a visual assessment of the amount of bank composed of root material. Also referred to as "Root Density" **Ratio of Root Depth: Bank Height**	Surface Protection = 80 - 100% Root depth: Bank Height = 1.0 - 0.9 	Surface Protection = 55 - 79% Root depth:Bank Height = 0.5 - 0.89 	Surface Protection= < 55% Root depth:Bank Height = < 0.5 	
12	**Biology / Landscape Connectivity**	Shoreline of study site, and the adjacent area, have native bank and vegetation materials. No rip-rap or hardened structures installed.	Shoreline of study site, and the adjacent area, have native vegetation and bank materials but are impaired by invasives and/or have rip-rap or hardened structure installed	Shoreline of study site and.or the adjacent area are hardened by a concrete headwall, or rip-rap or other structure. Limited vegetation present.	
				Total Rating (sum column):	

Images included in this form are adapted from graphics developed by David Rosgen in 1993 and presented on March 25, 2001 in "A Practical Method of Computing Streambank Erosion Rate" at the Federal Interagency Sedimentation Conference in Reno, NV.

This Instability Rating Form was developed for the Maine Coastal Program/Maine Department of Agriculture, Conservation and Forestry by the Cumberland County Soil and Water Conservation District. This work was supported by the National Oceanic and Atmospheric Administration (NOAA) Coastal Zone Management Cooperative Agreement #NA14NOS4190047 pursuant to the Coastal Zone Management Act of 1972 as amended. For more information about the Maine Geological Survey, contact mgs@maine.gov or 207-287-2801. For more information about the MCP, visit www.mainecoastalprogram.org or contact 207-287-2351.

Cumberland County Soil & Water Conservation District

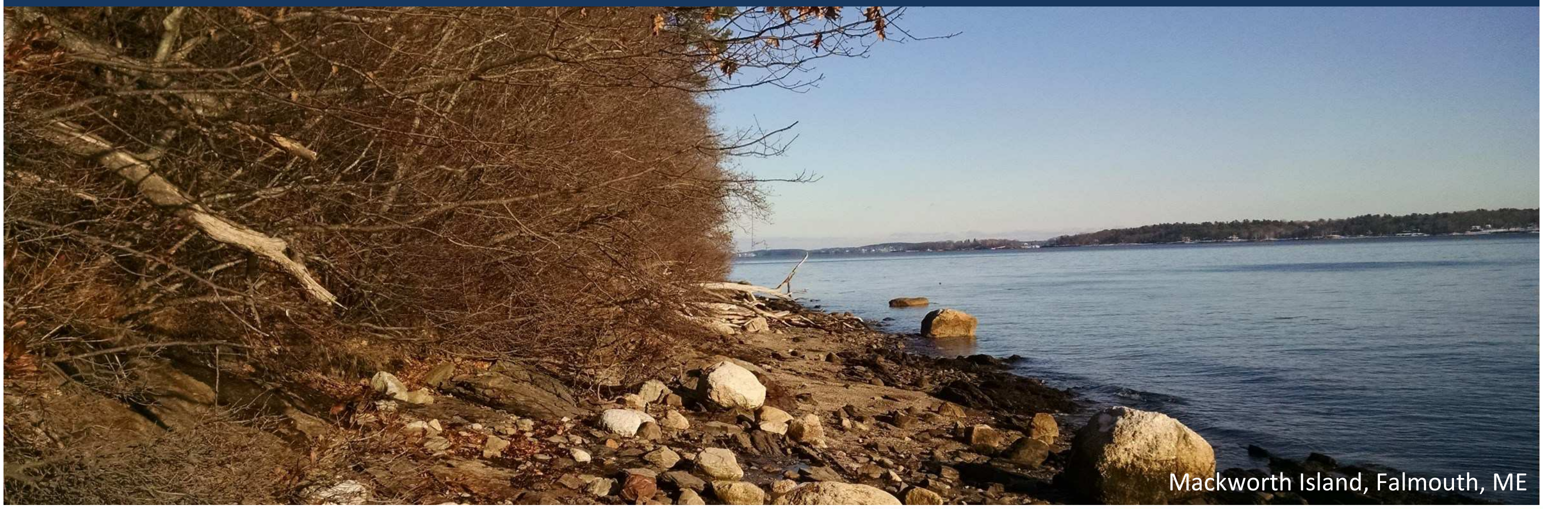
maine Department of Agriculture Conservation & Forestry

Maine Coastal Program

Cumberland County Soil & Water Conservation District

Building Resiliency Along Maine's Bluff Coastline

Case Study: Mackworth Island | Falmouth, ME



Mackworth Island, Falmouth, ME

Assessment Overview

Five factors influence slope stability of an embankment:

1) Shear strength of the soil;
2) Unit weight;
3) Embankment height;
4) Slope steepness; and
5) Pore pressure within the soil.

Failure generally occurs in two ways. The first is by physical sliding action of the slope, from a local shallow failure or as a larger toe failure. The second case is by shear failure of the soil itself when excess soil pore pressures exist from saturation. The condition of these factors at this location is described in the following paragraphs.

Site Visit Information

Evaluation date:	November 10, 2016
Evaluators:	Damon Yakovleff (CCSWCD), Troy Barry
Study sites:	8

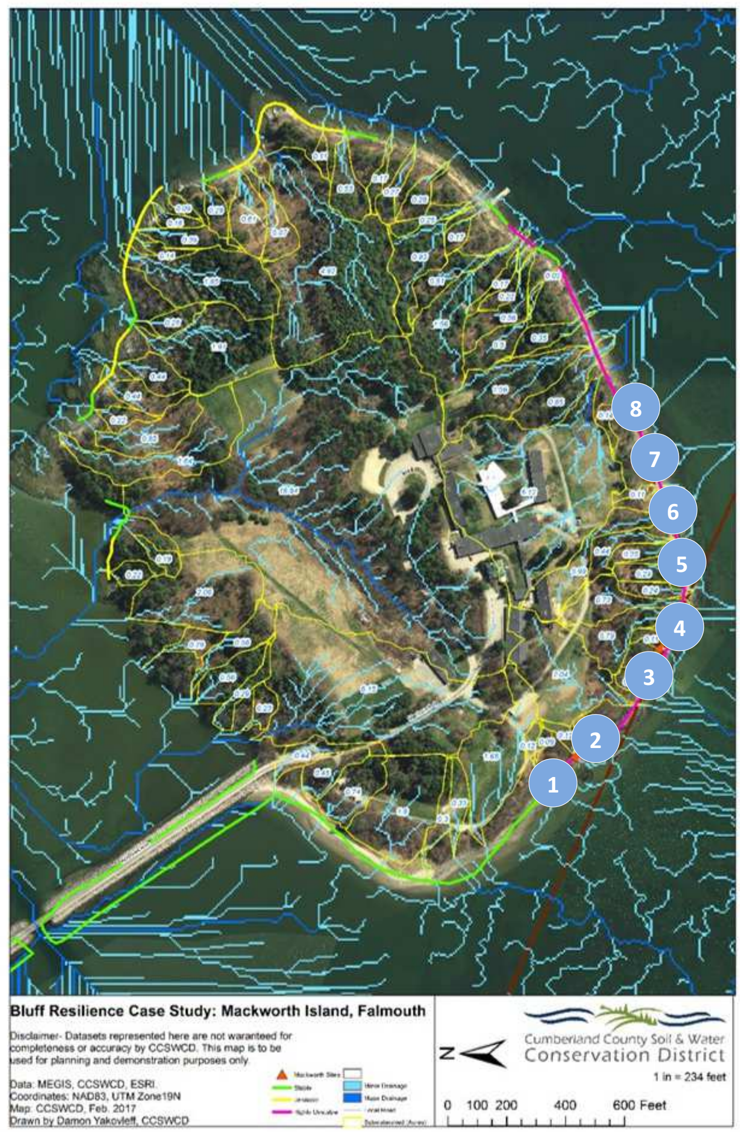


Figure 1. Eight Study Sites at Mackworth Island, Falmouth, ME

Assessment of Soils and Erosion

Because the soils in and around Mackworth Island consist primarily of till, the soil matrix has a high pore spacing between the sand and gravel particles. The toe of the bluff had intermittent ledge mixed with gravel and sand. Seaward of the toe intermittent beach is found consisting mainly of larger soil mixture of gravel and cobble with a scattering of boulders.

The Mackworth Island location has two areas considered to be "high landslide" probability according to the Maine Geological Survey. The remaining area is considered moderate, likely seeing increased erosion during freeze/thaw periods.

Figure 2. Soils at the Mackworth Island sites were primarily till.

Impact of Water on Slope Failure

There is strong evidence of a direct connection with the upland water runoff and the several shallow failures occurring along the southern shoreline. The addition of water from rainfall or snow infiltrates and replaces air in the pore spaces, adding weight. This water expands and contracts in the void spaces resulting in slope failure. Infiltrated water can change the angle at which the slope is stable.

At the time of the initial site visit seepage was not witnessed at the toe/lower bank interface. However, a second visit in December revealed prolific bank seepage that would be expected to be seen during the wet season.

It is likely that some of the toe erosion is being accelerated by perched groundwater seepage. Sites 3, 4, 5 and 6 all have undercut banks and toe heights of or exceeding three (3) feet or greater. This appears to be further compounded from the deflection effect from the surrounding hard ledge.

Assessment of Vegetation

This interaction between runoff and steep exposed banks is being enhanced by the reduced vegetation in the upland area that has reduced the potential for root structure to assist in binding soil near the bluff-upland interface. Areas that have lost vegetation are seeing accelerated erosion from runoff in the form of rills, allowing the vegetated areas to be vulnerable to rapid erosive change.

Figure 3. Removal of upland vegetation increases erosion at the Mackworth Island sites.

Factors Contributing to Instability

Specific factors contributing to instability at this location, and overall instability ratings for the eight Study Sites, are included in ***Table 1***.

Table 1: Instability Rating and Upland Runoff of Each Study Site at the Mackworth Island Location

STUDY SITE	UPPER BANK	LOWER BANK	TOE	
1	Coordinates: 70° 14' 6.506" W, 43° 41' 15.032" N			
C-Value: 0.30 227° SW	Drainage @ Top to Bluff, 35' 42° Large, Elm & Grass	25-30' Rip Rap Granite	Beach-Sand/Gravel/Rock	
Stable Material:	Trees/Grass	Boulder Rip-Rap	Native	
Rating:	Good/Fair (1.5)	Good/Fair (1.5)	Good (1)	**Total Rating: 4**
2	Coordinates: 70° 14' 4.970" W, 43° 41' 14.041" N			
C-Value: 0.30 217° SW Exposure	Drainage @ Top, Tree Buried, on upslope with Fill-Killing it, 45°	Rip-Rap, 35'-25'		
Stable Material:	Trees/Grass , Rip-Rap	Boulder Rip-Rap	Native	
Rating:	Fair (2)	Good/Fair (1.5)	Good (1)	**Total Rating: 4.5**
3	Coordinates: 70° 14' 1.530" W, 43° 41' 11.828" N			
C-Value: 0.30 237° SW Exposure	Oak Trees/Grass, 42-47°, 35'-40' Bluff	12-15' Bank Failure, Sand 85-90°	Undercut 15'-20', Sand-Bedrock interface	
Stable Material:	Trees/Grass on Loam Sand	Sand	Sand/Bedrock	
Rating:	Good (1)	Poor (3)	Poor (3)	**Total Rating: 7**
4	Coordinates: 70° 13' 59.900" W, 43° 41' 11.285" N			
C-Value: 0.30 210° SW Exposure	Trees/Grass 35-40' Bluff, Terrace @ 15' to 10' 15' (up) @ 47° 10' (up) @ 32°-90°	10'-90' Bank Failure	Undercutting, Bank Beach w/ sand	
Stable Material:	Some tree loss	Tree Loss	Flanked by Bedrock	
Rating:	Fair (2)	Fair/Poor (2.5)	Poor (3)	**Total Rating: 8.5**
5+6	Coordinates: 70° 13' 56.679" W, 43° 41' 10.476" N			
C-Value: 0.30 Vegetation change with wetland plants on banks 170° SW	150' -45° with distinct terrace @ top	80' Receding in places, 40-48°	40' Undercut Bank failure, Sand at beach Hydraulic Change in soil 90° @ Cuts Otherwise 40-48°	
Stable Material:	N/A	N/A	N/A	
Rating:	Good/Fair (1.5)	Fair/Poor (2.5)	Poor (3)	**Total Rating: 7**
7	Coordinates: 70° 14' 6.506" W, 43° 41' 15.032" N			
C-Value: 0.30 Stormdrain Gully Outfall 116° SE	20' Cutback from shoreline 80°-90° 15" Diameter Clay	Clay Exposed, eroded pipe pieces from outfall failure 20' Back. 15' Wide undercut	Toe is stable, due to material Water Running Granite	
Stable Material:	N/A	N/A	N/A	
Rating:	Poor (3)	Poor (3)	Poor (3)	**Total Rating: 9**
8	Coordinates: 70° 13' 52.056" W, 43° 41' 11.612" N			
C-Value: 0.30 Gulley Cutback 30' to terrace 180° S	60' Back, 30' Wide, Loam Soil, Tree Failure, 75°, Undercut Failure top 20'	Very Wet, Swamping. Trees missing, Hydraulic Soil Change, Plants are wetland, 12-30° stepped	Sand-Coble beach, framed by bedrock, 80-90°	
Stable Material:	N/A	N/A	N/A	
Rating:	Poor (3)	Poor (3)	Fair/Poor (2.5)	**Total Rating: 8.5**

Conclusions

The sand/gravel soil at this site contributes to is its inability to remain stable at steep slopes. Most in-place soils are stable at a 1:1 slope ratio (horizontal:vertical), but when soil is subjected to load, such as the surface water reaching the top of the bluff, that saturated soil can no longer support the load.

Soils and slopes like those in this location require healthy and deep-rooted vegetation to provide soil strength, in turn reducing erosion risk. It is likely that the multiple freeze-thaw events and water runoff from upland areas that reach the top of the bluff or the face through seepage is instrumental in the process. The sand/gravel soil matrix combined with low absorption root structure provided excellent conditions for the bluff to have multiple shallow failures. Water in and around the slope is a common agent in causing slope instability and erosion.

Potential Solutions and Treatments

Table 2 summarizes potential treatment concepts for the study sites at this location.

These treatments include:

- Considering a living shoreline approach along the toe
- Using plantings for stabilization to encourage sand piper habitat
- Stabilizing banks with root wads and utilizing brush mattress practices to encourage new growth
- Securing the toe of the slope with woody debris and establishing plants on the slope.

Table 2: Potential Treatment Concepts for the Mackworth Island Location

Site	Treatment Concept
1	Stabilize toe and lower bank. Mitigate surf runup.
2	Root wads at low and upper bank. Utilize brush mattress and encourage new growth.
3	Root wads at low and upper bank. Utilize brush mattress and encourage new growth.
4	Root wads at toe, low and upper banks. Utilize brush mattress and encourage new growth.
5	Root wads at toe, low and upper banks. Utilize brush mattress and encourage new growth.
6	Root wad debris, coir wraps and native planting
7	Fill in woody debris. Plant w/natives, use coir wraps, mitigate surface concentrated runoff
8	Toe rock w/ woody debris. Establish rooting plants on the slope.

Acknowledgement

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Case Study: Mere Point | Brunswick, ME

Assessment Overview

The failure at Mere Point begins at the edge of a field with dimensions of approximately 550' long by 200' wide. The field has been mowed consistently, removing all wood and herbaceous species for many years likely in desire to maintain a scenic view for the surrounding houses. The Mere Point location was experiencing seepage on the face of the failure at the time of the site visit, due to saturated ground conditions. This is coupled with surface runoff that reaches the top of the bluff face.

Five factors influence slope stability of an embankment: 1) shear strength of the soil; 2) unit weight; 3) embankment height; 4) slope steepness; and 5) pore pressure within the soil. Failure generally occurs in two ways.

Site Visit Information

Evaluation date:	April 28, 2017
Evaluators:	Troy Barry (CCSWCD) and Peter Slovinsky (Maine Geological Survey)

Site Characteristics

Top Perimeter:	200 feet
Toe Length at high tide:	185 feet
Vertical height from high tide:	15 feet
Conditions observed:	The location has a large mass wasting failure.

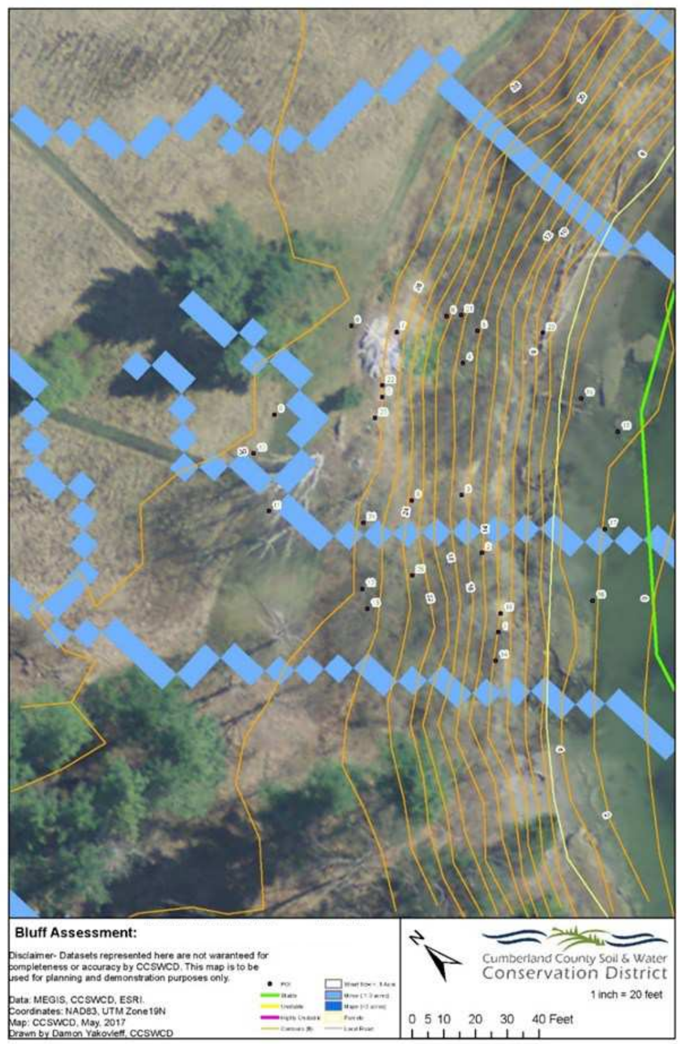

Figure 1. Mere Point Case Study Location, Brunswick, ME

The first is by physical sliding action of the slope, from a local shallow failure or as a larger toe failure. The second case is by deep-seated shear failure of the soil itself when excess soil pore pressures exist from saturation. The condition of these factors at this location is described in the following paragraphs.

Assessment of Soils and Erosion

Soils exposed by the landslide are predominantly clay in nature. Because clay particles are small and generally have large aspect ratios, interactions between the particles and water can result in reduced shear strength and underground movement and contribute to landslides. The Maine Geological Survey has identified two landslides along this shoreline of Mere Point.

Figure 2. Clay soils visible in bluff failure at Mere Point Case Study location.

Clay soil has low permeability and high water-holding capacity. Because the soil particles are small and close together, it takes water much longer to move through clay soil than it does with other soil types. Clay particles can absorb groundwater, expanding as they do and further slowing the flow of water through the soil. This not only prevents water from penetrating deep into the soil, but also creates saturated soil, increasing its weight. With water filling void spaces, particle cohesion and shear strength are reduced. Saturation combined with an unconfined 60-degree bluff is unstable and is subject to slope failure.

Assessment of Drainage Area

The drainage area that provides overland flow to the top of the failure is approximately 260' by 165' with three concentrated flow paths to the top of the bluff slope. One of these concentrated paths leads to the point of the bluff mass wasting failure (see Figure 2).

Assessment of Vegetation

Three large trees visible at the top of the bluff in the 2007 aerial imagery (Figure 1) and through spring 2016 have slid downslope and maintained upright growth by holding the failure block together during movement. These trees are birch and scotch pine, all of which are growing and appear to be healthy. Reduced vegetation in the upland area has reduced any potential for root structure to assist in binding soil near the bluff-upland interface. Smaller herbaceous bushes have also moved with the failure. Some have continued to grow upright, while others are currently growing at an angle. This is likely due to the shallower root structure of these plantings.

Impact of Weather Conditions on Instability

Maine experienced a summer of drought in 2016. This drought likely resulted in the drying of the clay bluff,

Figure 3. Saturated, clay soils with shallow slope failures.

during which time large soil shrinkage occurred. The fall of 2016 produced substantial wet weather events before transitioning into the soil frost and freeze conditions of winter. Several large winter 2016 snow events produced snow, which was stored on top of the frozen ground and added to the water storage. Spring 2017 brought three events of rain on snow during a period of elevated air temperatures, resulting in rapid runoff.

Conclusions

It is likely that the drought and weather conditions described previously, combined with active surface runoff, created rapid swell in the clay soil. This combination with little root structure to take up water during the saturation period provided excellent conditions for the bluff to fail as a landslide. It appears that this process has been occurring episodically and likely an evolution of failures has occurred in this cove. Evidence of former slumps can be seen in adjacent slopes where shallow failures are currently occurring.

Potential Solutions and Treatments

- Consider a living shoreline approach, using plantings for stabilization.
- Stabilize the toe and encourage a mud flat with a fringing salt marsh to establish itself.
- Plant additional woody and herbaceous planting throughout the terraces of the failure.
- Establish both woody and herbaceous vegetation in the upland areas of the bluff.
- Consider heavy planting in the concentrated flow path areas with plants that will provide large water absorption in the vadose zone.

To further the success of the plantings, understanding the soil pH will help determine what native plants would be most successful. Clay typically lacks important nutrients such as nitrogen, phosphorous and potassium and can be hard for roots to penetrate. Look at adjacent property that has a successful wood lot to assess what species would thrive on this clay-rich upland.

Figure 4. Plant additional woody and herbaceous planting throughout the terraces of the failure.

Acknowledgement

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Cumberland County Soil & Water Conservation District

maine Department of Agriculture Conservation & Forestry

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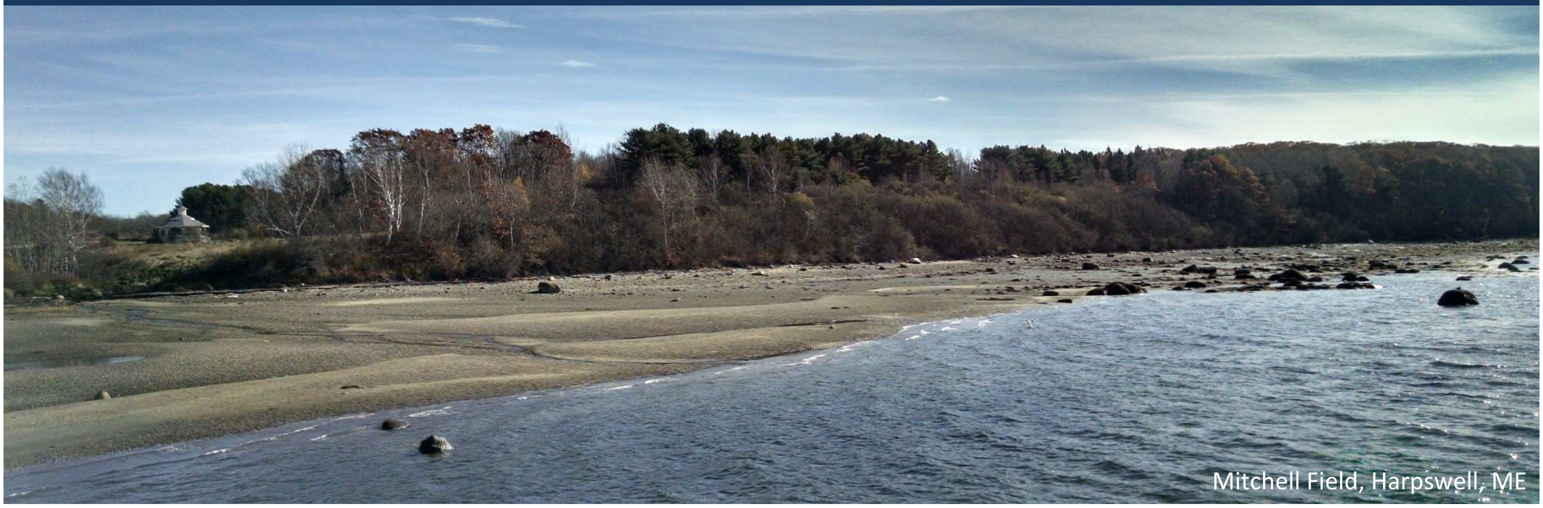
Building Resiliency Along Maine's Bluff Coastline

Case Study: Mitchell Field | Harpswell, ME



Assessment Overview

The site has various shoreline failures ranging in size from upper bank shallow failures to toe erosion due to wave scour. Five of these failures were analyzed, as shown on Figure 1. The largest shallow failure is located at study site 3 and is approximately 50 feet long by 20 feet wide.

Five factors influence slope stability of an embankment: 1) shear strength of the soil; 2) unit weight; 3) embankment height; 4) slope steepness; and 5) pore pressure within the soil. Failure generally occurs in two ways. The first is by physical sliding action of the slope, from a local shallow failure or as a larger toe failure. The second case is by shear failure of the soil itself when excess soil pore pressures exist from saturation. The condition of these factors at this location is described in the following paragraphs.

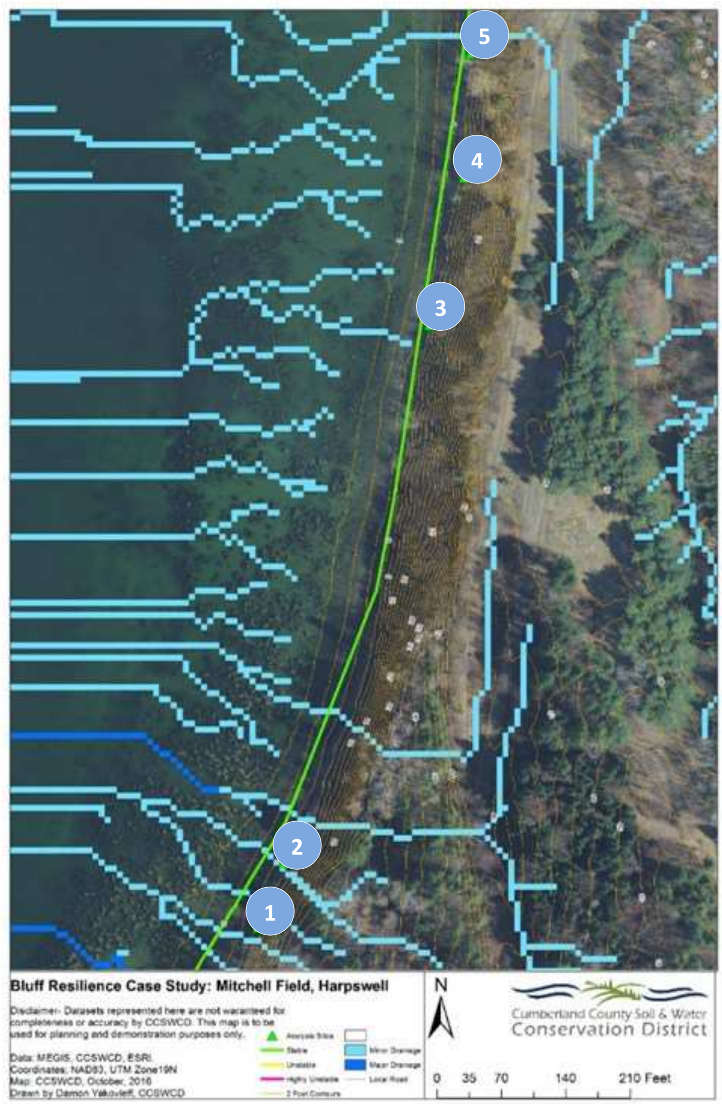


Figure 1. Five Study Sites at Mitchell Field, Harpswell, ME

Site Visit Information

Evaluation date:	November 10, 2016
Evaluators:	Damon Yakovleff (CCSWCD), Troy Barry
Study sites:	5

Site Characteristics

Upland top length:	1,485 feet
Toe length at low tide:	1,060 feet
Vertical height from high tide:	49 feet (15 meters)
Conditions observed:	Multiple top of bank shallow failures and multiple toe erosion sites.

Assessment of Soils and Erosion

Soils in and around Mitchell Field exposed by the shallow failure appear to be predominantly sandy and gravelly, consistent with the unconsolidated sand/gravel particles common in glacial till. The toe of the bluff is comprised of clay mixed with gravel and sand. The shore beyond the toe of the bluff consists mainly of sand and gravel helping form the beach found here.

All five study sites have erosion occurring at the toe of the slope, ranging from 12-50 feet long and 1.5-5 feet high. Several study sites are currently experiencing surface rills and minor gullying in the face of the failure due to unvegetated ground conditions.

Figure 2. Sandy and gravelly soils at Mitchell Field site.

Assessment of Drainage Area

There appears to be a direct connection with the **upland water interaction** associated with the shallow failure. Although the area is not considered a high landslide risk shoreline by the Maine Geological Survey, the addition of water from rainfall or snow infiltrates and replaces air in the soil pore spaces, adding weight. Infiltrated water reaching the study sites from the drainage areas (see ***Table 1***) can change the angle at which the slope is stable, which in this case is a saturated bank with high shear stress (60 degree bank angle). At the time of the site visit, there was no seepage at the toe/lower bank interface, but it is likely seepage would be observed during the wet season.

Table 1: Drainage Areas at the Mitchell Field Location

Drainage Area	Acres	Flow Paths
1	1 acre	5 concentrated flow paths, ending at the top of the bluff (near Study Sites 1 and 2)
2	75 acres of decommissioned military facility	1 perennial stream, discharging at the north end of the shoreline (near Study Site 5)

Assessment of Vegetation

The field upland to this location is regularly mowed, and trees and both woody and herbaceous plants are intentionally removed to maintain a walking and viewing area at the top of the bluff. Several smaller trees and herbaceous growth have slid down the slope, creating exposed soil during movement. Most of the remaining vegetation is currently growing at an angle, likely due to the shallower root structure of this vegetation. Lack of vegetation to stabilize slope is exacerbated by the effect of surface runoff reaching the face at the top of the bluff.

Figure 3. Much of the vegetation at the Mitchell Field site is growing at an angle, likely due to the plants' shallow root structure.

Factors Contributing to Instability

Specific factors contributing to instability at this location, and overall instability ratings for the five Study Sites, are included in ***Table 2***.

It is likely that some of the toe erosion is being accelerated by perched groundwater seepage. Study sites 1, 2, and 3 have toe scarp heights of three (3) feet or more, placing them technically on the lower bank, further compounding the effect and failure rate occurring during the shrink-swell process.

It is likely that the multiple freeze-thaw events and water runoff in the sand/gravel soil combined with low-absorption root structure provided excellent conditions for the bluff to fail as a shallow failure.

Table 2: Instability Rating and Upland Runoff of Each Study Site at the Mitchell Field Location

STUDY SITE	UPPER BANK	LOWER BANK	TOE	STORM FLOW
1 Coordinates: 70° 1' 4.037" W, 43° 46' 25.846" N				
Length: 12'-15' **Area:** 0.38 Acres **C-Value:** 0.30	Terrace	Blue Marine Clay 80° Bare Consolidated	Blue Marine Clay Mixed with Gravel 80° Unconsolidated	**2-yr:** 0.00 cfs **5-yr:** 0.00 cfs **25-yr:** 0.01 cfs **50-yr:** 0.04 cfs
Rating:	Good (1)	Fair/Poor (2.5)	Very Poor (3.5)	**Total Rating: 7**
2 Coordinates: 70° 1' 3.659" W, 43° 46' 26.548" N				
Length: 48' **Area:** 3.27 acres **C-Value:** 0.30	Terrace @ 15-20' Vegetated	Grassed 60° 15-20' Unconsolidated	Blue Marine Clay 70-80° 5' exposed	**2-yr:** 0.01 cfs **5-yr:** 0.05 cfs **25-yr:** 0.62 cfs **50-yr:** 1.31 cfs
Rating:	Good (1)	Fair/Poor (2.5)	Poor (3)	**Total Rating: 6.5**
3 Coordinates: 70° 1' 1.595" W, 43° 46' 32.343" N				
Length: *(Not measured)* **Area:** 0.58 acres **C-Value:** 0.30	Terrace 70°-80° *Ridge Slope: ~40 degrees*	Veg. Grass, trees, brush 70°	Marine Clay 90° 5' exposed Linear Failure	**2-yr:** 0.01 cfs **5-yr:** 0.03 cfs **25-yr:** 0.23 cfs **50-yr:** 0.42 cfs
Rating:	Poor (1)	Good/Fair (1.5)	Poor (3)	**Total Rating: 5.5**
4 Coordinates: 70° 1' 1.110" W, 43° 46' 33.935" N				
Length: 51' **Area:** 0.0 acres **C-Value:** 0.30 *Slump 3'-12' up*	Exposed Failure 80°-90° Top Drainage?	Grassed/Trees Brush 70°-80° Rills, Mass Failure	Clay 80° Rills Mass Failure	**2-yr:** 0.00 cfs **5-yr:** 0.01 cfs **25-yr:** 0.04 cfs **50-yr:** 0.07 cfs
Rating:	Good/Fair (1.5)	Poor (3)	Very Poor (3.5)	**Total Rating: 9**
5 Coordinates: 70° 1' 1.031" W, 43° 46' 35.274" N				
Length: *(Not measured)* **Area:** 0.4 acres **C-Value:** 0.30 *Linear*	*Ridge Slope: ~20 degrees*	Grassed-Trees 80°-70°	90° 3' exposed	**2-yr:** 0.00 cfs **5-yr:** 0.02 cfs **25-yr:** 0.17 cfs **50-yr:** 0.30 cfs
Rating:	Good (1)	Fair/Poor (2.5)	Poor (3)	**Total Rating: 7.5**

Conclusions

The sand/gravel soil at this site contributes to the instability of steep slopes. Most in-place soils are stable at a 1:1 slope ratio (horizontal:vertical), but when soil is subjected to additional weight, such as the surface water reaching the top of the bluff, that saturated soil can no longer support the load.

Soils and slopes like those in this location require healthy and deep-rooted vegetation to provide soil strength, in turn reducing erosion risk. Removal of vegetation in the upland area (and associated reduced transpiration) has reduced any potential for root structure to assist in binding soil near the bluff-upland interface. Areas that have already lost vegetation are rapidly eroded by runoff in the form of rills, and areas still vegetated can also see rapid erosive changes. Mowing and intentional removal of vegetation contributes to this erosion.

Potential Solutions and Treatments

- Consider a living shoreline approach along the toe, using plantings for stabilization.
- Stabilize the toe with wood to encourage the beach to remain in place.
- Plant additional woody and herbaceous vegetation throughout the face of the shallow failure.
- Establish both woody and herbaceous vegetation in the upland area beyond the top of the bluff.
- Consider heavy planting in the concentrated flow path areas. Use plants that will provide large water absorption in the vadose zone.
- Determine the soil pH to identify native plants that would be most successful.

Table 3: Potential Treatment Concepts for the Mitchell Field Location

Site	Treatment Concept
1	Stabilize toe and lower bank. Mitigate surf runup.
2	Stabilize toe and lower bank. Mitigate surf runup.
3	Stabilize upper slope with vegetation. Investigate hydrology runoff pattern in upland.
4	Stabilize toe and lower bank. Mitigate surf runup.
5	Stabilize toe and lower bank. Establish vegetation in lower bank.


Mitchell Field, Harpswell, ME

Acknowledgement

This Case Study was developed for the Maine Coastal Program/Maine Department of Agriculture, Conservation and Forestry by the Cumberland County Soil and Water Conservation District. This work was supported by the National Oceanic and Atmospheric Administration (NOAA) Coastal Zone Management Cooperative Agreement #NA14NOS4190047 pursuant to the Coastal Zone Management Act of 1972 as amended.

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For more information about the Maine Coastal Program, visit www.mainecoastalprogram.org or contact 207-287-2351.

Cumberland County Soil & Water Conservation District

maine Department of Agriculture Conservation & Forestry

Maine Coastal Program