Building Resiliency Along Maine's Bluff Coastline

Case Study: 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

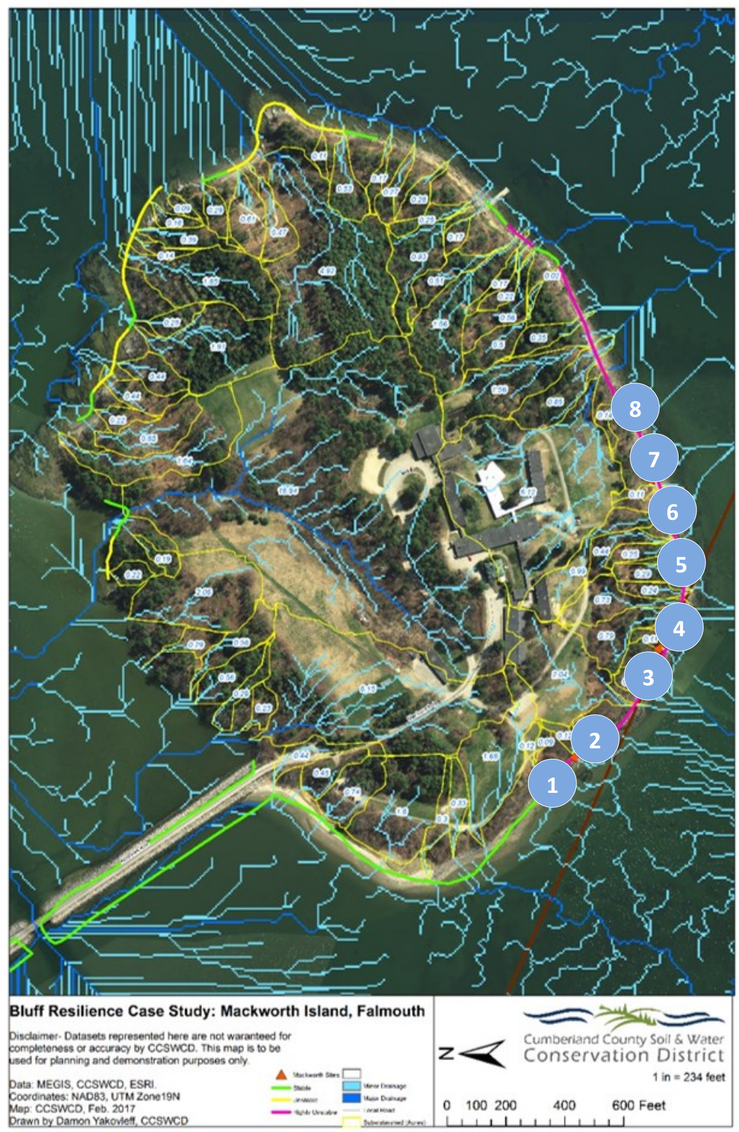

Figure 1. Eight Study Sites at Mackworth Island, Falmouth, ME

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

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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Cumberland County Soil & Water Conservation District

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Building Resiliency Along Maine's Bluff Coastline

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.

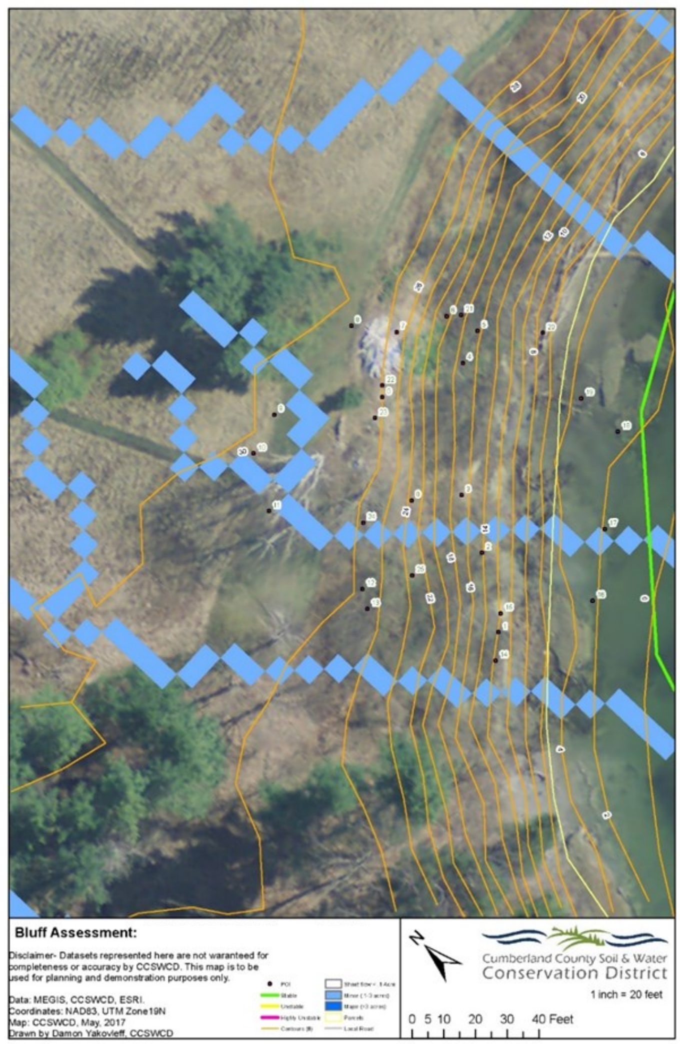

Figure 1. Mere Point Case Study Location, Brunswick, ME

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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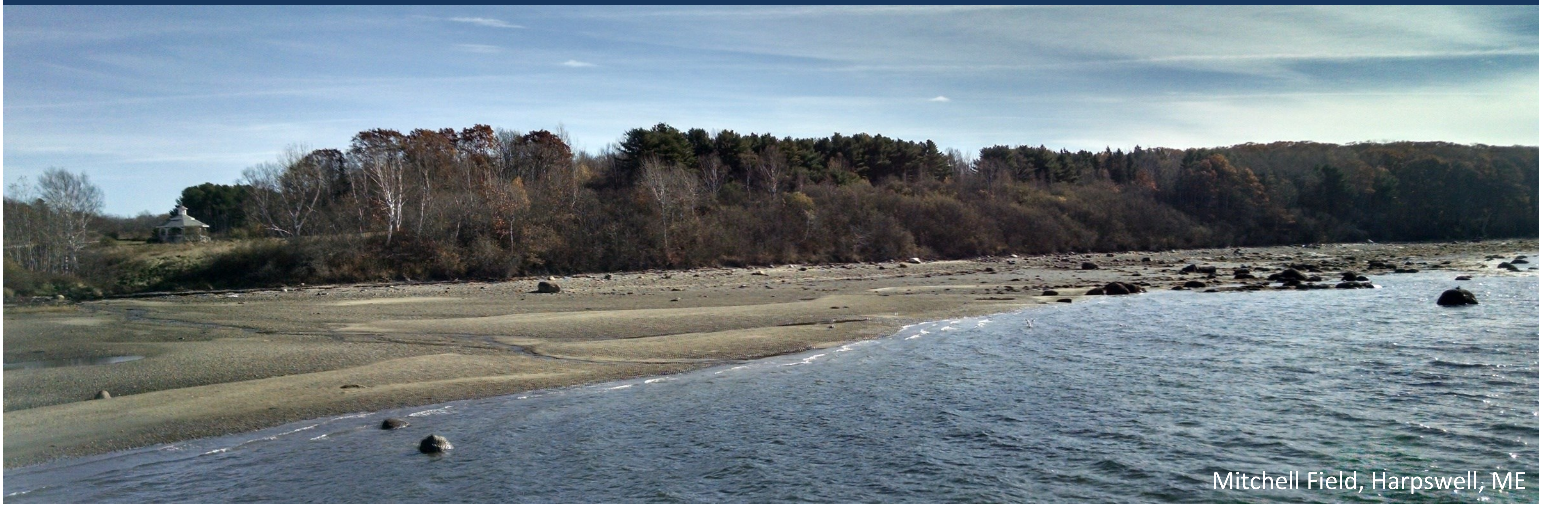
BUILDING RESILIENCY ALONG MAINE'S BLUFF COASTLINE

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.

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.

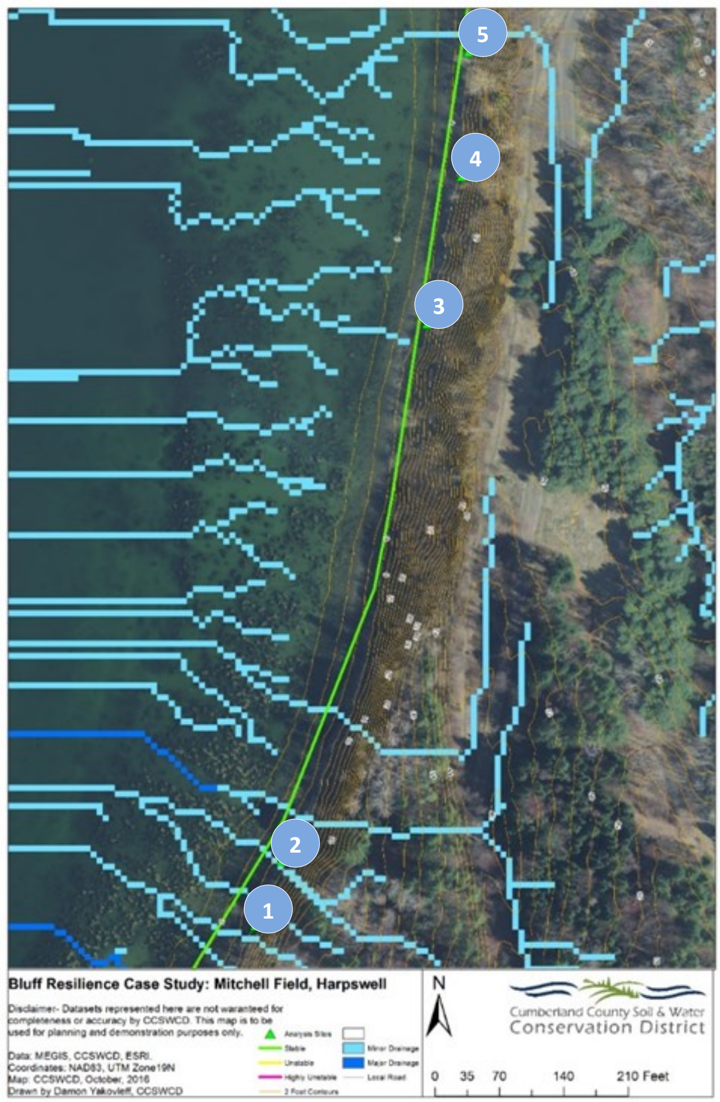


Figure 1. Five Study Sites at Mitchell Field, Harpswell, ME

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

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