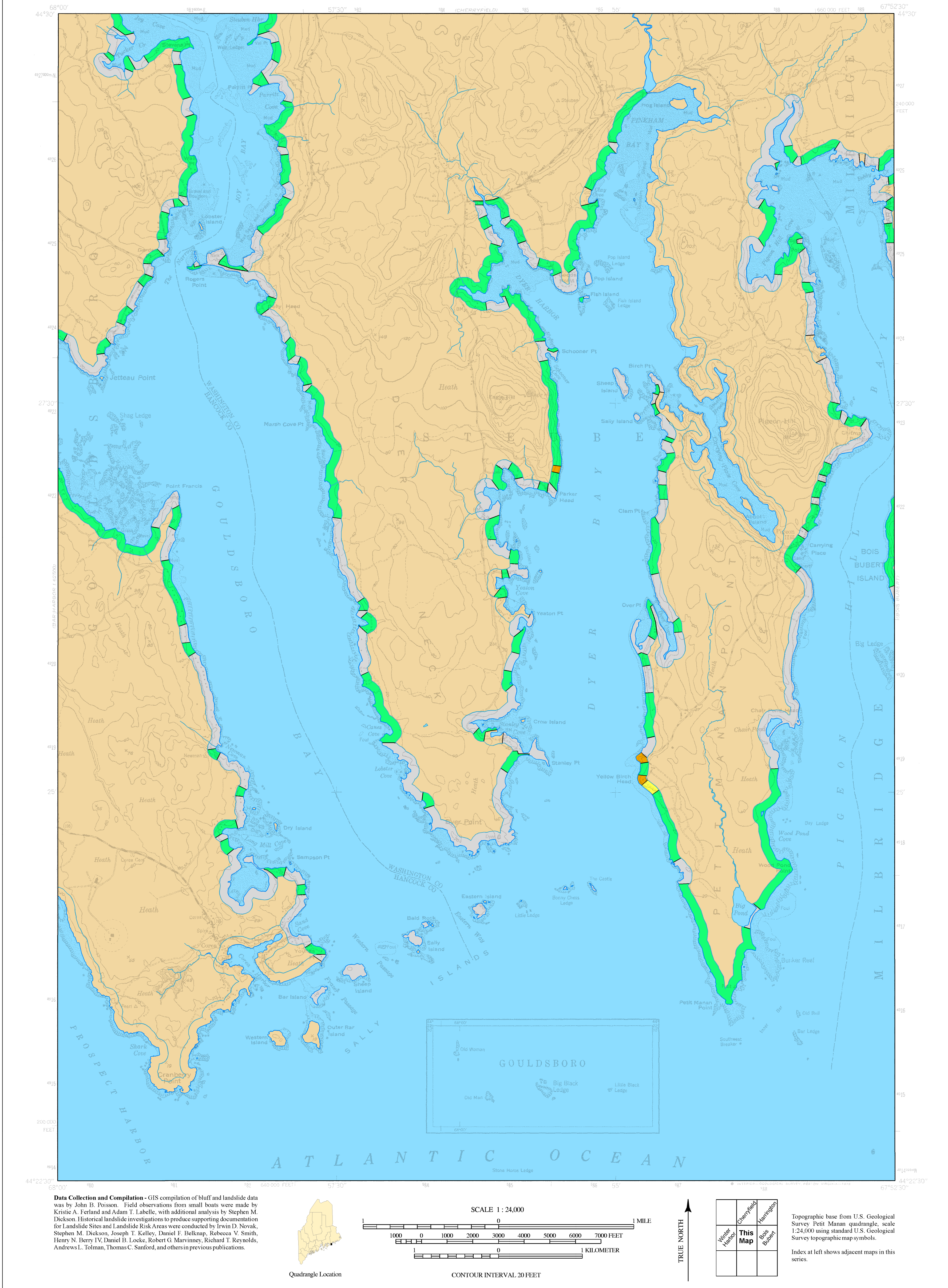


# Coastal Landslide Hazards



**Coastal Bluffs:** On this map, a bluff is defined as a steep shoreline slope formed in sediment (loose material such as clay, silt, sand, and gravel) that has three feet or more of vertical elevation just above the high-tide line. Cliffs or slopes in bedrock (ledge) surfaces are not sedimentary bluffs and are not subject to significant erosion in a century or more, although some may experience rockfalls. Beaches and dunes do not form bluffs, except along the seaward dune edge as a result of erosion. This map does NOT identify erosion trends on beaches or sand dunes.

**Note:** The landslide hazard classification is indicated by a colored, patterned band extending landward from the shoreline (dark blue line). The width of the band does NOT indicate the distance inland that a landslide may occur. This distance is difficult to predict and will vary from site to site. The colored buffer is for illustration purposes only. Due to variations in coastal geology, not all units in the explanation below will appear on this map.

**Landslide Site:** Location of known or interpreted coastal landslide. Includes historically recorded landslides and slides interpreted from air photos.

**Landslide Risk Area:** Earth features indicate conditions that may be suitable for a landslide to occur. Features often include a steep or arcuate scarp, slump blocks, sediment lobes, or uneven land surfaces. Bluff sediments are usually muddy and twenty feet or more in thickness.

**Potential Landslide Area:** Shoreline with a sedimentary coastal bluff twenty or more feet high. These bluff areas have not had field investigations that are necessary to evaluate the risk of a landslide. However, some similar high coastal bluffs have experienced landslides.

**Low Coastal Bluff:** Shoreline with a sedimentary coastal bluff that has less than twenty feet of relief immediately adjacent to the shoreline. Some bluffs over twenty feet in height are included in this map unit if the bluff face is not steep. In general, low coastal bluffs are not at risk of failing in the form of a landslide.

**Non-Bluff Shoreline:** Coastal areas without extensive sedimentary bluffs. Corresponds to the no-bluff unit on MGS Coastal Bluff Maps.

**Unmapped Shoreline:** These sites generally are in the inland reaches of estuaries or beyond the scope of the field effort in this region.

**Who to Contact for More Information**

It is important to realize that the coast of Maine is constantly being eroded. Coastal bluffs that show no evidence of erosion today may be endangered in the future as rising sea level continues to erode sediments at the base of a bluff. If you are concerned about ground movement on a coastal bluff, contact the Maine Geological Survey for more information helpful in evaluating the characteristics of coastal property. In addition to this landslide hazard map, a companion map series entitled "Coastal Bluffs" describes the stability and characteristics of Maine's shoreline. Maps showing topography, sediment composition, ground-water characteristics, and bedrock are also available in many areas. Survey geologists will explain the content of each of these maps.

If you find indications of ground movement on your coastal bluff, you may want a professional geologist or engineer to investigate your property. To reduce the risk of a landslide, these professionals may recommend re-sloping the bluff face, diverting water flow, armor the toe of the bluff, or planting erosion-resistant vegetation.

Building or engineering on Maine's coastal bluffs are subject to the Natural Resources Protection Act and the Mandatory Shoreland Zoning Act. Permits from the Department of Environmental Protection may be required for any bluff modifications. Local Town Code Enforcement Officers will give advice on local requirements.

**Maine Geological Survey**  
*Information available:* maps showing landslide hazards, coastal bluffs, surficial geology, surficial materials, ground-water bedrock, USGS topographic maps, geologists explain maps and coastal processes  
*Contact:* Maine Geological Survey at address shown in title block, or visit the MGS website and search your location.

**Geological Consultants**  
*Information available:* studies of specific property: ground-water studies, soil mechanics, coring of bluff, mapping of site, risk analysis, recommendations about hazard reduction and slope remediation  
*Contact:* consult local yellow pages under geologists or environmental services

**Engineers**  
*Information available:* plans to reduce hazard, ground-water diversion, shoreline engineering, slope alteration, soil mechanics, risk analysis  
*Contact:* consult local yellow pages under engineers - environmental or environmental services

**Maine Department of Environmental Protection**  
*Information available:* information on state laws including the Natural Resources Protection Act, Shoreland Zoning, and the permit process  
*Contact:* on the internet: <http://www.maine.gov/dep/bwlv/> phone: 888-769-1137 or 207-941-4370

**Town Code Enforcement Officers**  
*Information available:* provide advice on Shoreland Zoning and other municipal requirements  
*Contact:* local town office or <http://www.maine.gov/portal/living/cities/index.html>

- Related Maps**
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- Prescott, G. C., Jr., 2001, Surficial materials of the Petit Manan quadrangle, Maine: Maine Geological Survey, Open-File Map 01-537.
- Other Sources of Information**
- American Planning Association, Landslide hazards and planning: <http://www.planning.org/landslides/docs/main.html>
- Amos, J. T., and Sandford, T. C., 1987, Landslides in the Presumpscot Formation: An engineering study: Maine Geological Survey, Open-File Report 87-4, 68 p.
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- Novak, I. D., 1990, Air photo reconnaissance of slope failures in the Presumpscot Formation, Cumberland County, Maine: Maine Geological Survey, Open-File Report 90-22, 4 p., map (1:50,000).
- U.S. Geological Survey, Geologic hazards: Landslides: <http://landslides.usgs.gov/index.html>

**Limitations of the Data:** This map provides only general information on the overall stability of bluffs. It should not be the sole basis upon which specific land-use decisions are made. Some map information is based on visual inspection of the coast from offshore, and parts of the shoreline may have changed slightly since the field work was completed. Historical and potential landslide areas are partially based on air photos taken in the last four decades. Since the air photos were taken, land changes may have altered the map classification. Because of the map scale, shoreline characteristics are generalized into segments at least 150 feet long. It is important to realize that the

## Petit Manan Quadrangle, Maine

Coastal landslide hazard mapping by

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### Maine Geological Survey

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### Introduction

Landslides are the rapid movement of earth materials downslope under the force of gravity. Many landslides have occurred along the Maine coast in the last few centuries, and more landslides will happen in the future. Based on history and field evidence, a variety of scenarios and possible events, from large to small and fast to slow, can threaten property and, in a few cases, put human life at risk. It is not possible to predict exactly when and how large the next coastal landslide will be. Landslides have occurred frequently enough that geologic analysis and informed land use can lead to risk reduction and improved emergency response.

This map provides an introduction to understanding landslide risk and guidance on what steps to take if the risk of a landslide is a concern in a particular coastal area. Landslides can occur in high coastal bluffs composed of muddy sediment. This landslide hazards map describes the internal stability of sediment bluffs. A companion map, entitled Coastal Bluffs, describes the processes and stability of the face of a bluff. The coastal bluff maps provide additional information about the slope, shape, and amount of vegetation covering a coastal bluff and the adjacent shoreline. These factors are directly related to the susceptibility of the bluff face to ongoing erosion.

### The Life Cycle of a Coastal Maine Landslide

Sea level is gradually rising along the coast of Maine (Kelley and others, 1996). This rise in the ocean allows waves to erode beaches and flats at the base of coastal bluffs (see Figure 2A). Over time, erosion removes material from the base of a coastal bluff and steepens the face of the bluff (Figure 2B). Sediments at the base of the bluff stabilize it, and when they are removed, the bluff is no longer in equilibrium. Only the strength of the material within the bluff holds the bluff in place. Continued erosion or lubrication of the bluff materials by ground water may overcome this internal resistance, particularly in clay bluffs, and result in a landslide (Figure 2C). A landslide restores the equilibrium of the bluff, and the slumped materials at the foot of the bluff support a new bluff face with a gentler profile (Figure 2D). Erosion, however, is a continuing process because the level of the sea is rising, and coastal waves and currents immediately begin to remove the edges of the displaced sediment. Eventually, erosion destroys the equilibrium of the bluff and leads to another landslide, repeating the cycle shown at right.



Figure 1. A clay bluff on the north shore of Rockland Harbor failed in 1996. This landslide formed a new scarp about 200 feet landward of the original top of the bluff in just a few hours. Two homes were destroyed as a result of this catastrophic slide (see Berry and others, 1996).

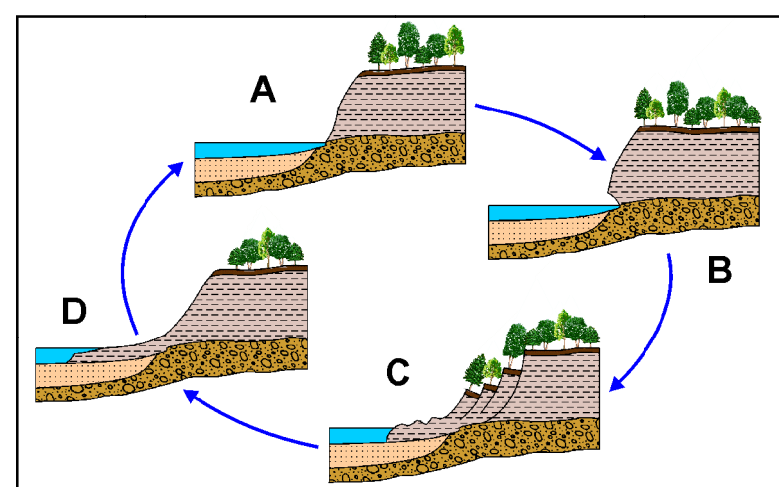


Figure 2. Life cycle of a landslide on a bluff composed of sediment (modified from Kelley and others, 1989).

### Evidence of Ground Motion and Instability on a Coastal Bluff

Careful observation of the land surface, vegetation, and shape of a coastal bluff reveals evidence of instability. Starting at the top of a bluff, an irregular or arcuate edge can indicate past landslides or areas of increased coastal erosion (Figure 3). When a weak point on a bluff fails, the slide moves inward into the slope face forming a curve around the original point of failure. Tension cracks may form near a weak zone where the soil surface is moving downslope (Figure 4). These cracks appear as splits in the ground where the soil and vegetation have moved apart. Cracks may be visible along the top edge of the bluff or on the bluff face itself. On the slope of a bluff, a hummocky land surface or terraces indicate past slumping or landslides (Figure 5). Unvegetated slump scars or slopes are obvious evidence of rapid soil movement. A bowl-shaped slope often shows the location of a former landslide, with the center of the bowl as the area of greatest failure. Distorted vegetation provides evidence of soil creep or former landslides. Tree trunks curved near their base are evidence of downslope movement (Figure 6). Trees tilted at different angles are evidence of former slides or undercutting by erosion. At the base of a bluff, toppled trees and bare roots are evidence of erosion that steepens the bluff (Figure 7). Undercutting and steepening of the bluff may destabilize the slope and lead to increased erosion and possibly a landslide. Lobes or terraces of sediment in the intertidal zone are often remnants of old landslides. Although the evidence of earth movement listed above cannot predict a landslide, it is used to recognize unstable shorelines. This landslide evidence is related to factors listed below that influence landslide risk.



Figure 3. The shape of the top edge of a bluff can be an indicator of landslide risk. Clay bluffs often fail at points of weakness. Such a "slump" can expand into a larger landslide that cuts into the bluff and forms a curve around the original point of failure. Multiple slides and slumps will form an irregular or arcuate top edge to the bluff as shown in the photo above. Bluffs made of coarse materials or sand have a more even upper edge caused by a more constant rate of erosion along the bluff face.



Figure 4. Downslope forces within a bluff cause surface layers to stretch. When the tension becomes great enough, a crack forms and the pressure is released. These "tension cracks" may form on the top edge of the bluff or on the bluff slope itself. They indicate instability and motion within the bluff. Some cracks are deep and extend below the soil layer.



Figure 5. Wave erosion at the base of a bluff removes slope sediment and steepens the bluff. Erosion has undercut the trees in the photo above and caused them to tilt toward the ocean. This steepening reduces the stability of the bluff, and a landslide may result. Ongoing sea-level rise along the Maine coast will cause wave erosion at the base of coastal bluffs and continue to make some coastal bluffs at risk of experiencing a landslide.



Figure 6. Wave erosion at the base of a bluff removes slope sediment and steepens the bluff. Erosion has undercut the trees in the photo above and caused them to tilt toward the ocean. This steepening reduces the stability of the bluff, and a landslide may result. Ongoing sea-level rise along the Maine coast will cause wave erosion at the base of coastal bluffs and continue to make some coastal bluffs at risk of experiencing a landslide.

### Factors Influencing Landslide Risk

#### BLUFF CHARACTERISTICS

**Height.** The height of a bluff can generally indicate landslide risk. While sediment strength depends on several factors, the thicker the sediment deposit, the more likely its weight will cause subsurface movement or slippage that leads to a landslide. The risk of a landslide increases when mud bluffs have a height of twenty feet or more. In general, the higher the exposed bluff face the greater the risk of a landslide.

**Sediment type.** Earth material that makes up a coastal bluff influences the risk of a landslide occurring. Clay and silty muddy sediment is the most unstable material that can make up a bluff. These fine-grained sediments are weak and prone to moving in the form of slow-motion creep, moderate-sized slumping, or large landslides. Sand and gravel deposits tend to be stronger and better drained than muddy sediment. Landslides can occur in coarse-grained bluffs although they are less frequent than muddy landslides along the Maine coast.

**Slope.** Coastal bluffs have a relatively steep ocean-facing slope. The angle of a bluff face varies due to factors such as the sediment type and rate of erosion at the base of the bluff. Slope is also affected by the history of slumps and landslides at the site. Some slopes are uniformly straight while others are terraced or uneven due to earth movements. In general, the steeper the slope, the easier it is for gravity to initiate a landslide.

**Vegetation.** Types, shapes, and distribution of vegetation above and on a bluff face can be used as an indication of site stability. In areas where the soil has shifted, either due to previous landslides or to gradual surface creep, many tree trunks can become tilted or twisted in the same direction. Curved tree trunks near the roots often indicate land movement down the face of a bluff. Large trees on the bluff face may be moved by wind and resulting root motion may loosen bluff sediment. Natural vegetation along the bluff face can be used as an indication of site stability. In areas where the soil has shifted, either due to previous landslides or to gradual surface creep, many tree trunks can become tilted or twisted in the same direction. Curved tree trunks near the roots often indicate land movement down the face of a bluff. Large trees on the bluff face may be moved by wind and resulting root motion may loosen bluff sediment. 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