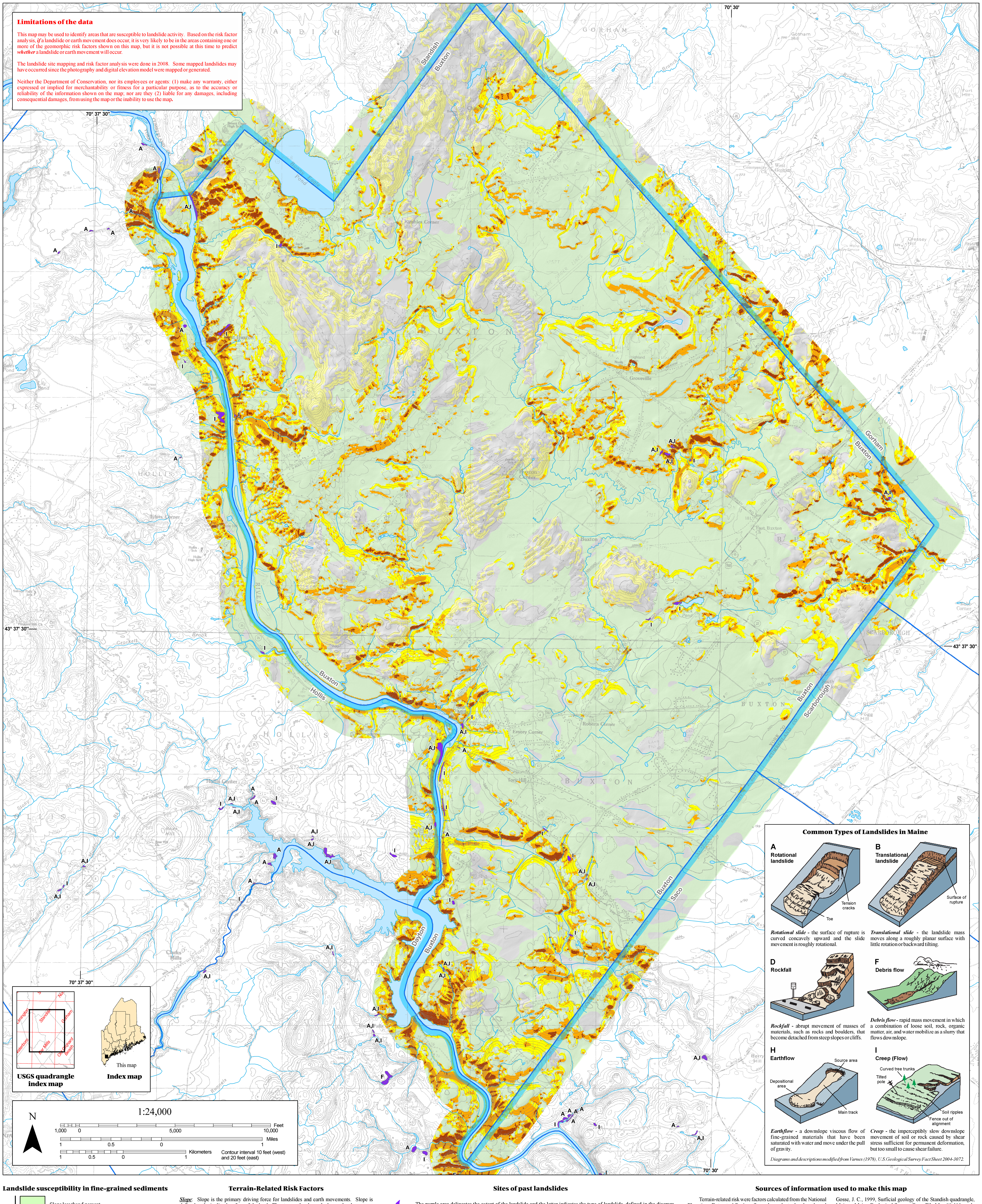
Landslide Sites and Areas of Landslide Susceptibility



Common Types of Landslides in Maine

Rotational slide - the surface of rupture is curved concavely upward and the slide movement is roughly rotational.

Translational slide - the landslide mass moves along a roughly planar surface with little rotation or backward tilting.

Rockfall - abrupt movement of masses of materials, such as rocks and boulders, that become detached from steep slopes or cliffs.

Debris flow - rapid mass movement in which a combination of loose soil, rock, organic matter, air, and water mobilize as a slurry that flows downslope.

Earthflow - a downslope viscous flow of fine-grained materials that have been saturated with water and move under the pull of gravity.

Creep - the imperceptibly slow downslope movement of soil or rock caused by shear stress sufficient for permanent deformation, but too small to cause shear failure.

Diagrams and descriptions modified from Varnes (1978), U.S.Geological Survey Fact Sheet 2004-3072.

Landslide susceptibility in fine-grained sediments

Increasing susceptibility

- Slope less than 5 percent.
- Slope equal to or greater than 5 percent.
- Slope equal to or greater than 5 percent and one of the following terrain-related risk factors: slope aspect, curvature, or local relief.
- Slope equal to or greater than 5 percent and two or three of the following terrain-related risk factors: slope aspect, curvature, or local relief.

Landslide susceptibility in other sediments

Increasing susceptibility

- Slope less than 5 percent.
- Slope equal to or greater than 5 percent.

Terrain-Related Risk Factors

Slope: Slope is the primary driving force for landslides and earth movements. Slope is defined as the inclined surface of the land. The steeper the slope, the larger the shear stress produced by the weight of the materials and the more susceptible the slope is to failure. For this map, a slope of 5% or greater is considered a risk factor.

Slope aspect: Slope aspect is the direction toward which the surface of the soil faces. South-facing slopes undergo more extensive freeze/thaw cycles in winter months than slopes with other aspects. Repeated freeze-thaw cycles preferentially reduce the shear strength of the shallow soil material and increase the likelihood of shallow soil slumps. Ultimately, small movements may steepen the slope and lead to larger slope failures. For this map, a slope aspect facing between South 45° East and South 45° W is considered an additional risk factor.

Curvature (concave shape): Hill shape influences landslides by its effects on soil and water distribution. Concave surface topography will tend to concentrate the flow of surface water and ground water, raising ground-water pore pressures and reducing the shear strength of the soil. As a result, concave slopes are more susceptible to failure than straight slopes or convex slopes. For this map, a concave shape is considered an additional risk factor.

Local relief (slope height): As the thickness of the potential landslide block increases, the shear stress on the lower section of the block increases and the block (or slope) is more susceptible to failure. As a consequence, thicker sections of surficial materials will be more susceptible to failure and possibly deeper and larger failures. For this map, local relief greater than 6 meters (approximately 20 feet) is considered an additional risk factor.

Sites of past landslides

A,I

The purple area delineates the extent of the landslide and the letter indicates the type of landslide, defined in the diagram entitled *Common Types of Landslides in Maine*. Two or more letters indicate multiple processes were involved at the site or contributed to landslide morphology. Past landslides were mapped from aerial photo interpretation and field investigations in 2008.

Mapped landslides in the town of Buxton

This map can be used to identify areas with historical landslide activity and to identify areas that are susceptible to future landslide activity where additional studies should be undertaken before construction or other development is started that could be at risk due to a future landslide.

Ninety-six percent of mapped landslide sites in the town of Buxton (24 of 25 features) are located in areas shown as having a slope of 5 percent or more, and 84 percent of the mapped landslide sites are located in areas containing at least one additional geomorphic risk factor.

From this, we conclude that there is a significantly greater risk of a landslide occurring in areas containing one or more of the geomorphic risk factors than in areas that do not contain any of these risk factors.

However, no information is presently available to assess the probability of a landslide occurring within these areas. That is, if a landslide or earth movement does occur, it is very likely to be in the areas containing one or more of the geomorphic risk factors, but it is not possible at this time to predict whether a landslide or earth movement will occur.

Forty percent of the mapped landslide sites in York County are located in the glacial marine Presumpscot Formation which is known for thick sections dominated by marine clay. Eighty-one percent of the mapped landslides show at least some involvement with glacial marine deposits of all types, although other surficial materials (such as till or alluvium) may be present. Less than 14 percent of the mapped landslides involve Holocene alluvial deposits.

Sources of information used to make this map

Terrain-related risk were factors calculated from the National Elevation Dataset 1/3 Arc Second product developed and published by the U.S. Geological Survey. The horizontal resolution of the 1/3 Arc Second dataset is approximately 10 meters. Horizontal accuracy meets the National Map Accuracy Standard for a 1:24,000 scale dataset of ± 40 feet or 12 meters. Absolute vertical accuracy of the elevation data is ±7 meters or approximately ± 21 feet. The shaded relief layer was generated from this dataset, with a sun angle of 45 degrees above the horizon, azimuth of 315 degrees (northwest), and vertical exaggeration of 4.

The distribution of surficial geologic materials was compiled from the Maine Geological Survey surficial geologic maps listed at right. The following geologic units were considered to be "fine-grained sediments" for the purpose of this map: Pp, Pm, Pmd, Pmdo, Pmf, Pmn, Pmrs, Pms, and Ha.

Gosse, J. C., 1999, Surficial geology of the Standish quadrangle, Maine: Maine Geological Survey, Open-File Map 99-101, scale 1:24,000.

Hunter, L. E., 1999, Surficial geology of the Bar Mills quadrangle, Maine: Maine Geological Survey, Open-File Map 99-77, scale 1:24,000.

Retelle, M. J., 1999, Surficial geology of the Old Orchard Beach quadrangle, Maine: Maine Geological Survey, Open-File Map 99-94, scale 1:24,000.

Smith, G. W., 1999, Surficial geology of the Gorham quadrangle, Maine: Maine Geological Survey, Open-File Map 99-84, scale 1:24,000.

Town of Buxton, Maine

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Introduction

Landslides are a common geologic hazard in Maine. Although they usually occur on a small scale and cause minimal damage, recent increased damage from landslide activity in the state (**Photo 1**) has raised awareness of this hazard and has demonstrated the need to examine the landslide threat on a regional basis. Landslide is a general term used to describe both the downslope movement of soil, rock, and organic material under the effects of gravity, and also the landform that results from such movement.

This map shows (1) sites of past landslides, and (2) areas susceptible to future landslide activity. This information is intended to describe the landslide risk, and to encourage mitigation strategies by individuals or local governments.

Sites of past landslides

Sites of past landslides, slope failures, and earth movements including slumps, debris slides, soil flows, and erosional debris flows are shown on the map in deep purple. They were identified based on aerial photo interpretation and field investigations in 2008, which documented evidence of past ground motion.

Evidence of ground motion and instability. Careful observation of the land surface and vegetation can reveal evidence of ground motion and slope instability. An irregular or arcuate edge along slopes adjacent to rivers, streams, and lakes can indicate past landslides or areas of increased erosion. When a weak point on a slope 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 (**Photo 2**). These cracks appear as splits in the ground where soil, a road surface, or vegetation have moved apart. Cracks may be visible along the top edge of the slope. On slopes of high relief, a hummocky land surface or terraces indicate past slumping or landslides. Unvegetated slump scars or slopes are obvious evidence of recent 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 failure and greatest land displacement. Distorted vegetation provides evidence of soil creep or former episodic landslides. Tree trunks curved near their base are evidence of downslope movement (**Photo 3**). Trees tilted at different angles are evidence of former slides. Trees tilted upslope indicate past downward slope movement and are good indicators of future slope failure (**Photo 4**). At the base of bluffs along streams, rivers, ponds, and lakes, toppled trees and bare roots are evidence of past landslides (**Photo 5**). Undercutting and steepening of the slope in areas of high relief may destabilize the slope and lead to increased erosion and possible landslides. Terraces of sediments at the base of such high relief areas are often remnants of old landslides (**Photo 6**).

Landslide types. Each landslide site shown on the map is accompanied by a letter symbol which indicates the landslide type. The landslide classification scheme is based on the primary mechanism by which the earth movement occurred (see diagram entitled *Common Types of Landslides in Maine*). Each of these landslide types produces characteristic evidence of ground motion that allows the landslide type to be assigned. In some cases, more than one mechanism may have been important, or successive landslides in one place may have occurred by different mechanisms. In either case, multiple letter symbols are shown on the map.

Areas susceptible to future landslides

Local clues to future slope failure. Although the evidence of ground movement listed above cannot predict a landslide, it can be used to recognize unstable areas that are susceptible to landslides and slope failure. Areas that have experienced past landslides are good candidates for future landslides. Generalizing from known occurrences and an understanding of landslide mechanisms, the pattern of documented landslides can be related to geologic risk factors, and to terrain-related risk factors. These risk factors have been used to construct the landslide susceptibility map presented here.

Geologic risk factors. The primary geologic factor influencing landslide susceptibility is sediment grain size. Correlation with geologic mapping shows that a majority of earth movements occur in fine-grained sediments such as clay, silt, and mud, which are prone to move by slumping (landslide type A), sliding (type B), or creep (type I) when saturated with water. The material properties of these sediments, especially their low shear strength, makes them more susceptible to landslides than other sediment types. Existing maps of the surficial geology (see ***Sources*** below) were used to divide the town crudely into areas with fine-grained sediment and areas with other sediment (or rock) mapped at the land surface. Areas of fine-grained sediment include glacial-marine deposits and alluvial deposits. Most of these areas are underlain by the Presumpscot Formation, a marine silt and clay deposit of variable thickness in which Maine's most notable landslides have occurred. Areas assigned to the "other sediment" category include glacial till, stratified drift, and bedrock outcrop.

Terrain-related risk factors. The most important terrain-related risk factor influencing slope stability is the steepness of the slope. Additional geomorphic or terrain-related risk factors that increase landslide susceptibility include slope aspect, slope curvature, and local relief. For more details, see the table entitled "Terrain-related risk factors."

Landslide susceptibility mapping. This map takes into account the geologic risk factors by using one set of colors for fine-grained sediments, and a second set of colors for other sediments. For each sediment type, colors indicate relative landslide risk due to the presence of one or more terrain-related risk factors.

For areas underlain by fine-grained sediments, areas with slope less than 5 percent (a 5-foot rise in 100 feet) are shown in green; areas with a steep slope (equal to or greater than 5 percent) are shown in bright yellow. Within the areas of steep slope, areas containing one additional terrain-related landslide risk factor are shown in orange, and areas with two or more additional terrain-related risk factors are shown in red. The brighter colors indicate relatively higher landslide risk, although this risk has not been quantified. The most important distinction is between areas of low slope (in green), and areas of steep slope (bright colors).

For areas underlain by other sediments, areas with low slope ($< 5\%$) are shown in gray; areas with steep slope ($\geq 5\%$) are shown in pale yellow. Additional risk factors are not shown for these areas, because their importance in these other sediments has not been assessed.

Mitigation strategies

This map can be used to identify areas with historical landslide activity and to identify areas that are susceptible to future landslide activity. In these areas, additional steps should be undertaken before construction or other development is started that could be at risk due to a future landslide. Most insurance policies do not cover damage from landslides.

It is important to realize that the land surface of Maine is continually being eroded. Areas susceptible to landslides should be monitored frequently for evidence of ground motion and instability (see above). If you are concerned about ground movement in your area, you may want to investigate other related geologic information. Maps available from the Maine Geological Survey show topography, sediment composition, ground-water characteristics, and bedrock geology. Some specific map titles are listed under ***Sources***. MGS geologists are available to explain these maps.

If you find indications of ground movement, you may want a professional geologist or engineer to investigate your property. If high landslide risk is confirmed, it may be prudent to avoid building new roads or structures. For existing structures or planned new construction, site utilization should take the hazard into account. To reduce the risk of a landslide, these professionals may recommend changing the slope of the land surface, diverting water flow, armoring the toe of an eroding slope, planting erosion-resistant vegetation, or taking other measures to control surface erosion. In some cases, relocation of roads or structures may be recommended. Different landslide types may requre different mitigation strategies.

Any such measures must be done in an environmentally acceptable way. Building or engineering on Maine's slopes and bluffs, especially along waterways or in coastal areas, may be subject to regulation under the Natural Resources Protection Act and the Mandatory Shoreland Zoning Act. Permits from the Maine Department of Environmental Protection may be required for site modifications. Local Town Code Enforcement Officers will give advice on local requirements.

Contacts for more information

Maine Geological Survey
Information available: maps of landslide hazards, coastal bluffs, surficial geology, surficial materials, ground-water, bedrock, USGS topographic maps
Contact: Maine Geological Survey at address shown in title block

Geological Consultants
Information available: studies of specific property: slope stability, ground-water, soil mechanics, subsurface coring, site mapping, risk analysis, advice on hazard reduction and slope remediation
Contact: consult local yellow pages -- geologists, geotechnical 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/blwq/

Town Code Enforcement Officers
Information available: provide advice on Shoreland Zoning and other municipal requirements
Contact: local town office or http://www.maine.gov/local/

Evidence of ground motion

Photo 1. In 2005 a landslide occurred in Wells, Maine along the banks of the Merriland River. The slide destroyed a portion of a walking trail in the Rachel Carson National Wildlife Refuge and removed the backyard of a nearby house. Parts of the house's foundation were left exposed and the house was declared unsafe to inhabit.

Photo 2. Tension cracks forming and movement along a roadway prior to full slope failure. Downslope forces cause surface layers to stretch. When the tension becomes great enough, a crack forms and some pressure is released. Tension cracks indicate instability and motion along the slope, and are precursors to complete slope failure.

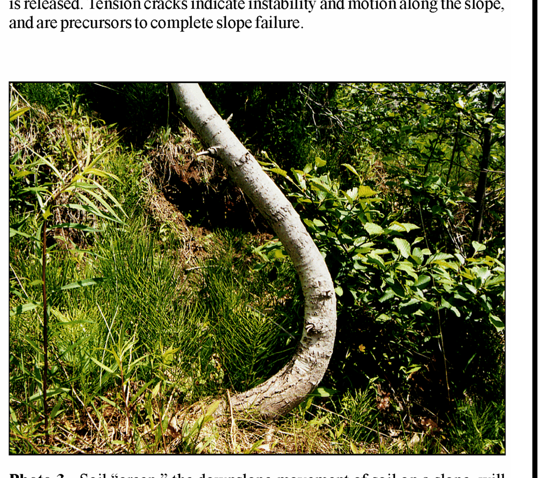

Photo 3. Soil "creep," the downslope movement of soil on a slope, will cause tree trunks to tilt toward the base of the slope. As a moving tree continues to grow, the trunk will curve as the tree tries to right itself and grow toward the sun. These trees are known as "pistol butt" trees, due to their curved shape.

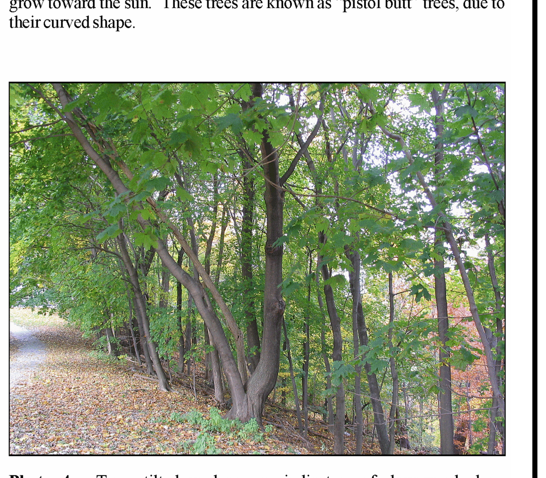

Photo 4. Trees tilted upslope are indicators of downward slope movement and indicate areas of possible future slope failure.

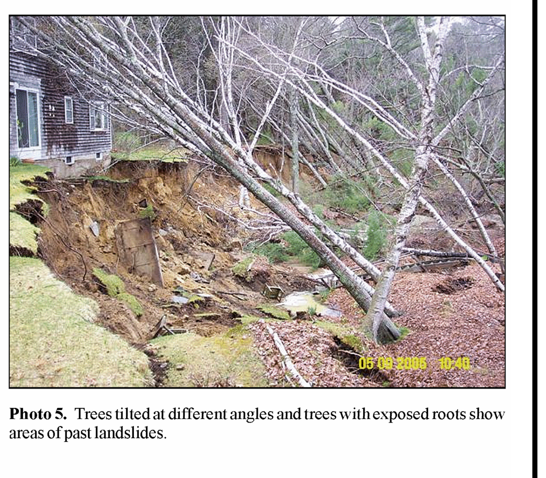

Photo 5. Trees tilted at different angles and trees with exposed roots show areas of past landslides.

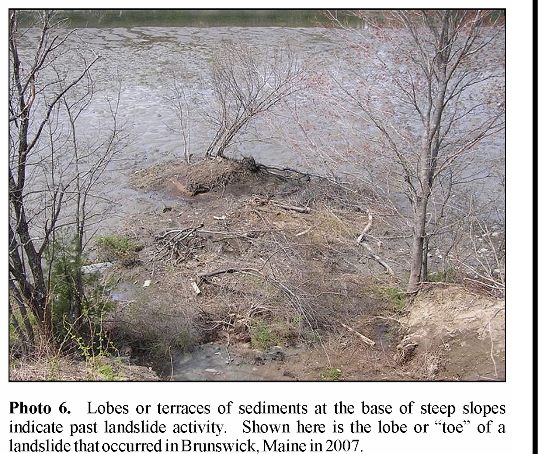

Photo 6. Lobes or terraces of sediments at the base of steep slopes indicate past landslide activity. Shown here is the lobe or "toe" of a landslide that occurred in Brunswick, Maine in 2007.

Related information for mitigation and planning

National Research Council, 2004, Partnerships for reducing landslide risk: The National Academies Press, Washington, D.C., 144 p.

Novak, Irwin D., 1987, Inventory and Bibliography of Maine Landslides; Maine Geological Survey, Open-File Report 87-2, 27 p. report and map.

Schwab, J. C., Gori, P. L., and Jeer, S. (editors), 2005, Landslide hazards and planning: American Planning Association, Planning Advisory Service Report no. 533/534.

Sidle, R. C., and Ochiai, H., 2006, Landslides: processes, prediction, and land use: American Geophysical Union, 312 p.

Spiker, E. C., and Gori, P. L., 2003, National landslide hazards mitigation strategy: a framework for loss reduction: U.S. Geological Survey, Circular 1244, 56 p.

Varnes, D. J., 1978, Slope movement types and processes, p. 11-33, *in* Schuster, R. L., and Krizek, R. J. (editors), Landslide analysis and control: Transportation Research Board, National Academy of Sciences, National Research Council, Special Report 176, Washington, D.C.