Maine Coastal Property Owner’s Guide to Erosion, Flooding, and Other Hazards

Peter A. Slovinsky, Marine Geologist, Maine Geological Survey

Purpose of this Guide

The Maine Geological Survey created this guide to educate coastal property owners on identifying features of the Maine coastline, their related hazards such as flooding and erosion, and based on the level of those hazards and property owner’s interests, the potential mitigation and adaptation strategies to deal with those hazards.

Specifically, this guide will help coastal property owners:

- identify important features of the Maine coastline;
- familiarize themselves with potential hazards associated with certain types of coastal features;
- identify specific characteristics of different types of coastal hazards;
- help coastal property owners identify the presence, absence, or potential level of certain hazard types on their property;
- identify potential strategies that can be undertaken to mitigate for identified hazards; and
- identify applicable rules and regulations associated with certain hazards.

Please note that this document should be used for *general guidance purposes only to help understand coastal features and their associated hazards.* Although this Guide covers features and hazards found on a great portion of the Maine coast, it is not meant to identify *all existing hazards* along the Maine coastline, nor is it intended to be the sole basis upon which specific land-use decisions are made by coastal property owners.

For an evaluation of specific coastline features, hazard risks or historical trends, certified geologists or geotechnical engineers should conduct site-specific studies. Neither the Department of Conservation, nor its employees or agents: (1) make any warranty, either expressed or implied for merchantability or fitness for a particular purpose, as to the accuracy or reliability of the information included herein; nor are they (2) liable for any damages, including consequential damages, from using this Guide or the inability to use this Guide.

For an online version of this Guide, see http://www.seagrant.umaine.edu/coastal-hazards-guide

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What is a Coastal Hazard?
Coastal hazards include both natural and man-made events (chronic and episodic) that threaten the health of coastal ecosystems and communities. This definition includes, but is not limited to, hurricanes, tsunamis, erosion, oil spills, harmful algal blooms, and pollution.

What is Hazard Mitigation and Adaptation?
Hazard mitigation is any sustained action taken to reduce or eliminate the long-term risk generated by hazards to people and the built and natural environment. Mitigation can take several forms, including: siting, construction techniques, protective works (erosion control structures, beach fills, dune construction), maintenance, land-use regulation, coastal zone management planning, and enhancement of natural buffers. Hazard mitigation seeks to reduce risk over long durations, rather than preparing for, or responding to, an impending event (Herrington, 2003).

The Intergovernmental Panel on Climate Change (IPCC 2007) defines adaptation as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."

Both of these concepts are instrumental to the development of a Hazard Management Plan, outlined below, which assesses and manages hazards and their associated risks.

Develop a Hazard Management Plan
Coastal property owners should consider developing a short- and long-term hazard management plan for their properties. These plans should be undertaken in the context of clearly defined **goals, priorities, and expectations** for the use of the property based on its proximity to natural resources and coastal hazards. These goals, priorities, and expectations must assume **certain levels of risk** associated with the presence or absence of coastal hazards, which will likely vary among individual property owners. ***A general overall goal for hazard management is to reduce or remove the level of risk associated with a certain hazard, while at the same time minimizing associated negative impacts to the natural environment and yet maintaining or achieving a desired use of a property.***

Remember that removing all risk from coastal property is likely impossible.

Other goals that can be part of a management plan include, but are not limited to: ensuring human safety; protecting, enhancing, or restoring property; protecting, enhancing, or restoring habitat; or maintaining or developing new uses of property or habitat.

Remember, achieving one or more of these goals may involve delicate balancing of the goals, priorities, expectations, and risks. Be realistic in setting your goals, priorities, and expectations, and be sure to understand the risks associated with these goals. The process of developing and implementing a management plan that addresses a coastal hazard can generally follow the steps of:

- identify appropriate management goals;
- understand and determine the nature of a given hazard;
- evaluate conditions of a property to identify the presence or absence of a certain hazard;
- determine the level of risk associated with identified hazards;
- determine the *level of acceptable risk* for you as a property owner;
- select appropriate strategies for managing said hazards that achieve the overall goals; and
- implement the chosen strategies to achieve the management goals.

General Coastal Hazard Management Strategies
Although specific strategies will be discussed in much more depth for each geographic section on hazards, generally, there are three main strategies that can be implemented. These three general management approaches are discussed briefly in this section to provide a context for more specific, subsequent sections. These strategies are independent of the type of coastline and include:

- allowing natural processes to occur;
- mitigating hazards; and
- altering or enhancing the shoreline.

These general management approaches are not mutually exclusive; more than one may apply to or be most effective for a given stretch of coastline or property. However, the decision as to which approach is best for your property will depend upon the property's geological, ecological, and economic considerations, and the goals, expectations, hazards, and risk levels identified in the overall management plan.

Adaptation and mitigation strategies are taken directly from the Protecting Maine's Beaches for the Future report (Beach Stakeholders' Group, 2006), which was the culmination of a two-year process involving a number coastal stakeholders. Each specific strategy is discussed further below.

Allow natural processes to occur. This approach of "non-intervention" allows natural processes to change the shoreline. In many cases where permanent structures are not present, this approach is preferred, particularly where critical habitats are involved. In some instances, this approach will best serve the goal of hazard avoidance or reduction.

Mitigate the hazard. The mitigation of coastal hazards refers to a series of techniques that lessen or reduce the effect of a hazard on the built environment. Relocating development away from high hazard areas, purchasing at-risk properties from willing sellers, elevating buildings, road and utilities, elevating and flood proofing building systems such as heating systems, and improving a building's ability to withstand storms through different construction practices are all considered hazard mitigation tools.

Alteration of the shoreline*.* In situations where other hazard management strategies are not practicable, human alteration of the shoreline may be required in order to achieve the goals of hazard management.

Generally, to the extent practicable for a given property or situation, approaching these strategies in the order listed will minimize impacts on the natural environment; however, that may not always be feasible. Also, in many cases, a combination of the listed strategies may be most applicable to your specific situation. Considering these different strategies and taking into account the goals, priorities, and expectations for a property, coastal property owners should:

- ***Understand your property.*** Use all available information, including this Guide, to understand the characteristics of your property and the risk associated with certain hazards. You may need to hire professional geologists, certified engineers, landscape architects, or environmental consultants in order to fully understand the level of risk and the entire planning and permitting process.

- ***Be realistic.*** In setting your goals and expectations for use of your property, be cognizant of the hazards and risks that you will face. For example, if you own a small piece of property that is in a flood zone, and is bound by an eroding wetland on one side, and a dramatically eroding beach on another, building your dream home that will be in the family for generations may not be as realistic as a small seasonal cottage that can be easily moved.

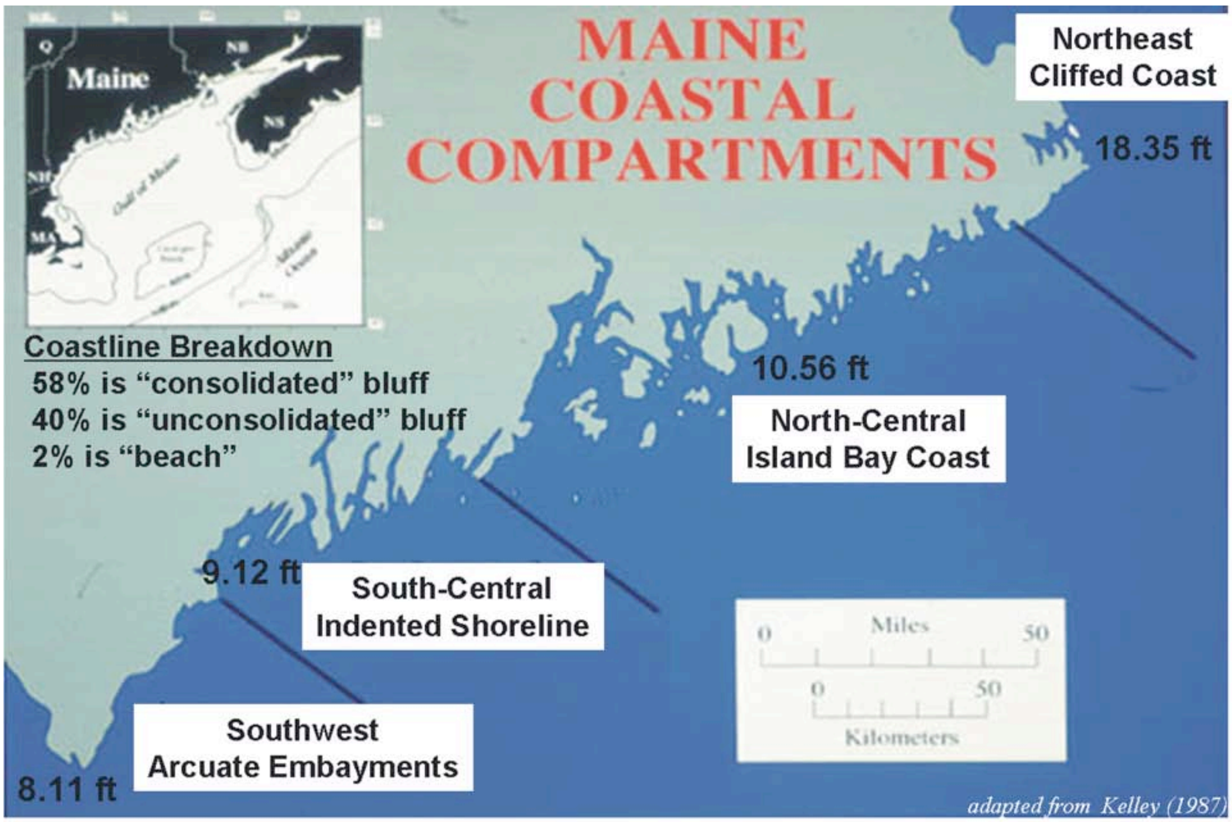
- ***Be neighborly.*** Think about potential impacts on your neighbor's property that may result from an activity on your property. At the same time, it may make sense to work with adjacent property owners if a common goal is found or regional approach is being adopted to deal with certain hazards.

- ***Consider the costs.*** When comparing strategies, consider the short- and long-term costs of different strategies. A lesser-priced strategy initially may actually cost more in the long term.

- ***Consider the permit requirements.*** Make sure to fully assess the local, state, and federal permitting requirements – and their associated timeframes and costs - which may relate to specific strategies and overall hazard management goals.

- ***Consider timeframes.*** Some activities or strategies may have extended permit review processes, certain sensitive habitat types, seasonal restrictions, or extended construction timeframes. Also think about the timeframe of expected usage of your property, and what might happen to that property in the future, be it family ownership, impacts from sea-level rise, etc. Take these into consideration when planning.

Introduction to the Maine Coastline
Maine's 3,478-mile tidally-influenced shoreline is the fourth longest of the United States (NOAA, 1975). The tidal range increases from about eight feet in the southwest, to over 18 feet along the downeast coast; along with geologic history, this dramatic difference in tidal range lends itself to some of the variety of coastline types, ranging from sandy beaches to cliffed rocky coasts. Generally, the Maine coastline can be classified into four different coastal compartments, described below.



Southwest Arcuate Embayments. A series of rocky headlands separate sandy bays of varying sizes, with extensive salt marshes and sand beaches.

South-Central Indented Shoreline. Deep, narrow estuaries separate long bedrock peninsulas. Deposits of muddy glacial sediment fill many of the valleys that were probably carved by rivers over millions of years.

North Central Island-Bay Coast. This area is shaped by numerous granitic islands sheltering broad embayments. Like the Indented Shoreline, mud and mixed mud and gravel flats are the most common intertidal settings.

Northeast Cliffed Coast. Bedrock faults create a straight coast with abundant bedrock in the intertidal zone. A 20-foot tidal range has led to considerable scouring of the seafloor by tidal currents and formation of extensive tidal flats.

The Maine shoreline can be generally characterized as cliffed rocky coast or consolidated bluffs (58% or about 2,000 miles), unconsolidated coastal bluffs comprised of erodable material (40% or about 1,400 miles), and beach (2% or about 70 miles). Each of these different shoreline types have different characteristics, and each their own inherent hazards. Understanding the different features and their associated hazards is the first step in developing management strategies from the local to regional level.

Hazards along the Maine Coastline

Maine's diverse coastline is made up of a variety of coastal features, including rocky shorelines, coastal bluffs, dunes and beaches, and marshes. Each of these features is influenced by a number of hazards that can directly impact natural habitat, and public and private property and infrastructure.

The first steps in identifying what hazards may be associated with your property is to identify what your shoreline type is on or directly near: rocky, unconsolidated coastal bluff, beach or dune, or coastal marsh. This guide will walk you through the process of identifying the different features and their associated hazards.

The most prominent features and hazards along the Maine coastline that will be discussed in depth within this guide include:

- Coastal Bluffs and Erosion and Landslide Hazards
- Beaches, Dunes, and Coastal Erosion and Flooding Hazards
- Coastal Wetlands and Coastal Flooding Hazards

Note that these hazards are the results of different processes that occur along the Maine coastline, including but not limited to sea-level rise, waves, storms, winds and tides. These processes are not discussed specifically as hazards themselves, but instead, as they impact dominant coastal features and property.

Beaches, Dunes, and Coastal Erosion and Flooding Hazards

Under Maine Law, "coastal sand dune systems" are defined as sand and gravel deposits within a marine beach system, including, but not limited to, beach berms, frontal dunes, dune ridges, back dunes, and other sand and gravel areas deposited by wave or wind action. Coastal sand dune systems may extend into coastal wetlands (38 MRSA 480-B(1)).

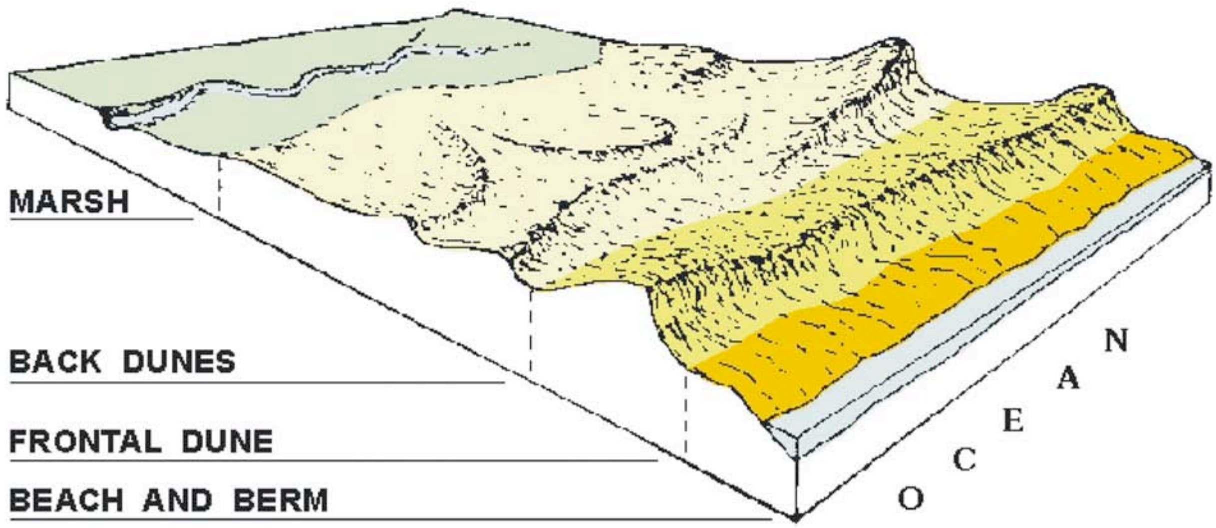
The term "sand dune system" is used interchangeably with the terms "beach system,” "coastal sand dune," "coastal sand dune system," and "dune system." The statutory definition of "coastal sand dune systems" applies equally to all these terms. Sand dune systems include sand deposits within a marine beach system which have been artificially covered by structures, lawns, roads, and fill. Sand dune systems also include all vegetation which is native to and occurring in the system (06-096 CMR 355(1)(W)).

Beaches comprise only about 2% or 75 miles of Maine’s coastline. Sand beaches account for less than 40 of the 75 miles, with coarser gravel and boulder beaches comprising the remainder. Most large sandy beaches occur along the southern coast between Kittery and Cape Elizabeth, although several stretches of sandy beach also occur in midcoast Maine near the mouth of the Kennebec River, and along the central and eastern coasts as pocket beaches. Maine’s beaches, however, are a resource of statewide significance. Maine’s beaches provide multiple values to many different user groups, provide a natural buffer from storm events, and vital critical habitat for a variety of plant, bird, and animal species.

Typical Beach and Dune Features

Maine’s beaches are dominantly a combination of barrier beach systems (such as the beaches along Popham Beach in Wells and Ogunquit, which typically consist of a beach, front and back dune, and a back-barrier coastal marsh system) and pocket beaches, such as Willard Beach in South Portland, which tend to be much smaller and are bound by bedrock headlands, and usually do not support an extensive back-barrier marsh system.

Sand dunes and beaches are part of the regulated Coastal Sand Dune System. Typical features include a beach berm, frontal dune and back dune, with a back barrier marsh system. The beaches vary in width and slope; most have a dry beach width (the distance from the high water mark to either the edge of vegetation or seawall) between 25 and 100 feet, dependent upon season. Based on measurements by MGS, the frontal dune is typically between 125 and 150 feet in width. MGS has mapped about 2,000 acres of sand dunes along 30 miles of the Maine coastline. About one-quarter of the dune systems in Maine are classified as frontal dune, with the rest being back dune environments.



A typical coastal sand dune system showing the beach and berm, frontal dune, back dune, and marsh system. Image from S.M. Dickson, MGS.

Beach and Dune Processes
Beaches and dunes are extremely dynamic features, changing almost daily in response to waves, wind, and tides. Beaches and dunes in Maine generally see several different kinds of erosion: seasonal changes, short-term (storm-induced) erosion, long-term erosion, and inlet erosion.

Seasonal changes: Typically, beaches and dunes undergo a seasonal transformation from a "summer" beach shape in the summer to early fall months to a "winter" beach shape in the winter and early spring months. The "summer" beach shape typically has a well-developed and wide berm on the beach, and more established, taller, and vegetated frontal dunes. As storminess and wave height (along with a general change in wave and wind direction) increase during the fall and winter months, beach berms and sometimes the dunes erode in response. This results in lowering of the beach; sand is typically pulled offshore from the upper portions of the beach in order to form protective offshore sandbars. The result is typically a flatter, more concave, beach shape during the winter than the summer. The sandbars that form offshore in winter help protect the beach by causing waves to break farther offshore. As conditions subside in the late spring and early summer months, smaller, calmer waves dominate, and sand slowly returns to the beach and berm, and the beach and dunes typically recover. This is a seasonal cycle that generally maintains a beach profile of equilibrium, as long as sediment is not lost offshore. The key here is that the berm is what generally undergoes the most seasonal change seen on the beach.

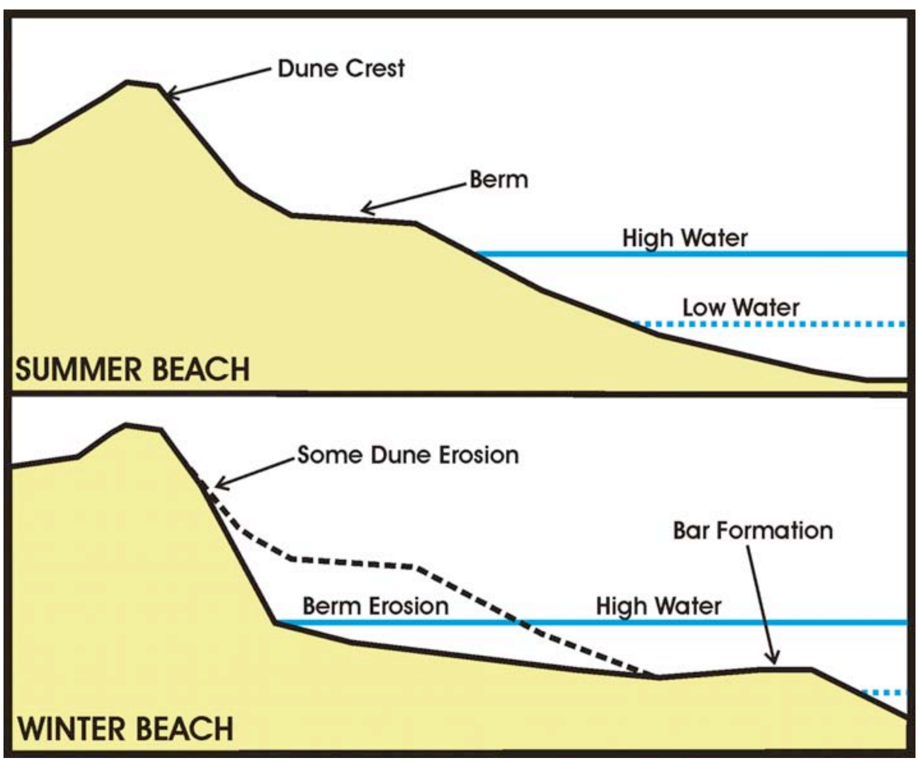
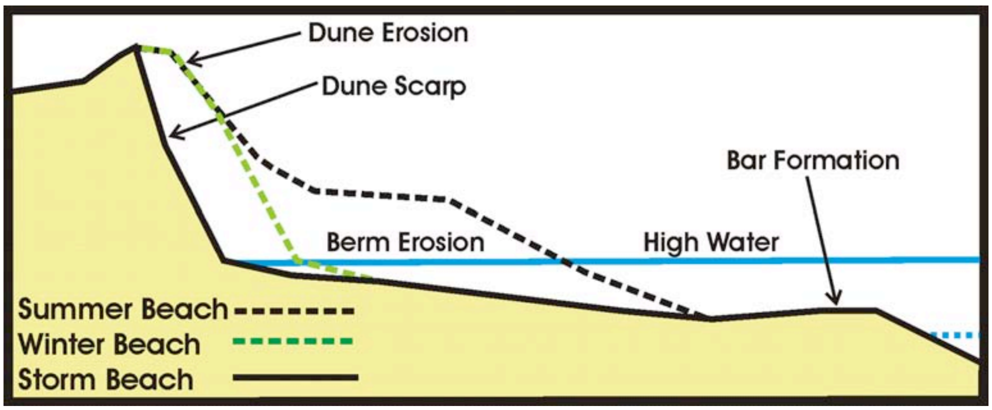


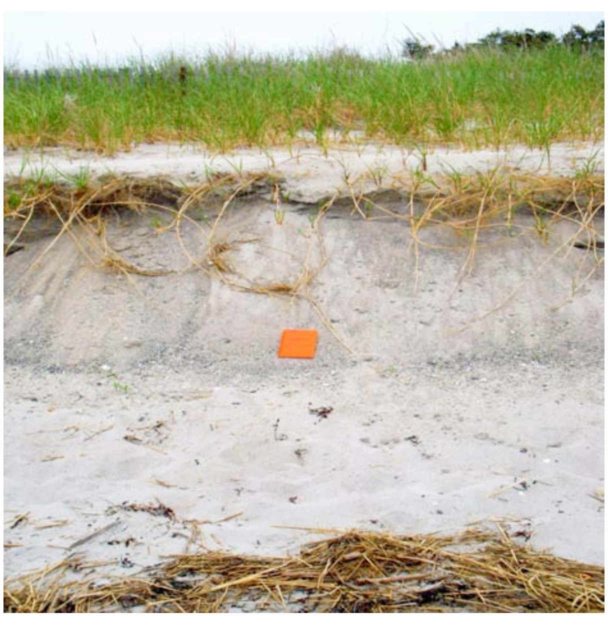
Figure 3 a) Winter profile shape, Kinney Shores, Saco. B) Summer profile shape, Kinney Shores, Saco. Images from the Maine Beach Profiling Program volunteers.

Comparison of winter (top) and summer (bottom) beach profile shapes from Kinney Shores, Saco. Images from Maine Beach Profiling Program volunteers, 2008. Figure by P.A. Slovinsky, MGS.

Short-term (storm-induced) erosion: Generally, this kind of erosion can be in response to a single large storm event or series of storm events that cause significant erosion. Typically, these occur in the fall, winter, or early spring months when the "seasonal" beach profile is already relatively lean in shape. Changes seen at the beach are similar to the seasonal changes, that is lowering of the beach, extensive loss of the berm, but typically includes relatively extensive dune erosion and scarping (formation of a vertical face in the front of the dune) or complete loss of the frontal dune.



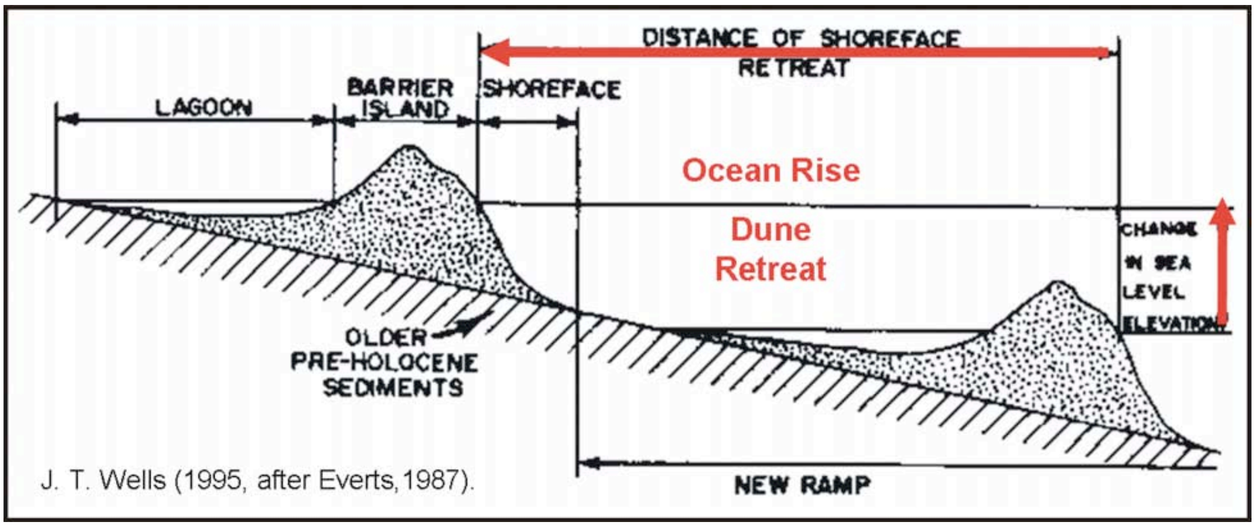
Storm recovery follows a similar process of the seasonal beach, with offshore sandbars providing protection, and slow, gradual build-up of the berm in response to smaller waves. This can occur in the course of one season, but may take a year or more. Dune recovery is a much slower process which involves re-establishing dune vegetation, wind transport of sand, and other processes. It can take several seasons to several years or more for a dune to recover naturally from a large storm.



Dune scarp after a storm event. Image from Western Beach, Scarborough, by P.A. Slovinsky, MGS.

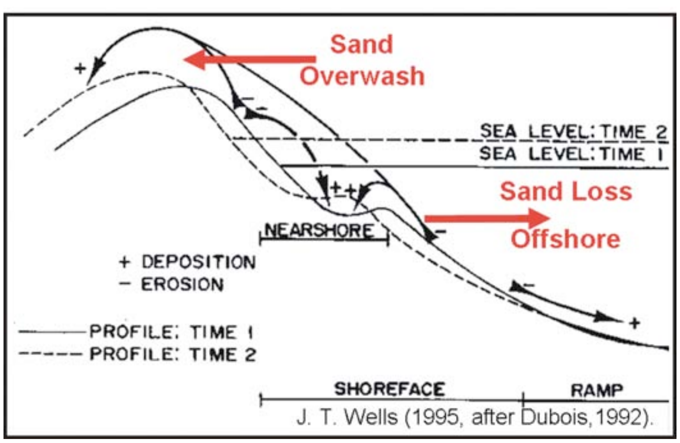
Long-term erosion: By definition, long-term erosion is permanent erosion occurring over longer periods of time, typically decades. Long-term erosion can be caused by numerous factors, including a deficiency in longshore sediment transport caused by engineering structures (i.e., a jetty) or a decrease in available sediment due to river damming. It can be caused by tidal river dynamics that cause the migration of sand into ebb-or flood-tidal deltas as sediment sinks or traps. It can also be caused by rising sea level and a deficient sediment budget, in which the rate that sand is delivered to a beach cannot keep up with sea-level rise or the rate of removal due to storm events.

Generally, almost all of Maine's beaches are transgressing; that is, they are moving landward in response to coastal storms and gradual sea-level rise at a rate of about an inch per decade. This landward migration of the beach and dune system is like the motion of a tank tread; the beach basically migrates over itself in response to storms and sea-level rise.



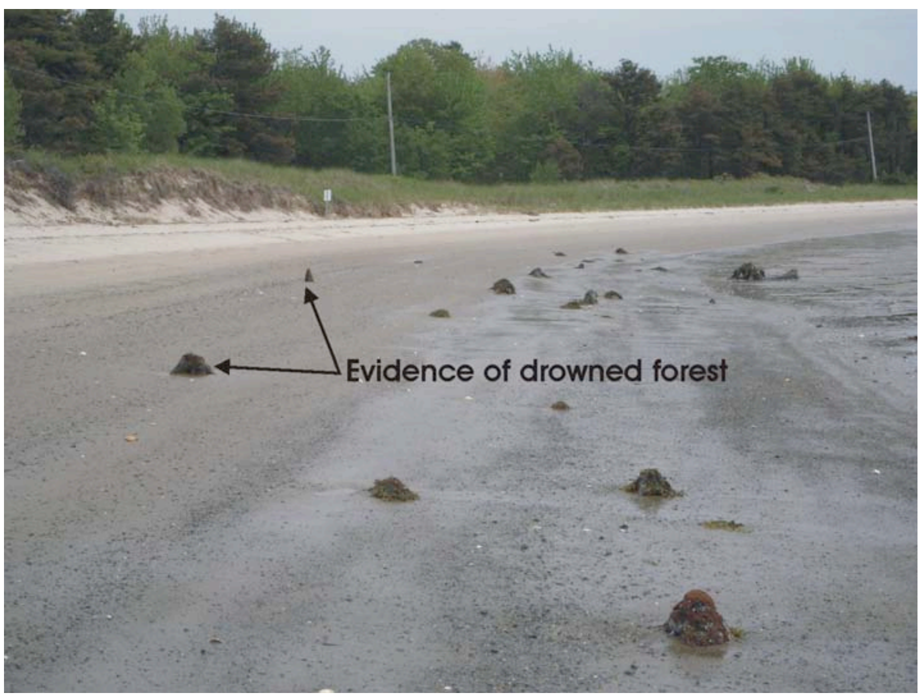
J. T. Wells (1995, after Everts, 1987).

This is a natural occurrence influenced by different processes seen during storm events, including seasonal changes, and storm-induced beach and dune erosion, and the process of overwash or dune washover.



J. T. Wells (1995, after Dubois, 1992).

Extensive dune overwash at Scarborough Beach following the Patriots' Day Storm of 2007. Image by P.A. Slovinsky, MGS.



A sure sign of beach and dune transgression is the continual presence of stumps or peat (marsh) deposits in the surf zone; these materials reveal where the backbarrier marsh and forested uplands once were, such as these tree stumps in the surf zone of Ferry Beach, Scarborough. Image by P.A. Slovinsky, MGS.

Inlet Erosion: Tidal inlets can be quite dynamic features, meandering and changing shape in response to storms and sediment supply. In fact, some of the fastest changing shorelines are typically found adjacent to tidal inlets (Rogers and Nash, 2003). Inlets can meander predictably or unexpectedly in one direction or another in response to storms. Some may migrate in a single direction continuously. Some inlets migrate in a single direction for a certain amount of time until they reach a point where they jump back to their original starting places. A great example of this phenomenon is the Morse River at Popham Beach State Park in Phippsburg. The channel of the Morse migrated dramatically to the northeast over the past few decades eroding large stretches of Popham Beach, and underwent a dramatic course change in 2010 and opened a new channel near its western point, adjacent to bedrock headlands.

In some inlets, jetties don't allow alongshore migration to occur, but nearby beach erosion still remains an issue, likely due to sediment movement associated with ebb-or flood-tidal delta formation. For example, Western Beach in Scarborough, adjacent to the Scarborough River, has undergone extensive erosion due to tidal river dynamics. The beach received nourishment in 2005, but has continued to erode at very high rates along the majority of its stretch, evidenced by the net shoreline movement of the high water line, measured by MGS from 2005-2009.

(See images on following pages.)

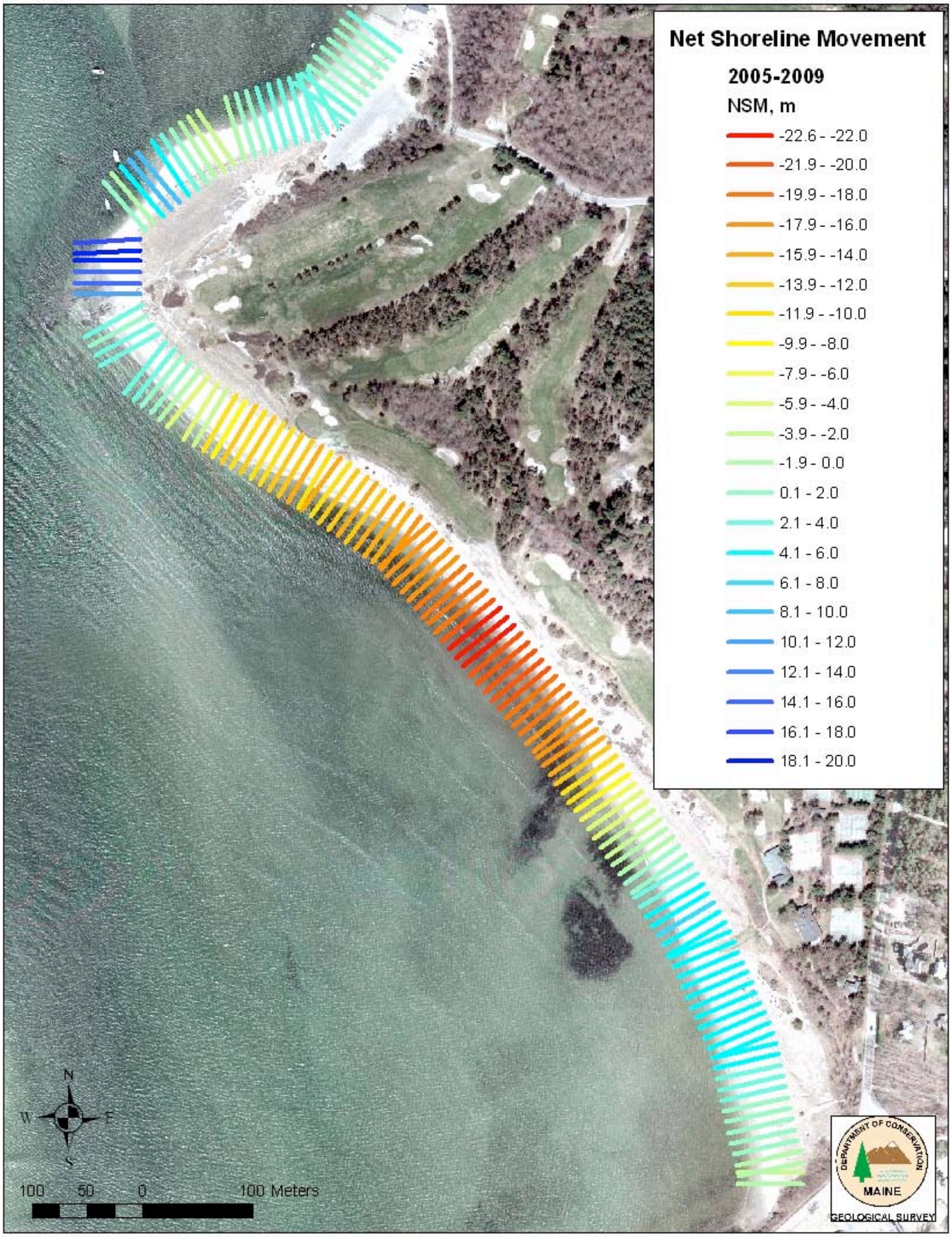
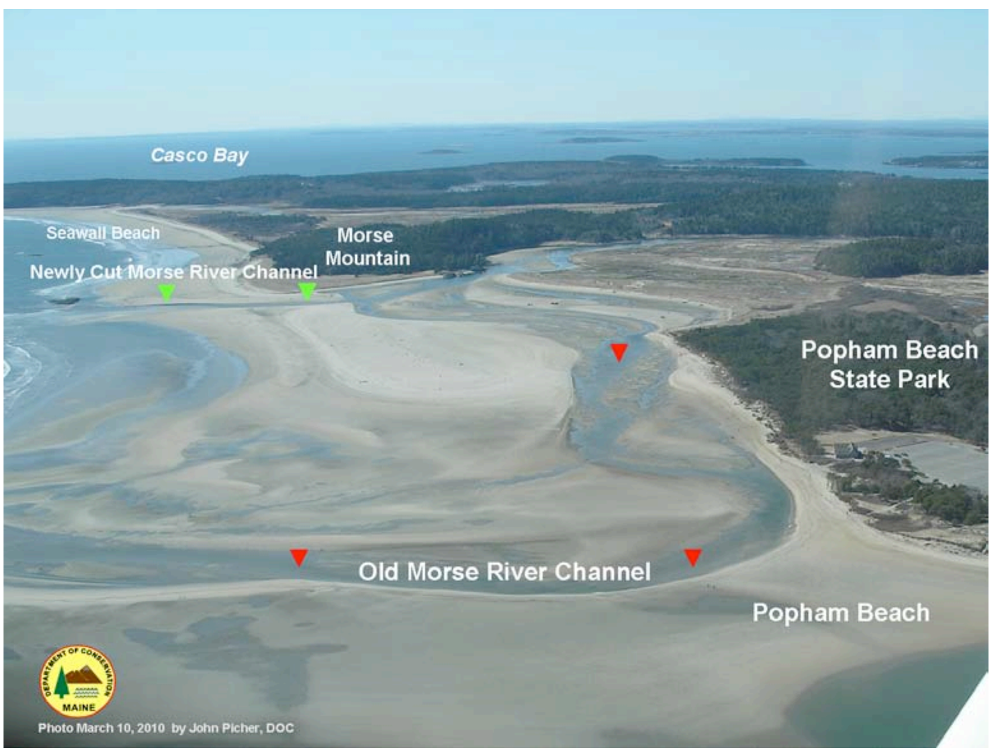


Image showing erosion (net shoreline movement) at Western Beach, adjacent to the Scarborough River, after beach nourishment occurred in 2005. Base image courtesy of MEGIS (2003), Figure by P.A. Slovinsky, MGS.



Aerial images of Popham Beach State Park and Morse River inlet position in November 2009 (top) and March 2010 (bottom). Image by J.Picher, DOC, Figure by S.M. Dickson, MGS.

Erosion of Maine's Beaches and Dunes
Coastal erosion and associated flooding from storm events not only impacts public and private property directly, but also compromises the ability of beaches to:

- buffer adjacent development from storms and flooding;
- provide vital natural habitat; and
- accommodate recreation and attract tourism.

Erosion problems in Maine are generally caused by a persistent rise in sea level, storms, changes in sand availability, and the construction of jetties and seawalls. MGS estimates that about 50% of Maine's sandy beaches are "armored" with these types of "hard" engineering structures, such as seawalls, that limit the natural ability of beaches and dunes to move in response to storm events and to properly maintain themselves by exchanging sediment.

*About 10% of Maine's beaches are *highly erosional*. In general, highly erosional shorelines have erosion rates of over two feet per year. Some of these beaches have seawalls along the frontal dune, while few have no seawalls. Most are in need of beach replenishment to replace eroded sand. Along many of these shorelines, there simply is no beach for about half of the tidal cycle.

*About 50% of Maine's beaches are *moderately erosional*, with erosion rates on the order of one to two feet per year. Along some of these beaches where seawalls are present, the seawalls are regularly overtopped during winter coastal storms, and a limited number of seawalls have been undermined during severe coastal storms. At some moderately erosional beaches with seawalls, undermining has been localized. Here, overtopping also occurs once or twice a year in winter, but is usually restricted to limited areas of beachfront properties. Natural beaches in this category have chronic dune scarps (steep drop-offs) and frontal dune erosion. Many beaches in this category have exposed gravel berms and limited recreational opportunities at high tide.

*About 40% of southern Maine beaches are only *slightly erosional*.

MGS prepared a table that generalizes the status of many of southern Maine's beaches. This information is taken directly from Appendix B of the Protecting Maine's Beaches for the Future (Beach Stakeholders' Group 2006) report. This table is meant to provide more information about the general characteristics of some of Maine's beaches, including development status, beach replenishment history, shoreline armoring status, shoreline change status, and public ownership.

General Characteristics of Selected Sand Beaches in Maine

Beach Name	Develop Status	Replenish. History	Armor Status#	Erosion Status*	Approx. Length (ft)^	Public Ownership+
Reid	None	None	None	Slight	3850	Yes
Hunnewell	Med	None	None	Mod	6770	No
Popham	Low	None	None	Mod	6300	Yes
Small Point	None	None	None	Slight	7400	Yes
Willard	Med	None	Low (16%)	Mod	2200	No
Crescent (Cape E.)	Low	None	None	slight	4330	Yes
Higgins	High	None	High (69%)	Mod	2700	Yes
Scarborough	Low	None	Low (32%)	Slight	7300	Yes
Western	Low	2004	None	High	3400	No
Ferry (Scar.)	Low	None	None	Slight	1200	Yes
Pine Point	Med	None	None	Slight	3800	Yes
East Grand	High	None	Med (44%)	Slight	3270	Yes
Surfside/Old Orchard	High	None	Med (59%)	Slight	10430	Yes
Ocean Park	Med	None	Low (5%)	Slight	6050	Yes
Kinney Shores/Bayview	Med	None	Med (59%)	Slight	5300	No
Ferry (Saco)	Med	None	Low (10%)	Mod	3200	Yes
Camp Ellis	Med	1919, 1969, 1970, 1978, 1982, 1992, 1996	Med (58%)	High	4200	No
Hills	Med	1989	Med (33%)	Mod	5350	No
Fortunes Rocks	Med	None	Med (56%)	Mod	11320	No
Goose Rocks	Med	None	Med (59%)	Slight	9960	No
Goochs	High	1985; 2004	High (88%)	High	3360	Yes
Great Hill Bch	Med	None	Med (47%)	Mod	1710	No
Parsons	Low	Mod	Low (14%)	Slight	3800	No
Crescent Surf	Low	None	None	Mod	3100	No
Laudholm	Low	None	None	Mod	2360	Yes
Drakes Island	High	2000-01	High (68%)	Mod	4630	**Yes**
Wells	High	1990, 1991, 2000-01	High (88%)	Mod	11800	Yes
Moody	High	None	High (~100%)	**Mod**	6280	No
Ogunquit	Low	Dune restoration 1974-75	Low (5%)	Mod	7280	Yes
Short Sands	Medium	None	High (100%)	Mod	1290	No
Long Sands	High	None	High (100%)	High	6950	Yes

Armoring status determined based on approximate measurements along the high tide shoreline using the MEGIS Aerial Photography Viewer. Landward of this position, some dunes also contain buried seawalls. Determination based on interpretation of the aerial photographs and knowledge of field conditions at most locations. Status determined as follows: High (>66% armored), Med (33-66% armored), Low (<33% armored.) Values indicate the percentage of the total beach length that is armored.

^ Beach lengths estimated from high water line measurements using the MEGIS Aerial Photography Viewer. Measurements not made based on exact town or city boundaries.

+ Public ownership: a "yes" in this category means that a portion of the beach is owned by the public.

Identification of Dunes, Beaches, and Erosion and Flooding Hazards

Beach and Dune Geology Aerial Photographs

The Maine Geological Survey created Beach and Dune Geology Aerial Photographs that identify the frontal dune and back dune areas along the majority of southern Maine beach systems. These two features of the beach and dune system are considered to be fragile, and activities in each of these areas may require specific permitting. The photographic maps are meant to identify the two dominant dune features of the coastal sand dune system – frontal and back dunes - but also show other features of the beach and dune system. Features identified include:

- dunes (frontal and back dunes, washover fans);
- beaches (sand, gravel, sand and gravel, boulder, or low energy);
- channels (tidal, dredged, channel bar/tidal delta, supratidal);
- coastal wetlands and shoals (high salt marsh, low salt marsh, freshwater marsh, freshwater pond, ledge); and
- coastal engineering and uplands (coastal engineering structure/fill, glacial/bedrock highlands).

These maps are also available through the local Maine DEP office, and at your town office. Not all coastal sand dunes and wetlands in Maine are mapped this way. Additional dune and beach environments are shown on the CMGE map (described below).

Note that these maps have been updated using newer topography and aerial photographs. The revised maps also include the location of the Erosion Hazard Area (EHA) boundary. The EHA represents the potential position of the shoreline after 100 years, taking into account short- and long-term erosion, and sea-level rise. Data have been developed using a Geographic Information System (GIS). Contact Maine DEP to determine the most updated dune boundaries for your area.

MGS also prepared 2007 and 2009 *State of Maine's Beaches* reports, which document general beach profile changes that have been monitored as part of the Maine Beach Profile Monitoring Program. The release of these reports coincided with the Maine Beaches Conference, which occurs every two years.

Volunteers associated with the Beach Profile Monitoring Program use simple techniques to monitor a number of southern Maine beaches each month throughout the year. These data are compiled by volunteers, and form the basis for subsequent reporting by MGS. We encourage property owners to become involved with the program in order to understand more of the changes that are happening at their beaches in response to storms and sea-level rise.

For communities located in Saco Bay, MGS created a report titled Variation of Beach Morphology along the Saco Bay Littoral Cell: An Analysis of Recent Trends and Management Alternatives that summarizes some of the shoreline trends along the bay.

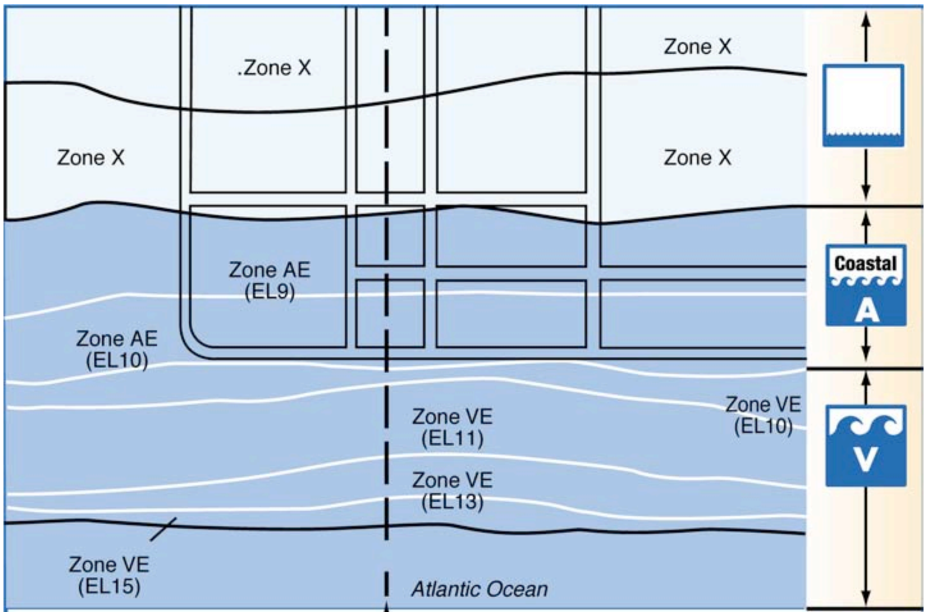
FEMA Flood Insurance Rate Maps: Coastal Flood Hazard Areas
Low-lying coastal areas along the open coast are susceptible to coastal flooding. Both "dynamic" (including the influence of waves) and "static" flood hazards are mapped by the Federal Emergency Management Agency (FEMA) in a series of maps called the Flood Insurance Rate Maps (FIRMs).

The FIRMs are used to identify flood insurance risk and insurance premiums in areas associated with different flooding events. These events include the 100-year or base flood elevation (i.e., 1% chance of being equaled or exceeded each year) and 500-year (0.2% chance of being equaled or exceeded each year) flood elevations. Special Flood Hazard Areas (SFHA) are defined as areas (VE, V, AO, AE, A, X, or C zones) that will be inundated by the flood event having a 1% chance of being equaled or exceeded in any given year. FEMA has developed information on each specific flood zone and how to read FIRMs.

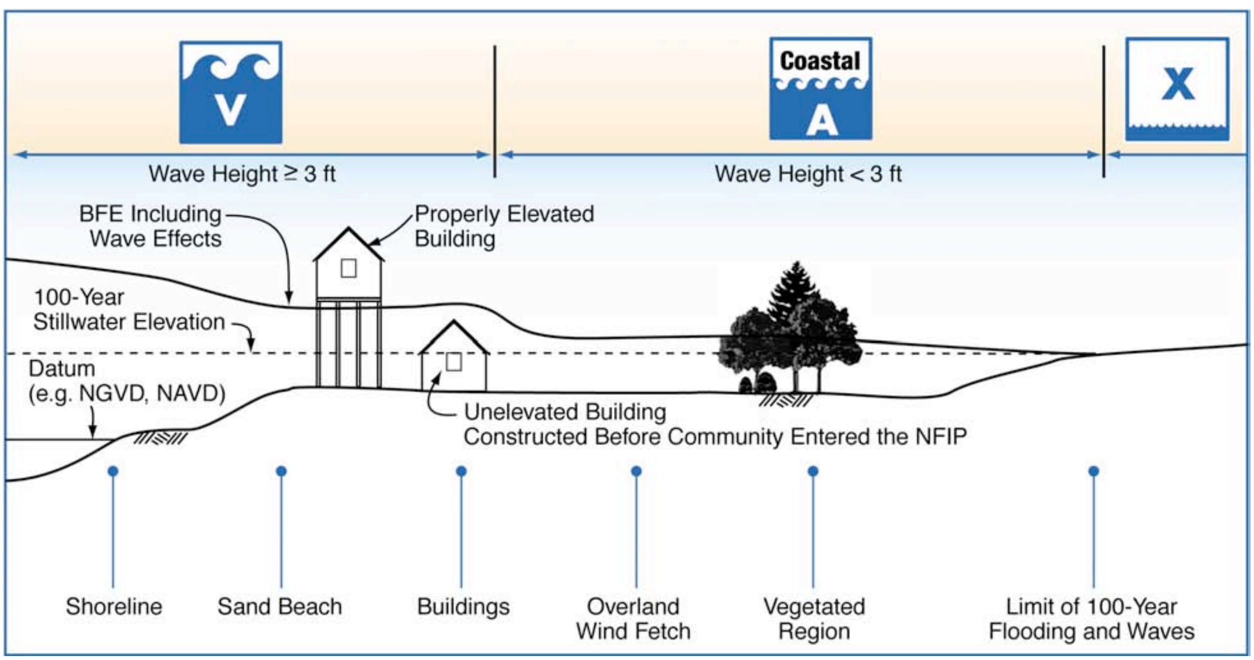
MGS conducted a *Coastal Erosion Assessment for Maine FIRMs and Map Modernization Program* report which outlined shoreline erosion impacts to FEMA FIRMs for the majority of southern Maine. The assessment includes some detailed information on different coastal communities regarding general erosion rates and trends.

FEMA FIRMs are available for viewing at your town office, can be requested from the Maine State Planning Office of Floodplain Management, or can be viewed online from the FEMA Map Service Center.

The Office of Floodplain Management's Maine Floodplain Management Handbook can be a great resource to property owners.



TOP: This portion of a Flood Insurance Rate Map (FIRM) shows a coastal Special Flood Hazard Area (SFHA) (dark gray), the 500-year flood hazard area (light gray), coastal Base Flood Elevations (numbers in parentheses), and flood insurance rate zones (AE and VE = SFHA, VE = Coastal High Hazard Area, X = areas outside the SFHA; FEMA, 2000). BOTTOM: The transect is used to analyze wave crest elevations. Adapted from FEMA Coastal Construction Manual figures 3-6 and 3-7.



Coastal Marine Geologic Environment (CMGE) Maps

The MGS Coastal Marine Geologic Environment (CMGE) maps show regional characteristics of the Maine coast. They illustrate which areas are rocky, muddy, sandy, etc. along the shoreline between the high- and low-tide lines. These maps include sand and gravel beaches and dunes in areas of the state where MGS has not published detailed Sand Dune Photos for use in the DEP permitting process. These maps illustrate the location of salt marshes and other tidal wetlands for evaluation of coastal habitats, impact of dredging, and siting of coastal facilities. The maps are available in paper version from the MGS office.

Coastal Barrier Resources System (CBRS) Maps

Some coastal beach and dune systems are classified as part of the Coastal Barrier Resources System (CBRS), comprised of generally undeveloped barrier beaches that were established as part of the Coastal Barrier Resources Act. In these locations, public funding for infrastructure or erosion protection is not permitted, and flood insurance is not available through FEMA. Most of Maine's largest developed beaches are not part of the CBRS. Maps showing the geographic extent of the Coastal Barrier Resources System in Maine are available for viewing by appointment at MGS, or can be viewed and downloaded from the U.S. Fish and Wildlife Service.

Coastal Inundation from Hurricanes: SLOSH

The National Hurricane Center runs a computer model called SLOSH (Sea, Lake, and Overland Surges from Hurricanes) that is used to estimate storm surge heights and winds associated with hurricanes. The US Army Corps of Engineers, in conjunction with the NHC, have developed Hurricane Surge Inundation Maps for the Maine coastline for hurricane events striking the coast at mean tide and mean high tide levels. These surge elevations and their inland graphical extent represent the potential maximum surge for a given location. These data, available for download through the Maine Office of GIS, can be used for *preliminary planning purposes* to help identify areas that may potentially be inundated during a tropical event.

Coastal Flooding Nomogram

The National Weather Service and the Gulf of Maine Ocean Observing System (GoMOOS) have developed a simple model that predicts when coastal flooding may occur given water levels and wave heights. This predictive model, called a nomogram, has been developed for the Portland area, and predicts when simple splashover begins, followed by mild, moderate, or severe beach erosion and coastal flooding. The nomogram is maintained on the GoMOOS website.

Coastal Light Detection and Ranging (LIDAR) data

Light Detection and Ranging (LIDAR) collects highly accurate topographic data (typical vertical resolution of 30 cm overall) using an aircraft and lasers that can be used for a multitude of coastal planning purposes. The NOAA Coastal Services Center maintains a database of collected LIDAR data for Maine, including LIDAR flown in 2000, 2004, and 2007 in its Digital Coast Viewer. If you have GIS capabilities, you can view LIDAR data collected along the Maine coastline and get a sense of coastal elevations on or adjacent to your property.

Regulations Governing Dunes, Beaches, and Coastal Flooding
There are many local and state regulations that apply to activities on or adjacent to beaches and dunes. To help guide property owners, the Maine DEP has released A Homeowner's Guide to Environmental Laws Affecting Shorefront Property in Maine's Organized Towns *(*Maine DEP, 2000).

Coastal Sand Dune Rules (Chapter 355)
The Maine Natural Resources Protection Act (NRPA) includes Chapter 355, Coastal Sand Dune Rules, which governs activities within the mapped Coastal Sand Dune System. The Coastal Sand Dune Rules, administered by Maine DEP, have specific guidelines for activities that require permits, or for de minimus activities, those not requiring permits. Specific sections of the Rules will be referenced in relation to mitigation activities and potential permits required, below.

The boundaries of the Coastal Sand Dune System are portrayed on the MGS Beach and Dune Geology Aerial Photographs. *Note that these maps have been updated in GIS format and are available upon request to the Maine DEP. The maps include the boundaries of the frontal dune and back dune systems, in addition to a defined Erosion Hazard Area, which is where the shoreline may migrate to in 100 years, combining the impacts of sea-level rise, short, and long-term erosion. Refer to the Coastal Sand Dune Rules for specific text supporting the definition.*

Maine Wetland Protection Rules (Chapter 310)
Specifically, portions of Maine NRPA regulate activities that occur in coastal wetlands, which may exist in the coastal sand dune system, or vice versa. Coastal wetlands are defined as

> *all tidal and subtidal lands; all areas with vegetation present that is tolerant of salt water and occurs primarily in a salt water or estuarine habitat; and any swamp, marsh, bog, beach, flat or other contiguous lowland that is subject to tidal action during the highest tide level for the year in which an activity is proposed as identified in tide tables published by the National Ocean Service. Coastal wetlands may include portions of coastal sand dunes. (Title 38, §480-B, 2).*

Activities that extend into defined coastal wetlands – based on the highest tide level for each year - will likely require a permit from Maine DEP. To support these regulations, MGS provides Maine DEP with a listing of the highest annual tide (HAT) elevations for many portions of the Maine coastline, based on NOAA tide gauge data.

Permit By Rule (Chapter 305)
Some activities within the coastal sand dune system can be undertaken with a Chapter 305, Permit By Rule (PBR). A PBR activity is considered one that will not significantly affect the environment if carried out in accordance with Chapter 305 standards, and generally has less of an impact on the environment than an activity requiring an individual permit. A PBR satisfies the Natural Resources Protection Act

(NRPA) permit requirement and Water Quality Certification requirement. Specific attention should be paid to Section 16. Activities in Coastal Sand Dunes.

Maine's Shoreland Zoning

By law, Maine communities adjacent to the ocean, lakes, rivers, some streams and wetlands, are subject to regulation under the Mandatory Shoreland Zoning Act. Generally, areas within 250 of one of the normal high water line are within the Shoreland Zone and subject to a community's Shoreland Zoning Ordinance.

Shoreland Zoning creates different types of districts within which you might be located that regulate certain activities within those districts, based on the presence of specific resources and uses. It is also used to establish certain setbacks from resources. The Maine DEP has released a Citizen's Guide to Shoreland Zoning (Maine DEP, 2000) which helps explain zoning districts and regulations.

Consult your local Town Code Enforcement or Planning Department to determine the specific regulations within your Municipal Shoreland Zone.

Federal Clean Waters Act and Rivers and Harbors Act

Sections of the federal Clean Water Act and Rivers and Harbors Act govern activities within coastal wetlands (and therefore waters associated with beaches) and tidal creeks and adjacent rivers. Permits are administered by both the US Army Corps of Engineers (US ACE) and the US Environmental Protection Agency (US EPA). Federal permitting includes comments provided by the US Fish and Wildlife Service and National Marine Fisheries Service. Text supporting both of these Acts can be seen at the Wetlands Regulation Center.

Section 10 of the Rivers and Harbors Act requires a US ACE permit for any work in navigable (tidal) waters below the mean high water line. Section 404 of the Clean Water Act requires a US ACE permit for the discharge of dredged or fill material into waters of the US.

The US EPA maintains good information describing the overall laws and applicable regulations that pertain to federal permitting of activities within waters of the United States.

Eroding Beaches and Dunes: What can I do?
Whether you are considering buying or building a coastal property, or already own one, there are several overall strategies for addressing erosion along open beaches.

1. Identify the hazard(s).
2. Classify the level of risk.
3. Determine if the hazard(s) identified can be mitigated.
4. Determine if the risks associated with known hazards are acceptable.
5. Determine setbacks or elevation standards.
6. Get appropriate permits.
7. Appropriately adapt to or mitigate the hazard.
    i. Do nothing.
    ii. Avoid the hazardous area.
    iii. Design and build properly.
    iv. Relocate existing infrastructure.
    v. Elevate structures.
    vi. Dune management, enhancement, or construction.
    vii. Beach scraping and/or beach nourishment.
    viii. Cobble trapping fences.
    ix. Emergency actions to protect property.
    x. Seawall reconstruction or enhancement.
    xi. Severe damage and reconstruction.

1. Identify the hazard(s).
One of the first things that an individual can do in determining beach, dune, and coastal flood hazards for his or her property is to ***identify the hazard*** using the numerous resources described previously in conjunction with doing a field inventory of the property. Some of these "in the field" signs are outlined below, and may illustrate short-term erosion problems, while others indicate a long-term shoreline response.

You may have a *generally stable beach* or *slightly erosional beach and minor isolated erosion and flooding problem* if:

- ***Your beach or dune is stable or accreting.*** For at least a decade, your beach or dune has been either stable or growing seaward.
- ***Your beach or dune is eroding at less than 1 foot per year*.** For at least a decade, your beach or dune has been eroding only slightly.
- ***You have a wide dry beach and large dunes*.** For Maine beaches, this means a seasonally recurring (i.e., summer to fall) wide, dry beach (generally a measurement of greater than 50 feet between the edge of high water and the edge of the dune vegetation) *and* a well developed coastal sand dune. Sand dunes with elevations that meet or exceed the shoreline's V zone BFE are optimal. Larger dry beaches and stable dunes typically form in areas with adequate sediment supply.
- ***Your beach or dune erodes but is able to recover.*** Your beach or dune generally only erodes in response to a large storm event. Erosion of the frontal dune can be on the order of 10-15 feet from larger events, with

scarping of the dune. However, your beach and dune recovers within a period of a year or two.

- ***You experience only isolated overwash and flooding***. Your property undergoes overwash (material and debris washed over the frontal dune and deposited in the backside of the frontal dune or in the back dune) or minor coastal flooding only in response to a large storm event.
- ***You are not located in a VE, V or AO flood zone****.* These flood zones are the most dynamic and unstable, indicating that stillwater flooding *and* waves of a certain size will wash through the property in a larger storm. If you are not located in a mapped AO or V zone, you likely don't have flood insurance because your overall risk of coastal flooding is low. Note that you may be located in an AO or VE zone but have only isolated problems, or you may be located in an A zone and have flooding problems.

An example of a stable beach and coastal sand dune, with minimal coastal flood hazards from the ocean side, might be Pine Point Beach in Scarborough or Ocean Park in Old Orchard Beach.

You may have a *moderately to severely eroding beach* and *frequent or recurring problem if:*

- ***Your beach is eroding at more than 1 foot per year.*** If over at least a decade, your beach is eroding at a foot per year or more, you may have a moderate to severe erosion hazard.
- ***Your beach or dunes are continually eroding.*** Continual erosion from year-to-year over the period of decades with little recovery signifies an ongoing erosion problem. Look for signs of continued dune lowering and loss with no recovery after storm season, continued beach lowering in front of seawalls, and direct evidence of beach transgression (see below).
- ***You have a narrow, dry beach year-round, with small dunes or a seawall.*** If you have a very narrow dry beach (<25 feet) with very small dunes or a seawall, you likely live along a stretch of coast with a recurrent erosion problem. Small dunes are generally considered to be those that are below the elevation of the FEMA FIRM V zone BFE. Typically, seawalls were placed in areas that underwent ongoing erosion prior to regulations being placed on their construction.
- ***You see direct evidence of transgression.*** Look for exposed roots from trees or peat deposits in the surf zone. These features used to be on the backside of the beach which is now in the surf zone. Note that presence of these features may only occur after large storms; if they are present from year-to-year, this may indicate a more recurring problem.
- ***You experience frequent overwash and flooding.*** You experience overwash and flooding on your property on a frequent basis (i.e., several times a winter) in response to smaller storm events.
- ***You experience chronic structure (seawall, bulkhead) damage.*** Chronic damage to a shore protection structure indicates that the beach is attempting to move in a landward direction.

- ***You are located in a VE or AO zone.*** These zones are the most dynamic and can see breaking waves and coastal flooding across their extent.
- ***You are located next to an inlet that migrates on a regular basis.*** Proximity to a tidal inlet that migrates can increase the erosion hazard of the beach and dune.

Don't forget that long-term erosion or a major short-term erosion event can increase the flood hazard of a coastal property.

2. Classify the level of risk.
Once you have determined the presence or absence of coastal hazards at your property, the next step is to classify the level of risk associated with each hazard. That is, if dune erosion is occurring, at what rate in the short term? The long term? How close is your structure to the high water line? Are you in an Erosion Hazard Area?

We have created a summary checklist that can aid property owners in determining the level of hazard posed to their beach and dune property to erosion and coastal flooding (see **Beach, Dune, and Coastal Flooding Checklist**).

Especially in areas of high erosion and instability or flooding, it is recommended that you have a certified geologist, licensed engineer, or a coastal floodplain expert investigate your property to help you further classify the risk.

3. Determine if the hazard(s) identified can be mitigated.
In conjunction with your professional, determine what hazards can expectantly be mitigated, and at what cost. For example, if you have identified an existing flood hazard, can you elevate your structure so that it is above a base flood elevation? As part of this process, remember some of the goals, priorities, and expectations of the use of your property.

- **Be realistic.** It may not be technologically or economically feasible to protect a structure on a beach that is eroding dramatically.
- **Be neighborly.** Think about potential impacts on your neighbor's property that may result from an activity on your property. At the same time, it may make sense to work with adjacent property owners if a common goal is found or regional approach is being adopted.
- **Consider the costs.** When comparing strategies, consider the short- and long-term costs of different strategies.
- **Consider the permit requirements.** Make sure to fully assess the local, state, and federal permitting requirements – and their associated timeframes and costs.
- **Consider timeframes.** Some activities or strategies may have extended permit review processes, certain habitat types or timing restrictions, and extended construction timeframes. Also think about the timeframe of expected usage of your property.

4. Determine if the risks associated with known hazards are acceptable.
Taking into account the information that you developed in terms of mitigation as part of #3, determine *the level of risk you are willing to accept* to meet your goals, priorities, and expectations relating to the use of your property. For example, if you identified an erosion hazard, are you willing to accept the risk associated with potential damage or loss of the structure in 5 years? 10 years? 15 years?

5. Determine setbacks or elevation standards.
If contemplating new construction, determine minimum appropriate setbacks based on your Municipal Shoreland Zoning Ordinance, floodplain ordinances, and applicable state rules. You may be required to not only set the structure back a certain distance, but to limit its overall size, or elevate it so that the lowest structural member is a certain height above the minimum base flood elevation if in a flood zone. Check with your local Code Enforcement Officer for specific information relating to setbacks and elevation standards.

6. Get appropriate permits.
Building in the Coastal Sand Dune System or a Flood Zone, including pursuing potential mitigation strategies, may be subject to regulation under the Natural Resources Protection Act and the Shoreland Zoning Act. Permits from the Maine DEP and your town may be required. Local Code Enforcement Officers, in addition to consultants and engineers, should be able to give advice on local and state requirements for permits based on the activities you may be proposing on your property. Maine DEP is available for a pre-application meeting to explain the state standards.

7. Appropriately adapt to or mitigate the hazard.
You can take action to manage or reduce the risk of beach and dune erosion or coastal flooding impacting your property (these may require permits; see #4 above). These should be developed in conjunction with the steps involved above, and input from appropriate local experts (certified geologists, geotechnical engineers, landscape architects, etc.).

Mitigating a hazard or hazards sometimes may need to involve groups of coastal property owners to be most effective (e.g., dune management or dune creation). The mitigation and adaptation strategies listed below can be undertaken one-at-a-time, or using a multi-strategy approach that is most applicable to your case.

NOTE: One consideration for adaptation and mitigation is to take into account sea-level rise. Maine has adopted an expected two feet of sea-level rise over the next 100 years in terms of its regulations (Chapter 355, Coastal Sand Dune Rules), and requires that sites show stability after two feet of sea-level rise. We recommend that any adaptation and mitigation plans relating to beaches and dunes consider sea-level rise when developing different adaptation or mitigation strategies.

Do nothing: The "do nothing" alternative sometimes makes the most sense. In cases where erosion is minimal and a structure is located a more than adequate distance from an eroding dune, and a defined erosion rate has been determined (in consultation with local experts), a coastal property owners can opt to do nothing. Doing nothing is sometimes considered last, after other, more expensive and intensive options have been undertaken with no success. Doing nothing is typically a least-cost alternative and does not require permitting, unless erosion causes damage to property or infrastructure. The do nothing alternative must take into account the level of risk you are willing to accept in conjunction with the expected uses of your property.

Avoid the hazardous area: Avoiding existing or potential hazards as much as possible can be a very efficient and cost effective method of mitigation. This alternative is especially effective for the siting of new development. Choosing to avoid some areas and not others should be based on the hazards identified, their levels, mitigation strategies, and the level of risk you are willing to accept. A common avoidance technique is to build a structure far landward as possible. You may need to request a variance from local setback ordinances in order to do so. Another method could include elevating a structure over and above certain base flood elevation standards.

As much as is practicable with your building considerations, consider *moving back and moving up to avoid some hazards. Consideration should also be given to significant habitat resources or environmentally sensitive areas*, which are usually identified by shoreland zoning or state regulations. However, it is not always practicable for existing development to avoid all hazards or habitats due to the location of a structure, presence of setbacks, cost, or other factors.

Design and build properly: Proper construction techniques involve not only construction siting (i.e., structure and support structures, including septic, utilities, etc.), but also design and building techniques that can withstand hazards and potential wind and water forces associated with the dynamic coastal zone.

Consideration should be given to the following:

- construction footprint in the face of applicable setbacks for hazards or sensitive areas;
- the extent of grading to achieve a stable building footprint;
- the level of engineering required to mitigate for hazards;
- potential hydrostatic and wind loading;
- siting of ancillary infrastructure; and
- general construction standards.

Some of the best and most comprehensive resources available regarding proper coastal construction techniques are the FEMA Coastal Construction Manual and the FEMA Home Builder's Guide to Coastal Construction Technical Fact Sheets. The Construction Manual is available as a CD or in print copy by calling FEMA Publications Distribution Facility at 1-800-480-2520, and should also be available for review at your local town office or public library.

Lot coverage requirements and building restrictions for different dune areas, including some flood hazard zones, are provided in the Coastal Sand Dune Rules (Chapter 355). Additional size limits may exist in your municipal shoreland zoning ordinance or other local regulations.

Relocate existing infrastructure: Where existing development is being threatened by coastal erosion or flooding, one of the most effective ways to ensure safety of a structure is to relocate the structure out of the hazardous area, typically in a landward direction, or elevate the structure higher. Although relocation can be very effective in minimizing or mitigating the hazard, this alternative can be quite expensive. Costs can be quite variable (ranging from several thousand to tens of thousands of dollars) and are based on the existing foundation of the structure, size of the structure, topography and underlying geology, and distance the structure may need to be moved or elevated. Consultation with a local contractor is suggested, and local and state permits may be needed. Relocation of a structure can also be constrained by the size of a property and any applicable local or state setbacks, such as from other existing structures or roadways. In many cases, a property owner can request variances from local setback ordinances in order to relocate a structure.

Elevate structures. Existing structures that are threatened with coastal flooding or erosion can benefit from elevation. If you are located in a FEMA Flood Zone, you may be required by your town's floodplain management ordinance to have the lowest structural part of your house be a minimum of one foot above the base flood elevation (this is typically the minimum standard).

If your structure is older and has been flooded and does not meet current standards, any time you are doing substantial improvements to your structure, you may want to consider the cost of elevating the structure using a flow-through foundation or a pile foundation. This may be a requirement if structure improvements meet or exceed 50% of the value of the structure. Flow-through foundations are typically block or poured cement foundations with adequate spacing for floodwaters to flow through the foundation without damaging the supports. These structures are acceptable in the A-zone areas of back dune environments that are not considered to be Erosion Hazard Areas. Pile foundations, though more prevalent on the open ocean coastline, are typically used in more active flooding areas, and provide much more open space for floodwaters to travel through. Piles are required in the frontal dune and in areas of the back dune classified as Erosion Hazard Areas.

The concept behind both these foundation types is that water, sediment, and debris can *travel through* the foundation, thus avoiding significant pressure and lateral force to the foundation which causes structural failure. Both foundation types can significantly reduce potential flood damage to a structure.

In some areas of the back dune, fill can be added below a foundation to increase the elevation of the structure to meet floodplain standards. **This technique is not**

recommended, as it can potentially increase flood hazard to adjacent properties, and thus might not meet NRPA standards.

Many of the state requirements regarding elevation of structures, including a review of techniques, are outlined in Chapter 5 of the Maine Floodplain Management Handbook. Your town may have additional requirements that meet or exceed minimum state standards. Contact your local Code Enforcement Office for more information.

We also recommend review of the FEMA Coastal Construction Manual and the FEMA Home Builder's Guide to Coastal Construction Technical Fact Sheets. The Construction Manual is available as a CD or in print copy by calling FEMA Publications Distribution Facility at 1-800-480-2520, and should also be available for review at your local town office or public library.

You will likely need a permit from your local municipality, in addition to Maine DEP, to elevate your structure. Federal permits from the US Army Corps of Engineers and US EPA may be required if impacts to navigable waters or discharges into waters of the United States occurs. Check with your local Code Enforcement Office or the Maine DEP for more information.

Refer to Chapter 305 (Permit by Rule), Chapter 310 (Wetlands) and Chapter 355 (Coastal Sand Dune Rules) for additional requirements relating to impacts to coastal sand dunes associated with elevating structures.

If you are considering elevating your structure, include improvements to make your home more storm and flood resilient. Consider elevating your structure over and above the elevation required by your floodplain ordinance, in order to take into account expected rates of sea-level rise and their impacts on future floodplain elevations. Maine has adopted an expected rise in sea level of two feet over the next 100 years.

Dune management, enhancement, or construction: Coastal sand dunes provide a natural buffer from storm events, and can help protect your coastal property. Dunes have a reservoir of sand that is released to the beach during such events. However, sand dunes can only offer so much protection in areas of long-term erosion or areas with chronic erosion problems.

Sand dunes will erode or move landward over time in response to long-term erosion and sea-level rise. Therefore, any dune management, enhancement or reconstruction activities need to keep in mind that the landform is mobile, and take into account dune migration in light of the short-term, long-term, storm, and inlet erosion at a particular site. For areas with low long-term erosion rates with an existing sand dune, **dune management and enhancement** might be all that is needed to help maintain the storm protectiveness of the sand dune. Activities that fall under this include:

- dune planting and maintenance with sand (snow) fencing;

- dune path and walkover management; and
- raising the elevation of the dune with sand and plantings.

In Maine, dune management activities are limited by specific timing windows, mostly related to seasonality of seed germination and the presence/absence of threatened or endangered species such as least terns or piping plovers. Most activities may be undertaken from March 1 to April 1, or from October 1 to November 15. Refer to Chapter 355 and Chapter 305 of the Sand Dune Rules for more information specific to certain types of activities.

Dune Planting and Maintenance: Planting vegetation to help stabilize existing sand dunes – especially in areas with low long-term erosion rates - can help build the elevation or width of a dune, and thus increase its storm protectiveness.

Dune planting typically uses species of vegetation that are native to the coastal sand dune system. In Maine, this includes American beach grass (*Ammophila breviligulata*), which is the dominant dune plant. Other common species include:

coastal panicgrass (*Panicum amarum*)
rugosa rose (*Rosa rugosa*)
seaside goldenrod (*Solidago sempervirens*)
beach pea (*Lathyrus japonicus*)

American beach grass is normally planted in late winter while the plants are still dormant. The grass can be planted using the broom stick method: A broomstick is inserted eight inches into the sand, and two sprigs of grass are placed in each hole. American beach grass is typically planted in staggered rows 12-18 inches apart, depending on the application. The plants can be fertilized by with dried seaweed from the beach.

American beach grass can be ordered from one of the following locations:

- Cape Coastal Nursery, MA
  - http://www.capecoastalnursery.com/
- Great Meadows Nursery, MA
  - http://www.greatmeadowsllc.com/main/page_home.html
- Quansett Nurseries, Inc., MA
  - http://www.quansettnurseries.com/
- Church’s Beachgrass & Nursery, Cape May, NJ
  - http://www.churchsbeachgrass.com/to_order.htm
- Octoraro Native Plant Nursery, PA
  - http://www.octoraro.com/nursery.php
- Cape Farms, Inc., DE
  - http://www.capebeachgrass.com/about.html

The USDA Natural Resources Conservation Service Cape May Plant Materials Center maintains numerous resources for information on Coastal and Shoreline Restoration and Protection.

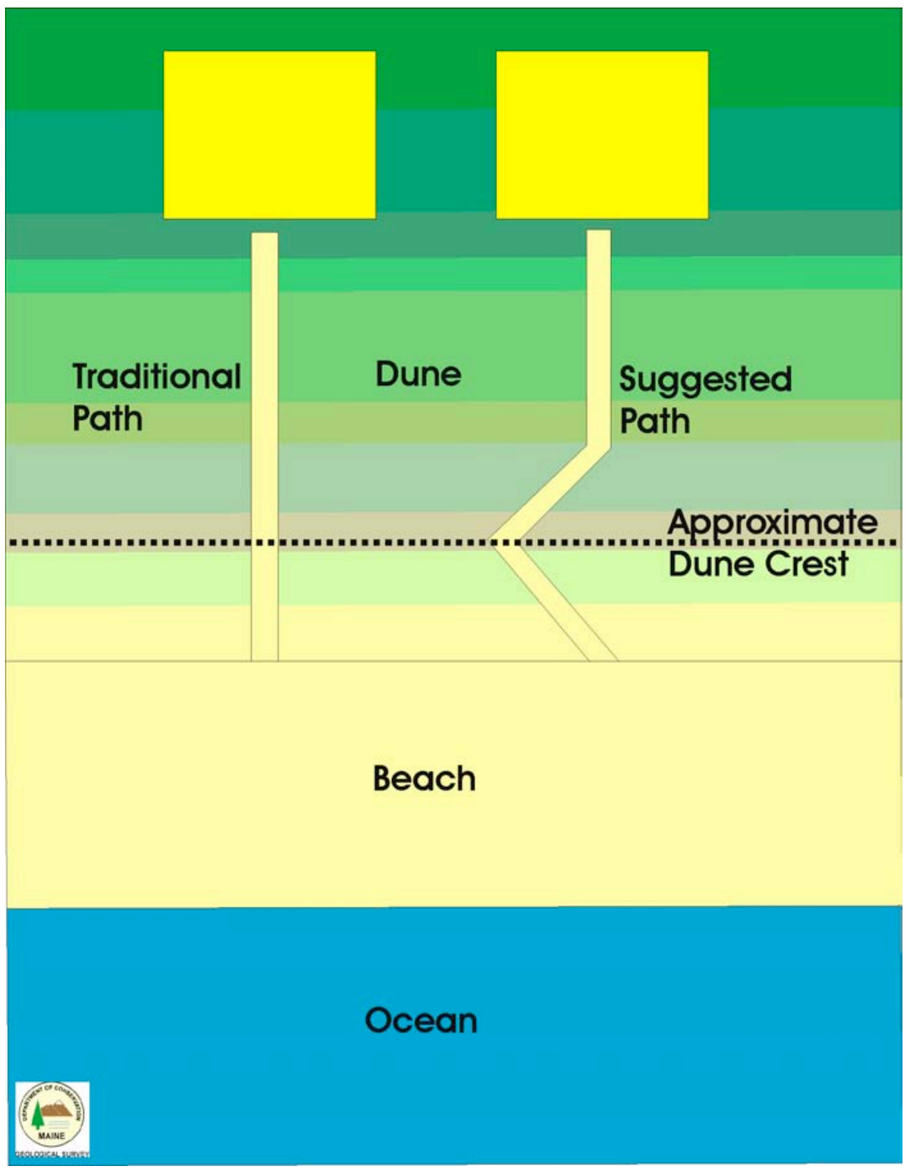
Open fencing (i.e., posts with string) can help limit foot traffic within the dune itself, but does little to help trap sand within the dune. Placement of open fencing is considered a de minimus activity in the Sand Dune Rules, and does not require a permit (Chapter 355, 4A(5)).

Sand/snow fencing can be used to help trap sediment adjacent to the dune system. However, this type of fence, unless it meets the “open” classification based on slat spacing standards (i.e., the opening between pickets must be at least four inches wide, or at least double the width of the picket, whichever is greater), will require a permit from Maine DEP.

Dune management projects are most effective for stretches of the coastline, not for individual properties. Therefore, this Guide recommends that projects be considered by multiple property owners when considering dune management strategies.

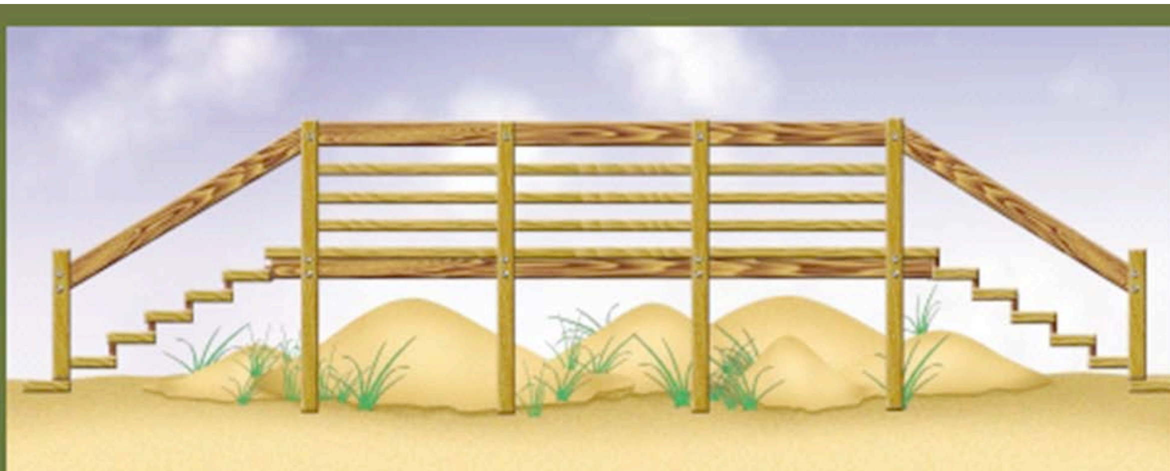
Dune Path and Walkover Management: Most of the time, a coastal property maintains access to the beach through the dunes with a simple, linear path that is cut through the dunes, perpendicular to the shoreline. Continued use of the path typically inhibits vegetative growth. Although this is typically the easiest way to access the beach, these paths many times act as direct conduits for floodwaters, wave runup, and overwash.

Instead of a perfectly straight path through the dunes, a slight zig-zag pattern, especially nearest the seaward edge of the dune, will slow erosion and help limit the path as a direct runway for flooding in the back dunes. The main turn of the path should occur near the crest of the dune. Dune paths for individual properties should be less than four feet wide. Path rerouting will likely require a permit-by-rule from the Maine DEP since it impacts dune vegetation.



Dune walkovers are typically constructed of wood or composite wood, placed perpendicular to the natural sand dune. Some are temporary, in place less than seven months of the year, and others are permanent. They are elevated, usually three feet, off the surface of the dune, with sufficient spacing between individual slats so that dune grass can receive needed sunlight. Most are constructed with handrails and steps, or if used for public access, ADA-compatible ramps. Typically, they must be less than 10 feet wide for public use, and less than four feet wide for private use. Several guides for construction guidance are available from other states, including Florida DEP, Texas, and the FEMA Coastal Construction Manual, Volume III, Appendix I.

In Maine, no specific guidance is provided by the DEP for construction of such structures in terms of elevation, slat spacing, or design, and is reviewed on a case-by-case basis. Maine DEP suggests contacting their southern Maine regional office to set up a pre-application conference if such a structure is proposed.



(A) Pier-supported with steps

Examples of dune walkovers. From Texas General Land Office.
http://coastal.tamug.edu/am/CapturedWebSites/GLO_Coastal_Dune_Manual/DuneManual-05.pdf

(B) Pier-supported with ramps

Dune Elevation or Construction: Typically, a good protective sand dune has an elevation that is at least at the minimum open coast base flood elevation on the applicable FEMA FIRM. MGS and the Coastal Sand Dune Rules suggest that any dune enhancement or construction ensures that the dune crest is at a minimum of one foot above the base flood elevation (Chapter 355, 5.I.). Dune construction requires, at a minimum, a Permit by Rule finding from the DEP, though larger projects may require an individual permit. See Chapter 305 16.A. Activities in Coastal Sand Dunes for specific guidance.

Further guidance regarding dune construction, fencing, and management is provided by the Maine DEP in a technical guide on dune management and construction that outlines techniques to use for planting and dune creation. Additionally, The Dune Book (Rogers and Nash, 2003), written by scientists in North Carolina, is a great resource. Also, the Woods Hole Sea Grant created a guide titled Coastal Dune Protection and Restoration: Using 'Cape' American Beach Grass and Fencing (O'Connell, 2002).

As with dune management, dune construction is most useful when undertaken by numerous properties along the coastline, instead of a single property. This can help defray construction costs, and create a more storm-resistant dune of regional significance.

Beach Scraping and/or Beach Nourishment: Beach scraping uses mechanical equipment to scrape sand from the lower portion of the beach into the upper portion of the beach, typically to or just below the sand dune (if work is done below the high water mark additional permits may be required, as this is considered a coastal wetland). Beach scraping is only a temporary measure to try to protect upland property, and is not necessarily effective beyond a single storm event, as sand from scraping is generally quickly dispersed. A Maine DEP permit is required for beach scraping, and additional restrictions may be imposed in terms of timing (typically between April 1 and September 1) by the Maine Department of Inland Fisheries and Wildlife.

Beach nourishment is defined as *the artificial addition of sand, gravel or other similar natural material to a beach or subtidal area adjacent to a beach* (Chapter 355, 3.,D) and is governed by the Coastal Sand Dune Rules.

Beach nourishment can be an effective, temporary response to coastal erosion, though it tends to be costly, and its effectiveness is generally short-lived (five years or less), especially in areas with high erosion rates. Two sources of beach compatible material in Maine have been used for beach nourishment:

1. "beneficial reuse" of dredged material, usually in conjunction with a federal (US Army Corps of Engineers) dredging project of navigable waterways; and
2. upland sourcing of material, typically from a gravel pit, where trucks are used to transport material from an upland source to the beach.

Beach nourishment using dredged material for beneficial reuse has been undertaken at Wells Beach, Wells in 2000 associated with federal dredging of the Webhannet River, and at Western Beach, Scarborough, in 2005, resulting from dredging of the Scarborough River.

Generally, if the US Army Corps dredges a project and the material is considered to be clean, beach compatible sand, the beneficial reuse of dredged materials as beach nourishment is encouraged. If beach nourishment is considered to be a least-cost alternative for disposal of the dredged material, the costs of dredging and material placement are borne by the federal government. If not, some cost-matching by a local sponsor (typically the receiving community) is required for the Corps to proceed with a project.

Private beach nourishment projects using dredged material – either from an adjacent river channel or other offshore source – have not been undertaken in Maine. One of the reasons for this is cost. Costs of finding, dredging, and transporting material can run between $10-20 per cubic yard of sand, depending on source and its proximity to the nourishment site.

Upland sources for beach nourishment have been used extensively at Camp Ellis Beach, Saco. Typically, compatible grain-size and textured sediment is sourced from a gravel pit, and trucked to the nourishment site. The cost of this type of source is generally around $10-15 per cubic yard, but transportation costs and road improvements may add additional costs based on the amount of material used.

Cobble Trapping Fences: In some specific sections of the Maine coast where cobble consistently washes over a seawall and threatens to damage private structures, seasonal cobble trapping fences may be installed under Chapter 305, Permit by Rule. These sections of coastline are specific, and only include those areas mapped as being adjacent to cobble or gravel beaches according to the Beach and Dune Geology Aerial Photographs and have developed areas between the building and the beach (such as lawn). Specific standards relating to these fences are described in the Sand Dune Rules Chapter 305, 16 C.

Emergency Actions to Protect Property: In an emergency, a coastal property owner can protect private infrastructure from storm damage by doing temporary, emergency fixes to an existing seawall. The specific activities are outlined in the Coastal Sand Dune Rules (Chapter 355, 5E).

Seawall Reconstruction or Enhancement: No new seawalls may be constructed along Maine's beaches or sand dune system. However, if a seawall protecting property is damaged, a coastal property owner may replace or repair the seawall in-kind and in-place (i.e., same materials, same dimensions) as the previously existing structure with a Permit by Rule (Chapter 305, 16). Seawall repair or reconstruction requires a survey plan prepared by a licensed engineer, surveyor, or geologist. If a property owner proposes to change their seawall in some way, a full permit through the Coastal Sand Dune Rules (Chapter 355) would be required.

Severe Damage and Reconstruction: Sometimes, the best opportunity for hazard mitigation unfortunately comes after significant damage to a structure has already occurred. In the cases of severely damaged structures (i.e., those with damage that exceeds 50% of a buildings value), Chapter 355 outlines specific criteria that cover how reconstruction may be permitted within the coastal sand dune system. Requirements depend on the location of the structure (frontal dune, V-zone, back dune, Erosion Hazard Area), whether or not the structure was damaged by an ocean storm or a different cause, and other standards.

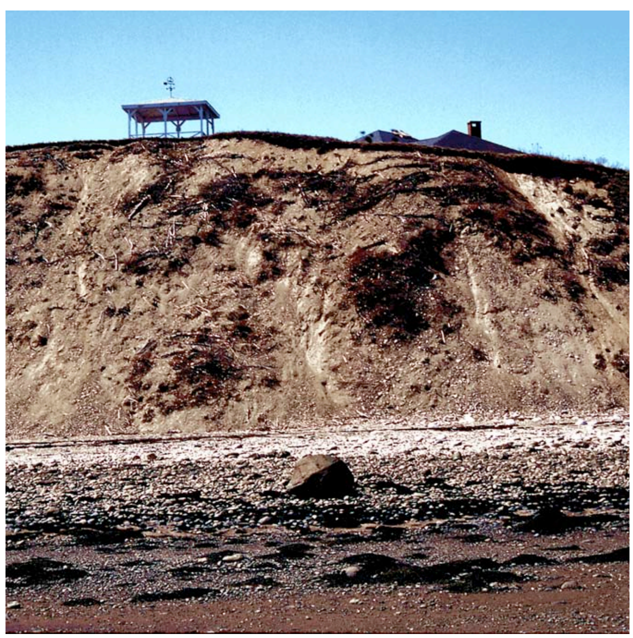
Generally, a project is considered a "reconstruction" if *rehabilitation, replacement or other improvement to a building the cost of which equals or exceeds 50% of the building's value prior to the start of the reconstruction* (Chapter 355, 3., EE.).

Reconstruction after severe damage, especially due to an ocean storm, is meant to allow for structures that were old and not necessarily built to modern coastal building standards to have a chance to be rebuilt on a coastal property while decreasing the overall risk to the structure, and its impact on the coastal sand dune system.

General guidance relating to reconstruction in the sand dune system to a structure severely damaged by an ocean storm is found at Chapter 355, 6., E. and F.

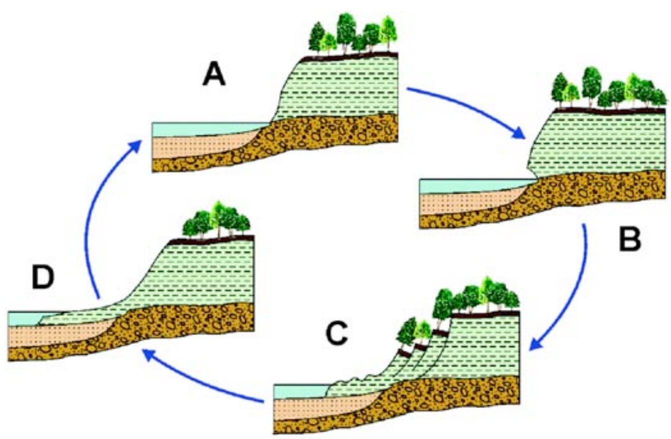
Coastal Bluffs and Erosion and Landslide Hazards
A coastal bluff is a steep shoreline slope formed in rock or sediment (clay, sand, gravel) that generally has three feet or more of vertical elevation just above the high tide line. Approximately 98% of Maine's shoreline is characterized as coastal bluff. Of this, 58% is considered to be "consolidated bluff," comprised of rocky material - these bluffs are not subject to significant erosion in a century or more.

The remaining 40% or 1,400 miles are classified as unconsolidated or "soft" bluff, comprised of erodable materials.



Unconsolidated bluffs are formed in a dynamic coastal environment by terrestrial and marine processes. Bluff erosion is part of a natural cycle with consequences for the land below and above the bluff. Fine-grained silt and clay eroded from bluffs may be deposited on mud flats or salt marshes and help reduce wave energy at the base of a bluff and slow the overall rate of bluff erosion. Coarse-grained sediments, such as sand and gravel, eroded from bluffs become part of a beach at the base of the bluff and help stabilize the shoreline position. Transfer of sediment from the land to the sea is natural and sometimes essential to sustain beaches, mud flats, or salt marshes. Bluff erosion can result in a landward shift of the top edge of the bluff. This shoreline change is a natural process that, by itself, is not a coastal hazard. Only when erosion threatens something of value, such as a building near the bluff edge, does bluff retreat become a hazard.

Bluffs typically respond to short term events such as storms and long-term sea-level rise by undergoing an erosive cycle as shown here. As part of this process, at time A, the water level increases and currents and waves attack the base of the bluff causing localized erosion at time B. This causes subsequent bluff instability, which can lead to a slump or a landslide at time C. The material within the slump sources the formation of an adjacent mudflat or salt marsh, and by time D, has helped stabilize the base of the bluff again.



Local bluff erosion rates affect the vulnerability, and perhaps longevity, of coastal development along a bluff edge. Even where steep banks line the shore, some bluffs may not change much over many years. Bluffs may not lose much ground in any one year, but instead slump a large amount of sediment once every few years. The bluff erosion rate will vary from year to year, much like the weather. A long-term average erosion rate is the most meaningful measure of bluff retreat and potential hazard to development on or above the bluff. Once the risk is evaluated, then appropriate solutions to reduce the risk can be considered and balanced with cost and environmental consequences.

Bluff erosion is a natural response to sea-level rise. Since bluff sediments formed thousands of years ago at the end of the Ice Age, no *new* bluff formation is expected. Bluff stability will vary based on the frequency of wave or storm attack, the inundation of the bluff to coastal flooding, and the ability of the bluff to shed sediment at a rate that would form a protective wetland or marsh in front of it.

Identification of Eroding Coastal Bluffs and Landslides
To aid individuals in identifying and characterizing the stability of coastal bluffs, MGS has produced a map series called Coastal Bluff Maps. MGS also created Landslide Hazard Maps that describe the *internal* stability of sediment bluffs. The companion Coastal Bluff Maps describe the processes and stability of the *face* of a bluff. These 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 and subsequent formation of landslides.

Additional map series available from the MGS show topography, sediment composition, groundwater characteristics, and bedrock geology – factors which influence the stability of a bluff or potential for landslides to occur. Some specific map titles are available online at the MGS website; others are available in print format at the MGS office. MGS geologists are available to explain these maps.

Features of Coastal Bluff Erosion
Generally, the sediments, slope, shape, and amount of vegetation covering a coastal bluff and the adjacent shoreline are directly related to the susceptibility of the bluff face to ongoing erosion. Unconsolidated "soft" bluffs can be categorized as being highly unstable, unstable, or stable.

Highly Unstable Bluff: Near-vertical or very steep bluff with little vegetation and common exposure of unstable, bare sediment. Fallen trees and displaced blocks of sediment are common on the bluff face and at the base of the bluff.

Example of highly unstable bluff exhibiting unvegetated bluff face and adjacent marsh at the base of the bluff. MGS file image.

Unstable Bluff: Steep to gently sloping bluff mostly covered by shrubs with a few bare spots. Bent and tilting trees may be present.

Stable Bluff: Gently sloping bluff with continuous cover of grass, shrubs, or mature trees. Relatively wide zone of ledge or sediment occurs at the base of the bluff. This category implies stability in the short term, based on observations at the time of mapping. Over time, stable bluffs can become unstable to cyclic changes (described above) or destabilizing natural or human events.

Landslides

One of the biggest hazards associated with coastal bluffs is the threat of landslides. In a landslide, earth materials move rapidly downslope under the force of gravity, usually in high coastal bluffs composed of muddy sediment.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.

The general term "landslide" is used to describe many types of earth movements, but in formal terms landslide should be used to refer only to mass movements, where there is a distinct zone of weakness that separates the displaced material from more stable underlying material. Landslides are classified into different types described below and on the opposite page (USGS, 2004).

Rotational slide (A). This is a slide in which the surface of rupture is curved concavely upward and the slide movement is roughly rotational.

Translational slide (B). In this type of slide, the landslide mass moves along a roughly planar surface with little rotation or backward tilting.

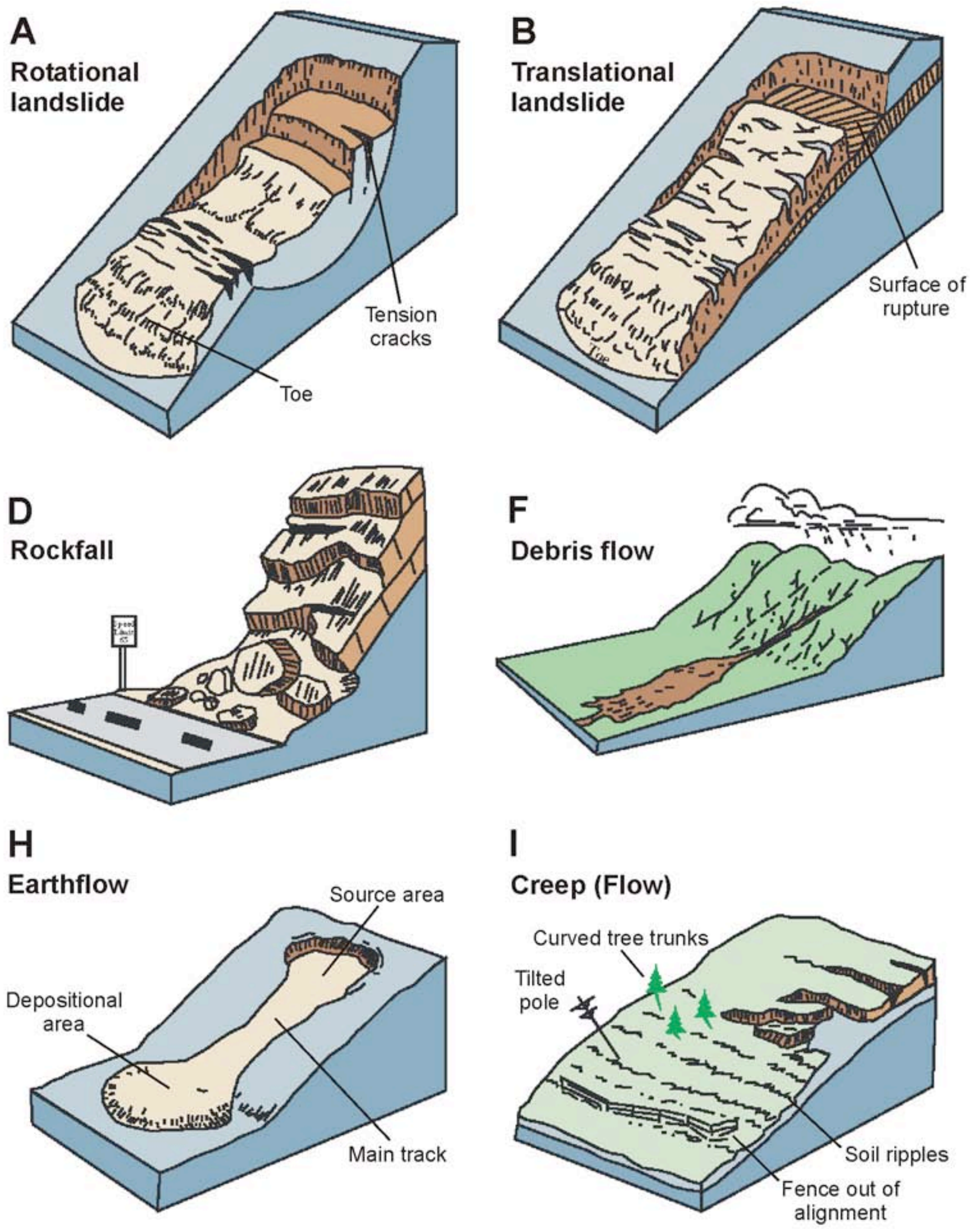
Rockfalls (D). Rockfalls are abrupt movements of masses of geologic materials, such as rocks and boulders, that become detached from steep slopes or cliffs.

Debris flow (F). A debris flow is a form of rapid mass movement, without a defined zone of weakness, in which a combination of loose soil, rock, organic matter, and water mobilize as a slurry that flows downslope.

Earthflow (H). An earthflow is a downslope viscous flow of fine-grained materials that have been saturated with water, and move under the pull of gravity.

Creep (I). Creep is the imperceptibly slow, steady, downward movement of slope-forming soil or rock. Movement is caused by shear stress sufficient to cause permanent deformation, but too small to cause shear failure.

Common Types of Landslides in Maine



Factors influencing Coastal Bluff Erosion and Landslides

Numerous, interconnected factors influence the overall stability of a bluff, bluff erosion, and the formation of landslides. Understanding these factors and looking for certain telltale characteristics associated with those factors can help you better understand the stability of your bluff.

The same factors that influence the formation of unstable coastal bluffs also affect landslide risk. The information provided below has been developed from text used for the MGS Landslide Hazard Maps, and information found at the State of Washington Department of Ecology website.

Height. The height of an unconsolidated "soft" bluff can indicate its overall stability and potential landslide risk, especially when taken into account with other factors. In general, the thicker (taller) the sediment deposit, the more likely its weight will cause subsurface movement or slippage that leads to a landslide. The risk of an unstable coastal bluff or landslide increases when mud bluffs have a height of 20 feet or more. The higher the exposed bluff face, the greater the risk of slope failure and a landslide.

Sediment type. As discussed previously, bluffs comprised of bedrock are eroding slowly, and their associated hazard is relatively low. But unconsolidated bluffs in Maine are comprised of a combination of materials.

Rock or ledge is much more stable than any sediment bluff and not likely to erode or slide. The elevation of bedrock at the shore and inland beneath a bluff is important in determining landslide risk. Bedrock exposures along the shoreline may slow erosion and make sediment less susceptible to landsliding. Beneath a sediment bluff, bedrock may rise toward the surface and reduce the overall thickness of sediment and thus reduce the risk of deep-seated movement below the ground surface.

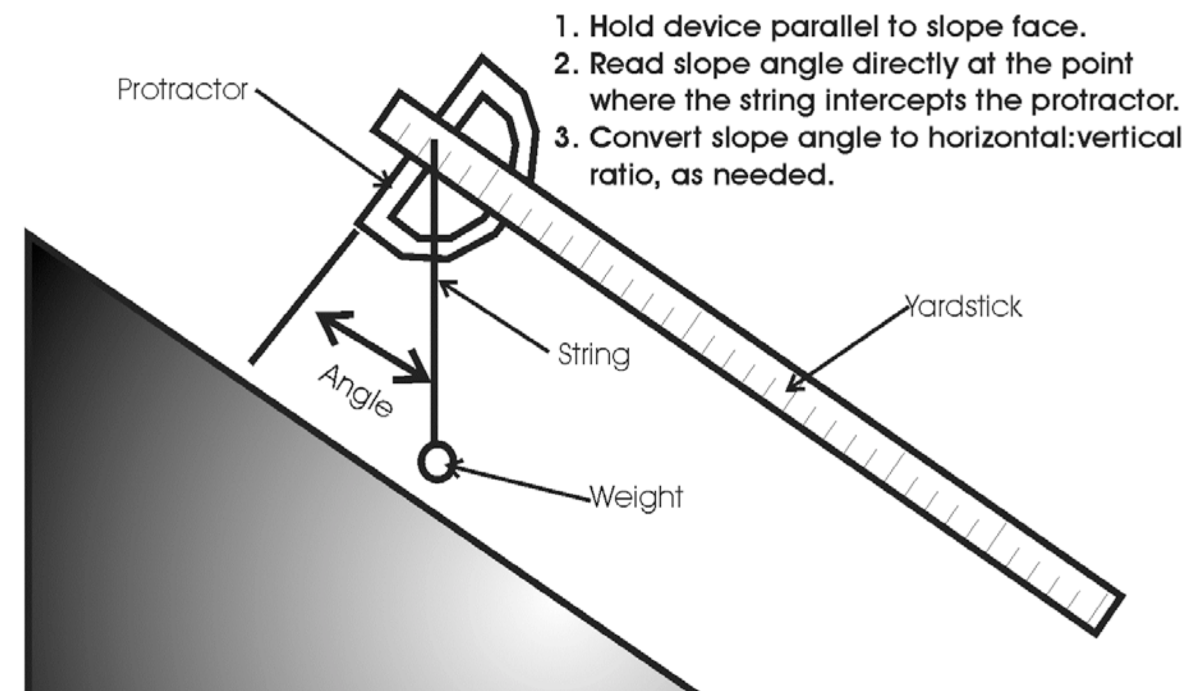
Clay and silt (mud) are the most unstable materials that can make up a bluff. These fine-grained sediments are weak and prone to slow-motion creep, moderate-sized slumping, or large landslides. Many bluffs in Maine are underlain with a gray clay known as the Presumpscot Formation.

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 prior earth movements. In general, the steeper the slope, the easier it is for gravity to initiate a landslide.

Concave surface topography will tend to concentrate the flow of surface water and ground water, raising ground-water pressures and reducing the strength of the soil. As a result, concave slopes are more susceptible to failure than straight slopes or convex slopes.

To determine the slope of a bluff, purchase an inclinometer or clinometer or make your own using a protractor, string, and a yardstick. The protractor is fastened securely to a yardstick with a string and weight attached. When the yardstick is held up and aligned with what appears to be the average slope of the land, the slope angle can be read directly from the protractor. This slope angle can then be converted to the appropriate horizontal/vertical ratio, if needed.



The quickest but least accurate way to estimate slope height is to visually estimate the height of some nearby vertical structure on the slope (i.e., tree or bluff face) and then estimate how many tree heights would equal the overall slope height.

Slope aspect. 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.

Microclimate and Aspect. The weather along Maine's diversely shaped coastline is strongly influenced by changing topographic and atmospheric conditions. The degree of precipitation, available sunlight, temperature, and wind can change radically from one section of coastline to another along the numerous bays, rivers, and headlands along the coast. The factors of microclimate and aspect (which direction your bluff faces) should be recognized in your site evaluations and planning effort which includes both planting and drainage control elements.

Waves, tides, and sea level. A gradual, but ongoing rise in sea level at a rate of about an inch per decade is causing chronic erosion along the base of many bluffs. As sea level rises, wave action and coastal flooding can reach higher and farther inland and scour more sediment from a bluff. Sea ice erodes tidal flats and the base of bluffs by abrasion and freezing sediment in ice blocks. Erosion can increase the steepness of a bluff slope and make it more susceptible to landsliding. Tides wash away eroded bluff sediment, allowing waves to move inland. Storm-driven wind, waves, and flooding can cause more extreme erosion at the base of a bluff, increase the bluff slope, and make a landslide more likely.

Topography. The presence of swales, gullies, or drainage channels on or adjacent to a shore site can affect surface water movement. These features can direct surface water flow towards or away from the bluff face and slope. They also affect the recharge of subsurface water and groundwater. The sometimes steep sides of such features can concentrate and accelerate runoff, increasing surface erosion. These features often indicate the site of past erosion or landslides. Modifications of existing topography should not be undertaken lightly.

Vegetation. The type, age, health, and abundance of vegetation growing on a bluff can offer valuable clues to slope stability. Even the presence of stumps and fallen trees can tell a story to a knowledgeable observer. This section discusses these clues and what they may indicate. Vegetative indicators are best interpreted in combination with soil and geological data.

In areas where the soil has shifted, either due to previous landslides or to gradual surface creep, 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.

Trees that appear to be jumbled in groups on slump blocks that have slid down a slope are called jackstrawed trees. Evidence of jackstrawed trees usually indicates that a groundwater problem or slope instability exists, which caused the mass of soil and associated vegetation to move downslope as a single unit or block.

Distinct lines of trees growing across a slope may indicate one of two different conditions. If the trees are young, fast-growing species, such as alder or willow, a previous landslide may have occurred, allowing these opportunistic species to colonize the slide site. The age of trees growing in this manner can be a clue to when the slide occurred.

A distinct line of water-loving (“hydrophilic”) tree species may indicate an area of perched water or groundwater seepage that in turn may indicate a layer of impervious material underlying a deposit of sandy soil. The presence of such trees may indicate site instability, and should be investigated by a geologist.

Drainage. Water in and on a coastal bluff - groundwater seepage within a bluff, or surface runoff on the bluff itself - are common factors influencing bluff instability. Observations of drainage factors are sometimes best made during or directly after periods of heavy rainfall, when surface runoff and groundwater discharge are at their peak. Water tables, and hence discharge, tend to be highest in spring as the ground thaws (Caswell, 1987).

Surface water. Wetlands, ponds, and streams above the bluff can supply water to the bluff face and also to the groundwater. Surface water, collected by roofs, driveways, paths, and lawns, flows toward and down the bluff face. Water that runs over the face of a bluff can wash sediment to sea, increase the bluff face slope, and weaken the remaining sediment holding up the bluff. Removal of sediment from the bluff face can increase the risk of erosion or a landslide. Direct rainfall to a bluff is sometimes the deciding factor influencing bluff stability. However, wind and frost wedging do act upon some exposed slopes.

Groundwater. Groundwater within a bluff comes from surface sources, such as rain or a stream, uphill in the local watershed. Groundwater tends to flow horizontally beneath the surface and may seep out the face of a bluff. Seeps and springs on the bluff face contribute to surface water flow and destabilize the bluff face. In addition, a high water table can saturate and weaken muddy sediment and make the ground more prone to slope failure.

Weathering. Weathering (aging) in clay and silt can affect the strength of bluff sediment and stability of the bluff face. Drying of clay can increase resistance to sliding. The seasonal cycle of freezing and thawing of the bluff face can lead to slumping after a thaw.

Earthquakes. Landslides can be triggered by earthquakes. Ground vibration loosens sediment enough to reduce the strength of material supporting a bluff and a landslide results. Most landslides triggered by earthquakes in sediment like that found in Maine have been of Richter magnitude 5 or more. These are relatively rare events, but a few have occurred in historical time in Maritime Canada.

Land use. Human activity and land use may contribute to or reduce the risk of a landslide. Actions that increase surface water flow to a bluff face, watering lawns or grading slopes, add to natural processes destabilizing the bluff face. Walkways down the face of a bluff can lead to greater erosion from foot traffic or the concentration of surface water flow. Elevated stairs can shade the slope and prevent vegetation from stabilizing the slope. Both surface and ground water above a bluff can be supplied by pipes, culverts, surface drains, and septic systems. Increased water below ground can weaken a bluff and contribute to internal weakness that leads to a landslide. Greater seepage of water out of the bluff face can also increase the risk.

Clearing vegetation from the bluff face can lead to greater bluff erosion and a steeper bluff that is more prone to landslide. Vegetation tends to remove ground water, strengthen soil with roots, and lessen the impact of heavy rain on the bluff face. *NOTE: Removal of vegetation within a shoreland zone increase the quality of a view may require a permit from the Maine DEP and/or your local town.*

Adding weight to the top of a bluff can increase the risk of a landslide. Buildings, landscaping, or fill on the top of the bluff can increase the forces that result in a landslide. Saturating the ground with water that raises the water table also adds weight. Even ground vibration, such as well drilling or deep excavation, may locally increase the risk of a landslide.

Shoreline engineering in the form of seawalls, rip-rap, or other solid structures used to reduce wave erosion at the toe of a bluff can increase the rate of beach or tidal flat erosion, undermine engineering, and result in less physical support of the base of the bluff by natural sediment. Where coastal engineering ends along a shoreline, "end effect" erosion can cause worse erosion on adjacent properties. Engineering alone cannot prevent some large landslides. In general, human activities that increase the amount or rate of natural processes may, in various ways, contribute to landslide risk.

See Appendix A for a **Coastal Property Owner: Bluff and Landslide Checklist** which outlines some of the key features to look for in assessing problems associated with bluff stability and landslide hazard. This checklist will allow you to organize your site observations, and help you determine the overall stability of bluffs on your property. We recommend that you use this checklist for general purposes only, and advise consultation with appropriate experts, such as licensed engineers or certified geologists.

Regulations Applicable to Activities on or near Coastal Bluffs

There are many local and state regulations that apply to activities on or adjacent to coastal bluffs relating to erosion and landslides. To help guide property owners, the Maine DEP has released A Homeowner's Guide to Environmental Laws Affecting Shorefront Property in Maine's Organized Towns *(*Maine DEP, 2000).

A general summary of applicable regulations to activities at Coastal Bluffs and Landslides are listed below.

Erosion and Sediment Control Law

The Erosion and Sediment Control Law erosion control provision is a very brief and basic standard requiring that a person who conducts an activity involving filling, displacing or exposing earthen materials take measures to prevent unreasonable erosion of soil or sediment beyond the project site or into a protected natural resource.

Shoreland Zoning Ordinance
By law, Maine communities adjacent to the ocean, lakes, rivers, some streams and wetlands, are subject to regulation under the Mandatory Shoreland Zoning Act. Generally, areas within 250 of one of the normal high water line are within the Shoreland Zone and subject to a community's Shoreland Zoning Ordinance.

Shoreland Zoning creates different types of districts within which you might be located that regulate certain activities within those districts, based on the presence of specific resources and uses. It is also used to establish certain setbacks from resources. The Maine DEP has released a Citizen's Guide to Shoreland Zoning which helps explain zoning districts and regulations (Maine DEP, 2008). Also note that vegetation removal within the Shoreland Zone is limited and may require a permit.

Consult your local Town Code Enforcement or Planning Department to determine the specific regulations within your Municipal Shoreland Zone.

Maine Natural Areas Protection Act (NRPA).
This includes Permit-by-Rule (PBR, permitting for *de minimus* activities), and full Individual Permits for certain activities. Activities within 75 feet of the Highest Annual Tide will require an NRPA permit. Activities within 25 feet of the HAT cannot be permitted with a PBR. Any coastal rip-rap stabilization will require a full NRPA permit.

Water Quality Certification.
An applicant for a federal license or permit to conduct an activity that may result in a discharge to a navigable water of the United States must supply the federal licensing authority with a water quality certification from the State that any such discharge will comply with State water quality standards. The federal license or permit may not be issued until water quality certification has been issued or waived.

Federal Clean Waters Act and Rivers and Harbors Act
Sections of the federal Clean Water Act and Rivers and Harbors Act govern activities within coastal wetlands (and therefore waters associated with bluffs) and tidal creeks and adjacent rivers. Permits are administered by both the US Army Corps of Engineers (US ACE) and the US Environmental Protection Agency (US EPA). Federal permitting includes comments provided by the US Fish and Wildlife Service and National Marine Fisheries Service. Text supporting both of these Acts can be seen at the Wetlands Regulation Center.

Section 10 of the Rivers and Harbors Act requires a US ACE permit for any work in navigable (tidal) waters below the mean high water line. Section 404 of the Clean Water Act requires a US ACE permit for the discharge of dredged or fill material into waters of the US.

The US EPA maintains good information describing the overall laws and applicable regulations that pertain to federal permitting of activities within waters of the United States.

What are my Adaptation Options?
The steps below summarize how coastal property owners can address problems associated with eroding coastal bluffs or landslide hazards.

1. Identify the hazard(s).
2. Classify the level of risk.
3. Determine if the hazard(s) identified can be mitigated.
4. Determine if the risks associated with known hazards are acceptable.
5. Determine setback standards.
6. Get appropriate permits.
7. Appropriately adapt to or mitigate the hazard.
    i. Doing nothing.
    ii. Avoid the hazardous area.
    iii. Relocate existing infrastructure.
    iv. Design and build properly.
    v. Plant erosion-resistant vegetation.
    vi. Divert water flow.
    vii. Change the slope of the land surface.
    viii. Stabilize the eroding slope.

1. Identify the hazard(s).
One of the first things that an individual can do in determining bluff hazards for their property is to ***identify your hazard*** *by using the numerous resources listed above* in conjunction with *doing a field inventory* of your property. Some of these "in the field" signs are outlined in the sections above and summarized in the Coastal Property Owner: Bluff and Landslide Checklist. Use available resources, including but not limited to the MGS series of maps, and additional applicable information, to preliminarily determine the stability of your bluff and the potential landslide hazard.

2. Classify the level of risk.
Once you have determined the presence or absence of hazards at your property, the next step is to classify the level of risk associated with each hazard. That is, if bluff erosion is occurring, at what rate in the short term? What is the long-term erosion rate? How close is your structure to the high water line?

Use the Coastal Property Owner: Bluff and Landslide Checklist to help determine the level of risk posed to your bluff property.

Especially in areas of high erosion and instability, it is recommended that you have a professional geologist or licensed geotechnical engineer investigate your property to help you further classify the risk.

3. Determine if the hazard(s) identified can be mitigated.
In conjunction with your professional(s), determine what hazards can expectantly be mitigated, and at what cost. For example, if you have identified an existing bluff erosion hazard, can you locate your structure so that it is well outside an expected

future erosion line? As part of this process, remember some of the goals, priorities, and expectations of the use of your property in conjunction with risk.

- **Be realistic.** It may not be technologically or economically feasible to stabilize certain types of slopes.
- **Be neighborly.** Think about potential impacts on your neighbor's property that may result from an activity on your property. At the same time, it may make sense to work with adjacent property owners if a common goal is found or regional approach is being adopted.
- **Consider the costs.** When comparing strategies, consider the short and long-term costs of different strategies.
- **Consider the permit requirements.** Make sure to fully assess the local, state, and federal permitting requirements – and their associated timeframes and costs.
- **Consider timeframes.** Some activities or strategies may have extended permit review processes, certain habitat types or timing restrictions, and extended construction timeframes. Also think about the timeframe of expected usage of your property.

4. Determine if the risks associated with known hazards are acceptable.
Taking into account the information that you developed in terms of mitigation as part of #3, determine *the level of risk you are willing to accept* to meet your goals, priorities, and expectations relating to the use of your property. For example, if you identified a bluff erosion or landslide hazard, are you willing to accept the risk associated with potential damage or loss of the structure in 5 years? 10 years? 15 years?

5. Determine setback standards.
If contemplating new construction, determine minimum appropriate setbacks based on your municipal shoreland zoning ordinance, other ordinances, and applicable state and federal rules. You may be required to not only set the structure back a certain distance, but to limit its overall size, or use certain types of setback construction techniques. Check with your local Code Enforcement Officer for specific information relating to setbacks and elevation standards.

6. Get appropriate permits.
Building or engineering on Maine's slopes and bluffs, especially along waterways or in coastal areas, is likely subject to regulation under the Natural Resources Protection Act and the Mandatory Shoreland Zoning Act. Permits from the Maine Department of Environmental Protection or your town may be required for site modifications. Local Code Enforcement Officers, in addition to consultants and engineers, should be able to give advice on local and state requirements for permits based on the activities you may be proposing on your property. Maine DEP is available for a pre-application meeting to explain the state standards.

7. Appropriately adapt to or mitigate the hazard.
You can take action to manage or reduce the risk of bluff erosion or landslide hazards impacting your property. These should be developed in conjunction with

the steps involved above, and input from appropriate local experts (certified geologists, licensed geotechnical engineers, landscape architects, etc.).

Addressing hazards sometimes may need to involve groups of coastal property owners to be most effective (e.g., bluff stabilization through plantings or construction or dewatering efforts). The mitigation and adaptation strategies listed below can be undertaken one-at-a-time, or using a site-specific, multi-strategy approach.

From an environmental impact standpoint, MGS generally recommends that alternatives be considered in the order listed. However, in many cases *a combination of several or all of the listed alternatives* can and should be considered in order to create a resilient coastal property. Appropriate mitigation strategies should be developed in conjunction with appropriate local experts.

To aid with development of appropriate mitigation alternatives, a guide to Maine Erosion and Sediment Control Best Management Practices, which contains techniques applicable to coastal bluff and landslide sites, has been developed by the Maine DEP. In support of this section on mitigating Coastal Bluffs and Landslides, specific attention should be given to supporting document links relating to:

- Land Grading and Slope Protection
- Permanent Vegetation
- Geotextiles
- Riprap Slope Stabilization
- Gabions
- Water Diversion
- Streambank Stabilization

Note that many of the techniques summarized may require permitting from the Maine DEP.

Doing nothing. Doing nothing makes the most sense where there is no structure on an eroding bluff, or if a structure is located a more than adequate distance from an eroding bluff or landslide site, and the bluff has a well-determined and steady erosion rate (determined in consultation with local experts). Doing nothing is sometimes considered last, after other, more expensive and intensive options have had no success. Doing nothing is *typically* a least-costly alternative and does not require permitting, unless erosion causes damage to property or infrastructure. The do nothing alternative *must* take into account the level of risk you are willing to accept in conjunction with the expected uses of your property. Coastal property owners located along eroding bluffs or near landslide prone areas should check their insurance policies relating to coverage.

Avoid the hazardous area. In a general sense, avoiding existing or potential hazards as much as possible is usually the most efficient and cost-effective method of mitigation, especially when siting new development. Choosing to avoid some areas and not others should be based on the hazards identified, their levels, mitigation strategies, and the level of risk you are willing to accept. A common avoidance technique is to build a structure far landward as possible. You may need to request a variance from local setback ordinances in order to do so.

As much as is practicable with your building considerations, consider **moving back to avoid some hazards. Consideration should also be given to significant habitat resources or environmentally sensitive areas**, which are usually identified by shoreland zoning or state regulations**.** However, it is not always practicable for existing development to avoid all hazards or habitats due to the location of a structure, presence of setbacks, lot size, cost, or other factors.

Relocate existing infrastructure. Where existing development is being threatened by bluff erosion or landslides, one of the most effective ways to ensure safety of a structure is to relocate the structure out of the hazardous area, typically in a landward direction. Although this method can be very effective in minimizing or mitigating the hazard, this alternative can be expensive. Costs can be quite variable (ranging from several thousand to tens of thousands of dollars) and are based on the existing foundation of the structure, size of the structure, topography, and distance the structure may need to be moved. Consultation with a local contractor is suggested, and local and state permits may be needed. Relocation of a structure can also be constrained by the size of a property and any applicable local or state setbacks, such as from other existing structures or roadways. In many cases, variances from local setback ordinances can be requested by a homeowner so that relocation may be undertaken.

Design and build properly. Following proper construction techniques involves not only construction siting (i.e., structure and support structures, including septic, utilities, etc.), but also design and building techniques that can withstand hazards and potential land, wind, and water forces associated with the dynamic coastal zone.

Give consideration to:

- The construction footprint in the face of applicable setbacks for hazards or sensitive areas;
- The extent of grading to achieve a stable building footprint;
- The level of engineering required to mitigate for hazards;
- Potential hydrostatic and wind loading;
- Water diversion;
- Siting of ancillary infrastructure; and
- General construction standards.

Some of the best and most comprehensive resources available to the general public regarding proper coastal construction techniques are the FEMA Coastal Construction Manual and the FEMA Home Builder's Guide to Coastal Construction Technical Fact Sheets. The Construction Manual is available as a CD or in print copy by calling FEMA Publications Distribution Facility at 1-800-480-2520, and should also be available for review at your local town office or public library.

Lot coverage requirements and building restrictions for different bluff areas may exist in municipal shoreland zoning ordinances or other local regulations.

Plant erosion-resistant vegetation. Stabilization of slightly eroding bluffs can be achieved through specific bluff planting techniques. The Washington Department of Ecology has provided a great guide on vegetative planting techniques. Many of the techniques are applicable to Maine, though species will be different.

The University of Maine Cooperative Extension has compiled a listing of native plant species in Maine, and a listing of nurseries and garden centers.

The Maine Natural Areas Program has created a book *Natural Landscapes of Maine: A Guide to Natural Communities and Ecosystems* that can generally be used to provide guidance on existing dominant vegetative species in different landscapes in Maine. MNAP also maintains a database of plant communities located at coastal headlands which can be used as general guidance for applicable species.

The Barnstable County Cooperative Extension office in Massachusetts maintains a list of trees and shrubs for coastal environments.

For additional information on appropriate vegetation species and techniques in Maine, consult with local landscape architects.

For the specific strategies listed below, we recommend consultation with a licensed geotechnical engineer and/or a professional geologist to determine which of these method(s) might be most applicable to and effective for an individual property.

Divert water flow. Installing surface and subsurface drainage devices within and adjacent to potentially unstable slopes. Surface and subsurface drainage design must include consideration of the effects of surface runoff and groundwater migration on the stability and water quality of adjacent sites. Surface contours can be designed to drain surface water on a site away from a bluff – this can substantially reduce infiltration and groundwater adjacent to a bluff face.

Some examples of techniques used for controlling surface and subsurface drainage along bluffs are well summarized by the California Coastal Commission.

Change the slope of the land surface. Reducing the overall slope or overhangs by grading the bluff to a lower angle can decrease the erosion and landslide hazard. Some slopes can be stabilized by terraces.

Stabilize the eroding slope. In locations where other strategies cannot be implemented, bluff stabilization could be considered. Techniques can include stabilization solely at the base of the eroding bluff, or stabilization of the entire bluff surface using a single technique or combination of tree rafts, wattles, geotextile fabrics, rip-rap, or gabion structures.

The costs associated with bluff stabilization can be quite high depending on the size and project design specifications. Permitting may be required for not only the actual activity, but also for staging or seasonal use of equipment, especially if it occurs from the seaward side of the project and is within the "coastal wetland" or below highest annual tide.

Refer to the Maine DEP BMP guide for more information specific to Maine. Additional resources regarding slope stabilization are provided by the US Army Corps of Engineers Coastal and Hydraulics Laboratory.

A note on rocky shores ("consolidated bluffs")
In the face of a rising sea, a homeowner may experience waves overtopping a rock-lined shore, causing erosion of upland property landward of the bluff face. There is no clear statutory or rule language on consideration of sea-level rise with regard to seawalls outside of the coastal sand dune system. Existing seawalls located along a consolidated bluff or on ledge *may potentially be expanded in height with an appropriate permit* on a case-by-case basis if regular flooding and overtopping and subsequent erosion can be proven. New seawalls are not permitted if they will adversely affect the Coastal Sand Dune System (see the section on beaches and dunes). The use of rip-rap on a consolidated bluff may be permitted by the DEP.

In these instances, activities would require permitting under the Maine NRPA, and Shoreland Zoning if they were 75 feet from the highest annual tide (see the section on applicable regulations above).

Coastal Wetlands

Under Maine Law, "coastal wetlands" are defined as *all tidal and subtidal lands; all areas with vegetation present that is tolerant of salt water and occurs primarily in salt water or estuarine habitat; and any swamp, marsh, bog, beach, flat or other contiguous lowland that is subject to tidal action during the maximum spring tide level as identified in tide tables published by the National Ocean Service* (38 MRSA, 480-B)*.*

Maine's coastline contains approximately 19,500 acres of coastal wetland, which is the most of any New England state, New York, or Canadian province on the Gulf of Maine (Jacobson and others, 1987). Marsh systems vary within Maine, generally based on the four different geomorphic compartments used to classify the Maine coast as outlined in the *Introduction to the Maine Coastline Section* of this Guide. These include, from southwest to northeast:

- Southwest Arcuate Embayments
- South-central Indented Shoreline
- North-central Island Bay Coast
- Northeast Cliffed Coast

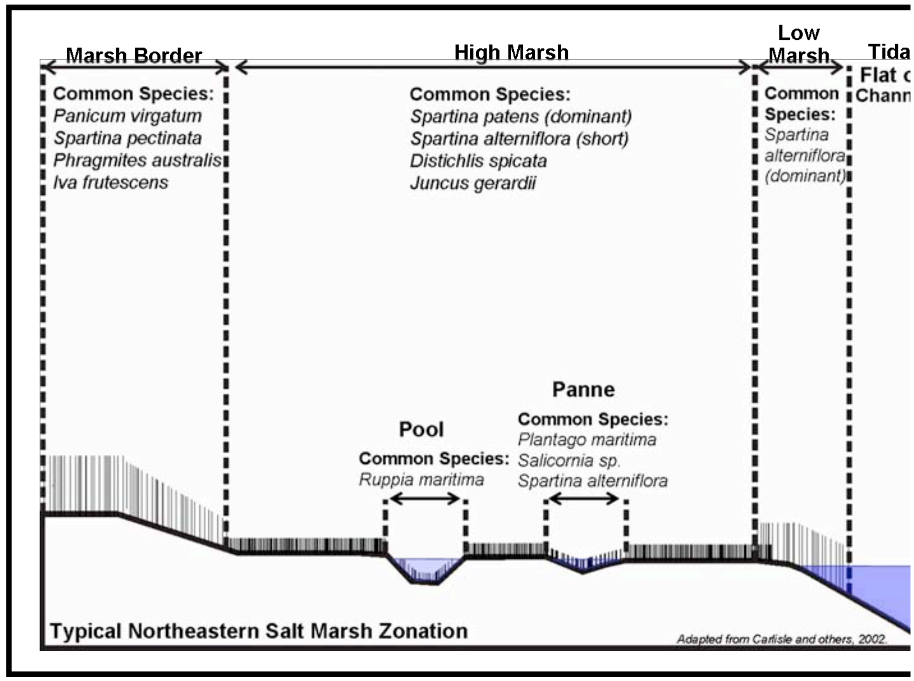
Coastal wetlands (or tidal marshes) systems within each of these compartments differ due to geology and tidal ranges. About 34% of Maine's marshes are found within the Arcuate Embayment compartment, which is dominated by extensive coastal barrier and marsh systems. Over 35% of Maine's marshes are located in the Indented Shoreline compartment, lending to the narrow embayments and tidal rivers that dominate this area. About 26% of marshes are located in the Island Bay Coast, which is dominated by high tidal ranges and large bays. Finally, only about 5% of Maine's marshes are located in the Northeast Cliffed Coast compartment due to the frequency of bedrock coast and few tidal rivers (Bryan and others, 1997).

Typical Coastal Wetland Features

Much of the information in this Guide is from Maine Citizen's Guide to Evaluating, Restoring, and Managing Tidal Marshes (Bryan and others, 1997). Several other sources for information on Maine's salt marshes include Maine Salt Marshes: Their Function, Values, and Restoration (Dionne and others, 2003) and Salt Marshes in the Gulf of Maine, Human Impacts, Habitat Restoration and Long-Term Change Analysis (Taylor, 2008).

Coastal wetlands within the State of Maine are typically comprised of several different zones of vegetation that are common to most coastal marsh systems. These features are dependent on the influence of tidal elevations, and include:

Low marsh, typically a sloping fringe of smooth cordgrass (*Spartina alterniflora*) between the high marsh and a tidal creek, is flooded twice daily by tidal action. Low marsh is much less common in Maine marsh systems than high marsh.



High marsh is at or just above mean high tide, and therefore is flooded only on monthly high tides (which occur for a few days during full and new moons) and irregularly by storm tides. Salt-hay grass (*Spartina patens*), and black grass (*Juncus gerardii*) are the dominant plants in most high marshes. In brackish marshes with a strong freshwater influence, plants such as prairie cordgrass (*Spartina pectinata*), narrow-leaved cattail (*Typha angustifolia*) or rushes (*Scirpus sp.*) may dominate. The high marsh is usually substantially level and occurs between the low marsh and uplands. Most of Maine's marsh systems are dominated by high marsh.

Pannes are shallow "ponds" that form in the high marsh peat. Flooded periodically, pannes provide an abundance of food for waterfowl and migrating shorebirds. A short form of smooth cordgrass frequently occurs in these areas. Common glasswort (*Salicornia europaea*) and other non-grassy plants often colonize shallow pannes that dry out. Much of the plant diversity on the salt marsh is associated with these shallow pannes. Deeper pannes that remain water filled may support widgeon grass (*Ruppia maritima*), which is valuable forage for waterfowl.

Tidal creeks, open water, and tidal flats are all-important components of the marsh ecosystem. Open water is generally defined as a permanently flooded (i.e., below mean low water) water body greater than 100 meters (330 feet) wide. Tidal creeks are less than 100 meters wide at mean low water. Tidal flats are nearly level to gently sloping unvegetated areas located within the intertidal zone. Tidal flats may support commercially significant marine worm and clam populations.

Together, these different zones form a marsh ecosystem. Marsh systems in Maine can generally be classified into three different types based on their overall geomorphology and shape. These include:

Coastal/Back Barrier Marshes • associated with barrier beaches • marshes are located adjacent to the Atlantic coast and have direct access to the ocean through tidal inlets • dominated by high marsh • Example from Webhannet River, Wells	
Finger Marshes • area of high marsh is large compared to size of channel • elongated marsh follows the long axis of a channel • Example from Cousins River, Yarmouth	
Fringe Marshes • found along protected shoreline in estuarine reaches and rivers (coves, indentations, small tributaries, meanders) or at the toe of eroding bluffs • limited development of high marsh • strongly influenced by ice erosion; also affected by erosion from river flow and waves • often bordered by mud flats • Example from Presumscot River, Portland	

Why are coastal wetlands important to the Maine coast?

Wetlands provide a variety of valuable ecological (e.g., habitat) and societal (e.g., economic) benefits, and these values are closely related (e.g., wildlife habitat and recreation). Some important functions of marshes include:

- **Shoreline anchoring** – coastal wetlands generally "anchor" barrier beaches to the mainland. To an extent, their accreting surfaces maintain elevation as sea level rises.
- **Storm surge protection** – coastal wetlands provide vital storm surge protection by slowing wind driven waves over the marsh, thereby helping to protect low-lying uplands and erodable shorelines during storms.
- **Natural pollutant buffer** - pollutants entering aquatic systems are attached to sediment particles that are deposited on the marsh, limiting their transport to other ecosystems. Some pollutants may then bind with soil particles and become unavailable for uptake by plants or animals.
- **Vital habitat** - Salt marshes are used for food and shelter by a diverse animal community, including many species of birds, fish, and shellfish.
- **Recreational and commercial potential** – coastal wetlands support activities such as hunting, fishing, birdwatching, clamming, etc.
- **Aesthetic quality** – coastal wetlands enhance the aesthetic qualities of the coastal landscape.

Many of these ecological functions have *tremendous societal value through economics*. For example, two-thirds of commercial shellfish and finfish landed in the US depend on coastal wetlands for nursery and breeding habitat or on forage fish that breed in our coastal wetlands (Gosselink and others, 1974). Recreational fishing, hunting, wildlife watching, and boating in coastal wetlands also contribute significant economic value.

Threats to Coastal Wetlands

The threats to coastal wetlands are many, both natural and human-made. Historically, coastal wetlands in Maine have been able to maintain themselves in relation to sea level because the rate of sedimentation (i.e., input of sediment to the marsh system) has generally met or exceeded the rate of sea-level rise. With the current rates of sea-level rise in Maine measured between 1.80-2.0 mm/yr (7.2-8") over the past century, marshes have generally been able to keep pace. However, if rates of sea-level rise increase as predicted to near 4 mm/yr, there is a chance that marsh drowning and loss could occur if sedimentation rates cannot keep up with the rate of sea-level rise (Wood and others, 2009).

Humans have drastically altered the coastal environment and wetland habitat, either through direct ditching for mosquito control or salt hay farming, to filling of wetlands, or bulkheading (with a wall or other barrier) the upland/wetland interface. Damming of rivers that empty into salt marshes, combined with engineering of the wetland/upland interface to protect from flooding and marsh encroachment, has decreased the amount of sediment available to the system. Wakes from motorboats can cause tidal bank erosion. Construction of roadways or the use of undersized culverts have caused tidal restrictions and inhibited required tidal flow for adequate flushing of coastal wetlands. Coastal wetlands are also significantly impacted by adjoining land uses and activities, including potential nutrient loading from lawn fertilization, and runoff from road surfaces and paved areas.

Coastal Wetland Hazards
Just like on the open coast, the boundary between coastal wetlands and adjacent uplands is not static, and changes in response to daily and annual high tides, storm events, and sea-level rise. Understanding and taking into account the natural functionality of the system – and the associated hazards – in conjunction with your intended uses of your property, is vital to developing an appropriate management and adaptation plan for the coastal wetlands on or adjacent to your coastal property.

At a minimum, you need to balance the natural, landward migration of coastal wetlands with the protection of your property from coastal erosion and coastal flooding, the two major hazards associated with this coastal environment. In many cases, significant balancing or trade-offs associated with other factors need to be taken into account, including the use of the property, costs, and impacts to adjacent properties or habitats.

Coastal Wetland Erosion
Erosion of marsh surfaces can be caused by tidal currents, wind-driven waves, boat wakes, foot traffic, and ice floes.

Tidal currents. Ebbing and flooding tidal currents can be fast enough to erode marsh surfaces, especially along the edges of tidal channels where a channel meanders, or bends sharply.

Wind-driven waves. Waves, especially those associated with storms, can erode marsh surfaces, especially at lower tides (at high tides during a storm, waves travel over the marsh surface). This relates to the aspect (or direction) that a marsh faces and the fetch (distance) that the wind can blow over the water. A larger fetch will allow larger waves to form. Typically, those marsh surfaces or channels that face to the northeast are most susceptible to erosion during Maine's common northeast storm events.

Boat wakes. Marsh banks along tidal channels can be impacted by wakes from heavy motorboat usage, which causes abnormally large waves to erode the edges of the marsh.

Foot traffic. In some areas where people walk across marsh surfaces to access fishing, fowling, or recreational locations, heavy foot traffic, even for a short amount of time, can damage marsh vegetation and erode the surface of the marsh.

Ice floes. In winter, high tides can lift frozen blocks of ice and transport them across the marsh. This process can erode sections of the marsh surface. In other instances, the ice floes actually transport sediment from one area of the marsh to another (e.g., a floe laden with sediment from the side of a tidal channel, can be carried by a spring tide or coastal flood over the high marsh and deposit sediment later when it melts).

Coastal Wetland Flooding
The flooding of uplands adjacent to coastal wetlands is a common occurrence, but usually limited to times of highest annual tide, heavy inland rain or spring melt, or during periods of storm surge. Low-lying areas that are inundated periodically during highest annual tide conditions, from a regulatory standpoint, are part of a coastal wetland since they are at or below the reach of the tides.

"Chronic" coastal flooding is when property is flooded on a regular basis by normal high tides or minimal storm surges, during periods of heavy rain or spring melt. "Acute" coastal property flooding typically occurs only in larger storm events and storm surges, and does not occur on a regular (annual or semi-annual) basis.

Identification of Coastal Wetlands and Flooding Hazards

National Wetlands Inventory (NWI) Maps
The National Wetlands Inventory created by the US Fish and Wildlife Service (USFWS) provides a good source for identification of coastal wetlands on a macro-scale. These maps, produced at a 1: 24,000 scale, provide *general* wetland characteristics for areas that coincide with the US Geological Survey 7.5 Minute Quadrangle maps. The series uses a wetlands classification scheme identified by codes on the maps. These codes identify wetland types. Most tidal or intertidal wetlands are classified as E2EM (Estuarine Intertidal Emergent, salt or brackish marsh) or R1EM (Riverine Intertidal Emergent, tidal freshwater marsh). An example of a portion of an NWI quadrangle is provided at the MGS website.

Note that NWI maps were created using 1980s aerial photographs, so existing marsh conditions may be different than those mapped. NWI maps should be available from your town office, or can be purchased from the Maine Geological Survey. They are also available for viewing online via the US Fish and Wildlife Service's geospatial wetlands digital data mapping service.

Coastal Marine Geologic Environment (CMGE) Maps
The MGS Coastal Marine Geologic Environment (CMGE) maps show regional characteristics of the Maine coast. They illustrate which areas are rocky, muddy, sandy, etc. along the shoreline between the high- and low-tide lines. These maps include coastal wetlands in areas of the state where MGS has not published detailed Beach and Dune Photos for use in the DEP permitting process. These maps illustrate the location of salt marshes and other tidal wetlands for evaluation of coastal habitats, impact of dredging, and siting of coastal facilities. The maps are available in paper version from the MGS office.

Shoreland Zoning Maps
By law, Maine communities adjacent to the ocean, lakes, rivers, some streams and wetlands, are subject to regulation under the Mandatory Shoreland Zoning Act. Generally, areas within 250 feet of the normal high water line are within the Shoreland Zone and subject to a community's Shoreland Zoning Ordinance. Maine DEP has released a Citizen's Guide to Shoreland Zoning which helps explain zoning districts and regulations.

For most areas, applicable shoreland zoning maps for your community typically identify coastal wetlands within your town's boundaries, which are then used to establish buffers and setbacks. These maps may use the NWI wetland maps for base information, or may incorporate more updated information.

Check with your town office to find the most recent shoreland zoning map for your area.

Beach and Dune Geology Aerial Photographs
The Beach and Dune Geology Aerial Photographs created by MGS identify the dominant features of the coastal sand dune system – frontal and back dunes - but also show other features of the beach and dune system, including coastal wetlands. These include:

- Dunes (frontal and back dunes, washover fans);
- Beaches (sand, gravel, boulder, or low-energy);
- Channels (tidal, dredged, channel bar/tidal delta, supratidal);
- Coastal wetlands and shoals (high salt marsh, low salt marsh, freshwater marsh, freshwater pond, ledge); and
- Coastal engineering and uplands (coastal engineering structure/fill, glacial/bedrock highlands).

These photographs are available for viewing online at the MGS website and are also available through the local Maine DEP office, and may also be available at your local town office. Not all coastal sand dunes and wetlands in Maine are mapped this way. Additional dune and beach environments are shown on the CMGE map (described previously).

MGS/DEP Tide Highest Annual Tide Tables
To support the Maine DEP, MGS has created a table which lists the highest annual tides (HAT) for many communities along the Maine coastline. The data are meant to establish the upper limits of the coastal wetland, based on the regulatory definition, using tide tables and tidal range data from the NOAA CO-OPS website. HAT elevation data for the current year are available for download from the Maine DEP Shoreland Zoning web page.

Coastal Light Detection and Ranging (LIDAR) data
Light Detection and Ranging (LIDAR), highly accurate topographic data (typical vertical resolution of 30 cm overall) collected using an aircraft and lasers, can be used for a multitude of coastal planning purposes. A good resource showing how

LIDAR data are collected is provided by the NOAA Coastal Services Center. The NOAA CSC also maintains a database of collected LIDAR data for Maine, including LIDAR flown in 2000, 2004, and 2007 in its Digital Coast Viewer. If you have GIS capabilities, you can view LIDAR data collected along the Maine coastline and get a sense of coastal elevations on or adjacent to your property.

Mapping of Potential Future Coastal Wetlands after Sea-level Rise
MGS has used tidal elevations and LIDAR data to simulate the potential impacts of sea-level rise on the coastal wetland boundary (highest annual tide). MGS completed pilot study mapping of the potential changes to the coastal wetland boundary after one, two, and three feet of sea-level rise for the Drakes Island and Wells Beach, Wells area (Slovinsky and Dickson, 2006). Additional online reports and maps for coastal communities in southern Maine will be posted on the MGS website.

FEMA Flood Insurance Rate Maps: Coastal Flood Hazard Areas
Both "dynamic" (including the influence of waves) and "static" flood hazards are mapped by the Federal Emergency Management Agency (FEMA) in a series of maps called the Flood Insurance Rate Maps (FIRMs), which are used to identify flood risk and insurance premiums in areas associated with different flooding events. These events include the 100-year (i.e., 1% chance of being equaled or exceed each year) and 500-year (0.2% chance of being equaled or exceeded each year) flood elevations. FEMA has developed information on each specific flood zone and how to read FIRMs.

MGS conducted a Coastal Erosion Assessment for Maine FIRMs and Map Modernization Program report (Dickson, 2003) which outlined shoreline erosion impacts to FEMA FIRMs for the majority of southern Maine. The assessment includes some detailed information on different coastal communities regarding general erosion rates and trends. FEMA FIRMs are available for viewing at your town office, can be requested from the Maine State Planning Office of Floodplain Management, or can be viewed online from the FEMA Map Service Center.

The Office of Floodplain Management has also released a Maine Floodplain Management Handbook which can be a great resource to property owners.

Coastal Inundation from Hurricanes: SLOSH
The National Hurricane Center runs a computer model called SLOSH (Sea, Lake, and Overland Surges from Hurricanes) to estimate storm surge heights and winds associated with hurricane events, ranging from Category 1 through 5 events. The US Army Corps of Engineers, in conjunction with the NHC, have developed Hurricane Surge Inundation Maps for the Maine coastline for hurricane events striking the coast at mean tide and mean high tide levels. These surge elevations and their inland graphical extent represent the potential maximum surge for a given location. This data can be used for *preliminary planning purposes* to help identify areas that may potentially be inundated during a tropical event. GIS data layers are available for download through the Maine Office of GIS.

Regulations Governing Coastal Wetlands and Coastal Flooding

Wetlands and Waterbodies Protection (Chapter 310)

The Maine Natural Resources Protection Act (NRPA) includes Chapter 310, Wetlands and Waterbodies Protection, which govern activities in or adjacent to wetlands of Maine, including coastal wetlands. This Chapter describes the value of wetlands, and reviews activities for which a permit may be required, outlines information required for permit applications, and information on mitigation, compensation, and enhancement. No permit is required if activities in coastal wetlands impact less than 500 square feet of intertidal or subtidal area, and has no adverse effect on marine resources or on wildlife habitat as determined by Maine DMR or Maine IF&W (Chapter 310, C., 6., (b)).

Coastal Sand Dune Rules (Chapter 355)

The Maine Natural Resources Protection Act (NRPA) includes Chapter 355, Coastal Sand Dune Rules, which governs activities within the mapped Coastal Sand Dune System, which can include coastal wetlands. The Coastal Sand Dune Rules, administered by Maine DEP, have specific guidelines for activities that require permits, or for *de minimus* activities, those not requiring permits. Specific sections of the Rules will be referenced in relation to mitigation activities and potential permits required, below.

The boundaries of the Coastal Sand Dune System, including coastal wetlands, are portrayed on the MGS Beach and Dune Geology Aerial Photographs described above.

Permit By Rule (Chapter 305)

Some activities within the coastal sand dune system can be undertaken with a Chapter 305, Permit By Rule (PBR). A PBR activity is considered one that will not significantly affect the environment if carried out in accordance with Chapter 305 standards, and generally has less of an impact on the environment than an activity requiring an individual permit. A PBR satisfies the Natural Resources Protection Act (NRPA) permit requirement and Water Quality Certification requirement. Many activities within coastal wetland can be permitted under Chapter 305.

Maine's Shoreland Zoning

By law, Maine communities adjacent to the ocean, lakes, rivers, some streams and wetlands, are subject to regulation under the Mandatory Shoreland Zoning Act. Generally, areas within 250 of one of the normal high water line are within the Shoreland Zone and subject to a community's Shoreland Zoning Ordinance.

Shoreland Zoning creates different types of districts within which you might be located that regulates certain activities within those districts, based on the presence of specific resources and uses. It is also used to establish certain setbacks from resources. The Maine DEP has released a Citizen's Guide to Shoreland Zoning which helps explain zoning districts and regulations.

Consult your local municipal Code Enforcement or Planning Department to determine the specific regulations within your town's Shoreland Zone.

Federal Clean Waters Act and Rivers and Harbors Act
Sections of the federal Clean Water Act and Rivers and Harbors Act govern activities within coastal wetlands and tidal creeks and adjacent rivers. Permits are administered by both the US Army Corps of Engineers (US ACE) and the US Environmental Protection Agency (US EPA). Federal permitting includes comments provided by the US Fish and Wildlife Service and National Marine Fisheries Service. Text supporting both of these Acts pertaining to coastal wetlands can be seen at the Wetlands Regulation Center.

Section 10 of the Rivers and Harbors Act requires a US ACE permit for any work in navigable (tidal) waters below the mean high water line. Section 404 of the Clean Water Act requires a US ACE permit for the discharge of dredged or fill material into waters of the United States.

The US EPA maintains good information describing the overall laws and applicable regulations that pertain to federal permitting of activities within wetlands in the United States.

Eroding Wetlands and Coastal Flooding: What can I do?
Whether you are considering buying or building on a coastal property, or already own coastal property, you have several overall strategies for addressing coastal wetlands and associated erosion and flooding hazards:

1. Identify the hazard(s).
2. Classify the level of risk.
3. Determine if the hazard(s) identified can be mitigated.
4. Determine if the risks associated with known hazards are acceptable.
5. Determine setbacks or elevation standards.
6. Get appropriate permits.
7. Appropriately adapt to or mitigate the hazard.
    i. Do nothing.
    ii. Avoid the hazardous area.
    iii. Build properly.
    iv. Relocate existing infrastructure.
    v. Elevate structures with flow through foundations.
    vi. Upland/wetland fringe vegetation management.
    vii. Marsh restoration or creation.
    viii. Rip-rap or bulkheads.

1. Identify the hazard(s).
One of the first things that an individual can do in determining hazards associated with coastal wetlands for their property is to identify the hazard by using the numerous resources listed above in conjunction with *doing a field inventory* of your property. Field identification of general coastal wetlands characteristics is outlined well in the Maine Citizens Tidal Marsh Guide, Section 4.

Once you have identified presence, absence, and extent of coastal wetlands on or adjacent to your property using the resources described here (e.g., NWI maps, Beach and Dune Photos, shoreland zoning maps), the next step is to classify the types and features of coastal wetlands on your property. This can include confirming information from the listed resources, and steps outlined in the Maine Citizens Tidal Marsh Guide. Additional assessments to identify existing hazards associated with the wetlands on or adjacent to your property may include the aspect of the property, elevation in relation to highest annual tide or base flood elevation, etc. Think about how existing wetlands, and their associated hazards like erosion and flooding, may respond to sea-level rise or increased storm events.

Although many levels of assessment can be done on your own, it may make sense to hire qualified experts.

2. Classify the level of risk.
Once you have determined the presence or absence of hazards at your property, the next step is to classify the level of risk associated with each hazard. That is, if tidal marsh or bank erosion is occurring, at what rate in the short term? The long term? How close is your structure to the highest annual tide?

We have created a summary checklist that can aid property owners in determining the level of hazard posed due to erosion and coastal flooding (see Appendix A, Coastal Wetland and Coastal Flooding Checklist).

It is recommended that you have a professional geologist, licensed geotechnical engineer, or coastal floodplain expert investigate your property to help you further classify the risk associated with identified hazards, including erosion and coastal flooding.

3. Determine if the hazard(s) identified can be mitigated.
In conjunction with your professional, determine what hazards can expectantly be mitigated, and at what cost. For example, if you have identified an existing flood hazard, can you elevate your structure so that it is well above a base flood elevation? Or, if you identify that a portion of your property is below the highest annual tide, can you site development outside of this low-lying area? As part of this process, remember some of the goals, priorities, and expectations of the use of your property.

- **Be realistic.** It may not be technologically or economically feasible to protect a structure on a coastal lowland that is eroding or flooding frequently.
- **Be neighborly.** Think about potential impacts on your neighbor's property that may result from an activity on your property. At the same time, it may make sense to work with adjacent property owners if a common goal is found or regional approach is being adopted.
- **Consider the costs.** When comparing strategies, consider the short and long-term costs of different strategies.
- **Consider the permit requirements.** Make sure to fully assess the local, state, and federal permitting requirements – and their associated timeframes and costs.
- **Consider timeframes.** Some activities or strategies may have extended permit review processes, limited activities in certain habitat types or time of year restrictions, or extended construction timeframes. Also think about the timeframe of expected usage of your property and the potential impacts of sea-level rise.

4. Determine if the risks associated with known hazards is acceptable.
Taking into account the information that you developed in terms of mitigation as part of #3, determine *the level of risk you are willing to accept* to meet your goals, priorities, and expectations relating to the use of your property. For example, if you identified a flood hazard that includes where your structure is (or will be) located, are you willing to accept the risk associated with potential damage or loss of the structure due to flooding?

5. Determine setbacks or elevation standards.
If contemplating new construction, determine minimum appropriate setbacks based on your municipal Shoreland Zoning Ordinance, floodplain ordinances, and applicable state rules. You may be required to not only set the structure back a certain distance, but to limit its overall size, or elevate it so that the lowest

structural member is a certain height above the minimum base flood elevation if in a flood zone. Check with your town's code enforcement office for specific information relating to setbacks and elevation standards.

6. Get appropriate permits.
Building in or adjacent to a coastal wetland, in the coastal sand dune system, or a flood zone, including pursuing potential mitigation strategies, may be subject to regulation under the Natural Resources Protection Act (Chapters 310, 355, 305) and the Shoreland Zoning Act. Permits from the Maine DEP and your town may be required. Local Code Enforcement Officers, in addition to consultants and engineers, should be able to give advice on local and state requirements for permits based on the activities you may be proposing on your property.

7. Appropriately adapt to or mitigate the hazard.
You can take action to manage or reduce the risk of upland property erosion or coastal flooding impacting your property. These activities should be developed in conjunction with the steps involved above, and input from appropriate local experts (certified geologists, geotechnical engineers, landscape architects, floodplain experts, etc.).

Mitigating a hazard or hazards sometimes may need to involve groups of coastal property owners to be most effective (e.g., wetland creation or restoration). The mitigation and adaptation strategies listed here can be undertaken one-at-a-time, or using a multi-strategy approach that is most applicable to your case.

NOTE: One consideration for adaptation and mitigation is the potential position of the future coastal wetland; that is, where the wetland boundary might be after sea-level rise is taken into account. Maine has adopted an expected two feet of sea-level rise over the next 100 years in terms of its regulations (Chapter 355, Coastal Sand Dune Rules). We recommend that any adaptation and mitigation plans relating to coastal wetlands take the expected change of the elevation of the highest annual tide (upper boundary of the coastal wetland) into consideration. MGS has completed pilot study mapping of the potential changes to the coastal wetland boundary after one, two, and three feet of sea-level rise for the Drakes Island, Wells area (Slovinsky and Dickson, 2006). Additional reports and maps for coastal communities in southern Maine will be released on the MGS we site.

Doing nothing. In cases where tidal bank erosion is minimal and a structure is located a more than adequate distance from the edge of a wetland, and a defined erosion rate has been determined (in consultation with local experts), a coastal property owner simply can opt to do nothing. Doing nothing is sometimes considered a last alternative – after other, more expensive and intensive options have been undertaken with no success, but doing nothing is *typically* a least-cost alternative and does not require permitting, unless erosion or flooding causes damage to property or infrastructure. The do nothing alternative *must* take into account the level of risk you are willing to accept in conjunction with the expected uses of your property.

Avoid the hazardous area. Avoiding existing or potential hazards as much as possible can be a very efficient and cost effective method of mitigation, especially when siting new development or considering future development. Choosing to avoid some areas and not others should be based on the hazards identified, their levels, mitigation strategies, and the level of risk you are willing to accept. A common avoidance technique is to build a structure as far away from the identified hazard as possible. You may need to request a variance from local setback ordinances in order to do so. Another method could include elevating a structure over and above minimum base flood elevation standards.

As much as is practicable with your building considerations, consider **moving back and moving up to avoid some hazards. Consideration should also be given to significant habitat resources or environmentally sensitive areas**, which are usually identified by shoreland zoning or state regulations**.** However, it is not always practicable for existing development to avoid all hazards or habitats due to the location of a structure, presence of setbacks, lot size, cost, or other factors.

Build properly. For construction in flood-prone areas, in the coastal sand dune environment, or on or adjacent to coastal wetlands, it is vital to follow proper construction techniques. This involves not only construction siting (i.e., structure and support structures, including septic, utilities, etc.), but also design and building techniques that can withstand hazards and potential wind and water forces associated with the dynamic coastal zone.

Consideration should be given to the following:

- the construction footprint in the face of applicable setbacks for hazards or sensitive areas;
- the extent of grading to achieve a stable building footprint;
- the level of engineering required to mitigate for hazards;
- potential hydrostatic and wind loading;
- siting of ancillary infrastructure; and
- general construction standards.

Some of the best and most comprehensive resources available regarding proper coastal construction techniques are the FEMA Coastal Construction Manual and the FEMA Home Builder’s Guide to Coastal Construction Technical Fact Sheets. The Construction Manual is available as a CD or in print copy by calling FEMA Publications Distribution Facility at 1-800-480-2520, and should also be available for review at your local town office or public library.

Lot coverage requirements and building restrictions for different dune areas, including some flood hazard zones, are provided in the Coastal Sand Dune Rules (Chapter 355).

Relocate existing infrastructure. Where existing development is being threatened by coastal erosion or flooding, one of the most effective ways to ensure safety of a structure is to relocate the structure out of the hazardous area, typically in a landward direction, or elevate the structure higher. Although this method can be very effective in minimizing or mitigating the hazard, this alternative can be quite expensive. Costs can be quite variable (ranging from several thousand to tens of thousands of dollars) and are based on the existing foundation of the structure, size of the structure, topography and underlying geology, and distance the structure may need to be moved or elevated. Consultation with a local contractor is suggested, and local and state permits may be needed. Relocation of a structure also can be constrained by the size of a property and any applicable local or state setbacks, such as from other existing structures or roadways. In many cases, variances from local setback ordinances can be requested by a homeowner in order to relocate a structure.

Elevate structures. Existing structures that are threatened with coastal flooding or erosion can benefit from elevation. If you are located in a FEMA Flood Zone, you may be required by your town's floodplain management ordinance to have the lowest structural part of your house be a minimum of one foot above the base flood elevation (this is typically the minimum standard).

If your structure is older and has been flooded and does not meet current standards, any time you are doing substantial improvements to your structure, you may want to consider the cost of elevating the structure using a flow-through foundation or a pile foundation. This may be a requirement if structure improvements meet or exceed 50% of the value of the structure.

Flow-through foundations are typically block or poured cement foundations with adequate spacing for floodwaters to flow through the foundation without damaging the supports. These structures are acceptable in the A-zone areas of back dune environments that are not considered to be Erosion Hazard Areas.

Pile foundations, though more prevalent on the open ocean coastline, are typically used in more active flooding areas, and provide much more open space for floodwaters to travel through. Piles are required in the frontal dune and in areas of the back dune classified as Erosion Hazard Areas.


Example of Pile Foundation, Saco, ME. Image by P.A. Slovinsky, 12/2009.

The concept behind both these foundation types is that water, sediment, and debris can *travel through* the foundation, thus avoiding significant pressure and lateral force to the foundation which causes structural failure. Both foundation types can significantly reduce potential flood damage to a structure.

In some areas of the back dune, fill can be added below a foundation to increase the elevation of the structure to meet floodplain standards. **This technique is not recommended, as it can potentially increase flood hazard to adjacent properties**, and thus might not meet NRPA standards.

Many of the state requirements regarding elevation of structures, including a review of techniques, are outlined in Chapter 5 of the Maine Floodplain Management Handbook. Your town may have additional requirements that meet or exceed minimum state standards. Contact your local Code Enforcement Office for more information.

We also recommend review of the FEMA Coastal Construction Manual and the FEMA Home Builder's Guide to Coastal Construction Technical Fact Sheets. The Construction Manual is available as a CD or in print copy by calling FEMA Publications Distribution Facility at 1-800-480-2520, and should also be available for review at your local town office or public library.

You will likely need a permit from your local municipality, in addition to Maine DEP, to elevate your structure. Federal permits from the US Army Corps of Engineers and US EPA may be required if impacts to navigable waters or discharges into waters of the United States occurs. Check with your local Code Enforcement Office or the Maine DEP for more information.

Refer to Chapter 305 (Permit by Rule), Chapter 310 (Wetlands) and Chapter 355 (Coastal Sand Dune Rules) for additional requirements relating to impacts to coastal wetlands associated with elevating structures.

If you are considering elevating your structure, include improvements to make your home more storm and flood resilient. Consider elevating your structure over and above the elevation required by your floodplain ordinance, in order to take into account expected rates of sea-level rise and their impacts on future floodplain elevations. Maine has adopted an expected rise in sea level of two feet over the next 100 years.

Upland/wetland fringe vegetation management. A naturally vegetated upland boundary adjacent to coastal wetlands is vital to maintaining healthy wetland habitat. Studies have shown that development and associated adjacent upland land uses can significantly impact coastal wetland plant diversity (Silliman and Bertness, 2004). Degradation of marsh vegetation and colonization by invasive species is related to fringe boundary disturbance, and nitrogen loading due to fertilizer usage. Subsequently, a best management practice for property adjacent to coastal wetlands includes maintaining, to the maximum width practicable, a naturally vegetated buffer between the "developed" (e.g., planted lawn or infrastructure) portion of the property, and adjacent coastal wetlands. Other practices include:

- enhancing the width of existing buffers with native vegetation;
- minimizing disturbances adjacent to coastal wetlands;
- limiting planting and maintenance of lawns and subsequent usage of nitrogen-rich fertilizers;
- removing invasive species within the buffer, especially common reed (*Phragmites australis*); and
- limiting the amount of unnatural freshwater runoff directed into coastal wetland from the adjacent uplands.

A great resource for buffer management is Save the Bay Narragansett Bay Backyards on the Bay's Yard Care Guide for the Coastal Homeowner (Cromwell and others, 1999).

Marsh restoration or creation: In many cases, adjacent uplands that might be prone to slight erosion or flooding can be protected with fringing salt marsh. Much of the following marsh restoration information was adapted from Managing Erosion on Estuarine Shorelines (Rogers and Skrabal, 2001), which was prepared for estuarine shorelines in North Carolina. However, much of the information and techniques outlined transfer to Maine's marshes. Additional online resources for marsh restoration and creation include Maine Salt Marshes: Their Function, Values, and Restoration (Dionne and others, 2003) and Salt Marshes in the Gulf of Maine, Human Impacts, Habitat Restoration and Long-Term Change Analysis (Taylor, 2008).

Fringing marshes protect property by gradually dissipating wave energy and serving as erosion control surfaces that absorb or dissipate the force of breaking waves, stabilizing the soft, underlying soil. Planting marsh grass is particularly effective on sites where previous marshes were destroyed by dredging and filling. Where appropriately sited, a planted marsh can be one of the most cost-effective erosion solutions. Planted marshes are generally considered to be one of the most environmentally desirable erosion-control approaches.

Marsh planting success depends heavily on shoreline exposure to wind, waves and boat wakes, and is most successful where the shoreline is exposed to less than one mile of fetch (distance of open water for wind to build waves). A marsh fringe at least 10 feet wide is necessary for erosion control, but 20 feet or more is preferred. Marsh fringes benefit the ecosystem by providing productive biological habitat and an additional vegetative buffer, which protects water quality by reducing the impact of stormwater runoff. If the marsh is not established continuously along the shoreline, erosion can continue on the unprotected beaches. The most common cause of failure is planting in an area that experiences severe wave conditions.

However, the cost of marsh creation is so low that it is often worth a try in areas with marginal exposure to waves. In some cases, two or more planting attempts may be required for the marsh to take hold. Commonly used grasses include species native to Maine salt marshes, such as saltmeadow hay (*Spartina patens*) and smooth cordgrass (*Spartina alterniflora*). In estuaries dominated by wind-driven tidal effects, planting elevations can vary but can be determined by observing the elevations of healthy native marshes nearby.

Marsh grasses may be purchased from specialized commercial nurseries (or can be potentially transplanted from existing marshes with a permit), including:

- Cape Coastal Nursery, MA
  - http://www.capecoastalnursery.com/
- Great Meadows Nursery, MA
  - http://www.greatmeadowsllc.com/
- Sylvan Nursery, Inc., MA
  - http://www.sylvannursery.com/
- Quansett Nurseries, Inc., MA
  - http://www.quansettnurseries.com/
- Mellow Marsh Farm, NC
  - http://www.mellowmarshfarm.com/plant/
- Spartina Farms, LLC, LA
  - http://www.spartinafarms.com/

Another way to restore or create a marsh is to remove or replace inadequately functioning road culverts. Enlarging or replacing culverts can dramatically increase tidal flow into marsh areas and help facilitate the proliferation of marsh species. Adequate tidal flushing is required for marsh growth, and will help eliminate invasive species that are not salt-tolerant. Note that permitting is likely required from Maine DEP and the US Army Corps of Engineers for work associated with road culverts.

A guide prepared for North Carolina titled Shoreline Erosion Control Using Marsh Vegetation and Low-Cost Structures (Broome and others, 1992) provides a good outline for how to plant and create a new coastal wetland. Similarly, the North

Carolina Coastal Federation Erosion Control: Non-Structural Alternatives, A Shorefront Property Owner's Guide (NCCF, undated) provides guidance for marsh plantings. The techniques and species discussed in these guides are applicable to Maine's marsh systems. Tidal bank protection using vegetative plantings is also outlined by the Maine DEP under their Maine Erosion and Sediment Control Best Management Practices Page, Site Specific Applications of BMPs, Sand Dune and Tidal Bank Protection.

From a regulatory standpoint, marsh creation or restoration will likely require permitting on several levels (local, state, and federal). From the state standpoint, permits from Maine DEP will be required. A Permit by Rule (Chapter 305) can be used to restore coastal wetlands (Chapter 305, 12); larger projects may need an Individual Permit from Maine DEP.

Rip-rap or bulkheading. Although not generally recommended because it limits coastal wetland migration and the transfer of sediment from uplands, rip-rap can be placed in or adjacent to a coastal wetland to protect property within 100 feet of an eroding bank under Chapter 305, Permit by Rule, *as long as the wetland does not have mudflats or salt marsh vegetation, or within the Coastal Sand Dune System* (Chapter 305, 8, A, (1)-(6). Otherwise, a general permit will likely be required from Maine DEP in order to pursue bank stabilization that impacts coastal wetlands. Specific standards, outlined in Chapter 305, 8, C, need to be followed in terms of rip-rap placement. Rip-rap best management practices for placement and construction techniques are available from Maine DEP.

The placement of a bulkhead adjacent to a coastal wetland will require permitting from Maine DEP. Like rip-rap, bulkheads limit the landward migration of wetlands, and cut off the natural transfer of sediment from eroding banks into the wetland. However, in some cases, their placement might be a necessity.

Some good sources for using bulkheads and rip-rap adjacent to marshes include the North Carolina Coastal Federation Erosion Control: Non-Structural Alternatives, A Shorefront Property Owner's Guide, Shoreline Erosion Control Using Marsh Vegetation and Low-Cost Structures, and Maine DEP's BMP guide for the use of gabions.

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APPENDIX A: PROPERTY OWNER CHECKLISTS

BEACH AND DUNE CHECKLIST

Is your property in a Coastal Sand Dune System?

______ No
______ Yes:
______Frontal Dune (D1)
______Back Dune (D2)
______Erosion Hazard Area (EHA)
______Coastal Wetland

Is your property within one or more FEMA Flood Hazard Zones?

______ No
______ Yes
If yes, list which zones:

Is your property within your town's Shoreland Zone?

______ Yes, within town shoreland zone
______ Required setback distance
______ Outside town shoreland zone

What is the distance of your structure from the edge of the normal high tide line?

__________ feet

Is there a vegetated sand dune at the seaward edge of the property?

______Yes ______No

Is there a seawall at the seaward edge of the property?

______Yes ______No

Is there evidence that your dune or seawall is *regularly* overtopped and overwashed by

Does your dune and beach naturally gain sand after each winter season?

______Yes ______No

Is a dry beach present (sand above normal high tide)?

______Yes ______No
If yes, what is the width of the dry beach?
______25 feet or less
______between 25 and 50 feet
______between 50 and 75 feet
______greater than 75 feet

How would you qualify the erosion of your dune or beach over the past decade?

______Highly Erosional (2 feet or more per year)
______Moderately Erosional (1-2 feet per year)
______Slightly Erosional (less than 1 foot per year)
______Stable (no change)
______Accretional (growing seaward)

Are you located adjacent to a tidal inlet that migrates?

______Yes ______No ______ Don't Know

<u>Existing Uses</u>

Is there an existing structure on the property?

______Yes ______No
If yes, is the structure bigger than 2,500 square feet?
______Yes ______No
Is the structure currently elevated above Base Flood Elevation?
______Yes ______No ______ Don't Know
Does the structure meet the existing floodplain management ordinance?
______Yes ______No ______ Don't Know
Has the structure been constructed, or retrofitted, to meet existing coastal construction standards?
______Yes ______No ______ Don't Know

How do you use or plan to use your property?

waves, and/or that flooding occurs landward of the dune or seawall crest? _____Yes _____No **Does your seawall have a history of being damaged on a regular basis?** _____Yes _____No	_____No use planned _____Access to the beach only (trail/road/stairs/other) _____Primary Residence _____Secondary Residence _____Expand existing structure size or retrofitting greater than 50% of structure's value? _____Yes _____No _____Build Additions or Porches greater than 50% of structure's value? _____Yes _____No _____Conservation Property/easement

NOTES:

BLUFF AND ROCKY SHORE CHECKLIST

Would you describe your shoreline as

_____ Hard, rocky shoreline or cliff
_____ Soft, muddy or sandy bluff
_____ Don't Know (click to learn more)

If your shoreline is soft, the sediment is:

_____Fine grained (mud, clay)
_____Mixed grain sizes
_____Coarse grained (sand, cobble)

Bluff Stability Classification (per Map)

_____Stable
_____Unstable
_____Highly Unstable

Landslide Hazard Susceptibility (per Map)

_____No Slopes Susceptible to Landslides
_____Slope < 5%
_____Slope => 5%
_____Slope =>5% and 1 terrain factor
_____Slope =>5% and 2 or more factors

What other landforms are present?

______Beach (Sand/Gravel/Cobbles)
______Fringing Wetland
______Ledge (outcrops in tidal waters)
______Other (explain)

Is there a Shoreland Zone bluff setback?

_____Yes _____No

Are other setbacks required?

_____Yes _____No

Distance of structure from the top edge of bluff?

_________ feet

What is the average angle of the bluff slope?

_________ degrees

What type of sediment is at the toe of the slope?

____

Has the bluff been planted, contoured, or armored?

_____Yes _____No

Is there evidence of rainfall impacts or surface runoff?

_____Rainfall impact erosion
_____Soil rills and gullies
_____Winter freeze-thaw evidence
_____Wind erosion
_____Pipe discharge erosion

What does your property contribute to runoff?

_____Significant upland impervious surface
_____Drainage pipe discharge onto slope
_____Sprinkling/irrigation/hot tub releases
_____Other

Is there evidence of groundwater in the slope (seepage, damp surfaces on slope face, etc.)?

_____Yes _____No

Do you have groundwater contributions?

_____Water infiltration areas (roof and curtain drains)
_____Septic system/leach field
_____Irrigation systems

Is there vegetation on or adjacent to the slope?

_____Yes _____No

If yes, are there curved trunks, or fallen trees?

_____Yes _____No

If no, is there evidence of past vegetation? What happened to it?

Evidence of vegetation movement down the slope?

_____Yes _____No

Check if any of the following occur on or near your property:

____ A beach is noticeable above the high tide line
____ Waves erode the toe of the slope/base of the bluff

Is this slope susceptible to landslides? _____Yes _____No ______ Don't Know **Are other terrain factors present?** ____No/Don't Know ____Slope Aspect (see Landslide Map) ____Curved/Irregular slopes ____Concave slopes **Are historic landslides present?** _____Yes _____No _____ Don't Know If yes, what type(s)? **Do waves or normal tides reach the toe of the bluff?** _____Yes _____No ______ Don't Know **Is the toe of the bluff eroding?** _____Yes _____No ______ Don't Know	____ Coastal erosion control structures are present along the beach of property or nearby (e.g. bulkheads) ____ If yes, are these structures causing erosion? ____ Property is prone to flooding **How do you use or plan to use the bluff?** _____No use planned _____Access to the beach (trail/road/stairs/other) _____Vegetation management for view (may need permit) _____Landscaping/horticultural/garden areas _____Waste/debris fills _____Natural greenbelt including slope crest

WETLAND CHECKLIST

Does your property contain wetlands mapped by the National Wetland Inventory?

_____No wetlands present on or near property
_____Wetlands present on or near property
_____Coastal wetlands not present
_____Coastal wetlands present
Types identified:

Are wetlands identified on the Maine Coastal Marine Geologic Environment Map?

_____Coastal wetlands not present
_____Coastal wetlands present
Types identified:

Highest Annual Tide nearest your property?

__________ feet

Is your property in a Coastal Sand Dune System?

_____ No
_____ Yes:
_____Frontal Dune (D1)
_____Back Dune (D2)
_____Erosion Hazard Area (EHA)
_____Coastal Wetland

Is your property within one or more FEMA Flood Hazard Zones?

_____ No
_____ Yes
If yes, list which zones:

Is your property within your town's Shoreland Zone?

_____ Yes, within town shoreland zone
_____ Required setback distance

Is there a seawall/rip rap at the seaward edge of the property?

_____Yes _____No

Is there evidence that your property undergoes *regular* flooding?

_____Yes _____No

Is there *mature upland vegetation* (trees, large shrubs, etc.) between your structure and the edge of the coastal wetland?

_____Yes _____No
If yes, list species:

How would you qualify the erosion of the bank or marsh adjacent to your property over the past decade?

_____Highly Erosional (2 feet or more per year)
_____Moderately Erosional (1-2 feet per year)
_____Slightly Erosional (less than 1 foot per year)
_____Stable (no change)
_____Accretional (growing seaward)

Is there an existing structure on the property?

_____Yes _____No

Is the structure currently elevated above Base Flood?

_____Yes _____No

Does the structure meet the existing floodplain management ordinance?

_____Yes _____No

Has the structure been constructed, or retrofitted, to meet existing coastal construction standards?

_____Yes _____No

How do you use or plan to use your property?

_____No use planned
_____Access (trail/road/stairs/other)
_____Primary Residence
_____Secondary Residence
_____Expand existing structure size or retrofitting

_____ Outside town shoreland zone **What is the distance of your structure from the edge of the highest annual tide?** _________ feet **Are you located adjacent to a tidal channel?** _____Yes _____No If yes, is the channel **straight** or are you located on a **meander**? **Is there a vegetated marsh at the edge of the property?** _____Yes _____No ______ Don't Know If yes, what is the width of the marsh?	greater than 50% of structure's value? _____Yes _____No _____Build Additions or Porches greater than 50% of structure's value? _____Yes _____No _____Conservation Property/easement _____Marsh restoration or enhancement _____Bulkhead/rip-rap construction

NOTES: