



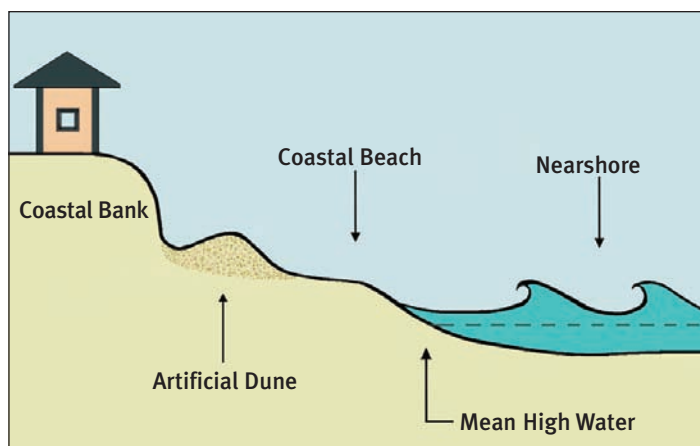
StormSmart Properties Fact Sheet 1: Artificial Dunes and Dune Nourishment

The coast is a very dynamic environment and coastal shorelines—especially beaches, dunes, and banks—change constantly in response to wind, waves, tides, and other factors such as seasonal variation, sea level rise, and human alterations to the shoreline system. Consequently, many coastal properties are at risk from storm damage, erosion, and flooding. Inappropriate shoreline stabilization methods can actually do more harm than good by exacerbating beach erosion, damaging neighboring properties, impacting marine habitats, and diminishing the capacity of beaches, dunes, and other natural landforms to protect inland areas from storm damage and flooding. StormSmart Properties—part of the Massachusetts Office of Coastal Zone Management’s (CZM) StormSmart Coasts program—provides coastal property owners with important information on a range of shoreline stabilization techniques that can effectively reduce erosion and storm damage while minimizing impacts to shoreline systems. This information is intended to help property owners work with consultants and other design professionals to select the best option for their circumstances.

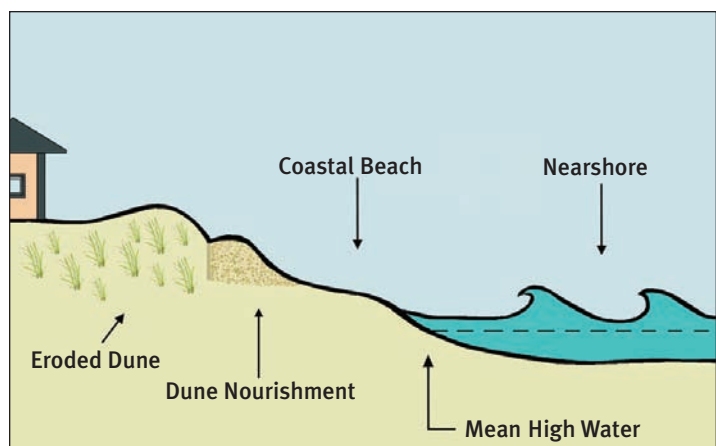
What Are Artificial Dunes and Dune Nourishment?

A dune is a hill, mound, or ridge of sediment that has been deposited by wind or waves landward of a coastal beach. In Massachusetts, the sediments that form beaches and dunes range from sand to gravel- and cobble-sized material. An artificial dune is a shoreline protection option where a new mound of compatible sediment (i.e., sediment of similar size or slightly coarser) is built along the back of the beach, seaward of the area to be protected. (Artificial dunes may be called cobble berms when larger pebble- and cobble-sized materials are used.) Dune nourishment provides shoreline protection by adding compatible sediment to an existing dune. With artificial dunes and dune nourishment, sediment is brought in from an offsite source, such as a sand and gravel pit or coastal dredging project.

No shoreline stabilization option permanently stops all erosion or storm damage. The level of protection provided depends on the option chosen, project design, and site-specific conditions such as the exposure to storms. All options require maintenance, and many also require steps to address adverse impacts to the shoreline system, called mitigation. Some options, such as seawalls and other hard structures, are only allowed in very limited situations because of their impacts to the shoreline system. When evaluating alternatives, property owners must first determine which options are allowable under state, federal, and local regulations and then evaluate their expected level of protection, predicted lifespan, impacts, and costs of project design, installation, mitigation, and long-term maintenance.



This diagram shows an artificial dune built seaward of an eroding coastal bank to protect the bank from further erosion that could endanger the house.



This diagram shows a dune nourishment project that added sediment to the seaward side of an eroded dune to enhance the ability of the dune to protect the house.

Artificial and nourished dunes can be used in conjunction with many other techniques for erosion management. See the following StormSmart Properties fact sheets for information on related techniques: *Controlling Overland Runoff to Reduce Coastal Erosion*, *Planting Vegetation to Reduce Erosion and Storm Damage*, *Bioengineering - Coir Rolls on Coastal Banks*, *Sand Fencing*, and *Beach Nourishment*.

How Artificial Dunes and Dune Nourishment Reduce Storm Damage

Dunes provide a physical buffer between the sea and inland areas—a buffer that can naturally shift during storms. As waves hit a dune and its sediments move and shift, the wave energy is absorbed, protecting landward areas from the full brunt of the storm. The height, length, and width of a dune relative to the size of the predicted storm waves and storm surge (water buildup above the average tide level) determines the

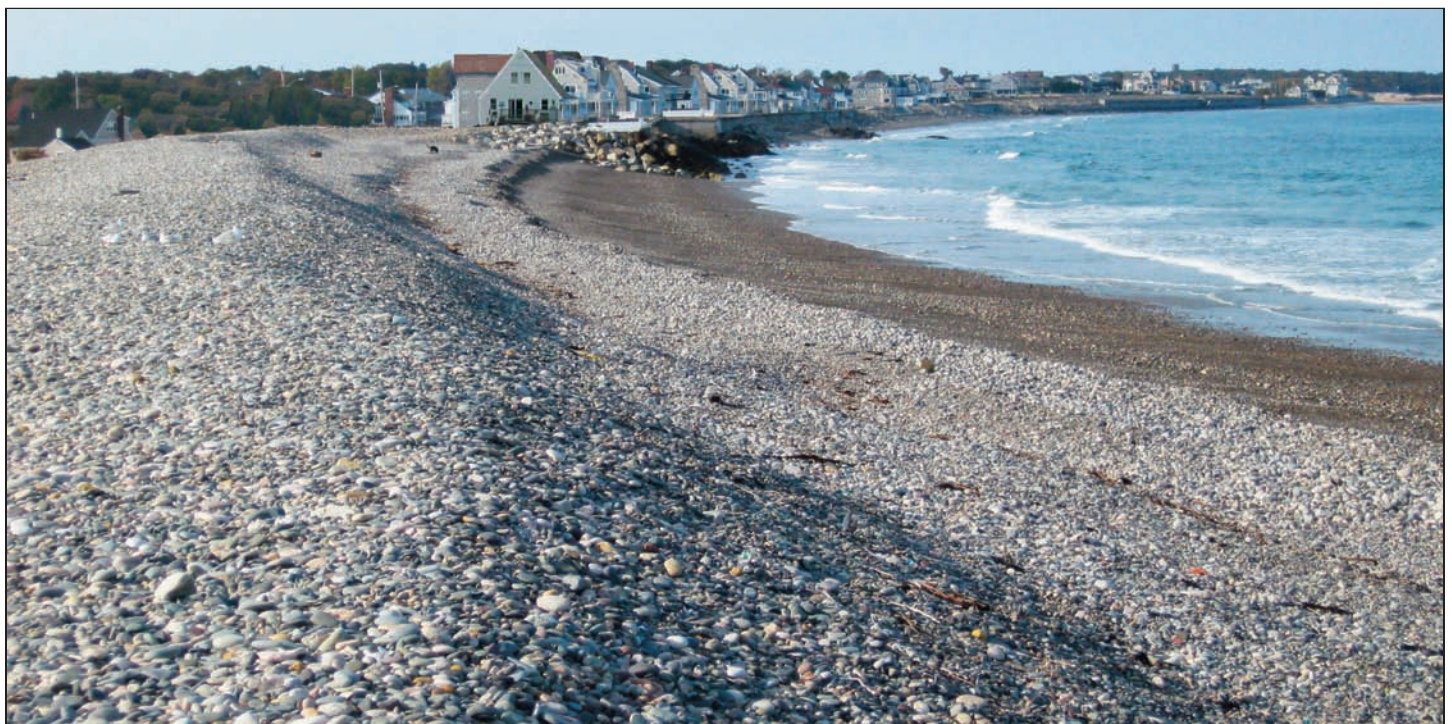
level of protection the dune can provide. The recommended size for an artificial or nourished dune will depend on the desired level of protection, the predicted wave energy and storm surge for the area, and site constraints (such as beach width and proximity to sensitive resource areas).

Artificial and nourished dunes not only increase the direct level of protection to inland areas by acting as a physical buffer, the added sediment from dune projects supports the protective capacity of the entire beach system (i.e., dune, beach, and nearshore area). Sand eroded from the dune during a storm is not lost or wasted, but added to the surrounding beach and nearshore area where it dissipates wave energy, reducing the strength of incoming storm waves. But to maintain the dunes as an effective physical buffer, sediment must be added regularly to keep dune’s height, width, and volume at appropriate levels.



The photo on the left shows a dune nourishment project where sand was added in front of the eroded face of an existing dune. The sand was planted with beach grass to enhance the protection provided to the house behind it.

In the project shown in the photo below, a dune that was severely eroded during the Blizzard of '78 was nourished with a combination of sand, gravel, and cobble—sediments of the same size range as the natural dune. The highest point of the dune is about 20 feet above sea level. This photograph was taken in October 2008, demonstrating how well the dune has held up over time.



Relative Benefits and Impacts Compared to Other Options

The major benefit of artificial dunes and dune nourishment projects is that unlike seawalls, rock revetments, or other “hard” shoreline stabilization structures, dunes dissipate wave energy rather than reflecting waves

onto beaches or neighboring properties. The design of a hard structure affects how much wave energy is reflected, for example vertical walls reflect more wave energy than sloping rock revetments. These reflected waves erode beaches in front of and next to a hard structure, eventually undermining

Under the Massachusetts Wetlands Protection Act, new hard structures are typically prohibited on all beaches and dunes. On coastal banks, hard structures are only allowed when necessary to protect buildings permitted before August 10, 1978, and only if no other alternative is feasible. In many cases, dune projects and other non-structural alternatives are therefore the only options available for reducing erosion and storm damage on coastal properties.

and reducing the effectiveness of the structure and leading to costly repairs. This erosion also results in a loss of dry beach at high tide, reducing the beach’s value for storm damage protection, recreation, and wildlife habitat. Hard structures also impede the natural flow of sand, which can cause erosion in down-current areas of the beach system. Dune projects, however, increase protection to landward areas while allowing the system’s natural process of erosion and accretion to continue. In addition, because of their more natural appearance, dunes can be more aesthetically pleasing than hard structures.

In general, therefore, the impacts of dune projects are relatively minor when compared to hard structures. The most significant factor in determining the potential impact is the proximity of the dune project to sensitive habitats. For example, dune projects near salt marsh, horseshoe crab spawning grounds, and other sensitive habitats can smother plants and animals if dune sediments are eroded quickly and carried to these areas. In addition, dune projects in nesting habitat for protected shorebird and turtle species (i.e., species that are considered endangered, threatened, or of special concern in Massachusetts) can inhibit nesting success.

Other potential impacts from dune projects can be caused by using sediment of an inappropriate grain size or building a dune with a slope that is too steep. If the sediments brought in are finer than the existing beach sediments, they can erode quickly and may smother nearby sensitive areas, such as shellfish and eelgrass. If the introduced sediments are too large, they may not move and shift as intended and can therefore reflect wave energy, causing erosion of the beach in front of or near the dune. As for the slope, steep dunes are unstable and erode rapidly. This can cause a scarp, which looks like a carved out area in the dune with an almost vertical slope. Scarps can make beach access dangerous and impede the movement of wildlife over the dune.

Design Considerations for Dune Projects

This section covers a variety of factors that should be considered to minimize adverse impacts and ensure successful design, permitting, construction, and maintenance of an artificial dune or dune nourishment project.

Appropriate Locations

Dune projects are appropriate for almost any area with dry beach at high tide and sufficient space to maintain some dry beach even after the new dune sediments are added to the site. Dune projects can be used in combination with other natural coastal landforms or hard structures. For example, artificial dunes can be placed seaward of an eroding bank to reduce bank erosion or seaward of an existing rock revetment or seawall to minimize wave reflection that exacerbates beach erosion and undermines the structure.

In areas with no beach at high tide, the protection provided by dune projects is relatively short-lived because the added sediments are readily eroded and redistributed to the nearshore by both regular waves and tides and storms. In these situations, increasing the width of the beach through beach nourishment may be a preferred shoreline protection option (see *StormSmart Properties Fact Sheet 8: Beach Nourishment*). For projects on narrow beaches where the seaward part of a dune would be reached by extreme high tides or minor storm tides, the dune will likely erode quickly and require frequent maintenance to retain the level of protection the project was designed to provide.

Sacrificial Dunes - Dunes constructed in areas with narrow beaches at high tide are often called “sacrificial dunes” because they are expected to provide relatively short-term protection before they are eroded and need to be replaced. Sacrificial dunes are typically constructed when there are fewer shoreline protection options available due to regulatory or physical limitations. With sacrificial dunes, it is often appropriate to use coarser sediments than the existing beach and dune to provide greater protection and increase project longevity.

“Compatible” Sediments - Size, Shape, Color, and Texture

Dune projects require the use of compatible sediments—sediments that are too fine will erode quickly, reducing project effectiveness and potentially impacting nearby resource areas, while sediments that are too large may not move and shift as intended and could increase erosion and other problems. Consequently, the percentage of sand-, gravel-, and cobble-sized sediment should match, or be slightly coarser than, the existing beach/dune sediments.

Using sediments with slightly larger grain sizes can provide improved erosion control and storm damage protection. More energy is needed to move this larger material, absorbing wave energy more effectively and eroding less readily. In addition, when a dune is overtopped during a storm, the sand is typically moved seaward into the beach system (where it dissipates wave energy). The larger sediments shift landward and provide direct protection from storm waves. However, because of the potential impacts of using material that is too large, decisions about the range of sediment sizes (i.e., percentage of sand, gravel, and cobble) should be based on specific site conditions, potential impacts, and the desired level of shoreline protection. In addition, if sediments with larger grain sizes shift to the beach area during a storm, they can negatively affect the quality of the beach for recreation and habitat for protected species.

The shape of the material brought in is also important, primarily for larger-grained sediments (gravel and cobble). These sediments should be rounded (like natural beach sediments) rather than angular (crushed). Rounded grains readily roll and slide against each other, and this movement dissipates more wave energy. If rounded material is not used, the ability of the dune to move and shift can actually be reduced rather than improved by the project.

The color and texture of the sediment purchased for a dune project can affect the aesthetics of the site—but because this impact is temporary and does not interfere with the way the shoreline system functions,

addressing it is optional. As for color, some sediment from upland sources appears orange when compared to the typical white-to-gray color of Massachusetts dunes. The orange hue is often due to iron staining, which does bleach out in the sun over time. With texture, some compatible sediment sources contain a small percentage of fine silt, which can stick to recreational beach users. Although the silt naturally blows or washes away with time, “washed” sediment with lower silt content can be requested from inland sand and gravel pits.

Volume of Material

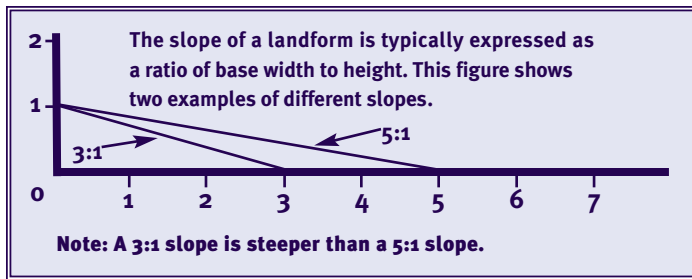
The volume of sediment needed for a dune project will depend on: 1) the elevation of the beach and existing dune (if any) relative to the predicted water level during a major coastal storm event, and 2) the level of protection desired. The lower the existing beach/dune and the higher the predicted water level during a storm, the greater the volume of material that is needed to achieve a certain level of protection.

Vegetation and Sand Fencing for Erosion Control

Planting the dune with native, salt-tolerant, erosion-control vegetation with extensive root systems is highly recommended to help hold the sediments in place. However, planting may be restricted in nesting habitat for protected shorebirds and turtles. Sand fencing can also be installed to trap windblown sand to help maintain and build the volume of a dune. See StormSmart Properties fact sheets: *Planting Vegetation to Reduce Erosion and Storm Damage* and *Sand Fencing* for more information. Christmas trees are not recommended for trapping sand because a large section of the dune is disturbed when they are removed by waves, increasing dune erosion. Placing brush and other dead plant material on the dune can prevent living plants from becoming established, causing further destabilization. Christmas trees and brush can also degrade nesting habitat for protected shorebirds by physically occupying otherwise suitable nesting habitat and impeding chick movement.

Dune Slope

Steep dunes are unstable and may erode rapidly and cause problematic scarps. To avoid this problem, the seaward slope of the dune should typically be less than 3:1 (base:height). The slope selected for the project will be based on the existing beach and dune slope, the width of the dry beach, and the grain size of the dune sediments. In addition, there should be some dry beach between the dune and the average high tide line to prevent rapid erosion.



Minimizing Impacts to Habitat and Wildlife

Impacts to sensitive habitats can be avoided by placing dunes as far landward as possible and using sediments of appropriate size. For dune projects proposed in or adjacent to nesting habitat for protected shorebirds and turtles, the slope and height of the dune, time of year for construction, and density of vegetation planted may need to be modified to allow for successful nesting. The Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife can provide information on the species listed as endangered, threatened, and of special concern in Massachusetts, including their location and any special design or permitting requirements under state regulations. For projects proposed near horseshoe crab spawning habitat, work should not be done during the spawning season. The Massachusetts Division of Marine Fisheries can provide additional information on horseshoe crab protection. Dune projects may also smother existing vegetation that helps to stabilize the area, an impact that can typically be addressed by replanting similar vegetation on the new dune.

Heavy Equipment Use

Access for heavy equipment must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, beaches, or other landforms; impacts to wildlife and nesting habitat for protected shorebird and turtle species; and related impacts. In addition, heavy equipment operators should avoid running over the dune multiple times, which can compact sediments and prevent them from moving and shifting to effectively dissipate wave energy. When mechanical equipment is being used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substances.

Permitting and Regulatory Standards

Most options for addressing coastal erosion, storm damage, and flooding are likely to require a permit under the Massachusetts Wetlands Protection Act through the local Conservation Commission. Additional permits may

be needed from the Massachusetts Department of Environmental Protection (MassDEP) Waterways Program and the U.S. Army Corps of Engineers if the project footprint extends below the mean high water line or seaward of the reach of the highest high tide of the year, respectively. Permits or approvals may also be required from other state agencies and local departments, depending on the project location and the work involved. Often, Conservation Commission staff are available to meet with applicants early in the design process to go over the important factors that need to be considered.

Generally, regulatory programs are supportive of projects that add sediment to the beach and dune system rather than proposing a hard structure. To obtain a permit, projects need to be designed with appropriate sediment and should not be located in sensitive resource areas (e.g., salt marsh), which are protected by the various regulatory programs.

Professional Services Required

A coastal geologist, engineer, or other environmental professional with expertise in designing dune projects should be consulted to: 1) identify regulatory requirements and ensure the project fully conforms with those requirements; 2) determine the conditions at the site that will affect the project (such as the width of dry beach above high tide, wave exposure, and predicted flood elevations); 3) determine if other shoreline stabilization techniques are needed in addition to the dune project; 4) determine the appropriate grain-size range to be used by taking and analyzing sediment samples of the existing beach and dune; 5) recommend appropriate volumes of sediment for various levels of protection; 6) select appropriate plant species and develop planting and maintenance plans; 7) identify the best time of year to install the various components of the project; 8) prepare plans for permitting; 9) develop an access plan if heavy equipment is needed; and 10) prepare design specifications for construction. The consultant can also oversee permitting, construction, monitoring, and maintenance of the project. For dune projects with gravel or cobble, it is particularly important that the consultant have direct experience designing shore-protection projects using this type of material.

Project Timeline

It may take as little as four to six months to have a dune project designed, permitted, and installed, assuming that only a Massachusetts Wetlands Protection Act permit is required—but it can take longer, depending on the factors involved. Factors influencing this timeline include the

contractor's experience with designing and permitting similar projects, completeness of permit applications, special considerations in the permitting process (such as objections by abutters, sensitive resources to be protected, and availability of access for construction), the need for special timing to avoid impacts (e.g., a prohibition on construction during endangered species nesting season), and/or weather conditions during construction.

Maintenance Requirements

Regular maintenance of dune projects will include adding sediment to retain the desired level of protection. The amount of sediment that should be added and how frequently it is needed will depend, in part, on the proximity of the dune to the reach of high tide, the frequency and severity of storms, the initial design of the dune (e.g., grain size, volume, height, and slope), and how established the root system of any vegetation is before a storm hits. For dune projects that include plantings, plants should be replaced (at the appropriate time of year) if they are removed by storms or die (until the plants become fully established, losses are more common). See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for more information. A schedule and plan for replacing sediments and plants should be included in the original permit application for the project so that maintenance can be conducted without additional permitting.

Project Costs

With dune projects, there are typically a range of options available that give increasing levels of protection with increased construction costs. In general, the greater the quantity of sediment that is used in the project, the greater the construction costs, the lower the maintenance costs, and the greater the level of protection provided for the site. In addition, whenever you hire a professional to conduct work on your property, total costs are expected to vary significantly based on site-specific considerations. The considerations that most influence the costs of dune projects are the severity of erosion, the width and elevation of the beach, the volume and availability of sediment needed, the complexity of project design and permitting, and the size and location of the proposed dune. For comparison with other shoreline stabilization options, dune projects typically have relatively low design and permitting costs, low construction costs, and low maintenance costs. See the StormSmart Properties web page at www.mass.gov/czm/stormsmart-properties for a *Relative Costs of Shoreline Stabilization Options* chart that gives a full comparison.

Additional Information

Artificial or nourished dunes can be used in conjunction with many other techniques for erosion management. See the following fact sheets on the CZM StormSmart Properties web page at www.mass.gov/czm/stormsmart-properties for additional information:

- *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage.*
- *StormSmart Properties Fact Sheet 4: Bioengineering - Coir Rolls on Coastal Banks.*
- *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks.*
- *StormSmart Properties Fact Sheet 6: Sand Fencing.*
- *StormSmart Properties Fact Sheet 8: Beach Nourishment.*

The following publications and websites also provide valuable information on dunes:

- *Beach Nourishment: MassDEP's Guide to Best Management Practices for Projects in Massachusetts* (www.mass.gov/dep/water/resources/bchbod.pdf; PDF, 1.61 MB) describes the steps for beach nourishment projects, which are very similar to dune projects. The Technical Attachments (www.mass.gov/eea/docs/dep/water/resources/a-thru-m/bchtech.pdf; PDF, 1.16 MB) give detailed information on sampling beach sediments, evaluating offsite source material, and monitoring project performance.
- CZM's Coastal Landscaping website (www.mass.gov/czm/coastal_landscaping) focuses on landscaping with salt-tolerant vegetation to reduce storm damage and erosion and includes information on appropriate plants, planting plans, invasive species, and tips on plant care, along with links to other references.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding* fact sheet (www.mass.gov/eea/docs/czm/stormsmart/ssc/ssc6-landscaping.pdf; PDF, 955.7 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.

- *Coastal Dune Protection and Restoration—Using ‘Cape’ American Beachgrass and Fencing* (www.who.edu/fileserver.do?id=87224&pt=2&p=88900; PDF, 3.2 MB) by the Woods Hole Sea Grant and Cape Cod Cooperative Extension Program includes case studies and tips on dune restoration, along with information on preserving shorebird habitat and understanding the permit process.
- *Salisbury Beach Dune Walkover Access Design Standards* (www.salisburyma.gov/PB-CC/CCbeachaccessdesignstandards.pdf; PDF, 14.2 KB) gives general design standards for walkways over coastal dunes that minimize potential adverse effects. These standards are widely applicable.
- *Ballston Beach Dune Restoration, Truro, Cape Cod* (<http://safeharborenv.com/coastal-restoration-strategies/barrier-dune-restoration-project-begins>), an article in Safe Harbor’s summer 2011 newsletter, documents innovative sand fencing techniques used to restore a dune on a barrier beach in Truro.
- *CZM’s Environmental Permitting in Massachusetts* (www.mass.gov/eea/agencies/czm/program-areas/federal-consistency-review/environmental-permitting-in-massachusetts.html) gives brief descriptions of major environmental permits required for projects proposed in Massachusetts.
- *Guidelines for Barrier Beach Management in Massachusetts* (www.mass.gov/eea/docs/czm/stormsmart/beaches/barrier-beach-guidelines.pdf; PDF, 12.5 MB), which was produced by the Massachusetts Barrier Beach Task Force in 1994, provides an overview of the Massachusetts Wetlands Protection Act Regulations and the function of beaches, dunes, and other resource areas (in Chapter 2). It also gives information on various erosion management techniques, their potential impacts, and measures to minimize those impacts (Chapter 5).
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) (www.mass.gov/eea/agencies/massdep/water/regulations/310-cmr-10-00-wetlands-protection-act-regulations.html) cover work in wetland resource areas and buffer zones.
- The Natural Heritage and Endangered Species Program website (www.mass.gov/eea/agencies/dfg/dfw/natural-heritage) provides information on protected species in Massachusetts, habitat maps, and regulatory review for projects in or adjacent to these habitats.
- The Massachusetts Division of Marine Fisheries can provide information on horseshoe crab protection and other fisheries resources. See their website at www.mass.gov/eea/agencies/dfg/dmf for contact information.
- The Massachusetts Ocean Resource Information System, or MORIS, is a web-based mapping tool for interactively viewing coastal data that is available at www.mass.gov/czm/mapping. It includes shoreline change data, which should be considered when evaluating and designing shoreline stabilization projects. Other data layers in MORIS (such as endangered species habitat, shellfish, and eelgrass) can help identify sensitive resource areas within or near the project site.

www.mass.gov/czm/stormsmart



COMMONWEALTH OF MASSACHUSETTS
Deval L. Patrick, Governor



EXECUTIVE OFFICE OF ENERGY
AND ENVIRONMENTAL AFFAIRS
Richard K. Sullivan Jr., Secretary



MASSACHUSETTS OFFICE OF
COASTAL ZONE MANAGEMENT
Bruce K. Carlisle, Director

MASSACHUSETTS OFFICE OF COASTAL ZONE MANAGEMENT | 251 Causeway Street, Suite 800 | Boston, MA 02114 | (617) 626-1200
CZM INFORMATION LINE: (617) 626-1212 | CZM WEBSITE: www.mass.gov/czm



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