StormSmart Properties Fact Sheet 7:

Repair and Reconstruction of Seawalls and Revetments

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 Seawalls and Revetments?

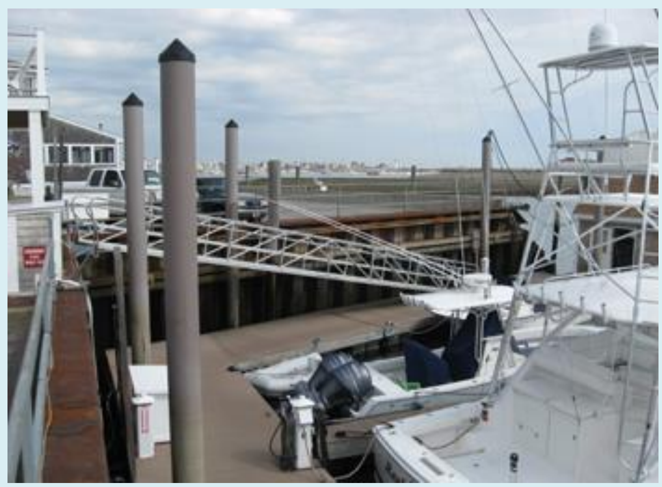
Seawalls and revetments are types of coastal engineering structures that run parallel to the shoreline. Also known as "armoring" or "hard structures," coastal engineering structures provide a physical barrier that directly protects inland areas. Seawalls are vertical walls that are typically constructed of concrete or stone, while revetments are sloping structures typically composed of rock (also called "rip rap"). Seawalls and revetments provide storm damage protection and erosion control from waves, tides, currents, and storm surge (water build up above the average tide level). They can be used in both exposed areas with high wave energy, as well as in areas with more sheltered conditions (e.g., relatively low wave energy). As discussed below, seawalls and revetments can significantly alter the coastal system and may have adverse impacts on the project site and neighboring properties. Because these effects are now well understood, *new construction* of these hard structures is only allowed in very limited circumstances. This fact sheet addresses the more common practice of repair and reconstruction of *existing* seawalls and revetments. Given the technical and permitting issues involved with seawall and revetment repair and reconstruction projects, a coastal engineer should be consulted for site-specific advice.

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 concrete seawall was built to protect the homes and infrastructure behind it. This seawall has a curved face built into the top of the wall, which redirects some of the reflected water and waves away from the wall. **(Photo: CZM)**

This rock revetment was installed on the lower part of a coastal bank, while salt-tolerant vegetation was planted to protect the upper bank. **(Photo: CZM)**

Bulkheads - Also a type of hard structure constructed parallel to the shoreline, bulkheads are vertical walls designed to hold soil in place and prevent it from sliding or slumping into the water. Although they may also provide some protection from waves and tides, bulkheads are not typically appropriate to address coastal erosion. They are typically made of wood, steel or vinyl sheeting, granite blocks, or concrete and are primarily used around developed harbors and marinas. Their vertical structure allows them to provide docking space for vessels in sheltered areas where wave action is relatively limited. The design considerations for bulkheads are similar to those recommended for seawalls (see below). A coastal engineer should be consulted for site-specific advice when bulkhead repairs are needed.



This steel bulkhead is built to hold the soil under this parking lot in place. **(Photo: CZM)**

Hard Structures - Their Role, History, and Impacts

Coastal engineering structures were originally utilized to prevent erosion and protect development and infrastructure from waves and storm surge. The unintended effects of hard structures on the shoreline system were not initially well understood, however, and significant long-term impacts have been documented in areas where these structures were constructed. While seawalls and revetments can help protect landward property and infrastructure from waves and tides, they do not stop (and may exacerbate) erosion. As natural erosive forces continue to remove sediment over time, beaches in front of the hard structures are diminished and can eventually be completely lost. Seawalls and revetments themselves can also exacerbate erosion problems by reflecting waves onto the beach in front of them or onto neighboring properties. As these sources of erosion continue, more of the hard structure is exposed, causing more wave reflection and erosion. Over time, the structure can become undermined, reducing its shoreline protection capacity, increasing maintenance costs, and ultimately leading to total structure failure. When used on coastal banks (also known as bluffs), seawalls and revetments prevent erosion of these landforms, which halts the natural supply of sand and other sediment to the shoreline system. The result is that beaches and dunes in downdrift (i.e., down current) areas experience increased erosion rates. Therefore, these structures not only affect the property owner, they also affect the natural resources necessary for storm damage prevention, recreation, and wildlife habitat.

The beach in front of this concrete seawall eroded, undermining the structure. (Photo: CZM)

Erosion of the beach in front of this revetment created a depression at the base of the structure. (Photo: CZM)

Alternatives to Revetments in Front of Seawalls - To address seawall undermining, small rock revetments have often been installed in front of seawalls to protect the structure from collapse. As erosion continues, however, the small revetment may also be undermined—leading to designs that consider a larger revetment. A larger revetment will extend farther seaward, increasing the frequency and intensity of interactions between the structure and tides, waves, and currents and further worsening beach erosion. The result can be a succession of larger structures, increased wave reflection and erosion, and loss of beach, with the beach being permanently replaced by the hard structures. Erosion-control options that add sediments in front of the structure, like beach nourishment and cobble berms, can be used instead to effectively protect upland development and infrastructure, reducing impacts to neighboring properties, and maintaining beach resources and habitat. In addition, adding a revetment does not effectively stop waves and water from overtopping the seawall during storms. In many cases, overtopping and storm damage are more effectively reduced by adding sediment seaward of the wall to dissipate wave energy before it reaches the structure. This practice is referred to as beach nourishment (see *StormSmart Properties Fact Sheet 8: Beach Nourishment* for additional information).

Repair and Reconstruction - An Opportunity to Improve Performance and Reduce Impacts

As the impacts of hard structures have become better understood over the last 50 years, recommended design practices for seawalls and revetments have advanced significantly. Any repair or reconstruction project—whether minor repairs or complete reconstruction—should therefore include design improvements based on the best available techniques to reduce impacts, improve structure longevity, and minimize maintenance costs. Typically, the more work the structure needs, the greater the opportunity for incorporating improvements into the redesign. Investing in significant improvements and best management practices can cost more in the short term, but such improvements reduce costs associated with mitigating for adverse effects of the structure and can significantly improve the protection provided in a major coastal storm. In addition, if minor repairs are simply patches that make the structure look better, they may not do enough to prevent the structure from failing in a storm, which would result in significant damage to the property and infrastructure landward of it.

Design Considerations for Repair or Reconstruction of Seawalls and Revetments

This section covers a variety of options that should be considered as part of seawall and revetment repair and reconstruction projects to minimize adverse impacts, maximize structure longevity, reduce maintenance costs, and ensure successful design, permitting, and construction of the project.

Placement

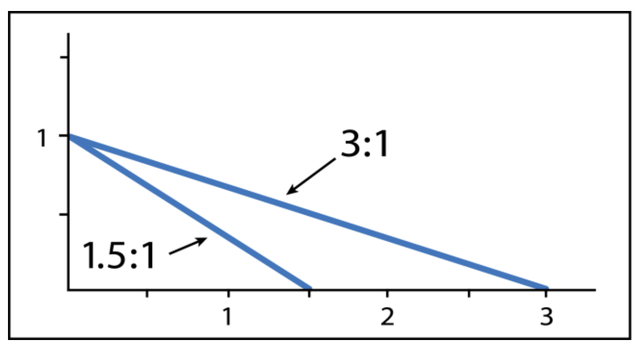
To minimize interaction with waves and tides and therefore reduce erosion to the fronting beach and adjacent areas, seawalls and revetments should be located as far landward as possible. When repairing or replacing an existing seawall or revetment, therefore, the structure should not be extended farther seaward. In addition, if erosion is occurring behind an existing structure, to minimize impacts, the structure should be pulled back to the base of the landward landform to prevent continued erosion from undermining the structure. Leaving the structure in place and using fill to reclaim land will likely continue the cycle of erosion. Seawalls and revetments should also conform to the natural shape of the shoreline without any segments extending seaward from the main structure, which would focus wave energy on the parts of the structure closer to the sea. This focused wave energy exacerbates erosion of the beach and reduces the longevity of the structure. In addition, the structure should not extend farther seaward than those on adjacent properties and every effort should be made to align the ends of the structure with adjacent structures.

This bulkhead has deteriorated and erosion has occurred landward of it. When reconstructed, the bulkhead should be replaced with a sloping rock revetment to dissipate energy more effectively and reduce wave reflection. In addition, the toe of the revetment should be constructed at the base of the eroding bank to minimize regular interaction with waves and tides. This improved placement will reduce impacts to the beach and extend the life of the structure. **(Photo: CZM)**

Slope

Sloping structures dissipate wave energy (i.e., reduce wave strength) more effectively than vertical structures. Therefore, when seawalls need significant repairs or reconstruction, replacing them with sloping rock revetments that do not extend farther seaward should be considered.

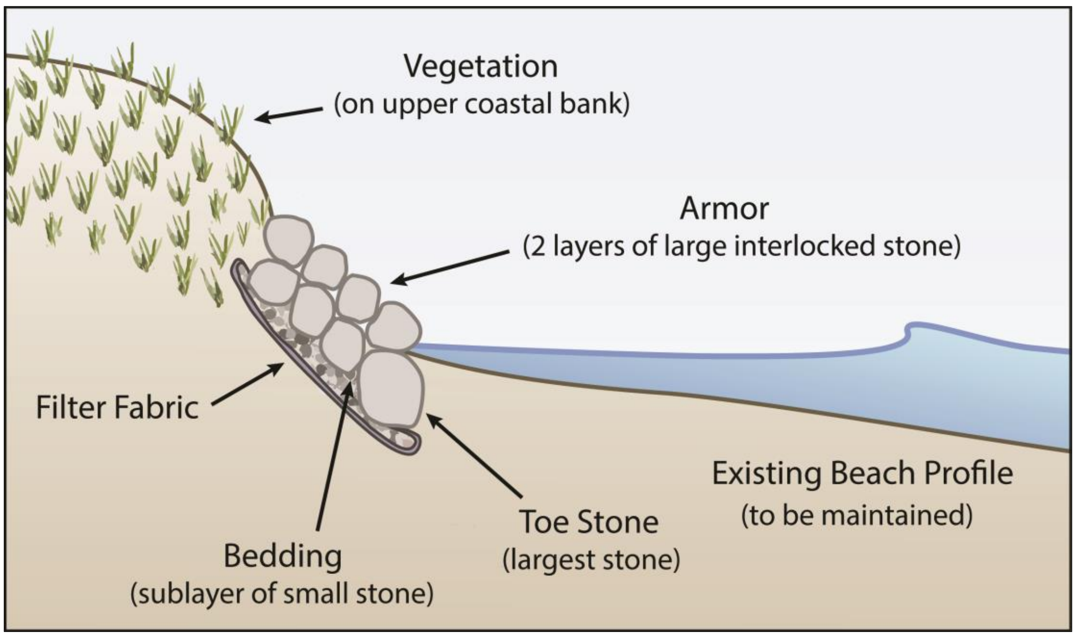
In addition, shallow slopes minimize wave reflection that causes erosion. Revetments should ideally have a slope no steeper than 1.5:1 to limit erosion of fronting beaches and adjacent properties. A coastal engineer can recommend an appropriate slope based on site-specific conditions, including beach width and elevation, bank height, erosion rate, wave energy, and integrity of the structure.



The slope is typically expressed as a ratio of the width of a structure's base to its height, or horizontal to vertical. This figure shows two examples of different slopes.

Reconstruction offers an excellent opportunity to reduce the steepness of a revetment. To achieve a shallower slope without extending the structure farther seaward, the bank or other landform behind the revetment can be regraded and the top of the structure moved landward. Though this landward extension results in a loss of ground surface between the revetment and the development or infrastructure behind it, the property will be better protected through the increased longevity of the structure and reduced erosion rates.

The vertical seawall at this site has been undermined and is failing. In this case, there is room on the site to replace the vertical wall with a sloping rock revetment that does not extend farther seaward onto the beach. **(Photo: CZM)**



Schematic of a typical revetment on a coastal bank.

Curved Face for the Top of the Seawall

Vertical seawalls reflect water straight down and straight up. The wave energy that is reflected downward erodes the beach, while the wave energy that goes up into the air can overtop the structure and cause erosion behind the wall, potentially damaging the development or infrastructure being protected. If the seawall cannot be replaced with a revetment, a curved face can be added to the top of a vertical concrete seawall to help direct some of the reflected water and waves out and away from the wall. A coastal engineer will need to evaluate the applicability and potential effectiveness of this approach for each site.

Waves are reflected by this vertical seawall, causing energy to be deflected straight down on the beach and straight up and over the wall, damaging the building behind it. **(Photo: CZM)**

Beach and Dune Nourishment

Beaches and dunes naturally dissipate energy associated with waves, tides, and currents. Therefore, the best way to reduce the wave energy that hits seawalls and revetments is to maintain the beach in front of these structures. In areas where there is a wide enough beach, dunes can provide additional protection. With an older seawall or revetment, the beach in front of the structure has often eroded over time. Replacing and maintaining these natural buffers can prolong the structure's longevity and minimize its adverse impacts—and can also provide a recreational beach. To build up beaches (and dunes where appropriate), "compatible" material (i.e., sediment of a similar size) is brought in from an offsite source and added to the beach. After the initial nourishment project is completed, sediment is added to maintain the desired beach and/or dune volume according to a monitoring and maintenance plan that includes details for determining when, how much, and what type of sediment should be added. Depending on erosion rates and storm impacts, sediment could be required on an annual basis, and will likely be necessary after coastal storms. See the following StormSmart Properties fact sheets for more information on where beach and dune nourishment are appropriate: *Artificial Dunes and Dune Nourishment* and *Beach Nourishment*, as well as the guidance document, *Beach Nourishment: MassDEP's Guide to Best Management Practices for Projects in Massachusetts* (PDF, 2 MB).

In most cases, the sediment added to the beach or dune is not permanent. How long it remains in front of the seawall or revetment will vary depending on many factors, including: the initial width of the dry beach, the length of beach where sediment is added, wave energy, erosion rate, grain size and volume of sediment added, and storm frequency and intensity. A coastal geologist or coastal engineer with experience designing beach and dune nourishment projects can make recommendations for the grain size and volume of sediment needed. When this added sediment erodes, it is not "lost" to the system—it moves into nearshore areas and/or alongshore to the adjacent shoreline where it dissipates wave energy, protects the shoreline, and improves wildlife habitat. And in many cases, this eroded sediment moves back onshore during the summer and after storms. See these StormSmart Properties fact sheets for design considerations to help reduce erosion of added sediment: *Artificial Dunes* and *Dune Nourishment* and *Beach Nourishment*.

On coastal banks, when a seawall or revetment is undergoing significant repairs or reconstruction, the project should also specifically include provisions to add sediment to compensate for the fact that the bank is no longer acting as a source of sediment to the beach system. Adding this sediment will also help maintain the beach volume in front of the structure, increasing its longevity. The minimum volume of sediment required should be based on the historic shoreline erosion rate, the height of the bank, and the length of the project. A professional with experience designing beach nourishment projects can make recommendations regarding the volume of sediment that will be needed. A monitoring plan should be implemented to document the change in beach elevation in front of the structure, along with beach and bank erosion adjacent to the structure. This plan should include requirements for adding sediment when beach elevation falls to a certain level. In addition, any sediment excavated from the beach as part of the repair or reconstruction project should be placed on the beach after construction to maintain the volume of sediment in the beach system.

Surface Texture and Chinking in Revetments

Rough surfaces dissipate more wave energy than smooth surfaces. Therefore, when individual rocks in revetments are replaced or repositioned, or when the structure is reconstructed, the seaward face should be rough instead of flat and smooth. The coastal engineer designing the project can specify the type of rock to use and how to build the structure to maximize dissipation of wave energy.

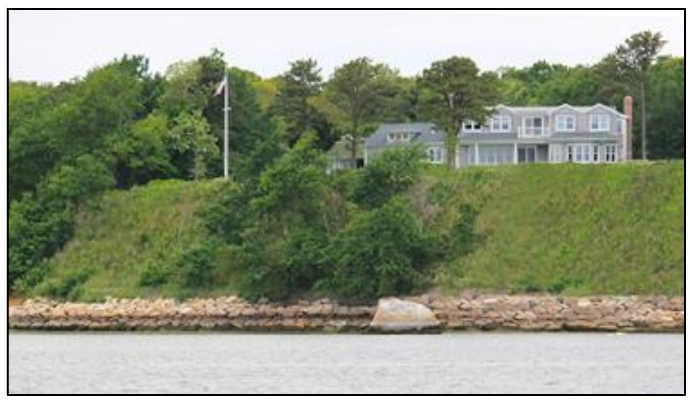
The surface of the rocks in this sloping revetment is relatively smooth and the spaces between the rocks have been filled with cement, further smoothing the structure. Smoother surfaces such as this reflect wave energy outward onto the beach and upward toward the house rather than dissipating the energy. The results are increased overtopping of the wall by waves, resulting in erosion and storm damage. **(Photo: CZM)**

In addition, no grout (e.g., cement) should be used in between the rocks in revetments because it smoothes the surface. Chinking (filling gaps with stones) should also only be done to the extent needed to structurally stabilize the revetment. Filling every void with small stones should be avoided because it reduces wave dissipation, and the small stones can become projectiles in a storm. Adequate void space between rocks also provides better habitat for marine species. Marine animals cannot hide or attach to flat, high energy surfaces. Rough surfaces with spaces in between rocks also reduce wave energy and provide spaces for encrusting organisms, like shellfish and anemones, and hiding spots for small fish. Through this approach, the area will be more diverse and biologically productivity, resulting in a more environmentally friendly seawall.

Structure Height

The higher the seawall or revetment, the more surface area there is to reflect wave energy. Therefore, projects that raise the height of an existing seawall or revetment must be considered carefully in light of the additional erosion that may be caused by wave energy reflected downward. The design height of seawalls and revetments is typically determined by balancing the desired level of protection to landward areas with construction costs and the need to minimize erosion of the fronting beach, which can compromise the structure in the future.

For sites with high banks, the bank itself also serves as a vertical buffer to waves and storm surge. Rather than increasing the height of the structure in these areas, efforts can be made to stabilize the upper bank using vegetation, natural fiber blankets, and/or coir rolls. See the following StormSmart Properties fact sheets for information on these techniques: *Planting Vegetation to Reduce Erosion and Storm Damage*, *Bioengineering - Coir Rolls on Coastal Banks*, and *Bioengineering - Natural Fiber Blankets on Coastal Banks*.



The bank above this revetment was stabilized with natural fiber blankets and native, salt-tolerant vegetation. **(Photo: Wilkinson Ecological Design)**

Water overtopping this seawall in a storm eroded the lawn and sediments behind it. Replacing the sediment and planting salt-tolerant vegetation may help to reduce erosion in future storms. **(Photo: CZM)**

For sites without high banks, raising the height of the structure may be appropriate to provide protection from overtopping waves during large storm events. However, the increased wave reflection will likely result in greater beach erosion. Where appropriate, an alternative approach would be to add sediment to the beach and/or dune seaward of the structure to dissipate wave energy before it reaches the structure. Salt-tolerant vegetation with deep roots can also be used in conjunction with natural fiber blankets to address erosion behind seawalls and revetments. See the following StormSmart Properties fact sheets for more information: *Artificial Dunes and Dune Nourishment*, *Planting Vegetation to Reduce Erosion and Storm Damage*, and *Beach Nourishment*.

Transition to Adjacent Properties

During repair and reconstruction, it may be necessary to consider changes to reduce "end effects"—the increased erosion and storm damage to adjacent properties caused by the seawall or revetment. Unless the structure connects to an existing structure on an adjacent property, it should be shortened so that it ends approximately 15 to 20 feet from the property line (where feasible and where adequately protective of the building on the site). The ends of the structure should also be tapered so that both its elevation and slope are gradually reduced to further minimize end effects.

The end effects of this concrete seawall are causing erosion of the bank and damage to the parking area on a neighboring property. **(Photo: CZM)**

Natural fiber blankets, coir rolls, artificial dunes, beach nourishment, and vegetation should also be considered for use at the end of the structure to both reduce end effects and provide the needed protection to the property. See the following StormSmart Properties fact sheets: *Artificial Dunes and Dune Nourishment*, *Planting Vegetation to Reduce Erosion and Storm Damage*, *Bioengineering - Coir Rolls on Coastal Banks*, *Bioengineering - Natural Fiber Blankets on Coastal Banks*, and *Beach Nourishment*.

Coir rolls, natural fiber blankets, and fill were installed to prevent erosion at the end of this bulkhead. **(Photo: Wilkinson Ecological Design)**

Controlling Erosion from Overland Runoff and Other Sources

To help ensure the success and longevity of a repaired or reconstructed structure, all sources of erosion on the site—including upland runoff and waves—should be identified and addressed as part of the site evaluation and design process. Signs that overland runoff or wave overtopping has caused erosion around seawalls and revetments include erosion of sediment behind seawalls or under revetments and sinkholes behind structures. If overland runoff is causing erosion, this runoff should be reduced or redirected (see *StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion* for details).

Seawall repair or reconstruction projects should include improvements to the drainage system to prevent pressure from building up behind the wall due to wave overtopping or ponding of rainwater. This pressure is one potential cause for structural failure.

To minimize soil erosion behind seawalls and under revetments—which can compromise the integrity of the structure and potentially cause it to fail—woven filter fabric should be placed between the structure and the ground surface during construction (see figure above of a cross section of a revetment). The fabric holds the sediment in place, while the water drains.

Beach Access

According to the requirements of the Massachusetts Public Waterfront Act, coastal property owners are required to maintain public access along the shore for the purposes of "fishing, fowling, and navigation." With hard structures, the best way to protect shoreline public access is to keep the structure as far landward as possible and maintain the height of the beach in front of the structure. When erosion results in no fronting beach at mean high tide, then the reconstruction or repair of the structure will require a license from the Massachusetts Department of Environmental Protection (MassDEP) Waterways Program that specifies how the property owner will maintain required public access. For additional details on these requirements, see the MassDEP Waterways Program web page.

Protecting Existing Vegetation

Vegetation plays an important role in erosion prevention and shoreline protection. Therefore, any destroyed or damaged vegetation should be replaced after project completion. If damaged vegetation consisted of invasive species, large trees that may have been destabilizing the top of the coastal bank or dune, or plants with shallow root structures, the vegetation may be replaced with native grasses and/or shrubs that are more appropriate for erosion control. See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for more information on the use of native, salt-tolerant species for erosion control, as well as information on how to protect newly planted vegetation while it gets established.

Minimizing Impacts to Habitat, Wildlife, and Fisheries

During repair or reconstruction, changes should be incorporated into a hard structure's design to reduce impacts to sensitive habitats. These changes include reducing the amount of wave reflection and erosion caused by the structure, as well as addressing the impact of the structure on sediment levels in the beach system. Any loss of sediment caused by the hard structure can result in erosion to and eventual loss of habitat for shorebirds and other species. In addition, redesigning seawalls to include shelves and crevices within the intertidal and subtidal areas provides more habitat for marine animals, including shellfish.

Restrictions on the time of year when repair or reconstruction can be conducted may also be required to avoid impacts to protected species. 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 the Massachusetts Endangered Species Act and the rare wildlife sections of the Wetlands Protection Act. The Massachusetts Division of Marine Fisheries Habitat Program can provide information on fish and shellfish species and locations that may have special design or permitting requirements.

Heavy Equipment Use

Access for heavy equipment must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, dunes, or other landforms; impacts to wildlife and nesting habitat for protected shorebird and turtle species; and related impacts. To the extent possible, heavy equipment operators should avoid running over beaches 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 seawall and revetment repair and reconstruction projects are likely to require a permit under the Massachusetts Wetlands Protection Act through the local Conservation Commission. Additional licenses and permits may be needed from MassDEP 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. Depending on the project location and the work involved, permits or approvals may also be required from other state agencies and local departments, particularly for larger projects. Massachusetts Environmental Policy Act (MEPA), Massachusetts Endangered Species Act, and CZM federal consistency review requirements may apply. Often, Conservation Commission staff, as well as state and federal agencies as applicable, are available to meet with applicants early in the design process to go over the important factors that need to be considered during the design and permitting.

Permitting requirements are typically more stringent for hard structures than for non-structural alternatives, such as beach and dune nourishment. However, regulatory programs are generally supportive of repair and reconstruction projects that are designed to reduce the adverse impacts being caused by the structure. Projects that have been designed so that the repaired or reconstructed structure is within the same general footprint as the existing structure (i.e., does not extending farther seaward) and include mitigation for any impacts to the fronting, adjacent, and downdrift beaches and banks and dunes generally have fewer issues during permit review and authorization.

Professional Services Required

A coastal engineer with expertise in designing, repairing, and reconstructing coastal engineering structures 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) assess the condition of the structure and the level of protection it is providing; 4) determine what design changes are needed to reduce the impacts of the structure and increase its longevity; 5) develop a monitoring and mitigation plan to address sediment loss to the beach system (i.e., the loss of sediment from armoring of sediment-source banks and increased erosion of the fronting beach); 6) determine if other shoreline stabilization techniques are needed in addition to the structure; 7) identify the best time of year to install the various components of the project; 8) prepare design plans for permitting; 9) develop an access plan for heavy equipment; and 10) prepare design specifications for construction. The consultant can also oversee permitting, construction, monitoring, mitigation, and maintenance of the project. As with hiring any contractor, consider meeting with multiple engineers to compare how they would address site-specific design issues.

Project Timeline

It may take six to eight months or more to have a repair or reconstruction project designed, permitted, and completed, 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 extent of the proposed repairs or reconstruction, whether the proposed work mitigates for adverse impacts of the existing structure, 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.

Monitoring, Mitigation, and Maintenance Requirements

As described in the design considerations section, regular maintenance of coastal engineering structures will likely include adding sediment to maintain the fronting beach. The amount of sediment that should be added and how frequently it is needed will depend, in part, on the proximity of the structure to the reach of high tide, the frequency and severity of storms, and the type and design of the structure (e.g., rough-faced sloping rock revetment vs. vertical wall). Pulling the structure back from the high tide line and reducing its steepness helps to minimize the need for maintenance and mitigation. A monitoring plan developed during the permitting process should specify the volume and grain size of sediment that should be placed on the beach, how the beach elevation will be monitored, who the monitoring reports will be submitted to, and when additional sediment may be needed to mitigate for beach erosion.

Other maintenance activities can include resetting rocks if they have moved or shifted significantly, re-chinking, adding soil behind the structure to replace eroded material, re-vegetating eroded areas behind the structure, filling cracks in concrete seawalls, and replacing rotted wood or metal components. For projects that include planting vegetation, the plants should be replaced (at the appropriate time of year) if they are removed by storms or die (until the plants become fully established, such 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 and approved as ongoing conditions of the permit so that maintenance can be conducted without additional permitting.

Project Costs

With projects involving repair or reconstruction of coastal engineering structures, permitting, design, and construction costs will vary depending on the extent of repairs needed and site-specific considerations. Maintenance costs will depend, in part, on the amount of sediment needed to maintain beach levels, as well as factors such as storm damage and erosion levels. Adding this sediment, however, can lower the costs of maintaining the structure itself. The considerations that most influence the costs of repair or reconstruction projects are the condition of the structure, severity of erosion, width and elevation of the beach, complexity of project design and permitting, and size and location of the proposed structure. For comparison with other shoreline stabilization options, reconstruction projects typically have relatively high design and permitting costs and high construction costs. Repair projects will vary depending on the amount of work to be done, but they typically are also relatively high. While yearly maintenance costs for repair and construction projects are relatively low, long-term maintenance costs (i.e., future major repairs or reconstruction) are high and costs to mitigate for adverse impacts are medium. For a full comparison, see the StormSmart Properties chart, *Relative Costs of Shoreline Stabilization Options* (PDF, 99 KB).

Additional Information

Many other erosion management techniques can be used in conjunction with repair and reconstruction projects to minimize the adverse impacts of these structures and increase their longevity. See the following CZM StormSmart Properties fact sheets for additional information:

- *StormSmart Properties Fact Sheet 1: Artificial Dunes and Dune Nourishment*
- *StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion*
- *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 8: Beach Nourishment*

The following publications and websites also provide valuable information on repair or reconstruction of seawalls and revetments:

- *Maintaining Shoreline Erosion Control Structures* (PDF, 2 MB) by the New York Sea Grant Program includes information on how to determine if coastal engineering structures need maintenance.
- CZM's Inventories of Seawalls and Other Coastal Structures web page includes information on the cost of repairs and reconstruction of seawalls.
- *Beach Nourishment: MassDEP's Guide to Best Management Practices for Projects in Massachusetts* (PDF, 2 MB) describes the steps for beach nourishment projects. The *Technical Attachments* (PDF, 1 MB) give detailed information on sampling beach sediments, evaluating offsite source material, and monitoring project performance.
- The U.S. Army Corps of Engineers *Coastal Engineering Manual* provides detailed guidance on the importance of using site-specific information on coastal erosion and other processes, as well as planning and design considerations.
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) cover work in wetland resource areas and buffer zones.
- Massachusetts Public Waterfront Act (Chapter 91) covers requirements for protecting public trust rights in tideland areas, such as with projects seaward of the current mean high tide line.
- CZM's *Environmental Permitting in Massachusetts* gives brief descriptions of major environmental permits required for projects proposed in Massachusetts.
- CZM's Public Rights Along the Shoreline web page explains the ownership of tidelands in Massachusetts and describes the scope of public and private rights under the Public Trust Doctrine.
- *Guidelines for Barrier Beach Management in Massachusetts* (PDF, 12 MB), which was produced by the Massachusetts Barrier Beach Task Force in 1994, provides an overview of the Wetlands Protection Act Regulations and the function of resource areas, along with information on various erosion management techniques.
- CZM's Coastal Landscaping website focuses on landscaping coastal beaches, dunes, and banks with salt-tolerant vegetation to reduce storm damage and erosion.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding fact sheet* (PDF, 962 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.
- The Natural Heritage and Endangered Species Program website provides information on threatened and endangered species in Massachusetts, maps of Estimated and Priority Habitats, and details on regulatory review for projects in or adjacent to these habitats.
- The Massachusetts Division of Marine Fisheries can provide information on protection of fisheries resources.
- The Massachusetts Ocean Resource Information System, or MORIS, is a user-friendly, web-based mapping tool for interactively viewing coastal data. It includes shoreline change data, which should be considered when evaluating and designing erosion-control or shoreline-stabilization projects. Other data layers in MORIS, such as endangered species habitat, shellfish, and eelgrass, can be used to help identify sensitive resource areas within or near the project site.

www.mass.gov/stormsmart-coasts-program

Commonwealth of Massachusetts
Charlie Baker, Governor

Executive Office of Energy and Environmental Affairs
Matthew A. Beaton, 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

This is a publication of the Massachusetts Office of Coastal Management (CZM) pursuant to the National Oceanic and Atmospheric Administration Award No. NA12NOS4190086. This publication is funded (in part) by a grant/cooperative agreement from the National Oceanic and Atmospheric Administration (NOAA). The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its sub-agencies. ***This information is available in alternate formats upon request.***

Publication Date: December 2013, with updates in 2018