StormSmart Properties Fact Sheet 4: Bioengineering - Coir Rolls on Coastal Banks

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 Bioengineering and Coir Rolls?

Coastal bioengineering projects reduce erosion and stabilize eroding shorelines by using a combination of deep-rooted plants and erosion-control products made of natural, biodegradable materials, such as coir rolls. Coir rolls are cylindrical rolls that span 12 to 20 inches in diameter, are packed with coir fibers (i.e., coconut husk fibers), and are held together with mesh. The rolls are typically 10- to 20-feet long and can be stitched together to provide continuous shoreline coverage. In contrast, coir envelopes are coir fabric filled with sand. Coir envelopes have very different impacts and design considerations and should not be confused with coir rolls.

As with all coastal bioengineering projects, salt-tolerant vegetation with extensive root systems is used with coir rolls to help stabilize the site. The vegetation is planted directly into the coir rolls and on the surrounding site. For important instructions on using plants in bioengineering projects, see the *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*, which includes specific information on how vegetation reduces erosion and storm damage; instructions on selecting, properly planting, and caring for appropriate species; tips on maximizing the effectiveness of vegetation projects and minimizing impacts; and specifics on project design and implementation.

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 fact sheet focuses on the use of coir rolls on coastal banks (also known as bluffs), where coir rolls are typically installed at the toe (i.e., base) of the bank—although they can also be installed up the bank face. In coastal areas, coir rolls can also be used to help reduce erosion problems created by hard structures (i.e., seawalls and revetments). See "Appropriate Locations" in the Design Consideration section below for additional information.

This coir roll has been planted with vegetation prior to installation. **(Photo: Wilkinson Ecological Design)**

Coir rolls are often used in conjunction with other techniques for erosion management, such as natural fiber blankets, runoff control, and beach nourishment. Natural fiber blankets are woven mats of natural fibers that are used to stabilize the ground surface while plants become established. Runoff control projects reduce and slow the flow of water over the ground surface, reducing coastal erosion problems. Beach nourishment adds sediment (i.e., sand, gravel, and cobble) from an off-site source to address beach erosion issues. See the following StormSmart Properties fact sheets for more information: *Controlling Overland Runoff to Reduce Coastal Erosion*, *Bioengineering - Natural Fiber Blankets on Coastal Banks*, and *Beach Nourishment*.

How Coir Rolls Reduce Storm Damage on Coastal Banks

If the toe of a bank is eroding, the upper bank may collapse even if it is well vegetated. Coir rolls can be used to protect and stabilize the toe by providing a physical barrier that buffers waves, tides, and currents, reducing erosion of exposed sediments.

Coir rolls provide stability and protection to the site while the vegetation planted in and above the rolls becomes established. As the coir rolls disintegrate, typically over 5-7 years, the plants take over the job of site stabilization. The dense root systems of the plants hold sand, gravel, and soils in place and help reduce erosion from rain, wind, tides, and waves. In addition, by taking up water directly from the ground and breaking the impact of raindrops or wave-splash, the plants slow the rate and reduce the quantity of upland water runoff that can lead to erosion.

For sites exposed to high wave energy, it may be necessary to replace and maintain coir rolls at the toe of the bank to provide longer-term stability. If the beach in front of the bank is narrow or narrows over time, if the beach elevation is too low or erodes down over time, or if the shoreline has a steep drop off below the low tide line, it may be necessary to combine bioengineering with other techniques, such as dune and beach nourishment, to ensure a successful project. (See the following StormSmart Properties fact sheets for more information: *Artificial Dunes and Dune Nourishment* and *Beach Nourishment*.) A professional with demonstrated success installing bioengineering projects in dynamic environments should be consulted to assess each site and make recommendations regarding the appropriate technique or combination of techniques.

Waves and tides eroded the toe of this bank, causing this collapse of a well vegetated section of the bank face. **(Photo: CZM)**

Top left: This photo shows an exposed bank that was eroding at two feet per year before coir rolls and erosion-control vegetation were installed.

Bottom left: This photo shows the site during installation of the coir rolls, which were placed at the toe and up the face of the bank. Natural fiber blankets were also installed on the bank face. The site was then planted with salt-tolerant vegetation.

Bottom right: This photo shows the same site 10 years after project completion. (Note: This site has survived Hurricane Irene and Hurricane Sandy.)

(Photos: New England Environmental)

Relative Benefits and Impacts Compared to Other Options

Coir rolls provide direct, physical protection to a bank. Because they are made from natural, biodegradable materials and are planted with vegetation, coir rolls absorb much more wave energy than seawalls, rock revetments, or other "hard" shoreline stabilization structures, which reflect significantly more of the wave energy that hits them 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 and reducing the effectiveness of the structure and leading to costly repairs. This erosion also lowers the elevation of the beach in front of the structure, ultimately leading to a loss of dry beach at high tide and reducing the beach's value for storm damage protection, recreation, and wildlife habitat. Coir roll projects also allow some natural erosion from the site while hard structures impede virtually all natural erosion of sediment. Without this sediment supply, down-current areas of the beach system are subject to increased erosion. In addition, coir rolls can often be installed without the use of mechanized equipment that can significantly impact the site. Because they are made with natural fibers and planted with vegetation, coir rolls also help preserve the natural character and habitat value of the coastal environment.

Like all shoreline stabilization options, however, coir roll projects can result in negative impacts when inappropriately designed or sited. While less severe than with hard structures, coir rolls can reflect some wave energy and they can inhibit the natural supply of sediment to down-current areas. Coir rolls made with synthetic materials or covered in wire mesh can cause additional significant impacts. Synthetic and wire mesh that remains after the rolls are degraded or is found on rolls that have been ripped away from a bank during a storm has the potential to entangle wildlife, disrupt

navigation (e.g., by getting wrapped around boat propellers), and harm recreational beach users (e.g., rusted wire can puncture bare feet). To help address this issue, local officials often require identification tags to be sewn on coir rolls when they are installed to ensure proper disposal if the rolls are dislodged from the project site. In addition, wire mesh should not be used on coastal sites and the use of synthetic mesh should be minimized. For sites with higher wave energy, it is often necessary to use high density rolls (7-9 pounds per foot) in the bottom row, which are only available with synthetic mesh. This targeted use of synthetic materials is preferable to using more structural options such as a rock revetment to stabilize the site, which have greater adverse impacts.

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, coir roll projects and other non-structural alternatives are therefore the only options available for reducing erosion and storm damage on coastal properties.

Design Considerations for Coir Rolls on Coastal Banks

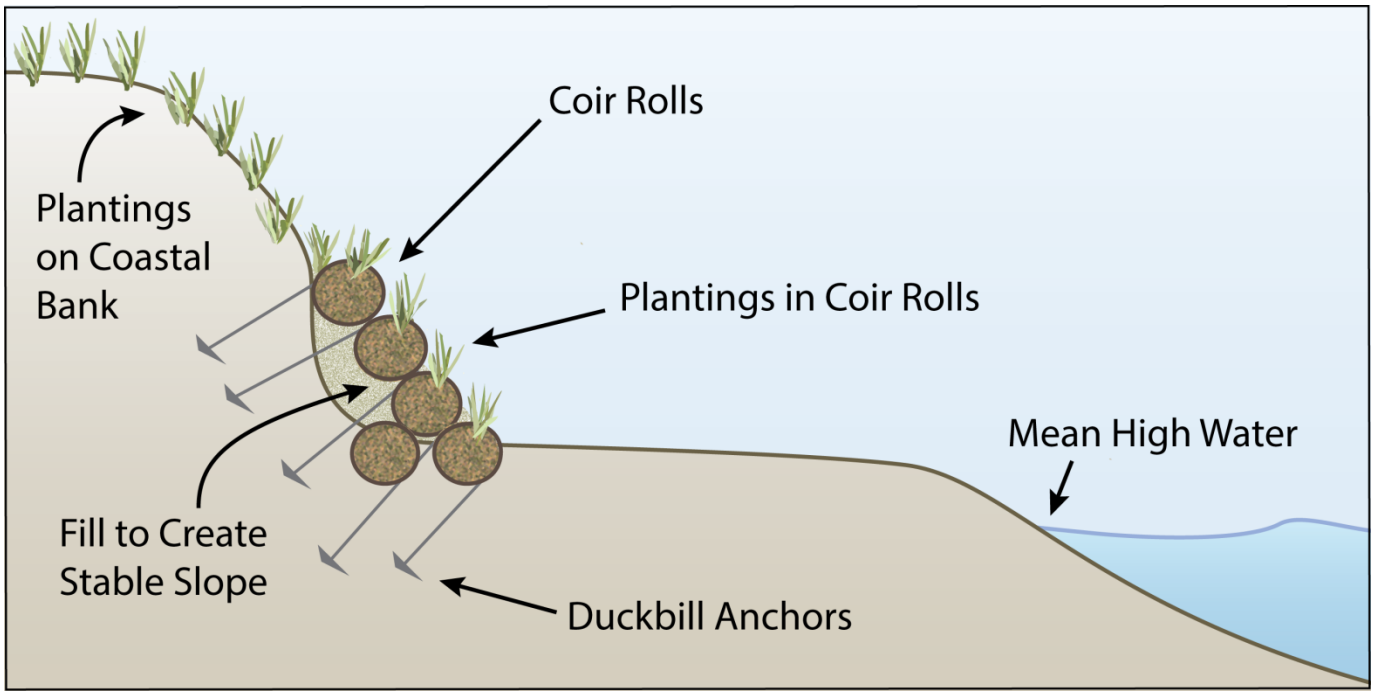
This section covers a variety of factors that should be considered to minimize adverse impacts and ensure successful design, permitting, construction, and maintenance of coir roll bioengineering projects on a coastal banks.

Appropriate Locations

For coastal bank projects, coir rolls can be used on both sheltered sites and sites exposed to wave energy. However, they are most effective in areas with higher beach elevations with some dry beach at high tide, where the rolls are not constantly subject to erosion from tides and waves. If the dry beach is narrow, the beach elevation is relatively low, and/or the site is exposed to moderate wave energy, more than one row of coir rolls will likely be needed on the face of the bank, as well as at the base. In these exposed conditions, the rolls will have a shorter lifespan and will require more frequent maintenance such as resetting, anchoring, or replacement. Additional erosion-control options may be needed at these sites, such as beach nourishment (see *StormSmart Properties Fact Sheet 8: Beach Nourishment*). It is essential to have a site-specific evaluation conducted by a professional with demonstrated experience and success implementing coir roll projects in exposed settings to determine the viability of coir rolls in these areas.

A coir roll, natural fiber blanket, and fill were installed to minimize erosion at the end of this bulkhead. **(Photo: Wilkinson Ecological Design)**

In some cases, coir rolls can also be used to effectively reduce erosion from hard structures such as seawalls. Coir rolls can be effectively installed at the base of and next to hard structures to help reduce erosion problems under the structure and on neighboring properties. They are also used on the face of the bank above the structure to stabilize the area.



Cross-section of a bioengineering project on a bank in an exposed setting.

Establishing a Stable Slope

On banks, a stable slope is essential for project success. If the bottom of the bank has eroded and its slope is steeper than the upper portion of the bank, the bank is likely unstable. Even when heavily planted with erosion-control vegetation, banks with unstable slopes are extremely vulnerable to slumping or collapse that can endanger property landward of the bank. Before installing coir rolls or planting vegetation, therefore, the bank slope should be stabilized.

Ideally, soil of a similar type to that on the bank or beach is brought in as fill and added to the lower part of the bank to create a slope that matches or is less steep than the upper slope. However, if adding fill brings the toe of the bank within the reach of high tides, the fill will erode quickly and undermine the rest of the bank. In these cases, regrading the bank slope by removing sediment from the top of the bank is a better option. While removing part of the upper portion of the bank does reduce the land area of the property, it can be done in a controlled fashion that improves the overall stability and storm-damage prevention capacity of the bank. And if the slope is not stabilized by either adding fill at the bank toe or regrading the top of the bank, bank collapse during a storm could cause substantially more loss of land area to the sea. In addition, any investment in coir rolls, vegetation, and other site stabilization methods will be lost if the bank collapses. On sites where the top of the bank is well vegetated with mature, salt-tolerant species with extensive roots, the appropriate approach to stabilize the bank should be carefully developed by a professional with extensive experience successfully stabilizing similar sites.

Removing/Replacing Invasive Plants

Invasive plants (i.e., introduced species that thrive at the expense of native plants) should be removed and replaced with appropriate native plants if they are preventing establishment of erosion-control vegetation on a bank. This effort is particularly warranted when bank stability is severely compromised by the invasive plant. Because of their tenacity, successful control of invasive plants can take years to accomplish and may require perpetual monitoring and management. Effective ways to manage invasive species on the bank should therefore be incorporated into project design. See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for more information.

Controlling Erosion from Overland Runoff and Other Sources

To help ensure the success of newly planted vegetation, 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. If overland runoff is causing erosion, this runoff should be reduced or redirected to give newly planted vegetation the best chance of survival (see *StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion* for details). In areas subject to regular erosion from waves, tides, currents, wind, and coastal storms, additional techniques can be used to improve site protection. For example, beach nourishment (i.e., adding sediments, such as sand, gravel, and cobble to widen the beach—see *StormSmart Fact Sheet 8: Beach Nourishment*) can protect coir roll projects by widening beaches in areas with relatively narrow beaches at high tide.

Protecting Vegetation

In addition to controlling erosion (see above), other steps should be taken to protect vegetation. Exposed areas should not be planted during the winter when the plants are dormant because wind or waves are likely to pull them out before they can get established. To prevent trampling of plants, pedestrian access to the shoreline should be restricted to designated access paths or walkways and the number of access points should be limited as much as possible. Often, multiple properties can use a common access point. To limit shading impacts to vegetation, access structures should be elevated on open pilings and their size should be minimized as much as possible.

Maintaining Sediment Supply to the System

Bank erosion is an important source of sediment to beaches and dunes in the shoreline system. To maintain this sediment supply, projects using two or more rows of coir rolls can bring in sediment from an offsite source on a regular basis (e.g., annually and after major storms) and place it on the beach in front of the rolls. This sediment will also help provide storm damage protection to the site by dissipating wave energy before it reaches the bank.

Minimizing Reflected Wave Energy

The ends of a coir roll project should be carefully designed to minimize any redirection of waves onto adjacent properties. Tapering the rolls down in number and height so that the project blends in to the adjacent bank helps address this problem.

This bioengineering project with coir rolls, natural fiber blankets, and vegetation was designed to minimize erosion on the adjacent property. At the end of the property, the number of rolls was tapered down to one and the bank's slope was reduced and blended in to the adjacent bank. **(Photo: CZM)**

Project Installation and Coir Roll Anchoring

Coir rolls should be placed end to end and laced together with jute or coir twine to create continuous rolls parallel to the shoreline. The rolls are typically anchored by stakes on the seaward side of the rolls, earth anchor systems, or a combination of these two techniques. Wooden stakes are biodegradable but do not always hold well in areas with higher wave energy. Earth anchors, which are typically used for sites exposed to higher rates of erosion, consist of a metal duckbill anchor that

extends into the bank and is connected to the coir roll by wire cables. Although earth anchors are not biodegradable, exposed portions of the cable system can be cut off and removed after the coir rolls have broken down to reduce marine debris impacts.

The anchoring system is critical to the success of the project. A professional is needed to determine the appropriate number and type of anchors for the site. It is also essential that the installation be carefully supervised and conducted by contractors with experience installing projects that have survived multiple storms. Anchors may need to be tightened after a period of time. To improve the longevity of the project, a professional can monitor the rolls over time and identify needed maintenance.

Coir rolls should be fully covered with sediment or tied into the existing bank at both ends of the project to minimize the potential for waves to get behind the rolls and erode the bank. The project can fail if the ends of the coir rolls become exposed.

Coir Roll Configuration and Size

The number of rows of coir rolls needed and their diameter depend on: 1) how exposed the site is to waves, 2) how frequently waves reach the base of the bank, and 3) the steepness of the bank face. In more sheltered sites or on relatively shallow bank slopes, one or two rows of 12-inch-diameter coir rolls may be sufficient. In more exposed areas and on steeper banks, multiple rows of 20-inch-diameter rolls may be needed up the face of the bank to provide effective site stabilization. The bottom row of coir rolls is often buried during installation to prevent undermining by beach erosion during a storm. In some cases, two side-by-side rows of rolls are installed at the base to provide more stability for the rows of rolls above.

Density of Coir Fibers

How densely the coconut husk fibers are packed into the coir rolls is also an important design element. While more densely packed rolls provide greater initial erosion protection, loosely packed rolls can be more heavily planted (because the vegetation can be easily inserted into the roll). This heavy planting allows the plants to become established more quickly, allowing the plant roots to effectively stabilize the site as the coconut fibers degrade. Both high-density and low-density coir rolls can be used together when heavily planted low-density rolls are installed adjacent to high-density rolls to help ensure the high-density rolls become vegetated over time. The professional designing the project should determine where rapid plant colonization or initial structural integrity is most important and then design a mix of rolls accordingly.

Reducing Damage from Sun Exposure

Plants can be used to shade the rolls and slow the degradation of the coir fibers that occurs from exposure to sunlight. The coir rolls can also be covered with sediment and natural fiber blankets (woven mats of natural fibers) to shade the coir rolls and slow degradation.

Heavy Equipment

While heavy equipment is not typically needed for coir roll projects, a mini-excavator or other small mechanized equipment may be necessary. Minimizing the use of heavy equipment can help reduce temporary disturbances from the project. Access for any 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 species (i.e., species that are considered endangered, threatened, or of special concern in Massachusetts); and related impacts. 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.

Wildlife and Fisheries Protection

If the project is proposed in or adjacent to habitat for protected wildlife species or horseshoe crab spawning areas, there may be limitations on the time of year that the project can be constructed. Information about the location of these resources and special permitting requirements is available from the Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife (for protected wildlife species) and the Massachusetts Division of Marine Fisheries (for horseshoe crabs).

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 location and the work involved. Often, Conservation Commission staff are available to meet with applicants to go over important factors that need to be considered early in the design process.

Generally, regulatory programs are supportive of projects that use non-structural approaches to manage coastal erosion, such as coir rolls and vegetation, as opposed to hard structures. To obtain a permit, projects need to be designed to comply with regulatory requirements, including minimizing or avoiding impacts to sensitive resource areas such as horseshoe crab spawning areas and protected species habitat, which are protected by the various regulatory programs.

Professional Services Required

An environmental professional with significant experience designing, implementing, and successfully maintaining coir rolls and vegetation projects in coastal areas should be chosen to: 1) identify regulatory requirements and ensure the project fully conforms with those requirements; 2) determine the size, density, and number of rows of coir rolls needed based on site conditions (such as erosion history; exposure to winds, wave climate, and soil types; and runoff patterns); 3) determine whether natural fiber blankets, beach nourishment, or other techniques should be used in conjunction with the rolls; 4) identify any additional site conditions (including oversteepened slopes, erosion from overland runoff, and the presence of invasive species) that must be addressed; 5) select plant species and develop a plan for planting and plant maintenance; 6) identify the volume and composition of fill (if needed to re-establish a stable slope); 7) determine the best time of year to install the various components of the project; 8) develop an access plan if heavy equipment is needed; 9) prepare plans for and oversee permitting; 10) prepare design specifications and oversee construction; and 11) monitor and maintain the project. To ensure that essential design elements are appropriately implemented, *construction should be conducted by a contractor with experience installing coir roll projects that have survived multiple storms and carefully supervised by a consultant with significant experience and demonstrated success with coastal coir roll projects. Monitoring and maintenance by a consultant with significant experience is also strongly recommended.*

Project Timeline

It may take as little as four to eight months to have a bioengineering project with coir rolls 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), special timing needed for planting vegetation, and/or weather conditions during construction.

Maintenance Requirements

Bioengineering projects with coir rolls and vegetation require ongoing maintenance to ensure their success. Maintenance needs will depend, in part, on the proximity of the coir rolls to the reach of high tide, the elevation and width of the beach, the frequency and severity of storms, and how established the plants are before a storm hits. To maintain the project's designed level of protection, the coir rolls and vegetation should be inspected regularly, particularly after rain and coastal storms. Any storm damage should be addressed immediately to avoid further deterioration—this includes replacing any sediment that erodes around the coir rolls, resetting or replacing coir rolls as needed, and replanting vegetation (which may have to be conducted at the appropriate time of year). The more frequently high tides and waves reach and overtop the coir rolls, the higher the likely erosion rate and deterioration rate of the rolls. Erosion rates will be even higher if the site is not vegetated. Because the replacement of sediment and plants removed by storms is typically necessary, the original permit application should include a maintenance plan. This plan should specify any replacement materials and activities that may be used on the site and how the site will be accessed so that maintenance can be conducted without additional permitting.

Experience with what works, what doesn't, and how to adjust a design as site conditions change is very important to the success of bioengineering projects, particularly in coastal areas. Therefore, it is strongly recommended that the consultant who designed the project be involved in the monitoring and maintenance after any erosion from rain or coastal storms.

Project Costs

With coir roll projects, a range of options are available that give increasing levels of protection with increased construction costs. 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 coir roll projects on coastal banks are: the severity of erosion, the width and elevation of the beach in front of the bank, the grading needed to create a stable slope, the diameter and number of rows of rolls, and the type and size of plants selected.

For comparison with other shoreline stabilization options, the relative costs for coir roll projects are:

- Low-medium for design and permitting.
- Medium-high for construction.
- Low-medium for maintenance.
- Low for mitigation.

See the StormSmart Properties chart, *Relative Costs of Shoreline Stabilization Options* (PDF, 99 KB), for a full comparison.

Additional Information

Bioengineering with coir rolls can be used in conjunction with many other techniques for erosion management. 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 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 bioengineering with coir rolls and vegetation:

- CZM's Coastal Landscaping website includes information on landscaping coastal areas 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.
- Woods Hole Sea Grant's Marine Extension Bulletin, *Biodegradable Erosion Control* (PDF, 723 KB), provides information on various components of a coir roll project for coastal erosion control.
- CZM's *Environmental Permitting in Massachusetts* briefly describes major environmental permits required for projects proposed in Massachusetts.
- *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 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) cover work in wetland resource areas and buffer zones.
- The Natural Heritage and Endangered Species Program website 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.
- The Massachusetts Ocean Resource Information System, or MORIS, is a web-based mapping tool for interactively viewing coastal data. MORIS data layers, such as endangered species habitat and shellfish, can help identify sensitive resource areas within or near the project site.

www.mass.gov/stormsmart-coasts-program

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