Fact Sheet 5.4: Shorelines

The mitigation objective of this Fact Sheet is to protect areas inland from shorelines from coastal erosion and flooding.

Coastal erosion typically is caused by wave action, coastal flooding, currents, water runoff, wind effects, and other impacts of storms. Coastal erosion can damage property and infrastructure, while also impacting beach construction and access. Protecting the shoreline using structural and non-structural stabilization methods can reduce the effects of coastal erosion and flooding. The ability to reduce losses from wave action, erosion and flooding depends on the elevation, configuration, strength and durability of stabilization.

Table 5.4.1 summarizes some common mitigation options for dealing with coastal erosion. The options marked with "O" are for ocean shorelines, the options marked with "S" are for sheltered water shorelines, and those marked with "O, S" are for both ocean and sheltered water shorelines.

Table 5.4.1. Common Shoreline Mitigation Solutions

Solutions and Options	***Reduce Wave Risk***	***Reduce Land Loss***	***Reduce Flooding***
Mitigation Solution: Structurally Stabilize Shorelines			
Option 1: Construct Seawalls	**O, S**	**O, S**	**O, S**
Option 2: Construct Bulkheads	**S**	**S**	**S**
Option 3: Install Revetments	**O, S**	**O, S**	**O, S**
Option 4: Place Detached Breakwaters	**O, S**	**O, S**	**O, S**
Option 5: Build Jetties and Groins	**S**	**S**	
Option 6: Reinforce Dunes	**O, S**	**O, S**	**O, S**
Mitigation Solution: Use Non-Structural Stabilization			
Option 1: Nourish Beaches and Restore Dunes	**O, S**	**O, S**	**O, S**
Option 2: Stabilize Using Living Shorelines	**S**	**S**	

O = ocean shoreline, **S** = sheltered water shoreline

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Mitigation Solution: Structurally Stabilize Shorelines

Mitigation options aim to stabilize coastal areas by building shoreline structures, such as seawalls, bulkheads, revetments, detached breakwaters, groins/jetties, reinforced dunes or coastal levees/dikes.

Seawalls, bulkheads, revetments and detached breakwaters are usually built parallel to the shore or at the base of a bluff. These structures are intended to keep the sediment or soil along the shoreline and to protect against high water levels, waves and erosion. Jetties and groins are built perpendicular to the shore to block the movement of sediment along the shore, hold back currents, protect areas from wave forces, guide sand movement and maintain navigation depth. Reinforced dunes have internal support that is designed to reduce dune loss and lessen flooding on the inland side of dunes.

Evaluate the following considerations when determining which structural shoreline stabilization method is an appropriate mitigation measure:

- The degree of protection these structural methods offer depends on their design, construction and maintenance. Some options may be suitable for ocean shoreline only or sheltered water areas only, while others may be suitable both ocean and sheltered water areas.
- These structural methods may not prevent erosion of the beach on the waterside of the structure and may, in fact, worsen ongoing erosion of the beach.
- Depending on the design, some structures can:
    - Trap sediments on the land that otherwise would erode and nourish the beach
    - Lead to passive erosion (eventual loss of the beach since the structure prevents movement of the beach toward the land)
    - Lead to active erosion (localized scour on the waterside of the structure and on unprotected property beyond the ends of the structure)

Some jurisdictions distinguish between erosion control structures built to protect existing development and those built to create a buildable area on an otherwise unbuildable site. Designers should investigate federal, state and local regulations and requirements for erosion control structures before starting design.

Option 1: Construct Seawalls

Seawalls are built to resist the effects of waves and protect against land loss from erosion, current and wave action. As the term is used here, seawalls are suitable for ocean shorelines and shorelines that receive lower wave energy. Seawalls can be constructed of concrete, steel, large stones or a combination of these materials. They can be built with several different face shapes to deflect wave energy (Figure 5.4.1).

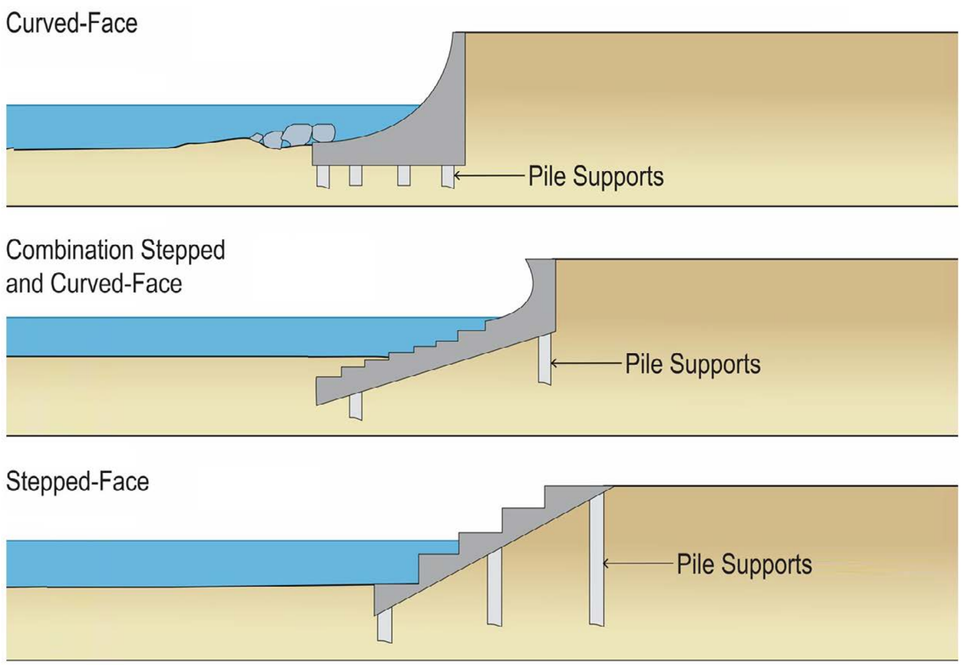


Figure 5.4.1. Example seawall cross-sections.

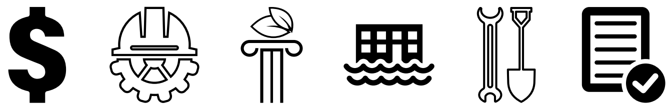
Drainage and designed filters can help maintain backfill behind seawalls. Void spaces that may develop under the toe of rock or armor-type protection can be resolved by grouting under the wall, depending on the elevation of the footing relative to tide levels. Where seawalls protect docks, wharfs, or piers that are elevated, elevate the top elevation of the seawall to match the dock, wharf, or pier.

When evaluating seawalls as a mitigation option, consider the following:

- Consider future conditions such as sea level rise and post-storm beach profiles in the design of a seawall.
- Vertical seawalls often deflect wave energy instead of dissipating it, which can make the shoreline more subject to erosion.
- Waves and tidal effects of large storms and hurricanes can erode the beach profile and undermine the seawall foundation, leading to failure.
- If the seawall is not constructed high enough, backfill behind seawalls can be lost when waves overtop. When the backfill is lost, structures on land can be undermined and damaged.

- Consider permitting requirements before choosing to use a seawall. Some jurisdictions may prohibit or limit the number of new seawalls. Check with the jurisdiction before selecting this, or any, stabilization option.
- Implement an inspection and maintenance program to maintain the seawall's stability throughout its intended life.

CONSIDERATIONS:



Option 2: Construct Bulkheads

Bulkheads are barriers constructed of wood, steel, stone, vinyl or concrete to prevent sliding or erosion of the land (Figure 5.4.2). The primary purpose of a bulkhead is to keep soil in place and prevent the shoreline from sliding during flooding and wave attack. Protecting the land beyond the bulkhead generally is a secondary consideration. Bulkheads are not as strong as seawalls and are not suitable for ocean shorelines.

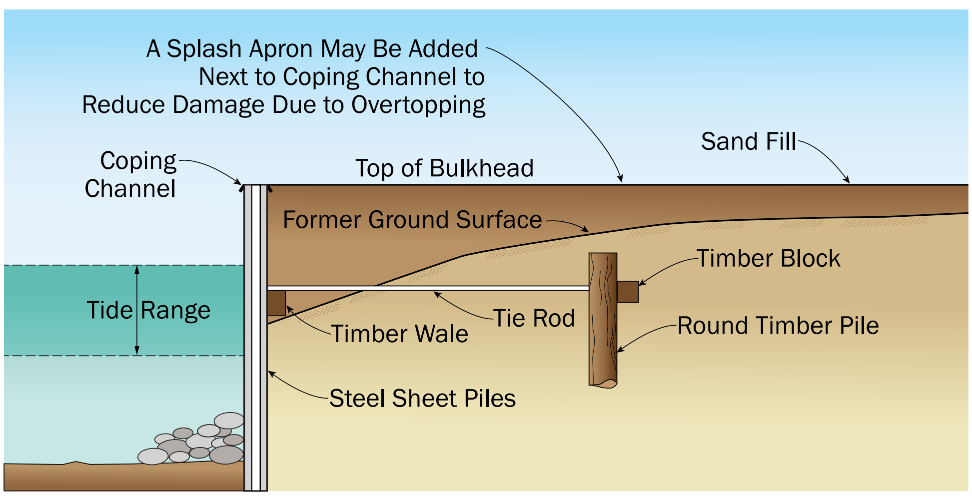


Figure 5.4.2. Example of an anchored sheet-pile bulkhead.

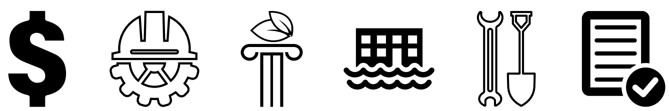
Bulkheads provide protection against low to moderate wave action. They can be used where deep water is needed directly at the shore to navigate or at harbors and marinas. Bulkheads can be cantilevered, anchored or gravity structures (such as rock-filled timber cribs). Piles or caissons can be reinforced by jacketing to provide additional strength. Void spaces that may develop under the toe of rock or armor-type protection can be resolved by grouting under the wall, depending on the elevation of the footing relative to tide levels. If the dock, wharf or pier being protected by a bulkhead is raised, the bulkhead itself also should be raised to match the dock, wharf or pier.

When evaluating bulkheads as a mitigation option, consider the following:

- Structurally, bulkheads do not resist wave action as well as seawalls.

- Consider future conditions, such as sea level rise, when designing the height of the bulkhead to reduce the likelihood of overtopping.
- Carefully consider the location if the bulkhead is built near existing structures since installation may impact existing structures and lead to potential maintenance issues with the bulkhead system.
- Consider permitting requirements before choosing to use a bulkhead. Some jurisdictions may prohibit or limit the installment of bulkheads. Check with the jurisdiction before selecting this, or any, stabilization option.
- Implement an inspection and maintenance program to maintain the bulkhead's stability throughout its intended life.

CONSIDERATIONS:



Option 3: Install Revetments

Coastal revetments generally are built of durable stone, concrete or other materials placed on an earthen slope to protect the shoreline from erosion caused by floodwater or wave action. Coastal revetments typically are comprised of an armor layer, filter layer(s), geotextile filter fabric, and toe protection (Figure 5.4.3). Revetments are suitable for ocean shorelines and sheltered water shorelines.

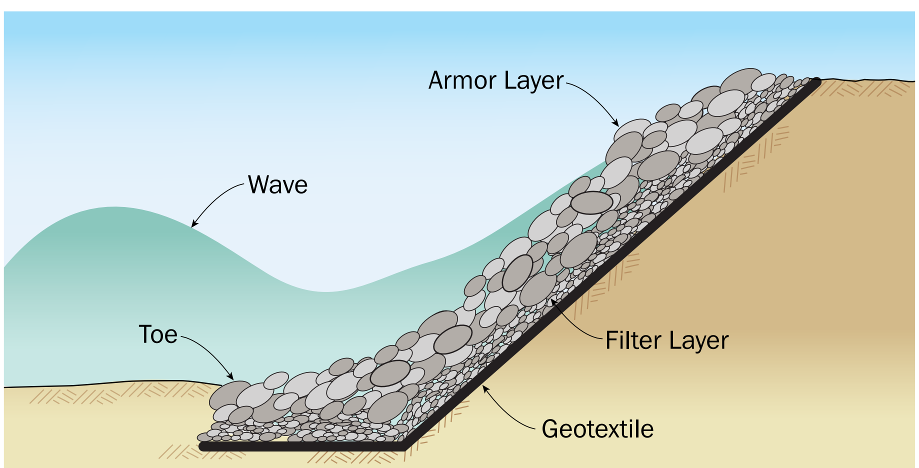


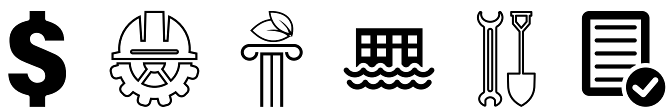
Figure 5.4.3. Typical cross section of an armor stone revetment.

The armor layer may be made from stone, concrete, concrete rubble or other structural elements such as gabions that are heavy enough to resist shifting during wave attack. The wave height and water velocity will determine the type and size of armor needed. The filter layer, also called the bedding layer, promotes drainage and helps seat the armor without damaging the geotextile fabric. Geotextile filter fabric generally is placed between the filter layer and the existing soil layer to prevent movement of soil through the revetment. Movement of the underlying soil can lead to revetment settlement or collapse, losing protection to land areas beyond the revetment. Finally, toe protection provides stability against undermining at the bottom of the structure. Increasing the size of the stones or armor units in the armor layer can improve revetments' ability to resist damage from larger waves.

When evaluating revetments as a mitigation option, consider the following:

- Consider future conditions, such as sea level rise, and post-storm beach profiles when deciding the revetment's height and slope to reduce the chance of overtopping.
- Consider minimum expected water levels in the design of the armor layer depth at the toe to avoid scour.
- Revetments may not be as strong against wave action as seawalls are.
- Implement an inspection and maintenance program to maintain the revetment's stability throughout its intended life.
- Consider Federal, state and local permitting requirements before choosing to use a revetment. Some jurisdictions may prohibit or limit the installment of revetments. Check with the jurisdiction before selecting this, or any, stabilization option.

CONSIDERATIONS:



Option 4: Place Detached Breakwaters

A detached breakwater is a manmade structure placed offshore to protect land areas beyond the shoreline from high waves, to maintain the structure of the beach, and to create or stabilize wetland areas. Detached breakwaters help disperse wave energy and encourage sediment to deposit along the shoreline in the area protected by the structure. Breakwaters generally are situated parallel to the shore (Figure 5.4.4).

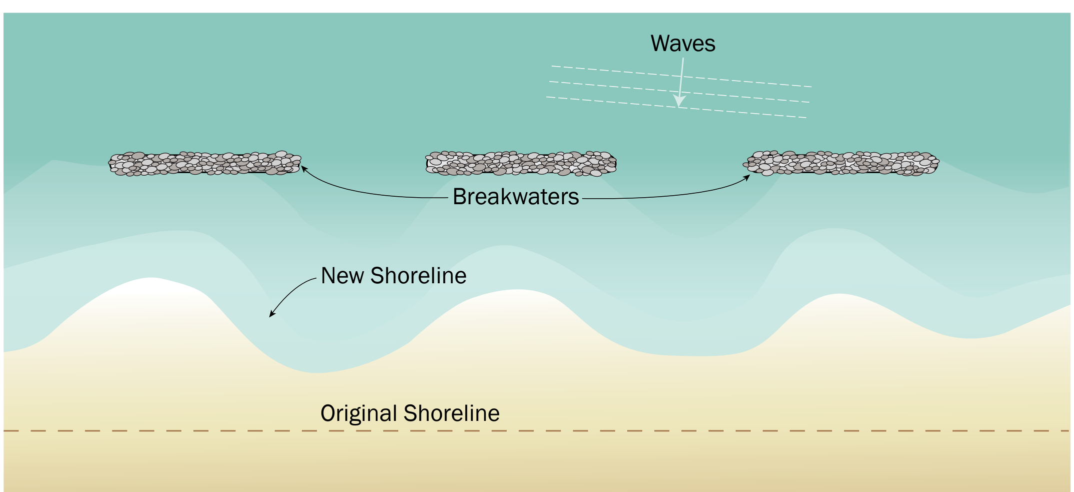
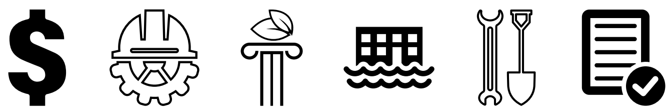


Figure 5.4.4. Typical plan view of a breakwater system.

Detached breakwaters can be high above the water level for maximum wave dispersal, low-crested to reduce construction costs (but these will allow greater wave transmission) or designed as reef-type breakwaters that are under water. Some systems use a combination of shore-connected and detached breakwaters. Most breakwaters in the U.S. are made of rubble-mound construction. The breakwater's crest elevation, width, permeability, slope angles and type of construction can be adjusted based on the desired level of wave energy dispersal and sand buildup.

When considering this mitigation option, evaluate the impact to sediment movement toward downdrift beaches, which may receive less sand deposit after a breakwater is built.

CONSIDERATIONS:



Option 5: Build Jetties and Groins

Jetties and groins are built perpendicular to the shore to slow down sediment transport along the shoreline, control currents, protect areas from wave forces, impact sand movement, and preserve navigation depth (Figure 5.4.5). Jetties usually are built at tidal inlets, river entrances or port or harbor entrances to reduce channel shoaling or stabilize the updrift shoreline. Single jetties can be built on one or both sides of the entrance.

Groins generally are built in larger numbers along a shoreline—there usually are several to many of them, spaced hundreds of feet apart. Jetties and groins can be built on both ocean and sheltered water shorelines. Sometimes a jetty is called a terminal groin (meaning a single groin at the end of a section of land, acting like a jetty).

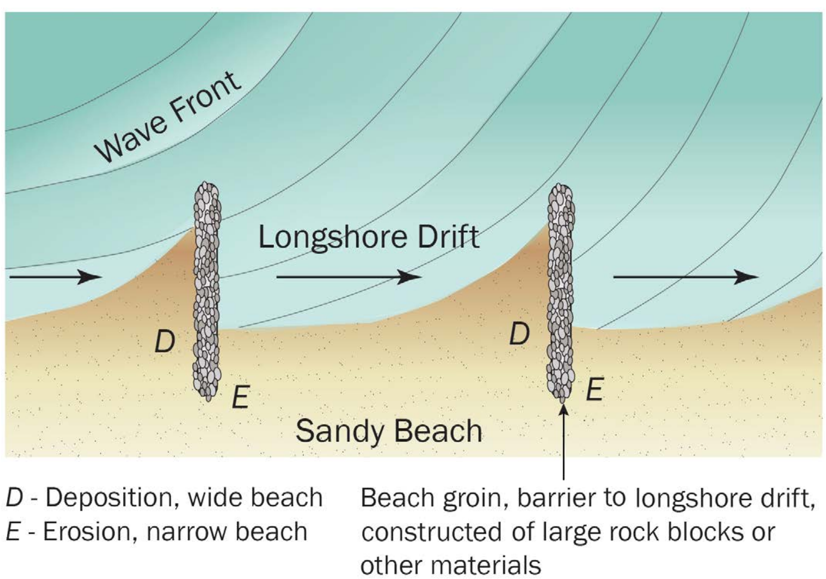


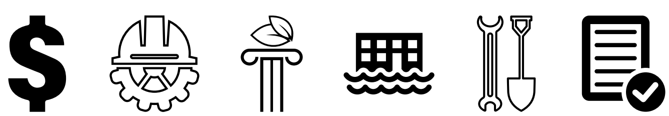
Figure 5.4.5. Example sand accretion and erosion patterns around a groin system.

Jetties and groins typically are built of various stone filter and base layers overlain by large armor stone or concrete armor units. Timber, steel and concrete also can be used in jetty design. Designers should know about coastal processes at the site, such as dominant wave directions and sediment movement along and across the coastline. The design also must consider wave forces, ocean currents and changing tidal patterns. Increasing the size of the stones or armor units in the armor layer can improve the ability of jetties and groins to resist damage from waves.

When evaluating jetties as a mitigation option, consider the following:

- Periodic dredging of the sand that builds up against the jetty or groin may be necessary to repair downdrift shorelines that do not receive sand due to the structure. Dredging to maintain navigation depth also may be necessary.
- Consider future conditions, such as sea level rise, and the expected maximum wave crest when deciding the structure's height to reduce the chance of overtopping.
- Consider impact protection from ships and other vessels in the design.
- Implement an inspection and maintenance program to maintain the jetty or groin throughout its intended life.
- Consider Federal, state and local permitting requirements before choosing to use a jetty or groin. Some jurisdictions may prohibit or limit the installment of jetties and groins. Check with the jurisdiction before selecting this, or any, stabilization option.

CONSIDERATIONS:



Option 6: Reinforce Dunes

Reinforced dunes protect the inland areas behind the dunes from flooding and loss of ecological value. Reinforced dunes are built with solid cores using components such as geotubes, rock revetments and sheet piles to maximize the dune's ability to resist erosion by waves and surge during severe storms. Figure 5.4.6 shows an example of a rock core used to reinforce a dune.

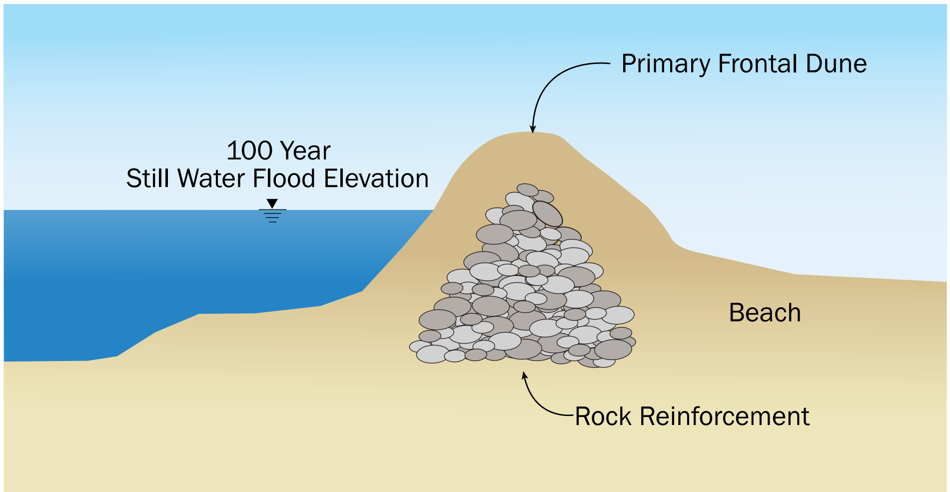
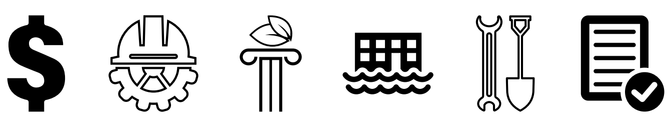


Figure 5.4.6. Rock cores can be used to build dunes that resist erosion from waves and surge.

When evaluating reinforced dunes as a mitigation option, consider the following:

- Raise the crests of reinforced dunes to reduce wave overtopping and landside flooding under extreme storm conditions.
- Grow vegetation on reinforced dunes to mitigate them further. This step is described in the following non-structural stabilization section.
- Design reinforced dunes to preserve the ecological functions of the original dunes.
- Reinforced dunes must comply with permit requirements.

CONSIDERATIONS:



Mitigation Solution: Use Non-Structural Stabilization

There are also non-structural mitigation solutions that can help stabilize the shoreline, including beach nourishment, dune restoration, and living shorelines. Natural or nature-based shoreline stabilization methods use living plants together with natural and synthetic construction materials to reduce coastal erosion, establish vegetation and stabilize shorelines.

Option 1: Nourish Beaches and Restore Dunes

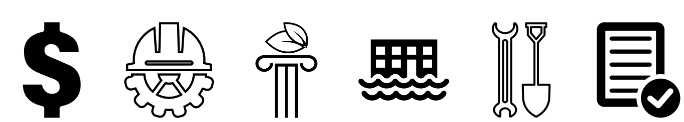
Beach nourishment replaces sand lost through longshore drift or erosion (Figure 5.4.7). Beach nourishment results in a wider beach between the water and the land, which can reduce storm damage and protect the land beyond the beach. Beach nourishment typically is not a one-time fix; it will need to be repeated because the beach is still subject to longshore drift and erosion at the original site.

Figure 5.4.7. Beach nourishment replaces sand lost through longshore drift or erosion and increases resilience. (Source: USACE, 2020).

Dune restoration is accomplished by building or rebuilding dunes, and it often includes planting native dune vegetation to stabilize the dune, trap windblown sand and add coastal habitat. Vegetated dune restoration involves re-establishing native plants and installing fencing to keep sand in place and help dunes grow. Vegetated dunes can help protect against storm surge and provide habitat for many animal species.

Dune restoration or beach nourishment combined with sediment stabilization with plantings and fencing can be used in addition to other stabilization measures to protect the shoreline and nearby structures.

CONSIDERATIONS:



Option 2: Stabilize Using Living Shorelines

Living shoreline stabilization involves using vegetation combined with geogrids, crib walls, brush mattresses, root wads or other bioengineered construction materials. Living shorelines can mitigate erosion in lesser-developed areas that do not experience high velocity waves (Figure 5.4.8).

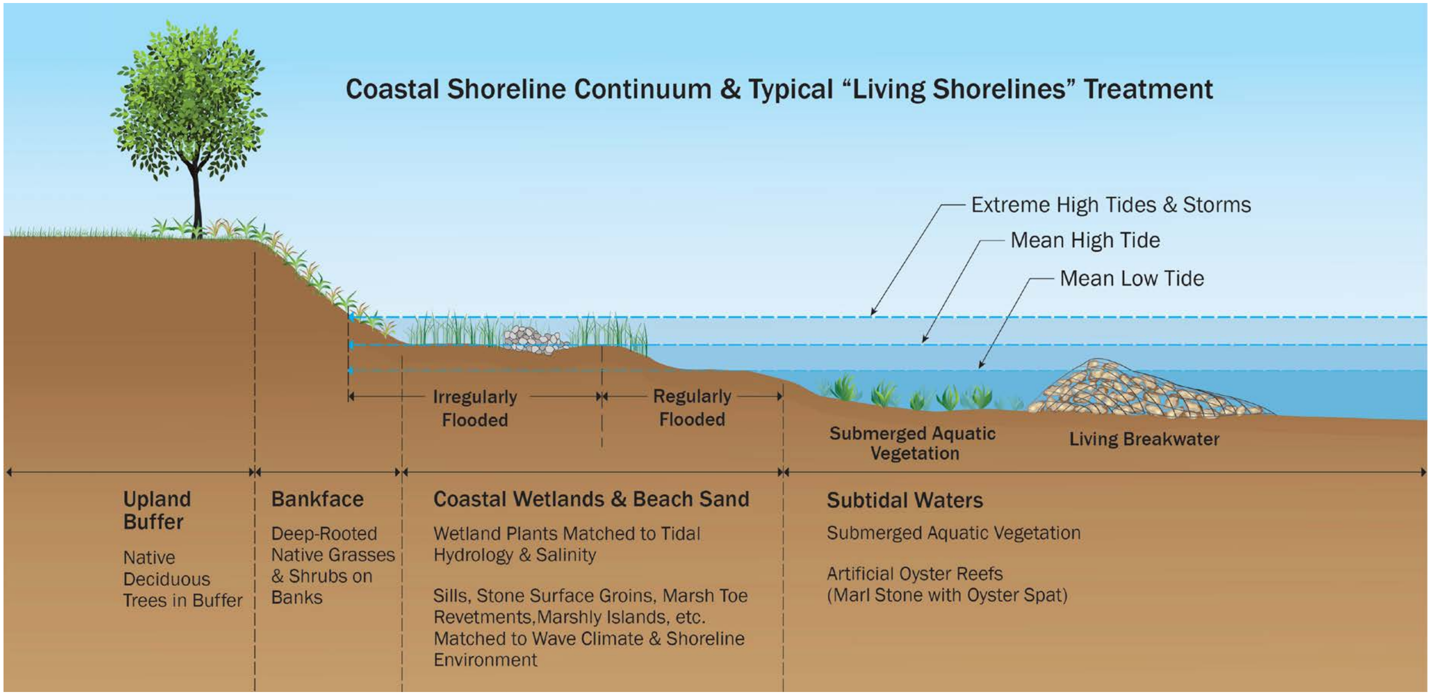


Figure 5.4.8. Nature-based solutions for shoreline stabilization via a “Living Shorelines” approach. (Source: Adapted from NOAA, 2016)

A living breakwater may include, but is not limited to, an oyster reef, seagrasses, mangroves, and vegetated dunes.

- Oyster reefs serve as natural breakwaters, which can calm waves and reduce erosion on the shoreline side of the reef. They also can provide habitat for fish and some invertebrates. Oyster reefs can be constructed of bagged oyster shells placed in the intertidal area. Shell bags may need to be anchored in place, particularly if they are stacked, or waves may overtop the structure.
- Seagrasses typically grow as underwater grass fields in shallow water off coastlines. They help protect the coastline by slowing wave energy and trapping sediment, thus reducing erosion. They also serve as a habitat to many different sea creatures.
- Mangroves are trees or shrubs that grow primarily in shallow tropical water. The dense root systems of mangrove forests help trap sediment, which can help stabilize the coastline and protect reefs and seagrasses from being trapped under sediments. Mangroves also can reduce the impacts of waves, and wide mangrove belts can help reduce wind speed.

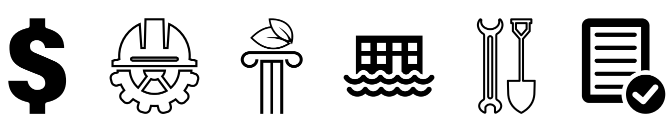
Bioengineered shoreline protection can:

- Protect against erosion while augmenting the natural ecosystem and providing habitat for plant and animal species.
- Provide low-maintenance shoreline stability when the vegetation’s root system is established and strengthened as it matures.
- Restore many natural ecosystem functions and have ancillary benefits to the human and the ecological communities.

When evaluating living shorelines as a mitigation option, consider the following:

- Designers need to understand the coastal sediment transport system and erosion cycle in the coastal zone in which the project is located.
- Designers should use sound engineering practices and ecological principles to assess, design, construct and maintain living vegetation systems that are blended into the shoreline and the supported coastal ecosystem.
- Living shorelines typically are effective only in low-energy environments and may need to be paired with other mitigation techniques to provide a desired level of protection.
- Projects likely will involve an interdisciplinary effort between scientists, engineers and landscape architects.
- Implement an inspection and maintenance program to maintain a bioengineered shoreline stabilization system throughout its intended life.
- Consider Federal, state and local permitting requirements before choosing to use living shoreline stabilization methods.
- As with structural mitigation methods, heavy storms can damage living shorelines, requiring them to be repaired to provide the same level of protection they did prior to the storm.

CONSIDERATIONS:



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