

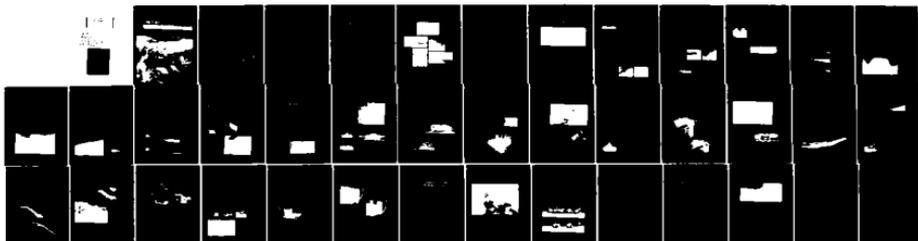
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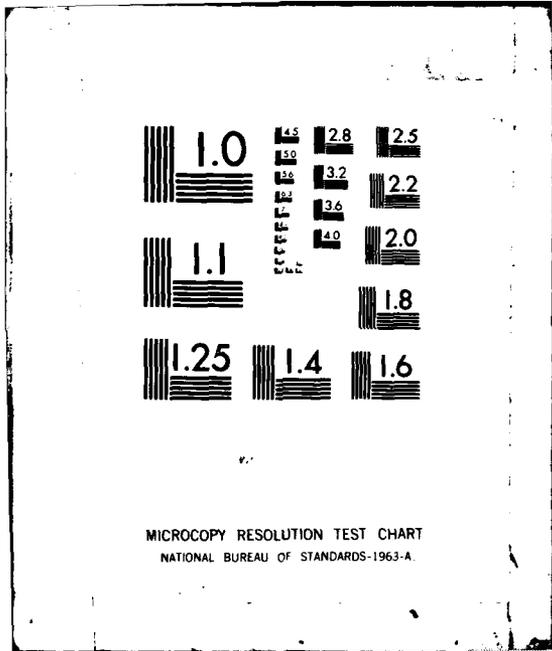
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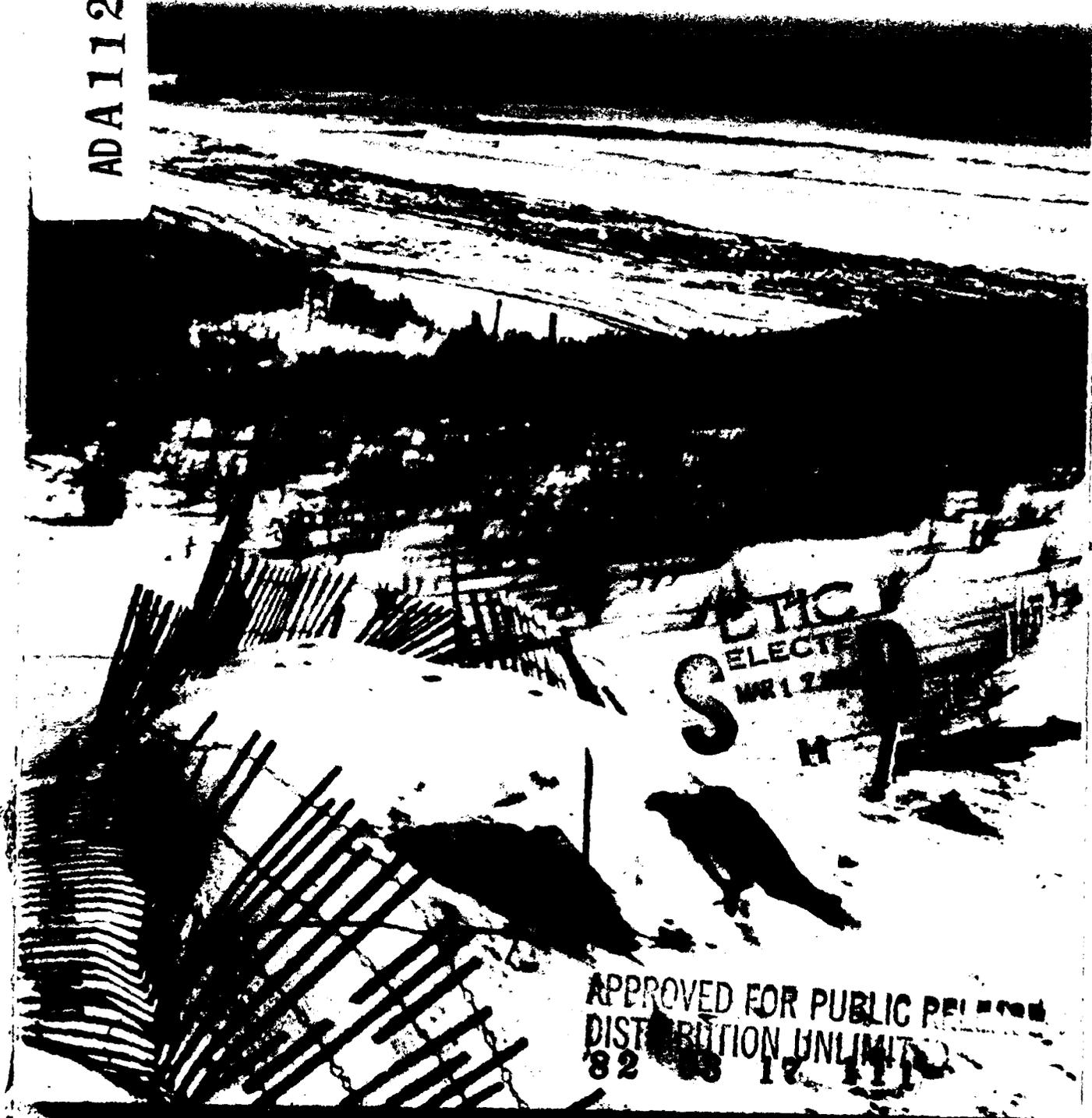
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Low Cost Shore Protection

This brochure presents low cost ways for the shoreline property owner to control or slow down shoreline erosion. It will also be of interest to community leaders, local government officials, and contractors and engineers involved in erosion control.

Prepared as a public service by the U.S. Army Corps of Engineers, the brochure is part of a program to demonstrate low cost erosion control measures. The methods described here apply to all protected and inland shores of the United States where wave height does not usually exceed six feet and severe storms or hurricanes are not annual events. These sheltered areas are the only ones where low cost, owner-implemented protection is likely to be successful. The measures described here should not normally be used on open coastlines exposed to heavy ocean waves.

The useful lifetimes of these methods vary from a year or two, for temporary structures, to over ten years, for longer-lasting installations. These numbers are approximate: unpredictable factors such as weather could shorten or prolong the expected lifetime of any shoreline structure.

While all these methods have been used to reduce erosion problems, no erosion control device will ever be completely successful in all applications. The government cannot guarantee, therefore, that a particular method will be successful in your case. If you think it is likely that one or more of the measures described here could help with your erosion problem, we urge you to seek further information and assistance in designing a solution that meets your needs.

In addition to this introductory brochure, the Corps of Engineers has prepared detailed reports to assist those who need further information. To obtain one of these reports, send in the postcard attached to the back cover. Additional sources of help are described in the back of the brochure under *Where To Go From Here*.



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This brochure has four main objectives.

First, it briefly presents the natural processes that affect your shoreline property and the factors involved in erosion and erosion control.

Second, it gives you information on types of low cost erosion control measures available to property owners whose waterfronts are threatened. While "low cost" does not necessarily mean "cheap," the methods described in this brochure are within the resources of many individual property owners or groups of individuals acting together. Each method is described here in terms of the shoreforms and situations where it can be used successfully, how it protects the shore, its advantages and disadvantages, and its general design features and construction materials.

The third objective of the brochure is to help you with planning for shoreline erosion control. After the discussion of erosion control measures, the brochure describes a number of general areas you should consider before deciding on a course of action.

Fourth, the brochure is designed to give you sources for further information and assistance in making decisions and implementing them. These are presented in a section at the end.

Knowledgeable professionals can help to ensure successful protection against erosion. Poorly designed or improperly installed devices may be worse than nothing at all. They may actually accelerate erosion, change the ways in which the shoreline can be used, or create an eyesore. This brochure serves as a general introduction only, not as a technical report. It does not present detailed specifications for design and installation of erosion control devices. Some low cost erosion control measures can be undertaken by the homeowner alone, but they should be attempted only after the site has been carefully evaluated and appropriate control measures designed.

While federal aid usually cannot be used to offset the costs of erosion control measures for protecting private property, the U.S. Army Corps of Engineers can provide information and technical assistance.

The Erosion Process



The waterfront is the scene of the most dramatic interactions between water, wind, and land. Moving air and water carry material from place to place, eroding and depositing, constantly changing the shoreline. If erosion is not balanced by accretion, the shore will be washed away. Understanding the dynamics of erosion and accretion along the shore is important: to safeguard your property, you need to know how to work with these natural forces, not against them.

Wind and Water

The energy to power the movement of air and water comes partly from the heat of the sun and partly from the gravitational forces of the sun, moon, and earth. Winds—currents in the air—are caused by

uneven solar heating, as warm air rises and cooler air rushes in to take its place. Uneven heating also causes currents in the water. Other causes of water currents include streams or rivers entering larger bodies of water, the action of winds moving the water as they might move a raft, and the tides. The range of the tides and the strength of tidal currents are determined by the combined gravitational effects of the sun, moon, and earth. "Spring tides" occur when the sun and moon are approximately in line with each other and their gravitational effects combine to produce the highest high tide and lowest low tide levels. At the times of quarter moons, "neap tides" are produced, with the least range between high and low tide water marks. The tidal currents are strongest at spring tides, when the range is greatest.



Waves are produced by wind blowing across a water surface. The water "moves in place," like stalks of grass bending and rising in the wind. Also like the grass, it does not move very far—this explains how a piece of driftwood, for instance, may stay offshore for a long time, bobbing up and down as waves pass beneath it. Within a wave, water moves in small vertical circles and keeps returning to its starting place, while the form and energy of the wave move forward. The water at the surface moves in the largest circles, forming the crest of the wave at the top of the circle and the trough of the wave at the lowest point of the path. Below the surface, the water moves in smaller and smaller circles, until at a depth greater than half the wave length the water hardly moves at all. As the wave moves toward shore, it begins to drag on the bottom, which eventually causes it to "break" or collapse. This produces a great deal of turbulence, stirring up material from the shore bottom or eroding it from banks and bluffs.

Different Shoreforms

Shorelines are distinguished by certain physical features. Recognizing your shoreform will help you evaluate its resistance to erosion and the measures you can take to diminish or control destruction of your property. Different shoreforms are shown in the photographs on this page and the following page.

Cliffs are usually steep rock formations which erode very slowly, if at all, during a human lifetime. Cliffs do not need the sort of protection described in this brochure, as the natural cliff material is more durable than any of the low cost measures available.

Bluffs are also steep shoreforms, but they are composed of softer erodible material such as clay, sand, or soft rock. Bluffs may be unstable because of the physical characteristics of the bluff materials, seepage of groundwater within the bluff, and erosion by wave action at the base. A drainage system, perhaps combined with a bulkhead, seawall, or revetment, may be an appropriate erosion control measure for a bluff, but due to the complexity of bluff material and the difficulty of analyzing the stability of this shoreform, protection of high bluffs should only be attempted with professional assistance.

Marshes are areas that are saturated with surface water or groundwater and support vegetation adapted for life in such moist conditions. These areas have only recently been appreciated for their contribution to shoreline ecology and for their capacity to protect inland areas by absorbing pollutants, trapping sediments, and buffering some wave action. Previously treated as nuisances to be drained or filled, marshes are now protected by federal and state regulations.



Low bluff



Marsh

Beaches, the most common shoreforms in the United States, are gentle slopes covered with loose sediment. The sediment particles, ranging from fine silt to coarse gravel or cobbles in size, are moved by wind and water to form the typical beach profile shown in the illustration.

In calm weather, waves at the beach are usually low, long swells. These waves have less energy than choppy storm waves and do not cause as much turbulence when they break. Swells break and run up over the foreshore of the beach until they use up their energy. Then they drop back under the force of gravity. They tend to deposit material on the beach up to the normal high water line. At the high water line, a low ridge or "berm" may be formed by this type of wave action. During storms, water overtops the berm crest and washes over the backshore.

The backshore is bordered on the inland side by dunes, which are formed by the wind blowing sand along the beach until it meets an obstruction. The carrying power of wind is much less than that of water, and even a small obstruction can result in significant deposition. The sizes of the berm and dunes depend on the local wave and wind conditions and may be influenced by some of the erosion control measures you can use to protect the beach.

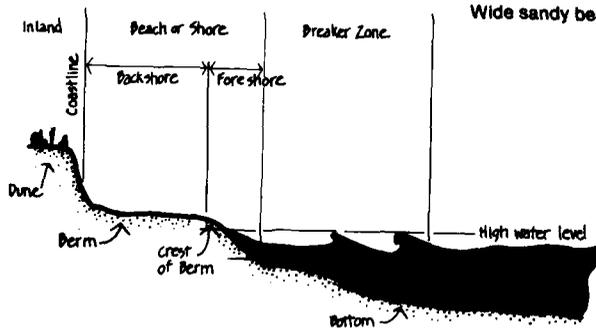
The shape of the shoreline is also important in the erosion process. The parts of the shore that extend into the water are more vigorously attacked than the shoreline of inlets or bays. As shown in the illustration, incoming waves tend to bend around these peninsulas, headlands, extended beaches, or seawalls, and concentrate their energy on the front and sides of the area. Extra protection or reinforcement is often needed on these exposed parts of the coast.

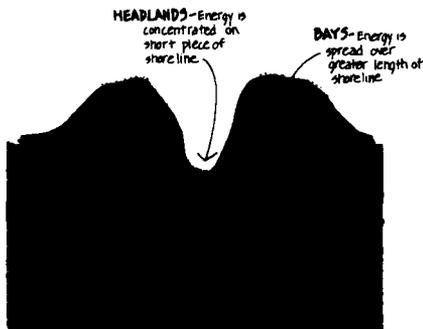


Wide sandy beach



Narrow cobbly beach



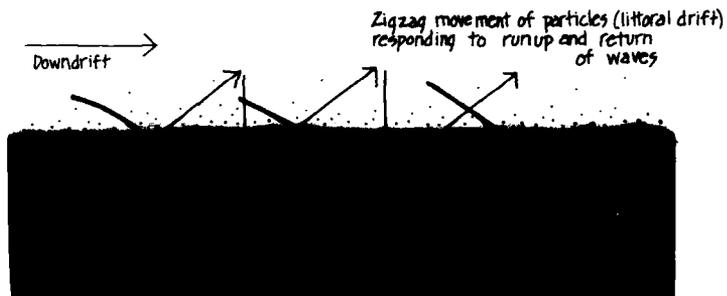


up again when the velocity of the water increases. Growing shores are fed, or "nourished," by material that has been eroded from somewhere else. Often attempts to reduce erosion and build up one area will result in reduced deposition elsewhere, "starving" another shoreline. Erosion and accretion are two faces of the same process, which may either occur at extremely slow rates or make dramatic changes in the shoreline within a human lifetime.

Shorebuilding and erosion

Wave motion, particularly that of breaking waves, is the most important active agent in the building and erosion of the shoreline. The characteristics of waves depend on the speed of the wind, its duration, and the unobstructed water distance, or "fetch," it blows over. As the waves break, run up the shore, and return, they carry sedimentary material onshore and offshore. This sedimentary material is called littoral drift. Most waves arrive at an angle to the shore and set up a longshore current, moving littoral drift in a series of zigzags as successive wave fronts advance and retreat. The illustration shows how this process works. The predominant direction of longshore transport is referred to as "downdrift"; the opposite direction is "updrift."

The ability of water to move material depends on its speed. Large waves or fast-moving currents can carry larger quantities and heavier littoral drift. Material picked up from inland heights, from river beds and banks, and from shoreline areas is deposited wherever the water is slowed down, and it may be picked

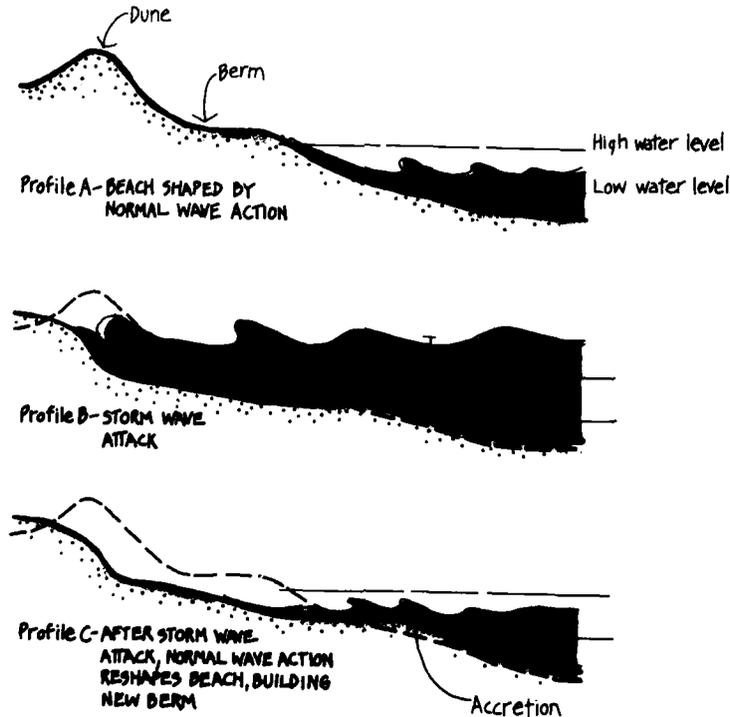


Water level also influences the erosion process. Changes in high and low water levels due to seasons, tides, storms, droughts, or floods can expose new surfaces to erosion.

Seasons and storms, which affect the movement and level of water and the strength and direction of wind, alter patterns of erosion and deposition. The illustrations on these pages show how storms and seasons act on a beach. Storms whip the water into waves higher than normal, resulting in rapid erosion of vulnerable areas and propelling stones or other debris onto shore with unusual force. As seasons turn, wind strength and direction also change, altering the path of waves

and currents and resulting in new areas of erosion or accretion. Where ice forms, it reduces wave action, which may slow erosion, and at the same time it exerts tremendous horizontal and vertical forces that may weaken structures on the shore. Winter freeze and spring thaw affect rivers, streams, and lakes, changing their water levels and the speed of currents.

Changes in erosion and deposition patterns due to seasons and storms are often mistaken for overall net loss or gain of shore material. Knowing the direction of net longshore transport is important in designing shore protection, especially for beach fill, groin fields, and breakwaters.

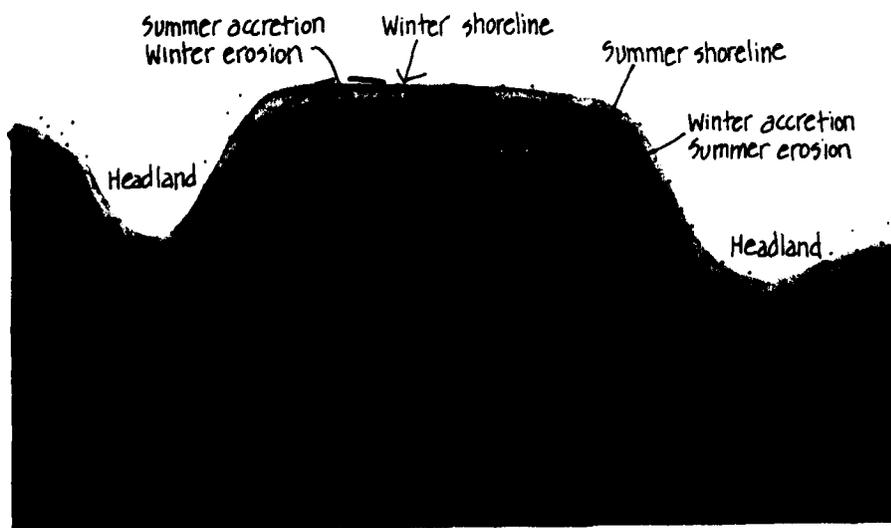


Natural defenses

Gently sloping shores, whether beaches or wetlands, are natural defenses against erosion. The slopes of the foreshore form a first line of defense, dissipating the energy of breaking waves. The berm prevents normal high water from reaching the backshore. Dunes and their vegetation offer protection against storm-driven high water and also provide a reservoir of sand for rebuilding the beach. Wise management of shore areas should include protection of these natural defenses where they exist.

Although erosion is essentially caused by natural shoreline processes, its rate and severity can be intensified by human activity. The shoreline and the water are highly valued for recreational activities, but heavy use and development may accelerate erosion. Those who build "permanent" homes and recreation

facilities often ignore the fact that the shoreline is being constantly built up and worn away again. They may also fail to take into account the periodic and unpredictable effects of storms. Dredging for marinas and bulldozing of dunes for improved seascape views remove natural protection against wind and waves. Pedestrian and vehicular traffic also contribute to the destruction of shoreline defenses by destroying vegetation, degrading dunes, and weakening bluffs and banks. Docks, jetties, and other structures interrupt the natural shoreline movement of water and redirect erosive forces in unexpected and possibly undesirable directions. Erosion control should begin with protection of the natural shoreline defenses wherever possible.



Confronted with an erosion problem, you have a variety of choices. They range from doing nothing about the problem, to installing a device or a combination of devices to combat erosion, to relocating or abandoning endangered structures, to selling your property. Your choice will depend on the ways you intend to use the shoreline, the degree of hazard posed by erosion, the existing investment, and the resources you can commit to the undertaking. The frequency, cost, and convenience of maintenance should be considered, as well as the initial costs and availability of labor and materials.

In many cases, the appropriate response to mild erosion is to let it take its course, since natural processes result in a certain amount of unavoidable erosion. Beyond this unavoidable minimum, erosion may be increased by human ignorance or neglect of shoreline processes. You can slow down the rate of erosion, but not eliminate it completely, by such shoreline management techniques as protecting dunes or restricting pedestrian and vehicular access to the waterfront.

Positive measures to control erosion depend on the type of shore in need of protection and the way you want to use the property. Marshes are best served by protecting the existing vegetation and restricting traffic. Beaches may be protected or enhanced by filling or by constructing retaining sills, breakwaters, or groin fields. Accelerated beach erosion usually associated with bulkhead and seawall construction make these measures most suitable for areas where the shore uses (such as boating) require deeper water or where steep bluffs are already severely threatened. Revetments protect sloping backshore areas and have a somewhat less erosive effect on the existing beach. These erosion control measures, as well as the options of relocating and evacuation, are discussed briefly on the following pages.



Vegetation

Vegetation is an effective and inexpensive way to stabilize dunes and protect marshes. It also enhances the natural beauty of the landscape, providing pleasing variety and contrast to the eye and attracting small animals to the food, nesting sites, and protective cover it affords.

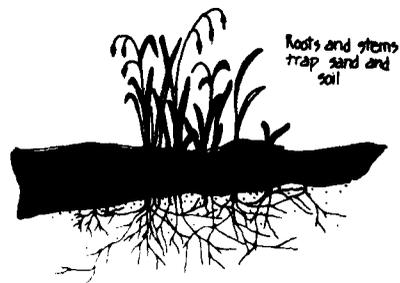
In undisturbed environments, vegetation is often one of the most important elements in the natural protection of the land. Roots and stems tend to trap fine sand and soil particles, forming an erosion-resistant layer once the plants are well established. In marshes, vegetation also absorbs some of the water's energy, slowing down potentially erosive currents. Vegetation does not protect against storms, however, and it is more fragile than other erosion control measures described in this

brochure. Because shoreline plants are especially sensitive to human intervention, they should be protected, wherever possible, by restricting pedestrian and vehicular traffic.

New planting is generally not required in marshes but can be used to reinforce dunes. When vegetation is used as an erosion control device, careful selection is needed to match particular varieties of plants to local conditions of soil, wind, and water. Generally, native plants are more likely to thrive than imported vegetation, but some plants are hardy in a wide range of habitats. In many cases, the chances of successful planting are improved by using protective structures to reduce sand and water movement, at least until the plants are well established. Sand fences and low breakwaters are particularly useful for this purpose. Professional guidance in plant selection and design of supplementary control measures may improve the performance of the vegetation.



Vegetation planted for erosion control



Beach Fill

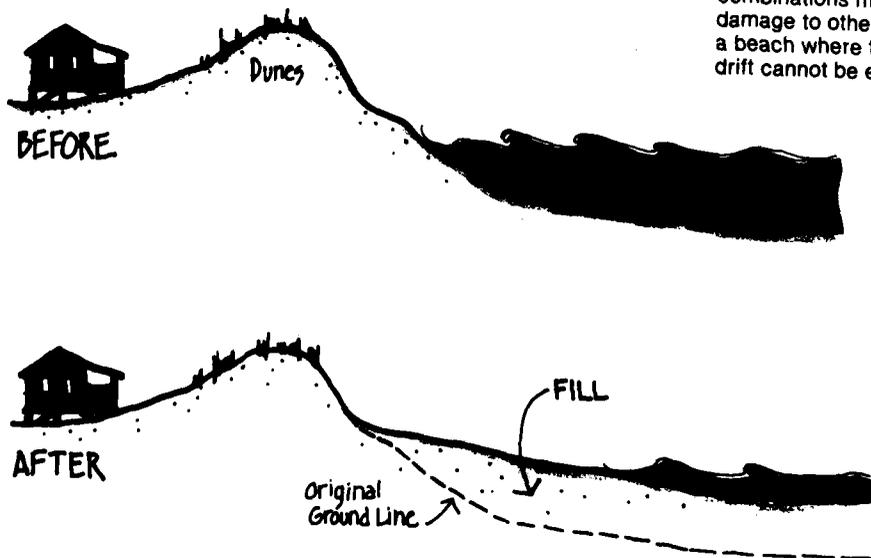
Beaches are usually thought of as one of the most attractive and valued elements of shoreline recreational activities, but they are also a first line of defense against erosion damage, protecting the area behind them. In normal weather, gently sloping beaches cause incoming waves to break and use up their energy before reaching inland areas.

As explained in the section on shoreline erosion processes, beach material and littoral drift usually move as waves advance and recede. A beach that is relatively stable or growing provides natural protection to the land behind it. When there is net loss, however, with the beach area shrinking, there is increased danger of damage as the water line advances inland.

Adding fill to a beach, either to replace the lost beach materials or to increase the size of an existing beach, is often both economical and effective. As shown below, addition of fill increases the width of the backshore, moving the high water line farther offshore. Fill should resemble the original beach material: coarser fill will erode more slowly, finer fill, more quickly, than the native beach. The slope of the filled beach should also match the natural slope as closely as possible.

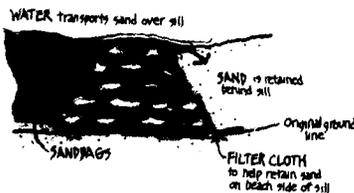
The cost and convenience of beach fill as a method of erosion control depend on the rate of loss from the beach. Where fill is readily available at a nearby location, the initial cost is relatively low, but refilling constitutes a regular maintenance cost. In some cases this can be substantially reduced or eliminated by the use of breakwaters or retaining structures.

Beach fill is often used in combination with construction of a perched beach or groin field. These combinations may minimize potential damage to other beaches or provide a beach where the natural littoral drift cannot be effectively trapped.



Perched Beaches

Construction of a low retaining sill to trap sand results in what is known as a "perched beach," one that is elevated above its original level. Perched beaches have many of the same qualities as natural beaches, and the submerged sill does not intrude on the view of the waterfront. Perched beaches are appropriate erosion control measures where a beach is desired and sand loss is too rapid for convenient or economical replacement. They can also be used to create a new beach for recreation and shore protection.



Construction materials and design considerations for perched-beach sills are generally similar to those for fixed breakwaters, described in the next section. The most important difference is that in order to effectively retain sand, sills must either have filter material on the landward side or be constructed of tongue-and-groove interlocking elements. Also, the location of the sill should be indicated in some way so that beach users do not step off the perched beach into unexpectedly deep water.

The sand for a perched beach may be trapped by the sill after being carried inshore by the normal wave action, or it may be transported from another site as beach fill. Trapping of sand could deplete adjacent beaches that would have received these deposits in the absence of the sill. Fill from other sand sources can be used to limit this effect on neighboring beaches and make the perched beaches available for protection and enjoyment sooner than wave-carried fill.



Perched beach being filled

Breakwaters

Breakwaters are structures placed offshore to dissipate the energy of incoming waves. Large breakwaters suitable for protecting deep harbors are generally beyond the resources of the individual property owner. The breakwaters discussed in this section are smaller structures, placed one to three hundred feet offshore in relatively shallow water, designed to protect a gently sloping beach.

As shown below, the dissipation of wave energy allows drift material to be deposited behind the breakwater. This accretion protects the shore and may also extend the beach. The amount of deposition depends on the site characteristics and the design of the breakwater. Breakwaters may be either fixed or floating; the choice depends on normal water depth and tidal range.

Design Considerations

The degree of protection desired from a breakwater must be carefully considered. If the

breakwater is too high, it will seriously interfere with shoreline processes; too low, and the shore will be inadequately protected.

The height and porosity of a fixed breakwater determine the extent to which drift will be deposited behind the structure. It is generally desirable to allow some of the wave action to pass over or through the breakwater because many people value the waves as part of the natural beauty of the shore and as an essential ingredient in their recreational experience. This wave energy also helps to keep the area between the breakwater and the shore from becoming overfilled with littoral drift. Breakwaters that are too porous are ineffective, however.

The material that fills in behind the breakwater might otherwise be deposited on someone else's beach, which may erode due to the breakwater. If this is likely, beach fill can be added between the shore and the breakwater until the rate of longshore transport resumes an acceptable level.

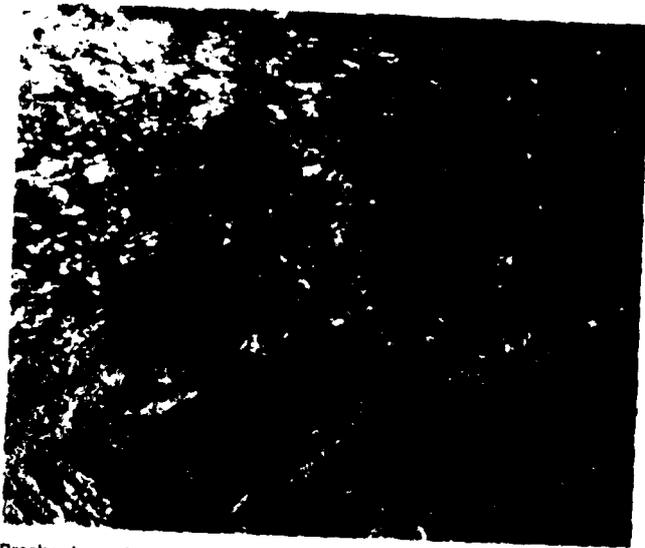
Like other vertical shoreline erosion control structures, fixed breakwaters are subject to



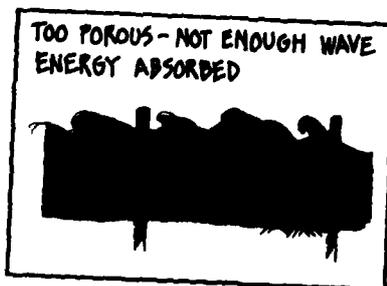
OVERHEAD VIEW

scour—erosion at the base of the structure, or the "toe," where the resistant construction material meets the erodible beach bottom. Extra width at the base of a stone rubble breakwater or a protective rubble apron along the toe of a sheet-piling breakwater can help prevent this erosion and keep the structure from tipping.

Because breakwaters are designed to receive much of the impact of incoming waves, they should be designed strong enough to remain in place during the usual local storms. Floating breakwaters must be firmly anchored to the bottom and adequately connected. They may be unsuitable where wave action is relatively heavy. Especially heavy or durable construction elements may be required for all breakwaters in areas where damage from vandalism is a problem.



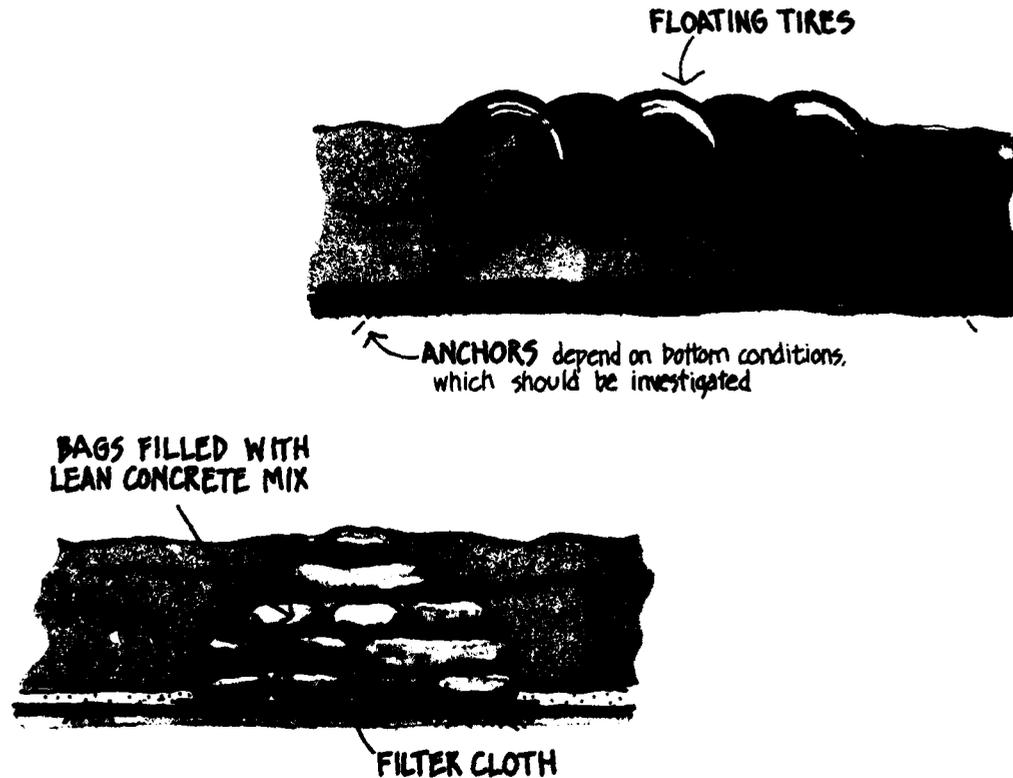
Breakwater under construction



Site Characteristics

Fixed breakwaters are most economical when the slope is gentle and the high water level at the proposed site is less than about four feet deep. If the water at high tide is deeper than four feet, the fixed breakwater would need to be built so high that its cost would be prohibitive. Floating breakwaters can adjust to higher tides, but they are effective only against waves of short length. If these conditions do not match your site, you might consider an alternative structure such as a revetment, bulkhead, or groin field.

The nature of the bottom material is also important. Stone rubble or sandbag breakwaters can rest on any type of bottom, but they may settle if placed on soft earth or sand. A filter layer between the structure and the bottom can relieve this problem. Special attention should also be paid to the anchors that hold floating breakwaters in place in soft-bottom locations. While sheet piles can only be driven or jetted into relatively soft bottoms, scouring and tipping may create problems in areas where bottom material is very soft.



Construction Materials

Breakwaters can be constructed from many different materials. As well as the choices discussed here for fixed and floating breakwaters, there are a number of patented breakwater systems available.

Stone rubble is useful as a fixed breakwater material if it is available in the vicinity at reasonable cost. Filter material between the stones and the bottom sand or earth can help prevent settling and deformation of the structure. The stone material should be arranged so that the smaller stones are in the interior of the structure, armored and retained by the larger stones.

Rubber tires on treated-timber piles may also be used for relatively low cost, effective fixed breakwaters where timber piles can be driven deep enough to ensure stability. Horizontal rope or timber crosspieces are needed to keep the tires from floating off the tops of the piles in high water.

Treated-timber sheet piling performs well when used for fixed breakwaters and is applicable wherever the bottom will permit driving or jetting the piling to sufficient depth. This construction material is illustrated in the sections on sills and groins.

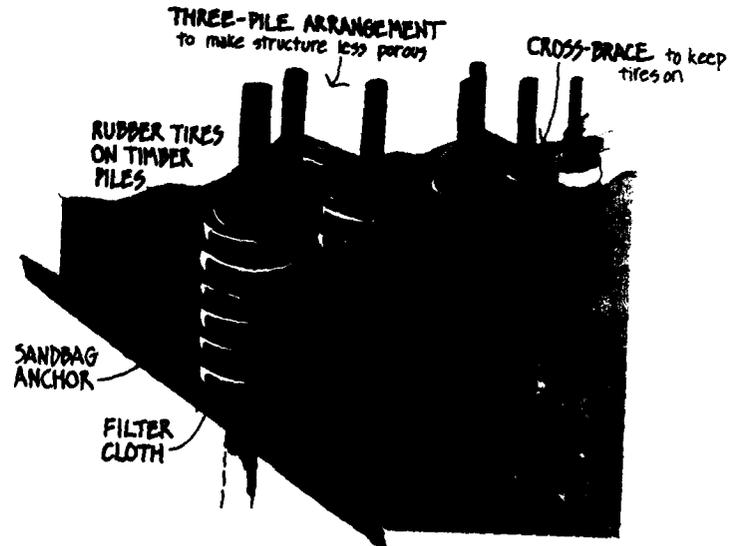
Burlap bags filled with a sand-cement mixture (lean concrete) are another low cost construction element. They are suitable only where the tidal range is moderate and the bottom slope is fairly flat. Filter material should be placed under the structure to prevent settling.

Fixed breakwaters can also be constructed with other materials that are only suitable in certain locations or require special installation or design adjustments. These materials include sandfilled bags, gabions, concrete boxes, and the patented Longard tube, Z-wall, Sandgrabber, and Surgebreaker concrete blocks. Patented systems are generally available only through franchised dealers and may require special equipment for installation, resulting in relatively higher initial costs.

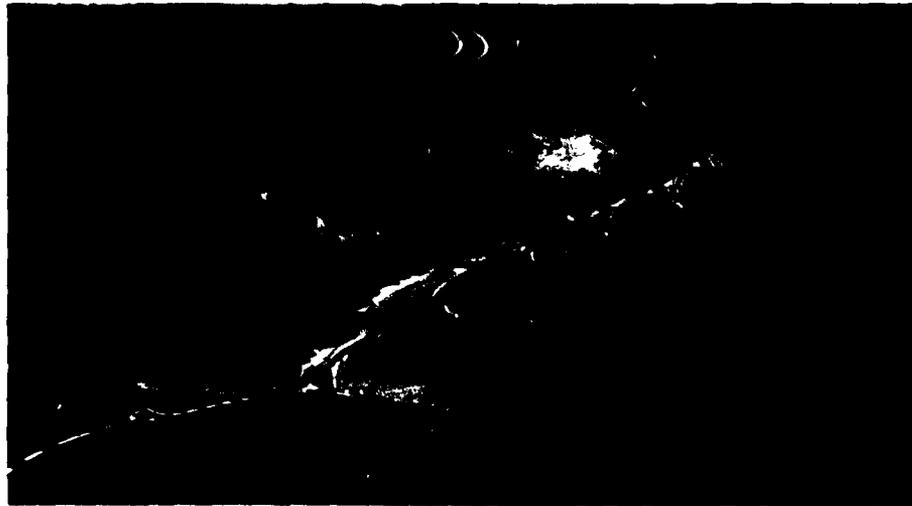
Floating breakwaters can be built with tires bolted or tied together. The type and material of fasteners should be chosen in light of local conditions, the degree of up-and-down motion due to waves, and the flexibility that will be required as the completed structure rides on the water. The floating breakwater must also be anchored. The type of anchor depends on tide and bottom conditions: generally, piles remain in place longer than other anchors.



Fastening method for floating breakwater



Groins



Groin field

Groins are structures that extend, fingerlike, perpendicularly from the shore. Usually constructed in groups called groin fields, their primary purpose is to trap and retain sand, nourishing the beach compartments between them. Groins initially interrupt the longshore transport of littoral drift. They are most effective where longshore transport is predominantly in one direction, and where their action will not cause unacceptable erosion of the downdrift shore. When a well-designed groin field fills to capacity with sand, longshore transport continues at about the same rate as before the groins were built, and a stable beach is maintained.

Groins are suitable erosion control measures where a beach is desirable, and they are compatible with most recreational activities. The beach fed by the sand trapped



between the groins acts as a buffer between the incoming waves and the backshore and inland areas: the waves break on the beach and expend most of their energy there. Filled groins provide this protection during normal weather conditions but offer only limited protection against storm-driven waves.

Design Considerations and Site Characteristics

Groin design completely depends on conditions at the site. The structures are most effective in trapping sand when littoral drift is transported in a single direction. If there is no predominant direction of longshore transport, or if the littoral drift is clay or silt rather than sand, filling a groin field with sand from a nearby source may be necessary. Beach fill can also provide a beach sooner than natural action and help to minimize undesirable downdrift consequences.

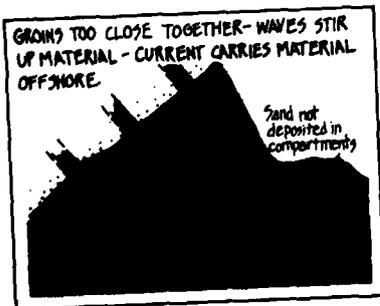
Groin fields must be carefully designed with respect to height, spacing, extension (both shoreward and into the water), and porosity. The structures should be no higher than the level of a reasonable beach, so that when they are filled the sand is free to pass downdrift to neighboring beaches.

Spacing of groins depends on local wave energy and the amount of usual littoral drift. Groins should be spaced so that drift accumulates along the entire distance between the structures. If the groins are too far apart, part of each compartment will be unprotected due to lack of accumulation; too close together, and

not enough littoral material will accumulate in the compartments. As a rule of thumb, groins should be spaced two to three groin lengths apart.

Groins must be built to extend far enough into the water to retain adequate amounts of sand. However, they should not be so long that rip currents develop along them, carrying sand offshore into deep water where waves cannot return it to the beach. Excessively long groins can also aggravate erosion elsewhere by trapping sand that would have been deposited on the downdrift shore by uninterrupted longshore transport. Also, groins should be built to extend far enough inland that storm waves cannot bypass them on the shoreward side, undercutting the structure and eroding the beach.

Vandalism or wave action may remove groin material, causing the structure to become ineffective. Groins that are too porous allow wave turbulence to wash too much sand through the voids, preventing material from accumulating to protect the backshore area.



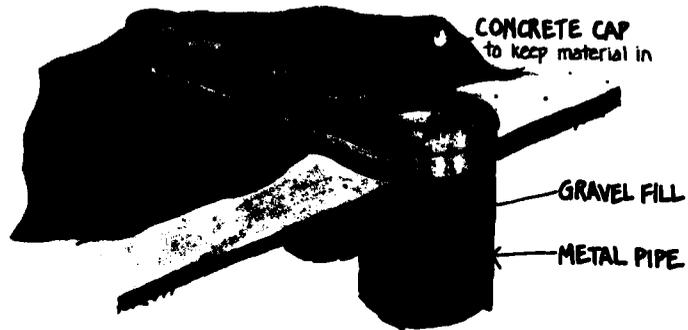
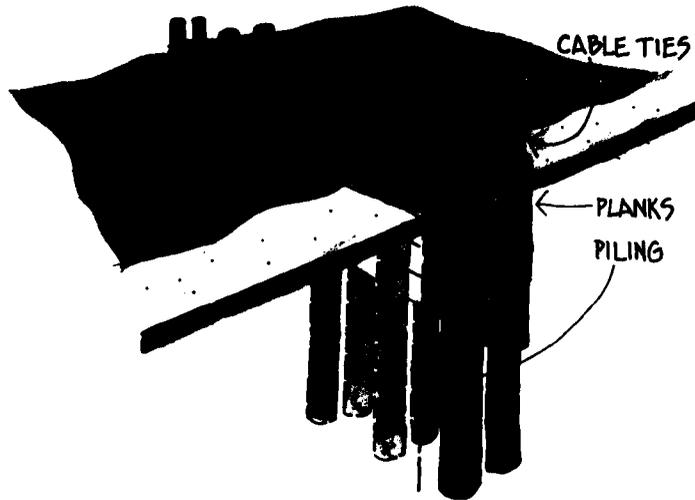
Construction Materials

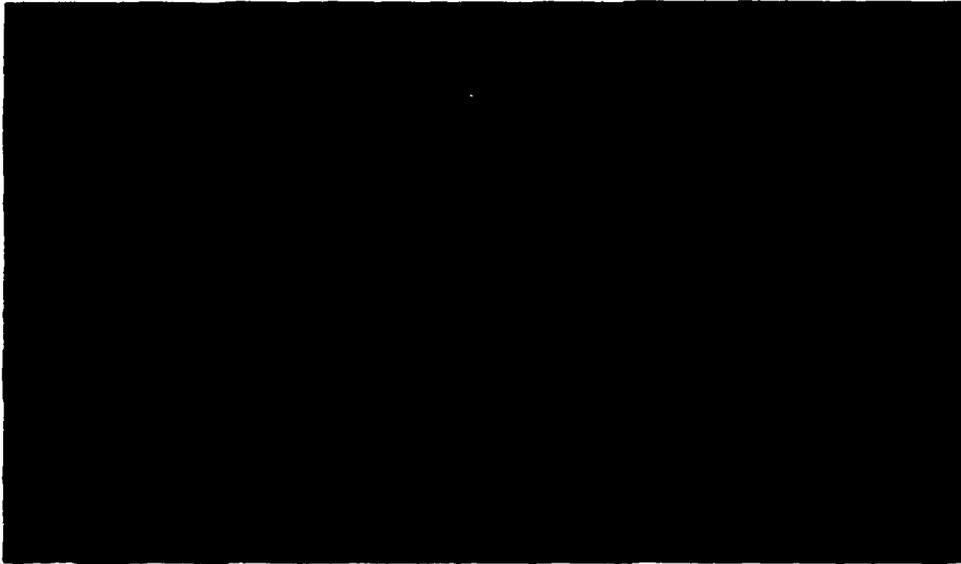
Sheet piles of treated timber, steel, or aluminum can be used to build effective and long-lasting groins in situations where they can be driven to adequate depth. Timber brace piles or mounds of rubble may be needed as reinforcement at the offshore end.

Another way to use treated timber in groins is to drive posts into the bottom in pairs, with planks

sandwiched between them. Because the planks cannot be embedded deeply when working under water, this method is limited to areas of wide tidal range where work can proceed during low tide.

Where piles cannot be driven, a treated-timber framework lined with wire mesh and filled with rock can be used. This relatively light construction is suitable in moderate wave climates where the water is not deeper than about two feet.





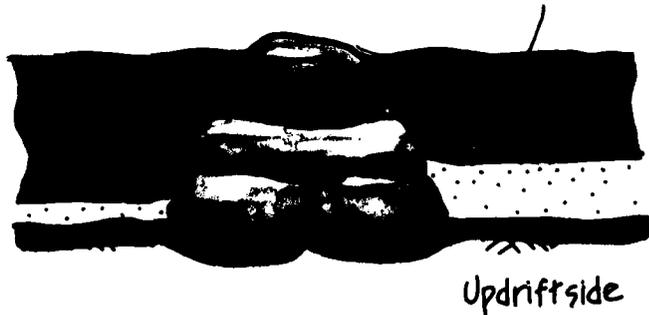
Treated-timber and rubble groin

Rubble or quarrystone groins are sturdy but have high construction costs. The cost of rubble groins increases considerably with water depth. Either concrete rubble or quarrystone may be used, depending on local availability and cost. The smaller sizes should form the core of the structure, armored by larger pieces.

Groins can also be built of stacked bags filled with sand or lean concrete mix, corrugated pipe driven deep into the bottom and filled with gravel, or rock mounds filled with asphalt mastic. Although these materials perform very well, they may be more expensive than the types described above.

Other materials that may be suitable in special cases are gabions (wire baskets filled with rock), Longard tubes, and steel fuel drums.

BAGS FILLED WITH
LEAN CONCRETE MIX



Updriftside

Revetments

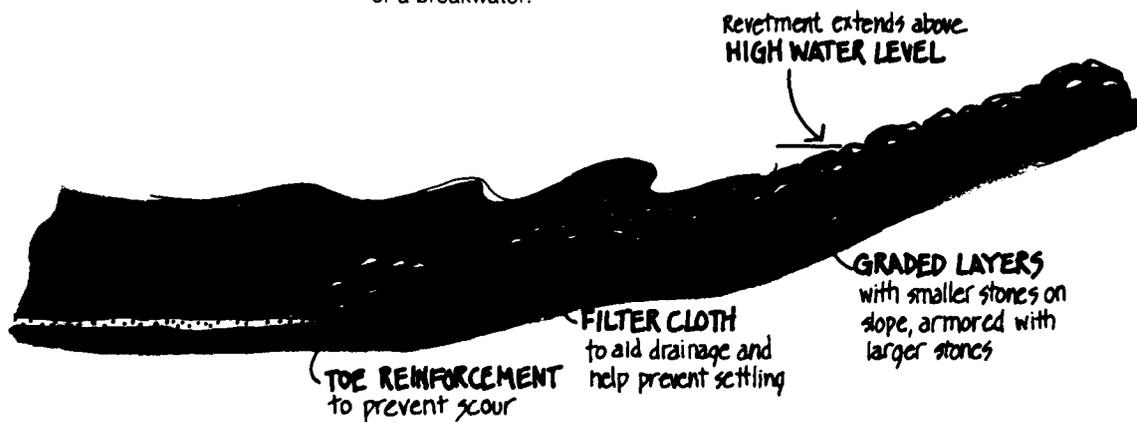
Revetments are structures placed on banks or bluffs in such a way as to absorb the energy of incoming waves. They are usually built to preserve the existing uses of the shoreline and to protect the slope. Like seawalls, revetments armor and protect the land behind them. They may be either watertight, covering the slope completely, or porous, to allow water to filter through after the wave energy has been dissipated.

Most revetments do not significantly interfere with transport of littoral drift. They do not redirect wave energy to vulnerable unprotected areas, although beaches in front of steep revetments are prone to erosion. Materials eroded from the slope before construction of a revetment may have nourished a neighboring area, however. Accelerated erosion there after the revetment is built can be controlled with a beach-building or beach-protecting structure such as a groin or a breakwater.

Design Considerations

Waves break on revetments as they would on an unprotected bank or bluff, and water runs up the slope. The extent of runup can be reduced by using stone or other irregular or rough-surfaced construction materials. A rough surface offers more resistance to the water's flow than the original shoreline surface, decreasing the energy of the wave more quickly and preventing the water from traveling as far.

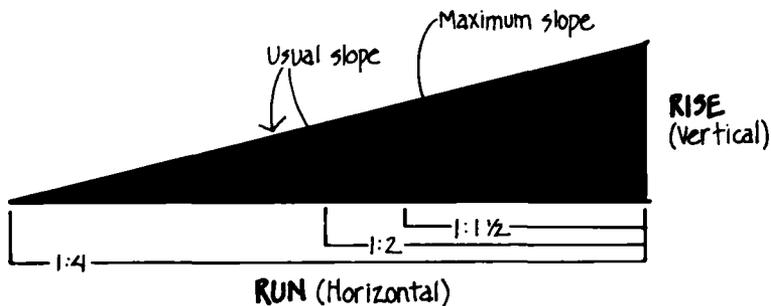
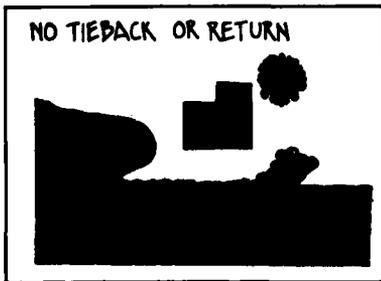
Important design considerations include providing appropriate height, width, and toe protection. Revetments should be high enough to prevent overtopping by high waves. To prevent flank erosion, the sides should be protected by tiebacks or returns. Scour at the toe can be prevented by a rock apron. Where there is a beach between the revetment and the water, access over the structure should be provided for beach users.



Revetment design should also allow for relief of groundwater pressure in the protected bank. Filters of cloth or small stones relieve water pressure in porous revetments, keeping drainage paths open and preventing settling. Solid revetments can be drained by evenly spaced "weep holes" along the bottom. This drainage channels the groundwater along noneroding paths and prevents it from seeking its own way along the softer material of the slope.

Revetments that are adequate under normal conditions may be damaged in severe storms, when the speed of water and carrying power of waves increase to several times their normal rates. Revetments must be thus strong enough to resist the battering action of waves and wave-carried debris. Heavy stones and an interlocking design in porous revetments can help prevent the construction material from being washed away.

Revetments can be adopted to a variety of local conditions and available materials. Some materials are more suitable to gentle slopes and light wave action, others are more sturdy. Armoring the revetment with a heavy face layer and providing drainage are key elements of success.



Site Characteristics

Revetments are stable if they are built on relatively gentle slopes, with two to four feet of run for every foot of rise. Revetments should not be built on slopes with less than a foot and a half of run per foot of rise. The slope on which a revetment is to be built may require grading or smoothing to prepare an adequate foundation for construction.

Erosion at the toe, common in steep revetments, further decreases the stability of the structure. In areas where unstable slope materials may displace the structure, other shoreline erosion devices should be considered. Where vandalism is likely to be a problem, especially heavy or durable construction elements are needed.

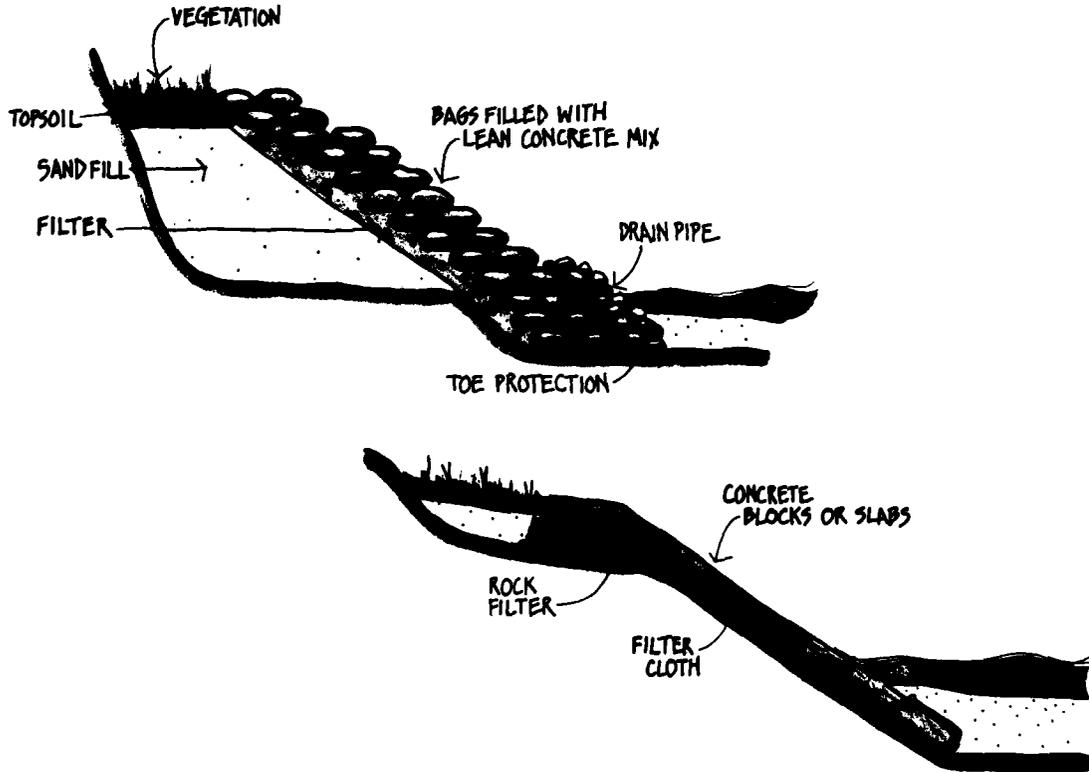
Construction Materials

Where they are readily available, rubble or quarystone make the most reliable and economical revetments. Adequate filters and armor stone size are important. The cost of labor or machinery necessary for slope preparation or placement of the largest sizes of stone may be high even where material is available at reasonable cost.

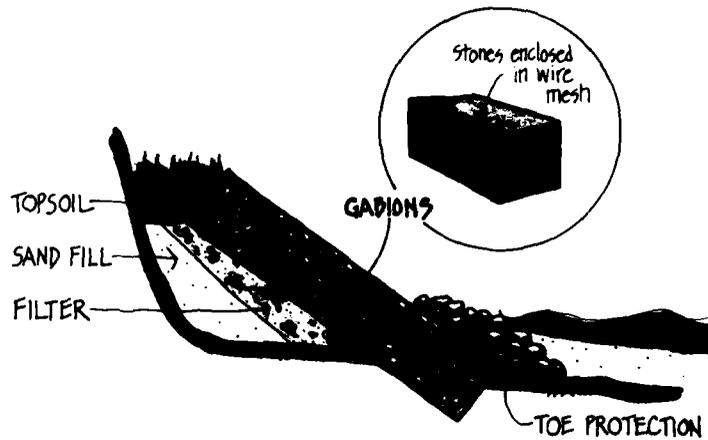
Burlap bags filled with sand or lean concrete mix are another low cost alternative, but they should be used only where waves are light. Bags filled with wet sand-cement

mixture and piled two-deep on the face of the slope interlock somewhat, resisting removal or displacement.

Concrete blocks or slabs of many shapes have proved effective in revetments. Large blocks and interlocking designs are the most successful. Special concrete mixes must be used, however, since standard concrete is too weak and will deteriorate until it crumbles under wave attack. Wave-carried ice, cobblestones, or other debris damage concrete blocks, even those formed with special mixes. Concrete blocks should not generally be used in areas where such damage is likely to occur.

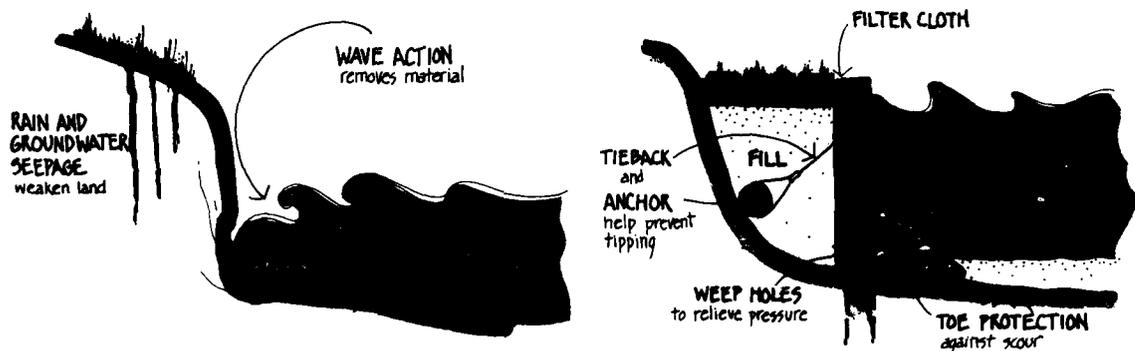


Gabions can also be used for revetments. The baskets must be solidly filled, or the wires will be abraded by movement of loose stones. The stones must be large enough, usually at least four inches in diameter, to prevent loss of stone through the gabion mesh. Maintenance may be required to refill baskets whose stones have settled or been lost. Gabions should not be used at all where damage from water-carried debris is likely or where foot traffic over the revetment is expected.



Gabion revetment

Bulkheads and Seawalls



Bulkheads and seawalls protect banks and bluffs by completely separating land from water. Bulkheads act as retaining walls, keeping the earth or sand behind them from crumbling or slumping. Seawalls are primarily used to resist wave action. Design considerations for these types of structures are similar. The illustrations on this page show the action of water on an unprotected bluff and demonstrate how bulkheads and seawalls help prevent erosion of the land behind them.

These structures do not protect the shore in front of them, however. In fact, when bulkheads and seawalls are used in areas where there is significant wave action, they may actually accelerate beach erosion. This happens because much of the energy of waves breaking on the structure is redirected downward, to the toe where the wall meets the soft

sand or earth. The shore on this side of the bulkhead or seawall is thus subjected to much more of the force of the waves than if there were no wall, and it erodes quickly.

Bulkheads and seawalls are most appropriate where fishing and boating are the primary uses of the shore, and gently sloping areas for sunbathing or shallow-water swimming are not essential.

Design Considerations

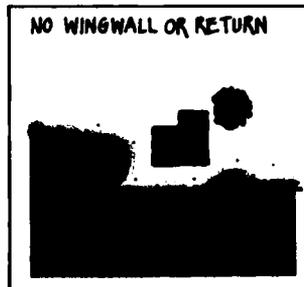
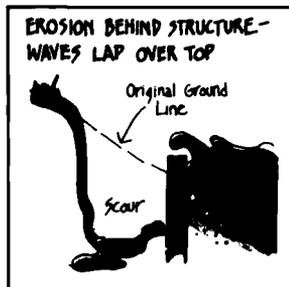
Bulkheads and seawalls can be built in three basic types of design. They may consist of thin, interlocking sheet piles driven deeply into the ground; individual piles used to support an above-ground structure; or a massive gravity construction resting on the shore bottom or embedded slightly in it, supported by its own weight rather than by piling.

Bulkheads and seawalls must be protected against the action of water, both in front of the wall and behind it. Waves that lap over the top could erode the land behind the structure as if the wall were not there, so the structure must be built high enough to prevent such overtopping. Groundwater and rain percolating through the soil may build up pressure behind the wall, eventually pushing it over. Weep holes regularly spaced along the bottom of the structure and equipped with filters to keep them clear relieve this pressure so that the bulkhead or seawall will remain upright.

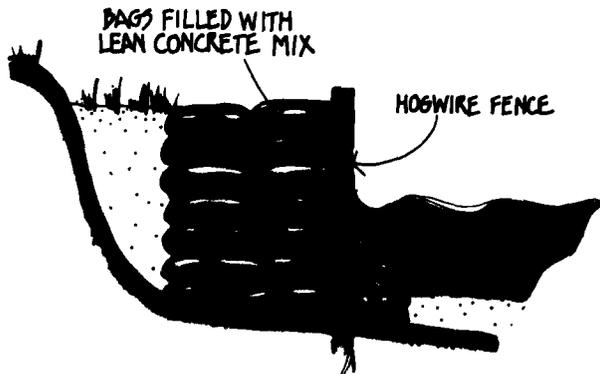
To be protected against the water's action on its face, a bulkhead

or seawall must be made of materials strong enough to withstand battering by waves and by wave-carried debris. Scour at the toe could eventually undermine the structure and tip it over. An apron of stones or other heavy material can be piled at the base of the wall to absorb the wave energy and protect the underlying soft earth or sand from being carried away.

Water flowing around the sides of the seawall or bulkhead can also cause severe erosion damage, so the structure must cover the entire surface that could be eroded. It should be well anchored to the bluff with wingwalls or returns to resist flank erosion.



Timber bulkhead



Site Characteristics

Erodible bluffs where bulkheads and seawalls are appropriate may rest on rocky, sand, or earth bottoms. The type of bottom influences the choice of bulkhead or seawall design, since none of the three basic designs can be used for all shore bottom types.

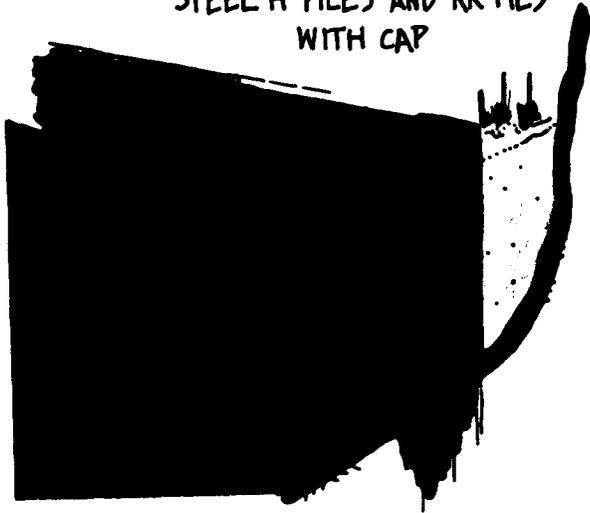
With bottoms of sand or earth, interlocking sheet piles can be driven or jettied deeply. Designs using individual piles to support above-ground structures can also be used in these areas. For sites with rocky bottoms, above-ground gravity structures are usually the most economical, but local wave energy or other considerations may make pile-supported structures the most appropriate choice. In soft rock, piles can be driven; bedrock requires drilling holes for the piles and anchoring them firmly with grout or concrete.

Local wave energy also significantly influences bulkhead and seawall design. Because bulkheads and seawalls receive the full force of the waves, strength of materials is vital in areas where waves are especially heavy. Where the cost of materials needed to withstand extremely rough waves (reinforced concrete, for example) is prohibitive, a breakwater or combination of protective structures might be more suitable than a bulkhead or seawall.

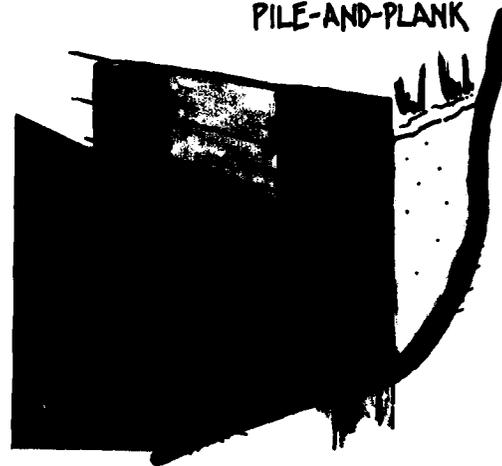
Construction Materials

Treated timber is generally the least expensive of the sturdy materials suitable for low cost seawalls and bulkheads, but it cannot be used in all designs. Timber is most useful in sheet-pile or in pile-and-plank designs. The combination of

STEEL H-PILES AND RTIES
WITH CAP



PILE-AND-PLANK



timber with steel H-piles is relatively more expensive, and its cost may limit this design to a small number of special applications.

Steel or aluminum may be used in sheet-pile form, the choice of material depending on cost and the nature of the shore bottom (steel can penetrate harder materials than aluminum). With all sheet-pile construction, however, special equipment is needed to drive the piles into the ground. The chief advantage of sheet piling in bulkhead and seawall construction is its neat

appearance and relatively maintenance-free protection.

Bags filled with lean concrete mix and held in place by hogwire fencing are suitable for above-ground construction of gravity structures.

Care should be taken with all materials, both those that are locally abundant and those that are widely available, to conform to the design considerations mentioned earlier. In addition, special modifications may be necessary to adapt designs for use with locally available materials.

Combination Methods

You can use erosion control measures in various combinations, either to complement each other or to accomplish together what a single measure might not do alone.

Beach fill and vegetation are two measures that are most effective when used with other protective devices. Temporary groins or breakwaters of light materials (timber cribs filled with brush, for example) can provide enough protection to allow vegetation to become established. Vegetation alone cannot protect against heavy wave action, nor can it maintain the face of a steep bluff threatened by groundwater seepage: structural methods are also needed in these cases. Like native beaches, filled beaches are subject to rapid erosion and are therefore often used in combination with sills, groin fields, and breakwaters.

Other measures can be combined also. For instance, breakwaters and bulkheads may work together to protect a bluff while minimizing erosion of the beach. Combinations are not limited in the number of methods that can be used together. Rather, they depend on the nature and extent of protection desired. In an extreme case, a single site might benefit from a perched beach and a revetment and drainage system to protect the bluff.

As in the case of single devices, careful evaluation is always required to identify the most appropriate combinations of erosion control measures for a given site.

Other Alternatives

The erosion control measures outlined here have been mainly concerned with protection of the shoreline, to allow continued recreation opportunities and defend manmade structures along our coasts. As well as using positive erosion control measures, however, you might consider making shorefront homes, docks, and other structures more resistant to damage. Bracing and reinforcement may be appropriate, sometimes in combination with relocation or elevation of the structure.

In thinking about relocating a house or other shoreline structure, you should consider whether the rate of erosion has been slow and steady for long periods of time (over twenty-five years), or if most of the erosion has occurred during shorter periods of time in severe storms. If the erosion is at a fairly constant rate, moving the house may add several years to its useful life. If the erosion is more unpredictable, moving the house is less advisable. The practicality of moving a house also depends on the availability of inshore sites and on the expense of moving, compared with simply building a new house on a site farther inland.

Structures may be reinforced, extended, or relocated as an alternative to positive erosion control measures, or in addition to them. Professional advice can help to clarify the choices to be made and the costs of the various options. In some cases, the expense far outweighs the value of the expected benefits, and sale of the property may be the wisest choice. A property that no longer suits one owner's needs may be ideal for another whose interests or resources are different.

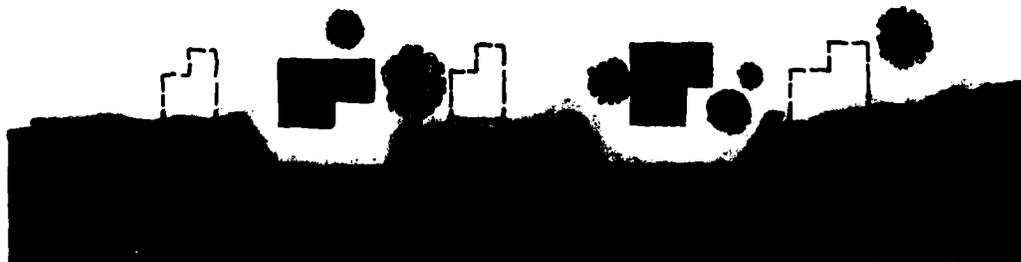


Vegetation protected by sand fences

Planning Considerations

If you are faced with erosion that threatens your use of the shore and perhaps also endangers a substantial investment in shorefront construction, you need to decide how much you are willing to do in order to save or improve your property. The "low cost" erosion control measures described in this brochure are not necessarily inexpensive, but they represent a range of choices likely to be within the resources of the individual property owner. These resources vary greatly, as do the values of shoreline properties and the severity of erosion threats. The ultimate decision rests with your own evaluation of the expected benefits from any erosion control measure and the investment you decide to make.

The first step in this evaluation is the identification of the specific nature of your problem. Do you have an eroding beach, marsh, or bluff? Is your primary concern the safety of buildings and structures, or the preservation of particular shore uses, such as swimming or boating? The preceding sections of this brochure gave you an idea of the suitability of various erosion protection measures for your particular problem and your intended uses of the waterfront. More information is available from sources listed in the next section.



In many cases, you will need to give some thought to the possible effects that erosion control measures on your property will have on the property of others. As discussed earlier, many of the measures that can be taken to protect your property may result in increased erosion of the neighboring shoreline. When several property owners share a waterfront, it often makes good economic sense to cooperate in building a single device to retard or arrest erosion, such as a filled or perched beach, breakwater, bulkhead, or revetment. A cooperative measure may well cost substantially less than the sum of the expenses of individual protection, and it has the added advantage of protecting against flank erosion. In some cases, it may be wise for entire communities to cooperate in erosion control. In other cases, it may be sufficient to modify designs in order to protect against damage to other properties that could be affected by your erosion control measures.

Cost and availability of materials are two important factors to be considered when planning erosion control. Other factors include the suitability of the material for the use you intend, the cost of labor and machinery that may be necessary for construction, access for equipment and crew at your site, and adaptations needed to adjust typical erosion control designs to special materials and local conditions. Apparent advantages, such as low cost or ease of construction, should not obscure the disadvantages and special requirements that may make these alternatives less attractive.

There are many low cost materials available. Among them are treated timber, marine concrete, used rubber tires, bags filled with lean concrete mix, gabions, Longard tubes, steel fuel barrels, and quarrystone or rubble. Each of these materials has its own advantages and disadvantages. For example, Longard tubes and other patented constructions must be provided by franchise dealers and often require special equipment for installation. Longard tubes are also vulnerable to vandalism and damage from waterborne debris in exposed locations. Rubber tires are almost universally available but need properly designed fasteners in order to be effective in most structures. Heavy rocks for breakwaters and revetments require construction equipment that may contribute to weakening of banks and destruction of vegetation when they are brought to your property. Professional help will usually ensure design and construction of erosion control devices or selection of vegetation to suit the particular requirements of your waterfront.

You should also be aware that federal and state permits are required prior to the construction of any work in, under, across, or on the banks of navigable waters of the United States. Local permits may also be required. Federal permits are issued by the Corps of Engineers, usually only after all other required permits have been obtained. Corps of Engineers district offices provide a pamphlet entitled **Permits for Work in Navigable Waters** that describes the procedures for applying for a federal permit. Information regarding the procedures for obtaining other permits should be obtained from the agencies in your area that have jurisdiction over water resources.

Where to Go From Here

Three in-depth reports have been prepared as supplements to this introductory brochure. **Low Cost Shore Protection: A Property Owner's Guide** gives detailed information about the subjects covered briefly in this brochure, as well as a list of other helpful publications (many of them free) and the addresses of government agencies that have jurisdiction or expertise in waterfront areas. The other two reports, **Low Cost Shore Protection: A Guide for Local Government Officials** and **Low Cost Shore Protection: A Guide for Engineers and Contractors**, include information pertinent to these groups, as well as lists of information sources and government agencies. To obtain one of these reports, send in the postcard attached to the back cover.

These reports are the latest products of the long-term commitment to coastal planning and engineering of the U.S. Army Corps of Engineers. In the Shoreline Erosion Control Demonstration Act of 1974, Congress authorized the Corps of Engineers to develop and demonstrate low cost methods of shoreline erosion protection in the sheltered and inland waters of the United States and disseminate the results of the demonstration program. The Corps of Engineers has produced other publications, many of which are available through the U.S. Government Printing Office, Washington, DC 20402. In addition, the Corps conducts research at the Coastal Engineering Research Center in Fort Belvoir, Virginia.

Information on local situations may be obtained from the district offices of the Corps of Engineers and from state and local agencies responsible for water, natural resources, or coastal management. Federal and state offices of the Soil Conservation Service and Fish & Wildlife Service will be able to help you locate professional advice about the ecology of your area and find ways to evaluate and minimize the environmental impact of any erosion control measure you decide to use. The National Ocean Survey can provide hydrographic charts and tide tables for all U.S. coastal areas; and lake level information for the Great Lakes is available from the Detroit District of the Corps of Engineers. Corps of Engineers coastal district offices are listed on the inside back cover.

Your state's board of higher education can help you locate agricultural and marine extension services, another source of information about local conditions and ecology. These services are usually associated with "land-grant" or "sea-grant" units of state or private colleges and universities.

Local businesses and associations concerned with waterfront uses may be able to refer you to competent professionals familiar with your area and its special characteristics.



Glossary

Backshore—The zone of the shore or beach lying between the foreshore and the coastline and acted upon by waves only during severe storms, especially when combined with exceptionally high water.

Beach—The zone of sedimentary material that extends landward from the low water line to the place where there is marked change in material or form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach—unless otherwise specified—is the mean low water line. A beach includes foreshore and backshore.

Berm—A nearly horizontal part of the beach or backshore formed at the high water line by waves depositing material. Some beaches have no berms, others have one or several.

Bluff—A high, steep bank composed of erodible materials.

Breaker—A wave meeting a shore, reef, sandbar, or rock and collapsing.

Breakwater—A fixed or floating structure that protects a shore area, harbor, anchorage, or basin by intercepting waves. See pages 14-17.

Bulkhead—A structure or partition placed on a bank or bluff to retain or prevent sliding of the land and protect the inland area against damage from wave action. See also sea-wall. See pages 26-29.

Cliff—A high, steep face of rock; a precipice.

Coast—The strip of land, of indefinite width (up to several miles), that extends from the shoreline inland to the first major change in terrain features.

Current—A flow of water.

Downdrift—The direction of predominant movement of littoral materials.

Dune—A ridge or mound of loose, wind-blown material, usually sand.

Erosion—The wearing away of land by the action of natural forces.

Fetch—The unobstructed distance over water in which waves are generated by wind of relatively constant direction and speed.

Foreshore—The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash) and the water's edge at low water. The foreshore is ordinarily traversed by the runup and return of the waves.

Functional life—The period of time during which a structure performs as intended. Performance can be expressed in terms of benefits obtained versus the cost of installation and maintenance.

Groin—A fingerlike structure built perpendicular to the shoreline, usually with other groins, to trap littoral drift or retard erosion of the shore. See pages 18-21.

Groundwater—Water within the earth that supplies wells and comes to the surface by seepage or in springs.

- Jetting**—A method of placing piles by forcing water around and under a pile to displace and lubricate the surrounding soil, allowing the pile to sink to the desired position.
- Littoral**—Of or pertaining to a shore.
- Littoral drift**—The sedimentary material moved along the shoreline under the influence of waves and currents.
- Littoral transport**—The movement of littoral drift along the shoreline by waves and currents. Includes movement parallel (longshore transport) and perpendicular (on-offshore transport) to the shore.
- Longshore**—Parallel to and near the shoreline.
- Marsh**—An area of soft, wet, or periodically submerged land, generally treeless and usually characterized by grasses and other low vegetation.
- Neap tide**—A tide having about 10 to 30 percent less range than the average, occurring about the time of quarter moons.
- Nourishment**—The process of replenishing a beach. It may be brought about naturally, by accretion due to the longshore transport, or artificially, by the deposition of dredged materials.
- Offshore**—The direction away from the shore, toward a large body of water.
- Onshore**—The landward direction, away from the water.
- Overtopping**—The passing of water over the top of a natural or man-made structure as a result of wave runup or surge.
- Perched beach**—A beach retained above the otherwise normal profile level by a submerged sill. See page 13.
- Permit**—A document issued that expresses the assent of a government agency, so far as concerns the public rights and the general public interest, for the accomplishment of certain works (e.g., construction).
- Pile**—A long, heavy timber or section of concrete or metal that is driven or jetted into the earth or bottom of a water body to serve as a structural support or protection.
- Revetment**—A facing placed on a bank or bluff of stone to protect a slope, embankment, or shore structure against erosion by wave action or currents. See pages 22-25.
- Riparian rights**—The rights of a person owning land containing or bordering on a water course or other body of water in or to its banks, bed, or waters.
- Riprap**—A layer, facing, or protective mound of rubble or stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment; also, the stone used for this purpose.
- Rubble**—Rough, irregular fragments of rock or concrete.
- Runup**—The rush of water up a beach or structure, associated with the breaking of a wave. The amount of runup is measured according to the vertical height above still water level that the rush of water reaches.
- Scour**—Removal of underwater material by waves and currents, especially at the base or toe of a shoreline structure.
- Seawall**—A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. See also **bulkhead**. See pages 26-29.
- Sheet pile**—A pile with a generally slender, flat cross-section that is driven into the ground or bottom of a water body and meshed or interlocked with like members to form a wall or bulkhead.
- Shore**—The narrow strip of land in immediate contact with the water, including the zone between high and low water lines. See also **backshore** and **foreshore**.
- Spring tide**—A tide that rises highest and falls lowest from mean sea level, occurring at new or full moon.
- Tide**—The periodic rising and falling of water that results from gravitational attraction of the moon and sun acting on the rotating earth.
- Updrift**—The direction opposite that of the predominant movement of littoral materials.
- Wave height**—The vertical distance between a wave crest and the preceding trough.
- Wave length**—The horizontal distance between similar points on two successive waves (for example, crest to crest or trough to trough), measured in the direction of wave travel.
- Wave period**—The time in which a wave crest travels a distance equal to one wave length. Can be measured as the time for two successive wave crests to pass a fixed point.

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These are the numbers you can call for information on shoreline erosion control problems and solutions.

Atlantic Coast from Maine to the Connecticut-New York line

U.S. Army Engineer Division, New England
Attention: NEDPL-C
424 Trapelo Road
Waltham, MA 02154
(617) 894-2400 x554

Atlantic Coast of New York State and New Jersey north of Manasquan Inlet

U.S. Army Engineer District, New York
Attention: NANEN-O
26 Federal Plaza
New York, NY 10007
(212) 264-5174

Atlantic Coast from Manasquan Inlet, New Jersey, south to the Delaware-Maryland line, including Delaware Bay and the C & D Canal

U.S. Army Engineer District, Philadelphia
Attention: NAPEN-P
U.S. Custom House
2nd & Chestnut Street
Philadelphia, PA 19106
(215) 597-4714

Atlantic and Chesapeake Bay shorelines of Maryland

U.S. Army Engineer District, Baltimore
Attention: NABPL-P
PO Box 1715
Baltimore, MD 21203
(301) 962-2545

Atlantic and Chesapeake Bay shorelines of Virginia

U.S. Army Engineer District, Norfolk
Attention: NAOCN-RI
803 Front Street
Norfolk, VA 23510
(804) 441-3765

Atlantic Coast and interior bays and sounds of North Carolina

U.S. Army Engineer District, Wilmington
Attention: SAWEN-PC
PO Box 1890
Wilmington, NC 28402
(919) 343-4778

Atlantic Coast of South Carolina

U.S. Army Engineer District, Charleston
Attention: SACEN-PS
PO Box 919
Charleston, SC 29402
(803) 724-4248

Atlantic Coast of Georgia

U.S. Army Engineer District, Savannah
Attention: SASEN-H
PO Box 889
Savannah, GA 31402
(912) 944-5502

Atlantic Coast of Florida and Gulf Coast of Florida to St. Marks Rivers

U.S. Army Engineer District, Jacksonville
Attention: SAJEN-RC
PO Box 4970
Jacksonville, FL 32201
(904) 791-2204

Gulf Coast from St. Marks River, Florida, west to the Mississippi-Louisiana line

U.S. Army Engineer District, Mobile
Attention: SAMEN-DN
PO Box 2289
Mobile, AL 36628
(205) 690-3482

Gulf Coast of Louisiana

U.S. Army Engineer District, New Orleans
Attention: LMNED-HC
PO Box 60267
New Orleans, LA 70160
(504) 865-1121 x2490

Gulf Coast of Texas

U.S. Army Engineer District, Galveston
Attention: SWGED-PC
PO Box 1229
Galveston, TX 77553
(713) 763-1211 x314

Pacific Coast of California from the Mexico border north to Cape San Martin

U.S. Army Engineer District, Los Angeles
Attention: SPLED-C
PO Box 2711
Los Angeles, CA 90053
(213) 688-5400

Pacific Coast of California from Cape San Martin north to the California-Oregon line, including San Francisco Bay

U.S. Army Engineer District, San Francisco
Attention: SPNED-HC
211 Main Street
San Francisco, CA 94105
(415) 556-3582

Pacific Coast of Oregon

U.S. Army Engineer District, Portland
Attention: NPPEL-PL-2
PO Box 2946
Portland, OR 97208
(503) 221-6477

Pacific Coast of Washington and Puget Sound shoreline

U.S. Army Engineer District, Seattle
Attention: NPSN-PL-NC
PO Box C-3755
Seattle, WA 98124
(206) 764-3556

Coast of Alaska

U.S. Army Engineer District, Alaska
Attention: NPAEN-H-HD
PO Box 7002
Anchorage, AK 99510
(907) 752-3925

Coasts of Hawaii and the Pacific Trust Territories

U.S. Army Engineer Division, Pacific Ocean
Attention: PODED-T
Building 230
Fort Shafter, HI 96858
(808) 438-2837

U.S. Coasts of Lakes Superior, Huron, and Michigan (Lake Michigan Coasts of Wisconsin, Michigan, and Indiana only), and U.S. Coast of Lake St. Clair

U.S. Army Engineer District, Detroit
Attention: NCEED-L
PO Box 1027
Detroit, MI 48231
(313) 226-6791

Lake Michigan Coast of Illinois

U.S. Army Engineer District, Chicago
Attention: NCCPE-HS
219 South Dearborn Street
Chicago, IL 60604
(312) 353-0789

U.S. Coasts of Lakes Erie and Ontario

U.S. Army Engineer District, Buffalo
Attention: NCBED-DC
1776 Niagara Street
Buffalo, NY 14207
(716) 876-5454 x2230

U.S. Coasts of Lakes Erie and Ontario

U.S. Army Engineer District, Buffalo
Attention: NCBED-DC
1776 Niagara Street
Buffalo, NY 14207
(716) 876-5454 x2230

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