Shorelines

Wave action and the associated drift of shoreline materials and ice, as well as wind, are common causes of shoreline erosion. When the updrift supply of material is deficient (in some cases, because protection has been provided), downdrift shoreline sustains a net loss. Loss of material at any given site is necessarily correlated with deposition/sedimentation elsewhere.

Responses to shoreline erosion include taking no action, delaying action until the observed rate of erosion decreases, relocating endangered structures, taking action to mitigate upland erosion (see *Watershed Surfaces*, pages 1-22), and taking action in the immediate vicinity of the erosion problem. Alternatives strategies and techniques described in this section include:

- Intercepting or diminishing wave energy before it reaches shore:
  - ✓ Beach fills
  - ✓ Breakwaters
  - ✓ Plantings
- Regrading and/or armoring the shoreline:
  - ✓ Bulkheads
  - ✓ Gabions
  - ✓ Groin Fields
  - ✓ Perched Beaches
  - ✓ Revetments
  - ✓ Plantings

Diffraction:

The progressive reduction in wave height as a wave passes the end of a barrier and spreads into its shadow zone.

Refraction:

The process by which the direction of a wave bends to align with bottom contours. A wave running over shallow bottom slows, while the deep-water portion of the wave continues to travel at its original speed.

Wave height:

The vertical distance between wave trough and crest

Wave period:

The time required for successive crests to pass a stationary point

Fetch:

The distance wind travels over water while generating waves

Setup:

Vertical rise in the stillwater level of a reservoir or lake caused by wind piling water against one shore.

- ✓ Consider composition of shoreline materials. Layers of various materials significantly affect percolation, seepage, and stability.
- ✓ Consider ice formation and associated horizontal and vertical stress on structures, as well as seasonal minimization of wave action.
- ✓ Consider seasonal shifts in wind direction, frequency, and intensity.
- ✓ The most prevalent causes of bluff recession and erosion are scour at the base/toe by wave action and instability of bluff materials themselves. Stability decreases with height of the bluff.

Beach fills

DEFINITION:

- ※ Quantities of sand placed on the shoreline

APPROPRIATE FOR:

- ❖ increasing beach area;
- ❖ protecting an area immediately above fill from erosion;
- ❖ providing a recreational resource; and
- ❖ situations which call for low initial cost and can accommodate the need for periodic replenishment.

DESIGN/CONSTRUCTION:

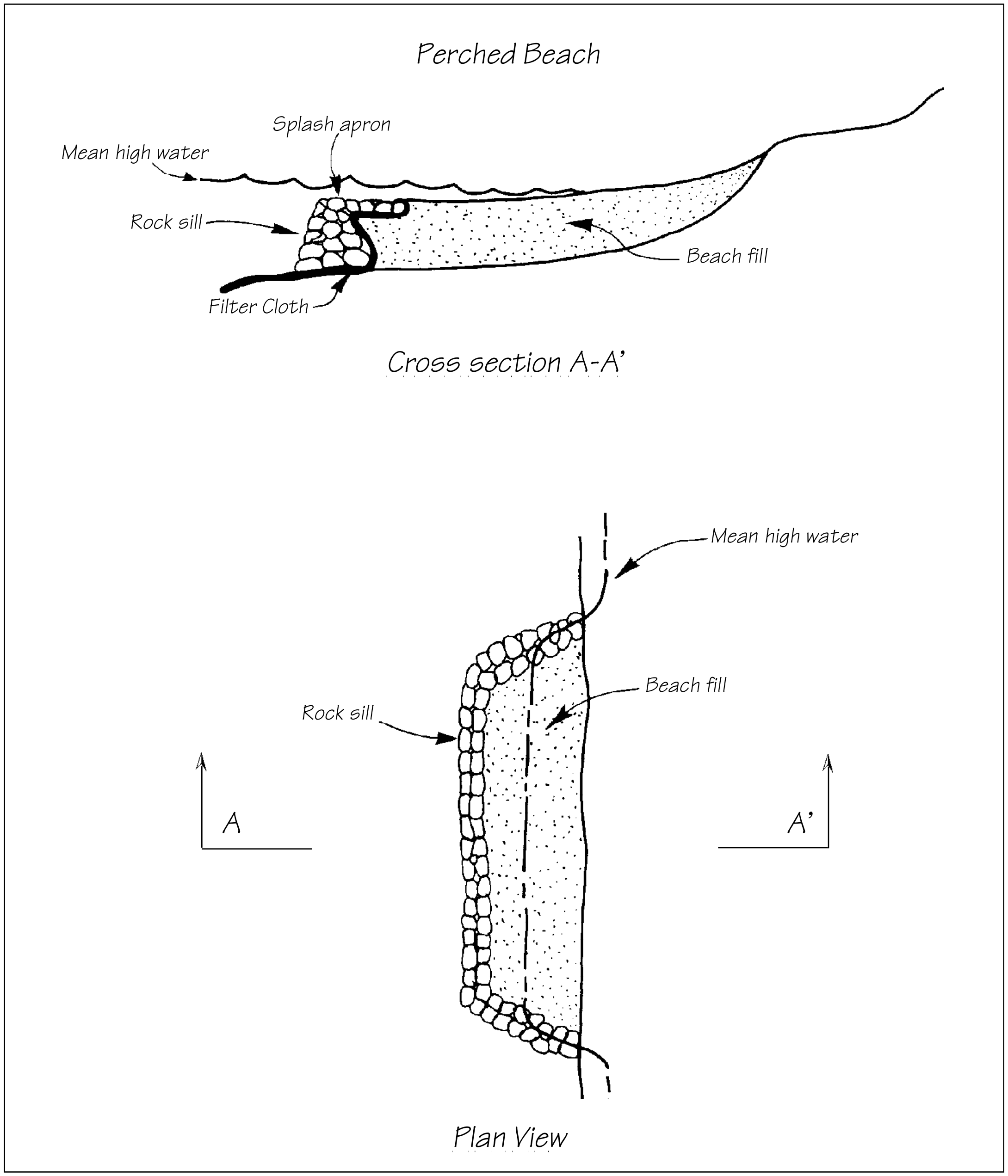
- ✓ Match coarseness of native and fill material as closely as possible. Slightly coarser fill resists erosion and results in steeper beach.
- ✓ Overfill by 50% to allow for loss of fines.
- ✓ Design berm to prevent overtopping by waves and to accommodate several years of erosion.
- ✓ Design slope to match existing slope and profile.
- ✓ Design transition from fill to existing shoreline over long distance, to avoid aggressive erosion of prominent filled section. This may require cooperation of neighboring landowners.

NOTES:

- ⊙ Shallow offshore bottoms dissipate wave energy before it reaches shoreline.
- ⊙ During periods of high water or increased wave heights, beach sands are eroded and deposited offshore. Eventually, offshore deposits cause storm waves to break farther offshore, reducing wave action on the beach. At open sites, long-period swells may gradually return sand to the beach; at sheltered sites, storm-caused erosion is permanent.
- ⊙ Increased roughness of a beach or structural surface decreases the height of the wave's runup.
- ⊙ Turbidity during placement may temporarily impair fishing.

Runup/Surge:

The uprush of water after a wave breaks, expending the wave's remaining energy.



(Illustration adapted from U.S. Army Corps of Engineers 1981)

Beach (perched)

DEFINITION:

※ Beaches which are elevated or perched above normal level; they combine a low breakwater or sill and beach fill

APPROPRIATE FOR:

❖ providing a buffer zone against wave action;

❖ providing recreation area; and

❖ sites where offshore slopes are gradual enough for location of sill at reasonable distance from shore.

DESIGN/CONSTRUCTION:

✓ Sill is structurally akin to a low, fixed breakwater. Must be impermeable to beach fill material.

✓ Include splash apron as erosion protection.

NOTES:

⊙ All submerged structures are potentially hazardous to boaters.

⊙ Sharp drop-off poses hazards to bathers and swimmers.

DEFINITION:

※ A fixed or floating structure placed in standing water aligned parallel to shore (sometimes connected to shore)

APPROPRIATE FOR:

- ❖ intercepting the energy of approaching waves;
- ❖ forming a low-energy shadow zone on the landward side;
- ❖ providing partial protection for swimmers and boaters;
- ❖ providing shoreline protection from wave action without interfering with access to the beachfront;
- ❖ providing aquatic habitat (stone structures); and
- ❖ increasing deposition of sand, and associated beach area.

NOTES:

- ⊙ When waves are parallel to breakwater, reflection augments incoming waves, generating standing waves twice the height of incoming waves.
- ⊙ Submerged breakwaters pose a hazard to boaters and swimmers.

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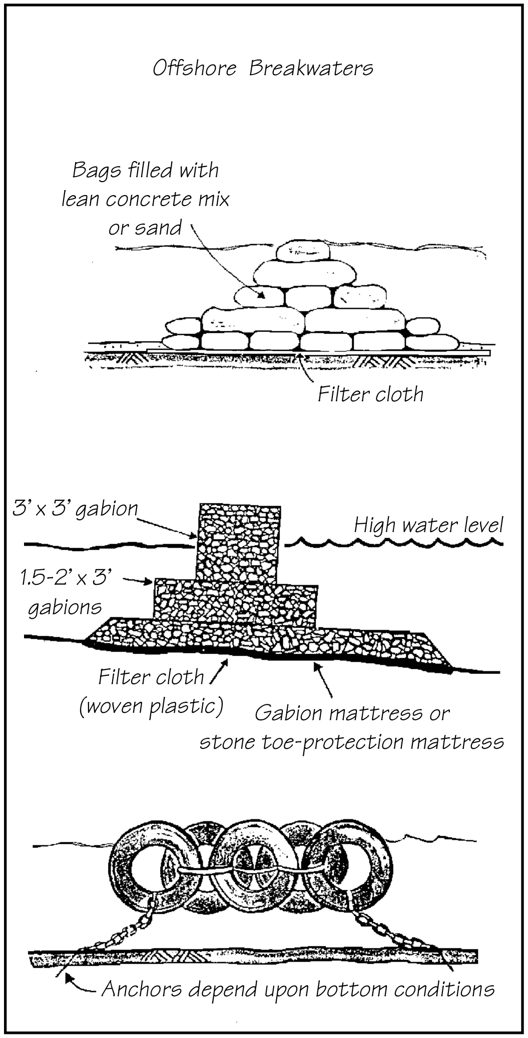
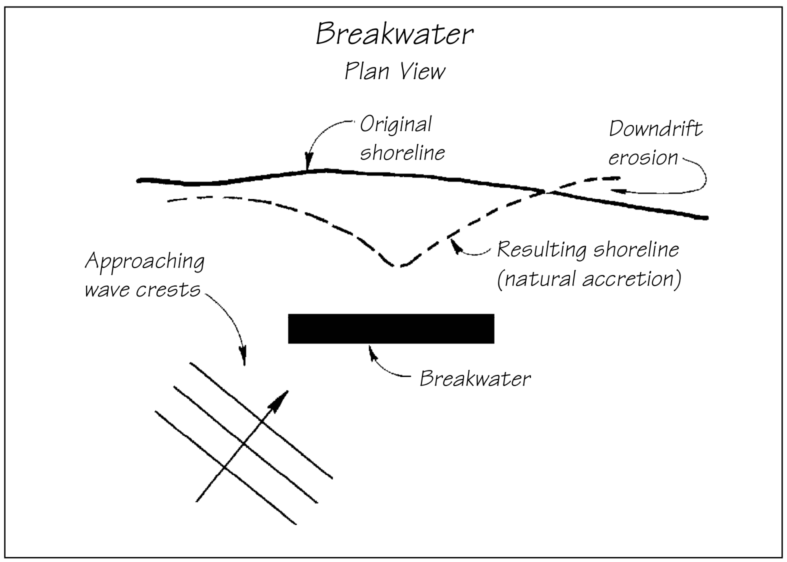


(Illustration adapted from D.D. Davidson in U.S. Army Corps of Engineers 1995)

Breakwater (Floating)

DESIGN/CONSTRUCTION:

- ✓ The width (parallel to the wavecrest) must be 2.5 times the square of the wave period.
- ✓ Draft must be greater than 1/2 wave height.
- ✓ Anchor must be secure (chain to a driven pile is best).



(Illustration adapted from U.S. Army Corps of Engineers 1981)

Breakwater (Fixed)

DESIGN/CONSTRUCTION:

- ✓ Height determines effectiveness. Submerged structures allow the passage of small waves, while breaking the impact of larger waves.
- ✓ Distance from shore is 1/2 the length of any segment of the structure. Positioning in shallow water is more economical than in deep water.
- ✓ Gaps in the length of the structure allow for the passage of deep water.
- ✓ Allow for settling, depending upon substrate and weight of structure.
- ✓ Quarrystone is most frequently used for wave heights above 5'.
- ✓ Sand-filled bags are vulnerable to vandalism; 100-pound bags are displaced by moderate waves.
- ✓ Gabions must be tightly packed to avoid distortion by wave impacts, stacked in a staggered pattern, and surrounded by gabion mats to prevent scouring. Extend toe protection lakeward 4 times the width of uppermost gabion, shoreward 2 times the width of uppermost gabion.
- ✓ For temporary protection of new vegetation, a brush breakwater is suitable. Drive two parallel rows of piles in standing water. Cut brush to lengths longer than spacing between piles. Lay parallel to structure alignment. Secure with timber crossties.

BULKHEADS

DEFINITION

※ Retaining walls designed to prevent movement of soil or to provide protection from wave action

APPROPRIATE FOR:

❖ maintaining water depth at shoreline;

❖ providing direct boat access to the shore.

NOTES:

⊙ Bulkheads protect only the shoreline immediately above them. In fact, reflection of waves may increase scouring in front of the structure. Downdrift sites may be deprived of sediment.

⊙ Cement structures have not proven to be durable.

⊙ Unless bulkheads are set high on the beach, they may interfere with access for swimming, jogging, and walking. Stairs may be needed to afford access from upper to lower beach.

⊙ The steep banks associated with bulkheads eliminate habitat and associated dynamics of vegetation that occupies gentle shoreline slopes and adjusts to changing water regimes over time.

BULKHEADS (POST-SUPPORTED)

DEFINITION:

※ Regularly spaced posts, usually timber, with an attached facing material that forms a retaining wall less than 5' tall.

DESIGN/CONSTRUCTION:

✓ To prevent erosion of structure, drive posts to a depth of:
D = (2 to 3) x (desired free-standing height + one wave height [to accommodate scouring]).

✓ Deadmen or brace piles may be used as anchors to stabilize low bulkhead when sheets cannot be driven more than 1.5-2.0 times the depth of the necessary free-standing wall (see illustration on next page).

✓ Excavate trench at least to depth of one wave height (to accommodate scouring).

✓ Attach facing material to landward side (*e.g.*, hogwire fencing and stacked bags, treated timber, steel H-pipes and railroad ties). Untreated logs may be used as facing but are not recommended, because gaps stress filter cloth and expose it to vandalism. Tires strung over staggered two rows of posts and filled with gravel are not recommended, because (1) close spacing of posts reduces cost/benefit ratio, and (2) gravel tends to wash out of tires.

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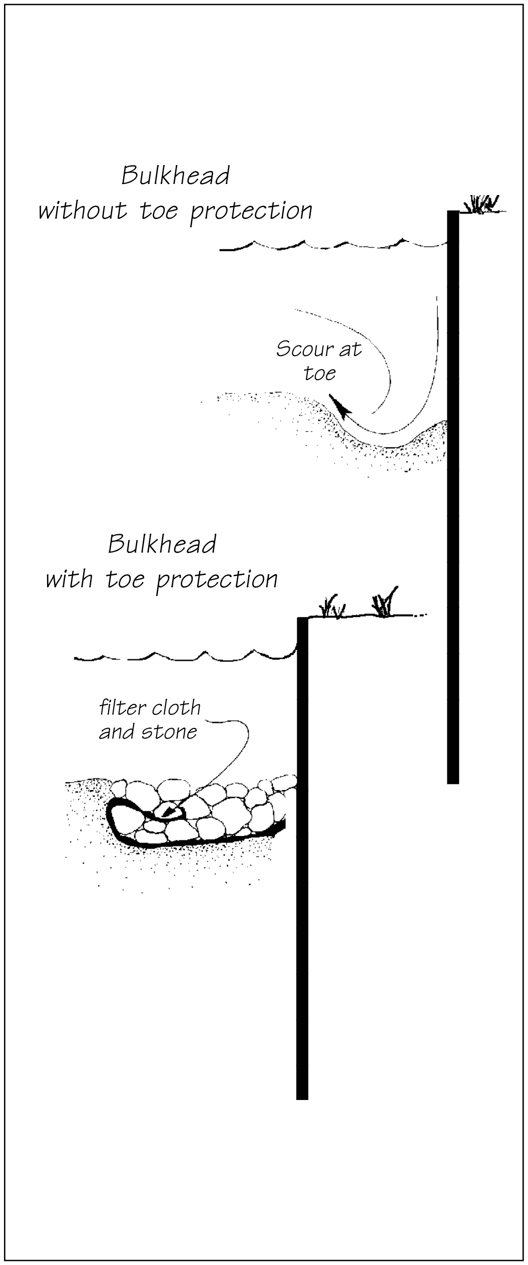


(Illustration adapted from U.S. Army Corps of Engineers 1981)

DEFINITION:

- ※ Interconnecting or very tightly spaced sheets of steel, timber, or aluminum driven vertically into the ground with pile-driving equipment.

APPROPRIATE FOR:

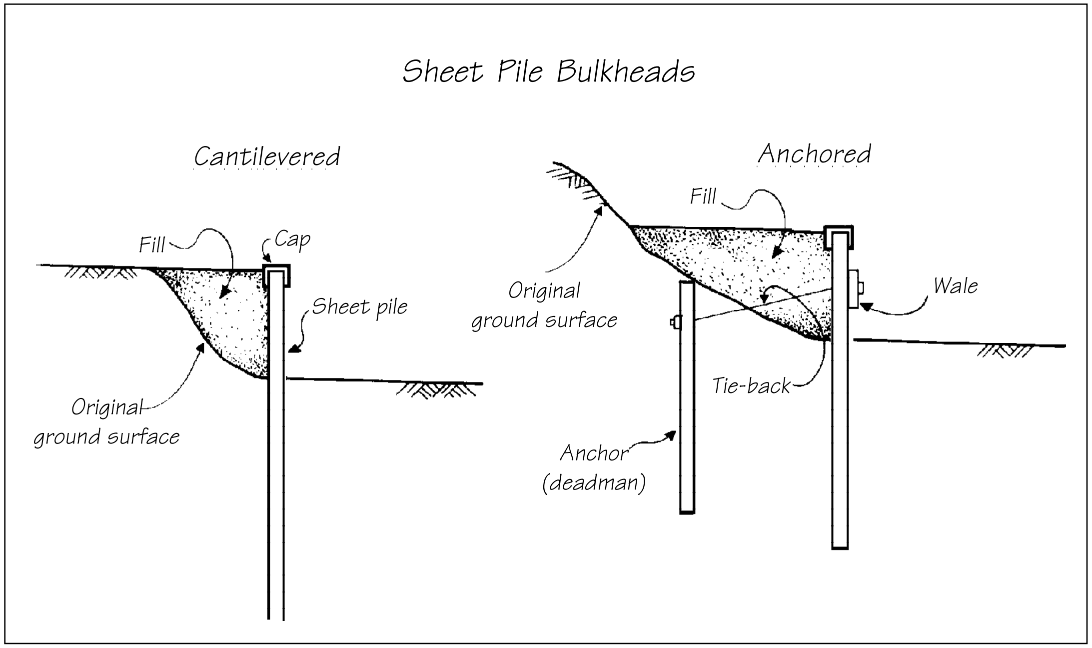
- ❖ low bulkheads where long life of structure and uniform appearance are desired.

DESIGN/CONSTRUCTION:

- ✓ Determine substrate before ordering materials. Steel is necessary at sites characterized by hard soils and/or some soft rock; aluminum and treated timber are suitable for softer soils.
- ✓ To prevent erosion of structure, drive posts to a depth of:
  D = (2 to 3) x (desired free-standing height + one wave height [to accommodate scouring]).
- ✓ Minimize spaces in joints, as loss of backfill material threatens the stability of the entire structure.
- ✓ Use only corrosion-resistant hardware. Wrought-iron anchor rods with turnbuckles and bolts have proven to be durable. Galvanized fasteners are also recommended. Carbon steel must be coated with coal-tar epoxy or other bituminous materials.
- ✓ To reduce the length of exposed bolt shanks, minimize the number of washers under bolt heads and nuts, and ensure a tight fit between bolted timbers. Drill bolt holes no more than 1/16” larger than bolt shank.
- ✓ If timbers are used, line barrier with filter fabric before backfilling, to prevent loss of material through cracks.
- ✓ If steel or aluminum sheeting is used, interlocking feature precludes need for filter fabric. Drain holes backed with stone filters or filter fabric are necessary.
- ✓ To facilitate passage of water from behind barrier, drill supplemental drain/weep holes. Back these with crushed stone filters or filter fabric.
- ✓ Use only granular material as backfill.
- ✓ Backfill over anchor piles before backfilling against bulkhead.
- ✓ Deadmen or brace piles may be used as anchors to stabilize low bulkhead when sheets cannot be driven more than 1.5-2.0 times the depth of the necessary free-standing wall.
- ✓ Anchoring must be added to secure tall sheet-piling bulkhead.

NOTE:

- ⊙ Consider using steel or concrete posts rather than treated timbers, to avoid contamination.



(Illustration adapted from U.S. Army Corps of Engineers 1981)

Bulkheads (Stacked-Bag)

DEFINITION:

※ Sand- or cement-filled bags

APPROPRIATE FOR:

❖ low bulkheads;

❖ situations where the use of heavy pile-driving equipment is not advisable,

❖ situations where substrate is not penetrable;

❖ firm foundation is available to support weight. NOT appropriate for sites where substrate is likely to fail (clay and silt substrates).

Gabions

DEFINITION:

※ A steel-wire mesh basket filled with stone

APPROPRIATE FOR:

❖ use in revetments, check dams, breakwaters;

❖ situations in which available stone is too small to resist erosion;

❖ banks steeper than 1:2;

❖ slowing the flow of water;

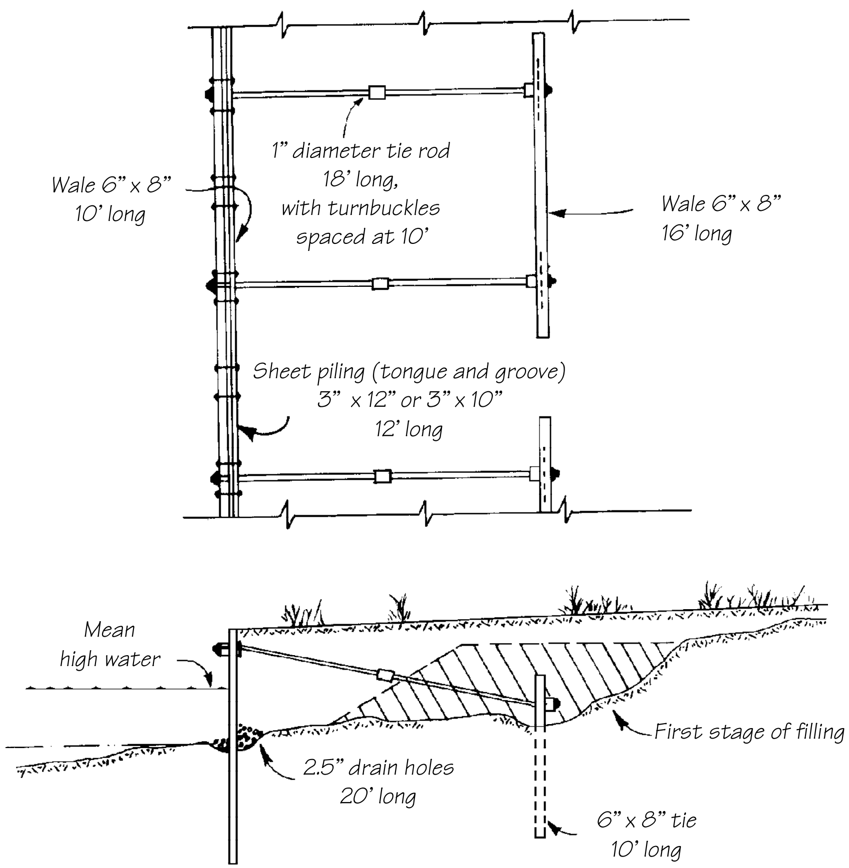
❖ trapping sediment; and

❖ increasing penetration of water into soil.

DESIGN/CONSTRUCTION:

✓ (See "Gabions" in *Streams & Banks*, page 64.)

Stabilizing Bulkheads



NOTE: Actual dimensions depend on site conditions

(Illustration adapted from U.S. Army Corps of Engineers 1981 and American Wood Preservers Institute 1970)

GROIN FIELDS

DEFINITION:

- ※ Sets of shore-protection structures extending into water perpendicular from shore

NOTES:

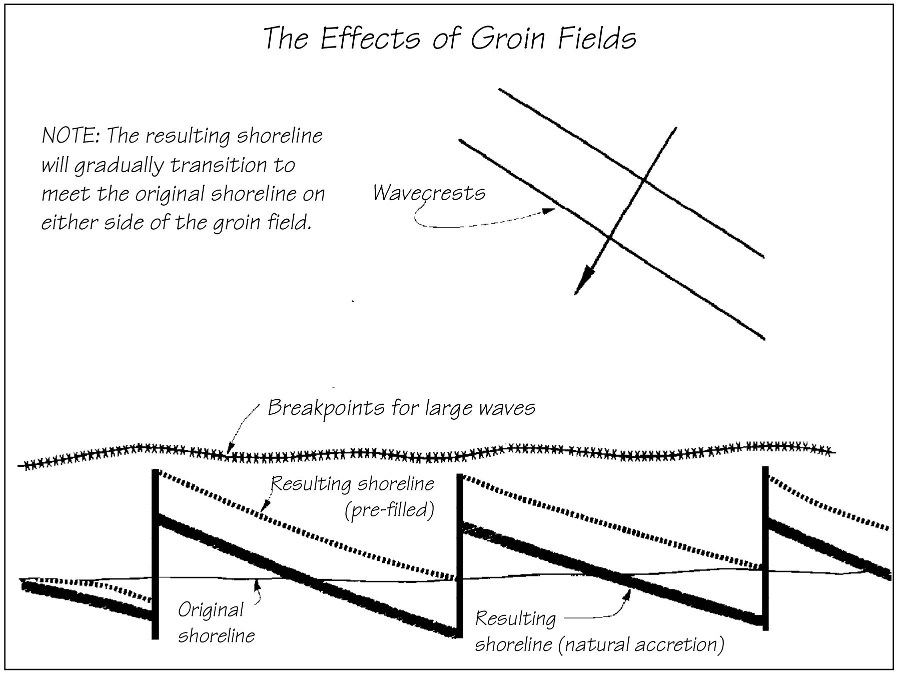
- ⦿ Hazardous rip currents may be created.
- ⦿ Submerged groins pose a hazard to swimmers and boaters.

APPROPRIATE FOR:

- ❖ trapping or slowing movement of sand along shoreline and/or deflect current, thereby retarding shore erosion;
- ❖ accumulating littoral sediments coarser than fine sands behind groins (finer materials move in suspension) and, thereby, increasing beach area;
- ❖ protecting the original shoreline from direct wave action;
- ❖ providing aquatic habitat (rubble or stone structures); and
- ❖ providing access to deeper water for fishing.

DESIGN/CONSTRUCTION:

- ✓ Low groins, designed to be overtopped by waves during storms, permit sand to pass over the structure and nourish downdrift beaches.
- ✓ Groins should not extend into breaker zone. Longer groins trap more sand.
- ✓ Space between groins should be 2-3 times the length of groin from water's edge. Closer spacing prevents deposition of sediment. Farther spacing allows erosion and flanking to occur between groins.
- ✓ Design groin to withstand pressure of sediments accumulation on updraft side, as well as wave action, current, and floating debris.
- ✓ Fill updrift sides with sand to protect shoreward end of groin from erosion and to minimize deprivation of sand from downdrift shoreline. Successful performance depends upon adequate longshore transport of sand to create fill on updrift side of groin.



(Illustration adapted from U.S. Army Corps of Engineers 1981)

REVETMENTS

DEFINITION:

※ A heavy armor laid on a slope to protect it from wave scouring

APPROPRIATE FOR:

❖ shoreline slopes which are stable and less than 30° (1’ rise for each 2’ lateral distance).

DESIGN AND CONSTRUCTION:

✓ Comprised of armor layer (*e.g.*, at least two layers of rubble, angular rock, riprap, gabions), filter layer (*e.g.*, graded stone), woven filter fabric, and toe protection.

✓ Provide a gabion mattress 18” thick as a foundation for a gabion revetment. Extend toe-protection mattress lakeward 1.5 times design depth (water depth at 50’ offshore).

✓ For a stone revetment, design the height above high water to be equal to the depth of the water 50’ offshore. For a gabion revetment, height above high water is equal to the depth of the water at 50’ offshore plus 1’. Do NOT allow overtopping by wave runup.

✓ Armor layer must be stable in wave action. Movement indicates inadequate stone size, foundation failure, or scour at the toe.

✓ Bury toe protection at least 3’ or the equivalent of one wave height below existing toe-slope surface, or create a berm of rubble and filter material.

✓ Anchor lakeward end of the stone toe protection with large stone or anchor screws.

✓ Beware of erosion on flanks.

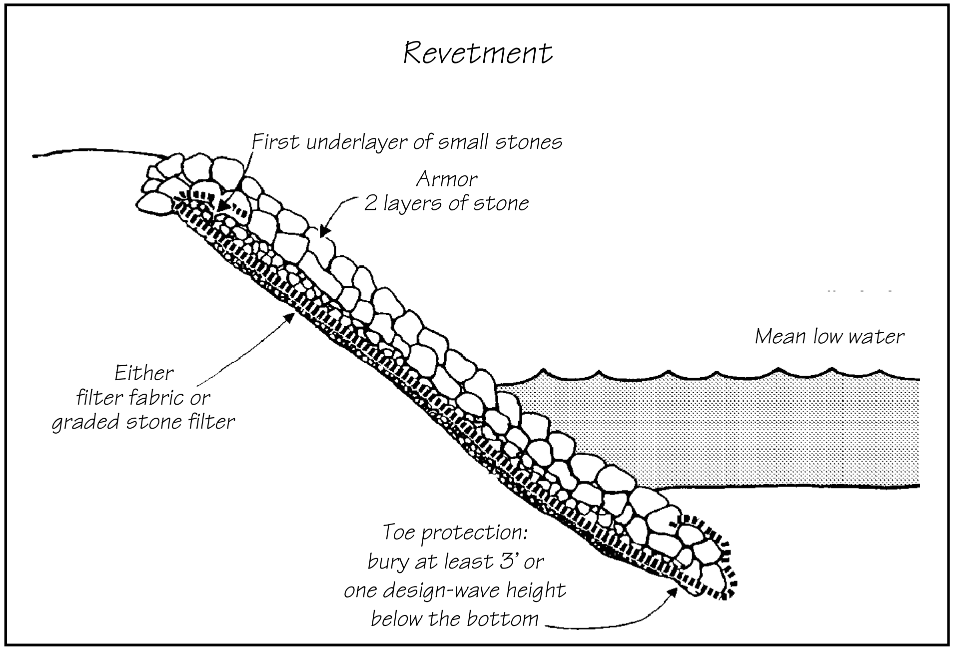
✓ (See “Revetments” in *Streams & Banks*, page 65)

NOTE:

⊙ Unless revetments are set high on the beach, they may interfere with access for swimming, jogging, and walking. A partially submerged revetment may pose hazards for swimmers.

MAINTENANCE:

☒ Repair any storm damage immediately.



(Illustration adapted from U.S. Army Corps of Engineers 1981)

Vegetation

APPROPRIATE FOR:

- ❖ providing habitat.

NOTE:

- ⊙ Because plantings must be protected from traffic, they may limit access to the waterfront.

DESIGN/IMPLEMENTATION:

- ✓ (See *Plantings & Vegetation*, pages 23-55.)

References and Suggested Reading

Allen, H.H. and C.V. Klimas. 1986. Reservoir Shoreline Revegetation Guidelines. Technical Report E-86-13, U.S. Army Corps of Engineer Waterways Experiment Station, Vicksburg, MS.

Gray, D.H. and A.T. Leiser. 1982. Biotechnical Slope Protection and Erosion Control. Van Nostrand Reinhold, New York.