



Shoreline and Channel Erosion Protection: Overview of Alternatives

PURPOSE: This technical note describes alternatives that can be used separately or in combination to control erosion along wetland shorelines and bank lines. The advantages and disadvantages of each alternative are discussed in this technical note, along with the common reasons for failure.

BACKGROUND: After determining the causes and mechanisms of bank erosion and quantifying the environmental setting of the wetland to be protected against erosion, a list of applicable protection methods can be developed. In general, the minimal amount of protection should be used, and any impact to the wetland should be avoided.

NO-ACTION ALTERNATIVE: This alternative is selected when the environmental setting is mild enough to not require protection. It is possible, at times, to let an erosion problem continue if it appears that it will stabilize with time or that the wetland will not suffer unrecoverable losses. Experience and familiarity with the location is important in the somewhat subjective decision whether to take no action or apply protection.

ACTION ALTERNATIVES: A number of alternatives, alone or in combination, are available for consideration. Summary descriptions of these alternatives (listed in the tabulation below) are provided in this technical note.

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VEGETATION AND NATURAL MATERIALS:

Advantages:

1. Vegetation and natural materials used for protection complement, or become an element of the wetland.
2. Additional habitat can be created. Since the protection is often at the interface between open water and heavily vegetated water or land, it lies within the very productive portion of the wetland. Vegetated banks provide more appealing vistas for humans and more attractive habitat for wildlife, which may otherwise be deterred by unnatural settings.
3. Vegetation is self-perpetuating.
4. Vegetation will continue to strengthen and stabilize the bank, assuming that no destabilizing forces overcome the vegetation.
5. Successional or invasional species colonizing a site can add natural variety to the original protection scheme.
6. Vegetation minimizes the potential obstructions to the ingress and egress of organisms to the wetland, as well as the movement of water into and out of the wetland.

Disadvantages:

1. This alternative takes 1-3 years to fully develop.
2. Often requires stabilization measures to protect the vegetation during development.
3. Can be applied only in mild erosional climates.
4. Requires monitoring and maintenance.
5. Minimal guidance is available for designing erosion protection based on wave and current conditions.

Common reasons for failure:

1. No protection during development stage.
2. Improper plant selection, handling, planting technique, or positioning.
3. Poor-quality substrate.
4. No monitoring and maintenance.

General considerations: Vegetation used for bank protection must often be protected itself (or its foundation enhanced) until it has had time to develop root systems and a thick stand. Vegetation is sensitive to the conditions of its environment, such as water depth, water clarity, water quality, sediment type, and nutrients. A good indication of whether vegetation will survive at a given location is to look for similar conditions in the region where vegetation has survived.

Vegetation has a limited range over which it is able to maintain sediment stability. That is, vegetation can only withstand a certain level of wave and current magnitude, before it is undermined or otherwise destroyed. However, even in cases where something other than vegetation is proposed for erosion control, one should always consider the possibility of adding vegetation to the design. For example, if rock revetment is necessary, it may be possible to plant vegetation between the rocks.

FIBER MATTRESS: Fiber mattresses consist of intertwined natural or synthetic fibers. The mattresses are porous, allowing water to permeate while retaining some sediments. Fiber mattresses are strong but depend on the quality of the materials for durability. The success of a mattress depends on its strength, durability, and the system used to anchor it.

Advantages:

1. Biodegradable fiber mattresses can be used as temporary protection during the establishment of vegetation.
2. Vegetation can be sprigged in the mattress.
3. Mattresses are relatively inexpensive. (However, depending on the application, the labor costs required to anchor the mattresses can be high.)
4. Properly selected and installed mattresses are less noticeable and enhance aesthetic values.

Disadvantages:

1. Sometimes difficult to anchor sufficiently because the broad surface may experience large uplift forces.
2. If the anchoring system is damaged, the mattresses that are free to move may damage wetland vegetation and create an unsightly appearance.
3. No design guidance is available for proper selection of mattresses for given currents or wave conditions.
4. No guidance is available for sufficient anchoring techniques for given currents or wave conditions.

Common reasons for failure:

1. Materials used in the mattress degrade too rapidly. For example, some glues used to hold the mesh together may soften in a wet environment.
2. Anchoring systems are pulled out by wave- or current-induced uplift and drag forces on the mattresses.
3. Anchoring systems are undermined by currents or waves.

CELLULAR CONCRETE MATTRESSES (CCM) BLOCK REVETMENTS: Erosion protection from wave attack or streamflow can be provided by man-made concrete blocks (often labeled CCM, for cellular concrete mattress). These interlocking or cable-tied blocks form a revetment similar to a gabion mattress. Cable-tied blocks are usually placed mechanically by crane and spreader bar, whereas interlocking blocks can be mechanically or hand placed.

Advantages:

1. CCM open area of 20 to 25 percent allows colonization by vegetation.
2. Cost-effective in urban streams.
3. Flexible and durable. Can conform to minor bank settlement.
4. Requires less tonnage than riprap. Thickness one third to one fifth that of riprap for channel flow applications.
5. Easily maintained. Can be mowed if vegetation must be controlled.
6. Voids and hardened substrate provide habitat for various biota.

Disadvantages:

1. Cable-tied and geotextile-bonded systems are usually proprietary.
2. Can be expensive in rural areas.
3. Susceptible to vandals removing blocks (noncabled application).
4. Presently, design guidance is lacking for some CCMs.
5. Unnatural appearance unless vegetation is allowed to hide protection.

Common reasons for failure:

1. Toe scour undermines revetment.
2. Excessive settlement that leads to irregular block surface, which can expose blocks to large hydraulic forces.

3. Inadequate treatment and attention to edges, ends, and transitions to other surfaces.

Attention to detail is critical with CCM blocks. Special care should be given to selecting experienced contractors who practice good quality control.

RIPRAP REVETMENT: Riprap revetments are placed on a sloping bank and depend on the stability of the underlying soil for support. Fill material beneath a revetment must be adequately compacted prior to installing the riprap. Riprap revetment, like other revetments, consists of two or more layers (filter and armor).

Advantages:

4. Riprap is self-adjusting to small amounts of substrate consolidation or movement.
5. Riprap may experience minor damage and still continue to function adequately without further damage.
6. The rough surface of riprap dissipates local currents and minimizes wave runup more so than a smooth revetment such as a concrete block revetment.
7. Material is readily available in many locations and can be less expensive than other structural alternatives.
8. Aquatic organisms can use the riprap as suitable habitat.
9. Riprap can be repaired easily by placing additional stone when needed (if access to the location is reasonable).

Disadvantages:

1. If material is not locally and readily available and easily transported to the site, costs can be prohibitive.
2. Riprap may present a barrier to organisms entering and leaving the wetland.
3. Riprap may not be aesthetically pleasing to some people.
4. Riprap may pose a hazard to people who must access the revetment.

Common reasons for failure:

1. Flanking, overtopping, and undermining of the revetment.
2. Settlement of sections of the revetment due to poorly consolidated substrate material.
3. Improperly designed or installed filter layer or fabric.
4. Undersized stone riprap displaced by large waves or currents.

DYNAMIC REVETMENT: A dynamic revetment consists of a larger volume of smaller stones as compared to a standard riprap revetment (described above). Because of the smaller stone size, the cross-sectional form of a dynamic revetment will be adjusted by the forces acting on it, creating an equilibrium form for the given forcing. The larger volume of stone is required to ensure that the bank is fully protected even after the cross-sectional shape of the revetment is altered.

Advantages:

1. Smaller equipment is required to place the smaller stones.
2. Placement of stone requires less care than a standard riprap revetment.
3. Smaller stone may cost less than the larger stones required for a standard riprap revetment.
4. The final cross-sectional shape is more natural looking than a typical revetment. The composition and form is similar to that of a pebble or shingle beach.
5. The smaller stone size presents less of an obstruction to smaller organisms that need to enter or leave the wetland.
6. The smaller stone size presents less of a hazard to foot traffic.

Disadvantages:

1. Smaller stones are not always less expensive than conventional riprap sizes. Without lower costs, the greater uncertainty in the performance of dynamic revetments (over conventional riprap revetments) may not be warranted.
2. Foot traffic and other activities may damage the equilibrium cross section obtained by the revetment. The cross section of a conventional riprap revetment is not likely to be damaged by foot traffic.
3. Less guidance and verification of guidance is available for dynamic revetments as opposed to conventional riprap revetments.

Common reasons for failure:

1. The stone size is too small to remain stable under the given wave conditions.
2. Insufficient volume of stone is placed on the bank.
3. The stones are not constrained from moving laterally along the shoreline.
4. The revetment is undermined by poor filter layer or fabric, or overwash.

GABIONS: Gabions are rectangular baskets or mattresses made of galvanized (and sometimes polyvinyl chloride-coated) steel wire in a hexagonal mesh. The gabion is subdivided into approximately equal-sized cells. At the job site, the baskets are unfolded and assembled by lacing the edges together with steel wire. The individual baskets are then wired together and filled with stone. The lids are finally closed and laced to the baskets, forming a large, heavy mass.

Advantages:

1. The smaller stone used in a gabion can offer equivalent protection as the much larger stone needed in a riprap revetment. (Assumes no destruction of the wire baskets.)
2. Can support some vegetation.
3. Can be cost effective when using locally available stone filler.
4. Requires less tonnage than riprap. Gabion thickness is roughly one third that of riprap revetment.
5. Flexible and durable if properly maintained.
6. Can be stacked to obtain near-vertical side slopes where available right-of-way is limited.
7. Gabion baskets can be built without heavy equipment.
8. Gabions are flexible and can adjust to minor settlement of their substrate.
9. Gabions can be repaired easily by mending or replacing damaged baskets and refilling them as needed.

Disadvantages:

1. Wire mesh is subject to damage from strong waves, floating debris, corrosion, wear from high-velocity sediments, and vandalism.
2. Labor-intensive installation required.
3. Gabions require monitoring and maintenance to identify wear before failure occurs.

Common reasons for failure:

1. Baskets are not filled adequately. This allows them to move, and results in abrasion and fatigue failures of the wire.
2. Baskets are damaged by floating debris, wear, or corrosion.

PARTIAL BANK PROTECTION: On small to intermediate streams, most banks can be protected by a combination of structural protection on the lower bank and vegetation on the upper bank. As a general rule, the larger the stream, the greater the portion of the bank that must be protected with structures. Partial bank protection reduces the quantity of structural protection, which is often costly, and promotes vegetation in the riparian zone.

WINDROW AND TRENCH-FILL REVETMENTS AND TOE PROTECTION: Windrow and trench-fill revetments are armor methods used in the riverine environment in which the stream erosion places the riprap revetment. Riprap is the most common method for providing toe protection in the riverine environment. The riprap is either placed down to the elevation of the maximum scour or, similar to windrow and trench-fill revetments, is placed in a section of riprap called a weighted toe to launch down as toe scour occurs. The weighted toe method is particularly useful in protection that is constructed underwater. The volume of stone in the weighted toe is more important than the shape of the before-launch section.

Advantage: Eliminates underwater excavation.

Disadvantages:

1. Requires greater stone volume due to uncertainty in the launch process.
2. Requires noncohesive bank to properly function.

MILD OFFSHORE SLOPES: In wave-dominated climates, a mild bottom slope (especially, when vegetated) is less likely to develop a serious erosion problem. A mild offshore slope helps to dissipate wave energy before it reaches the edge of the wetland. If the slope is vegetated, additional energy losses occur.

SAND: In some wave-dominated projects where wave heights are small, if a sufficient amount of sand can be placed offshore of the wetland, this can cause waves to break and dissipate their energy before reaching the wetland. This is similar to the idea of developing very mild offshore slopes, as mentioned above. If the sand is contained within the project area (bounded laterally by land or structures), then it may shift around within the region due to wave action and eventually form an efficient energy dissipation zone. A “back wall” is needed.

SILLS: A sill is an offshore structure with its crest usually submerged. Sills are designed to retain sand and sediments and to prevent migration offshore. Design of a low-permeability structure is therefore important. A sill is often used in conjunction with other shoreward structures.

BERMS: These submerged linear mounds of sediment can be placed offshore from the project site. Berms reduce wave energy incident to the site by causing waves to break as they pass over the structure. Berms should be used in conjunction with other alternatives for bank protection.

Advantages:

1. Add interesting features and variations to local bathymetry.
2. Afford (at least temporarily) some protection against wave energy.
3. Add sediment to the local sediment transport system.
4. Provide a useful means of using otherwise excess sediment from a restoration or creation project.

Disadvantages: The disadvantages occur when the advantages do not apply. That is, berms are a disadvantage when they do not add useful variations to the local bathymetry but merely cover up existing bathymetry; when they add too much sediment to the sediment transport system; and when they require significant effort to construct but do not survive long enough to provide much protection against incident waves.

BREAKWATERS: Breakwaters are generally shore-parallel structures that reduce the amount of wave energy that reaches a protected area by dissipating, reflecting, or refracting incoming waves. The reduction of wave action promotes sediment deposition shoreward of the structure. Littoral material is

deposited, and sediment is retained in the sheltered area behind the breakwater. Breakwaters may be totally detached from shore or connected at one or both ends.

Advantages:

1. Breakwaters can provide protection in medium- to high-wave energy environments.
2. Extensive experience is available for design and construction of rubble mound breakwaters in terms of stability and expected wave transmission.
3. Rubble mound breakwaters that suffer minor damage can still be functional.
4. Breakwaters provide protection with minimum disturbance to the existing shoreline.
5. Segmented, detached breakwaters allow uninterrupted movement of littoral material and aquatic organisms.
6. Aquatic organisms use some breakwaters as habitat.
7. Displaced stone in a rubble mound breakwater can be easily repaired or modified.

Disadvantages:

1. Construction costs can be high due to equipment access requirements for offshore breakwaters.
2. Limited design guidance is available to predict the response of vegetated shorelines behind detached breakwaters.
3. Continuous shore-connected breakwaters may present a barrier to organisms entering and leaving the wetland.
4. Breakwaters may not be aesthetically pleasing to some people.

Common reasons for failure:

1. Undersized stone displaced by large waves.
2. Excessive wave energy allowed to reach shoreline due to improper crest elevation or gap widths.
3. Improperly designed filter layers that allow substrate material to be removed from structure.
4. Flanking and scour at the toe of the structure.
5. Excessive settlement due to poor foundation conditions.

GEOTEXTILE TUBES: Geotextile tubes usually consist of two sheets of geotextile (woven or non-woven) sewn together with inlets and outlets sewn at intervals when necessary. The tubes are hydraulically or mechanically filled onsite with a variety of dredged material types to form the desired tube dimensions.

Geotextile tubes are used as an alternate material for constructing some of the structures listed above. The tubes have been used in a broad range of applications, including berms, dikes, sills, breakwaters, and groins. Additional information on the use of geotextile tube structures is provided in WRP Technical Note HS-RS-3.2.

Advantages:

1. Wide variety of uses.
2. Simplicity in placement and construction.
3. Structures can be easily removed if needed only temporarily.

Disadvantages:

1. Limited design guidance on stability in moderate wave environment.
2. Construction costs can be high if construction requires specialized equipment.
3. Can be damaged by large debris, boat propellers, vandalism, and ice.

Common reasons for failure:

1. Poor stability in wave climates on sloping plane.
2. Improper geotextile selection.
3. Final crest elevation too low due to improper filling of tube, excessive consolidation of material within tube, or excessive structural settlement due to poor foundation conditions.
4. Damage from floating debris or vandalism.
5. Toe scour results in shifting of tube.

CONCLUSIONS: Many alternatives are available for erosion protection in the mild- to moderate-energy environments in which wetlands are found. Often, a combination of alternatives can be used to provide the most satisfactory result. In selecting an alternative or alternatives, consideration should be given to the advantages, disadvantages, and common causes of failure, as well as minimizing adverse environmental impacts. For example, the alternative and its design should, as much as possible, not hinder the ingress or egress of organisms to the site.

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