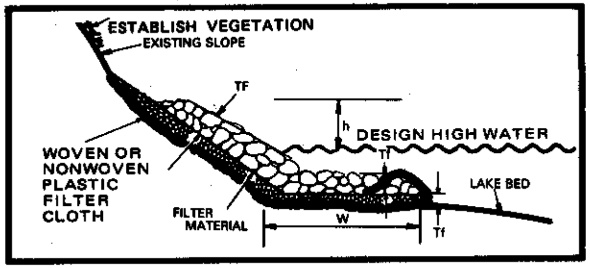
REVETMENTS

Revetments are structures placed at the toe of bluff parallel or nearly parallel to the shoreline to protect against wave action. Three examples are shown below.

STONE REVETMENT



Stone revetment is the preferred method of shore protection. It is economical and suitable for all types of erosion problems when stone is available in sufficient size and quantity. The key design considerations, are the dimensions, foundation treatment, and stone size. Construction is not complicated and no special equipment, other than a crane and trucks are needed.

NOTES:

1. Slope should be compacted and graded to 1:2 or flatter.
2. Place a gravel, small rock, filter blanket, and/or filter cloth on the prepared slope.
3. Place rock carefully with a crane; rock should be supported at three locations.
4. Insure rock sizes are well mixed. Larger and smaller rock should not be visibly segregated.

MAINTENANCE REQUIREMENTS

This structure is subject to displacement. The effectiveness of the structure will be impaired by thinning of the protective layer or settling of the structure. Restoration of the rock slope protection to the designed top elevation, equivalent thickness and reduction of voids in the facing should be accomplished when needed. The list of materials and general costs information is given in the following tabulation.

Description	Design depth of water 50′ offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Thickness (ft)	2	4	5
Average Wt of Stone (#)	200 – 500	750 – 2000	2000 – 5000
Height of Structure (ft)	4	6	8
Toe Protection Width (ft)	2	4	5
Filter material	Cloth		
List of Materials (per ft)			
Stone (tons)	1.89	4.94	7.36
Filter (sq ft)	13	19	22
Cost $/Lin. Ft.	50	130	230

ADVANTAGES

Most effective structure for absorbing wave energy.

Flexible—not weakened by slight movements.

Natural rough surface reduces wave runup.

Lends itself to stage construction.

Easily repaired—low maintenance cost.

The preferred method of protection when rock is readily available at a low cost.

DISADVANTAGES

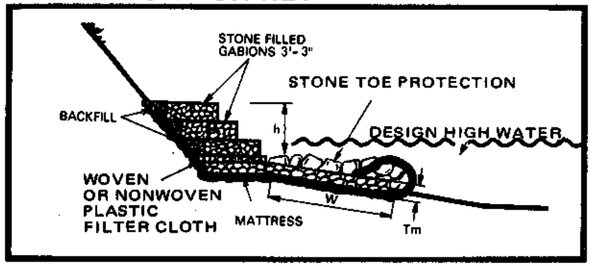
Heavy equipment required for construction.

Limits use and access to beach.

Moderately high first cost.

Difficult to construct where access is limited.

GABION REVETMENT



A gabion is a steel wire mesh basket available commercially. Revetments can be constructed from stone-filled gabions by groups of individuals without special construction equipment. Gabion structures can be built to any height required. A step design is suggested to reduce wave runup. The manufacturer's instructions should be followed closely. The structure should rest on an 18″ thick gabion mattress to protect against scour. This type of construction is applicable to all shore-protection problems.

NOTES:

1. Gabions can be filled with any stone material larger than the mesh.
2. Gabion structures maintain their strength even if the foundation settles somewhat.
3. You should stagger the joints between baskets the same way you stagger the joints between courses in a brick wall to make a stronger structure.
4. You would be wise to anchor the lakeward end of the mattress with large stone or anchor screws.
5. Your mattress should extend out as far from the toe as one and one-half times the design depth.

MAINTENANCE

The life of gabion protection depends on the durability of the wire. Replace broken wires with galvanized or plastic-coated wire. The baskets occasionally are moved during severe storms, but can often be replaced after the storm. Such movement indicates foundation failure or scour at the toe. Repair all storm damage as quickly as possible.

Description	Design depth of water 50′ offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (ft.)	5	7	9
Apron length (ft.)	2	5	7
Filter material	Cloth		
Materials (per ft.)			
Gabions (#)	1	3	4
Gabions—Stone filled (yd^3)	0.2	0.7	0.9
Gabion type mattress (yd^3)	0.2	0.4	0.7
Cost $/Lin. Ft.	40	90	120

ADVANTAGES

No special construction equipment required, rated best 'do-it-yourself' type of protection.

Flexible, easily repaired after storm damage.

Low first cost, if do-it-yourself project.

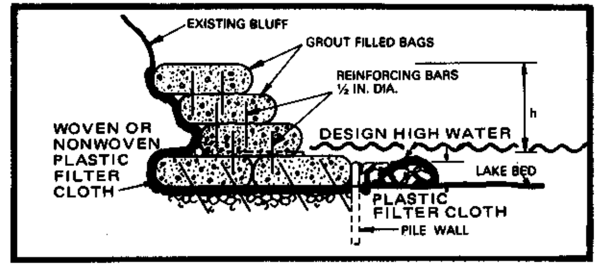
DISADVANTAGES

Subject to rusting and deterioration unless wire baskets are plastic coated.

Limits use and access to beach.

Moderate maintenance costs.

GROUT FILLED BAGS REVETMENT



Large grout-filled nylon bags (20′ x 5′ x 1.6″) may be used to protect eroding shorelines. This type of structure is adaptable to all types of slopes. Bags should be placed parallel to the shore with reinforcing bars installed both vertically and horizontally as shown in the section above. This type of structure may be applicable where access is limited and rock is not readily available. No special material is needed other than the bags and construction is not complicated. A grout pump is required to fill the bags. Prices in the table below were computed with the assumption that ready-mix grout will be used but a concrete mixer could be substituted at the site.

MAINTENANCE REQUIREMENTS

Remedial work on this type of structure is not easily accomplished. Special attention should be given to toe protection. Uneven settlement or undermining might cause fracture or collapse. If excessive scour causes toe stone to settle, more material should be added. This type of structure is readily adaptable to add-on construction. Additional structure height can be easily accomplished if necessary.

Description	Design depth of water 50′ offshore (ft.)		
	3 – 5	5 – 6	7 – 8
Dimensions			
Height of Structure (ft)	6.4	8.0	11.2
(Bags)	(5)	(6)	(8)
List of Materials (per ft.)			
Grout (Yds.^{3})	1.5	1.8	2.4
Reinforcing bars (lbs.)	10	12	16
Filter Cloth (sq. ft.)	18	21	26
Cost $/Lin. Ft.	135	160	215

ADVANTAGES

Moderate first cost.

Adaptable to stage construction.

DISADVANTAGES

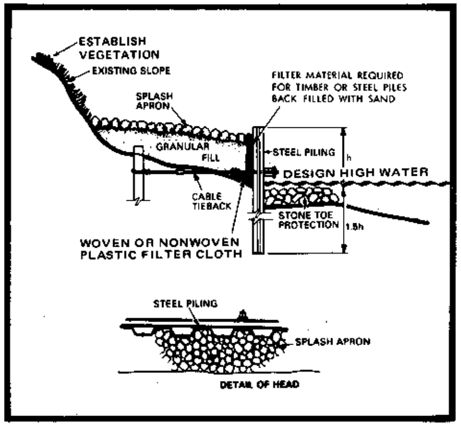
More subject to catastrophic failure if the toe is undermined.

PROS, CONS AND COSTS
PROTECTION

BULKHEADS OR SEAWALLS

Bulkheads are structures placed at the toe of bluff parallel or nearly parallel to the shoreline with the primary purpose of preventing the sliding of land or slope failure. The secondary purpose is to provide protection against wave action. Examples of several different types of bulkheads are shown below.

STEEL BULKHEAD



A steel bulkhead serves to armor the bank. The face must be designed to absorb all wave energy. Severe scour occurs at the bulkhead line. The sheeting depends upon penetration and tie backs for its stability. The structural design of sheet piling is highly specialized and not subject to standard plans. For this reason the service of a qualified engineer is essential. Key design considerations are foundation conditions, penetration of the piling, height and alignment, and scour protection. Sufficient access must be available for pile-driving equipment.

Piles shall be carefully located as shown on the drawings and driven in a plumb position, each pile interlocked with adjoining piles for its entire length, so as to form a continuous diaphragm, throughout the length of each run of wall. The Contractor shall drive all piles as true to lines as practicable and shall provide suitable temporary wales or guide structures to insure that the piles are driven in correct alignment.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (h)	5	8	10
Piling length	13	20	25
Toe protection apron length	2 x 2	4 x 4	5 x 6
List of Materials (per ft.)			
Steel Piling (s.f.)	13	20	25
Waler (ft.)	1	1	1
Fill material (yds.)	.9	2.0	3.0
Toe Protection (yds.)	.15	.60	.95
Cost $/Lin. Ft.	290	460	580

ADVANTAGES

Provides substantial protection.

Maintains shoreline in fixed position.

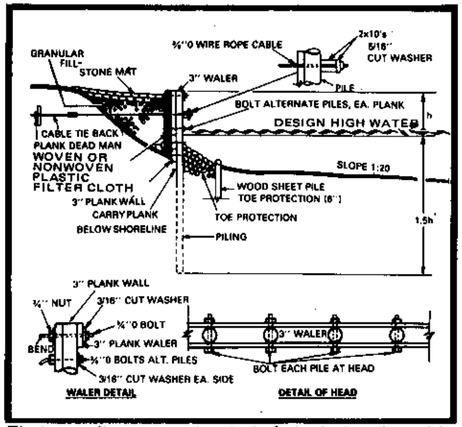
Low maintenance cost.

Materials are readily available.

DISADVANTAGES

Structural integrity depends upon adequate toe protection.

TIMBER WALL BULKHEAD



Timber walls are constructed of plank sheeting with round piles. They consist of two rows of 3-inch plank sheeting and a row of round piling with heavy horizontal walls between the planks and the piling. They must be tied back to anchor piling. The most common cause of failure of sea walls is undermining of material from the bottom of the toe of the structure, resulting in inadequate penetration of piling. The pressure of the soil and water on the back side can then tip the structure. The tie-backs provide additional strength to resist this force. Timber bulkheads also require positive toe protection.

The piling and sheeting are driven with the aid of a jet from a small pump. The use of this design is controlled by subsurface foundation conditions. It is suitable for sand or sand and gravel shores where the sand deposit is 12-15 feet below the lake bottom. Wooden structures must be securely fastened together with bolts.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (ft.)	5	8	10
Diameter of Piles (in.)	6	8	10
Pile length (ft.)	13	20	25
Wall plank thickness. (in.)	3	3	3
Toe protection wt (lbs.)	70	140	200
List of Materials (per ft.)			
Piling	5.3	8.0	9.3
Waler	1	1	1
Wall Plank (s.f.)	6	9	11
Filter Blanket (s.f.)	9	12	16
Toe Stone (c.y.)	.3	.7	.95
Fill Material (c.Y	.9	2.0	3.0
Costs $/Lin. Ft.	70	95	150

Vertical walls induce severe scour at their base.

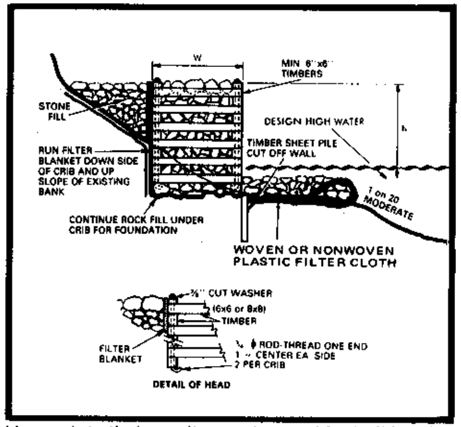
High first cost.

Pile driving requires special skill and heavy construction equipment.

Complex engineering design problem.

Limits access and use of beach.

TIMBER CRIB BULKHEAD



Heavy duty timber cribs can be used for bulkheads. Timber cribs use log-headers and stretchers. Headers must be long enough to integrate a stable mass of backfill. Dimension lumber can also be used. Backfill for cribs must be self-draining and secure against erosion. The base of the toe must be protected from scour.

NOTES:

Notch logs to reduce spacings between members. Fill cribs with field stone up to 50 pounds. Provide a gravel bed foundation. Backfill area between bluff and crib with bank run gravel.

Place a storm splash apron on backfill.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (ft.)	5	7	Not Recom-mended
Width (ft.)	4	5	
Cut off wall (ft.)	6	9	
Cap stone (lbs.)	100	200	
Stone fill (lbs.)	10 – 50	10 – 50	
List of Materials (per ft.)			
Timber cribbing 6"x 6")	20	24	
Rock fill (cu. yds.)	.9	1.0	
Capstone (cu. yds.)	.2	.2	
Sheeting (sq. ft.)	6	9	
Anchor rods (ft.)	6' – 0"	8' – 0"	
Cost $/Lin. Ft.	70	85	

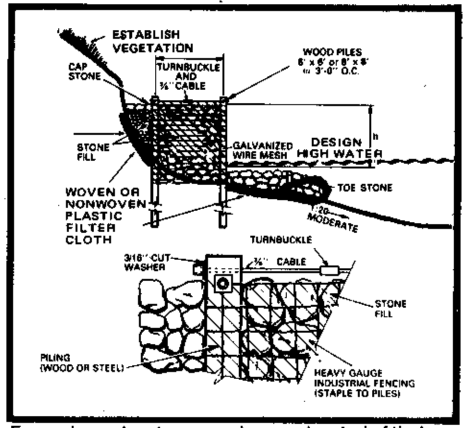
ADVANTAGES

Lends itself to protecting short reaches.

Can be constructed of materials that are readily available.

Structure is easily repaired.

WIRE FENCE BULKHEAD



Fence-type structures can be constructed of timber, or metal posts or piling, and wire fence or lumber. The fences can be built of single, double, or triple rows. Posts should be driven below possible scour. Woven-wire fabric is preferred to welded wire fabric.

This type of protection consists of fence, filled with stone, and anchored to the embankment. The fence is used to hold small stones in place that would be displaced by wave action.

The more important design considerations include: the piling length, the size of the wire fence fabric, the design of the compartment to hold the stone, and the method of anchoring the stone-filled fence to the embankment.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (ft.)	5	6	9
Length-wood piles (ft.)	13	15	23
Diameter wood piles (in.)	8	8	10
Stone fill (lbs.)	30 – 50	30 – 50	30 – 50
Cap stone (lbs.)	100	200	300
List of Materials (per ft.)			
Piling (lin. ft.)	17	20	30
Stone fill (cu. yd.)	.53	.60	.90
Cap stone (cu. yd.)	.17	.17	.17
Fencing (sq. ft.)	27	30	42
Cable (ft.)	2.3	2.3	2.3
Toe Rock (cu. Yd.)	.40	.46	.53
Costs $/Lin. Ft.	110	125	180

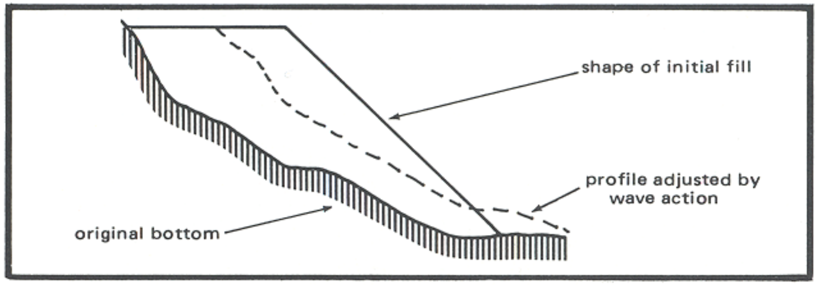
DISADVANTAGES

Structural integrity depends upon adequate toe protection. Vertical walls induce severe scour at their base.

Limits use and access to beach.

BEACH FILL OR ARTIFICIAL NOURISHMENT

A beach fill artificially replaces material lost naturally to littoral processes.



Depending on the beach width and slope, a beach fill affords some storm protection for the land area behind the beach by dissipating wave energy as the waves break on the beach. Artificially placing suitable material (predominantly medium sand) on the shore to restore or create a protective beach directly replaces the littoral materials that are removed and not replaced by natural processes without inducing damage to shore areas beyond the project area. When sand is placed on a beach, waves sort the surface layer of the fill moving the finer particles lakeward while the coarser particles remain near the point where the waves break. This causes an adjustment of the beach fill profile as shown in the above figure. The adjustment continues until the grain sizes on the beach are compatible with the normal wave climate.

Planning for a protective beach by artificial nourishment requires: knowledge of the littoral transport rate and direction at the site; information on the grain sizes of the beach material at the site, as well as that of the material to be placed on the beach; and determination of the shape of the initial fill and how the beach profile will adjust when subjected to wave action. Although beach fill may often be the most environmentally acceptable solution to shore erosion control, the preceding requirements make designing a protective beach difficult.

MAINTENANCE REQUIREMENTS

Beach fill often needs to be periodically nourished because of littoral transport. It may be difficult to find economic sources of borrow material with grain sizes similar to the existing or native beach material. However, if the borrow material is much finer than the native material, large losses generally occur soon after placement of the material.

COST

The cost of a beach fill varies with amount of initial fill, frequency and amount of nourishment required, and transport methods and distances. Initial costs may be low if an adequate borrow source is nearby.

ADVANTAGES

Recreational area is provided if beach is of suitable dimensions.

Beach nourishment benefits rather than endangers downdrift area.

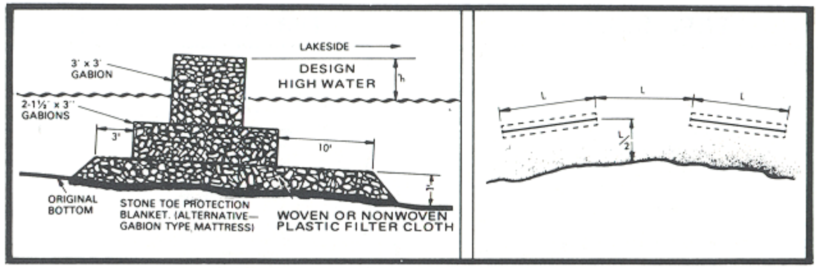
DISADVANTAGES

May be difficult to maintain in areas of rapid erosion or where no previous beach existed.

OFFSHORE BREAKWATER

The breakwater is placed offshore from and usually parallel to the shoreline to protect a shore area from waves.

GABION BREAKWATER



Offshore breakwaters are an acceptable method of shore protection for flat or moderate offshore slopes. The design wave is based on water depth 50 feet lakeward of the structure.

Offshore breakwaters can be constructed of any material capable of withstanding the wave energies impinging upon them, including stone, gabions, steel, wood, and concrete shapes. A toe protection blanket is essential. Offshore breakwaters may be low structures to allow passage of wave energy or they can be high structures to completely block waves. They should be built in shallow water nearshore for reasons of economy. They can be continuous for long distances or segmented with passages between them to allow exchange of water.

Caution: Offshore breakwaters interfere with shore processes; their use demands extreme caution to preclude major downdrift erosion. Consider them only in areas of substantial sand movement. Make them low so they will be overtopped by waves during storms. Offshore breakwaters are difficult and expensive to maintain.

Description	Design depth of water 50′ offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (ft.)	1.5	2.0	Not Recommended
Apron length (ft.)	10.0	10.0	
List of Materials			
Gabions—Stone filled (yd^3)	0.7	0.7	
Stone toe protection (yd^3)			
Cost $/Lin. Ft.	100	120	

ADVANTAGES

Beneficial effect can extend over a considerable length of shoreline.

Maintains or enhances recreational value of a beach.

The structure is not subject to flanking—it can be built in separate reaches.

Gabions can be constructed on shore and transported to site by ordinary earth-moving equipment.

Tends to build a natural beach between the breakwater and the shore.

DISADVANTAGES

May modify beach line and cause erosion in downdrift areas.

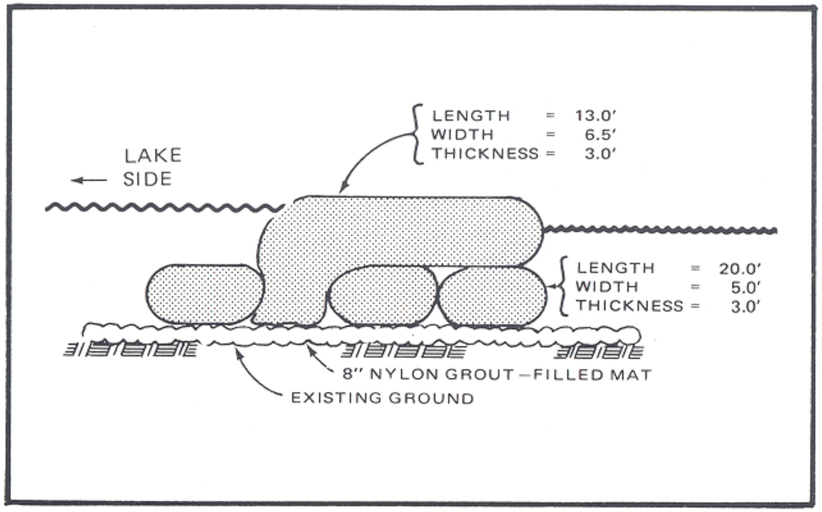
Structure is subject to foundation and scour failures; floating plant and heavy equipment may be required for construction.

Gabions may be damaged by floating ice or logs.

Extremely difficult to repair.

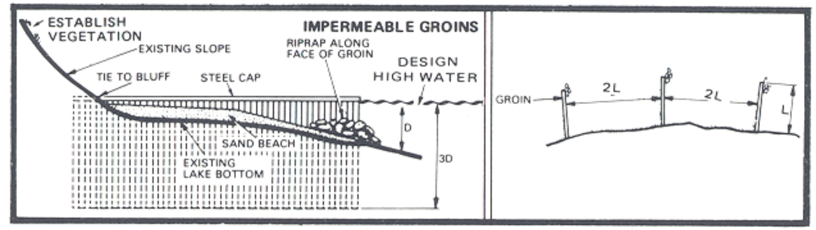
Offshore breakwaters also function as wave height reduction or attenuation devices on their landward side. An alternative design to the gabion breakwater on the opposite page is shown below. Offshore breakwaters function by reducing the wave energy which strikes the shore and by creating a quiet zone where sand is trapped. The height, length and distance offshore at the breakwater will control the size of the beach which develops behind the structure.

GROUT FILLED NYLON BAGS



IMPERMEABLE GROIN

Groins are usually constructed perpendicular to the shoreline and extend into the water far enough to effectively trap and retain littoral drift to build a beach or minimize erosion of an existing beach.



Protection of the shoreline by groins assumes sand is available and is moving along the shoreline. Groins can have the undesirable effect of damaging downdrift shores. The layout of groins is very important. Groins should be kept low, only one foot above the expected high water, and short, terminating at the 3-foot depth. Groins must be protected from flanking by tying them well into the bank. The maximum length of groins should not exceed 100 feet. If possible groins should be artificially nourished by placing sand on the updrift side of each groin.

Caution: Groins are shore protection structures that interfere with shore processes and entrap beach materials. Their use demands extreme caution to preclude major downdrift erosion. Consider them only in areas of substantial sand movement. Make them low so they will be overtopped by waves during storms. Groins should be constructed in stages, starting at the extreme downdrift end of the area to be protected. Study the effects of the single groin carefully before completing the layout of the groin field.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Steel Piling (length) (ft.)	115	65	Not Recom – mended
Steel Piling (wetted length) (ft.)	100	50	
Depth (ft.)	15	15	
Groin Spacing (ft.)	200	100	
List of Materials (per groin)			
Sheet Piling (tons)	27	16	
Timber Walers (tons)	3	2	
Stone Filter Blanket (tons)	90	90	
Stone Rip rap (tons)	140	140	
Cost $/Lin. Ft.	200	215	

ADVANTAGES

Resulting beach protects upland areas and provides recreational benefit.

Moderate first cost and low maintenance cost.

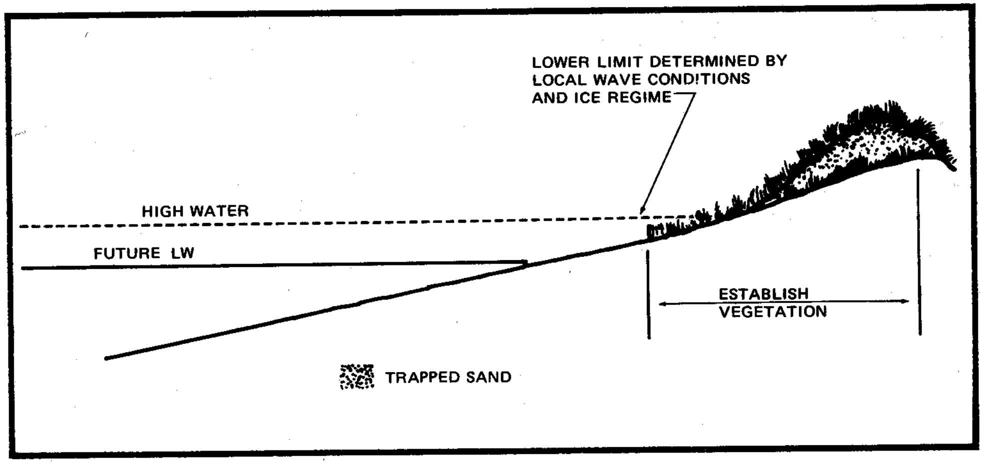
DISADVANTAGES

Extremely complex coastal engineering design problem. Qualified coastal engineering services are essential. Groins rarely function strictly as intended.

Areas downdrift will probably experience erosion.

Unsuitable in areas of low littoral drift. (Sand movement)

Subject to flanking; must be securely tied into bluff.



VEGETATION

Sandy beach areas lose sand inland through wind transport. Much of the sand transported from the beach area can be trapped by planting and/or fertilizing appropriate vegetation in the area above the wave activity. As shown in the accompanying figure, the vegetation actually helps form a sand dune system and when storms occur, particularly during periods of high water level, this reservoir of sand serves to absorb wave energy and slows shore erosion.

Many factors affect the efficiency of vegetation to trap sand. The availability and volume of sand being transported from the beach, and a sand transport season that coincides with the vegetative growth season, are of prime importance in the Great Lakes area. When high wave action occurs, particularly during high lake levels, the vegetation may be destroyed and the trapped sand redistributed to the beach. Therefore, the shorefront owner should be aware that the life span of a portion of the planted or natural vegetation may be as short as the period between major storm wave attacks and periodic maintenance of the vegetation may be required.

Caution: Dune stabilizing vegetation is designed to develop the dry back beach area by trapping wind-blown beach material. Consider them only in areas of substantial sand supply. Direct wave attack will eventually destroy the protective dunes.

COST

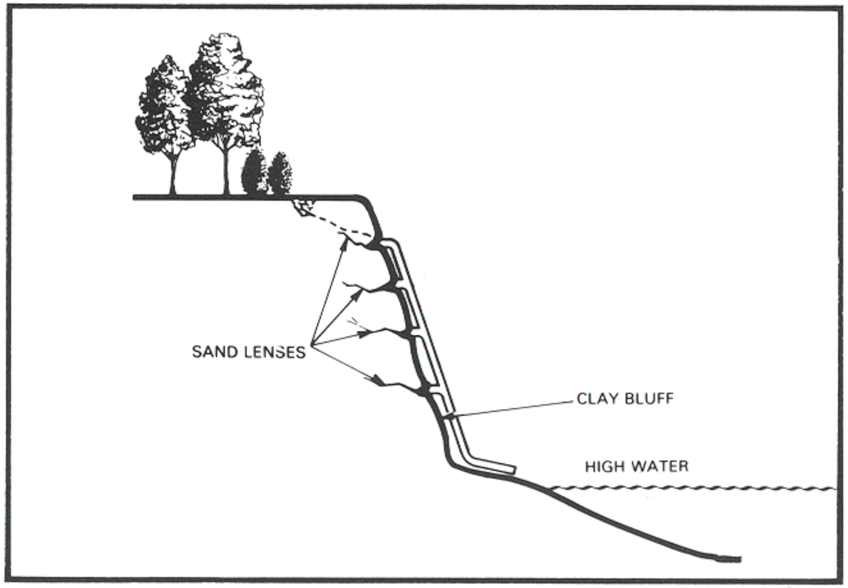
The cost of vegetative plantings could be as low as $10 per foot of shore front depending on plant species availability and area to be covered.

Information about plants and sources, site preparation, transplanting and maintenance procedures is available from your local USDA Soil Conservation Service representative.

Also, the Great Lakes Basin Commission, in cooperation with other Federal and state agencies has prepared a publication entitled "The Role of Vegetation In Shoreline Management" as a guide for Great Lakes shoreline property owners.

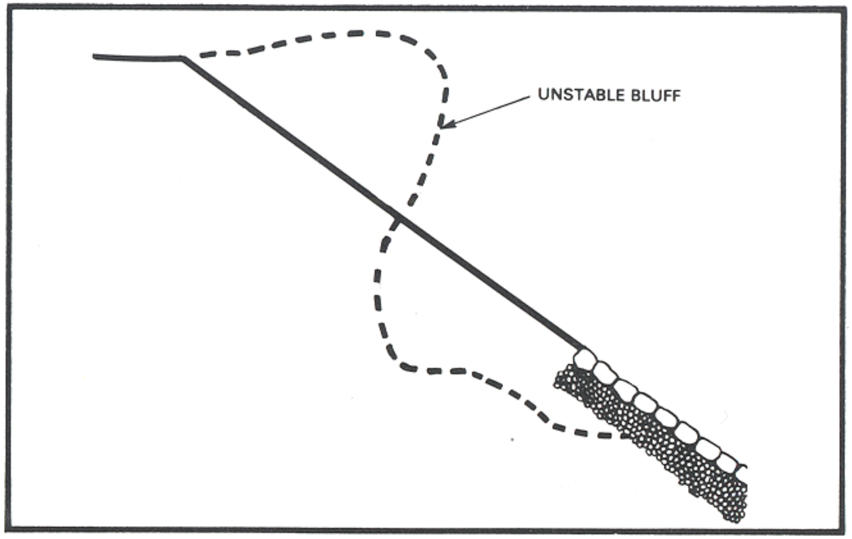
BLUFF SEEPAGE PROBLEMS

Bluff seepage problems are common for the clay bluff shoreline. Drainage should be provided where sloughing of banks caused by water seepage occurs through the upper relatively pervious strata to the impervious hardpan which underlies it. The saturated upper layer is unstable and sloughs off in large sections after which it is easily carried away by wave action. Wherever the natural slope of the ground surface behind the top of the bluff is toward the lake, drains paralleling the top of the bluff should be installed to collect the surface run-off. An open joint tile drain laid in a trench about 2 feet deep located 10 feet back from the top of the bluff and backfilled with crushed stone or gravel can be provided for this purpose. Paved gutters or tile drains down the face of the slope are necessary to carry the water which is collected by this drain to the lake. A tile drain along the foot of the slope just above the impervious strata with branches leading to the lake can be added to collect the seepage at this point and prevent softening of the toe of the slope.



CAUTION: This will not eliminate erosion due to wave action.

Frequently the combination of bluff seepage and wave erosion is responsible for continual bluff loss. In this case it will be necessary to protect the toe of the bluff in addition to the drainage work.



An alternative approach to the problem of steep and unstable slopes is excavation and slope protection. This plan consists of grading and landscaping the bluffs to a stable slope and the armoring of the toe of the slope as shown above. Revetments, beach accretion devices and bulkheads can be used for protecting the toe of the slope. The general cost of bluff treatment including excavation fill and seeding is $25 per foot. This cost does not include mobilization and demobilization costs for the required construction equipment.

The contractor should carefully plan his work to minimize the erosion damages during construction. The work should be accomplished by reach. Toe protection for the graded slope should be provided as soon as possible after the excavation and filling operations are completed.

Bulkheads are considered as a method for armoring an erodible bluff. Bulkheads can also be used for retaining an unstable slope from sliding. The design of retaining walls is beyond the scope of this pamphlet.

CAUTION:
Unstable bluffs shall be graded to a safe slope before anyone is allowed on the beach.

NOTE:
Additional information on bluff stabilization may be found in "Harmony With the Lake: Guide to Bluff Stabilization", distributed by the Illinois Department of Transportation, Room 1010, Marina City Office Building, 300 North State Street, Chicago, Illinois 60610.