

A Homeowner's Guide to Estuarine Bulkheads



Credits

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Bulkheads, often called seawalls, are a commonly used method of erosion control along the estuaries, sounds, bays and tidal rivers. When properly designed and constructed, bulkheads can be both effective and relatively economical. This report will discuss some of the benefits and limitations of estuarine bulkheads, as well as some of the most common construction problems which often lead to early failures in the structures. Also included are design considerations to look for before purchasing a bulkhead. Bulkheads on oceanfront property will not be considered in this discussion because they must withstand much more severe storm conditions and extreme shoreline changes.

What to expect from your bulkhead

The purpose of a bulkhead is to prevent erosion of the high ground upland of the wall and above the estuarine beach. Estuarine beaches are usually composed of sand, but also included are those shorelines with a gradually sloping clay bottom in front of a steep bank. Bulkheads cannot reduce the erosion rate of the beach. Therefore, when considering a bulkhead to protect the upland property, it is important to understand that the tradeoff will usually be the continued erosion and eventual disappearance of the beach. The disappearance of the beach after construction is almost certain along shorelines with higher erosion rates or with long, slowly eroding stretches of continuous bulkheads. If your intended purpose is either to prevent erosion of the upland property or to protect a structure from erosion, and you are willing to trade that protection for a possible loss of the beach, a bulkhead or variety of other erosion control structures may be useful.

Plan and design for future conditions

For many reasons, much of the North Carolina estuarine shoreline is experiencing continued erosion. This erosion is an expected and normal geological process. Erosion rates averaging one or two feet per year are typical, and erosion of more than five feet per year is not uncommon. The erosion of the shoreline usually occurs during periods of storm waves. A single wave can exert extremely high forces on any freestanding structure. As the height of the wave increases, the forces it exerts on a structure increase very rapidly.

Bulkheads are able to withstand these forces not by the strength of their materials, but by transferring the forces to the soil behind the wall. The volume of soil is so large it can readily absorb those forces without any effect on either the wall or the soil behind it. If for some reason soil is either lost or is not in contact with the wall, then all of the force must be handled by the bulkhead itself. **Backfill** is the sandy soil used to fill in the hole landward of the bulkhead after it is constructed. Loss of backfill followed by overstressing of the wall by waves is a common cause of failure in even new, well-designed bulkheads.

The design of a bulkhead is dictated then, not by the wave forces, as one might expect, but by the weight of the soil pushing toward the water on the landward side of the wall. The greater the difference in soil elevation from one side of the wall to the other, the larger the soil forces and the stronger the wall must be designed (Fig. 1). In other words, the higher the bulkhead, the higher the cost for a proper design. Therefore, it is generally best to keep the **top** or **cap** of the bulkhead as low as possible. It will still be able to protect the shore during normal water levels even though it may be partially overtopped by waves in severe storms or floods.

Erosion, or **scour**, seaward of the wall can be expected to continue at the

original rate or higher. The beach with a gentle slope causes waves to break gradually over a wide distance. A vertical wall will cause almost instantaneous breaking of the waves at the toe or bottom of the wall. Turbulence created as well as several other factors can lead to faster erosion of the beach after a bulkhead is constructed. Since the bulkhead will normally be expected to last for 20 years, it is imperative that the depth of erosion by the end of its useful life be anticipated. Failures are common in walls designed for the initial conditions but unable to withstand the erosion during the first several years.

In natural bodies of water, depth of future erosion can be estimated from the depth of water farther seaward. If the bottom between the shoreline and a hundred feet or so offshore is deep and steeply slopes to the beach, then much deeper erosion can usually be expected at the shoreline seaward of a bulkhead. If the offshore slope is fairly flat and the water shallow, then shallower erosion

can be expected at the bulkhead. In a typical, shallow sound, future erosion will lower the bottom at the toe of a bulkhead at least several feet. Near man-made canals or dredged channels, future erosion is more difficult to estimate. Check the history of the shoreline from longtime residents and aerial photography. Any future dredging for channel or harbor maintenance nearby can also place severe stress on the bulkhead and should be considered.

Special care must also be taken at each end of the bulkhead to ensure that the expected continued erosion on the adjacent shorelines does not allow the backfill to wash away (Fig. 2). Rain and storm waves can create surface runoff that can carry soil around the ends of the structure and into the water. Wave action can then overstress the wall. A bulkhead should either connect to an adjoining substantial bulkhead or should be extended landward on each end so that it will not be flanked by future erosion.

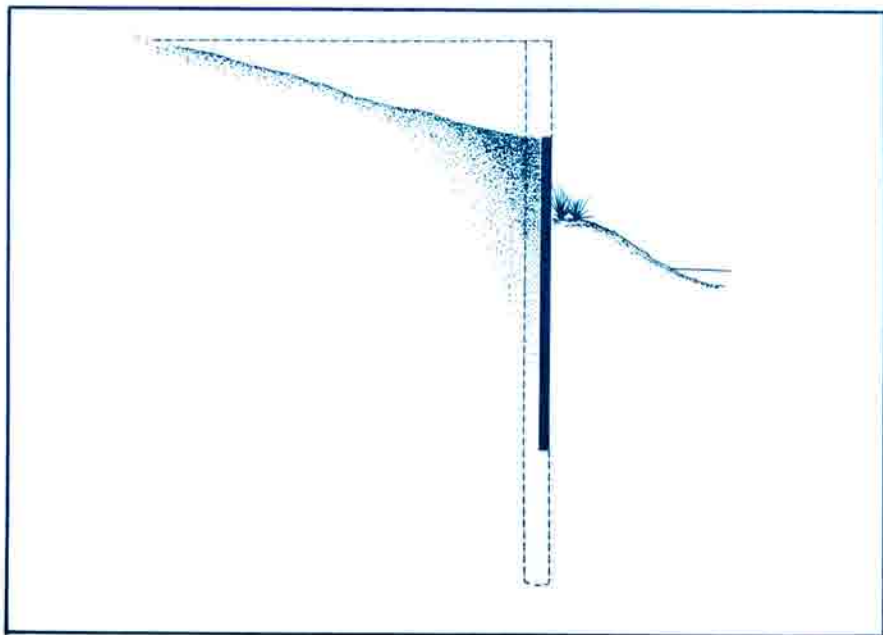


Fig. 1 Bulkheads require heavier materials and deeper construction to support higher soil elevations

These end walls are designed like the rest of the bulkhead and are often called **return** or **wing walls**. If an adjacent bulkhead is not substantial it is still best to connect your wall to it, but include your own return wall. If the strength of the adjacent wall is in doubt, add your own return wall also. Failure of your neighbor's bulkhead could lead to serious damage to your bulkhead if it allows your backfill to be lost. Often the construction of a bulkhead also causes increased erosion on one or both of the adjacent shorelines. It is very important that the return walls be extended far enough landward to prevent flanking by future erosion.

Heavy rainfall and high tides commonly accompany storms. If the bulkhead is not porous, water is trapped behind the wall until the soil becomes saturated. The bulkhead must then support the normal weight of the soil plus the added weight of the water. It is generally best to design the bulkhead to be porous enough to drain the water,

yet tight enough to retain the backfill. One of the most effective methods to ensure water drainage and soil retention is to place a layer of **filter cloth** between the soil and the bulkhead. Water is allowed to run out through the porous cloth and escape through the normal joints and cracks in the bulkhead, but the soil or backfill is too coarse to pass through the cloth and is thus retained. (Filter cloth is discussed in greater detail in a later section.)

Bulkhead materials

While a well-designed bulkhead will not last forever, it should have a useful life of 20 to 30 years. A variety of sufficiently durable construction materials are currently being used. These include pressure-treated wood, concrete, aluminum and steel. Each material has its particular advantages and limitations, which determine the suitability at a particular construction site. The materials selected should be strong enough to

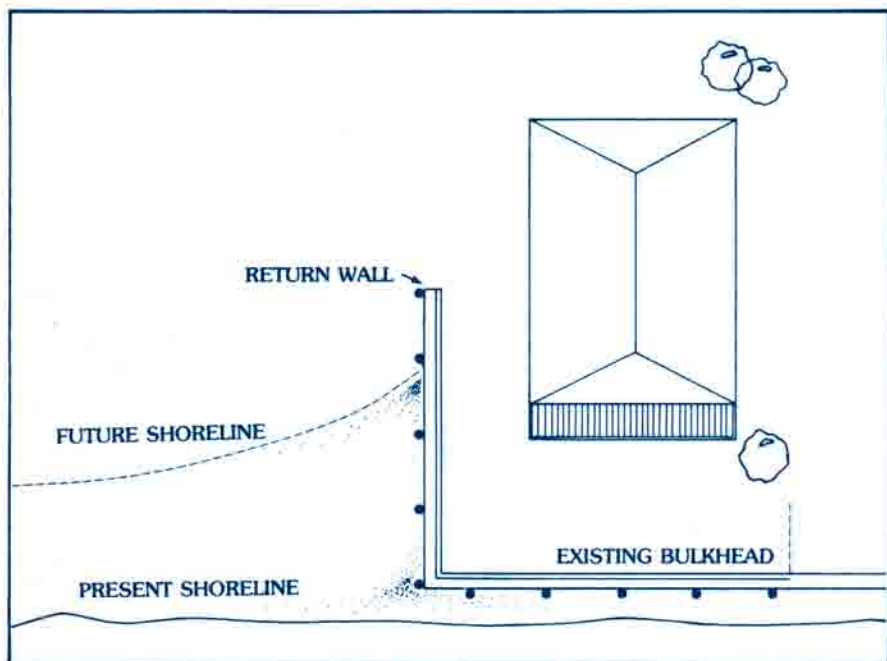


Fig. 2 Return walls extended landward of the bulkhead can prevent loss of backfill

withstand the anticipated forces throughout its useful life. They should also be durable enough to withstand decay, **marine borers** and corrosion conditions at the site and be compatible with the local soil and water conditions.

All wood for bulkhead use should be pressure-treated to resist rot and decay. In brackish or salt water, protection from marine borers requires a heavy level of treatment. While the surface of all treated lumber may look similar in color, the amount of chemical within the wood can vary considerably. Wood properly treated to withstand marine borers can contain six times as much chemical as that suitable for sundecks or dock decking. The use of more lightly treated materials, like old power poles or railroad ties, can lead to early failure from marine borers and a short, useful life. In fresh water, lower levels of treatment and a wider variety of treatment chemicals are acceptable. Contact Sea Grant for more detailed information on the use of pressure-treated wood.

Reinforced concrete is used in prestressed, or more commonly, precast sheet piles with a concrete cap. They can be cast on the site to a variety of lengths and thicknesses. The concrete mixture used should be suitable for marine applications. A sufficient thickness of concrete is necessary to prevent air and salt water from rusting the steel reinforcing. Heavy rust expands the diameter of the steel bars and cracks the concrete, a condition known as **spalling**. To prevent spalling, a minimum of three inches of concrete cover is recommended over all reinforcing, requiring a total sheet pile thickness of more than six inches. Concrete is more often used when a very high strength is required.

Aluminum and steel sheet piles are available in marine alloys which are very strong, highly resistant to corrosion and unaffected by marine borers. Metal bulkheads work well in relatively clean waters and sandy soils. Heavy industrial pollution or some, but not all, clay soil

conditions can cause severe corrosion rates. Soils which are either very acidic or alkaline can also be a problem. When in doubt, contact a professional engineer or the manufacturer for assistance.

Corrugated asbestos cement sheets with a concrete cap have also been used for bulkheads. However, these sheets have been shown to deteriorate rapidly in certain common water and soil conditions. Asbestos cement sheets should be used with caution for other than short-term use. (For more information, see Sea Grant's working paper 78-1, *Deterioration of asbestos cement sheet material in the marine environment* by J. Machemehl, L. Watson and B. Barnes. \$4.00)

In coastal North Carolina, pressure-treated wooden bulkheads are probably the most commonly used method of erosion control because of cost, availability, familiarity and ease of construction. The following discussion will address this type of construction. However, the general principles will apply to the other materials as well. Other bulkheading materials will be advantageous in certain situations. Alternative methods, such as revetments or groins, may also be effective solutions.

How a bulkhead works

A bulkhead supports the weight of the soil by transferring the forces to its various parts (Fig. 3). Boards, often called **sheathing**, **sheeting** or sheet piles, are placed side by side vertically into the ground to hold up the soil. One or more layers of sheathing are used depending on the thickness of the boards selected and the strength of the bulkhead required. It is recommended that a layer of filter cloth always be placed on the landward side of the sheathing, regardless of how many layers are used, to help retain the soil and drain collected water. Tongue-and-groove boards are normally an advantage in single layers of sheathing. The

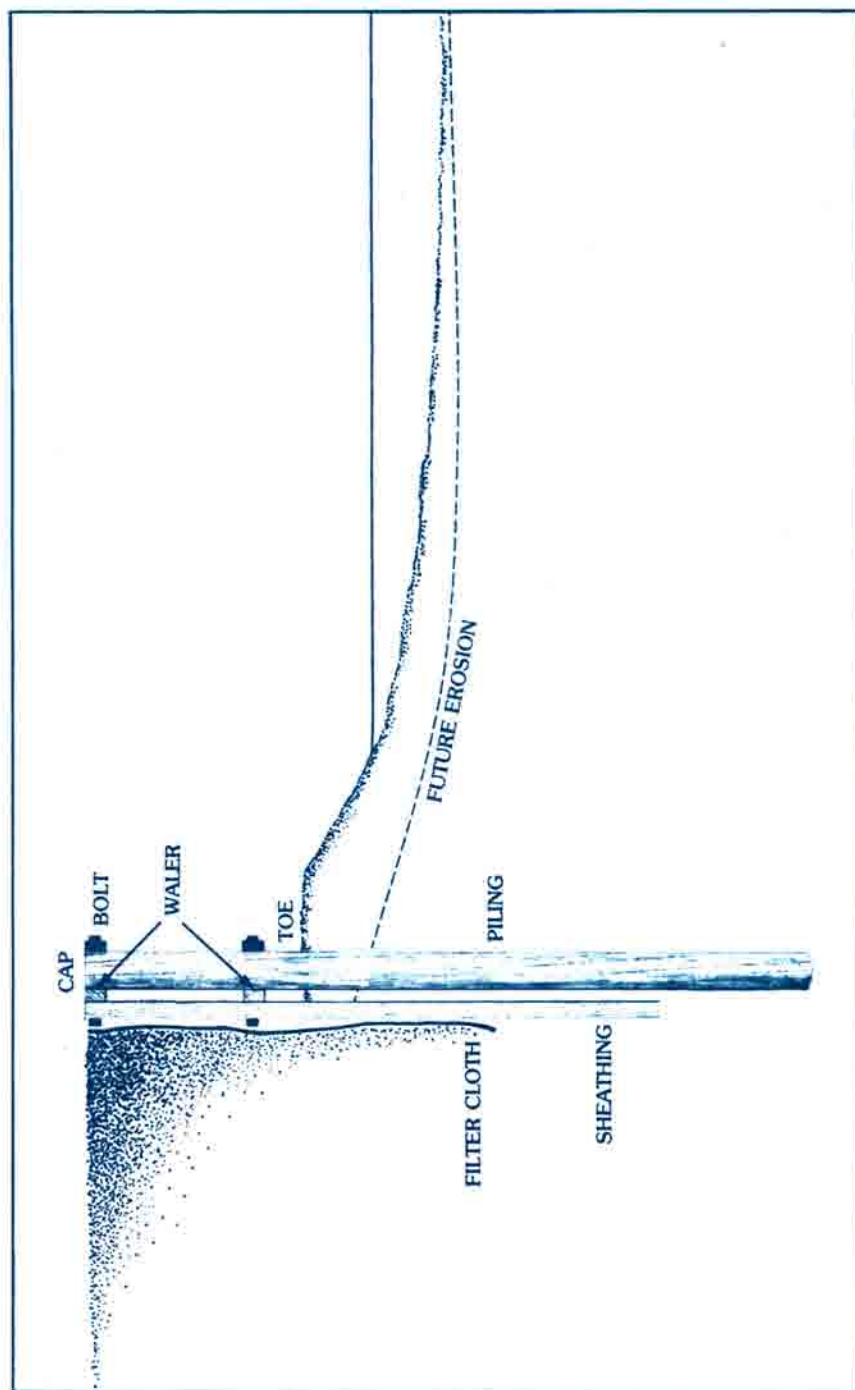


Fig. 3 Construction of a bulkhead

interlocking connection retains backfill better. Additionally, if for some reason larger stresses are placed on a single board, part of the force is transferred to the adjacent boards.

Heavy timbers, called **walers** or **wales**, are used to transfer a portion of the soil forces to the bulkhead pilings. Walers are placed horizontally along the top of the sheathing on the seaward side. Usually one or more additional rows of walers are placed between the top waler and the beach elevation.

The pilings used in a bulkhead can either be round or square and are generally longer than the sheathing. Both the pilings and the sheathing are usually jetted into sandy soils with a water pump, but they can also be driven by light pile driving methods. The normal construction sequence is to install the pilings on the proper alignment first. The walers are attached next and used as a guide to accurately align the sheathing. The walers and pilings are usually connected by bolts, nuts and

washers while the sheathing is nailed to the walers.

There are two general types of bulkhead designs based on how they support the soil. The simplest form of bulkhead uses a stiff combination of vertical sheathing and pilings placed deep enough in the ground to prevent the top of the wall from being pushed seaward by the soil. The top of the bulkhead is supported by the deep penetration of the bottom of the wall. This type is called a **cantilevered** design and is most frequently used for low, wooden walls less than three feet high (Fig. 4). For larger design heights, cantilevered walls must be very deep and also very strong to keep the wood from breaking near the seaward toe of the structure.

For bulkheads higher than a couple of feet, an **anchored bulkhead** is normally more economical to build (Fig. 5). To prevent the top of the wall from being pushed seaward by the soil, it is connected to strong anchors buried further landward. The sheathing and pilings

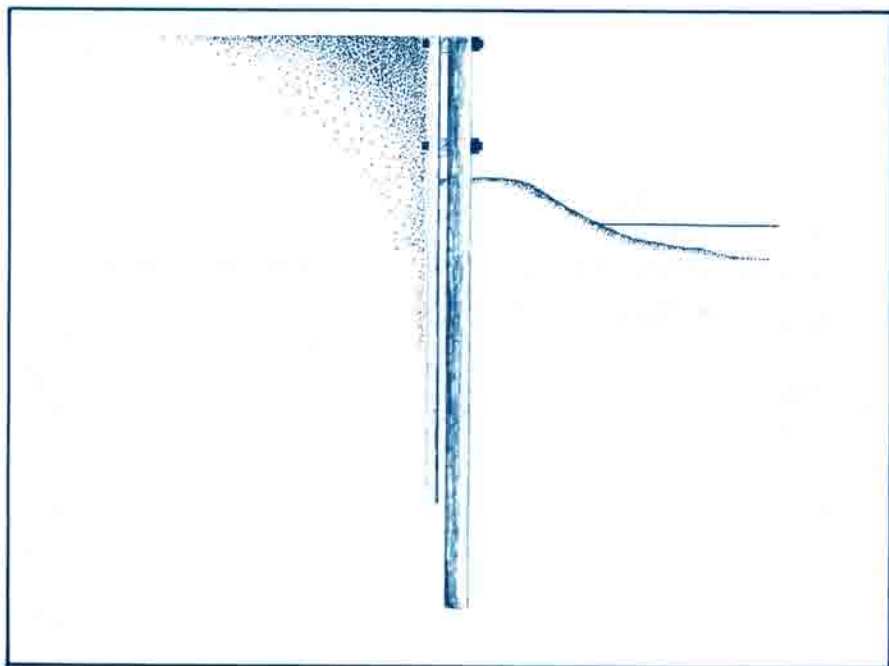


Fig. 4 Types of bulkheads: cantilevered design

can be shorter and lighter, but must still be buried deep enough to prevent the bottom of the wall from being pushed seaward after future erosion. For equal heights, a cantilevered bulkhead needs deeper embedment and heavier construction materials than an anchored design bulkhead.

Anchors can be designed many different ways depending on soil condition and material costs. The most common types are heavy blocks of poured concrete, wooden pilings laid horizontally, pilings driven vertically, anchor plates, screw anchors or various combinations of them all. The anchor must be located well landward of the bulkhead or it will be pulled seaward with the top of the wall as the soil collapses. The higher the bulkhead, the farther landward an anchor must be placed.

The anchor is usually connected near the top of the wall at each piling with rods, cables or timbers called **tiebacks**. Probably more bulkheads fail prematurely due to poor design of the

tiebacks than for any other cause. Of these failures, inadequate corrosion protection is most widespread. Metal fasteners and connectors used to hold together wooden bulkheads are constantly dampened with salt spray, which is an ideal environment for high rates of rusting and other forms of corrosion. Tiebacks, along with all other nails and bolts, should have a heavy factory coating of hot-dipped galvanizing or other equivalent protection. Since ground contact increases the corrosion rate, tiebacks often require additional treatment with tar, bitumen or other heavy waterproofing treatment. Thin layers of paint are ineffective in such conditions.

Filter cloth and backfill

Major benefits of filter cloth include not only a reduction in the force on the wall, but also fewer maintenance problems. As the years pass, even well-constructed bulkheads will slightly settle

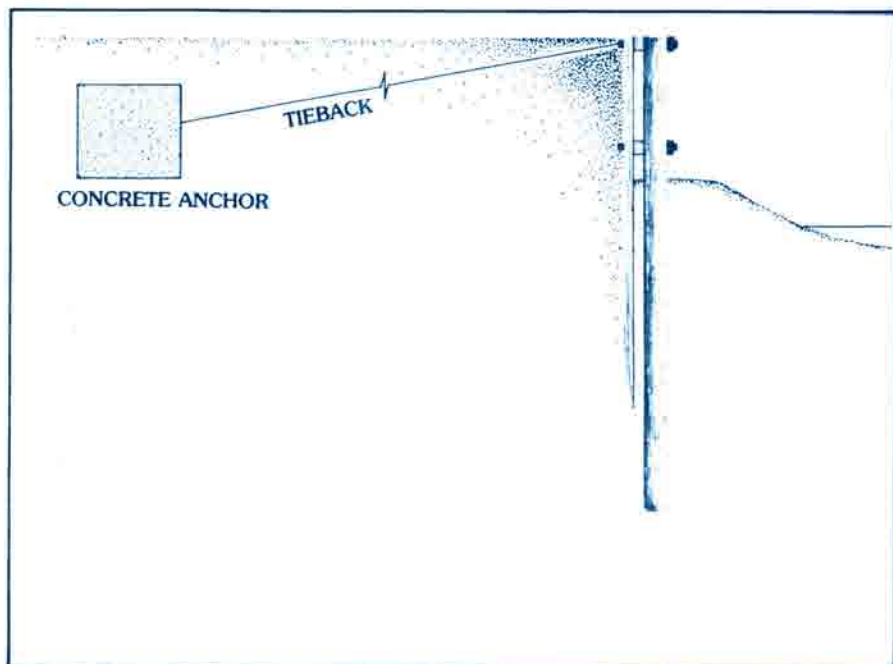


Fig. 5 Types of bulkheads: anchored design

allowing small cracks to leak backfill. Small craters will develop immediately behind the wall. While it is not too difficult to build an initially sand-tight bulkhead, keeping it that way for 20 years is difficult unless a filter cloth is used. Installing it during initial construction can save a lot of future headaches.

The better types of filter cloth are woven, nylon-like, man-made fabrics that are stronger than the alternative non-woven, felt-like, matted type. Both types are rot and marine-fouling resistant, but can gradually decay if exposed to continued sunlight. As long as the cloth is buried behind the bulkhead, it should last longer than the rest of the material in the wall. During installation, it is important to place the cloth as deep behind the wall as possible. For the cloth to be effective, it must extend deeper than the eventual erosion seaward of the bulkhead.

Tar paper and nonporous plastic sheets are not good substitutes for filter cloth. They tend to trap water and concentrate all of the drainage through a

few seams or holes rather than spread the drainage over the entire structure. They also aren't as durable.

The type of soil material used to backfill the bulkhead after construction is also important. Coarse, sandy soils are best due to their porous nature and other characteristics. Sandy backfill is desirable even when the upland bank is mostly clay. Clays and other fine soils can be too small to be retained, allowing backfill to be washed through the joints in the wall even if filter cloth is used.

After the actual construction of a bulkhead, the sequence in which the backfill is placed should be considered. The area around the anchors should be filled and compacted first. Only then should backfill be placed against the wall. If the area against the wall is backfilled first, the anchors could be pulled loose allowing the top of the wall to fall seaward.

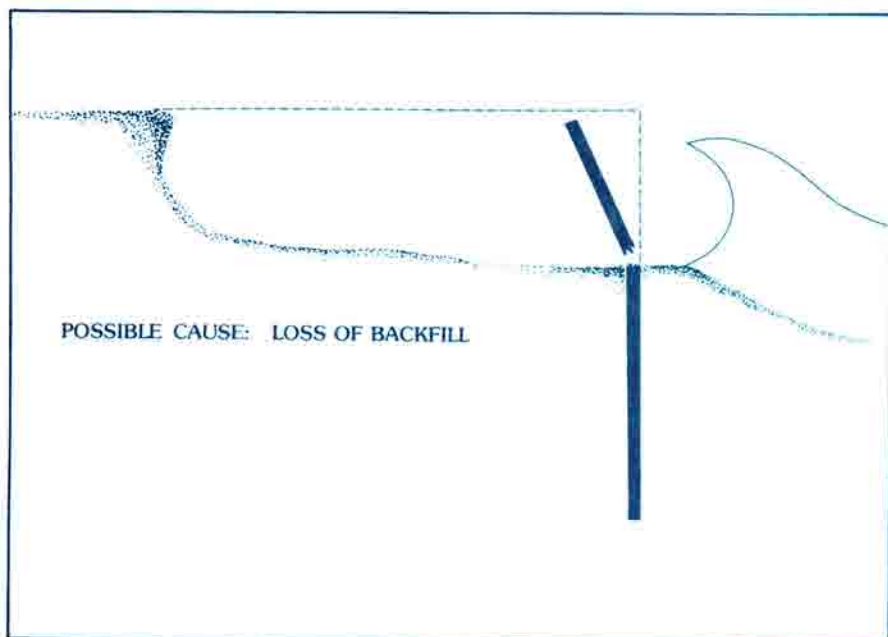


Fig. 6 Common bulkhead failures: wave damage

Bulkhead maintenance and common problems

Partial loss of backfill behind existing bulkheads is a common problem (Fig. 6). The small craters at the top of the wall indicate soil is being washed by rain and tides through a crack or hole lower in the bulkhead. If a structural weakness or large hole is the cause, it should be repaired prior to backfilling. If only normal cracks and small holes are the cause, it is often best to excavate behind the wall and add a layer of filter cloth from the cap to a depth well below the anticipated erosion on the seaward side. Then, backfill with a sandy soil. If excavation is not possible the problem can sometimes be corrected by backfilling with gravel every time the craters appear rather than adding more sand. The gravel should be larger than the size of the hole. It, like filter cloth, will retain the soil but allow water to drain.

Although often used, concrete dumped into the craters is generally not an

effective solution. The original hole in the bulkhead is seldom sealed, or it is later opened as the heavy concrete settles. Water is able to flow just under the concrete, creating another crater. Since the concrete is not porous, water trapped behind the wall as well as the weight of the concrete can cause additional stress on the bulkhead. Concrete is also more expensive than other fill.

In older bulkheads, another common problem becomes apparent when the top of the wall begins to lean toward the water (Fig. 7). The most common cause is a broken tieback. Placement of tiebacks too close to the wall and underestimating the erosion at the toe can also be the cause (Fig. 8). This problem should be repaired before the lean becomes too severe, or the wall will collapse. Excavate behind the bulkhead and straighten. Correct the tieback problem, or add a rock revetment to prevent excessive erosion scour at the toe. Adding fill behind a severely leaning wall usually hastens its collapse.

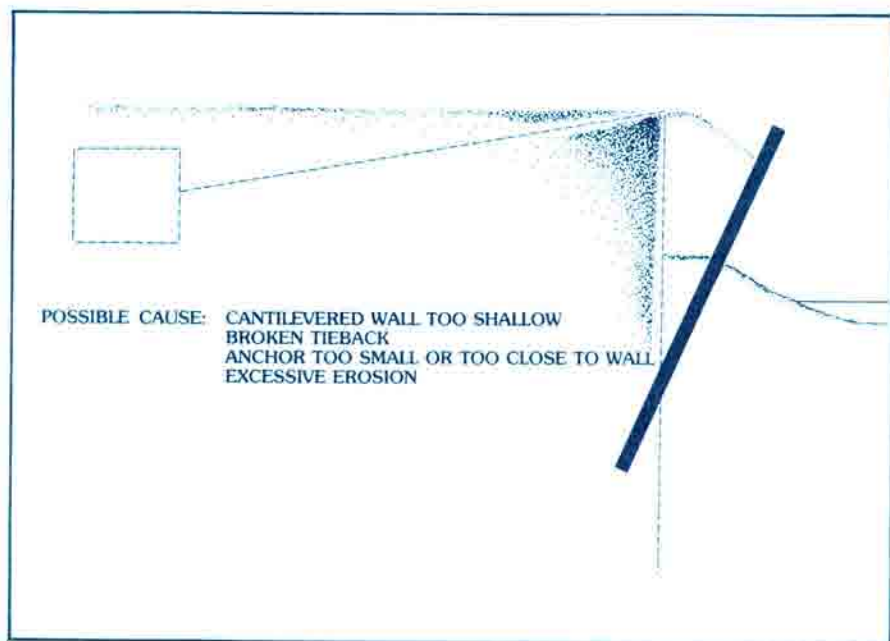


Fig. 7 Common bulkhead failures: top failure

Loss of backfill is particularly common at corners, at connections to adjoining bulkheads and around any openings through the sheathing, such as tiebacks or drainage pipes. Special care in construction and repair of these areas is necessary to ensure strong and sand-tight connections as the wall gradually settles with age. (Other maintenance problems, Fig. 9)

Unanticipated forces can cause even well-designed bulkheads to fail. Additional weight placed on the soil behind the wall increases the force on the structure. Parking or driving vehicles near the wall requires a substantial increase in the design strength (Fig. 10). Heavy vehicles should be kept at least 10 to 20 feet behind the bulkhead. Care should be taken even during final construction if heavy equipment is used to place the backfill. The anchors may be pulled loose or the tieback may be overstressed and break.

A steep slope behind a bulkhead also increases the soil forces (Fig. 11). The

added weight of the soil is transferred to the structure requiring longer and stronger materials. Slopes steeper than a rise of one foot in 10 feet behind the wall should be considered in the initial design. New buildings supported by the soil surface should not be constructed immediately adjacent to an existing bulkhead (Fig. 12). Piling-supported structures are usually acceptable if sufficient room for maintenance and repair is left. Care is necessary to prevent damage to the anchors and tiebacks when the new foundation is installed.

Rock revetments

The future depth of erosion seaward of a bulkhead is critical for its design yet is difficult to predict accurately. An effective method to protect the wall from excessive erosion or scour is the placement of rock armor at the seaward toe of the structure (Fig. 13). Properly sized and placed, like a small revetment, the sloping irregular surface helps to break

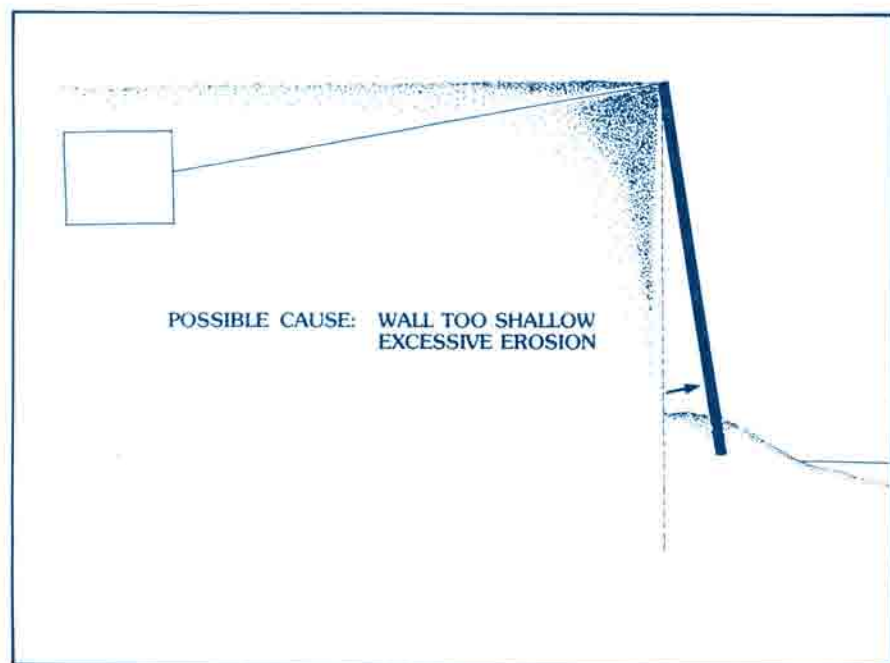


Fig. 8 Common bulkhead failures: toe failure

the waves more gradually and armor the bottom to prevent serious scour. The bigger the wave, the bigger a rock it can move. Rocks weighing one hundred pounds or more are best if waves two and a half feet high are anticipated. Brick-sized pieces and concrete slabs with a large, flat surface area compared to their weight are more easily moved by the waves and will require higher maintenance or occasional replacement. A layer of filter cloth underneath helps to prevent gradual settling of the rocks into the sand. Rocks can also be used to shore up existing bulkheads endangered by excessive scour.

Contractors

Bulkhead construction is often handled by specialized marine contractors. While most contractors provide a good finished product, it is always a good idea to check examples of their work. Ask for references of recent jobs as well as work completed five to 10 years earlier. Most

construction problems should be apparent in the older bulkheads. Check out bulkheads with shoreline conditions similar to yours: exposed height, erosion rates, directional exposure to winds and waves, offshore slope, etc. In addition, look at other successful bulkhead projects and find out who did the work.

Professional engineers

Taller bulkheads must support very large soil forces. It is often a wise investment to have a qualified professional engineer design the structure, particularly when the exposed face including anticipated erosion is greater than five feet. An engineer can also inspect the work as it progresses and ensure proper construction as well as design. All ocean bulkheads experience such extreme conditions that they should only be designed by a qualified professional engineer.

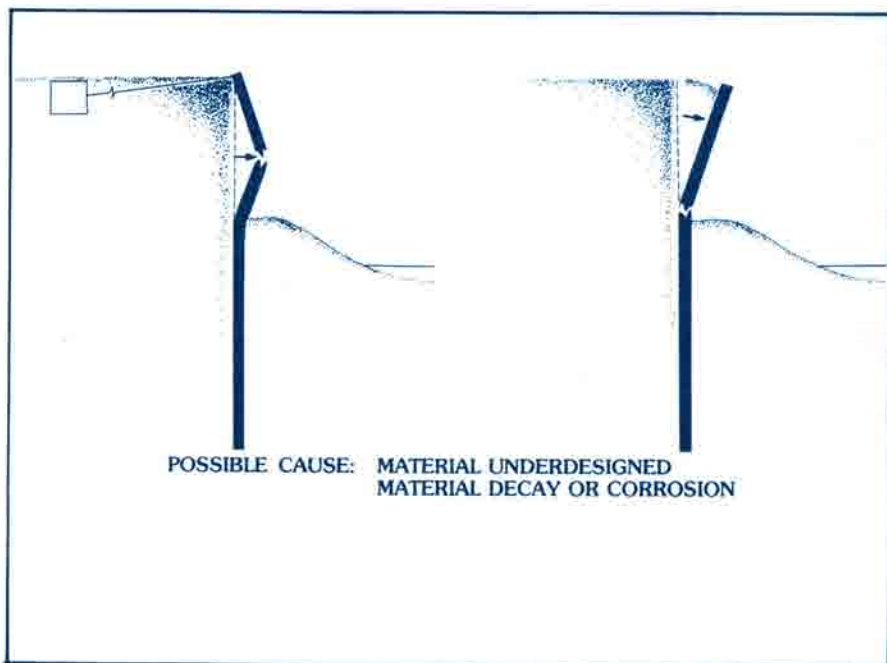


Fig. 9 Common bulkhead failures: material breaks

Permits

One or more local, state or federal permits may be required prior to beginning any filling or bulkhead construction. Frequently, a regular local building permit and both a state and a Corps of Engineers environmental permit will be necessary. In general, it is easier and faster to obtain environmental permits if the bulkhead is located completely above the high tide line rather than in the water. The permit agencies will usually send someone to the site to mark the location for speedy processing. Call them early in your planning because the permit process can take considerable time for public notices and for review by other agencies. It is always best to check on the permit requirements well in advance, before detailed planning or purchase of materials. If you are not familiar with processing a permit, a good person to contact for information is the local building inspector. Ask him about environmental permits.

Conclusion

Probably the best method of handling erosion is to learn to live with it. All permanent structures are best built far enough landward not to be threatened by future erosion. Realistically, this is not always possible and some method of erosion control is often necessary. If you are willing to trade the recreational value of the beach for protection of the upland property, a well-designed bulkhead may be the best solution.

While nothing lasts forever, a well-designed bulkhead using quality materials should last for 20 to 30 years with a minimum of maintenance. A wide variety of inexpensive methods and materials can also be used, but you generally get what you pay for. A low-cost alternative invariably means high maintenance and often an early replacement cost. The quality that goes into the materials and design of a bulkhead usually determines how long it will last.

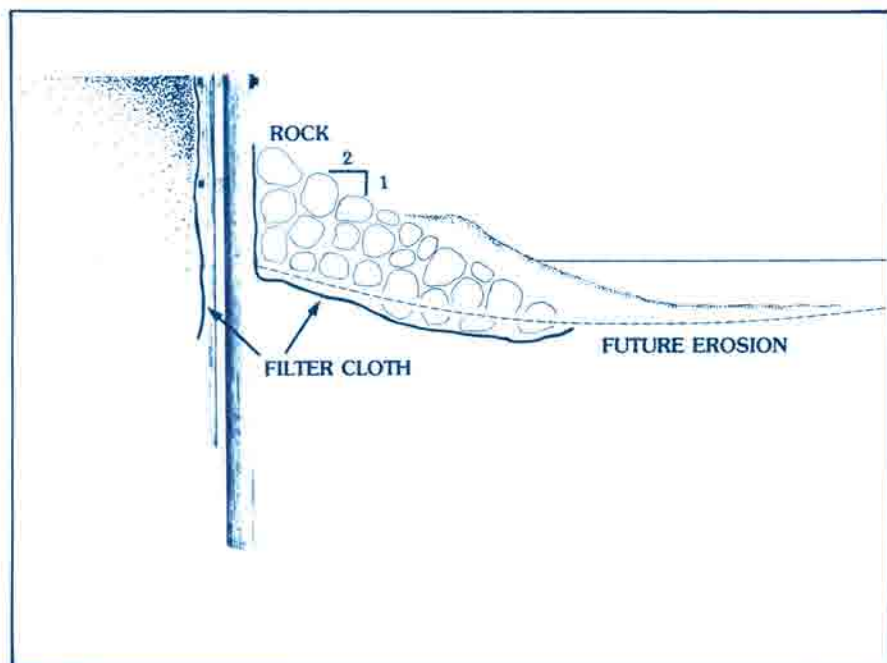


Fig. 10 Additional bulkhead forces: vehicle loads

Sources of additional information

For additional assistance on bulkheads or other erosion control methods, contact the author through the Sea Grant Marine Advisory Service, North Carolina Marine Resources Center/Ft. Fisher, General Delivery, Kure Beach, North Carolina 28449. (919) 458-5780

Help Yourself. Discusses a variety of erosion protection methods. Available free from the U.S. Army Corps of Engineers' offices.

Shoreline Erosion in Virginia by Hardaway and Anderson. Discusses the causes of shoreline erosion and a variety of shore protection methods in addition to bulkheads. Available for \$1.00 from Sea Grant Marine Advisory Service, Virginia Institute of Marine Science, Gloucester Point, Va. 23062.

The following publications are available free by writing Sea Grant, Box 5001, Raleigh, N.C. 27650-5001:

Estuarine Shoreline Erosion in North Carolina by Stan Riggs, Mike O'Connor, Vince Bellis and Tony Duque. A series of five colorful posters depicting erosion in four of the state's major estuaries: Core/Bogue Sounds, Albemarle Sound, Pamlico River and Neuse River. The fifth poster, Cause and Effect, explains the reasons for estuarine erosion. Please specify which poster(s). No publication number.

Relative Estuarine Shoreline Erosion Potential in North Carolina by Stan Riggs, Mike O'Connor and Vince Bellis. Presents a method designed to help planners and landowners determine how susceptible their estuarine shorelines are to erosion. No publication number.

Planting Marsh Grasses for Erosion Control by S.W. Broome, E.D. Seneca and W.W. Woodhouse, Jr. A property owner's guide to growing and transplanting salt marsh vegetation for estuarine shoreline erosion control. Ask for publication UNC-SG-81-09.

Glossary

Anchored Bulkhead—A bulkhead design in which anchors are placed landward of the wall to prevent the soil from pushing the top of the bulkhead seaward.

Backfill—Sandy soil used to fill the hole landward of a bulkhead after it is constructed.

Bulkhead—A vertical wall constructed to prevent erosion of the shoreline.

Cantilevered bulkhead—A bulkhead design without tiebacks or anchors.

Cap—Top of the bulkhead structure.

Estuary—A sound, bay, river, creek or other sheltered body of water where salt and fresh waters mix.

Filter cloth—A woven man-made fabric placed on the landward side of a bulkhead to prevent soil from escaping through cracks but allowing water behind the bulkhead to drain.

Marine borers—Saltwater or brackish water organisms which can destroy wood which is not chemically treated.

Return wall—Walls extended landward on each end of a bulkhead to prevent it from being flanked by erosion.

Scour—Erosion of the beach or soil on the seaward side of a bulkhead.

Sheathing or Sheeting—Vertical wooden planks of a bulkhead used to prevent soil from moving seaward.

Spalling—The cracking of concrete construction caused by rusting and expansion of steel reinforcing bars.

Tiebacks—A bar, cable or timber used to connect a bulkhead to its anchor.

Toe—Bottom of the bulkhead structure.

Walers or Wales—Horizontal timbers on the seaward side of a bulkhead which transfer part of the soil forces from the sheathing to the pilings.

Notes

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